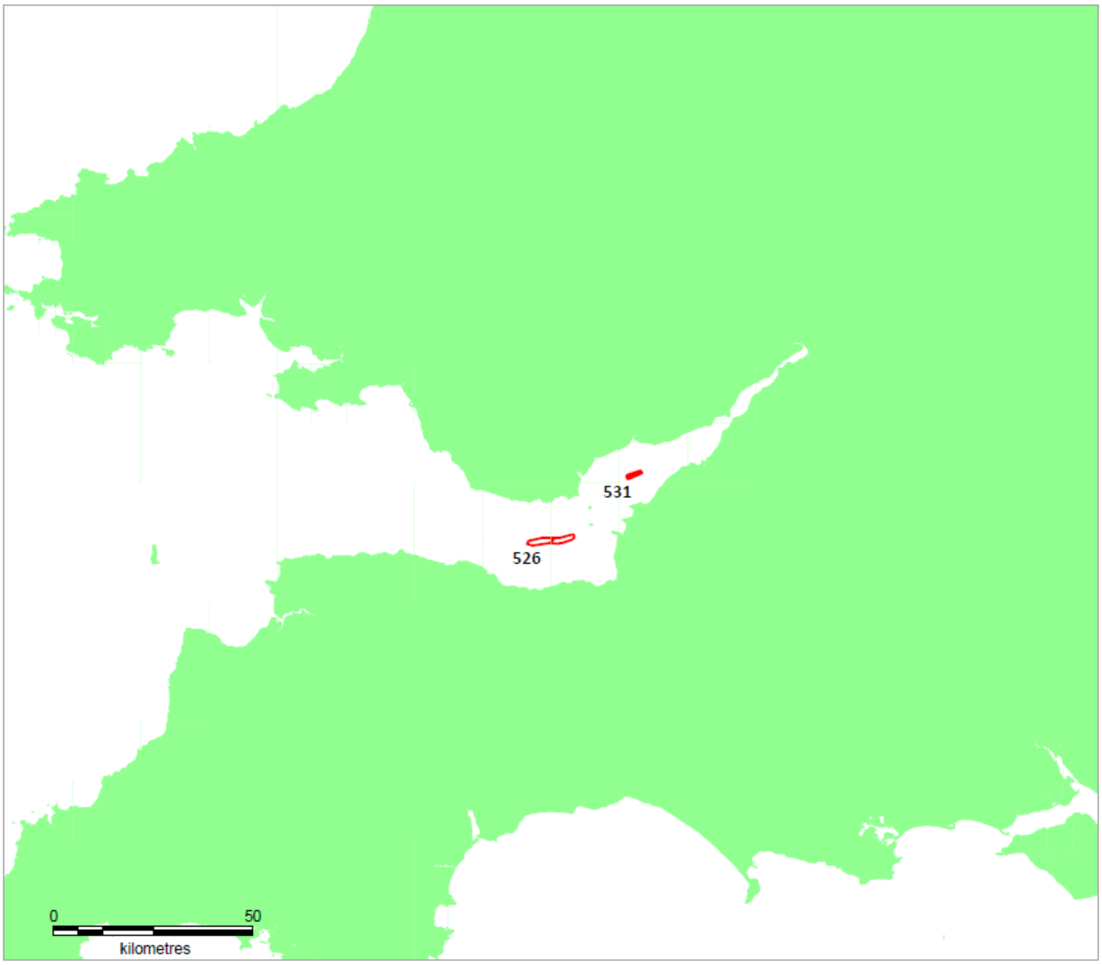
Regional Seabed Monitoring Programme
Survey Specification

Bristol Channel Sampling Surveys 2026

Licence Areas 526 & 531



August 2025

1. Introduction

Cemex UK Marine Ltd, Heidelberg Materials UK and Tarmac Marine Ltd, known as the Resource Management Association (RMA), are required to undertake a regional seabed monitoring programme in 2026. This document provides details of the location of the works required, the operations and specifications for the survey works and the requirements for sample processing and data analysis and reporting.

2. Overview of Proposed Works and General Requirements

This specification covers the seabed monitoring required for the Bristol Channel dredging region in 2026.

At present, the works are expected to require grab sampling of the seabed for at least 50 stations per Licence, distributed along the two primary licences: Areas 526 & 531. Area 526 is owned equally by all three members whilst Area 531 is evenly split between Tarmac and Heidelberg Materials. The monitoring data generated by the survey works will be used by the dredging licence operators to compare against baseline environmental conditions. It will also be used to inform consideration of the potential for recovery of the sites post-dredging.

The survey array may be amended following consultation with the Marine Management Organisation (MMO), Natural Resources Wales (NRW), and The Crown Estate (TCE) which will be undertaken before the start of the survey.

The array will include sampling of primary dredging impact zones, secondary dredging impact zones, as well as reference stations and context stations.

The principal works will employ a $0.1m^2$ Hamon grab to obtain benthic and/or seabed sediment samples across a pre-determined regional survey array.

In addition, should the final approved MMO or NRW specification require it, deployment of a seabed video system, 2m beam trawl or seabed sediment samples using a clamshell grab may be required at a limited number of sites during the works

It is anticipated that the survey will be completed between March 2026 and September 2026, and all PSA and faunal analysis works will be completed by end March 2027.

Survey operations will be undertaken in accordance with the BMAPA Fisheries Code of Practice (Appendix C). Four weeks of notice will be given to fisheries interests prior to the planned commencement of survey operations. Regular updates on timetable will be given to allow interested parties to be advised of any changes to the survey programme.

Whilst surveying, the vessel crew and survey team will give due regard to any RMA dredging vessels as well as any offshore installations and be mindful of any navigation requirements and fishing interests, particularly fixed gear. Where appropriate, measures will be put in place to minimise and/or avoid interaction with these and any other hazards. Prior to deploying the survey equipment at each sample station, the survey team will ensure that the position is well clear of any infrastructure, obstructions, fishing gear or anything that may damage or be damaged by the survey equipment.

Where appropriate during survey operations, regular (daily) notifications on survey location and progress will be made from the survey vessel.

3. Planned survey array

Figure 2 shows the outline survey array for the Bristol Channel region, whilst Figure 1 shows the Licence Areas within the wider Bristol Channel region. Table 1 provides details of the total number of stations and required analyses for the regional programme. Full positional information for the sampling stations is provided in Appendix A.

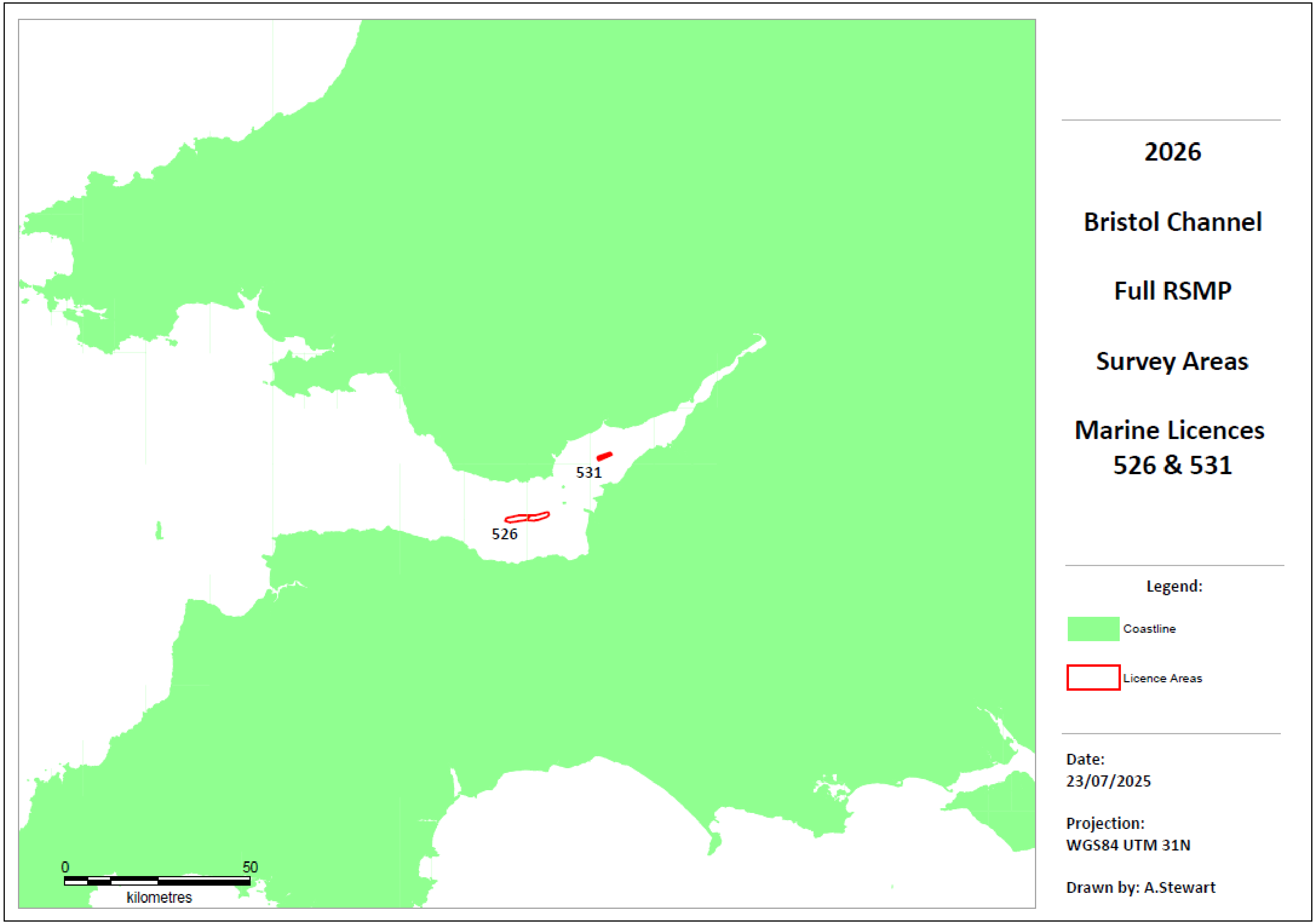


Figure 1. Location of Licence Areas with the Bristol Channel

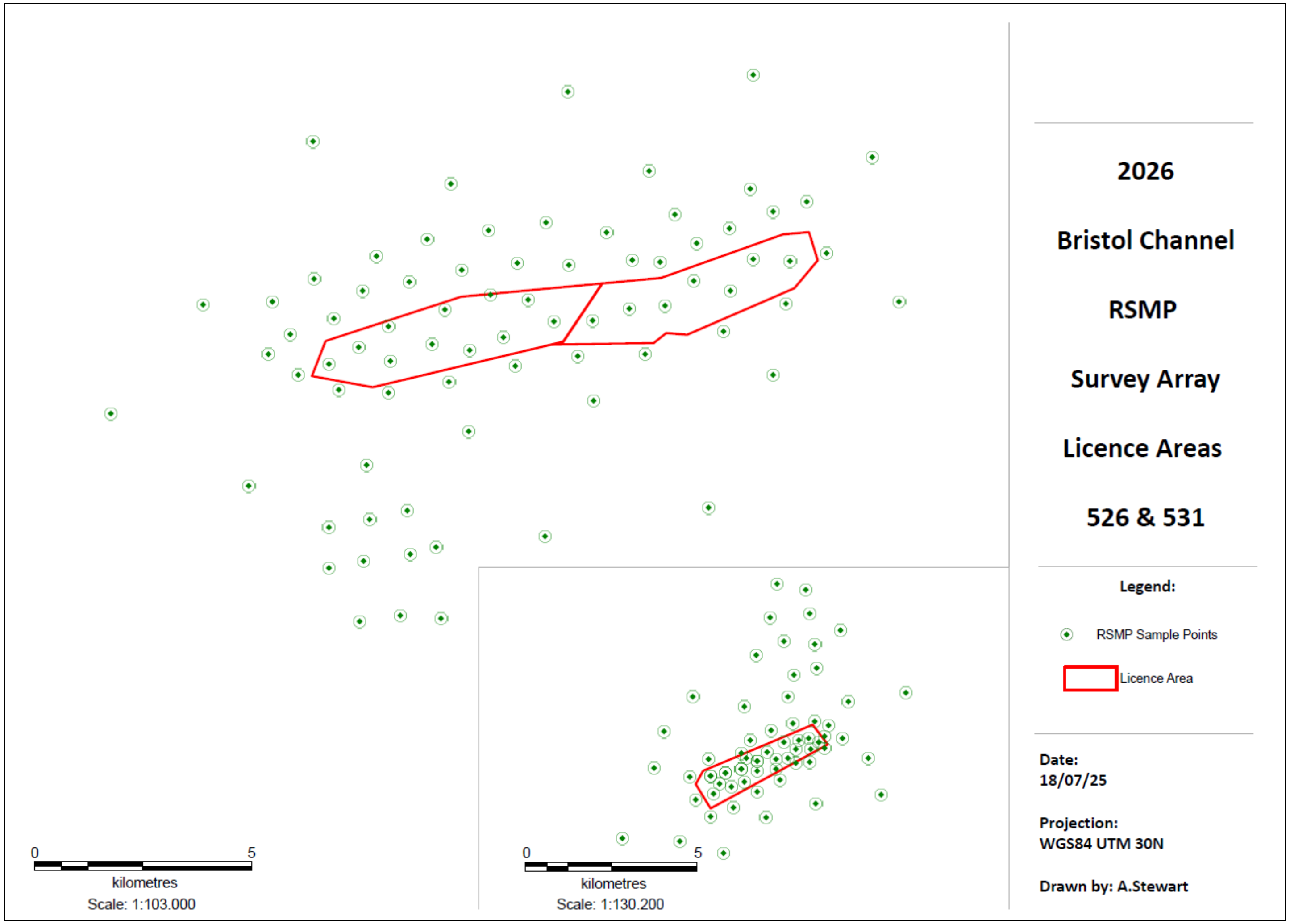


Figure 2. Location of current proposed grab sample survey sites *NB. This chart shows the proposed 2026 sampling array and is only intended to provide a general indication of the spatial distribution of sample stations in this region. It should not be taken to represent the definitive distribution or number of samples that will be required. The number and location of sampling sites may change before the survey takes place following approval.*

