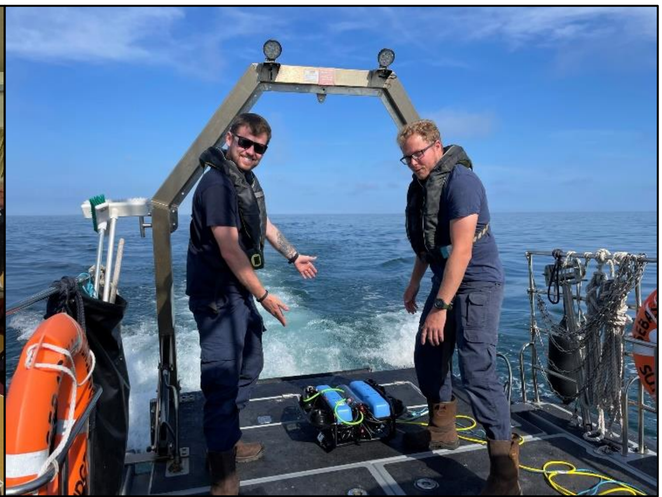
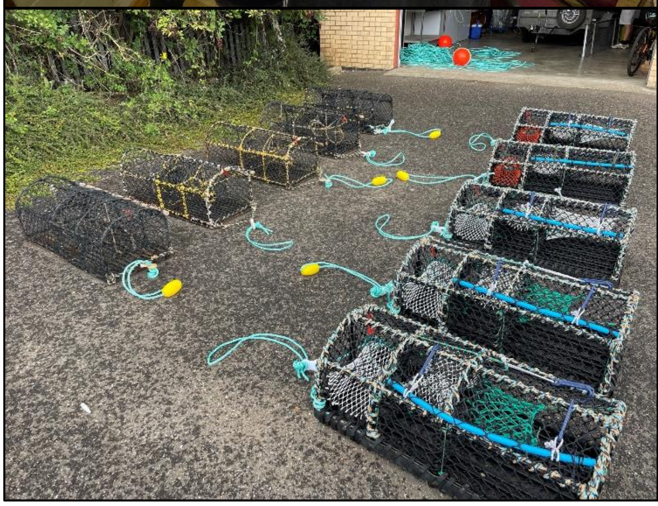
Eastern Inshore Fisheries and Conservation Authority

Cromer Shoal Chalk Beds Marine Conservation Zone: Adaptive Risk Management

2023 Research Interim Report

Samantha Hormbrey, Ron Jessop, Fletcher Noble, Elena Jaxtheimer, Judith Stoutt

April 2023: Version 1.0


Document Control:

Revision History				
Date	**Version**	**Edits**	**Status**	**Editor**
15/11/2022	1.0	Document created	Draft	SH
21/03/2023	1.0	Contributions added from SH	Draft	SH
23/03/2023	1.0	Contributions added from SH and FN	Draft	SH & FN
24/03/2023	1.0	Contributions added from FN, RWJ, EJ & JS	Draft	All
31/03/2023	1.0	Reviewed by RWJ	Draft	RWJ
06/04/2023	1.0	Edits made by SH, FN, JS	Draft	All
11/04/2023	1.0	Document finalised	Final	SH

Contact details:
Eastern Inshore Fisheries & Conservation Authority
6 North Lynn Business Village
Bergen Way
King's Lynn
Norfolk
PE30 2JG
Phone: (01553) 775321
Email: mail@eastern-ifca.gov.uk

Table of Contents

Table of Figures

Table of Tables

1 Introduction

1.1 Cromer Shoal Chalk Beds Marine Conservation Zone

Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) was designated in January 2016. The site lies 200 metres off the North Norfolk Coast between Weybourne and Happisborough and extends around 10 km out to sea. The site was designated to protect habitat and geological features, including subtidal chalk and peat and clay exposures, which provide structural complexity, and in turn, stable surfaces for seaweeds and static animals to settle on as well as nursery areas. At the time of designation, the site was also recognised as supporting traditional crab and lobster fisheries and it was assessed that the designation would not have any financial impact on the local fishery because of the general understanding that potting fisheries did not cause significant lasting impacts to rocky habitats.

However, since designation, new evidence came to light in 2018 comprising photos of damaged chalk features, some with potting gear in situ and others the cause of damage unknown (Seasearch, 2018). This evidence led to concern around potting gear interactions with chalk and the development of further research led by Natural England to better understand the interaction, scale of impact and potential hindrance to the achievement of the sites Conservation Objectives (Tibbitt *et al.,* 2020). Subsequent to this, and based on the findings from their further research (Tibbitt *et al.,* 2020), updated conservation advice was provided by Natural England in August 2020. This formal advice stated that potting could be hindering the achievement of the site's Conservation Objectives because of the cumulative effects of damage to raised, outcropping chalk features which provide structural complexity to habitat. Natural England also advised that an Adaptive Risk Management (ARM) approach would be an appropriate alternative to an immediate precautionary ban on potting.

1.2 Potting assessment

In line with the requirements under the Marine and Coastal Access Act 2009, Eastern Inshore Fisheries and Conservation Authority (IFCA) have updated their assessment of potting activities within the MCZ, taking into account this new advice provided by Natural England[1]. This assessment concluded that the risk of the potting fishery hindering the achievement of the MCZ's Conservation Objectives could not be ruled out in the long term, due to the potential for cumulative effects of interactions between active and lost potting gear with rugged chalk features to have significant impacts over a long period of time. To mitigate this risk, the Authority has adopted an Adaptive Risk Management (ARM) approach to management of the fishery.

1.3 Adaptive Risk Management

Adaptive management is 'learning by doing' then adapting based on that learning (JNCC, 2019). Such an approach provides a framework for managing ecosystems

[1]Eastern IFCA's Marine Conservation Zone Assessment for Cromer Shoal Chalk Beds MCZ: Pots/creels (crustacea/gastropods) V. 5.0. Draft: April 2022 (Not yet published).

where there are multiple sources of uncertainty (Williams and Brown, 2018) and allows evidence based, proportionate and participatory management to be developed through an iterative process, where monitoring and research inform management in a feedback loop (JNCC, 2019).

To implement this approach Eastern IFCA have established several collaborative groups to lead on and develop management and research workstreams which aim to address uncertainties and mitigate risks to the site. These groups are the:

- Project Board
- Management Task and Finish Group (T&FG)
- Research and Development Task & Finish Group (R&D T&FG)
- Stakeholder Group

More information about how these groups contribute to ARM can be found on our website[2] in our ARM plan which sets how Eastern IFCA aim to apply ARM by providing a long-term plan for management and monitoring of the fishery (EIFCA, 2023).

The Management T&FG have so far led on the development and implementation of management, proportionate, and adequately precautionary, to the identified risk, and the ongoing process of monitoring, evaluation and refinement. More detailed information on this can be found in Eastern IFCA's ARM plan. This Interim Report focuses on the work overseen by the Research and Development T&FG.

1.4 Research and Development Task & Finish Group

Eastern IFCA's assessment of potting activities identified several uncertainties which meant that precaution was needed when drawing conclusions. The Research and Development T&FG was established to develop research which would address these uncertainties so that the mitigation developed can be informed by evidence and overly precautionary measures can be avoided. The collaborative group is made up of members from Eastern IFCA, fishing industry, Natural England, the University of Essex, Cefas and the North Sea Wildlife Trust (Image 1).

Image 1 R&D T&F Group site visit to West Runton to look at chalk exposed at low water (left) and presenting research work developed so far at the December 2022 stakeholder group meeting (right).

[2] https://www.eastern-ifca.gov.uk/draft-page-implementing-arm-in-the-mcz/

The aims and objectives of the group are summarised in Table 1 and the uncertainties and workstreams identified to address them are presented in Figure 1. The group published a Project Plan in 2022 summarising the work they planned to develop at the start of the ARM process which is available on Eastern IFCA's website (EIFCA, 2022).

Table 1 Purpose, aims and objectives of the Research and Development Task and Finish Group

<table>
<tr><th colspan="4">Research and Development Task and Finish Group (T&FG)</th></tr>
<tr><td colspan="4">Responsible for providing the scientific evidence required by the Project Board to inform Adaptive Risk Management, including the development of management measures. This group brings together scientists, fishermen, and other key advisors to draw on their scientific, fisheries and site knowledge, determine what information is required, to develop appropriate methodologies, and then to deliver the research.</td></tr>
<tr><td colspan="4">Overall Aim:
1) To ensure that the information required to implement an effective Adaptive Risk Management approach of the impacts from potting fishing activity on the rock (chalk) seabed of the Cromer Shoal MCZ is available.
2) To identify if impacts are within an acceptable range, in respect of the conservation objectives of the site.
3) To identify viable alternatives to existing fishing methods (practices and/or gear) through an Adaptive Risk Management Approach.</td></tr>
<tr><td>Objective 1</td><td>Objective 2</td><td>Objective 3</td><td>Objective 4</td></tr>
<tr><td>Determination of the locations of the chalk feature which is sensitive to damage from potting -
a) Definition / Description of what character of "chalk" renders it susceptible to effects from potting.
b) Determination of the range of sensitivities of chalk to different types (characteristics – equipment and methods) of potting.
c) Determination of the effects that changes in the physical structure of the chalk due to potting have on the species and ecology.
d) Determination of the location of Chalk of varying sensitivities.</td><td>Characterisation of potting fishing activity within the MCZ – where, when, how (methods, equipment) and how much. Where feasible, identify the drivers for particular approaches to potting.</td><td>Determination of the effect of potting on the sensitive chalk feature
a) Determination and quantification of effects from potting, and how this varies within the range of potting activities conducted in Cromer Shoal MCZ and the varying sensitivities of chalk.
a) b) Determination of the "acceptable" level of impact to be consistent with the conservation objectives of the site.</td><td>Identifying if there are viable alternative ways (equipment, techniques, methods, locations) of potting that will have an effect within the "acceptable" range.</td></tr>
</table>

This following chapters aim to provide an update on the research work developed by the group since the ARM approach was adopted in 2021, present any progress and/or findings made so far and summarise the key areas of focus for the next three years.

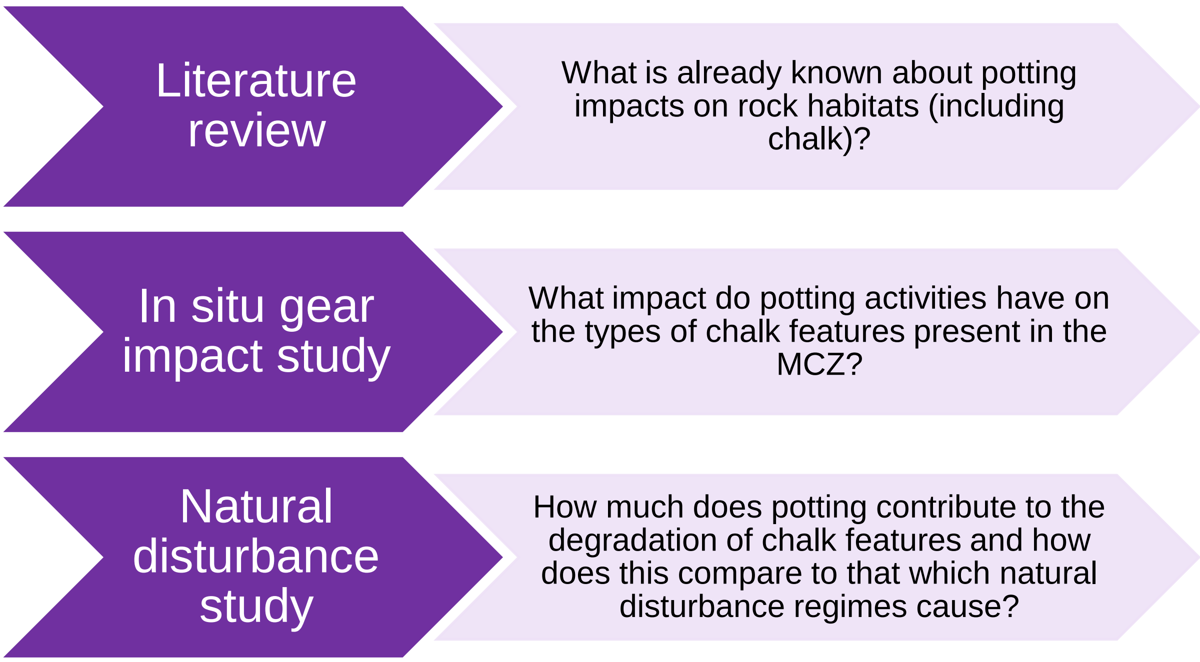
Uncertainty	Workstream	Driver	Approach
The scale of potting impacts across the MCZ, the potential for long term risk to CO's and the significance against a background of natural erosion	**Assessing impacts of potting**	Determine current impacts against targets Inform potential effort limitation mitigation What makes chalk sentitive?	Literature review In situ ROV gear surveys Long term disturbance study
The location of sensitive features across the MCZ	**Mapping sensitive features**	Inform spatial mitigation Assess level of impact across the MCZ	Reanalysis of existing imagery and acoustic data ROV habitat surveys Extend coverage of acoustic data
The location, scale and seasonal variation of potting activties	**Mapping fishing activities**	Inform spatial and potential effort limitation mitigation Determine current impacts against targets	Distribution of trackers amongst fleet Pot buoy counts (from shore or using drones) Beach clean data
Alternative practices that could mitigate risk	**Trialling alternative fishing practices**	Inform gear or technological mitigation	Adaptive gear trials
Importance of rugged chalk to the potting industry and the fishery to wider society	**Determing the value of the rugged chalk**	Inform impact assessment	Economic assessment (on vs. off rugged chalk) Social value study

Figure 1 workstreams developed by the Research and Development Task and Finish Group to address uncertainties identified in Eastern IFCA's assessment of potting activities v5.0

2 Assessing impacts of potting

Eastern IFCA's assessment of potting impacts has so far been informed by the completion of our updated potting assessment which in turn was informed by the new evidence received (Seasearch, 2018) and Natural England's updated advice (August 2020) and dive survey report (Tibbitt *et al.,* 2020). However, whilst these sources of information provided direct evidence of potting gears interacting with rugged chalk features and having abrasion and/or penetration impacts, they did not provide any quantitative data on the frequency and scale of impact which could be used to quantify the level of impact across the site and assess against Conservation Objectives. Furthermore, these evidence sources also identified instances of impacted or disturbed chalk which could not be directly attributed to potting or other anthropogenic activity highlighting the potential effect of natural disturbance regimes in the area which is anecdotally known to be significant. Where potting impacts are observed, the evidence suggest that impacts to chalk are typically small in size and do not remove, or significantly change, outcropping chalk structures to the point where structural complexity of the habitat is reduced or removed. However, there is concern that if repeated impacts occur on the same features over time, they will gradually become flattened, structural complexity will be reduced and eventually the habitat may no longer support the same biological communities.

The Research and Development T&FG have developed the below projects as part of this workstream to answer the corresponding key research questions, each aimed at understanding and assessing the impacts that potting can have on chalk features, to ultimately, inform Eastern IFCA's assessment of potting activities within the MCZ:



2.1 Literature review

RQ: What is already known about potting impacts on rock habitats, including chalk?

Approach

Following the change in conservation advice provided by Natural England in August 2020, Eastern IFCA completed a literature review on the physical impacts of potting on subtidal rock habitats, including soft rock habitats such as chalk, and the biological communities they support (Hormbrey, 2022).

Progress so far

The review found that most of the available literature focused on 'rocky reef' habitats characterised by erect emergent epifauna on hard rock substates and that the literature investigating the physical impacts of pots on softer chalk habitats and their associated communities was highly limited. Furthermore, there were no studies which had investigated physical impacts of potting on rock communities over periods of more than four years and so the longer-term effects were less clear. Despite this, a number of conclusions were drawn:

- Firstly, it was evident that potting could cause abrasion impacts to, and/or physical removal of, soft rock substrates and sessile epifauna attached to soft and hard rock habitats and that such physical damage can result from the direct contact between pots, ropes and anchors and the substrate or epifauna during deployment, soaking and hauling phases of activity.

- As with bottom towed gears, the extent to which physical impacts from pots can damage rock habitats and their biological communities appears to be site specific and dependent on several factors including substrate and habitat type (Stephenson *et al*., 2017; Tibbett *et al*., 2020), species sensitives and life histories (Kaiser *et al*., 2018), local environmental conditions (Lewis *et al*., 2009) and potting activity levels (Rees *et al*., 2021).

- The nature of pot fishing, its small spatial footprint of activity and highly localised area of impact means that the likelihood of areas to be repeatedly disturbed by the activity on successive trips is considered low. This has generally led to the conclusion that most species and communities will be able to recover between any repeat occurrences of impact unless they have long recovery periods. However, for some crustacean fisheries, certain areas could receive higher intensities of activity than others because of the aggregated and territorial nature of commercial practices and so site-specific factors should be considered before applying such conclusions.

- For soft rock habitats where physical impacts can extend to the substrate itself, substrate cannot recover and so any changes to the structure of the habitat will be permanent. Changes to the structure of the substrate might not result in community level effects, but if they do, these too will be permanent.

- When assessing the potential for physical impacts to have long term adverse effects on rock communities, it is vital to fully understand the habitats interacting with potting gears, the communities and key species which they support, and the sensitivity and ability of these species to recover from abrasion and/or removal. For example, erect emergent epifauna appear to be most sensitive to physical impacts from pots (Gall *et al*., 2020; Rees *et al.,* 2021) because of their fragility and longevity. In contrast, mobile species, including relatively sedentary species, and communities dominated by species with shorter life histories and higher resistance to disturbance appear much less sensitive or, in some cases, not sensitive at all to physical impacts of potting (Stephenson *et al*., 2017; Gall *et al*., 2020; Rees *et al*., 2021).

The conclusions and findings drawn as part of this review have been used to inform Eastern IFCA's updated assessment of potting activities and to identify the uncertainties to be addressed as part of this workstream.

2.2 In situ gear impact study

RQ: What impact do potting activities have on the types of chalk features present in the MCZ?

Background

In 2019, Natural England, in collaboration with the University of Essex, conducted a dive survey to examine the physical interactions between crab and lobster potting and the subtidal chalk features within the MCZ. The “Phase I” study, reported in Tibbitt *et al*., (2020), identified and described a variety of types of damage that current potting gear was observed to have caused to some of the subtidal chalk features. This study used divers to look at impacts from gear in situ, and was able to identify and describe the types of damage that could be attributed to specific parts of the gear. This damage was quantified in a limited capacity, but due to the scale of this project, still left a lot of uncertainty around the overall quantity of damage and potential for site level impact.

The project also utilised 3D photogrammetry that could describe the features using 3D modelling techniques. The University of Essex have subsequently taken the analysis of this study further to determine whether chalk elevation can be used as a complexity metric and investigate the relationship between biodiversity, human impacts and the complexity of rocky reefs.

Approach

Following the same approach used by Natural England in 2019 (Tibbitt *et al.,* 2020), to further investigate potting interactions with chalk features Eastern IFCA planned to build on this work and conduct further in situ gear surveys to identify, assess and quantify impacts across the site.

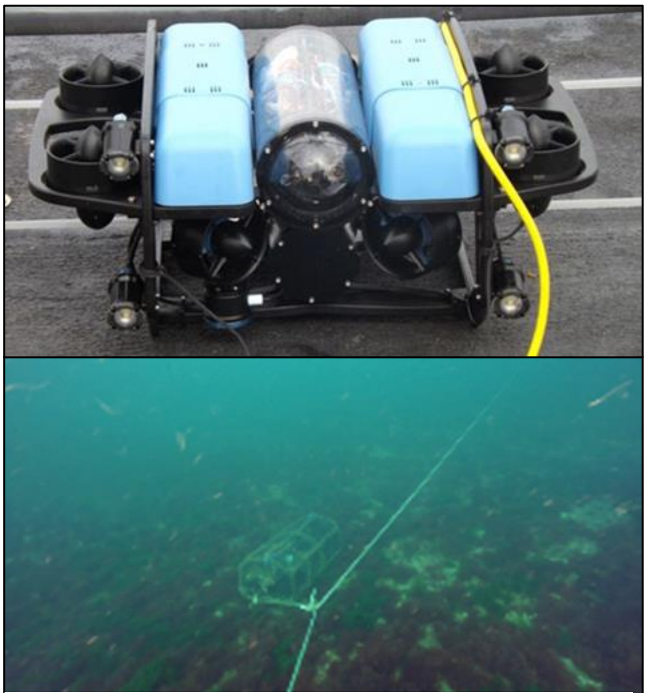


Image 2 Blue ROV 2 (top) and example of footage from in situ gear surveys (bottom).

Whilst Natural England had used divers to conduct gear surveys, the cost and practicalities of doing this on a larger scale was considered prohibitive. Instead, it was hoped that a Remotely Operated Vehicle (ROV) could be used to conduct in situ gear video surveys on a larger scale. However, using an ROV to carry out such work had not been done before by the Eastern IFCA team and was likely to present several challenges due to the typically poor visibility and strong tide and wind conditions experienced in the area. In addition to these difficult environmental conditions, navigating an ROV connected by a tether along a shank of pots connected by ropes and anchored to the seabed, presented a significant snagging risk. Despite these challenges, Eastern IFCA purchased a BlueROV2 in the summer of 2021 to collect seabed imagery to inform mapping of chalk habitats and to conduct in situ gear surveys. Trials using the ROV to carry out in situ gear surveys were successfully carried out in August and September 2021, demonstrating its ability to be flown along shanks of pots when conditions and visibility were good.

Following the success of the trials, further in situ gear surveys with the ROV were completed during the summer of 2022. These surveys targeted 10 areas along the inshore section of rugged chalk between Weybourne and Overstrand to ensure spatial representation across the site (Figure 2).

Video footage collected has been analysed externally (funded by Natural England) and internally by Eastern IFCA. The Research and Development T&FG held a workshop in December 2021 to develop a standardised method of assessing impacts to chalk that can be used moving forward to ensure consistency with existing (Tibbitt *et al*., 2020) and future work and methods used by Seasearch divers. This included defining various categories of impact type, size and severity, amongst other descriptors, to provide a standard (O'Dell and Dewey, 2022).