Table 3.1. Sample station numbers – Bristol Channel Region – Indicative total array

AREA	Area 526		Area 531		Reference		Context	
ANALYSIS	Number of stations requiring particle size analysis only	Number of stations requiring faunal and particle size analysis	Number of stations requiring particle size analysis only	Number of stations requiring faunal and particle size analysis	Number of stations requiring particle size analysis only	Number of stations requiring faunal and particle size analysis	Number of stations requiring particle size analysis only	Number of stations requiring faunal and particle size analysis
PIZ	11	19	13	11	-	-	-	-
SIZ	4	17	8	10	-	-	-	-
Reference	-	-	-	-	7	13	-	-
Context	-	-	-	-	-	-	-	30
Total Number of Stations	**143**							

4. Sample Analysis Requirements

Hamon grab samples acquired during the surveys will be analysed for sediment particle size and for faunal content when required. Detailed methods for sample collection and processing under the aggregate industry's Regional Seabed Monitoring Plan (RSMP) are presented in Appendix B.

5. Vessels, Personnel and Equipment Specifications

5.1. Vessels and Personnel

Grab sampling, as required for the programme of works, will be undertaken from a dedicated survey vessel(s). The dedicated survey vessel(s) will be certificated to a relevant standard for survey operations in the region of the works.

The vessel(s) used as a platform for the survey will be suitably certified for work at the distances offshore required to sample in the locations specified.

The vessel(s) will comply with all relevant Merchant Shipping and other legislation. The vessel(s) will be manned by an experienced and competent crew in line with STCW 95. All crew will be experienced in the use of the survey equipment that will be employed during the works. The survey team and equipment will also comply with all relevant Health and Safety legislation.

5.2. Positioning Systems

A positioning system will be employed during the survey that provides an accuracy of ±2m or better. Contractors will provide details of the positioning system that will be utilised during the works and methods used for its calibration and its accuracy.

5.3. Sampling Equipment

5.3.1. Hamon Grab

During the survey works, as a minimum requirement, a $0.1m^2$ Hamon grab will be employed to acquire seabed sediment and faunal samples. Contractors will provide the specifications of the Hamon grab apparatus that will be deployed during the works.

5.3.2. Seabed Video

Should the final specification require it, a drop-down video camera may be required to acquire images of sampling stations prior to deployment of the Hamon grab. Contractors will provide the specifications of the seabed video apparatus that would be deployed should its use be required.

5.3.3. 2m Scientific Beam Trawl

A 2m scientific beam trawl may be required to sample mobile epifauna during the survey. The requirement for its use will be confirmed with survey companies prior to initiation of the survey. Contractors will provide the specifications of the 2m beam trawl apparatus that would be deployed should its use be required.

5.3.4. Hydraulic Clamshell Grab

A hydraulic clamshell grab may be required to acquire large volume seabed sediment samples at a limited number of sites during the survey. The requirement for its use will be confirmed with survey companies prior to initiation of the survey. Contractors will provide the specifications of the clamshell grab apparatus that would be deployed should its use be required.

6. Survey, Sample Processing and Sample Analysis Protocols

A valid Hamon grab sample is required at every sampling station within a 50m radius of the survey station location. The validity of a sample will be judged on the volume of seabed sediment acquired. Samples will contain a minimum of 5 litres of sediment to be considered valid.

At stations where the initial samples do not achieve the required volume, repeat sampling will be undertaken until a valid sample has been acquired. If, following three attempts, a valid sample cannot be acquired, re-positioning of the sample station will be sanctioned.

Samples will be processed on board the vessel to provide a sub-sample for PSA and at stations where it is required, a sub-sample for faunal analysis.

More detailed guidelines for the methods to be employed for survey, sample processing and sample analysis are provided in the RSMP survey protocol document presented in Appendix B.

7. Data Presentation and Reporting

All data and reports from the surveys will be presented by the contractor following completion of the works. The following will be provided as a minimum, in conjunction with *Section 4. Final Reporting* in Appendix B:

- Daily survey logs including records of numbers of sample attempts, numbers of successful samples acquired, numbers of failures to achieve a sample, and all HSE events and incidents;
- Sample logs including photographic images of all samples acquired;
- A full survey report detailing the vessels specifications, positioning and survey methodology and all significant survey events;
- A data analysis and presentation report describing the analyses performed on the samples; and
- Data tables of PSD and faunal data ascribed to relevant positional geodesic data (including sample station water depth). Please see attached Cefas Protocols PDF for examples

8. Estimated Timescales for Completion of the Works

All surveys will be completed by September 2026. All PSA and faunal analysis works will be completed by end of March 2027.

Appendix A. Co-ordinates of Proposed 2026 Sampling Stations in the Bristol Channel Region

Station Code	Longitude (WGS84)	Latitude (WGS84)	Area	Treatment	Required Samples
BC_0177	-3.317541	51.285585	526	SIZ	PSA ONLY
BC_0199	-3.301019	51.285101	526	SIZ	PSA ONLY
BC_0321	-3.392765	51.280655	NA	CONTEXT	PSA & MACRO
BC_0322	-3.286595	51.295176	526	PIZ	PSA ONLY
BC_0326	-3.362478	51.303371	NA	CONTEXT	PSA & MACRO
BC_0419	-3.188199	51.319178	526	PIZ	PSA & MACRO
BC_0420	-3.173651	51.322514	526	PIZ	PSA & MACRO
BC_0421	-3.309681	51.306107	526	PIZ	PSA & MACRO
BC_0422	-3.293999	51.308128	526	PIZ	PSA & MACRO
BC_0423	-3.276794	51.310526	526	PIZ	PSA & MACRO
BC_0424	-3.258446	51.311971	526	PIZ	PSA & MACRO
BC_0425	-3.24143	51.31151	526	PIZ	PSA & MACRO
BC_0426	-3.220416	51.312569	526	PIZ	PSA & MACRO
BC_0427	-3.198922	51.316	526	PIZ	PSA & MACRO
BC_0428	-3.18021	51.312688	526	PIZ	PSA & MACRO
BC_0429	-3.333409	51.297107	526	PIZ	PSA & MACRO
BC_0430	-3.319255	51.300462	526	PIZ	PSA & MACRO
BC_0431	-3.300913	51.298867	526	PIZ	PSA & MACRO
BC_0432	-3.282283	51.302218	526	PIZ	PSA & MACRO
BC_0433	-3.254855	51.304253	526	PIZ	PSA ONLY
BC_0434	-3.221369	51.302466	526	PIZ	PSA ONLY
BC_0435	-3.209415	51.303047	526	PIZ	PSA & MACRO
BC_0436	-3.187923	51.306181	526	PIZ	PSA & MACRO
BC_0437	-3.168037	51.31229	526	PIZ	PSA & MACRO
BC_0438	-3.320642	51.29101	526	PIZ	PSA ONLY
BC_0439	-3.274188	51.293833	526	PIZ	PSA & MACRO
BC_0440	-3.268005	51.318726	526	SIZ	PSA & MACRO
BC_0441	-3.162476	51.324707	526	SIZ	PSA & MACRO
BC_0442	-3.155884	51.314087	526	SIZ	PSA & MACRO
BC_0443	-3.169523	51.30354	526	SIZ	PSA & MACRO
BC_0444	-3.190254	51.297759	526	SIZ	PSA & MACRO
BC_0445	-3.216187	51.293091	526	SIZ	PSA & MACRO
BC_0446	-3.238478	51.292548	526	SIZ	PSA ONLY
BC_0447	-3.259029	51.290631	526	SIZ	PSA & MACRO
BC_0448	-3.280884	51.287292	526	SIZ	PSA & MACRO

BC_0449	-3.248901	51.320313	526	SIZ	PSA & MACRO
BC_0450	-3.228699	51.318298	526	SIZ	PSA & MACRO
BC_0451	-3.206289	51.322071	526	SIZ	PSA & MACRO
BC_0452	-3.181213	51.327271	526	SIZ	PSA & MACRO
BC_0453	-3.288086	51.316895	526	SIZ	PSA & MACRO
BC_0454	-3.305115	51.313293	526	SIZ	PSA & MACRO
BC_0455	-3.3255	51.308716	526	SIZ	PSA & MACRO
BC_0456	-3.339478	51.303894	526	SIZ	PSA & MACRO
BC_0457	-3.340881	51.293091	526	SIZ	PSA & MACRO
BC_0458	-3.173716	51.28877	NA	CONTEXT	PSA & MACRO
BC_0459	-3.280293	51.328426	NA	CONTEXT	PSA & MACRO
BC_0460	-3.24167	51.347519	NA	CONTEXT	PSA & MACRO
BC_0461	-3.180375	51.350952	NA	CONTEXT	PSA & MACRO
BC_0462	-3.131965	51.303938	NA	CONTEXT	PSA & MACRO
BC_0463	-3.140983	51.333837	NA	CONTEXT	PSA & MACRO
BC_0464	-3.326128	51.337089	NA	CONTEXT	PSA & MACRO
BC_0465	-3.214693	51.331115	NA	CONTEXT	PSA & MACRO
BC_0466	-3.300478	51.291633	526	PIZ	PSA ONLY
BC_0467	-3.267306	51.30535	526	PIZ	PSA ONLY
BC_0468	-3.262852	51.296663	526	PIZ	PSA ONLY
BC_0469	-3.330822	51.28881	526	SIZ	PSA ONLY
BC_0470	-3.211185	51.312164	526	PIZ	PSA ONLY
BC_0471	-3.2	51.30835	526	PIZ	PSA ONLY
BC_0472	-3.233367	51.299967	526	PIZ	PSA ONLY
BC_0473	-3.246365	51.29981	526	PIZ	PSA & MACRO
BC_0474	-3.310749	51.294504	526	PIZ	PSA ONLY
BC_0475	-3.27454	51.277027	NA	CONTEXT	PSA & MACRO
BC_0476	-3.233233	51.2834	NA	CONTEXT	PSA & MACRO
BC_0477	-3.249307	51.255251	NA	CONTEXT	PSA & MACRO
BC_0478	-3.195075	51.261188	NA	CONTEXT	PSA & MACRO
BC_0479	-3.347152	51.265648	NA	CONTEXT	PSA & MACRO
BC_0480	-3.30837	51.270034	NA	CONTEXT	PSA & MACRO
BC_0589	-3.320831	51.257217	BC Box 4	REF	PSA & MACRO
BC_0590	-3.294884	51.260711	BC Box 4	REF	PSA & MACRO
BC_0591	-3.307099	51.258826	BC Box 4	REF	PSA & MACRO
BC_0592	-3.283484	51.238345	BC Box 4	REF	PSA & MACRO
BC_0593	-3.293786	51.251535	BC Box 4	REF	PSA & MACRO
BC_0594	-3.309244	51.250201	BC Box 4	REF	PSA & MACRO
BC_0595	-3.320627	51.24872	BC Box 4	REF	PSA & MACRO
BC_0596	-3.297166	51.238822	BC Box 4	REF	PSA & MACRO
BC_0597	-3.28516	51.253088	BC Box 4	REF	PSA & MACRO
BC_0598	-3.310574	51.237544	BC Box 4	REF	PSA & MACRO
BC_0481	-2.96066405	51.467986	531	PIZ	PSA ONLY
BC_0482	-2.95186076	51.466419	531	PIZ	PSA ONLY
BC_0483	-2.98068106	51.459694	531	PIZ	PSA ONLY