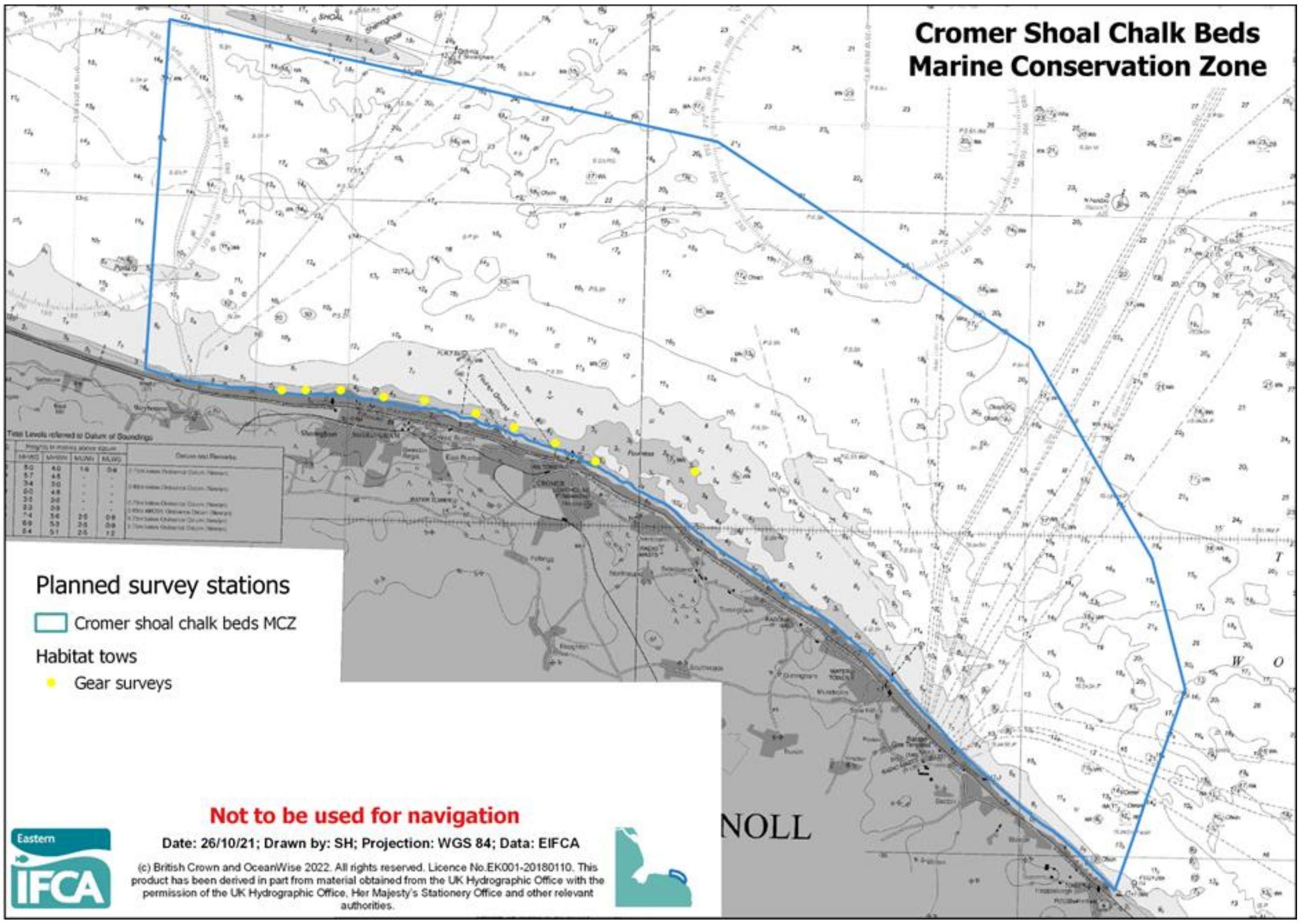


Figure 2 Chart showing the locations where in situ gear surveys were targeted with the ROV in 2022

Progress so far

Analysis of the footage collected during the 2021 ROV trials is presented in O'Dell and Dewey (2022) and provides a summary of the anthropogenic impacts observed. O'Dell and Dewey (2022) found the most common form of chalk impact to be grates, typically small in size (head to arm size) and of low severity (removal of the surface layer of chalk) (Figure 3a). It was noted that for such impacts, it was rare that chalk debris was observed below the impact site, that it was common to observe multiple bare chalk patches of a similar size on the same rock face and that the cause of impact was not generally apparent (i.e. gear could not be seen to be causing the impact) even if it was visible in the vicinity (Figure 3b). Of the 76 impacts recorded, 11 of these were categorised as cuts, which in all cases rope was present in situ (Figure 3c), 1 was categorised as a burn again with the rope in situ (Figure 3d) and one a level shear likely caused by a rope present in the nearby vicinity (Figure 3e). Angular rubble was recorded occasionally and provided examples of large chalk impact (Figure 3f). Other types of chalk impact were rarely observed.

Footage collected during the 2022 ROV surveys is still being analysed so do not contribute to this interim report.

Whilst the trials conducted in 2021 proved a success, when it came to using the footage to provide quantitative and robust data that can be used to scale up the level of impact across the site, its usability was limited for the following reasons:

- Impacts can only be attributed to potting if gear is observed in situ during the soak period when surveys are completed. Impacts resultant from setting cannot be observed as gears will likely have settled away from the impacted area and will no longer be directly in situ. Whilst such impacts may be observed and their likely cause surmised, there will always be uncertainty over their actual cause. Furthermore, hauling impacts will not yet have happened when surveying the gear and so cannot be observed. Similarly, while some impacts may have been caused by previous sets of gear, because these are no longer in situ, their causes cannot be attributed with any certainty.
- When flying the ROV along active gear, care must be taken to avoid snagging with the gear. In addition to this, to ensure in situ impacts are not missed the gear needs to be viewed from all angles. In manoeuvring the ROV to achieve this, it is often flown at various heights and headings around the gear with the camera often positioned at different angles resulting in a constantly changing field of view. Whilst providing a more detailed view of the gear this does not lend itself to providing data that can be quantified and standardised in terms of area. This makes determining the level of impact and scaling up across the site impossible to do with any confidence.
- Analysis of impacts can only be made from the video footage available and not from in situ observation thus is mostly provided through qualitative means rather than quantitative measurements, this means that analysis can be highly subjective. For example, when estimating the size or severity of impacts.

Whilst these limitations restrict the use of the data, the observations made can still help understand more about how potting gears interact with chalk features. For example, ropes typically appear to be raised or floating rather than lying flat on the seabed and appear to only come into contact with features when the features are raised above the height of the rope (Figure 3c). Furthermore, very few pot impacts were observed during in situ surveys, suggesting movement of pots once set is minimal. Greater understanding of how gear behaves in the water can inform the development of gear adaptations that reduce the frequency or severity of interactions (see section 5.1).

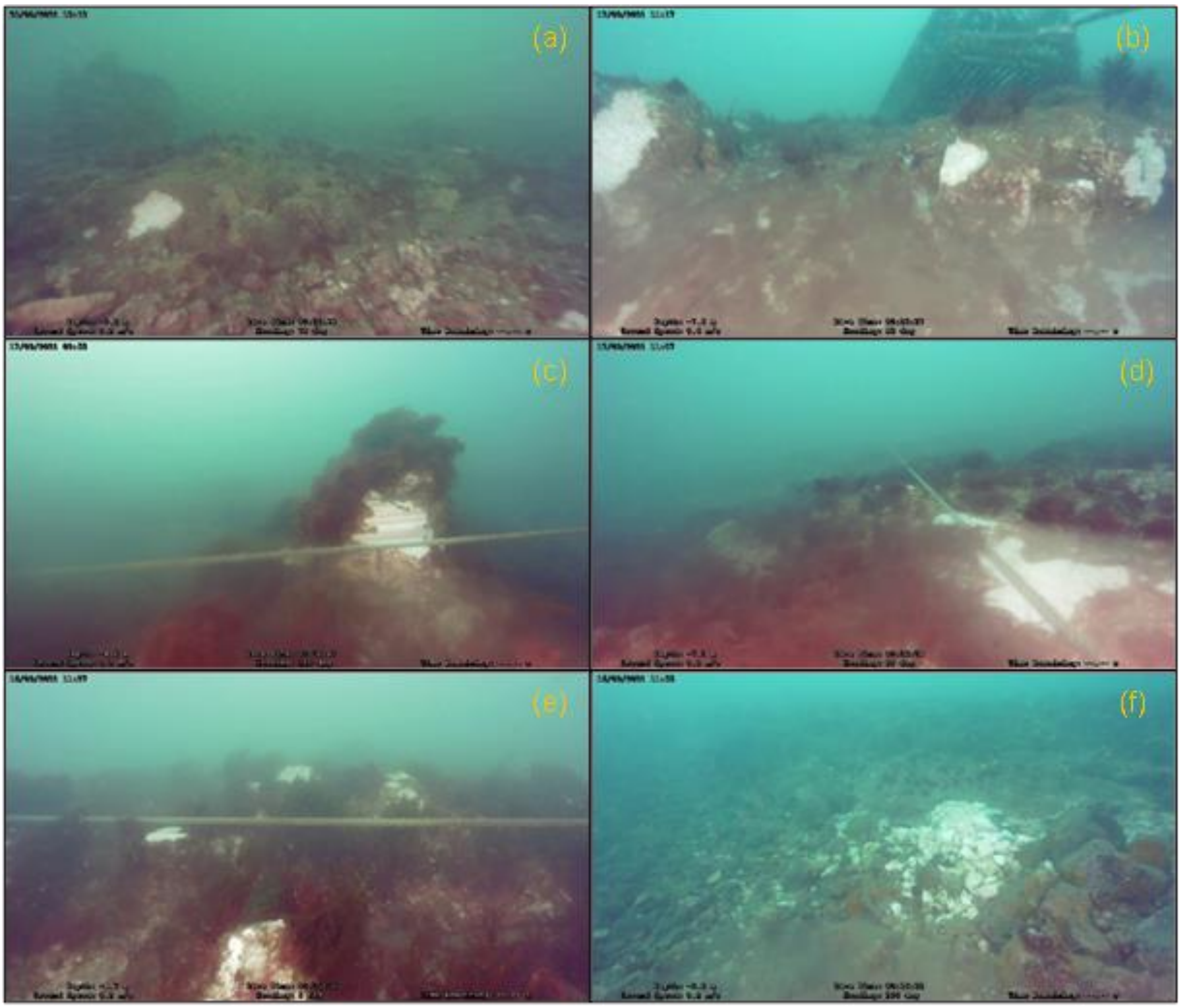


Figure 3 Examples of types of chalk impacts identified as part of the analysis of ROV video footage collected by Eastern IFCA from Cromer Shoal Chalk Beds MCZ in summer 2021: (a) single grating; (b) multiple grates on chalk outcrop with pot in situ; (c) cut on chalk stack; (d) burn; (e) level shear; (f) chalk rubble. Taken from O'Dell and Dewy (2022).

Future work

Analysis of the existing ROV footage is ongoing and once complete will be used to compare the frequency and severity of impacts across chalk habitats of differing rugosity. In addition to directly attributing damage from pots, preliminary analysis of the 2022 data indicates that in lower rugosity "rugged" areas, there are very few instances of visible impacts. If these areas can be mapped, they can be scoped out.

2.3 Natural disturbance study

RQ: How much does potting contribute to the degradation of chalk features and how does this compare to that natural disturbance regimes have?

Background

One of the key questions that needs to be answered to inform an evidence-based assessment of activities is the scale and rate of impact that occurs across the site, to determine if it is at a level which could result in hindering the achievement of Conservation Objectives. Whilst it is known that chalk cannot recover from impacts, and so over time impacts will have cumulative effects, it is also known that the site experiences high levels of natural disturbance from strong wave and tidal currents as well as regular storm surges, which result in significant movements of sediment and larger particles on the seabed, this combined with the soft and friable nature of chalk means erosion and degradation of chalk features is expected naturally. Thus, when assessing the level of impact that results from potting, it is important to also understand the rate at which chalk features degrade naturally, so that the two can be separated from each other.

Approach

To address these questions a comparative study is required to compare the level of disturbance in areas where no potting activity occurs with areas of normal potting activity. Towards the end of summer 2022 the Research and Development T&FG reached out to Blue Marine Foundation (BMF) who have experience and expertise in developing such studies in close collaboration with fisherman, such as the Lyme Bay Potting study (Rees *et al*., 2018). Since these initial conversations were had, the group have been working closely with BMF to explore opportunities and develop a proposal for such a study.

The proposed study will have the overall goal of informing the Adaptive Risk Management process of the impact of potting activity on the chalk reef in relation to natural change and to investigate the importance of raised chalk areas for biodiversity through the following aims:

Aim 1: Determine what is the natural rate of disturbance of chalk features?

Aim 2: Determine what is the rate of disturbance caused by human impacts?

Aim 3: Determine the ecological importance of elevated chalk reef habitats to biodiversity?

The study will seek to answer these questions by monitoring chalk features within fished and closed areas to answer the overall question:

RQ1: Is there an observed difference in chalk disturbance and biodiversity in the exclusion area over time compared to the control area?

The study will test two treatments: *open* (open to fishing) and *closed* (closed to fishing). This will involve monitoring three replicate areas for each treatment over a three-year period. The six experimental areas will be approximately 150m x 150m in size and *closed* areas will include a minimum buffer of 30m to prevent any accidental drift of pots into areas closed to fishing[3]. All experimental treatment areas will:

- Contain well-established, substantial rugged chalk reef complexes (based on current knowledge and available evidence)
- Be exposed to similar environmental conditions (depths, exposure, temp.)
- Be located within or near areas where commercial potting occurs
- Be located in areas where other anthropogenic disturbances are less likely to occur (e.g., diving, anchoring)

Experimental *closed* areas will be closed to all anthropogenic activities on a voluntary basis and so the project must be supported by industry members and recreational users of the site for the study to be a success. Experimental *open* areas will be established in areas of 'normal' fishing pressure, based on current knowledge and available evidence. The identification and orientation of each experimental area will be determined through best available evidence and engagement with local experts and relevant stakeholders. Figure 4 provides a summary of this proposed experimental design.

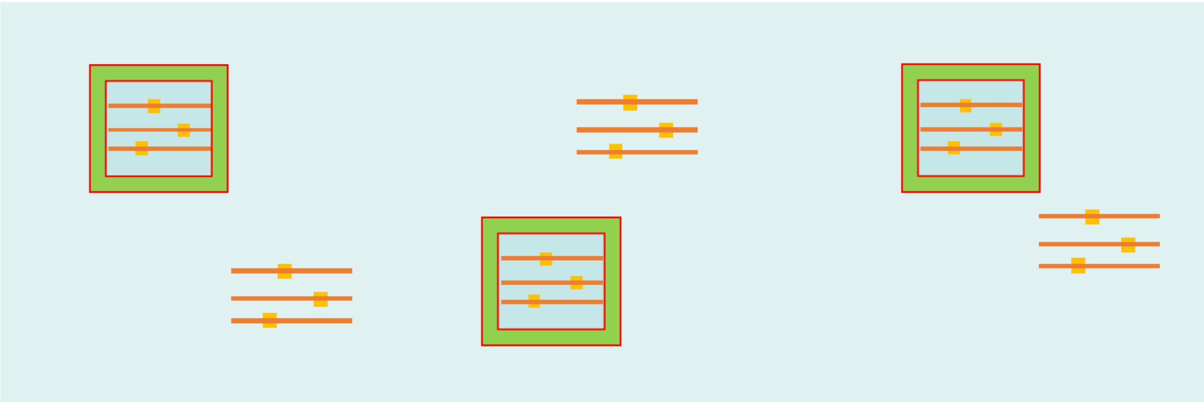


Figure 4 Proposed experimental design, three 150m x150m *closed* areas (outlined in red) with a 30m buffer (green) and three experimental *open* areas (no outline). Each experimental area includes three replicate transects for ROV surveys (orange lines) and three replicate 20m x 20m survey areas for 3D photogrammetry of features (yellow boxes). Blue shaded area represents rugged chalk located with the MCZ, experiencing similar environmental conditions.

Within the experimental areas the following data collection methods are planned to be applied at least once per year:

- Diver feature mapping using 3d photogrammetry to create 3D models of identifiable features of the seabed (e.g., chalk arches, stacks, outcrops) to assess and compare changes to the structure of features over time.
- Seabed video transects using the ROV and/or divers (minimum of 3 replicates) to map impacts, rugosity and assess diversity.

[3] Subject to change if preliminary research suggests a larger buffer is required.

- Seabed mapping using high resolution multibeam to map the rugosity of the seabed.
- Diver surveys using quadrats to assess micro and macro habitat diversity and to collect chalk samples for eDNA analysis.

Progress so far

An industry meeting organised by Blue Marine Foundation was held on the 14th February to discuss the proposed work with members to see if they would be supportive of such a project. The meeting was positive and received a high turnout from industry with over 20 fishermen attending and providing virtually unanimous support for the project. Using available data sources, Eastern IFCA officers have identified areas within the MCZ which fulfil the criteria set out above and would be suitable for the study. These areas were shared with industry members at the meeting on the 14th February to seek feedback on their positioning in terms of practicality, suitability and the potential impact on potting activities. The general consensus from the members attending the meeting was that the three closed areas should be spread out to lessen the impact on individual fishermen. Other feedback received suggested that buoys (as well as positional coordinates) will be the best way to mark the closed areas.

The proposed areas have also been shared with other recreational users and the Evidence Review Group who have provided further feedback. This includes the suggestion that 30m buffers may not be sufficient in allowing for pot drift. The T&FG are currently investigating this further to ensure an appropriate buffer is applied.

Future work

Whilst the group are in the process of developing a final proposal and costing the project, one key challenge that remains is addressing issues around fishermen and recreational users locating closed areas as it is understood that a proportion of the fishing fleet do not carry plotters onboard their vessels (many are small open skiffs). The group is currently investigating several different solutions to this challenge which include:

- Using marker buoys
- Providing fishermen who do not have plotters, either hand-held GPS devices or licences to use map applications on their smart phones
- Identifying transit bearings from markers on land that can be used for positioning

If a practical solution cannot be found an alternative proposal may need to be considered whereby the three experimental closed areas are positioned next to each other in one large closure that extends from the northerly limit of the rugged chalk to the shore, making it easier to mark. Whilst this option is more logistically practical and still considered robust, in terms of the experimental design, it is not a preferred option because of the potential for significant impact on individual fishermen and the subsequent loss of support on industry.

The next few months will focus on addressing this issue, determining an appropriate buffer, identifying funding sources and planning for area identification and baseline surveys to be completed in Summer 2023. The group are also exploring opportunities for the project to be run as a PhD led by the University of Essex. Whilst Eastern IFCA will provide an overall co-ordinating role, the project will be a collaborative effort with industry and partner organisations that sit on the T&FG, as well as receiving support form Blue Marine Foundation.

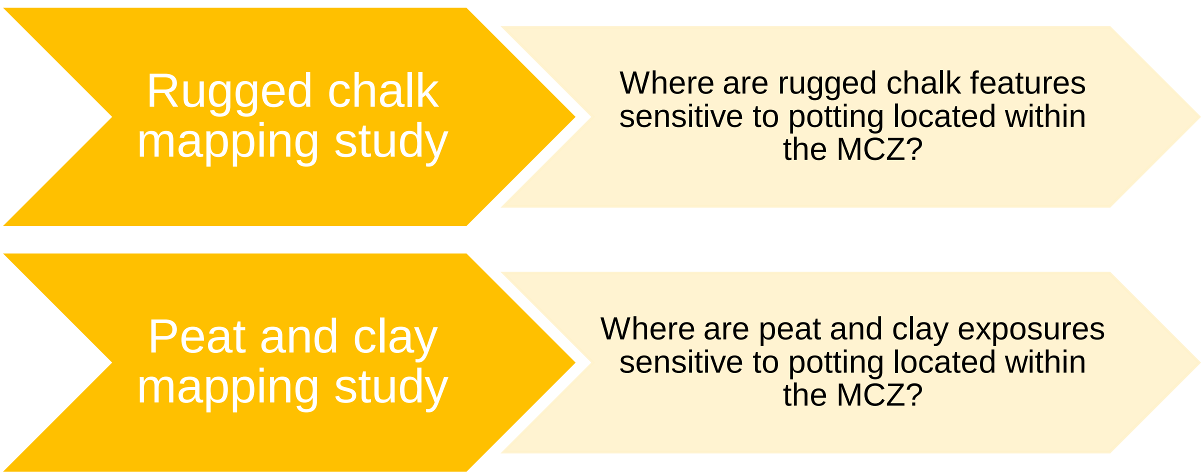
The project will form one of the main focuses of the group over the next four years and resource may have to be prioritised over other lower priority workstreams to ensure the project runs successfully. This reflects the importance of this work in providing us with the answers to better understanding the interaction between potting activities and rugged chalk features and, subsequently, informing ARM.

3 Mapping sensitive features

The MCZ supports a variety of seabed features including shallow and deeper rocky seabed, subtidal chalk, coarse, mixed and sandy sediments, and peat and clay exposures. The subtidal chalk feature includes flat bedrock, pebbles, cobbles and boulders, gullies and more prominent raised, rugged structures. The Phase I study identified that some of these features are more susceptible to damage from fishing gear than others, with three chalk bed sites showing numerous occurrences of low, medium and severe damage, in comparison to one chalk/ flint cobble plain site where no damage was observed during the study (Tibbitt *et al*., 2020). As the different types of chalk feature present within the site are likely to impacted differently by the various components of the fishing gear used, effective management will require understanding the sensitivities of the different features to the gear and knowing where these features are located.

The Research and Development T&FG have developed the below projects as part of this workstream to answer the corresponding research questions, each aimed at understanding the extent and location of sensitive features across the site to inform any spatial mitigation required and to assess the level of impact across the site.

Whilst Eastern IFCA's latest assessment did not conclude that potting activities posed a significant risk to peat and clay exposures, conservation advice provided to Eastern IFCA by Natural England in November 2018 and January 2023 states that peat and clay exposures (also a designated feature of the site) should be managed in an equivalent manner to chalk due to their inability to structurally recover from damage. To address the uncertainties around impacts to peat and clay exposures, mapping the extent of non-rugged and rugged forms of the features has been included in this workstream so that the same management approach can be applied.



3.1 Rugged chalk mapping study

RQ: Where are rugged chalk features sensitive to potting located within the MCZ?

Background

In 2020 officers completed a desk-based study which identified all available evidence sources that provided information on the extent of rugged chalk features within the MCZ. After analysing available data, officers were able to identify a preliminary and precautionary area to be considered as rugged chalk (Figure 5).

Since completing the review in December 2020, several additional evidence sources have become available that can be used to improve our understanding as to the extent of the rugged chalk features. It is considered appropriate, therefore, to review the preliminary rugged chalk area, considering this new evidence. However, it is important to note that this review will not provide a final rugged chalk extent, but will form part of an ongoing process to improve our knowledge of its extent. As we continue with ARM and collect, or obtain, further data and evidence we will continue to review and update the rugged chalk extent to reflect best available evidence.

Additional data sources used to form this review have come from a variety of sources and have largely been identified or developed through the Research and Development T&FG or the Evidence Review Group which sits within the Stakeholder Group.

Approach

Table 2 provides a list of data sources used in this review and summarises the processing and analysis undertaken by Eastern IFCA. Chalk categories used during analysis are detailed in Table 3. Data used in this review is presented in Figure 6.

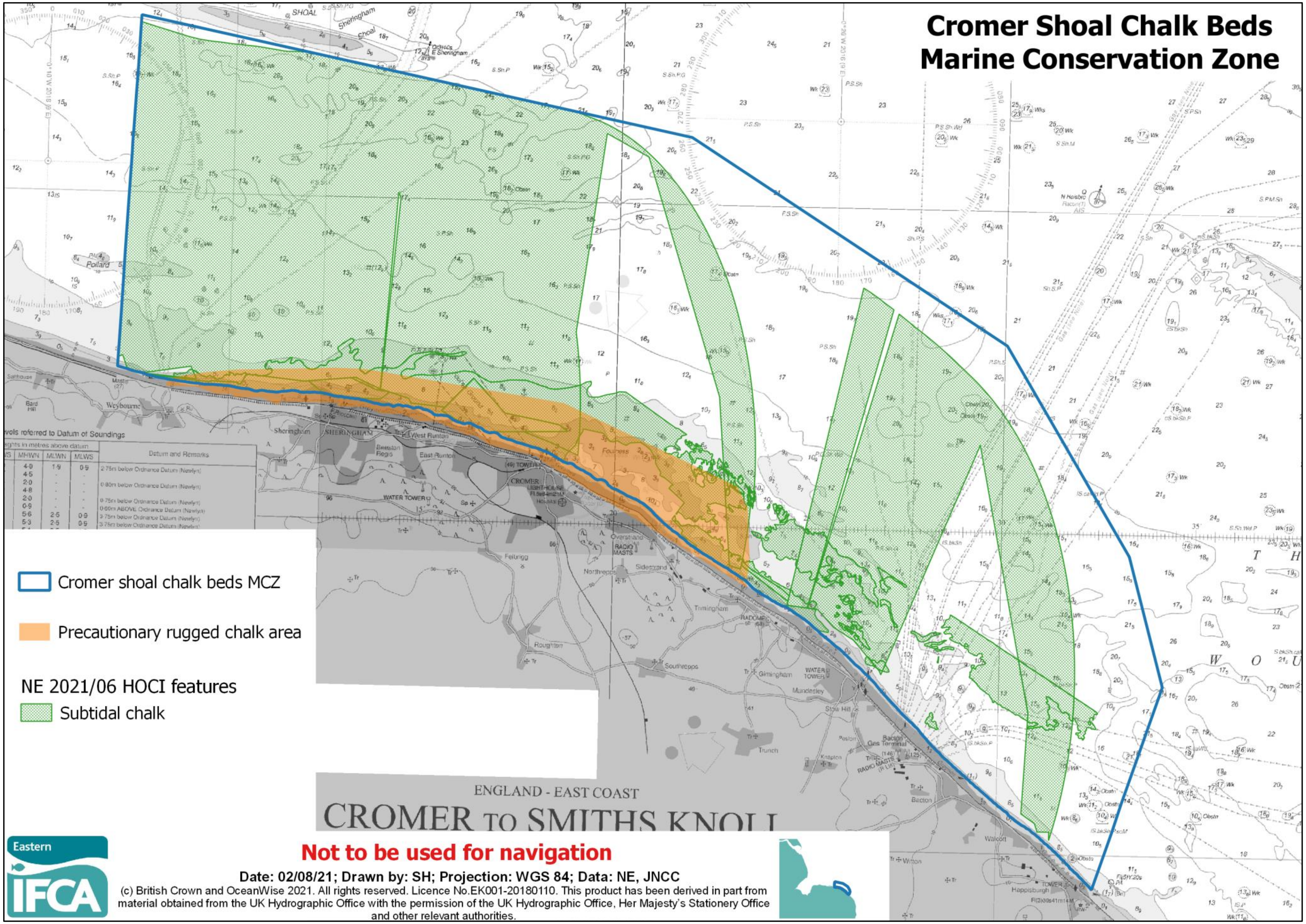


Figure 5 Chart showing preliminary rugged chalk area identified after the review of habitat data completed in 2020

Table 2 Summary of data sources used to review rugged chalk area

Source	Date	Processing, analysis and incorporation of data	Link/reference to data
Sources used in 2020 review			
Cefas Cromer Shoal Chalk Beds rMCZ survey	August 2014	1) Identified stations identified as A3 or A4 rock features in area of interest using NE Broad Scale Habitat feature point data (2020_04 data release). This came to a total of 18 stations[4]. 2) For each of these stations the raw data was obtained. Stills for each station were analysed and assigned a chalk category (Table 3) with an associated confidence level (where confidence was low a precautionary assessment was made) and a station assessment sheet was completed detailing the observations and assessment made. 3) Start and end positions for each station tow were mapped and colour coded according to chalk category.	https://data.cefas.co.uk/view/3823 Station assessment sheets provided in Appendix 1 of original document.
Eastern IFCA Cromer Shoal Chalk Beds MCZ drop down camera survey	May 2019	1) Drop down video camera surveys completed within the MCZ across a total of 17 stations. 2) For each of these stations video footage was analysed and assigned a chalk category (Table 3) with an associated confidence level (where confidence was low a precautionary assessment was made) and a station assessment sheet completed. 3) Positions for each drop were mapped and colour coded according to chalk category.	Not yet published Station assessment sheets provided in Appendix 2 of original document.