BC_0484	-2.98309148	51.457016	531	PIZ	PSA ONLY
BC_0485	-2.96915294	51.466354	531	PIZ	PSA & MACRO
BC_0486	-2.98517	51.46619	531	SIZ	PSA & MACRO
BC_0487	-2.94735431	51.471054	531	PIZ	PSA ONLY
BC_0488	-2.93886542	51.470532	531	PIZ	PSA & MACRO
BC_0489	-2.98424429	51.450943	531	SIZ	PSA & MACRO
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BC_0491	-2.99327	51.46149	531	SIZ	PSA ONLY
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BC_0493	-2.96758092	51.471119	531	SIZ	PSA ONLY
BC_0494	-2.95877763	51.473535	531	SIZ	PSA ONLY
BC_0495	-2.96456955	51.457503	531	SIZ	PSA & MACRO
BC_0496	-2.95521439	51.460542	531	SIZ	PSA & MACRO
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BC_0502	-2.96114478	51.450826	NA	CONTEXT	PSA & MACRO
BC_0503	-2.93991343	51.454404	NA	CONTEXT	PSA & MACRO
BC_0504	-2.99734443	51.444477	NA	CONTEXT	PSA & MACRO
BC_0505	-2.91795859	51.466261	NA	CONTEXT	PSA & MACRO
BC_0506	-2.984357	51.461566	531	PIZ	PSA ONLY
BC_0506	-2.984357	51.461566	531	PIZ	PSA ONLY
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BC_0507	-2.978158	51.462598	531	PIZ	PSA ONLY
BC_0508	-2.97569	51.458944	531	PIZ	PSA ONLY
BC_0509	-2.971599	51.463633	531	PIZ	PSA & MACRO
BC_0509	-2.971599	51.463633	531	PIZ	PSA ONLY
BC_0510	-2.97	51.46	531	PIZ	PSA ONLY
BC_0511	-2.964684	51.462984	531	PIZ	PSA & MACRO
BC_0512	-2.964606	51.465574	531	PIZ	PSA & MACRO
BC_0512	-2.964606	51.465574	531	PIZ	PSA ONLY
BC_0513	-2.956793	51.46352	531	PIZ	PSA & MACRO
BC_0514	-2.956888	51.466077	531	PIZ	PSA & MACRO
BC_0515	-2.953506	51.470602	531	PIZ	PSA & MACRO
BC_0516	-2.948297	51.468589	531	PIZ	PSA & MACRO
BC_0517	-2.943161	51.471566	531	PIZ	PSA & MACRO
BC_0518	-2.94198	51.468799	531	PIZ	PSA ONLY
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BC_0525	-2.948322	51.465155	531	SIZ	PSA ONLY
BC_0526	-3.00403426	51.473297	NA	CONTEXT	PSA & MACRO
BC_0527	-2.97	51.48	NA	CONTEXT	PSA & MACRO
BC_0528	-2.926469	51.481269	NA	CONTEXT	PSA & MACRO
BC_0529	-2.902231	51.483613	NA	CONTEXT	PSA & MACRO
BC_0530	-2.912581	51.456686	NA	CONTEXT	PSA & MACRO
BC_0531	-2.97879982	51.441406	NA	CONTEXT	PSA & MACRO
BC_0532	-3.021425	51.445215	NA	CONTEXT	PSA & MACRO
BC_0533	-2.953425	51.497176	BC Box 3	REF	PSA ONLY
BC_0534	-2.965056	51.493314	BC Box 3	REF	PSA & MACRO
BC_0535	-2.959341	51.503187	BC Box 3	REF	PSA & MACRO
BC_0536	-2.940261	51.496138	BC Box 3	REF	PSA ONLY
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BC_0538	-2.939798	51.489925	BC Box 3	REF	PSA ONLY
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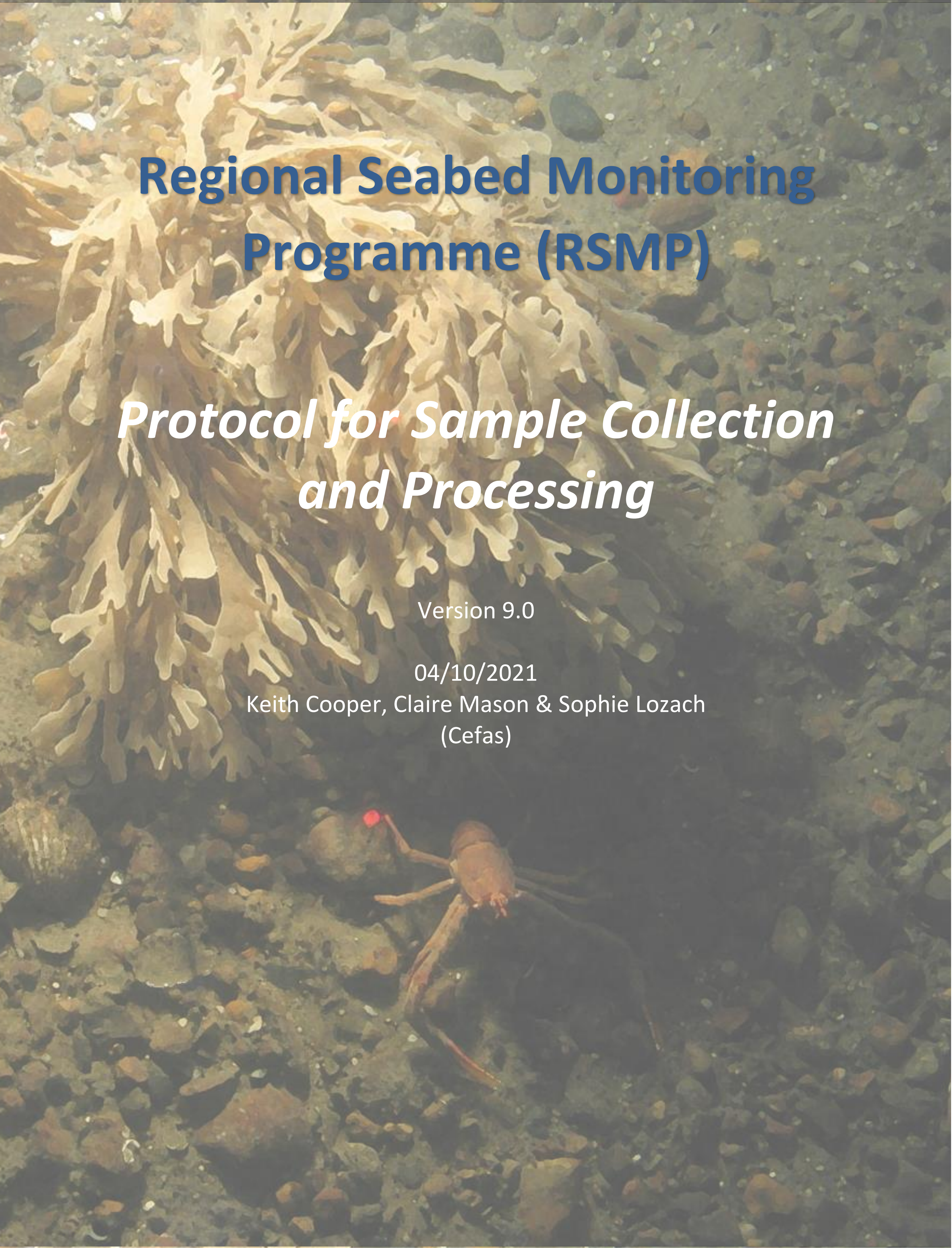
BC_0540	-2.944334	51.510546	BC Box 3	REF	PSA ONLY
BC_0541	-2.942572	51.504319	BC Box 3	REF	PSA ONLY
BC_0542	-2.929714	51.499981	BC Box 3	REF	PSA ONLY

Appendix B. RSMP Protocols



Regional Seabed Monitoring Programme (RSMP)

Protocol for Sample Collection and Processing

Version 9.0

04/10/2021

Keith Cooper, Claire Mason & Sophie Lozach
(Cefas)

Document amendments

Section	Change	Who	Version
2.1.6 – Item 1	Requirement to increase the PSA sub-sample volume to >500ml at stations where benthos is not required; aim to improve estimate of sediment particle size.	KC	3.0
2.1.6 – Item 2	Detailed instructions provided for the treatment of cobbles. Cobbles	KC	3.0
2.1.6 – Item 6	Rationale provided for the taking of a photograph of sediment retained on the 5mm sieve mesh following benthic sample processing. Suggested approach for contractors who don't have a 5mm mesh as part of their sieving table arrangement	KC	3.0
2.2.4	Additional requirement to record the total volume and condition of any *Sabellaria* reef present in trawl samples.	KC	3.0
3.1.4	Note added to allow for QA of 'own samples' to be performed in 1/3 batches.	KC	3.0
3.1.4	Requirement for 'own sample' fauna to be split into separate vial for each taxon found.	KC	3.0
3.1.4	Requirement added for the checking of the entire reference collection by the QA lab.	KC	3.0
3.2.6	Clarification given on how PSA samples selected for the 'own sample' check should be presented.	KC	3.0
2.1.6, 2.3.3, 2.4.4, 4.	Requirement to provide photos and video as .jpeg and .avi files. Details of file naming convention provided.	KC	3.0
Appendix A	Decision tree added (see Appendix) to show steps involved in the event of a 'no sample'. The strategy is designed to ensure good spatial coverage of grab samples.	KC	3.0
3.1.4	Section updated to allow own samples to be processed through the NMBAQC scheme.	KC	4.0
1.	Update of introductory text which previously focused on the baseline characterisation surveys	KC	5.0
2.1.6	In recognition that freezer facilities may not be available, the requirement to freeze sediment particle size samples has been changed to advisory (chill or freeze). Note added to keep samples in the dark to prevent growth of algae.	KC	5.0
2.1.6 Step 6	The sentence allowing for the disposal of the >5mm sediment (following photographing and checking for fauna) has been removed in recognition that this could potentially result in a loss of faunal specimens.	KC	5.0
3.1.4	Requirement to use the NMBAQC scheme contractor for external sample processing has been changed to allow auditing by another competent benthic lab participant in the NMBAQC scheme.	KC	5.0

3.2.4	Now acceptable to sub-sample fine sediment fraction (<63 µm) for freeze-drying/laser sizing.	CM	6.0
3.2.6	It will be the responsibility of the contracting laboratory to arrange for the external QC of 3 sediment particle size samples	CM	6.0
3.2	Removing requirement for laser analysis of the fine sediment fraction (<63µm) in PS methodology. Note oven drying and/or freeze-drying of the fine sediment fraction (<63µm) is acceptable.	CM	6.0
1.0	Introduction updated	KC	7.0
4.0	Requirement for taxon matrix to conform to WORMS	KC	7.0
3.2	Acknowledgement for method development and clarification from Professor Kenneth Pye (Kenneth Pye Associates Ltd) and James Hutchinson (Fugro).	CM	8.0
3.2.3 and Appendix B	Requirement to include <2mm pan sediment from dry sieving to <2 mm to >63 µm fraction before completing analysis of this fraction.	CM	8.0
3.2.3	Benefit of representative subsampling for dry sieving to prevent overloading of sieves using a sample splitter.	CM	8.0
Appendix C	Example of wet splitting sample methodology as a new appendix C.	CM	8.0
Introduction	Updates to text including links to apps.	KC	8.0
Introduction	Reader referred to APPENDIX D and E re SIZ extent. Update of app URLs etc.	KC	9.0
Appendix D	SIZ extent justification for main dredging regions (Humber, Anglian, Thames, East Channel, South Coast, North West).	SL	9.0
Appendix E	Addition of BMAPA report concerning SIZ extent for Bristol Channel and Severn Estuary.	KC	9.0
Attached file	Updated RSMP PSA template to include presence of *Sabellaria.*	CM	9.0
3.1.4 Quality management	Confirmation that the QC process must be repeated following remedial action.	KC	9.0

KC - Keith Cooper (Cefas), CM – Claire Mason, SL – Sophie Lozach

Contents

1. Introduction

1.1 The RSMP approach

The Regional Seabed Monitoring Programme (RSMP) is an innovative approach to monitoring the condition of the seabed, adopted by the UK marine aggregate dredging industry in 2014. It aims to ensure the seabed can support recolonisation, and the return of a similar animal community type after dredging activities have ended, thereby improving environmental sustainability (Cooper, 2013a; Cooper and Barry, 2017). Underpinning the approach is an extensive dataset used to understand the relationship between animal communities and sediment composition. The data (33,198 grab samples from 777 surveys) originate from government and wider industry sources and represent the accumulated knowledge from 48 years of benthic surveys covering large parts of the UK continental shelf (Fig. 1). This is the largest ever collation of such data, providing new insights into the distribution of seabed animal communities. Approximately one third of the data originates from the marine aggregates sector.