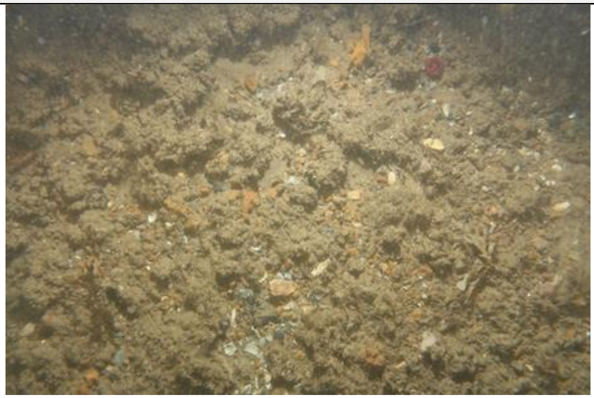
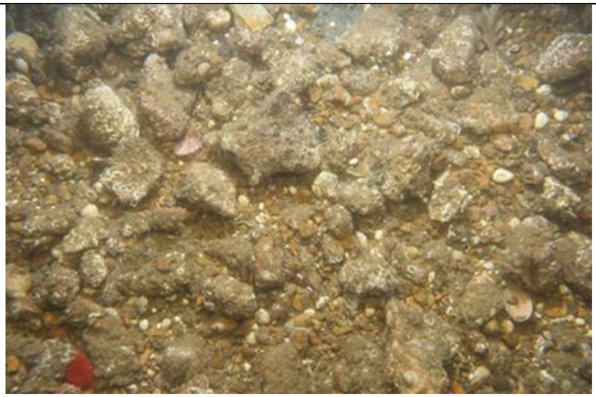
[4] Station numbers: 11, 12, 38, 39, 30, 32, 56, 60, 43, 44, 6, 10, 64, 4, 5, 16, 28, 17

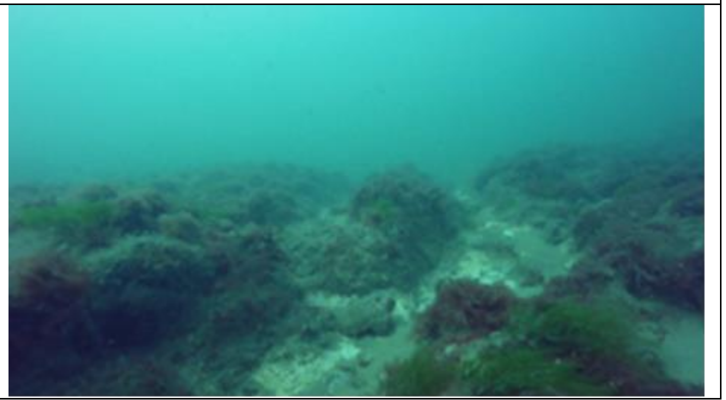
EA Cromer Shoal Chalk Beds MCZ survey	October 2019	1) A total of 30 stations [5]were surveyed by the EA. Identified 20 stations of interest based on whether they overlapped or were adjacent to the NE A4 Circalittoral rock extent (2020_04 data release). 2) For each of these stations, identified and analysed video and stills and completed a station assessment sheet and assigned a chalk category (Table 3) and confidence level (where confidence was low a precautionary assessment was made). 3) Start and end positions for each tow were mapped and colour coded according to chalk category.	Not yet published Station assessment sheets provided in Appendix 3[6]
Bathymetry data (Cefas)	2012	No further analysis by Eastern IFCA, tiff. files imported and used to inform rugged chalk extent review. Data not presented here.	https://data.cefas.co.uk/view/3330
Bathymetry data (EA)	2011 and 2017	No further analysis by Eastern IFCA, tiff. files imported and used to inform rugged chalk extent review.	https://environment.data.gov.uk/DefraDataDownload/?Mode=survey&fbclid=IwAR2XIk-tFvjwjzh3dVP7ZL8lfaaMccSl5uW8g9mumGoXqs27KQfp9pWaOaw

[5] Station numbers: 27, 11, 10, 8, 9, 7, 28, 6, 29, 12, 13, 14, 5, 30, 4, 15, 16, 21, 3, 26.
[6] Available at: T:\D_Research\WSXX_Habitat_Mapping \2020_Habitat_Mapping\2019_EA_ CSCB_MCZ_survey\Station sheets

Additional sources used in this review (2022)			
Cefas reanalysis of multibeam data Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) Bathymetric Re-gridding and Rugosity Assessment.	2011, 2012, 2014 and 2017 (Reanalysis completed in 2021)	1) Four bathymetric datasets re-gridded to 0.5m resolution by Cefas and assessed by rugosity 2) Tiff. files imported and used to inform rugged chalk extent review.	Hawes and Pettafor (2021)
NE Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) Dive survey	2020	1) Positional data mapped and colour coded according to chalk category based on description provided in report. (Data not presented here for sensitivity reasons).	Tibbitt *et al*. (2020) - Available on our website: https://www.eastern-ifca.gov.uk/wp-content/uploads/2020/10/D2020-00111615-NERR-Human-Impacts-on-the-Cromer-Shoal-Chalk-Beds-MCZ.pdf
Eastern IFCA Cromer Shoal Chalk Beds MCZ ROV surveys	August/September 2021	1) A total of 87 ROV surveys completed within the MCZ whilst trialling the ROV to look at habitats and interaction with potting gears. 2) Analysis contracted out and completed by Seastar Survey Ltd. 3) Positional data for each drop were mapped and colour coded according to chalk category (Table 3).	O'Dell and Dewey (2022) - Available on our website: https://www.eastern-ifca.gov.uk/wp-content/uploads/2022/07/2022-Cromer-Shoal-Chalk-Beds-MCZ-Imagery-Analysis.pdf Videos available on Biigle.
Seasearch Dive (2022)	2022	1) Provided georeferenced data assigned a chalk category (Table 3) and mapped.	Not yet published or publicly available

Table 3: Chalk categories assigned to seabed imagery

Category	Description	Examples	
Absent	Chalk not observed/mobile sediment		
Pebble/cobble	Seabed predominantly made up of pebble/cobble (likely chalk or flint)		

Chalk pavement	Flat chalk pavement/ veneered chalk observed		
Rugged chalk	Elevated and complex chalk features observed		

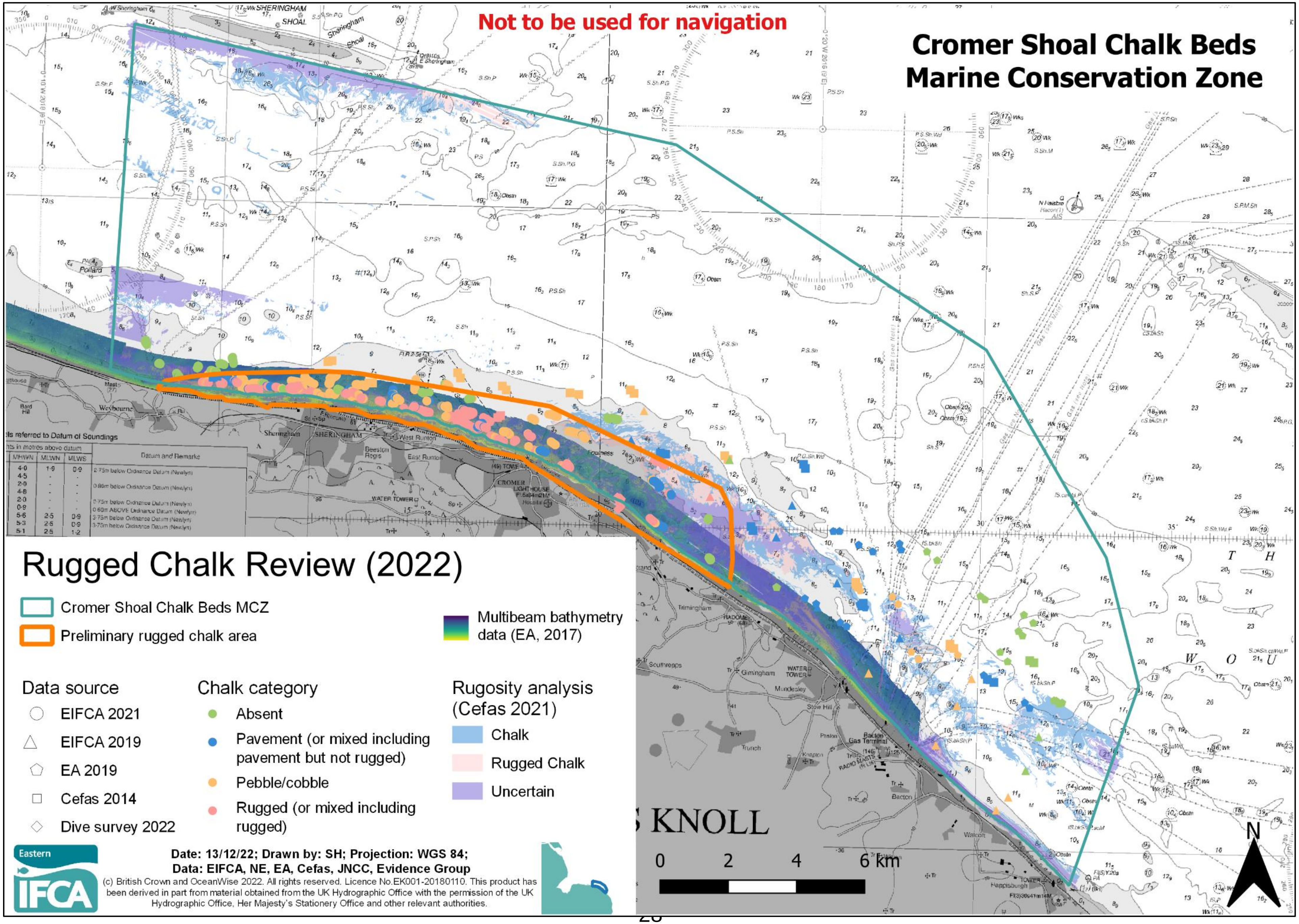


Figure 6 Chart showing preliminary rugged chalk area identified after the review of habitat data completed in 2020 and data sources used to inform 2022 review

Progress so far

All additional and existing data sources were plotted in QGIS 3.16.4 (Figure 6), reviewed and a proposed rugged chalk area drawn based on these data along with expert judgement (Figure 7). Precautionarily, areas have remained in the proposed rugged area where their data is limited, causing uncertainty in determining the ruggedness of the seabed.

The evidence suggests that the structure of the seabed is not uniform throughout and that patches of flatter seabed do exist within rugged features, forming a mosaic of chalk habitat types in places. Managing rugged chalk at a feature level would not be possible, so mapping individual rugged chalk features is not considered necessary for fishery management purposes. As mapping the extent of the rugged chalk is considered more appropriate to inform any spatial management required for the potting fishery, this review focused on identifying the extent of the rugged chalk.

The most rugged areas of seabed appear to occur very close inshore between Weybourne and Cromer (up to 500m from shore), particularly around Sheringham and West and East Runton. Here, raised chalk outcrops typically form ridges interspersed with gullies running north-south, composed of coarse sediment, flat chalk pavement with a sediment veneer, or pebbles and cobbles. These rugged features can be seen clearly on EIFCA's ROV footage (2021) (O'Dell and Dewey, 2022), dive footage (Tibbitt *et al.*, 2020) and are also visible on the available multibeam data (EA, 2017). Beyond this inshore strip of rugged chalk, the seabed appears to reduce in rugosity and instead forms a relatively flat, and mostly flint, pebble and cobble plain, with the occasional boulder. Again, these observations made from ROV footage (O'Dell and Dewey, 2022) support the multibeam imagery where data are available. These observations are also consistent with the anecdotal information provided by local fishermen and divers.

East of Cromer, the inshore strip of rugged chalk appears to narrow, disappearing altogether just past Overstrand as a deeper channel runs parallel to shore, visible from the available multibeam data (EA, 2017). However, seabed imagery data is limited in this area, and as we only have multibeam data out to 1km from shore the available habitat data beyond this is very limited overall. Cefas's rugosity analysis (Hawes and Pettafor, 2021), using a variety of multibeam data sets, indicates there is another area of rugged ground roughly between Cromer and Trimmingham, between 1 to 2 km offshore, however this does appear to be patchy and largely interspersed with flatter areas. This area has been included in the 2022 proposed rugged chalk area on a precautionary basis, as we cannot yet be confident that this area is not rugged chalk. Eastern IFCA's 2022 habitat surveys have targeted this area to fill in these data gaps and preliminary observations of footage suggest that raised outcropping features do occur in this area but that they are typically of relatively low relief and frequency, forming a less rugged habitat than that observed inshore. This data is currently undergoing analysis and will be considered in the next review.

Outside of these areas, an area off Overstrand and an area off Trimmingam has also been included in the 2022 proposed rugged chalk area. This is because both ROV footage, multibeam data and rugosity analysis indicate raised rugged chalk outcrops.

Other areas identified as rugged chalk by the rugosity analysis, however, have not been included in the proposed rugged chalk areas as other evidence suggests that whilst they may indicate a rugose seabed this is not rugged chalk. For example, rugged areas identified off Bacton appear to lie along pipelines and areas north of the MCZ boundary have subsequently been identified as sand waves.

Whilst all of the datasets have been used when reviewing this proposed 2022 rugged chalk area, they each have their limitations and have been reviewed considering these. Limitations for each of the data sources are set out in Table 4.

Table 4: Limitations of data sources used to review rugged chalk area

Data source	Limitations
Cefas Cromer Shoal Chalk Beds rMCZ survey	• Assessment made using stills which makes it hard to determine the overall structure of the seabed if taken too close to seabed. • Size of rock features cannot be quantified and can only be estimated. • Data collected in 2014
Eastern IFCA Cromer Shoal Chalk Beds MCZ drop down camera survey	• Size of rock features cannot be quantified and can only be estimated. • Data collected in 2019
EA Cromer Shoal Chalk Beds MCZ survey	• Assessment made using stills which make it hard to determine the overall structure of the seabed if taken close to seabed. • Size of rock features cannot be quantified and can only be estimated. • Data collected in 2019
Bathymetry (multibeam) data (Cefas)	• Data is limited in area. • Data collected in 2014
Bathymetry (multibeam) data (EA)	• Data is limited to within 1km from the shore. Data collected in 2017
Cefas reanalysis of multibeam data Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) Bathymetric Re-gridding and Rugosity Assessment.	• Rugosity analysis has not been ground truthed and so must be considered with caution. • Areas identified as rugged could indicate areas of seabed with lots of small changes in relief such as a pebble/cobble dominated seabed as well as areas with fewer large changes in relief likely to reflect rugged chalk outcrops.
NE Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) Dive survey	• Positional data mapped at the start and end of dives (not shown in this report for sensitivity reasons)
Eastern IFCA Cromer Shoal Chalk Beds MCZ ROV surveys	• Size of rock features cannot be quantified and can only be estimated. • Accuracy of positional data is low and up to ±100m at times
Seasearch Dive (2022)	• Positional data collected using a floating GPS

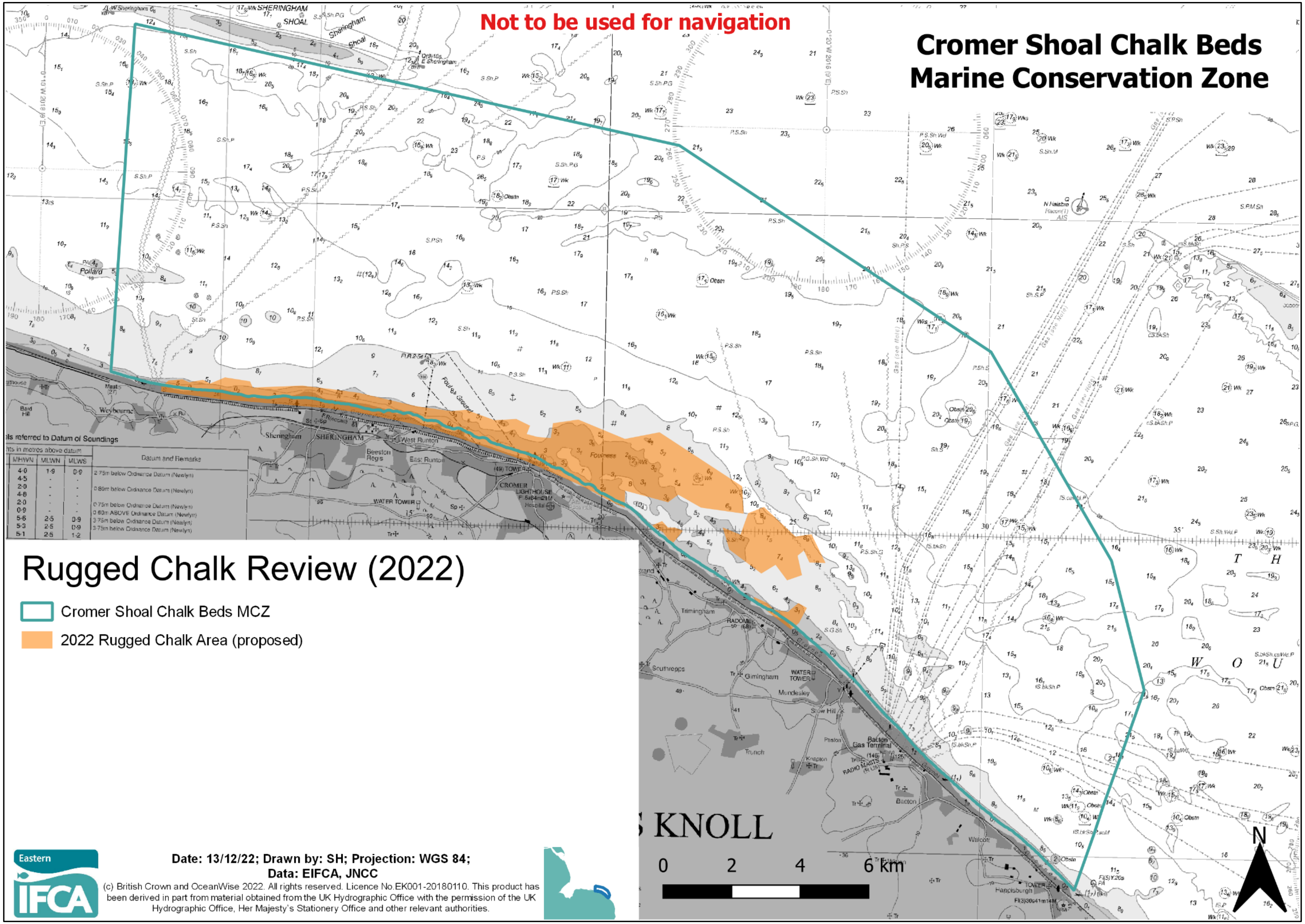


Figure 7 Chart showing proposed rugged chalk area identified after the review of habitat data completed in 2022

Future work

Eastern IFCA have completed a further 177 ROV dives in the MCZ in 2022 which provide further habitat data (2022 planned stations are shown in Figure 8). These dives have been targeted to fill in data gaps and to ground truth rugosity data. As the ROV footage from these stations are currently being analysed by external contractors, they have not been considered in this review but will be used to inform future reviews. ROV dives completed in 2022 collected altimetry data in addition to seabed video footage. This will allow high-resolution seabed rugosity profiles to be created and provide quantitative data to support visual imagery and multibeam data.

Since completing this review further sources of habitat data have been made available. These include an augment dataset and mapping project of Seaseach dives which provides spatial data on where chalk habitats have been observed during dives (North Sea Wildlife Trust and Seasearch East, 2021) and a study commissioned by Natural England which uses Seasearch data and local knowledge to improve our understanding of spatial distribution of habitats and structural features, taxonomic diversity and presence of associations between species and structural features (Jackson *et al.,* 2022) . Spatial information on habitats provided in both of these studies will be incorporated into the next iteration of rugged chalk review.

The 2022 Rugged Chalk Review (Hormbrey, 2023) is available online and includes appendices detailing the data sources used and additional charts for references.

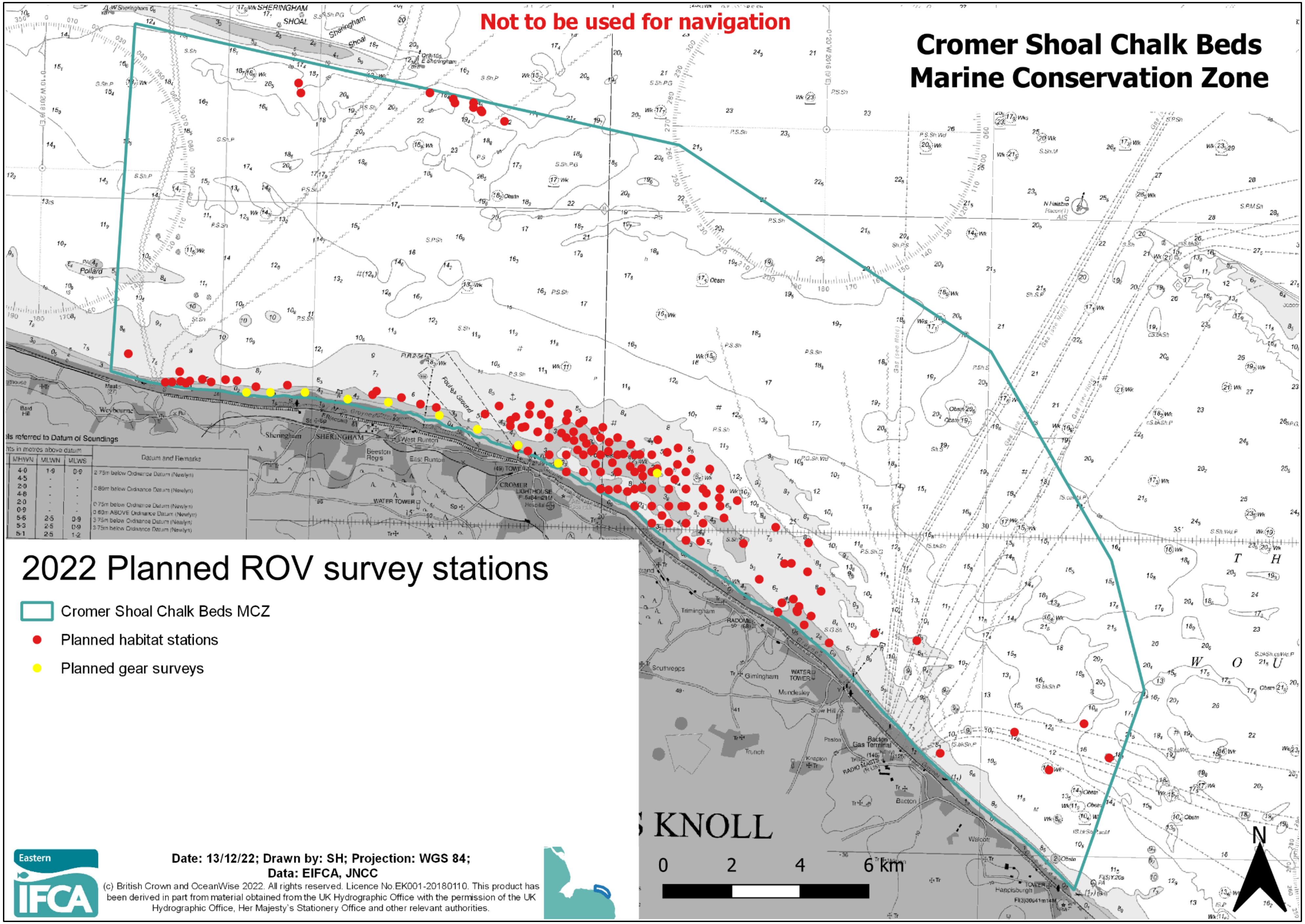


Figure 8 Chart showing stations targeted using the ROV during 2022 to complete habitat (red) and in situ gear (yellow) surveys

3.2 Peat and Clay mapping study

RQ: Where are peat and clay exposures sensitive to potting located within the MCZ?

There are believed to be several small areas of peat and clay habitat within the MCZ, although their location and extent require verification (Figure 9). Conservation advice provided to Eastern IFCA by Natural England in November 2018 and January 2023 states that peat and clay exposures (also a designated feature of the site) should be managed in an equivalent manner to chalk due to their inability to structurally recover from damage. In line with this advice, Eastern IFCA will consider flat and rugged forms of the feature separately. Further work is required to differentiate between the two forms and map areas where rugged forms, which are considered more sensitive, exist. As with rugged chalk, where data on the structure of exposures is limited, exposures will be precautionarily assessed as rugged.

Up until now the Research and Development T&FG have prioritised mapping rugged chalk habitats and little progress has been made on the mapping rugged peat and clay exposures. However, Eastern IFCA aim to start surveying peat and clay exposures as part of the 2023 survey programme so work on this project can start progressing.

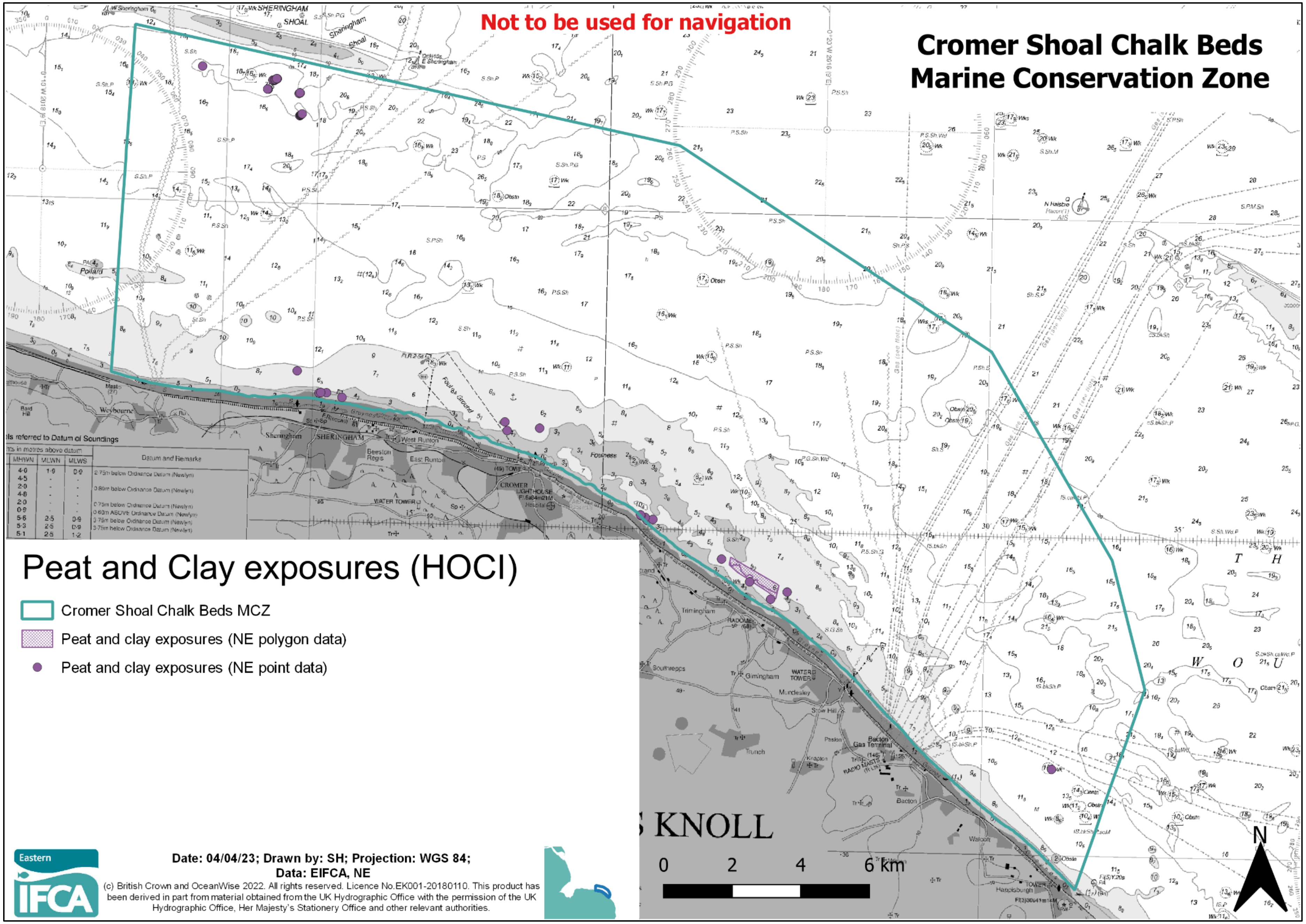


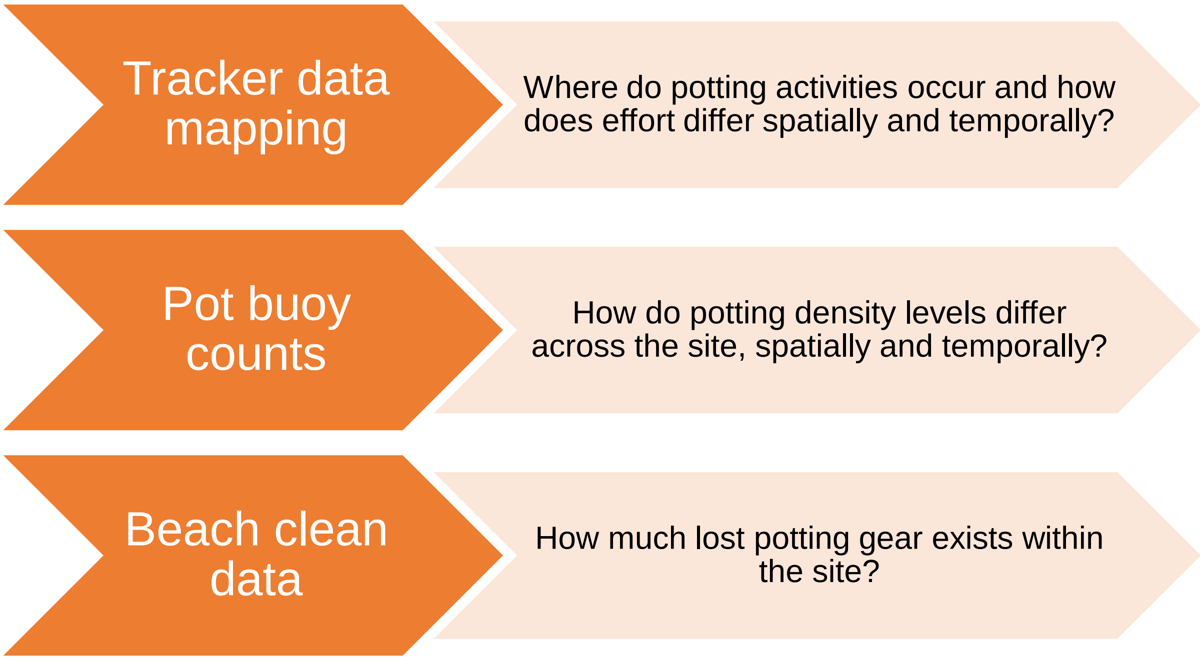
Figure 9 NE feature extent data (June 2021) for HOCI: Peat and Clay exposures within Cromer Shoal Chalk Beds MCZ

4 Mapping fishing activities

Understanding and mapping potting effort is fundamental for informing and refining Eastern IFCA's assessment of potting activities and in supporting the development of management measures through ARM. This is particularly important for the North Norfolk crab and lobster potting fishery, which occurs almost entirely within the MCZ and, anecdotally, is known to overlap predominantly with areas where designated subtidal chalk features outcrop and form rugged structures. These rugged features are known to provide structural complexity to the site (Moffat, 2019) and are considered most sensitive to interactions with potting gears (Seasearch, 2018; Tibbitt *et al*., 2020).

The Research and Development T&FG and the Evidence Review Group (which sits within the Stakeholder Group) have developed the below projects as part of this workstream to answer the corresponding key research question. These questions have the aim of determining the concentration of potting effort, and understanding spatial and temporal patterns to inform quantitative assessments which can measure impact against conservation targets.

Mapping activities will also allow Eastern IFCA to make inferences and predictions about the potential impacts of proposed management measures and determine how local fishermen may be affected. Furthermore, by mapping the potting activity, spatial management techniques can have more information feeding them and therefore allow more informed decisions to be taken.



4.1 Tracker data mapping

RQ: Where do potting activities occur and how does effort differ spatially and temporally?

Background

The local crab and lobster industry have historically recorded details of their fishing activities to the Marine Management Organisation (MMO) using Monthly Shellfish Activity Returns (MSAR) forms, which the MMO have recently replaced with an electronic data recording system. While these returns forms provide details of catches landed and the number of pots deployed, the spatial information required in them is only to the scale of ICES Statistical Sub-rectangles. This level of spatial granularity is insufficient to accurately determine which activities are occurring within the MCZ, let alone specifically on the rugged chalk parts of it. The Authority, therefore, has developed a two-pronged approach for obtaining higher resolution spatial information about potting activities within the MCZ. The first has involved consulting with local fishermen, both with face-to-face interviews and a formal consultation questionnaire to ascertain details of where they target their potting activities and how many pots they deploy etc. The second approach uses devices which provide GPS positions at regular intervals, similar to Vessel Monitoring Sytems (VMS), allowing the spatial activities of fishing vessels to be tracked.

Approach

Image 3 Magnetic tracker used by volunteer fishermen to monitor position, speed and direction. £1 coin for scale.

Eastern IFCA have been working closely with the local potting community to gather evidence of activity throughout the MCZ by utilising small magnetic vehicle trackers (Image 3). This project started in June 2021 with one volunteer but has since grown to 14 volunteers who have agreed to place one of these trackers on their vessel. This equates to roughly between one third to a half of the fleet, Table 5). There are multiple ports throughout the MCZ which are utilised by fishermen, however Cromer is the most prevalent home port among volunteers with 57% of all volunteers being based there (Table 5). The trackers submit GPS positions (known as “pings”) at regular intervals allowing Eastern IFCA to plot the route they are taking. In addition to location data, these pings also transmit information on speed and direction.

Based on knowledge of potting techniques gathered by Eastern IFCA officers’ conversations with fishermen, we can eliminate the pings from when the vessels were simply traveling, keeping only those submitted when the vessel was hauling or setting pots. This is achieved by accounting for the typical speed utilised by fishermen when setting and hauling pots and the heading of the vessel during the activity. Vessels typically haul and set pots parallel to the shore, so by filtering for a range of bearings to encompass these vectors (45˚- 135˚ and 225˚- 315˚) we can remove pings which are likely not during crab and lobster potting activity, such as travelling or potting for whelk (typically done along a N-S bearing). We can filter further by speed. As vessels set and haul pots typically at speeds of 0.5-6knts, by removing pings outside of this range, we eliminate pings which are likely other activities such as travelling (Figure 9). This means we can accurately plot fishing activity inside the MCZ using GIS software.

Table 5 The location of volunteers carrying trackers within the MCZ and the proportions at each port and within the entire MCZ.

Port	Total Number of Vessels at Port (known to pot in MCZ)	Number of Vessels at Port with Trackers	Percentage of Vessels with Trackers at Port	Percentage of Vessels in MCZ operating from Port	Percentage of Volunteers at Port from entire MCZ
Cley-next-the-Sea	3	0	0.00	9.38	0.00
Cromer	14	8	57.14	43.75	57.14
East Runton	3	1	33.33	9.38	7.14
Morston/Blakeney	1	0	0.00	3.13	0
Mundesley	1	1	100.00	3.13	7.14
Overstrand	2	1	50.00	6.25	7.14
Sea Palling	2	2	100.00	6.25	14.29
Sheringham	2	0	0.00	6.25	0
Wells-next-the-Sea	1	0	0.00	3.13	0
West Runton	2	0	0.00	6.25	0
Weybourne	1	1	100.00	3.13	7.14
Total	32	14		[redacted]	43.75

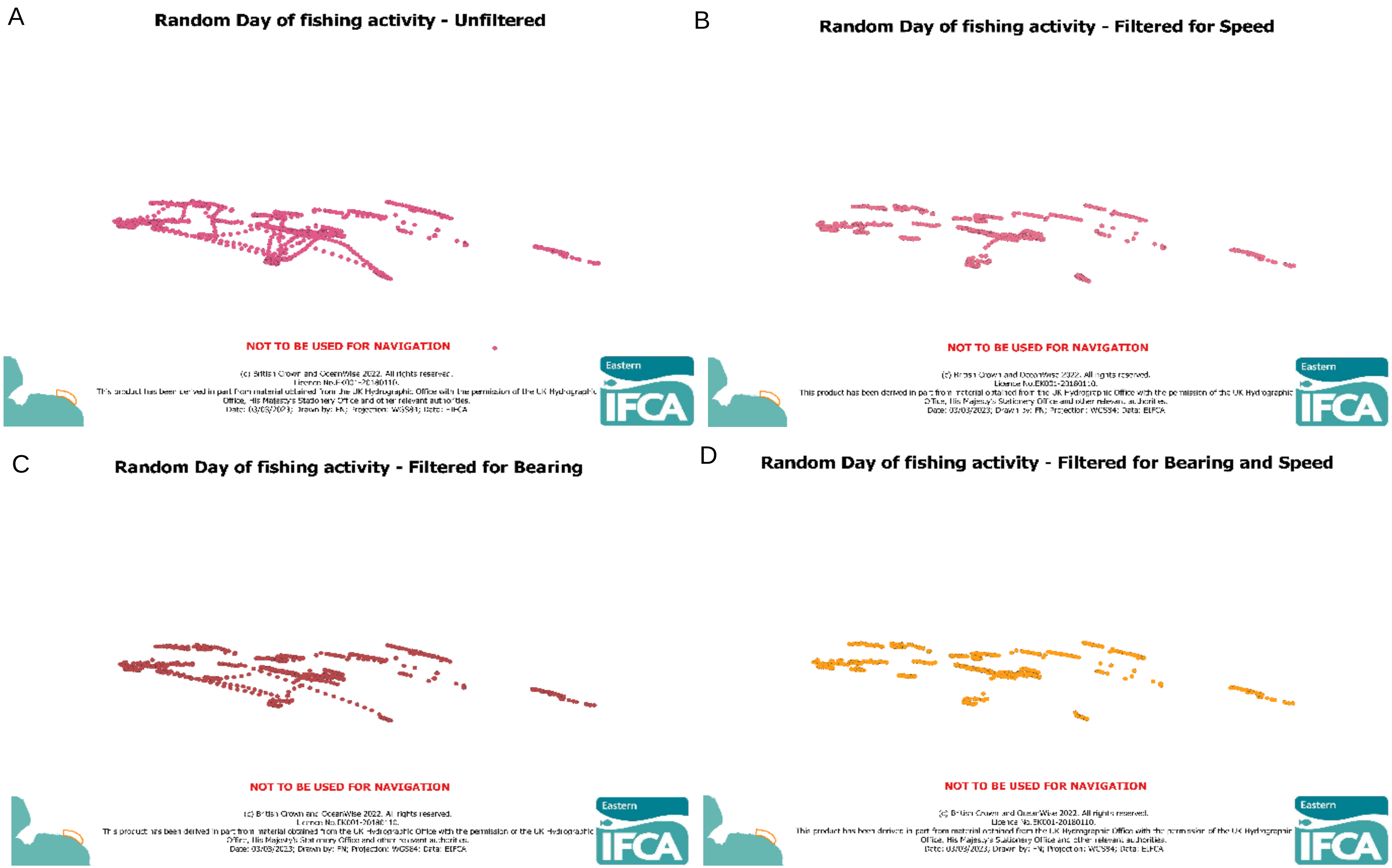


Figure 10 The process of filtering GPS ping data to remove noise and show only fishing activity. A = Initial data: Unfiltered GPS data, B = Intermediate Data: Filtered only for Speed, C = Intermediate Data = filtered only for Bearing, D = Processed data: only fishing data (filtered for Speed and Bearing).

Progress so far

Now the trackers have been running since June 2021, Eastern IFCA hold a full year's worth of fishing activity data. This has allowed officers to start analysing the data spatially, highlighting activity hotspots within the MCZ (Figure 11), but also temporally, by looking at seasonal changes throughout the year of 2022 (Figure 12 and 13). To help this analysis, the MCZ has been divided into a grid of cells of equal 100m x 100m areas. The number of pings inside each grid cell have been counted and used to calculate the percentage value from the total number of pings. It appears that fishing activity is most concentrated around the very inshore waters between Sheringham and Cromer (within 1nm) and slightly further out between Cromer and Overstrand (between 1-2nm) (Figure 11-13). This is likely due to the type of the vessels used in the fishery, being small and beach launched meaning they are limited by both their range and the types of weather they are able to handle safely. As such, it is intuitive that the levels of fishing activity decline as the distance from key fishing ports increases. Areas further offshore are likely only reliably accessible by larger vessels. What is maybe slightly unexpected is that the proportion of fishing activity adjacent to Cromer declines during the peak season months of April-October. However, this period would also be less likely to be subjected to adverse weather conditions which may pin the smaller vessels close to the beach launch site. With these better conditions, vessels may be more able to fish in more grounds than the colder months. Alternatively, a higher proportion of the gear is being set outside of the rugged areas during the months of Jan-March, when stormy weather is more likely to damage pots deployed on rugged ground.

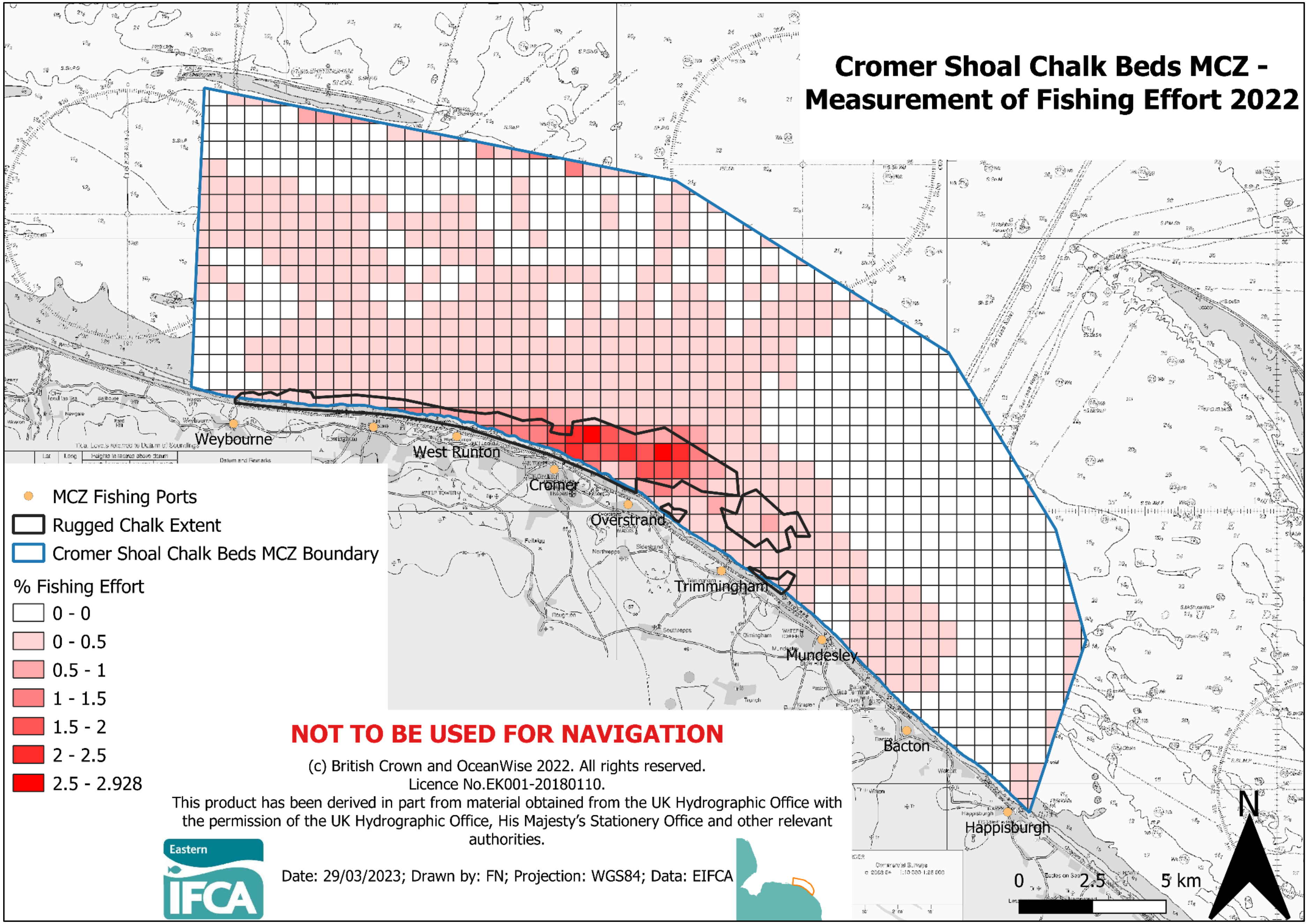


Figure 11 Chart showing the percentage of pings (filtered for speed and bearing) received in the Cromer Shoal Chalk Beds MCZ from trackers voluntary used by fishermen within each 100mx100m grid cell for 2022. Rugged chalk extent outlined in black.