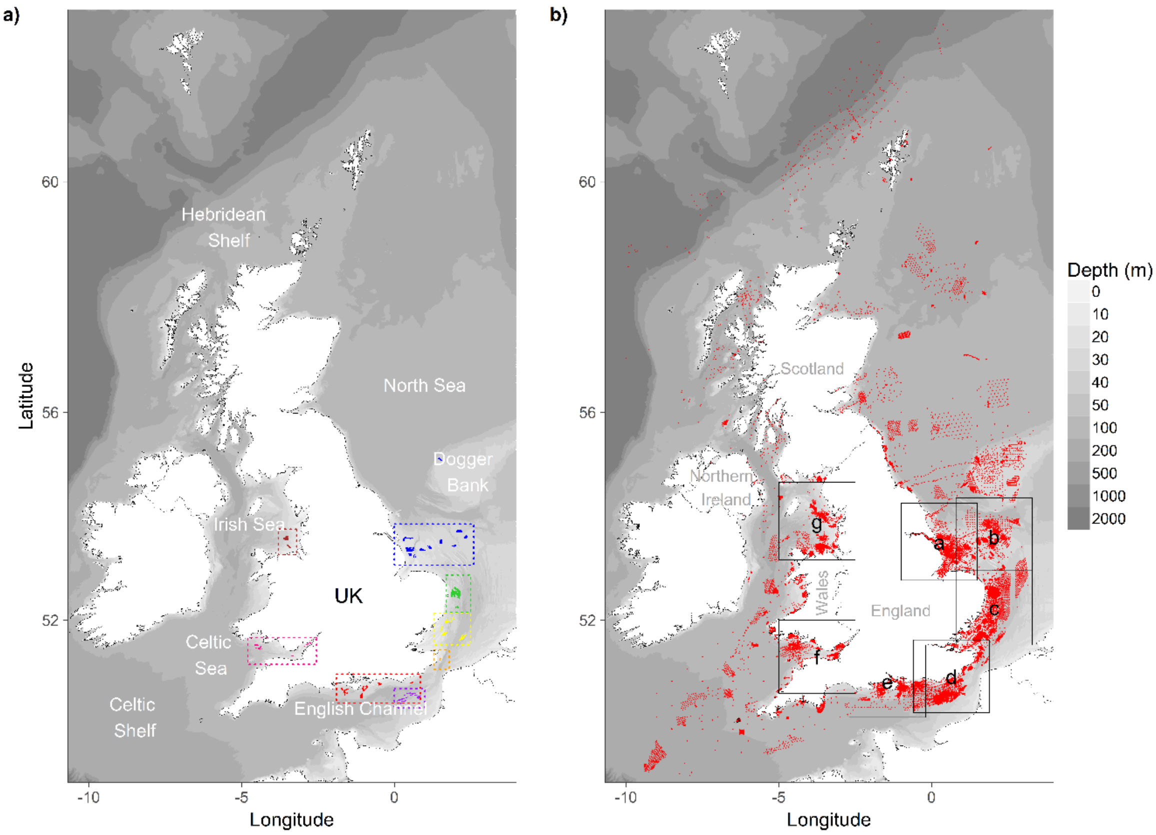


Fig. 1. (a) Study area showing locations of aggregate dredging interest (blue - Humber dredging region, green - Anglian dredging region, yellow - Thames dredging region, orange - Goodwin Sands dredging licence, purple - eastern English Channel dredging region, red - South Coast dredging region, dark pink - Bristol Channel/Severn Estuary dredging region, brown - North-West dredging region). (b) Sample locations

1.2 How it works

Baseline

- An array of sampling stations is established across each dredging region, with a focus on extraction areas (i.e. PIZ) and their zones of potential secondary effect (i.e. SIZ) (see Fig. 2). For further information regarding the extent of SIZs see APPENDIX D and E.
- Before dredging, grab samples are collected from all stations and analysed for macrofauna and sediment particle size composition.
- Using the large dataset, the animal community type is established for each sampling station (Fig. 3). A tool for identifying community type is available at https://openscience.cefas.co.uk/faunal_cluster_id/
- Sediment conditions associated with each faunal community type are established (Fig. 4)

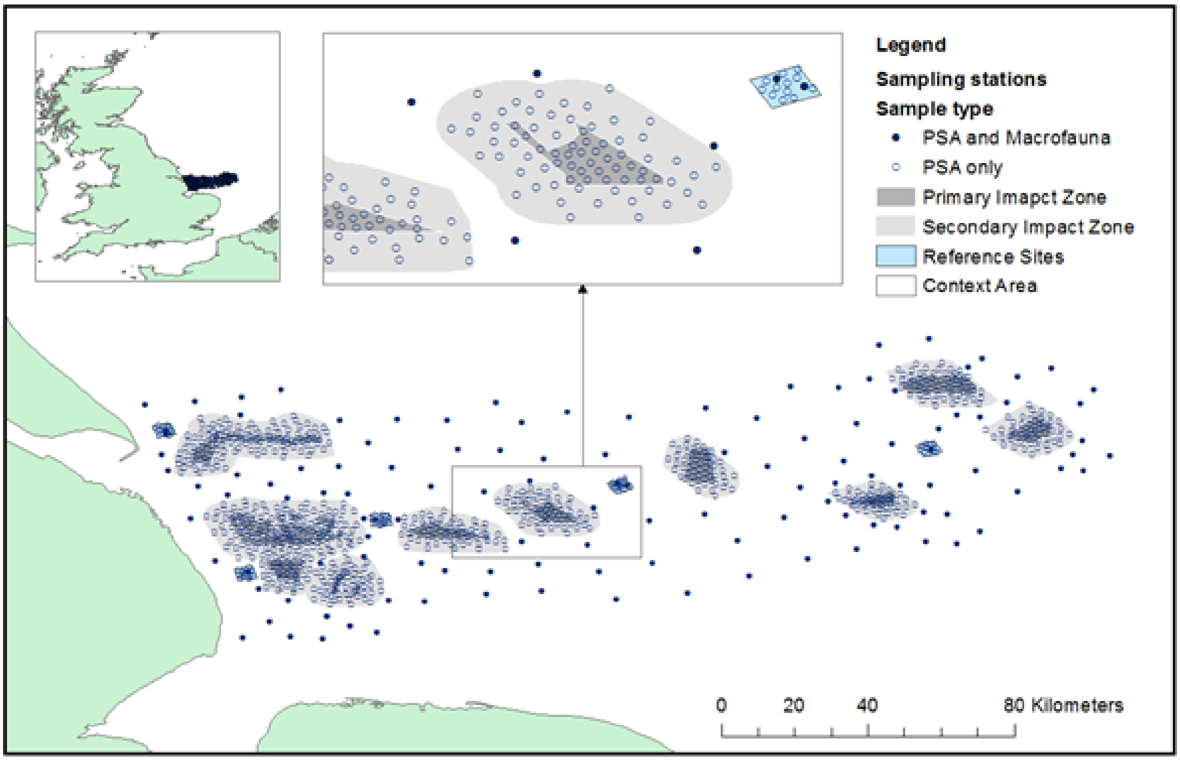


Fig. 2. The RSMP for the Humber dredging region.

Monitoring

- Once dredging begins, only sediment composition is routinely monitored within the area of potential dredging effect (i.e. PIZ/SIZ) to check conditions remain favourable for faunal recolonisation. The logic here being that if sedimentary conditions remain within the acceptable range then it should be possible for the return of the original faunal assemblage type after dredging has ceased (Cooper et al., 2008, 2011; Barrio Froján et al., 2011; Cooper, 2012, 2013b).
- Where unacceptable changes in sediment composition occur as a result of aggregate dredging, this will typically lead to management measures to try to return conditions back to within the acceptable range.

- Monitoring stations outside the influence of dredging (i.e. Reference and Context areas) are sampled for sediment particle size composition and macrofauna (see Fig. 2). These samples are used to: (i) help differentiate between natural and dredging induced sediment change, and (ii) check the health of faunal communities in the wider region. These communities will have an important role in recolonisation once dredging activities have finished.
- RSMP monitoring is routinely undertaken every 5 years. However, in cases where unacceptable changes have occurred, an interim survey may be required to check on the success of any management intervention.

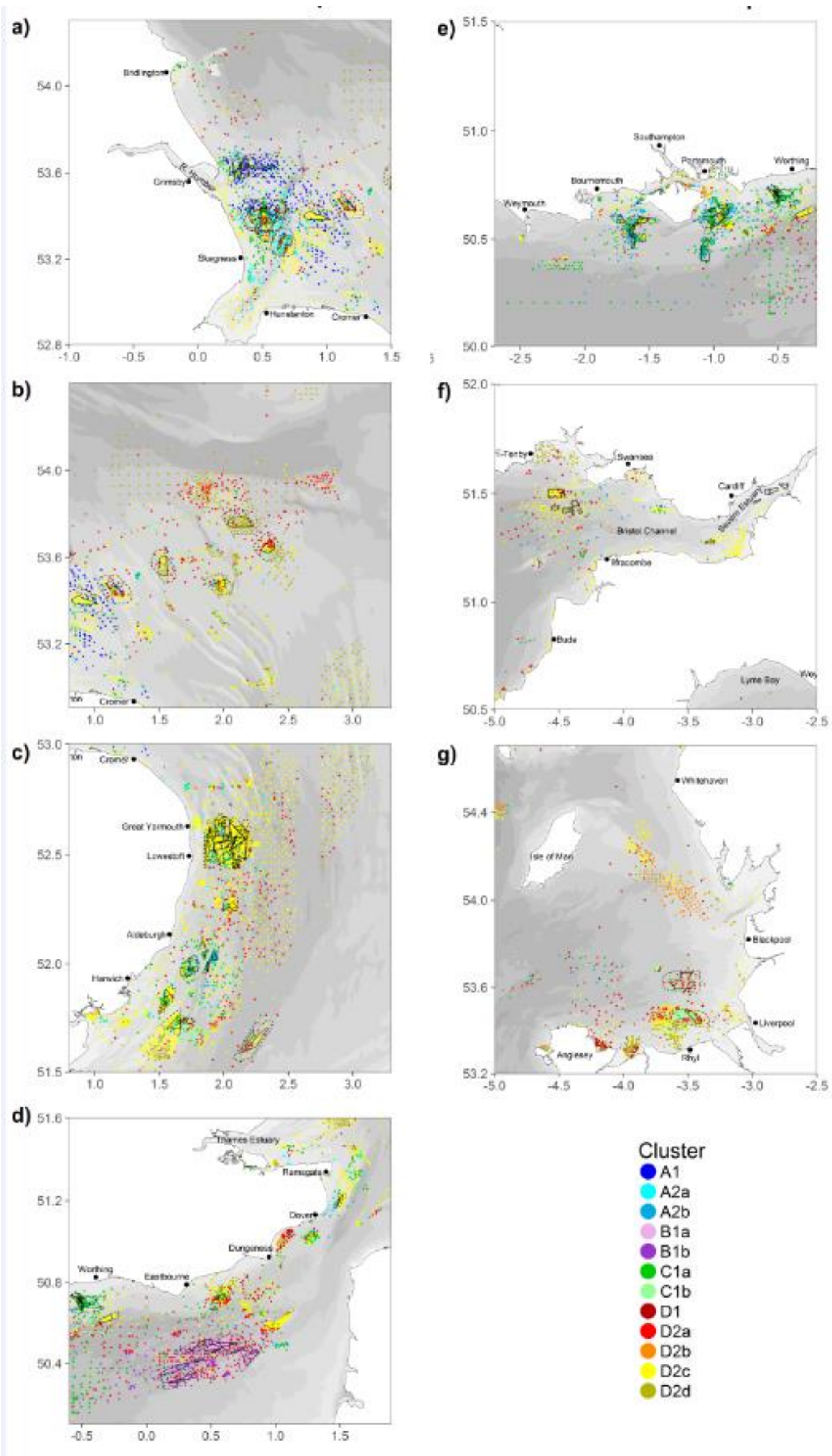


Fig. 3. Animal community identity of stations from the Anglian and Thames dredging regions. Note that RSMP stations form a subset of these points.