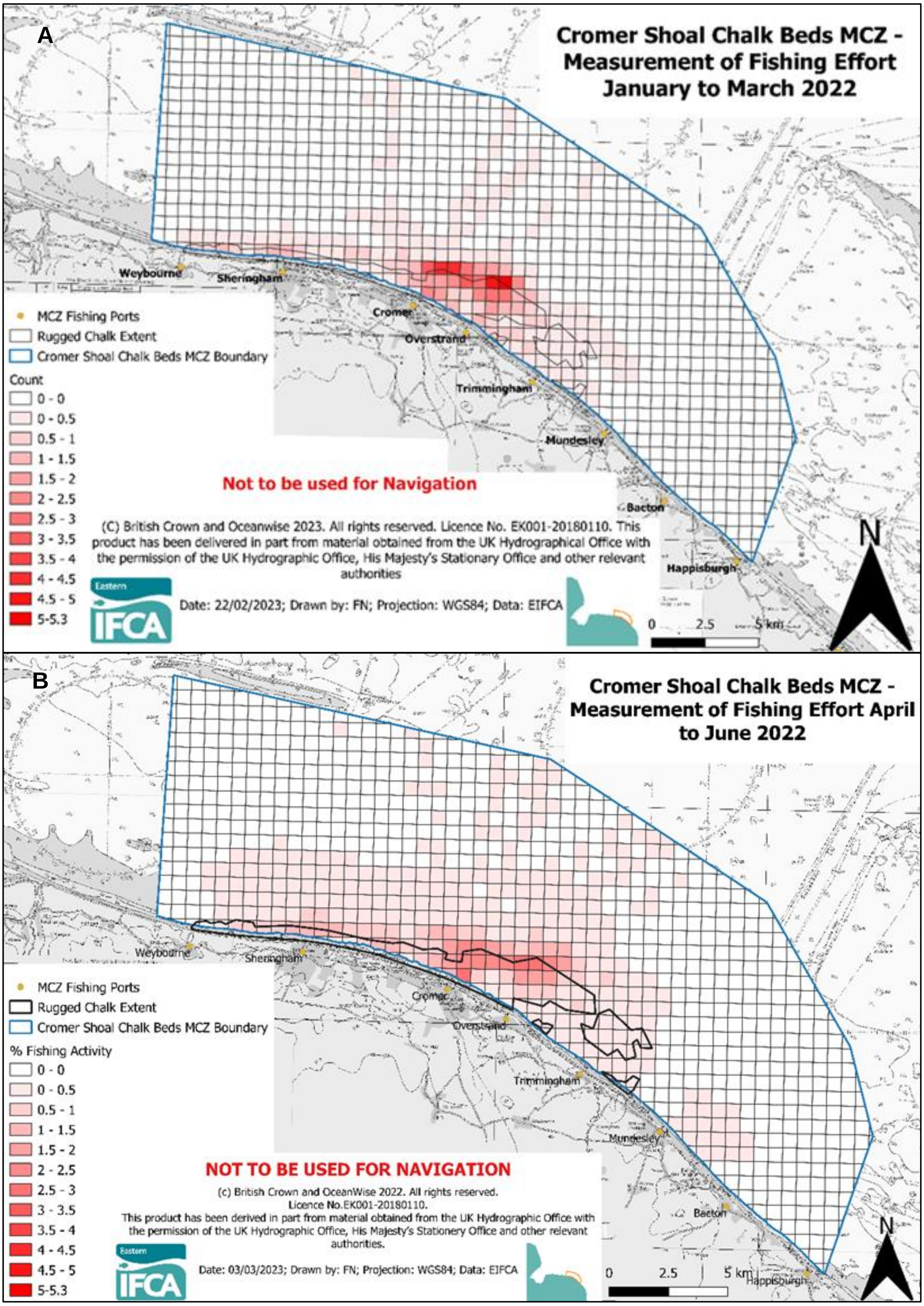


Figure 12 The percentage of pings (filtered for speed and bearing) received in the Cromer Shoal Chalk Beds MCZ from trackers voluntary used by fishermen within each 100mx100m grid cell for the months January to March (A), April to June (B) 2022. Rugged chalk extent outlined in black.

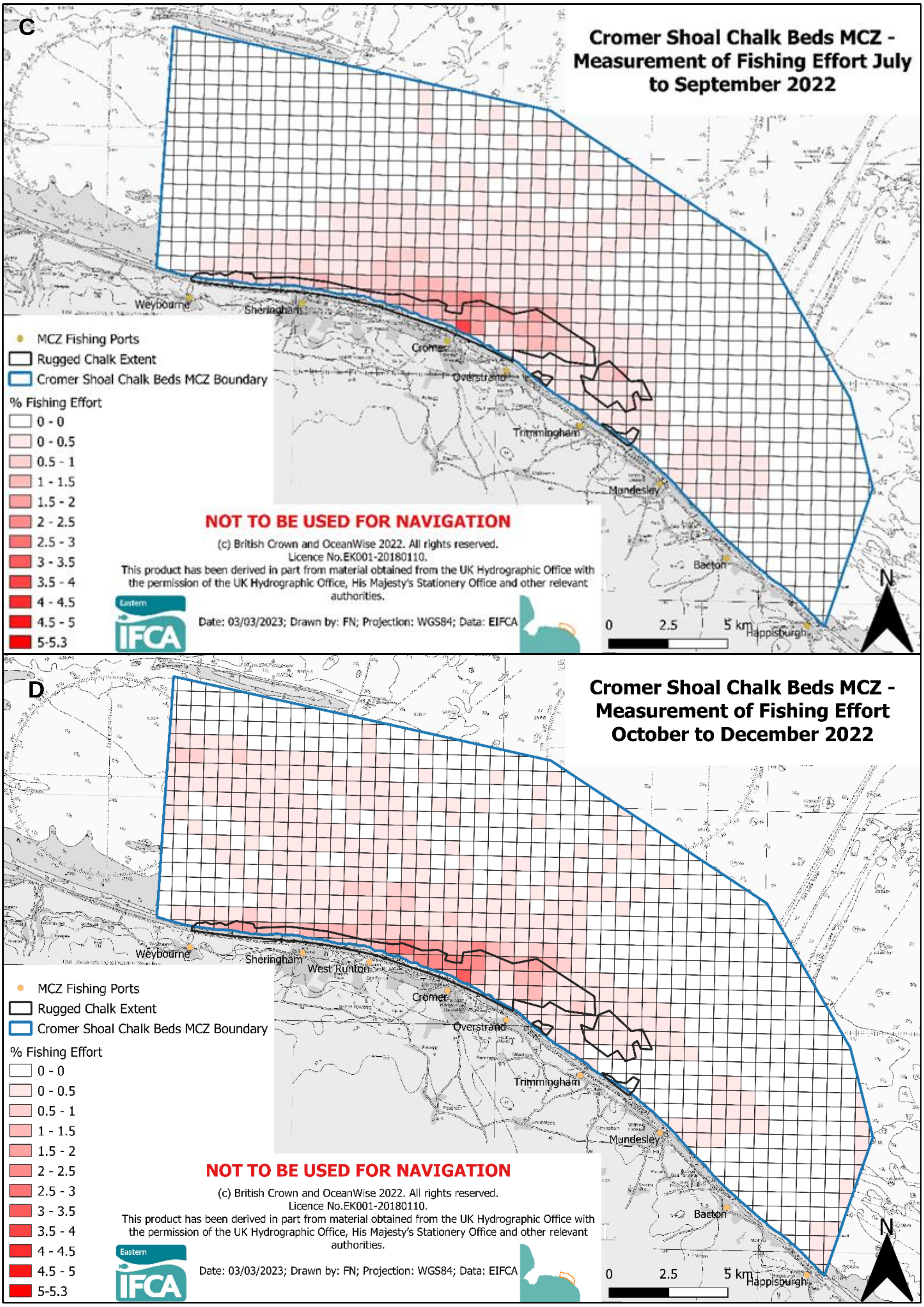


Figure 13 The percentage of pings (filtered for speed and bearing) received in the Cromer Shoal Chalk Beds MCZ from trackers voluntary used by fishermen within each 100mx100m grid cell for the months July to September (C), October to December (D) 2022. Rugged chalk extent outlined in black.

While data collection and subsequent analysis is ongoing, it appears so far that for the fishermen voluntarily using trackers, roughly half of their activity within the MCZ is located on the “rugged chalk” (Table 6). Anecdotally, it was thought that most of the effort occurs on the rugged chalk, however, the data suggest that a significant proportion also occurs off the rugged chalk. Furthermore, the area Northeast of Cromer consistently received the highest level of effort throughout 2022 (Figure 10-12). The activity within the MCZ peaked during the months of April-June, with activity increasing by a factor of 1.68 on the seasonal mean.

It is important to note that this analysis only provides data for one year and so continued collection of tracker data will allow us to look at year to year variation. In addition to this, the data represent approximately one third to one half of the fleet. Whilst this would generally be considered a good representation of fishing activities, potting activity can be territorial with fishermen favouring certain fishing grounds. Efforts, therefore, need to be made to ensure those carrying trackers provide equal representation across the different ports. The distribution of trackers across the different ports currently does not provide an even representation (Table 5).

Table 6 The number of GPS pings recorded in the MCZ and rugged chalk, and the percentage of the latter (filtered for speed and bearing).

Season	Pings on Rugged chalk	Pings in MCZ	Percentage on Rugged chalk
Jan-March	31815	61051	52.11
April-June	69101	140079	49.33
July-September	43872	84565	51.88
October-December	26767	46887	54.75

The limitations in this study revolve in part around the trackers themselves, as the volunteers are responsible for their use and maintenance. This can lead to issues such as the batteries not being charged, the trackers being lost or simply been forgotten to be taken aboard the vessel. All of which means some data are lost. Furthermore, as the study works on a voluntary basis, there is not full coverage of the fleet as some fishermen are either unaware, or do not wish to take place with the study. As such, the study is biased towards the 43.75% of vessels whose skippers agreed to participate (Table 5). Finally, while the study provides location data and information on where fishing is occurring, it provides no data on the number of pots being deployed. While fishermen may have similar set-ups, none are exactly alike and variation exists, for instance in the number of pots per shank and the space between pots on the shank. Therefore, this work, so far, can only provide an indication of potting densities within the MCZ based on effort.

Future work

Eastern IFCA will continue to work with fishermen by using the trackers to record and map fishing activity in the MCZ. This will be done by using the trackers currently in the possession of fishermen, but also by expanding to encompass as much of the fleet as possible making efforts to ensure a representative sample. This will be done using either the existing method of magnetic trackers, or via the rollout of Inshore Vessel Monitoring Systems (iVMS) which all under 10m vessels will be required to have installed and running by 2024. This rollout of iVMS, will also provide the opportunity to compare and contrast the two methods of vessel monitoring and the ability to use the data to accurately map fishing activity. The main difference between the two systems is the ping rate, which is every thirty seconds for the vehicle trackers and every three minutes for the iVMS units. There is also the potential to combine this dataset with others to help better inform fishing activities within the MCZ. Potential scope for additional data include pot buoy counts, using both coast-based surveys and/or drone surveys, as both of these approaches have their pros and cons, a combination of the two methods for counting buoys is likely. Other potential data sources include the tagging of pots and using fishing returns to investigate soak times.

4.2 Pot buoy counts

RQ: How do potting density levels differ across the site, spatially and temporally?

Background

There are many ways of mapping fishing activity. While vessel trackers are one, diversifying sources of information may lead to a more complete picture. Tracking vessels gives no direct measure of potting effort (pot densities); instead it provides data on where activities occur and so is limited in its use. This can be overcome by conducting counts of the pot buoys used by fishermen to locate their shanks of pots, which provides a direct measure of effort and can be replicated and compared over time. It also has the potential to provide a way of monitoring the uptake of the voluntary measures introduced in the Code of Best Practice to remove pots from the sea prior to inclement weather to avoid damage to the chalk during these high risk periods.

Approach

Eastern IFCA are currently receiving data on pot buoy counts from multiple sources, primarily Natural England and MCNAG. The latter counts visible buoys from seven lookout stations along the MCZ coastline. These data are then recorded and forwarded to Eastern IFCA.

Progress so far

The data presently gathered has limited use in its current form, so Eastern IFCA are currently working to refine the methodology to ensure greater utility. Limitations of the current method are due to the lack of spatial referencing. Whist the lookout locations are known and so can be referenced, there is no way of knowing or informing an accurate position of pot buoys. This is due to the lack of information judging distance from the lookout to the buoy, and so the position of the buoys cannot be plotted. This also prevents an inference being made into the total area surveyed, preventing density of effort being calculated. Due to the lack of information on distance, it is also unknown how many of these pots lie on the rugged chalk, therefore preventing any investigation as to any potential impact upon the chalk.

Future work

Future work focuses on refining two separate methodologies:

- **Shore based** – counting buoys from the shore from the same or adapted lookout points. This will be refined by endeavouring to create discrete zones which can be compared to reduce the chances of pseudo-replication by recounting the same buoy markers. There are currently two working ideas on how to achieve this, by either taking bearings and distances from the lookouts and therefore being able to record the area surveyed. Thus, allowing for areas of overlap to be eliminated or at the very least accounted for. This will use rangefinders to record distance from the lookout, or alternatively, the placement of our own marker buoys to demark specific areas which are visible from the lookout, therefore preventing overlapping areas. Each method has pros and cons associated with it and the most beneficial is currently being decided on.

- **Drone based** – counting buoys by using a drone to fly a specific path and photograph the area. This then allows for pot buoys to be counted and recorded. The benefits of this approach are that it creates a constant survey area and provides consistency for the surveys. It is however limited by the distance the drone can legally be deployed from the pilot (500m) and therefore limits the survey area where visual range for counting from a lookout may extend further.

4.3 Beach clean data

RQ: How much lost potting gear exists within the site?

Background

Litter is an important factor to consider within a conservation area as it can severely impact the habitats and their supported features. Studies prove how current designations in place often do not happen to mitigate litter distribution, where the fishing industry is the second most found litter source within UK MPAs (Nelms *et al*., 2020). The risks of these findings on the marine environment might vary and range from plastic ingestion or toxin dispersal up to habitat degradation and navigational obstruction (Gilman *et al*., 2021). A considerable impact may also be represented by microplastic production when considering the number of particles that a single object could produce and how this contamination could affect the entire trophic cascade (Green and Johnson, 2020). However, besides these more noticeable products, the fishing industry also contributes to a persistent form of marine pollution through *ghost fishing*, a passive consequence of lost and discarded gear that continues to have an impact on the marine environment. In this scenario, pots do play an important role (Pham *et al*., 2014) which might not only involve the physical alteration of the seabed (Petetta *et al*., 2021), but also involuntary fatal catches of target and non-target species (Laist, 1995). Here, within the Cromer MCZ, this parameter is particularly important when looking at the sensitivity of chalk features as well as the stock of crabs and lobsters.

Lost potting gear has the potential to have repeated and cumulative impacts on chalk features through abrasion and penetration pressures. Whilst Eastern IFCA's potting assessment identified some sources of qualitative information on the level of active potting gear within the MCZ, sources of quantitative information on the amount of lost fishing gear present within the MCZ were non-existent. The only available information that could be used to inform the assessment was anecdotal information provided by fishermen and local stakeholders. To address this data gap, Eastern IFCA have been working with local stakeholders, specifically beach cleaners who are part of the Evidence Review Group (Stakeholder Group), to develop a method and process for beach clean data to be reported in a way that quantitative information can be pulled out and used as a proxy to assess the level of lost gear within the MCZ and to provide a baseline for future monitoring.

Approach

These data have been collected throughout the entire year of 2022 by the Norfolk Beach Cleaners Collective, a group of volunteers and subdivision of the Marine Conservation of Norfolk Action Group (MCNAG). Beach cleaners were asked to complete a form after each beach cleaning event, detailing the effort it took (number of people, length, duration) as well as the amount and origin of items found. This translated into two litter categories, namely Small Waste (SW - from the public, angling or fishing industry) logged as volume (cm^3) and Big Waste (BW - including canisters, pots, and pieces of ropes) recorded as numbers.

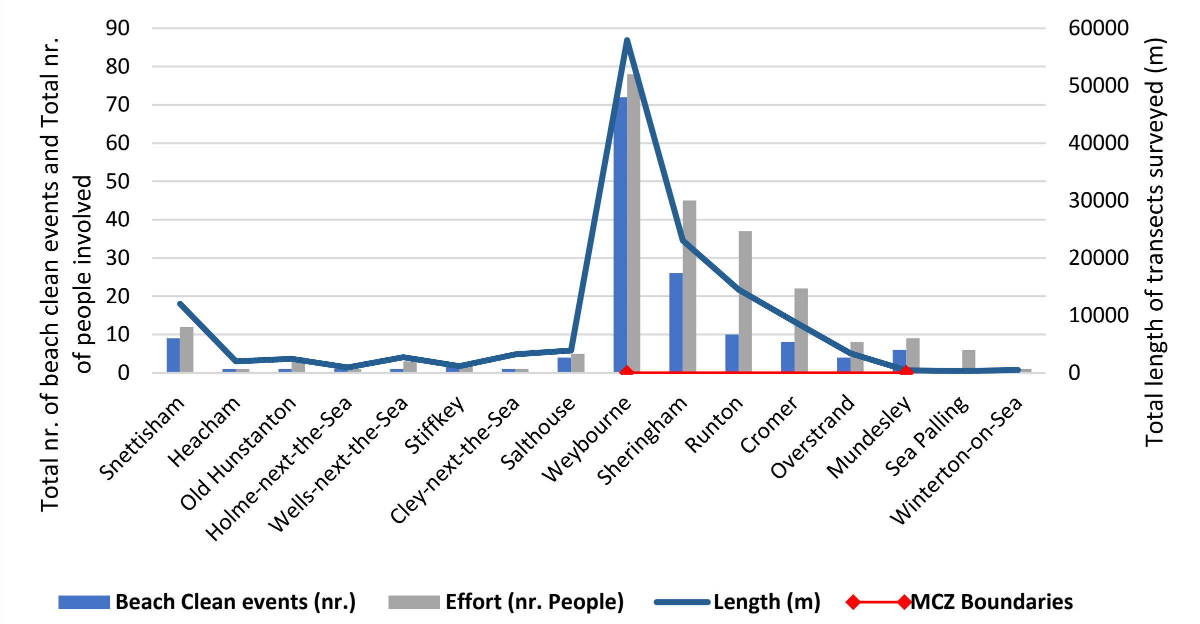


Figure 14 Total number of litter pick events compared to the total length of transects surveyed (in metres) and the total number of people involved over the year across different locations of the North Norfolk Coast, listed from West to East. Data: Norfolk Beach Cleaners Collective.

These data were collected on an ad hoc voluntary basis, rather than following a standardised approach, which has resulted in strong variations of effort across locations (Figure 14). However, having corresponding information about the effort, has allowed us to standardise the data to compensate for this imparity of sampling effort across locations. Standardisation was achieved by dividing the total amount of litter collected at each location by the total number of people involved in the beach clean events and by the length of the transect surveyed. This gave us a measure of the amount of litter found (cm^3) per meter (m) per person at a specific location (cm^3. m^{-1} $person^{-1}$ for Small Waste and nr. m^{-1} $person^{-1}$ for Big Waste).

Progress so far

In terms of small waste data, these were recorded as volume (cm^3 m^{-1}) and divided into four broad categories as follows: Polystyrene/Foam, Angling (SAW), Fishing Industry (SIW) and Public (SPW) waste. When looking at the total amount of these categories collected over a year (Figure 15), waste associated with fishing activities (including both industry and angling), was generally as present as public waste (around 50% overall, see Appendix 1 Fig.1). In three of the surveyed locations, small waste coming from fishing was less than public small waste (see Stiffkey or Sea Palling) while in other four locations, including Salthouse and Mundesley, it reached higher results than the latter. With that said, four areas of the North Norfolk Coast, namely Heacham, Old Hunstanton, Wells and Winterton displayed totally equal results among the two categories. This preliminary comparison partially leaves out the locations within the MCZ as the absolute numbers are too low to be compared amongst each other, although a percentage breakdown suggests a slightly higher amount of fishing category due to the contribution of angling waste (Appendix 1, Fig. 1). This latter, when treated separately from commercial fishing, seems to appear in every location within or adjacent to the MCZ, as opposed to the outside of it, suggesting a stronger presence of anglers utilising the site. As regards Polystyrene, whilst it can find many uses in the marine environment (e.g., for buoys or floats) most of its litter form does come from land-based sectors (Flora and Fauna, no date). For this reason, it has been treated here as an independent category which seems to be consistently present across all locations sampled.

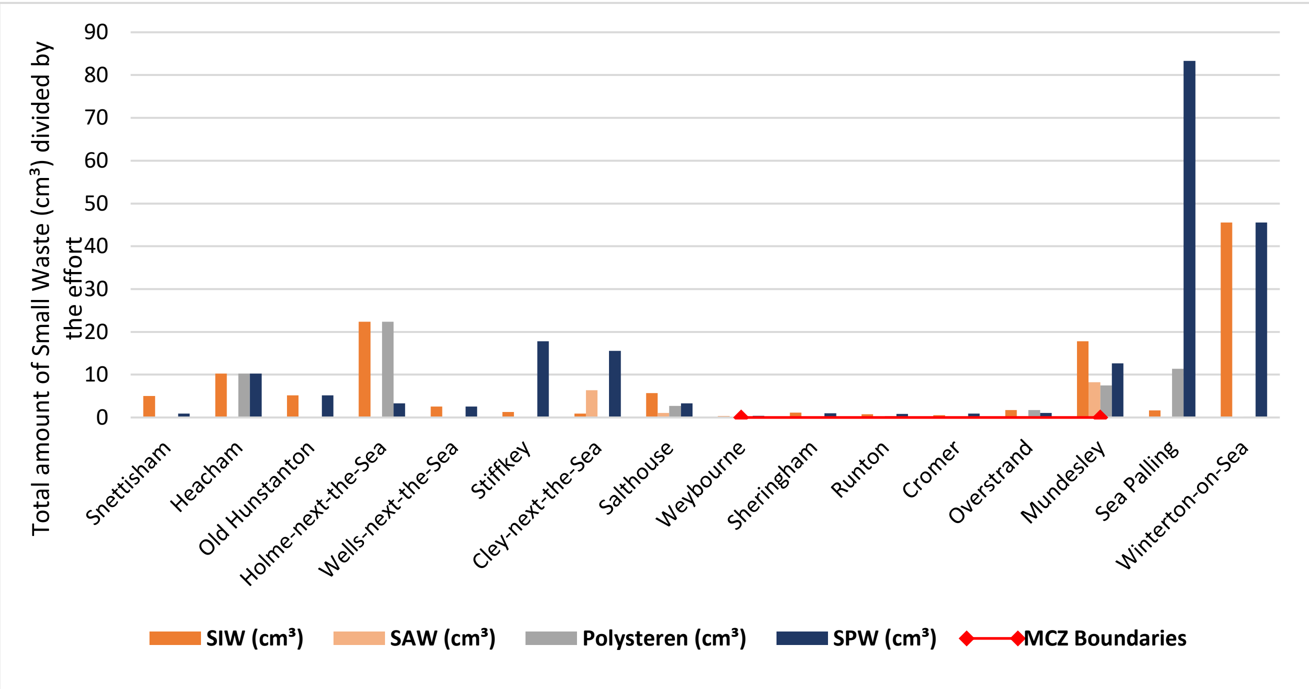


Figure 15 Total amount of different small litter categories, namely Small Public Waste (SPW), Small Industry Waste (SIW), Small Angling Waste (SAW) and Polyester/Foam (all recorded as $cm^3\ m^{-1}$) divided by the effort across different locations of the North Norfolk Coast listed from West to East. Data: Norfolk Beach Cleaners Collective.

A similar analysis was also carried out for Big Waste (Figure 16) with the exception that this time, all categories were related to the fishing sector. When looking at the graph, pot coverings are by far the most found item along the coast. Within the boundaries of the MCZ particularly, in places like Overstrand and Mundesley, pot coverings have a particularly high percentage (60% up to over 80%, see Appendix 1, Fig. 2). In contrast to this, the majority of Big Waste found on the western side of the MCZ, from Snettisham to Salthouse, often were large pieces of rope together with Nets. As regards the rest of the findings relating to Pots, Buoys and Canisters they were not as abundant although it needs to be noted how these can be considered larger items and are therefore usually characterised by lower numbers when compared to small pieces (e.g., pots coverings). For this reason, different categories are hardly comparable amongst each other as some items (like pot coverings) are much smaller and thus more numerous than others (like entire pots).

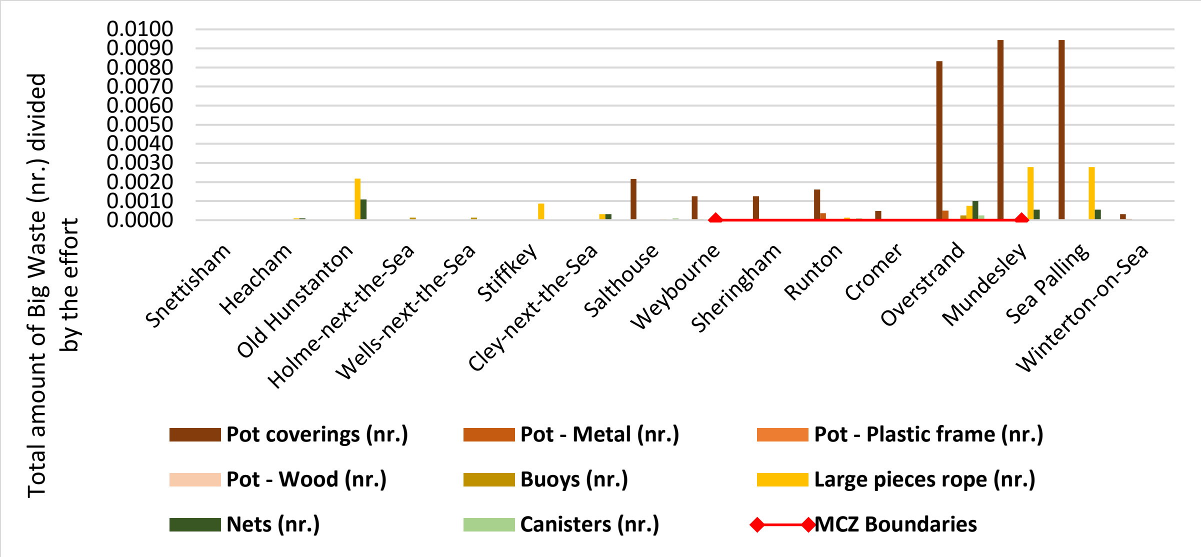


Figure 16 Total amount of different big litter categories, namely Pot coverings, Pot with metal frame, plastic or wooden frame, Buoys, Large pieces of rope, Nets and Canisters (all recorded as nr m^{-1}) divided by the effort across different locations of the North Norfolk Coast listed from West to East. Data: Norfolk Beach Cleaners Collective.

When comparing the data for Small Waste and Big Waste, an interesting observation can be made (Figure 17). Most of the locations adjacent to the MCZ display a lower volume of Small Waste (Figure 17A - 0 to 2 cm^3 m^{-1} of fishing waste) when compared to those outside, especially compared to the western side of the coast (Snettisham, Heacham, Old Hunstanton and Holme, all showing 4 to 46 cm^3 m^{-1} of fishing waste). Mundesley is the exception to this, showing the highest results for the entire MCZ area. On the other hand, there seems to be a difference when it comes to Big Waste coming entirely from the industry, where results are almost opposite to those just described (Figure 17B). The area around the MCZ shows, in fact, records of high numbers of industry waste (from 0.004 to 0.01 pieces m^{-1}) while the western side (and furthest away from the Cromer Shoal) shows the lowest numbers (0 to 0.00004 pieces m^{-1}).

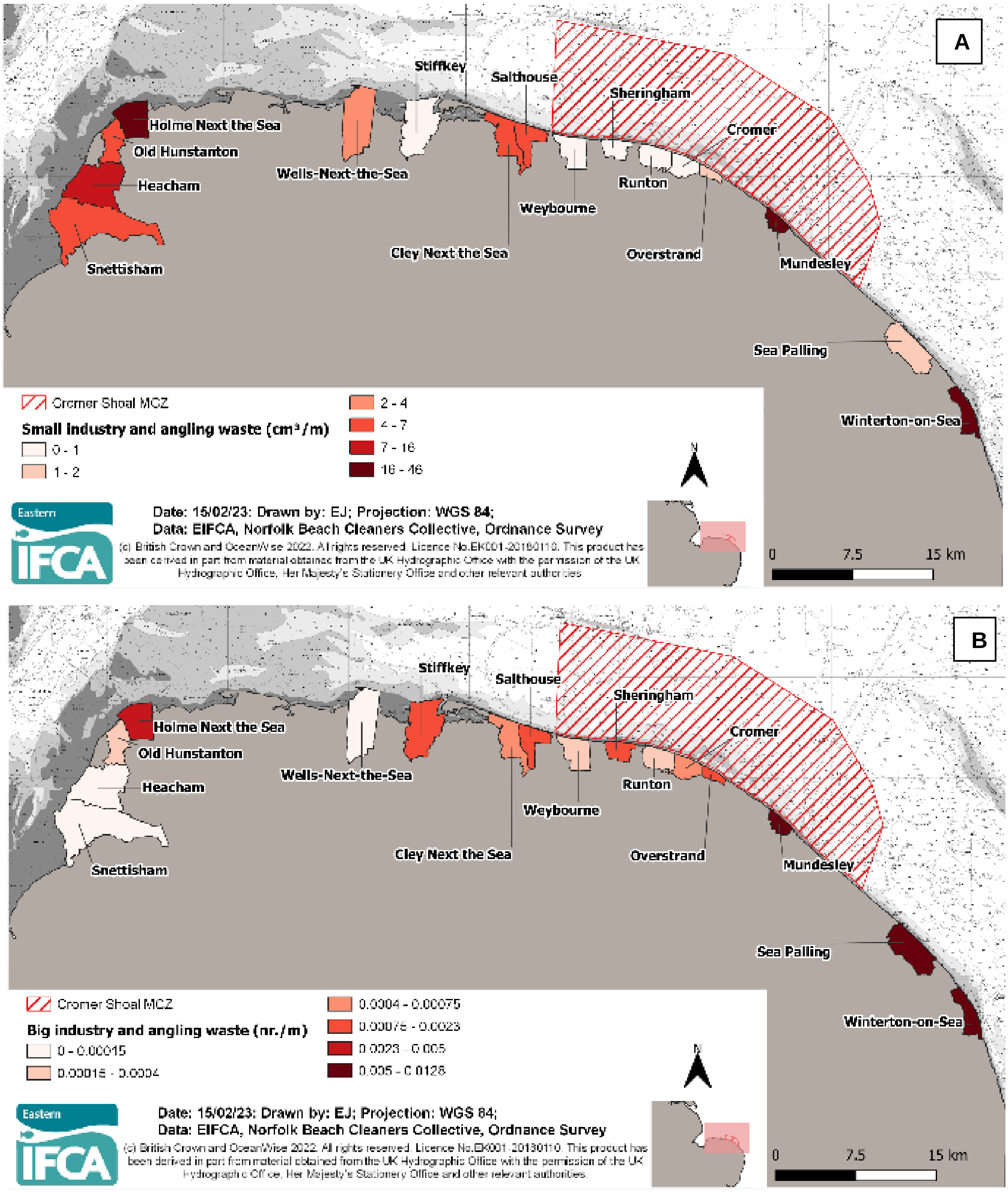


Figure 17 Amount of industry waste collected along the North Norfolk Coast. Figure A displays the volume of Small Waste gathered, such as small industry and angling waste recorded as cm^3 m^{-1}. Figure B represents the Big Waste and therefore the number of industry litter pieces, including items such as canisters, pots, rope parts or nets recorded as nr. m^{-1}. Please note that the area of each town refers to the parish boundary rather than the survey area. Data: Norfolk Beach Cleaners Collective.

Future work

Looking at these results, it can be concluded that the amount of lost gear, especially when talking about big waste categories, is higher around those locations targeted by the potting fishery. This area mainly extends from Stiffkey and Cley all the way to Winterton, thus including those locations within the MCZ, which represents a heavily used potting ground. Though these numbers provide a rough idea about the litter within the MCZ when compared to other locations across the North Norfolk Coast, there is a limit to the level of reliability of these results. Litter-picking events have been random throughout the year and across locations, resulting in some locations with a much higher frequency of litter-picking events than others, which might have potentially resulted in some survey bias. Furthermore, volunteers completed data forms estimating the requested parameters, such as the length walked and the volume of litter collected, rather than taking accurate measurements. Thus, these results, even if standardised, should be interpreted with these limitations in mind. A potential verification for this dataset could be carried out by crossing them with the existing pattern for water as well as wind currents, which have potentially affected the litter hotspots recorded in this study. Nevertheless, the information provided by this dataset can become of use as a baseline for future monitoring, especially when it comes to providing a proxy for the level of lost gear within the site, or to providing locations where retrieval or disposal efforts should be focused.

At the moment, Eastern IFCA is monitoring compliance to the Code of Best Practice signed by the two Fisheries Association of the North Norfolk Coast to tackle lost gear. In addition to that, there has been some engagement with Ghost Fishing UK to help with the retrieval and disposal of lost and abandoned pots, together with a potential allocation of funding for pot tags in collaboration with the Plastic Coalition. Future steps also see the inclusion of measures to manage lost pots, starting from the requirement to collect personal gear when notified by EIFCA, which will be part of the coming Cromer Shoal Permit Bylaw. Besides that, recent engagements with the Norfolk Beach Cleaners Collective have confirmed the introduction of a new dataset type in 2023 which aims not only at identifying lost gear within the site but will also help in tracking the results (removal, recycling or disposal) of that reporting. Eventually, the development of this system will enable a more structured record of waste dispersal across the North Norfolk Coast and Cromer Shoal MCZ with the aim of better informing future management measures.

5 Trailing alternative fishing practices

A dive survey conducted by Natural England and the University of Essex in 2019, to examine the physical interactions between crab and lobster potting and the subtidal chalk features found at Cromer Shoal, identified and described several different types of damage the fishing gear had been observed to have caused to the chalk structures (Tibbitt *et al.,* 2020). These impacts included damage types that were associated with pots striking, chipping and/or abrading the chalk features and ropes sawing, cutting and abrading them.

In 2021 the Research and Development T&FG considered a range of measures that could help to reduce or eliminate the impacts associated with potting on sensitive rugged chalk features. Measures considered by the group included ideas suggested by the group members and others suggested by fishermen either during previous consultations or face-to-face meetings with IFCOs. These suggestions fell into broad themes of spatial and/or temporal management, effort control and gear adaptation. Table 7 shows the strengths and weaknesses of the suggested measures.

Of these listed measures, the only one that would eliminate all impacts to the sensitive chalk features from active potting gear would be the permanent closure of potting within the sensitive areas (with a sufficient spatial buffer to minimise the risk of lost gear washing into the closed area). However, these rugged chalk areas are of vital importance to the local fishermen, where anecdotally, catch rates and the quality of crabs are better than outside of the rugged chalk areas. The tracker data collected since 2021 certainly shows the importance of this area in terms of the fishing effort directed into this area, while a further study seeks to better understand whether the abundance and quality of the crabs and lobsters are also higher in these areas. Implementing a permanent spatial closure over the rugged chalk features would, undoubtably, have a large deleterious impact on the local fishery and as such, should only be considered as a last resort if other mitigation cannot reduce impacts to acceptable levels. Alternative mitigation includes temporal closures and pot limitation schemes that could potentially reduce fishing effort to acceptable levels, and a range of gear adaptations that could help to reduce specific impacts caused by elements of the gear.

While legally it is paramount that the impacts of the fishery on the site features are within acceptable thresholds, when considering potential mitigation measures, it is also important to consider whether those measures would be financially and practically viable for the industry to adopt. If a measure is not financially or practical viable, its introduction would prevent fishing continuing within the affected area, ultimately having a similar effect as a spatial closure. Fishermen were, therefore, consulted on the suggested measures and any concerns about feasibility have been captured in table 7. Similarly, consideration was also given to whether measures could be practically enforced because the inability to do so would seriously weaken their effectiveness if compliance became an issue.

Table 7 Strengths and weaknesses of measures that could be introduced to prevent or reduce the impacts of potting gear on sensitive chalk features (Blue – Spatial/temporal measures, Green – Effort limitation, Yellow – Pot adaptations, Orange – Rope adaptations)

Measure	Benefits	Difficulties
Spatial closures on sensitive features	• Would eliminate potting impacts within closed areas.	• Sensitive rugged areas are large, so to be effective, closures would also need to be large. • The boundary of the sensitive area is convoluted and not continuous. For effective regulation, a closed area would need to box in the protected area. • Anecdotal evidence and tracker data show the sensitive rugged areas are very important fishing grounds for the potting fishery. • The rugged areas are situated in a band close to shore. Some of the smaller boats fish exclusively in that area and would struggle to work further offshore safely. • Sensitive areas need to be accurately charted to enable effective and proportionate closures
Winter closed season for sensitive areas	• A closed season would reduce overall impacts from potting fishery. • A winter closed season would prevent the movement and loss of gear caused by winter storms. • Catches are lower over winter so a closed season then would have less financial impact than other times of the year	• Some small vessels fish the rugged chalk close to shore in winter when it is dangerous to fish further offshore. • Sensitive areas need to be accurately charted to enable effective and proportionate closures
Introduce a separate permit to fish within sensitive rugged chalk area	• By implementing a separate permit for those wishing to fish the rugged chalk areas, stricter bespoke mitigation measures could be introduced for those areas rather than requiring them over the whole MCZ.	• A legislative framework (permit byelaw) would need to be introduced. • Scheme would require additional administration and cost to fishermen. • Sensitive areas need to be accurately charted to enable effective and proportionate closures
Introduction of pot limitation scheme	• Reducing the number of pots within an area would have a proportionate decrease in gear/feature impacts • Reduction of effort would also help the sustainability of the fishery and could improve Catch Per Unit Effort (CPUE)	• Pot limitation would only reduce, not eliminate impacts. • Although pot limitations have been suggested by some fishermen, there is no consensus on what pot numbers should be limited to. • In some cases, pot limitation schemes can lead to increased effort if fishermen try to build a track record or see the maximum number of pots as a target.

		• Such schemes can create displacement impacts from those needing to reduce their number of pots. • Compliance would require regulators to lift and inspect gear at sea
Restricting fishery within MCZ to beach-launched boats	• Would help to maintain the “small-scale” character of the fishery by limiting the size of new local boats entering the fishery and preventing the potential for larger vessels from further away to deploy gear in the area. • Would reduce the risk of larger vessels deploying 1,000s of pots in the area.	• While the measure would prevent escalation of larger vessels joining the fishery, it wouldn’t necessarily cap or limit effort occurring on the sensitive features rom current vessels. • Vessels fishing within the MCZ would need to be monitored to enforce compliance.
Require soft-armouring on pots	• Soft armouring on pots could reduce the impact that hard, sharp edges on pots would have on the chalk, both during deployment and recovery, plus during pot movements while deployed. • Soft armouring could be added to existing gear, negating need to totally replace gear • Armoured pots could help reduce damage caused to the pots from the environment, off-setting costs with improved longevity	• Armouring whole fleets of pots would require significant financial investment from fishermen. • Out of the water, armoured pots are heavier to lift than standard pots so could cause handling and storage issues. • Armoured pots contain more plastic than standard pots. Uncertainty as to how much this would contribute towards plastic and micro-plastic marine litter. • The effectiveness of reducing impacts would require testing.
Using different pot designs (size, weight, material, design)	• Smaller, lighter pots could reduce impact on contacted features than heavier pots. • Flexible plastic frames could reduce impacts to chalk. • Some designs of pots can allow improved stacking aboard boats.	• Wholescale requirement to change pots to incorporate new designs would require significant financial investment from fishermen. • Increased use of plastic in designs could result in more plastic and micro-plastic marine litter. • Fishermen feel lighter plastic pots would require heavier weights to sink them and to keep them stationary on seabed. This could negate any benefit gained from changing to plastic pots. • Different pot designs might not fish as efficiently, which could result in an increase in effort to offset loss of earnings.
Requirement to use escape gaps in pots	• The reduced need to sort the catch when the pot reaches the boat, reduces the time boats spend hanging from each shank during recovery. • Benefits sustainability of the fishery by reducing bycatch of undersize crabs. • A relatively cheap adaptation to implement.	• Escape gaps would not directly help to reduce impacts of potting on chalk so effectiveness would be minimal. • By reducing the time required to sort the catch, the introduction of escape gaps could lead to an increase in potting effort.

	• Escape gaps are already widely used by many fishermen.	
Requirement to only use single pots within sensitive areas	• Use of single pots rather than shanks would eliminate the ground rope and its associated damage. • Pots would be less likely to ball up during storms.	• Use of single pots would significantly increase the number of anchors in use, and any damage associated with them. • Number of marker buoys (and surface ropes) would increase significantly, making navigation in the area more difficult. • Fishermen feel single pots would move more than when fastened in shanks, so benefits gained from reducing rope impacts could be negated by more abrasion from pots. • Fishermen concerned that more pots would be lost, which over time could increase damage. • Working single pots would be less efficient for the industry and potentially commercially unviable.
Requirement to use ropeless technology in sensitive areas. This is gear in which the surface rope is stored attached to the pot and released to rise to the surface on receipt of a signal.	• Use of this technology would eliminate impacts from ground ropes and surface ropes. • There would be fewer buoys/ropes on surface, reducing navigational issues.	• Similar to single pots, this would significantly increase the number of anchors in use, and any damage associated with them. • Fishermen feel single pots would move more than when fastened in shanks, so benefits gained from reducing rope impacts could be negated by more abrasion from pots. • Failure of gear to release buoy rope could lead to increase in lost gear and associated impacts. • Introducing this technology would require significant start-up investment and ongoing running costs for the industry. • Working single pots would be less efficient for the industry and potentially commercially unviable.
Eliminate drop ropes by attaching pots directly to ground rope	• Could help to reduce abrasive impacts caused by pots hanging in gullies	• Would cause serious H&S problems when recovering gear as ground rope would not be free to go through the pot hauler as pots came aboard. • Absence of drop ropes would mean ground ropes would float lower, potentially causing more impacts to higher relief chalk features.
Fasten drop lines to ground rope with a running knot, enabling limited running of the drop line	• Could enable pots hanging into gullies to settle on bottom rather than remaining suspended on gully sides. • Relatively cheap to implement.	• Could cause H&S problems when hauling gear.

• Various measures to increase the buoyancy of the ground ropes, enabling them to float above the sensitive chalk features that they would otherwise be impacting. Such measures could include: • Require all ground ropes to be made from buoyant material. • Fasten small floats on the drop lines. • Setting gear under less tension • Increasing the length of drop lines. • Tether drop lines to the top of pot rather than bottom.	• Enabling the ground ropes to float above the seabed would result in fewer interactions between the ground rope and sensitive features. • Many fishermen already use buoyant ropes so they have proven track-record in the fishery and would require minimal investment to introduce. • Small floats on drop lines, less tension in the ground rope, increasing the length of the drop lines and tethering the drop lines to the top of the pots should all enable the ground ropes to float higher.	• Investment costs for those who don't currently use buoyant ropes or floats on drop lines. • The length of the drop lines is determined by operational considerations (size of boat, height of gunwale, height of pot hauler). Changing length of drop lines would create operational difficulties when hauling gear. • Tethering drop lines to the top of the pots could create operational difficulties when hauling gear. • Effectiveness of adopted measures would need to be tested. Possibility that making the gear more buoyant and/or ground rope looser would cause gear to move more on seabed, increasing disturbance

Whilst this workstream aims to identify and consider ways that interactions could be mitigated by adopting alternative fishing practices through a variety of approaches which include using different methods or gear technologies, so far the Research and Development T&FG have focused on identifying and developing gear adaptations that address the below research question:

Adaptive gear trials

Do specific gear adaptations reduce the frequency and severity of potting gear interactions with rugged chalk features?

5.1 Adaptive gear trials

RQ: Do specific gear adaptations reduce the frequency and severity of potting gear interactions with rugged chalk features?

Although the measures in table 7 could each help to reduce impacts, it is not currently understood how effective each would be, or for that matter, to what extent, if any, potting impacts need to be reduced. While research continues at Cromer Shoal to answer the latter question by assessing the impact of the current potting activities on the site features, plans were developed to assess the effectiveness of two of the suggested gear adaptations – soft-armouring on pots and placing floats on drop lines. These two adaptations were chosen for testing because in addition to being considered theoretically effective at reducing impacts, they were both considered feasible for the industry to adopt if required.

Approach

The 2019 dive study conducted by Natural England had identified eleven categories of damage that potting gear was observed to cause to chalk features. These included strikes, grates and abrasion damage caused by pots. The standard type of pots used at Cromer Shoal tend to be parlour pots, similar to the one shown in image 4A. These are typically steel-framed and have an underside fabricated from steel bar. In addition to being made from an "unforgiving" material that could cause abrasions to softer materials that they rub against, their design has sharp angles on the corners that could inflict strike damage to softer features that they hit. In many fisheries that currently occur on hard rocky ground, pots are soft-armoured to protect them from the environment. Here, it was suggested that by placing soft-armouring on a pot, the impact on the features could be reduced. Images 4B and 4C show a standard pot that has been soft-armoured with rubber around the bottom frame and a plastic base covering the underside.

In addition to damage caused by pots, the Natural England dive study had also identified types of damage caused by ropes. These included cuts, burns and shears where ropes had either sawn into raised chalk features or caused abrasions to their horizontal or vertical surfaces. Due to the length of the ground ropes that link together the pots within a shank, the majority of these impacts were caused by the ground ropes.

Image 4 A standard parlour pot, viewed from underside (A). A soft-armoured pot (foreground) with rubber banding around frame compared to standard pot (background) (B) and a plastic base (C).

During 2021 and 2022 Eastern-IFCA used a BlueROV2 remotely operated vehicle (ROV) to observe impacts caused by active potting gear on rugged chalk features. During these surveys it was noted that the majority of the ground ropes viewed were floating above the seabed. Anchored by the weight of the pots between them, the height the ground rope tended to be determined by the length of the drop line attaching them to the pots (Image 5). Precise measurements of the ground rope height were not taken, but using the size of pots as a scale, average heights were estimated to be between 50-100cm.

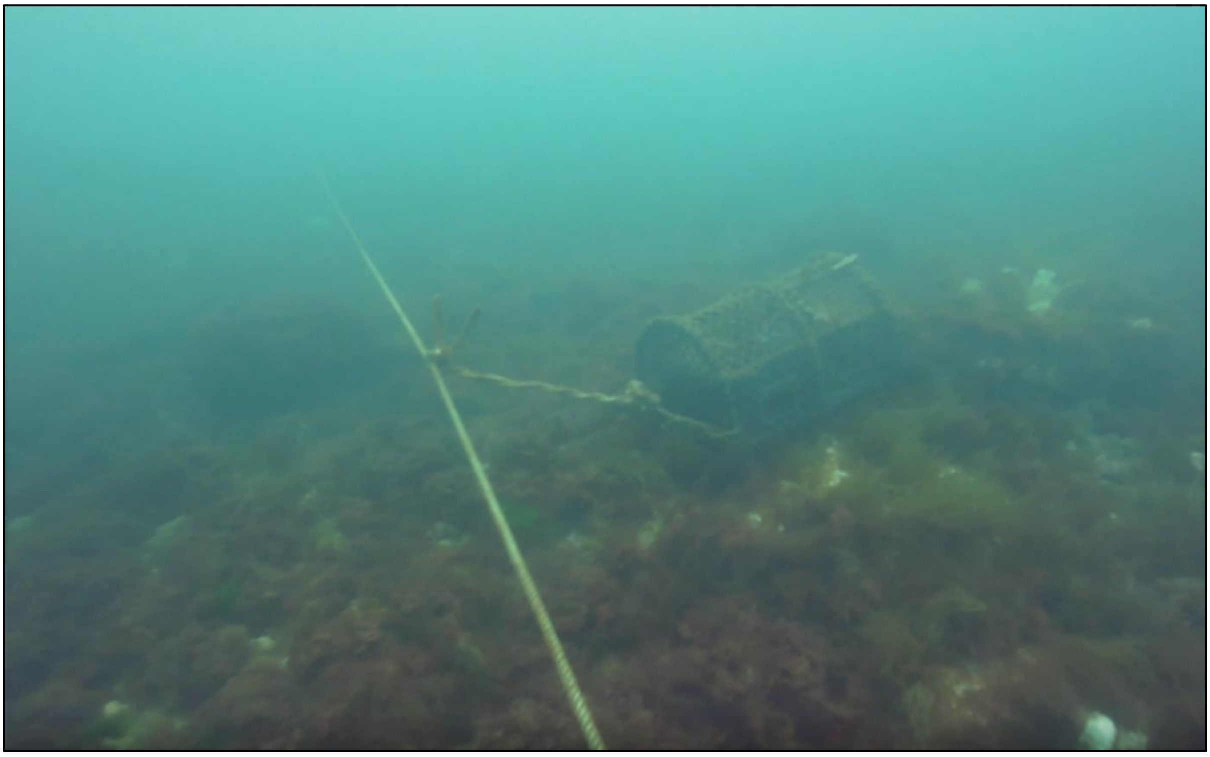


Image 5 Image taken from BlueROV2 video footage showing a floating ground rope anchored to a pot by a drop line

In places where the seabed features were mostly flat, or raised features were lower than the height of floating ground ropes, few interactions between the ground ropes and chalk features were observed. Based on these observations, it was suggested that if all ground ropes could be made to float above the seabed features, interactions between the two could be minimised. Feedback from fishermen suggested attaching small floats to the drop lines would be a feasible method of increasing the buoyancy of a ground rope without interfering with hauling. However, while it was thought that setting the gear with less tension on the ground ropes, increasing the length of the drop lines and tethering the drop lines to the top of the pots would all help to increase the height that a ground rope could float, fishermen had concerns about their practical application. They felt ground ropes under lower tension would allow pots to move more, while increasing the length of the drop lines or attaching them to the top of pots would make hauling difficult. It was decided, therefore, that in addition to testing the effectiveness of using soft-armouring on pots to reduce impacts, the study would also include looking at the effectiveness small floats on the drop lines would have. Image 6 shows a soft-armoured pot with a float on the dropline.