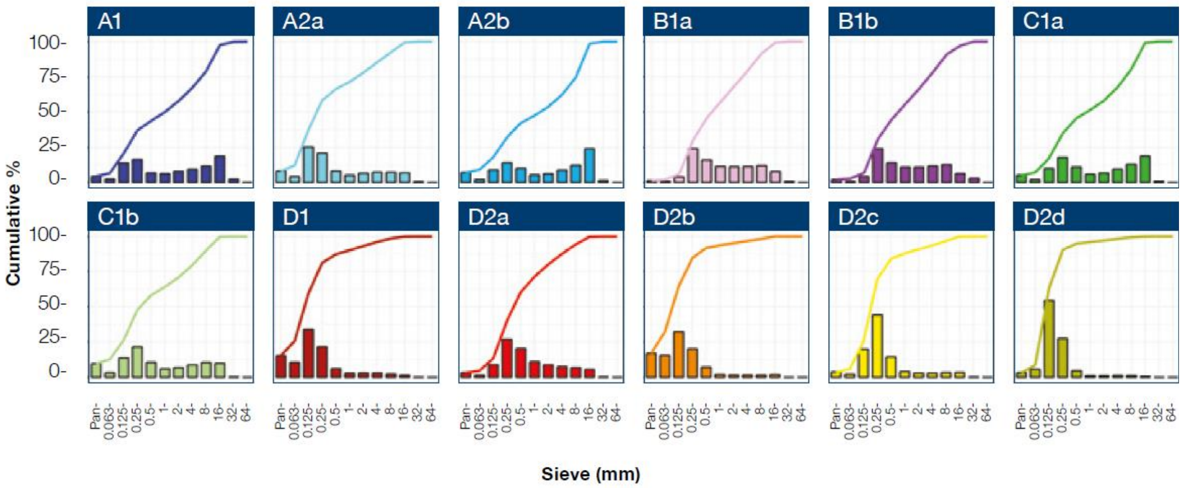


Fig. 4. Mean composition of sediments associated with the different animal community types.

Research sites

A dedicated regional research site can be established (where necessary) to answer outstanding questions (e.g., scale of effects, recovery). This approach allows for available resources to be focussed at one site, leading to a more robust understanding of effects.

1.3 Implementation

Baseline RSMP surveys were undertaken during 2014/15 across the main aggregate dredging regions, resulting in the collection of over 3,500 seabed sediment grab samples. Data from these surveys, together with those from existing datasets, have been used to: (i) to establish a ‘baseline’ for seabed macrofaunal communities in UK water (see Fig. 3 & Fig. 5), (ii) assess the relationship between animal communities and sediments (Fig. 4), and (iii) develop a methodology for assessing the ecological significance of changes in sediment composition. Full details of this work can be found in Cooper and Barry (2017).

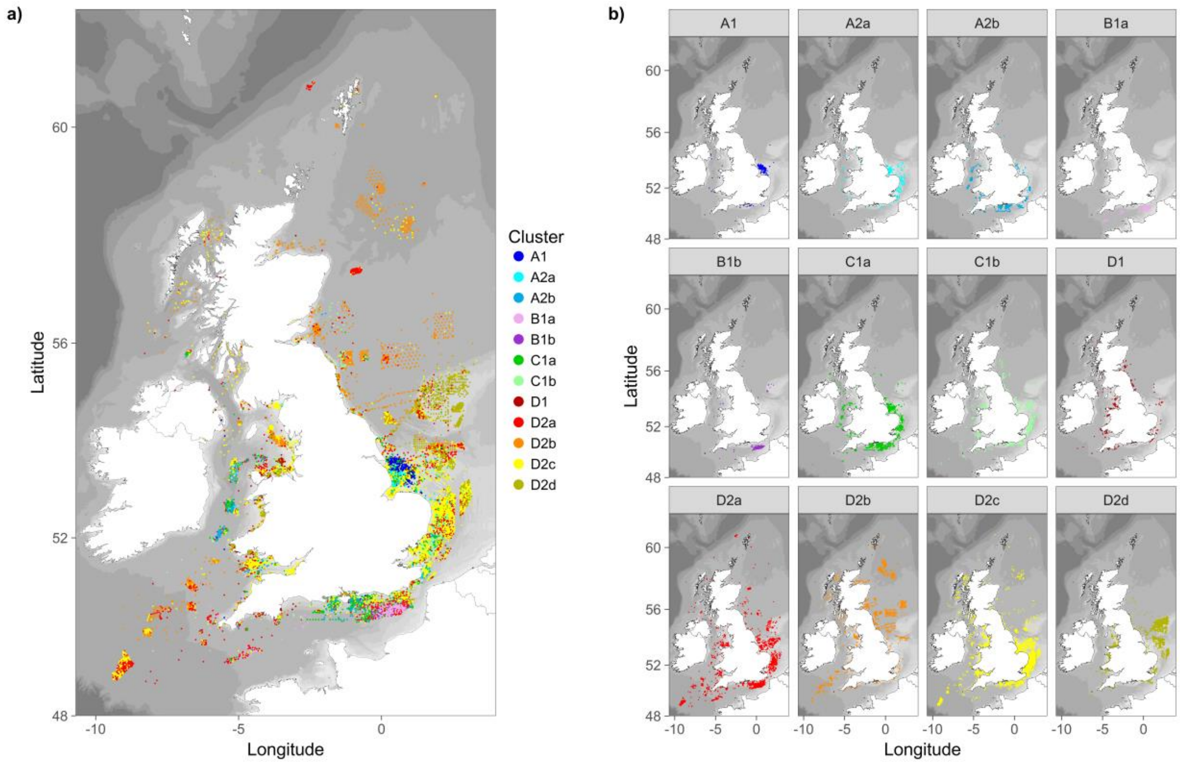


Fig. 5. Distribution of animal communities from the baseline dataset (see Cooper & Barry, 2017).

Following completion of the RSMP baseline, the first monitoring survey was undertaken in the South Coast region during 2017. This was followed by the Anglian and Thames in 2018, and the Humber and East Channel regions will follow in 2019 and 2020.

Clear benefits of the approach:

- Clear scientific rationale
- Allows for change
- Effective licence condition
- Environment defines limits of acceptable change
- Ability to differentiate between statistical and ecological significance
- Reduced monitoring costs
- Regional perspective
- More consistent and better-quality data
- Simpler reporting and assessment
- Better for operators, regulators and statutory advisors

1.4. Data analysis and reporting

A number of on-line applications allow for presentation and analysis of RSMP baseline and monitoring data. These tools are all linked to *OneBenthic,* a PostgreSQL database built to bring together all publicly available benthic data, thereby ensuring outputs are based on the very latest available data. Apps are made available through the **Cefas Open Science** portal (https://openscience.cefas.co.uk/) and currently include:

OneBenthic **Baseline tool** https://openscience.cefas.co.uk/ob_baseline/
OneBenthic **M-test tool** https://openscience.cefas.co.uk/ob_mtest/
OneBenthic **Faunal cluster ID tool** https://rconnect.cefas.co.uk/onebenthic_faunalclusterid/
OneBenthic **Non-native species tool** https://rconnect.cefas.co.uk/onebenthic_nonnativespecies/
OneBenthic **Survey Array tool** https://rconnect.cefas.co.uk/onebenthic_surveyarray/
OneBenthic* **Taxa Extraction tool https://openscience.cefas.co.uk/onebenthic_taxaextraction/
OneBenthic **Data Extraction tool** https://rconnect.cefas.co.uk/onebenthic_dataextractiongrabcore/
OneBenthic **Dashboard** https://rconnect.cefas.co.uk/onebenthic_dashboard/
OneBenthic **Sediment Change tool** https://rconnect.cefas.co.uk/onebenthic_sedimentchange/

** to go live in 2021*

Screenshots from each app are shown in Fig. 6. The **Baseline tool** allows users to see the faunal cluster identity of samples in the dataset. Reports can be generated for licenced areas. The **M-test Tool** allows users to assess whether changes in sediment composition are likely to be ecologically significant. The **Non-Native Species (NNS) tool** allows users to see locations where such species have been encountered and to track their spread over time. **The Faunal Cluster ID tool** allows new macrofaunal data to be matched to existing baseline cluster groups. The **Survey Array tool** provides a record of survey arrays and associated protocols. This app is the first step in working towards greater integration of monitoring programmes (see Barrio Froján, Cooper & Bolam, 2016). The **Taxon Extraction tool** allows users to extract occurrence records and associated habitat data, particularly in the context of the conservation of individual species. The **Data Extraction Tool** allows users to identify and download data from *OneBenthic*, facilitating research and reducing the need for collection of new samples. The **Sediment Change tool** allows users to determine whether there is any evidence of statistically significant changes in sediment composition between baseline and monitoring surveys. Finally, the **Dashboard** provides a view of the data held within the *OneBenthic* database. A number of other apps are currently in development.

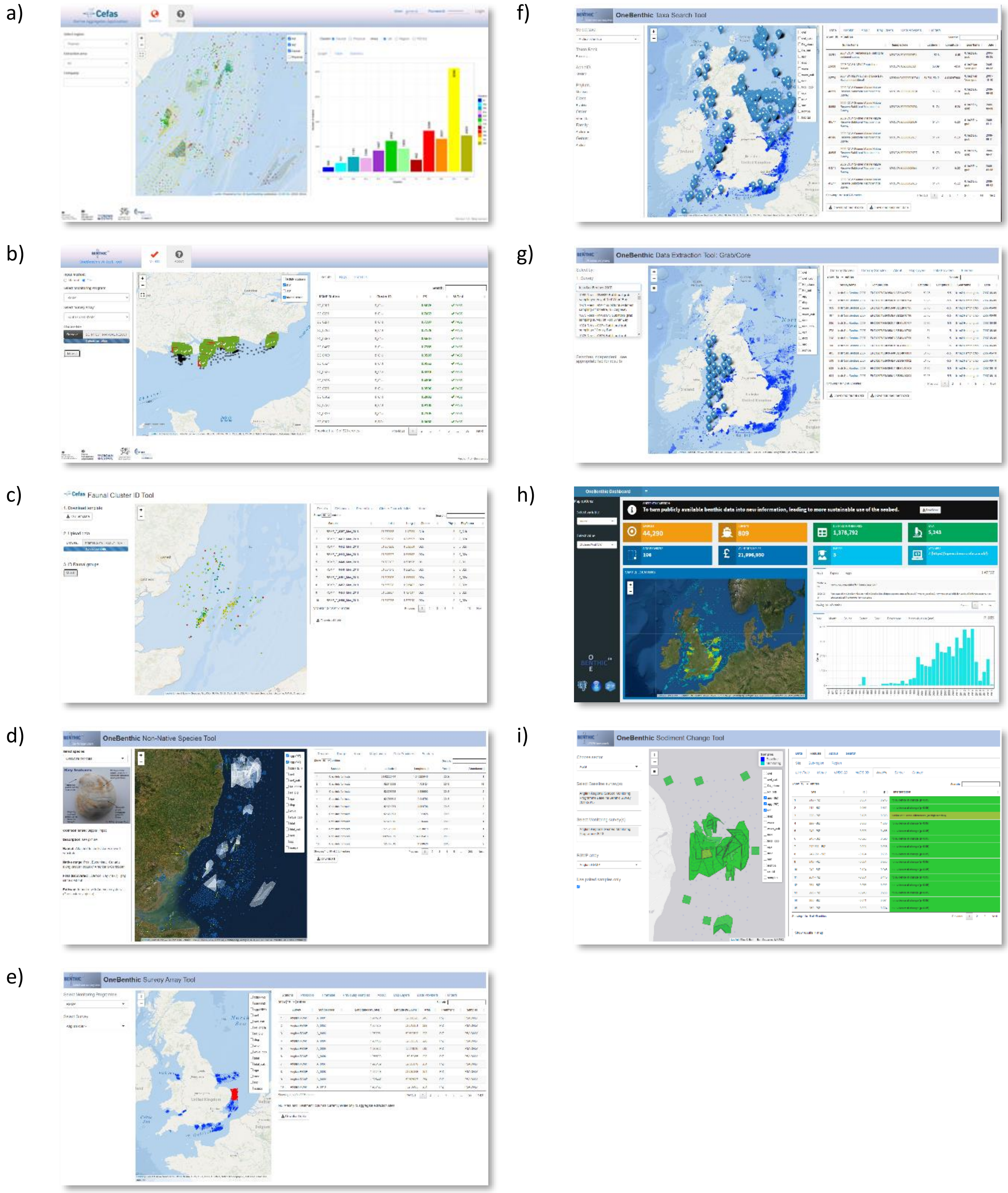


Fig. 6. Screen shots the a) *OneBenthic* Baseline tool b) *OneBenthic* M-test tool, c) *OneBenthic* Non-Native Species tool, d) *OneBenthic* Faunal cluster ID tool, e) *OneBenthic* Survey Array tool, f) *OneBenthic* Taxa Search tool, g) *OneBenthic* Data Extraction tool (grab/core), h) *OneBenthic* Dasboard, i) *OneBenthic* Sediment Change tool. All tools available from https://openscience.cefas.co.uk/.

The purpose of this document, which draws heavily from earlier guidelines (Ware & Kenny, 2011), is to set out the sample collection and processing methods which should be followed to ensure generation of consistent high-quality data.

2. Field sampling

2.1 Hamon grabbing

2.1.1 Introduction

The mini-Hamon grab (Oele, 1978; Eleftheriou and Moore, 2005) is the gear most frequently employed for the collection of sediment samples in coarse sediments, and should be used for all RSMP surveys. It consists of a rectangular frame forming a stable support for a sampling bucket attached to a pivoted arm (Fig. 7). On reaching the seabed, tension in the wire is released allowing the grab arm to pivot freely. Tension in the wire during hauling moves the pivoted arm through a rotation of 90°, driving the sample bucket through the sediment. At the end of its movement, the bucket opening presses onto an inclined rubber-covered steel plate, sealing it completely. The mini-Hamon grab is robust, simple to operate, and has been shown to be particularly effective on coarse sediments.