Image 6 Pot with a small float attached to the drop line

Progress so far

It was planned to conduct the adaptive gear trials in 2022 between June and September, when the water clarity would be clearest. The trials would involve deploying an experimental shank of test gear and studying it in situ using a BlueROV2. The experimental shank would comprise ten 38” steel-framed parlour pots, each separated by 17m of ground rope. Five of the pots would be soft-armoured (as shown in image 4B and 4C) and five would be unarmoured (as shown in Image 4A). These would be set alternately along the length of the shank (e.g. armoured, unarmoured, armoured etc). To test the effectiveness of attaching floats to the drop lines, the first five pots in the shank were to be fitted with floats on their drop lines and the remaining five without (e.g one half of the ground rope would have floats attached to the drop lines and the other half wouldn’t). The plan was to deploy the gear for three days at a time and study its interactions in situ on each of those days with a BlueROV2.

Although the experimental pots were ordered in May, they were not delivered until July, delaying the start of the study. The plan was to deploy and recover them from Eastern-IFCA’s patrol vessel, *Sebastian Terelinck*, a 12m cabin RHIB. This would enable more control on when the gear could be deployed than relying on available fishermen to help. However, prior to the first survey, Health and Safety concerns were raised about the dangers of deploying a shank of gear from a flush-decked vessel that was not designed for potting. As the issues could not be remedied within the timeframe of the study period, industry support was sought for deploying and recovering the gear. Unfortunately, the fisherman who volunteered to help suffered a series of vessel and tractor breakdowns that meant his boat could not be launched. This prevented the gear from being deployed during the 2022 study period.

Future work

Although the plan to test adaptive gear designs has not been terminated, in 2023 a major project is planned to study the impact that natural disturbance has on the chalk features compared to potting impacts. This project will require significant resources, necessitating placing the adaptive gear study temporarily on hold. The fishing gear acquired for the adaptive gear trials is planned to be used to support elements of the new project, utilising electronic sensors attached to pots and ropes to help determine how much they move during the course of a tide. It is expected that the natural disturbance study will improve our understanding of natural and potting impacts, which in turn will inform future adaptive gear trials.

6 Determining the value of rugged chalk

Habitat mapping shows that the band of rugged chalk lies within the inner one to two kilometres of the Cromer Shoal Chalk Beds Marine Conservation Zone. The less sensitive, flatter chalk forms are generally found further offshore in the MCZ, and are typically located under a naturally-protective layer of sand, gravel or mixed sediment. The rugged chalk area is generally regarded as being of greater importance to the Cromer crab fishing fleet than offshore parts of the MCZ, anecdotally producing greater quantities and higher quality crab. As rugged chalk is more sensitive to impacts from interactions with potting gear than flat chalk is, it is likely that some form of management to reduce impacts will be required in the rugged chalk area.

For any management that Eastern IFCA develops, it is important to understand the implications that management will have for those impacted by the measures. The aim of this workstream is to inform Eastern IFCA's assessment of impacts of any mitigation proposed as part of ARM, considering both economic impacts on industry as well as wider impacts on society. The Research and Development T&FG have developed the below projects as part of this workstream to address the following research questions:

Economic assessment

Does crab caught on the rugged chalk have a higher value than crab caught off the rugged chalk?

Social value study

What is the social value of the MCZ crab and lobster fishery?

6.1 Economic assessment

RQ: Does crab caught on the rugged chalk have a higher value than crab caught off the rugged chalk?

Background

The rugged chalk habitat at the Cromer Shoal Chalk Beds MCZ has often been cited as economically vital by the fishermen who fish in the MPA, with many in the fleet claiming to fish almost exclusively on the rugged habitat. Subtidal chalk, which includes the rugged chalk features, is a designated feature of the MCZ. As such, Eastern IFCA must ensure any fisheries occurring within the site do not prevent the conservation objectives for the site from being met. An assessment of the fishery impacts has not been able to rule out the possibility that the potting fishery may be having a long-term impact on the sub-tidal chalk feature, particularly the rugged chalk features.

An Adaptive Risk Management (ARM) approach is being undertaken to research the impacts of the fishery more thoroughly and to introduce appropriate management. In the absence of sufficient evidence, a precautionary approach must be taken. While the ARM process is in progress, fishermen are naturally concerned about the possible consequences on their livelihoods. As evidenced by tracker data and anecdotal claims from the fishermen, the rugged chalk area is an important fishing ground for the local potting industry. In addition to being close to shore for the boats to travel to, fishermen claim the quality of catch from this area is better and is the source of Cromer Crab's reputation for high quality. Until now, no comparative study has been completed within the MCZ to compare the relative value of the catch from the rugged chalk to that off it. To be able to fully understand the impacts of any potential management on the rugged chalk within the MCZ, the current economic contributions of the catch sourced from it must be quantified and the difference compared to that caught from the non-rugged chalk areas.

Aims

- To understand the economic importance of rugged chalk to the local crab and lobster fishery.
- To compare the quantity and quality of the crabs and lobsters caught from the rugged chalk area to those caught from nearby non-rugged chalk areas.
- To identify the subjective markers of quality industry judge catch by.

Approach

To collect the required biometric data, the following approach was taken:

- Sampling would be conducted on a fishing vessel twice a month during the peak fishing season of April to October (Image 7).

Image 7 Eastern IFCA Science Officer conducting biosampling regime

- On each trip 10 shanks would be sampled, with at least 10% of the pots within each shank being sampled.
- The pots would be sampled at random, but the first and last pots of a shank were only sampled twice per trip, as these have been described by fishermen as typically containing more catch than the rest of the shank.
- While crabs should only be sampled from the randomly selected pots, due to their scarcity, every lobster caught from the shank should be surveyed.
- For both species, the sex of each individual would be identified and its size measured along the carapace as appropriate for the species. (Image 8)
- For all individuals measured, the berried status would be recorded and whether the individual is white-footed (soft-shelled/recently moulted). Individuals below minimum landing size (115mm and 87mm for crab and lobster respectively) would be returned to the sea after measuring, as would white-footed and berried individuals. Fishermen may decide to return an individual for another reason e.g. excessive blackspot, missing both chelae etc, if so they will be recorded under discards.

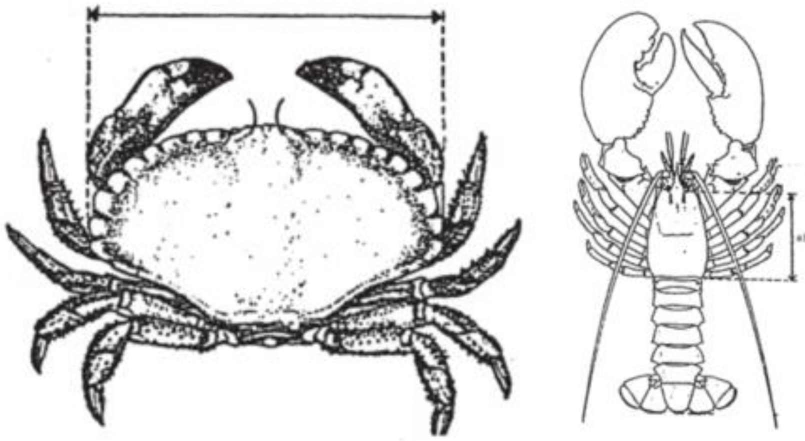


Image 8: The correct measurement of carapace length for both Brown Crab and European Lobster

In addition to sampling catches at sea, the following method is planned to be used to determine the relative value of the catches caught on or off the rugged chalk.

- Size will be used as a determinant of quality by utilising meat-yield curves.
- Samples will be taken from both the rugged and non-rugged chalk.
- Their pre-processed mass and size will be measured and recorded.
- The individuals will then be processed as standard within the industry and the meat yields measured and recorded.
- The resulting data will allow for the generation of two meat yield curves, one for the rugged and one for the non-rugged chalk habitats.
- The resulting meat-yield curves will then be used to estimate the meat yields which would be generated from the individuals above minimum landing size in the biometric database.
- This will then allow for an economic comparison between the catch from the two habitat types.

Progress so far

Trips did not start until June 2022, due to the lead officer joining Eastern IFCA in April and requiring time to organise and plan the study. Since June, at least one trip was completed every month with the exception of September, where none were completed. This was due to poor weather conditions and the skipper's Health and Safety concerns about having a guest on board the vessel during these times. This also resulted in one trip being lost in October. During the second trips of both July and August, the full 10 shanks of pots were not surveyed. This was due to ill health limiting the capabilities of the officer in July and poor light conditions limiting the quality of data during an early-morning trip in August, resulting in some shanks not being sampled until light conditions improved.

After one fishing season from June to October, a total of 62 shanks were sampled. From these, a total of 2,407 individual specimens were measured. Of these 1,250 had been sampled from on the rugged chalk consisting of 810 brown crab and 440 European lobster. Of the 1,157 specimens sampled from the non-rugged chalk, 754 were crab and 403 were lobster (Figure 18). There were 1,352 sizeable individuals, with 691 being from the rugged chalk and 661 from the non-rugged (Figure 18).

Preliminary findings are presented below. It is important to note that sampling is ongoing and these do not present final results.

Overall, the mean size of crabs was 116.2mm. The average size of those caught from rugged chalk areas was found to be larger (at 117.4mm) than those caught from the non-rugged areas (114.8mm). Two-sample t-tests found that this difference was significant (p-value = 0.003, t-value = -2.959, df = 1562) (Figure 19 and 20).

Overall, the mean size of the lobsters was 87mm, with those caught from the rugged areas being smaller on average (85.9mm) than those caught from non-rugged areas (88.4mm). As with the crab catches, these differences were found to be statistically significant (p-value = <0.001, t-value = 4.526, df = 841) (Figure 19 and 20).

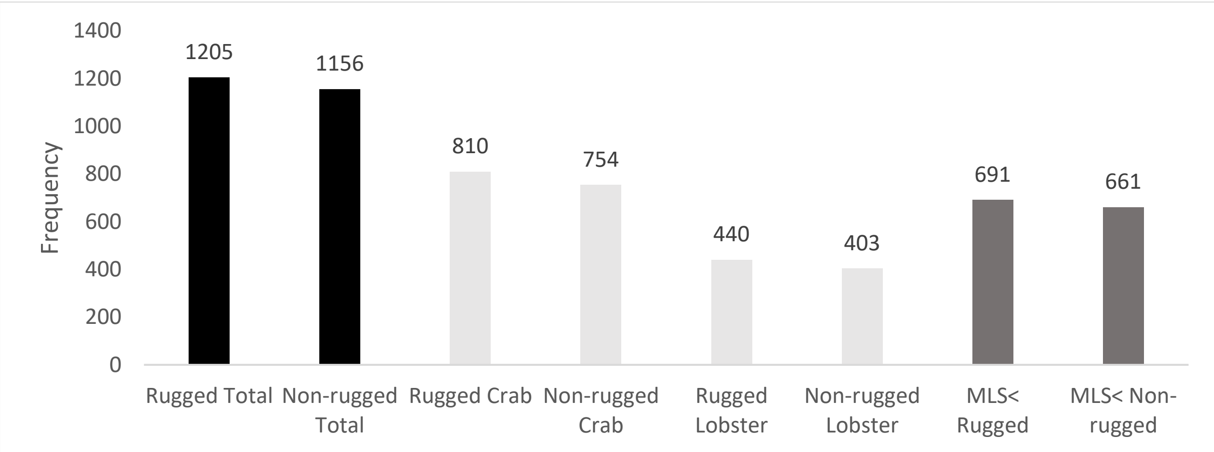


Figure 18 Total number of sampled individuals grouped by habitat (black), habitat and species (light grey) and habitat and being above minimum landing size (dark grey)

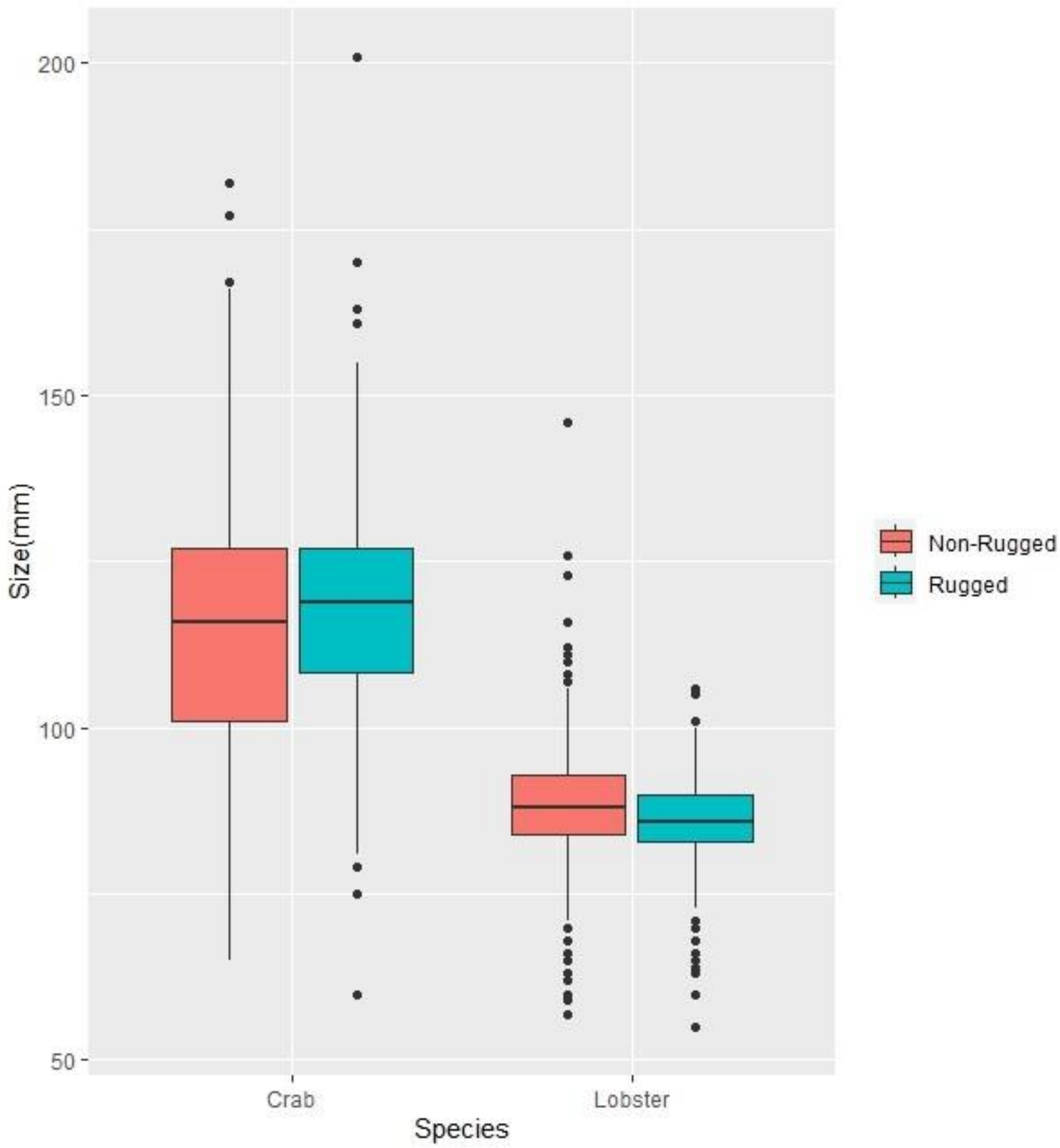


Figure 19 Means and distributions of both crab and lobster sizes on both Rugged (blue) and non-rugged (red) habitats.

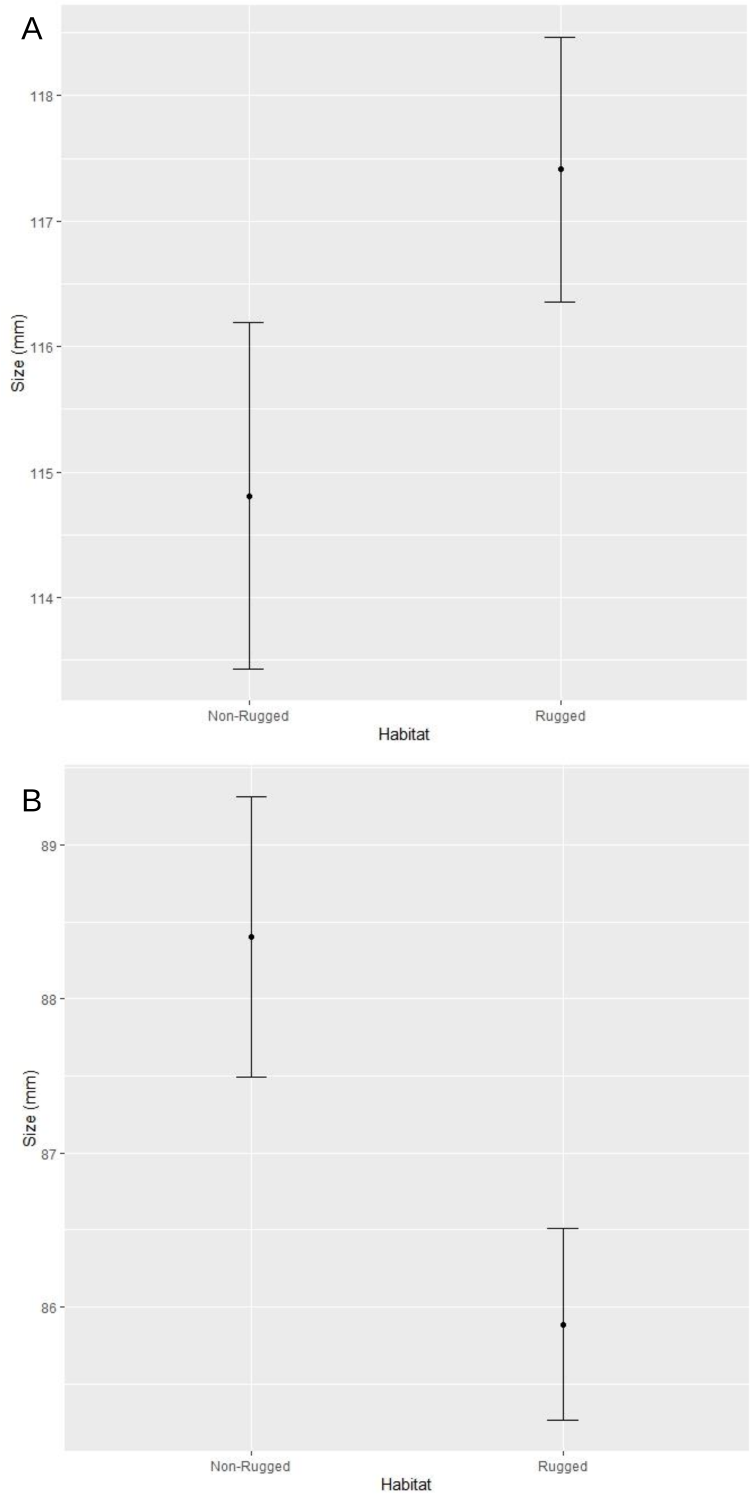


Figure 20 Mean size (mm) ± 95%CI of catch from each habitat type for crabs (A) and lobster (B).

Of crabs which are above minimum landing size, the mean size was 127.6mm while it was 92.5mm for lobster. The mean size of crabs caught on the rugged area was 126.9mm compared to 128.4mm for those from non-rugged areas (Figure 21). Lobster were also larger from the non-rugged at 93.5mm, compared to 91.3mm on the rugged Figure 21). There was a significant difference between the crab above MLS caught on the rugged compared to the non-rugged, with the latter being 1.5mm larger (p-value = 0.034, t-value = 2.126, df = 914). Likewise for lobster, there was significant difference between the samples caught between the two habitats with non-rugged being 2.2mm larger than rugged (p-value = <0.001, t-value = 3.9492, df = 434).

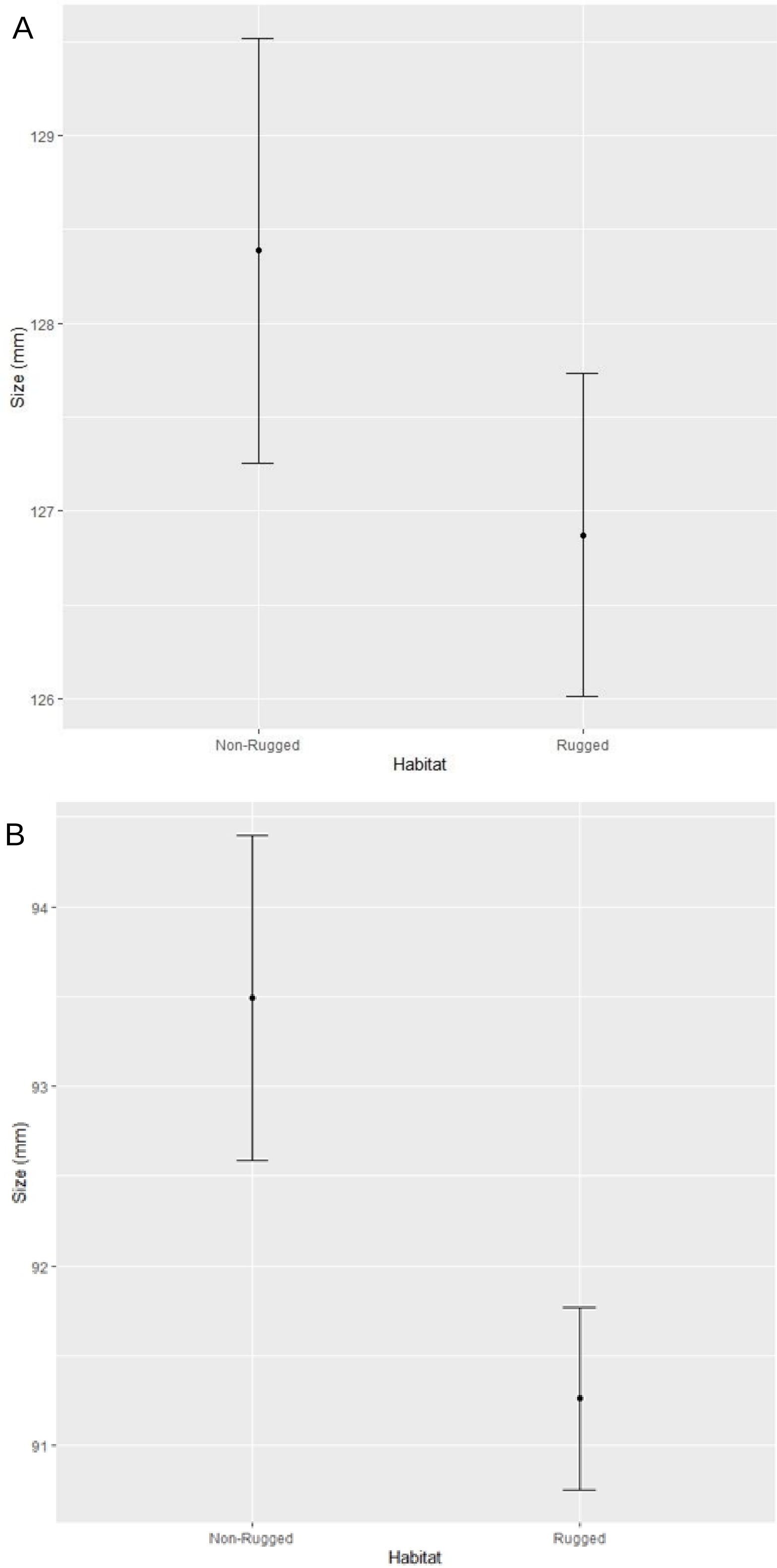


Figure 21 The mean size (mm) ± 95%CI of individuals above minimum landing size as caught on both the rugged and non-rugged chalk for both crabs (A) and lobster (B).

Table 8 Percentage Sex Ratios of entire crab and lobster catch and catch above MLS

% Sex Ratio	All Crab		Crab >MLS		All Lobster		Lobster>MLS	
Sex	M	F	M	F	M	F	M	F
Rugged	55.8	44.2	52.4	47.6	48.4	51.6	49.7	50.3
Non-Rugged	47.5	52.5	36.7	63.3	59.1	40.9	58.5	41.5

Table 8 shows that overall more male crabs were caught on the rugged and more females on the non-rugged. When looking at crabs above MLS, only slightly more males were caught on the rugged chalk, whereas approximately twice as many females were caught on the non-rugged when compared to males. Meanwhile catch ratios among lobsters are fairly consistent for the entire catch and above MLS, with female catch rates being slightly greater than males on the rugged, but males being noticeably larger than females on the non-rugged (Table 11).

Table 9 Percentage Whitefooted of entire crab and lobster catch and catch above MLS

% Whitefooted	All Crab	Crab > MLS	All Lobster	Lobster > MLS
Rugged	13.1	20.8	1.6	1.0
Non-Rugged	22.3	36.4	1.5	2.1

The proportion of whitefooted crabs was greater from the rugged chalk than the non-rugged (Table 9). The difference in proportion between the two habitats increases when examining crabs above MLS, with a fifth from the rugged and over a third on the non-rugged chalk being whitefooted.

Table 10 Percentage discarded of entire crab and lobster catch and catch above MLS

% Discards	All Crab	Crab > MLS	All Lobster	Lobster > MLS
Rugged	49.0	16.7	42.0	6.7
Non-Rugged	64.9	37.1	43.7	6.2

Table 10 shows that almost half the crabs were discarded from the rugged and almost two thirds from the non-rugged. For lobster both on the rugged and non-rugged the rates are slightly over two fifths. However, for both crab and lobster, these discard rates will include all the individuals below MLS. For crabs above MLS, the discard rate is just below a fifth on the rugged and is just over a third on the non-rugged. This is in large part due to whitefooted crabs contributing to discard rates. Meanwhile lobster has very similar discard rates for both the rugged and non-rugged chalk, being just over 6%. Unlike with crabs, the rate for discarded lobster is significantly higher than that for soft lobster. This is likely due to the berried status of females being in the pots, whereas lobster which have recently moulted are very unlikely to appear in a trap.

To test whether or not the differences in population proportions between the rugged and non-rugged chalk were significant, chi squared tests were conducted (Table 11). Of these 12 results all but 5 were statistically significant. All the tests ran on crab populations returned significant results, suggesting that the rugged chalk effects the population composition in a way which cannot be explained by chance. Whereas lobster populations had a mix of results, all tests run on sizeable lobsters returned non-significant results, suggesting that population composition is not affected by chance.

Table 11 χ^2 test results for crab and lobster populations for expected and observed proportions of sex ratios, whitefooted and discarded. All statistically significant results are denoted with *.

Table	Species	Dataset	X^2 value	Degrees of freedom	P-value
Sex Ratios	Crab	All Crab	10.833	1	<0.001*
		Crab > MLS	22.784	1	<0.001*
	Lobster	All Lobster	4.741	1	0.029*
		Lobster > MLS	3.339	1	0.067
Whitefooted	Crab	All Crab	22.847	1	<0.001*
		Crab > MLS	27.705	1	<0.001*
	Lobster	All Lobster	0.014	1	0.904
		Lobster > MLS	0.751	1	0.386
Discards	Crab	All Crab	40.591	1	<0.001*
		Crab > MLS	49.123	1	<0.001*
	Lobster	All Lobster	17.171	1	<0.001*
		Lobster > MLS	0.035	1	0.851

Future work

There will be another season of bio sampling in 2023 covering the same time period of April-October. This will help provide robustness to the data and offer some insight into annual variation of stock abundance that might influence the results (e.g. “boom” or “bust” years).

Work on the development of the meat yields to start being able to calculate economic value will begin in 2023. This will involve the participation of both processors and fishermen, the latter providing samples from the rugged and non-rugged chalk which will then be processed by IFCA Officers at a the premises of a volunteer processor. In addition to the meat yields, a short questionnaire will be compiled and distributed to fishermen, processors and fishmongers throughout the Cromer area and wider Norfolk. This questionnaire will focus on the less qualitative indicators of quality, such as taste and colour. The exact indicators will be decided upon following a conversation with local Cromer fishermen. The questionnaire will be used to determine whether these qualities are viewed by processors and fishmongers as being of greater quality from Cromer sourced catch than other catches in Norfolk, and if as result they are worth a higher price.

Finally, the fishermen's perception of the extent of the rugged chalk area will be sought and compared to the mapping work being undertaken by Eastern IFCA. This is important, for if the fishermen's perception of the rugged area differs greatly from the mapped area, they may be under, or overestimating the impact management may potentially have upon them.

Due to this study being only partly complete, no conclusions will be drawn until the full body of data is gathered.

6.2 Social value study

RQ: What is the social value of the MCZ crab and lobster fishery?

Background

Eastern IFCA is tasked with statutory duties, set out in the Marine & Coastal Access Act 2009, to "*seek to ensure that the conservation objectives of Marine Conservation Zones are furthered*" by managing fisheries in MCZs in the district. The same Act requires IFCAs to "*balance social and economic benefits of fisheries with the need to limit environmental impacts and support sustainable fisheries*" – although the legislation is clear that this latter requirement must not affect the performance of the duty to impose the former[7].

The Cromer crab fishery operates within and around the Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ). Eastern IFCA and partners are implementing an adaptive risk management approach to ensure the fishery aligns with the MCZ's conservation objectives. To help inform the developing management, various areas of additional research are being undertaken, as reported in this document.

One of these additional research objectives is to improve our understanding of the social value of the Cromer crab fishery. Whilst it is broadly accepted that the Cromer crab fishery provides wider social benefits than its economic value, this value has not yet been collated, systematically analysed, and reported. A better understanding of the social value of the Cromer crab fishery will assist Eastern IFCA in achieving balanced management. The aim is to achieve fisheries management that furthers the MCZ conservation objectives whilst, as far as possible without jeopardising these objectives, supporting the local communities by balancing the social and economic benefits of the fishery with the need to limit environmental impacts and support sustainable fisheries.

Approach

The MCZ Project Board agreed in 2022 to commission a bespoke Social Values study, with a focus on the Cromer Crab fishery in the Marine Conservation Zone. The Marine Conservation Society agreed to contribute resource for this work in the form of a social scientist to undertake an initial Social Values study, in February and March 2023. It was intended to build upon the successful Community Voice project undertaken jointly by Marine Conservation Society and Eastern IFCA in 2016, which had identified values about the marine environment and inshore fisheries that were shared by a wide range of people in the coastal community, including local residents, fishing industry members, and conservationists[8].

The initial Social Values study will identify the social values that link to the Cromer Crab fishery, by applying peer-reviewed social values methods and reporting to the

[7] https://www.legislation.gov.uk/ukpga/2009/23/section/154
[8] Available at: https://www.eastern-ifca.gov.uk/wp-content/uploads/2020/03/Common-Ground_final-report1.pdf

Project Board. The study will also determine whether further research in this area would be of benefit, in terms of informing the development of appropriate management that meets environmental requirements whilst best supporting socio-economic interests.

Progress so far

The Marine Conservation Society has not been able to undertake the initial study within the intended timescale (February-March 2023) because of staffing changes. However, MCS remains committed to progressing this work later in 2023. Eastern IFCA welcomes this ongoing support from MCS's social science team.

Future work

Eastern IFCA will continue to seek opportunities for this work to be developed with the Marine Conservation Society, seeking additional funding for new data gathering if required.

7 Future priorities

Table 12 summarises the key priorities for the Task and Finish Group for 2023/2024. Figure 22 provides a longer-term plan for ARM detailing the key research and management workstreams that will be developed over the next five years and the timeframes which key milestones are expected. These timelines are indicative, as in many cases will depend on a number of factors outside of Eastern IFCA's control but demonstrate how the development of management will be informed, evaluated and adapted by ongoing research and monitoring.

Table 12 Key priorities for the Research and Development Task and Finish Group for 2023 and corresponding workstream and projects.

Workstream	Project	Focus for 2023 (Red = High, Orange = Medium, Green = Low, Blue = Complete)	Priority
Assessing impacts of potting	Literature review	Complete	
	In situ gear impact study	Continued analysis of ROV footage	
	Natural disturbance study	Development of proposal, identification of survey areas, completion of baseline surveys	
Mapping sensitive features	Rugged chalk mapping study	2023 rugged chalk review	
		Further ROV habitat survey to fill in data gaps	
	Peat and clay mapping study	ROV habitat surveys to inform location of sensitive features	
Mapping fishing activities	Tracker data mapping	Continued monitoring of fishing activities using trackers, iVMS, pot buoy count data and the development of methods to assess and monitor potting densities (e.g. tagging and fishing returns)	
	Pot buoy counts		
	Beach clean data	Continued monitoring of beach clean data to provide a proxy for lost gear	
Trialling alternative fishing practices	Adaptive gear trials	Not a priority for 2023	
Determining the value of rugged chalk	Economic assessment	Continued collection of data to inform assessment	
	Social value study	Low priority	

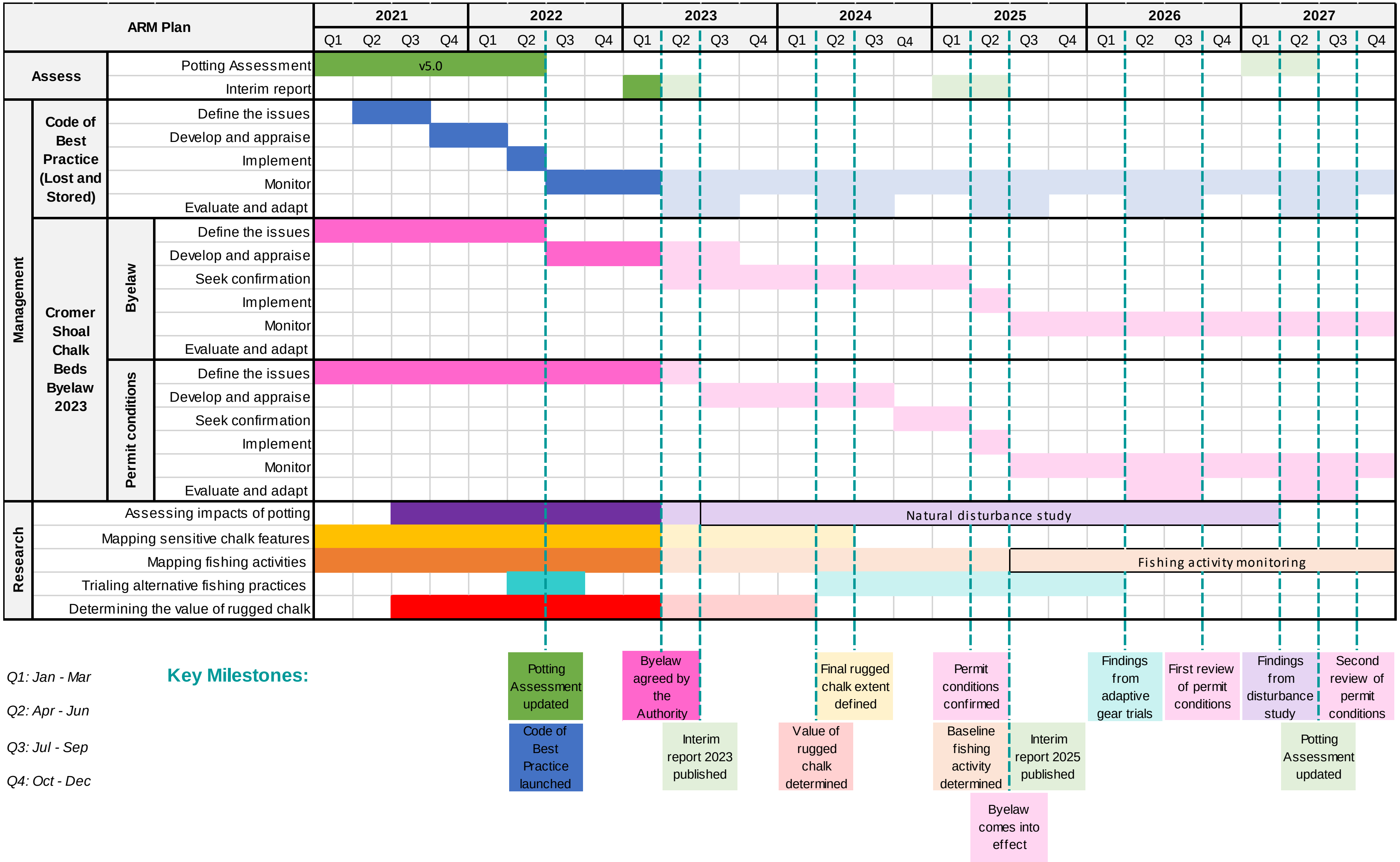


Figure 22 Projected ARM timeline for the next five years, please note that timelines are indicative and will depend on a number of factors outside of Eastern IFCA's control

8 References

EIFCA, 2022. Cromer Shoal MCZ Adaptive Risk Management: Research & Development Task & Finish Group Project Summary 2021- 2022. Eastern Inshore Fisheries and Conservation Authority. Available online: https://www.eastern-ifca.gov.uk/wp-content/uploads/2022/03/2021-2022-Research-Development-Task-Finish-Group-Project-Plan.pdf [accessed 24th March 2023].

EIFCA, 2023. Cromer Shoal Chalk Beds MCZ: Adaptive Risk Management (ARM) Plan. 2023. Eastern Inshore Fisheries and Conservation Authority. Not yet published.

Fauna and Flora International (no date). Breaking down ocean polystyrene: an initial investigation into marine uses of foamed polystyrene. Scoping Report

Gall, S. C., Rodwell, L. D., Clark, S., Robbins, T., Attrill, M. J., Holmes, L. A. and Sheehan, E. V. 2020. The impact of potting for crustaceans on temperate rocky reef habitats: Implications for management. Marine Environmental Research, 162 (2020) 105134.

Gilman E. et al. (2021). Highest risk abandoned, lost and discarded fishing gear. *Scientific Reports*, 11:7195

Green B.C. and Johnson C.L.E. (2020). Characterisation of microplastic contamination in sediment of England's inshore waters. *Marine Pollution Bulletin*, 151.

Hawes, J. & Pettafor, A. (2021). Cromer Shoal Chalk Beds Marine Conservation Zone (MCZ) Bathymetric Re-gridding and rugosity assessment. Natural England

Hormbrey, S., 2022. A literature review on the physical impacts of potting on subtidal soft and hard rock habitats and the biological communities they support. Eastern Inshore Fisheries and Conservation Authority.

Hormbrey, S., 2023: Cromer Shoal Chalk Beds MCZ: Rugged Chalk Review 2023. Eastern Inshore Fisheries and Conservation Authority. Available online: https://www.eastern-ifca.gov.uk/cromer-shoal-chalk-beds-mcz-update-2022-rugged-chalk-review-and-interactive-maps-now-available/ [accessed 13th April 2023].

Jackson, A. 2016. Pentapora foliacea Ross. In Tyler-Walters H. and Hiscock K. (eds) Marine Life Information Network: Biology and Sensitivity Key Information Reviews, [on-line]. Plymouth: Marine Biological Association of the United Kingdom. [cited 26-10-2021]. Available from: https://www.marlin.ac.uk/species/detail/1389

Jackson, A.C., Watson, D & Spray, R. 2022. Benthic assemblages in Cromer Shoal Chalk Beds MCZ: Comparisons among different types of terrain. NECR462. Natural England.

JNCC, NE, Bangor University, MMO and NFFO, 2019. Review of the current context of Adaptive Risk Management. Available at: <https://data.jncc.gov.uk/data/80152204-

c084-4b5c-8516-c5cde4a63318/Current-context-of-Adaptive-Risk-Management-review-V1.0.pdf> [accessed 28th March 2023].

Kaiser, M.J., Hormbrey, S., Booth, J.R., Hinz, H., Hiddink, J.G., 2018. Recovery linked to life history of sessile epifauna following exclusion of towed mobile fishing gear. J. Appl. Ecol. 55 (3), 1060–1070

Laist D. (1995). Marine Debris Entanglement and Ghost Fishing: A Cryptic and Significant Type of Bycatch? in *Solving Bycatch: Considerations for Today and Tomorrow*.

Lewis, C.F., Slade, S.L., Maxwell, K.E., Matthews, T.R., 2009. Lobster trap impact on coral reefs: effects of wind-driven trap movement. N. Z. J. Mar. Freshw. Res. 43, 271–282.

Moffat, C., Richardson, H., Roberts, G. 2019. Natural England marine chalk characterisation project. Natural England Research Reports, Number 080

Nelms S. et al. (2020). Investigating the distribution and regional occurrence of anthropogenic litter in English marine protected areas using 25 years of citizen-science beach clean data. *Environmental Pollution*, 263.

North Sea Wildlife Trust and Seasearch East, 2021. Augmented Diver Survey mapping – Cromer MCZ Interactive mapping and geopackage release.

O'Dell, J. and Dewey, S. (2022). Cromer Shoal Chalk Beds MCZ Imagery Analysis Final report. A report to Natural England by Seastar Survey Ltd. 63 pages.

Petetta A. et al. (2021). Pots as alternative and sustainable fishing gears in the Mediterranean Sea: an overview. *Rev. Fish. Biol. Fisheries*, 31.

Pham C.K. et al. (2014). Marine Litter Distribution and Density in European Seas, from the Shelves to Deep Basin. *Plos One*, 9(4).

Rees, A., Sheehan, E. V., Attrill, M. J., 2018. The Lyme Bay experimental potting study: A collaborative programme to assess the ecological effects of increasing potting density in the Lyme Bay Marine Protected Area. A report to the Blue Marine Foundation and Defra, by the Marine Institute at the University of Plymouth.

Rees, A., Sheehan, E.V., & Atrill, M.J., 2021. Optimal fishing effort benefits fisheries and conservation. Nature (2021) 11:3784

Seasearch East, 2018. Observations of potting interaction with the chalk reef. Seasearch East. November 2018.

Stephenson, F., Mill, A.C., Scott, C.L., Polunin, N.V.C., Fitzsimmons, C., 2017. Experimental potting impacts on common UK reef habitats in areas of high and low fishing pressure. ICES (Int. Counc. Explor. Sea) J. Mar. Sci. 74 (6), 1648–1659.

Suuronen P. et al (2012). Low impact and fuel efficient fishing – Looking beyond the horizon. *Fisheries Research*, 119-120.

Tibbitt, F., Love, J., Wright, J., Chamberlain, J. 2020. Human Impacts on Cromer Shoal Chalk Beds MCZ: Chalk complexity and population dynamics of commercial crustaceans. Natural England Research Report number 04412.

Williams, B. K. & Brown, E. D., (2018). Double-Loop Learning in Adaptive Management: The Need, the Challenge, and the Opportunity. Environ Manag, p1-12

Appendix 1

Beach clean data: Percentage breakdown of waste categories collected

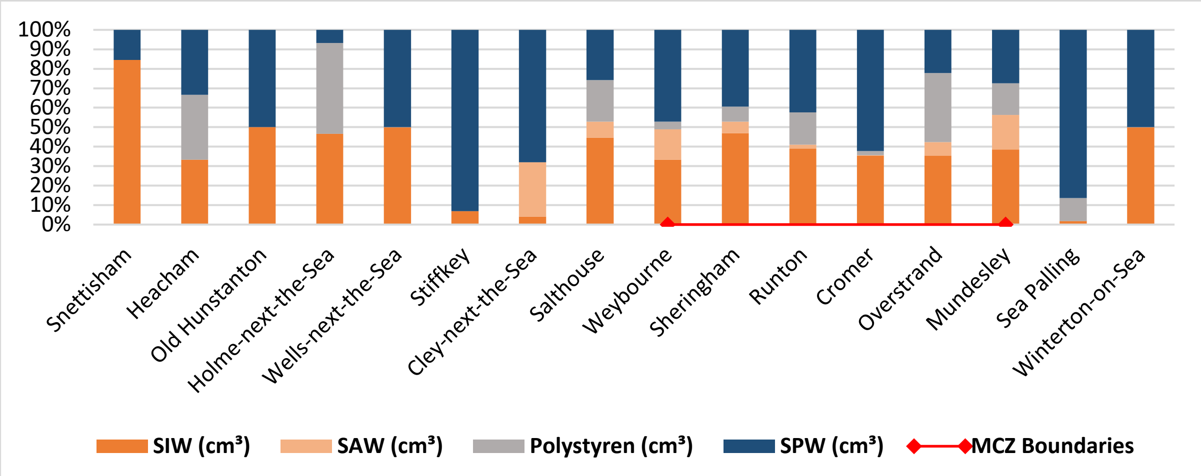


Figure 1. Percentage of different small litter categories, namely Small Public Waste (SPW), Small Industry Waste (SIW), Small Angling Waste (SAW) and Polyester/Foam (all recorded as cm³ m⁻¹) across different locations of the North Norfolk Coast listed from West to East. Data: Norfolk Beach Cleaners Collective.

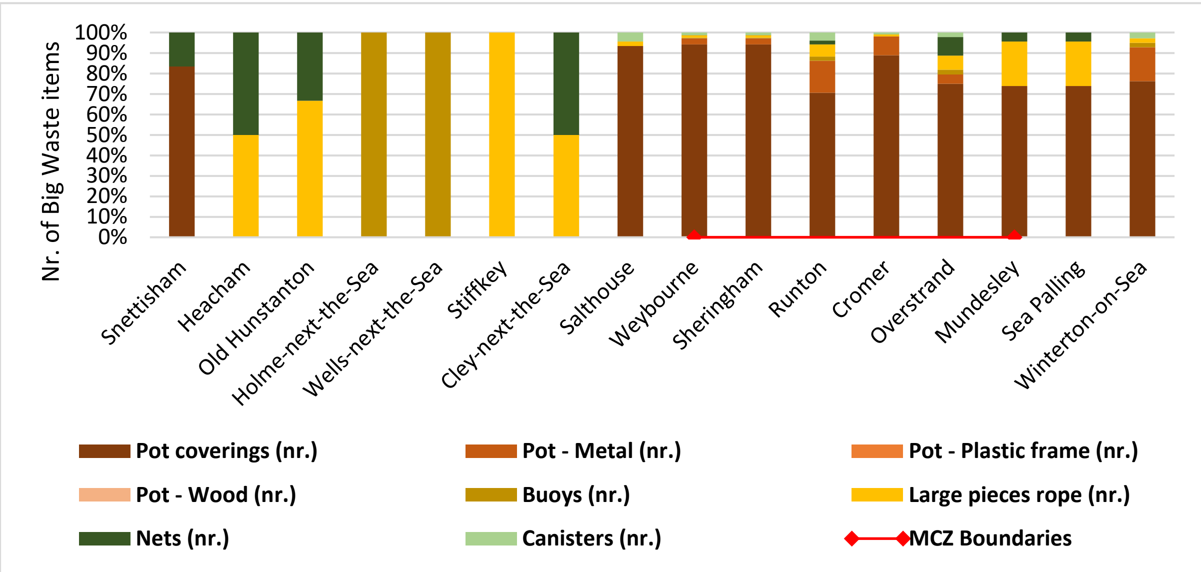


Figure 2. Percentage of different big litter categories, namely Pot coverings, Pot with metal frame, plastic or wooden frame, Buoys, Large pieces of rope, Nets and Canisters (all recorded as nr m⁻¹) across different locations of the North Norfolk Coast listed from West to East. Data: Norfolk Beach Cleaners Collective.