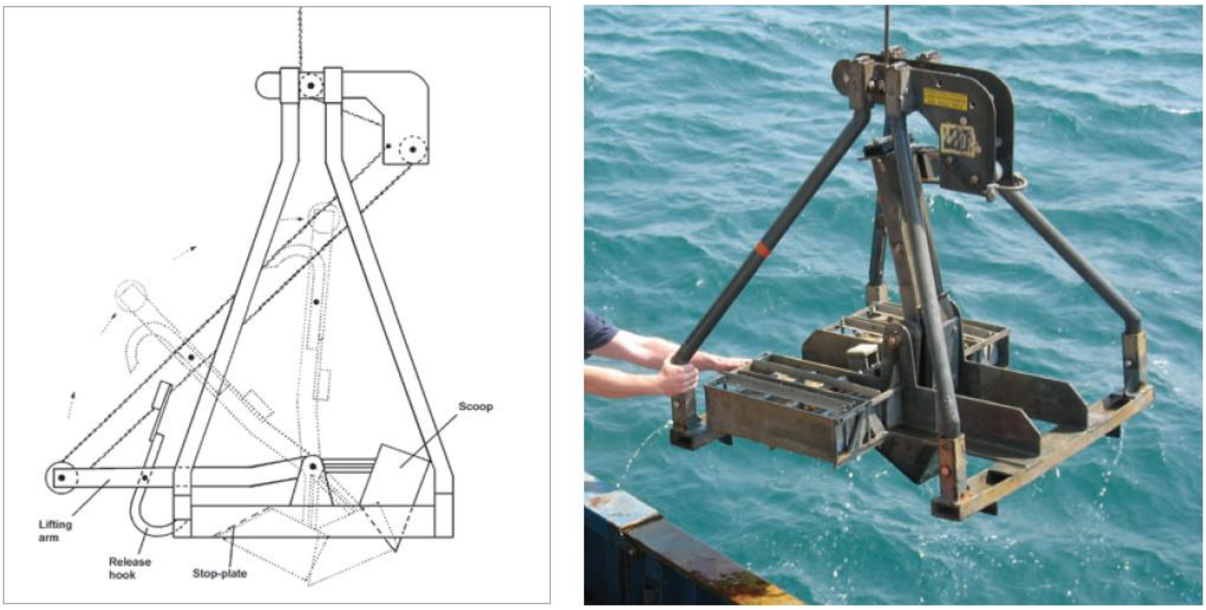


Fig 7. Mini-Hamon grab, showing mode of action (left) and on deck in cocked position (right). Schematic from Eleftheriou and Moore (2005).

2.1.2 Sampling strategy

A single grab sample will be collected from each station in the regional array using a 0.1m^2 Hamon grab. The sample should be taken as close to the target position as possible, and within 50 m of the target position (Fig. 8). Station positions are available from the *OneBenthic* **Survey Array Tool**.

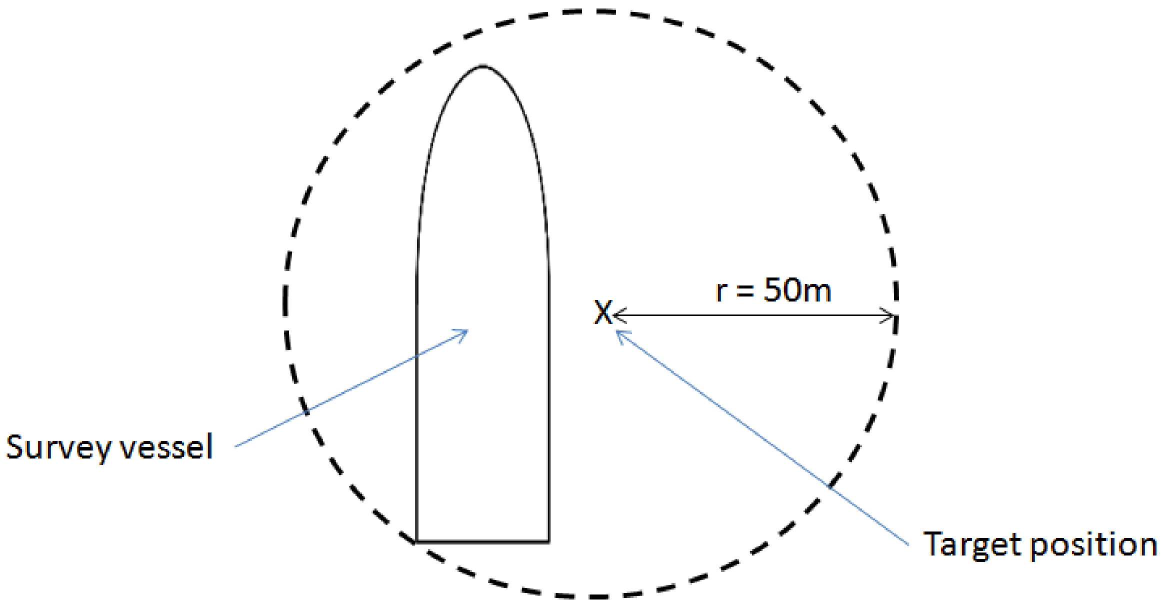


Fig. 8. 100m range ring surrounding the target station position.

Where the grab fails to return an acceptable sample (see below) then a minimum of a further three attempts should be made. The first of these can be made at the initial sampling location. Should further attempts be required then the vessel should move to different locations within the 100m range ring. Where small samples are recovered then these should be retained until all 4 attempts have been made. The largest of the small samples should then be processed. Clearly some judgment will need to be made regarding the acceptability of the sample, and this will depend on whether the sample is required for both particle size analysis and macrofauna. Pooling of small samples must NOT be undertaken.

Where it proves impossible, despite repeated attempts, to obtain an acceptable grab sample from within the range ring, then a new 'ad-hoc' station should be identified in the near vicinity (e.g. 100-200 metres away from the target position). If an acceptable sample cannot be obtained from this new station then it will be necessary to return to the original station, and to use optical methods to characterise the seabed (see below).

A decision tree showing the actions to take in the event of a 'no sample' is included in APPENDIX A.

2.1.3 Deployment

Once the grab has been deployed and is in the water, the winch should be veered at a rate of approximately 1 ms^{-1}. As the grab approaches the seabed this rate should be slowed to avoid the creation of a 'bow wave' which could wash away surface material. On reaching the seabed the winch wire will slacken, providing a signal for the winch operator to stop the winch. The scientist(s) assisting with the deployment should immediately fix the sample position and record it manually on the grab logsheet (Fig. 12) along with the time (in GMT) of the sampling event.

2.1.4 Recovery

After a short period (~ 5 seconds) the winch operator should start raising the grab, initially very slowly to maximize sampling efficiency. When the grab reaches the surface, it should be stabilised (usually by two people), brought aboard in a controlled manner and lowered gently onto the supporting frame (Fig. 9).

Fig. 9. Deployment and recovery of the Hamon Grab.

Once the grab is rested on the frame the winch cable is slackened further to allow the lifting arm to be lowered into the horizontal position. This action should result in the sample being released into the plastic box positioned beneath the frame. While the arm is held in the horizontal position, the scoop of the grab should be checked to ensure the entire sample has been released. The grab mechanism is then reset by holding down the grab arm in the horizontal position and gently heaving the winch until the arm catch engages. The grab is then ready for the next deployment.

2.1.5 Sample collection

When the grab has been reset, the sample collection box is removed from beneath the grab and the sample inspected. A verbal description of the sediment type is given and noted on the sample section of the grab logsheet (Fig. 17). The description should broadly follow the Folk system of sediment classification (e.g. muddy sand, slightly shelly gravel, slightly shelly, sandy mud) and is best given by an experienced sedimentologist. The Scientist-in-Charge (SIC), project manager, or delegated scientist will then decide if the sample is valid.

To be valid, a sample must meet two criteria. Firstly, it must be of an acceptable volume, usually > 5 litres. Smaller samples may be accepted if it proves impossible to obtain a larger sample, or if the sample is only required for sediment particle size analysis (see above). Secondly, there must be no indication of a significant malfunction in the grab. If, during sampling, the scoop of the grab fails to engage fully with the stop plate (e.g. as a result of a stone obstructing closure), resulting in the loss of sample material, the entire sample should be discarded and the grab re-deployed. At least four attempts should be made at each sampling station before it is abandoned (see above). The pooling of failed samples must <u>NOT</u> be undertaken.

If the sample is declared valid, the appropriately labelled sediment pot (containing completed labels for both sediment and benthos samples) is placed into the sample box before it is taken away for processing.

When the sample has been moved away from the grab operation area, the scoop of the grab should be washed with sea water and the grab reset for the next deployment.

2.1.6 Sample processing

The basic elements of the ship-based processing must be followed in strict order*, as follows:

1) Take a sediment sub-sample for PSA

2) Pour off the excess water from the sample over the sieve table

3) Photograph the sample (with label)

4) Measure the sample volume

5) Wash and sieve the sample on the sieve table

6) Photograph the material retained on the sieve table mesh

7) Preserve and label the sieved sample

**For PSA only stations follow steps 1-4. For stations requiring PSA and benthos follow steps 1–7.*

1) Take a sediment sub-sample for Particle Size Analysis (PSA)
Using a plastic scoop, extract a representative sub-sample of the sediment by collecting a number of aliquots from the full depth and surface area of the sample. A sub-sample of ~500 ml is considered an appropriate compromise for providing sufficient material for particle size analysis, whilst not removing significant proportions of the biota; for small samples it may be necessary to take less than 500 ml. When collecting the sediment sub-sample, it is important to include some of the sample water as this contains fine suspended particulate matter (the 'fines'). The sediment sample should be stored in a sealable container (e.g. 'Tupperware' box heavy duty plastic bag, or double bagging) which should be kept upright to avoid spillages. Samples should be kept in the dark (to prevent growth of algae), and, where possible, chilled or ideally frozen at -18^{o}C. Record the relevant details under the 'sediment sample' section of the sample record on the grab sample logsheet (Fig. 17). Also record the presence of any coarse material which is not represented in the sediment sub-sample (e.g. cobbles). Where present, cobbles must be counted, dimensions checked (i.e. min 64mm), and preferably weighed. Where weighing is not possible then an estimate should be made of the total cobble volume as a % of the total sample volume.

For sediment only stations, the volume of sediment taken for the PSA sub-sample can, and should, be greater than 500ml. The taking of a greater quantity of material will help improve the estimate of particle size composition at these sites, particularly where there is an appreciable quantity of coarser sediment.

2) Remove excess water from the sample
Remove excess water from the bulk sample by pouring it over the sieving table (ensuring all sieves are in place) and then place the container back on the deck. If a benthos sample is not required, then the excess water does not need to be poured over a 1mm sieve.

3) Photograph the sample

Take a photograph of the whole sample whilst it is still in this large container (Fig. 10). The photograph should include a large, fully detailed sample label which includes the following information:

- Cruise number or code (e.g. prefix - vessel name: End – Endeavour, Cor – Corystes followed by cruise number/year)
- RSMP Region (year)*
- RSMP Station code
- Station number and replicate (where appropriate)
- Sample type (macrofauna /PSA)

** replaces survey name in Fig. 13.*

For example:

Cruise code:	*CEnd_03/14*
RSMP Region (year):	*Humber 2014*
Station Code:	*H_0001*
Station number* (rep):	*1a*
Sample type:	*PSA*

This label should be retained for later use.

Figure 10. Photograph of Hamon grab sample, including meta-data label (Tupperware lid) taken prior to processing.

Image files should be named using the following convention:

RSMP REGION_YEAR_STATION CODE_STATION NUMBER_REP_IMAGE NUMBER e.g. HUMBER_ 2014_H_0001_001_A_001.jpeg

4) Measure the sample volume
Using a plastic scoop, transfer the sample into a graduated bucket (litres) and record the sediment volume on the grab logsheet (Fig. 17).

5) Wash and sieve the sample on the sieve table
The objective of the sieving process is to wash away all the fine material from the sample, leaving the macrofauna and the coarser sediment, which are then preserved in suitable containers prior to detailed faunal analysis back in the laboratory. Ensure the sieving table is properly set up with all meshes and sieves in place. For Hamon grab samples, a typical arrangement is to have a 5mm mesh inside the sieving table and a 1mm sieve under the outlet pipe. The sieving process will split the sample into a >5mm fraction and a 1-5mm fraction. Following processing these fractions should be recombined and preserved in the same container.

Put the graduated bucket containing the grab sample inside the sieving table and gently begin to wash the sediment from the bucket through the 5mm mesh, using a low-pressure salt-water hose (Fig. 11). This will allow many of the lighter organisms to be released from the sediment with the minimum amount of damage. Also, wash any small remnants of material from the original sample box onto the sieve table to ensure that all the sediment and organisms have been included.

Fig. 11. Sample processing using a purpose-built sieving table. The sample is being washed over a 5 mm square mesh aperture sieve supported by a removable square stainless-steel frame. Note also the 1 mm mesh sieve held within a sieve holder beneath the outlet pipe of the table.

As washing proceeds, keep a close watch on the 1mm sieve located under the outlet pipe of the table, to ensure that it does not become full of sediment or blocked by a build-up of fine material (which will cause it to overflow). When the sieve is full, temporarily stop the washing process and replace with an empty sieve of the same mesh size. Blocked sieves can frequently be cleared by gentle 'puddling' in a large container of seawater. A short, rapid up and down motion should be used during puddling, as horizontal movement can cause animals to be damaged through abrasion. Be sure not to allow the sample to spill over the top of the sieve (Fig. 12).

Fig. 12. Puddling of a benthic sample to remove excess sediment.

6) Photograph material retained on the sieve table mesh

When all the fine material has been washed through, take a photograph of the material retained on the 5mm grid (Fig. 13). The photograph should include the same fully detailed sample label as used when photographing the entire sample (see step 3). An image of the greater than 5mm material will provide a useful quality control check when it comes to reviewing the PSA data (i.e. where material of >5mm is seen in the photograph then this should also be evident in the PSA results). Where labs do not have a 5mm mesh then the sieved sample should be spread out on the 1mm mesh and photographed.

Fig. 13. Photograph of material from the sample retained on the 5mm coarse mesh sieve that sits inside the sieving table, including meta-data label (Tupperware lid).

After photographing this coarse material, carefully invert the 5mm mesh grid inside the sieving table and wash the material onto the 1mm sieve. Finally, check the grid for any trapped organisms and remove these with fine forceps, washing them onto the 1mm sieve.

Image files should be named using the following convention:

RSMP REGION_YEAR_STATION CODE_STATION NUMBER_REP_IMAGE NUMBER

e.g. HUMBER_ 2014_H_0001_001_A_001.jpeg

7) Preserving and labelling the samples

Each sample must be suitably labelled. Labels should be applied both to the outside and inside of the sample pots/buckets so that any damage to the external label does not prevent the identification of the sample. All labels should contain the following information:

- Cruise number or code (e.g. prefix - vessel name: End – Endeavour, Cor – Corystes followed by cruise number/year)
- RSMP Region (year)*
- RSMP Station code
- Station number and replicate (where appropriate)
- Sample type (macrofauna /PSA)

** replaces survey name in Fig. 13*

For example:

Cruise code:	*CEnd_03/14*
RSMP Region (year):	*Humber 2014*
Station Code:	*H_0001*
Station number* (rep):	*1a*
Sample type:	*PSA*

At the preserving table, bring together all the sieves that have been used for the sample and select a suitably sized sample container (Nalgene bottle or plastic bucket), remembering that sufficient space must be left in the container to add the formalin fixative.

Check the internal and external sample labels (Fig. 14) have the correct Station Number and Replicate letter, written in permanent ink. If necessary, add any other information required on the label.

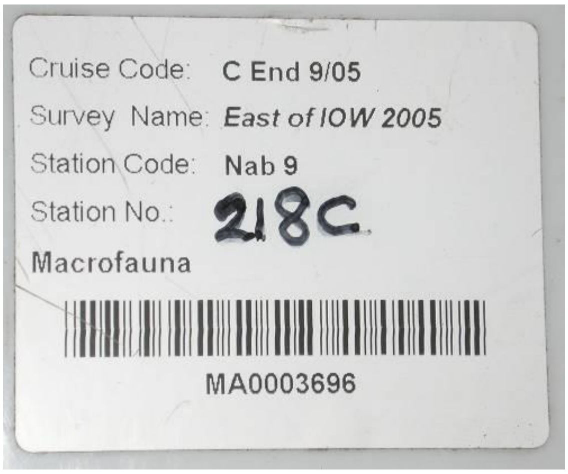


Fig. 14. Example of a pro-forma, bar-coded, printed label for a macrofaunal sample. The field for 'Station Number' is completed manually; here showing Station 218, Replicate C. All other fields are printed on the label.

A wide necked funnel should be used to help transfer the sample into the sample container. If using a Nalgene bottle, set up the bottle and funnel as illustrated in Fig. 15. If using a bucket, place the funnel inside the bucket. Transfer the material from the sieve into the funnel and wash into the container. Collect the final remnants from the sieve by back washing it with gentle water pressure, holding the sieve at a 45° angle so the material collects at the base of the rim. This process should be carried out over a large container so that any accidental spillages can be contained and rinsed back onto the sieve. Wash the last pieces of material into the funnel using a wash bottle. Pick out any remaining organisms from the sieve mesh using fine forceps.

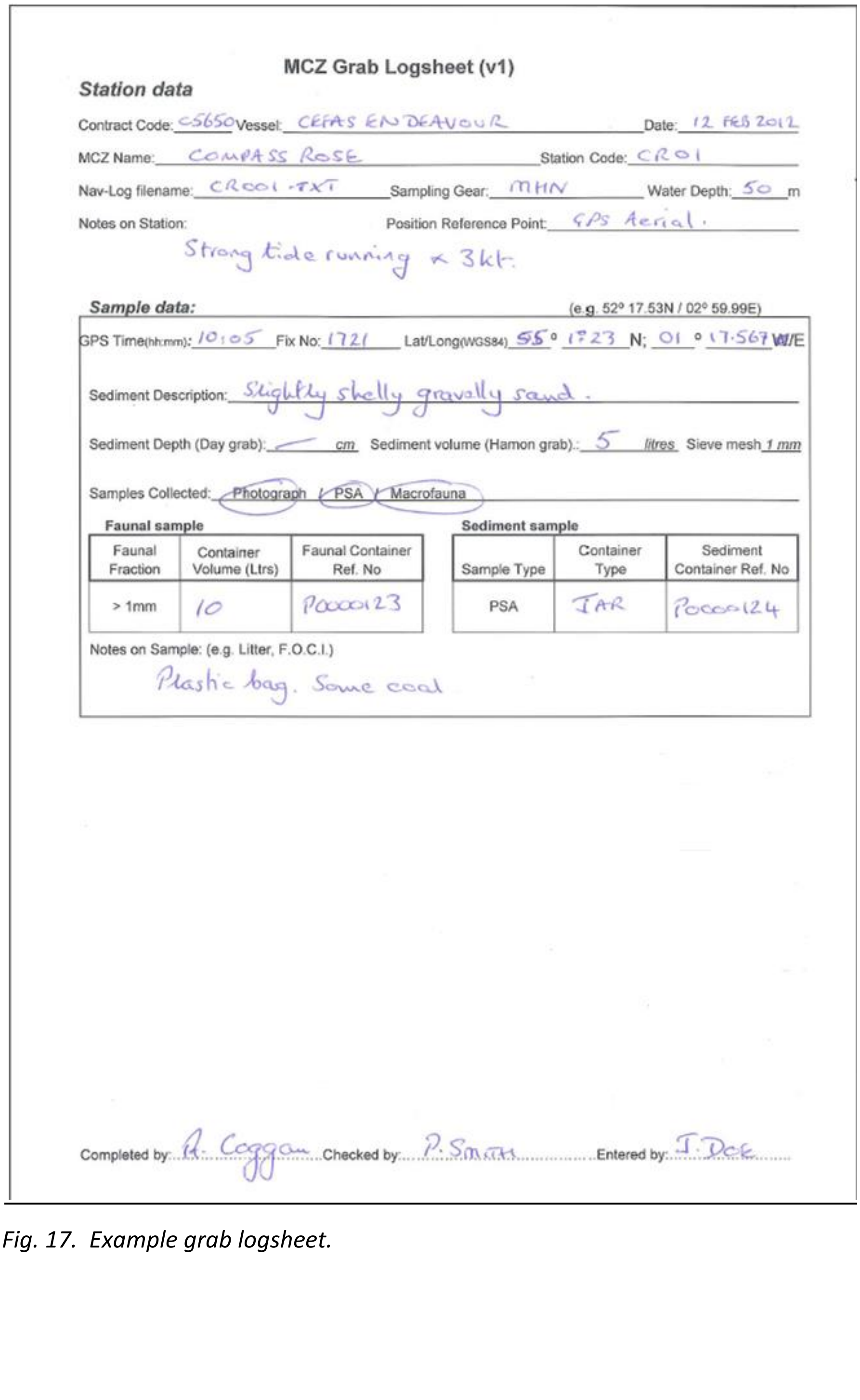
Fig. 15. Funnel and stand to assist in the transfer of the biological sample into the sample container.

Place the internal sample label in the bottle (or bucket) and take it to the formalin aspirator (on deck) where an appropriate volume of a 10% solution of formaldehyde should be added. The aim is to approximately double the volume of liquid in the sample in order to achieve a final concentration of 4-5% formaldehyde. Ensure the sediment and fauna are covered by the formaldehyde solution.

Place the lid on top on the sample and dry the outside of the container where the external label will be applied. For buckets, stick the label flat onto the bucket lid. For bottles, stick the label onto the outside of the bottle.

Once labelled, record the required information under the 'faunal sample' section of the sample record on the grab logsheet (Fig. 17), giving details of the sample fraction (>1mm) and the size of sample container (0.25, 0.5, 1.0, 2.5, 5, 10 litres). Finally, place the sample in a suitable weather-proof crate for storage/transportation (Fig. 16).

Fig. 16. Storage crates for bottles and buckets.



MCZ Grab Logsheet (v1)

Station data

Contract Code: C5650 Vessel: CEFAS ENDEAVOUR Date: 12 FEB 2012

MCZ Name: COMPASS ROSE Station Code: CR01

Nav-Log filename: CR001.TXT Sampling Gear: MHN Water Depth: 50 m

Notes on Station: Position Reference Point: GPS Aerial.

Strong tide running ≈ 3kt.

Sample data: (e.g. 52° 17.53N / 02° 59.99E)

GPS Time(hh:mm): 10:05 Fix No: 1721 Lat/Long(WGS84) 55 ° 17.23 N; 01 ° 17.567 W/E

Sediment Description: Slightly shelly gravelly sand.

Sediment Depth (Day grab): —— cm Sediment volume (Hamon grab): 5 litres Sieve mesh 1 mm

Samples Collected: Photograph / PSA / Macrofauna

Faunal sample

Faunal Fraction	Container Volume (Ltrs)	Faunal Container Ref. No
> 1mm	10	P0000123

Sediment sample

Sample Type	Container Type	Sediment Container Ref. No
PSA	JAR	P0000124

Notes on Sample: (e.g. Litter, F.O.C.I.)

Plastic bag. Some coal

Completed by: R. Coggan Checked by: P. Smith Entered by: J. Doe

Fig. 17. Example grab logsheet.

2.2 2m Beam trawling

2.2.1 Introduction

The 2 m Beam Trawl (Fig. 18) is routinely employed for the collection of epifaunal samples from a variety of sediment types. The trawl consists of a metal or wooden beam, a chain mat designed to prevent the collection of larger boulders, and chafers to limit damage to the net; the net itself consists of a belly (98 rows m^{-2}) and codend (157 rows m^{-2}), with a 3 mm mesh codend liner to capture smaller organisms (Jennings *et al.*, 1999; Figure 13). The 2 m Beam Trawl is designed to sample at and just above the surface of the seabed. Its small size makes it easy to deploy and usually results in the collection of a manageable sample size. For these reasons it is recommended for sampling the epifauna at marine aggregate extraction sites for the purposes of characterisation.

Fig. 18. 'Jennings' 2 m Beam Trawl with metal beam (Cefas © Crown Copyright 2011).

2.2.2 Sampling strategy

On each deployment, 2 m Beam Trawls should be towed over a distance which will collect a sufficiently large sample to adequately characterise the resident epifaunal assemblage, but not so large that the sample is unmanageable. Typically, the trawl is towed across a pre-determined range ring to allow the direction of travel to be decided according to prevailing tidal direction.

A speed of 1-2 knots over the ground is recommended. It is essential that information on tidal state and weather conditions are recorded, as they may contribute to observed differences between stations and/or sampling times.

2.2.3 Deployment

The gear is lowered ('shot') over the stern and the winch is 'veered' (cable is paid-out) to a distance equivalent to approximately three times the depth of water. When nearly all the cable ('warp') has been paid-out, the vessel slows down to the nominal towing speed (1-2 knots). Further guidance can be found in the ‘Recommended operating guidelines (ROG) for MESH trawls and dredges’ (Curtis and Coggan, 2006).

2.2.4 Processing semi-quantitative epifaunal samples from trawls and dredges

On retrieval of the trawl, the catch should be concentrated in the cod-end of the net. The contents of the cod-end should be released into suitable sample containers and an estimate made of the total volume of the catch including a photograph should be taken. It is essential that all the fauna is retrieved from the full length of the net and included in the analysis of material.

Fig. 19. Volume of a beam trawl sample being measured using a graduated bucket before being washed and sorted over a 5 mm mesh screen (Cefas © Crown Copyright 2011).

Epifaunal trawl samples often require sub-sampling in order to manage the large number of organisms encountered. Further guidance on sub-sampling procedures can be found in the Recommended Operating Guidelines (ROG) for MESH trawls and dredges (Curtis and Coggan, 2006).

Samples should be processed over a frame-supported 5 mm mesh (Fig. 19), discarding any material passing through the mesh. Counts of very abundant solitary species may be derived by sub-sampling. Colonial species (notably hydroids and bryozoans) are generally recorded on a presence/absence basis.

Where there is evidence of possible *Sabellaria* reef (e.g. aggregations of tubes), pictures should be taken and the following information recorded:

- Aggregation type (reef, clumps, veneer or rubble)
- Estimated total volume of *Sabellaria* in litres
- Presence / Absence of live worms
- Max tube aperture and average tube aperture (min’ of 10 measurements)
- Max tube length and average tube length (min’ of 10 measurements)

Where there is any uncertainty over the identification of individual taxa then representative samples should be returned to the laboratory for further investigation.

All relevant data and metadata should be recorded from each deployment (see Fig. 20).

Image files should be named using the following convention:

RSMP REGION_YEAR_STATION CODE_STATION NUMBER_REP_IMAGE NUMBER

e.g. HUMBER_ 2014_H_0001_001_A_001.jpeg

Sheet____of____

Towed Gear Logsheet (2013)

Station

Cruise:______________ Survey:________________________________ Project:_____________ Stn No.:_______

Stn Code:____________ Date:_______________ Tower log folder:_____________________________________

Log method: *time / distance* Log freq.:________ *seconds / metres* Vessel speed:_______ knots Distance: _____ m

Gear:_____________________ Water Depth:________ m

Notes:

Posn Ref Point:	TIME	FIX	Position
Lock			
Haul			

Sample

Status: *Processed? Ref. sp. kept? Photograph?* Sieve mesh size: *5 mm* Sample volume:_______ *litres*

Sub-sample volumes: 1st__________ 2nd__________ 3rd__________ BARCODE: ___________________

Taxon	Kept? Y/N	Count	Sub Vol.	Raised Total

Completed by:................................Checked by:.......................................Entered by:..........................

Fig. 20. Example trawl logsheet.

2.3 Optical methods

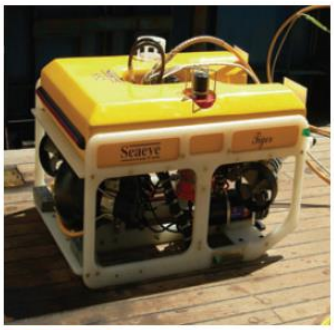
2.3.1 Introduction

Underwater video and stills photography are valuable, non-destructive methods for the assessment of all types of seabed habitat. They can be particularly useful over hard and consolidated ground where the sampling efficiency of other physical sampling methods is low. Remotely controlled underwater photography has been in use for a number of years to obtain static images of the seabed, and high-quality images can be obtained which enable the identification of much of the macro-epifauna present. These images cover a small area of seabed and while useful in pilot surveys, do not readily provide information on the wider spatial distribution of faunal communities.

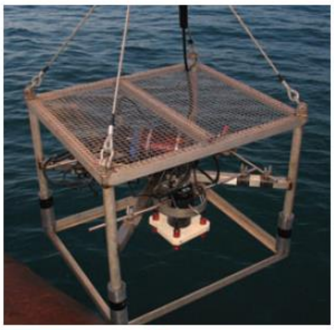
2.3.2 Equipment

To allow wider spatial coverage of the seabed, photographic and video cameras have been mounted on a variety of platforms. Cameras have also been attached to a variety of grabs to provide real time images of the nature of the substratum being sampled. However, in most instances platforms will fall into one of the following categories:

Devices which are capable of moving or being directed under their own power such as Remotely Operated Vehicles (ROVs).



Samplers which are lowered to a point above the seabed (e.g. drop cameras).



Devices which are towed along the seabed (e.g. camera sledges).

Samplers which are lowered onto the seabed and penetrate the sediment to acquire a vertical profile image of the sediment (e.g. Sediment Profile Imaging (SPI) camera).

2.3.3 Strategy

Where it proves impossible to acquire a grab sample then optical methods should be used to characterise the seabed using either a camera mounted on either a sledge or drop frame. The device should be deployed outside the 100m range ring with the aim of acquiring good quality data from one side of the ring to the other, passing as near to the centre of the ring (target position) as possible (Fig. 21). Video/stills footage should be collected in accordance with the MESH guidelines 'Recommended operating guidelines (ROG) for underwater video and photographic imaging techniques' which accompanies this document. Any labels used must include the following information:

Cruise code:	*CEnd_03/14*
RSMP Region (year):	*Humber 2014*
Station Code:	*H_0001*
Station number* (rep):	*1a*
Sample type:	*Cam sledge video*

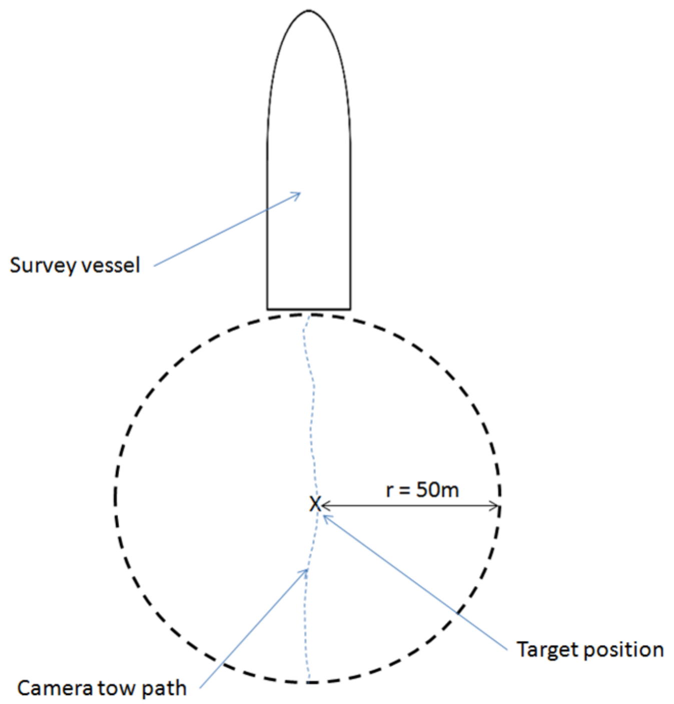


Fig. 21. Camera tow path from one side of the 100m range ring to the other.

Image/video files should be named using the following convention:

RSMP REGION_YEAR_STATION CODE_STATION NUMBER_REP_IMAGE NUMBER

e.g. HUMBER_ 2014_H_0001_001_A_001.jpeg
SOUTH COAST_2014_SC_0007_023_A_001.avi

2.3.4 Underwater images in low visibility

In low visibility conditions (caused by high levels of turbidity in the water column) the acquisition of good quality images may not be possible using the conventional systems described above. Under such circumstances, quality images of the seabed may still be acquired using a camera system that incorporates a freshwater lens (Fig. 22). However, such systems may still fail to obtain useable images in areas where high levels of turbidity are encountered.

Fig. 22. Examples of camera systems incorporating a freshwater lens. Reproduced by kind permission (MES Ltd 2009).

3. Laboratory processing

3.1 Faunal analysis

Elutriation, extraction, identification, enumeration and biomassing should be carried out following the NMBAQC Processing Requirement Protocol (PRP), (Worsfold, T.M., Hall, D.J. & O'Reilly, M. (Ed.) 2010).

3.1.1 Elutriation and sorting

Before any processing takes place, the formaldehyde fixative must first be washed out from the sample and disposed of appropriately. This process must be carried out with adequate ventilation and using appropriate personal protective equipment (PPE). Organisms are then sorted and removed from the sample through a combination of elutriation and hand picking using suitable equipment (Fig. 23).

Fig. 23. (left) Gridded tray containing sorted sample. Note the illuminated magnifier. (right) Binocular microscope being used for specimen identification (Cefas © Crown Copyright 2011).

3.1.2 Identification and enumeration

<u>All</u> fauna/flora (including colonial taxa) contained within the sample should be identified down to the lowest possible taxonomic level (usually species) using standard taxonomic keys and enumerated. Taxonomic nomenclature should be compliant with the World Register of Marine Species (WoRMS). Only specimens with an anterior end are counted. Distinction should be made between adult and juvenile specimens where possible. Colonial species (e.g. hydroids and bryozoans) should be recorded on a presence/absence basis. The presence of any eggs should also be recorded and, where possible, identified.

3.1.3 Biomass determination

Biomass should be determined and reported as wet weights. Prior to analysis, wet weights should be converted to Ash Free Dry Weight (AFDW) using standard conversion factors (e.g. Rumohr *et al.* 1987; Ricciardi and Bourget, 1998 and Eleftheriou and Basford, 1989). Biomass only needs to be determined at the level of major taxonomic groups (i.e. Annelida, Crustacea, Echinodermata, Mollusca, Miscellanea).

3.1.4 Quality management

Internal

A lab must have in place their own in-house quality control (QC) procedures to assure the quality of the resulting data. Measures may include the re-analysis of 10% of the samples processed, including a resort of the sample residues. In addition, it may also be useful to check the identity of each taxon in the reference collection (see below).

External

In addition to the 'in-house' QC measures described above, sample processing will be subject to external quality control checks by an independent, competent benthic laboratory participant in the NMBAQC scheme (http://www.nmbaqcs.org/). The process will work as follows: On completion of sample processing, the processing lab will email their benthic dataset to Cefas (keith.cooper@cefas.co.uk) for selection of 3 samples for auditing purposes. The sample processing lab will then send the sediment residues and extracted fauna (with separate vials for each taxon) from each of the 3 selected samples to the QA lab for processing. The results of the QA checks will be assessed according to the NMBAQC Scheme 'Own Sample' criteria (see http://www.nmbaqcs.org/scheme-components/invertebrates.aspx), with any suggested remedial action highlighted by the QA lab as necessary. Whether remedial action is undertaken, and what form it should take, will be determined by the customer (aggregate industry), with input from the processing lab, QA lab and Cefas (the aim here will be to find a consensus on the way forward). Any remedial actions which are deemed necessary will be undertaken at the contractor's own expense, and may involve work on the entire sample batch, not just the checked samples in question. On completion of remedial action, the above QC exercise must be repeated, with a further 3 samples selected for external checking. Where remedial action has targeted specific samples (i.e. those similar in nature to the one(s) that initially failed), then at least one of these should be included in the checks.

Sample material (sediment residues and fauna) from all samples (entire batch) must be stored until confirmation that agreed remedial actions have been completed to the satisfaction of the customer. <u>Own sample checks can be completed on 1/3 batches of samples, with one sample selected for each batch. This will allow the lab to dispose of sample residues at the earliest opportunity</u>.

In addition to the above sample checks, the processing lab will be required to submit their completed benthic reference collection for checking by the QA lab. On completion of the reference collection identification checks, the QA lab will send their results back to the originator. Labs should work together to resolve any taxonomic discrepancies in the identifications before finalising the species/sample matrix. The results of external QA should be reported alongside the final benthic dataset.

All emails concerning the above external QA checks should be cc'd to Cefas (keith.cooper@cefas.co.uk).

3.1.5 Sample tracking

Sample tracking (i.e. information concerning the location and status of samples at all stages following collection) is an essential part of any Quality Assurance programme.

3.1.6 Preservation and storage

Specimens from each sample should be transferred to a single container, and a preservative solution of 70% ethanol/IMS applied. It is also acceptable to have a separate vial for each taxon found in a sample. Splitting the sample in this way can help expedite the QA process.

3.1.7 Reference collections

A reference collection containing at least one individual of each species/taxon should be generated. Identifications should be checked with the laboratories own reference material to ensure faunal identifications are correct. All reference material must be retained for future reference, and will be subject to a external quality control (see above).

3.2 Particle size analysis (PSA)

The PSA laboratory sample processing methodology for the RSMP involves sieving samples to 63µm at 0.5 phi resolution combined with a weight determination only for the <63µm fraction (see flow diagram in APPENDIX B Flow diagram for PSA laboratory sample methodology. This differs from the NMBAQC PSA methodology, which is a combination of sieving and laser sizing (NMBAQC's Best Practice Guidance - Particle Size Analysis; Mason, 2016). Laser sizing is not used for the RSMP because the aggregate industry's historic data has been generated primarily using sieves. The reliance on sieves is justified by the coarse nature of sediments found in the vicinity of aggregate extraction areas. Never-the-less, the RSMP PSA methodology has been standardised to consider previous work, as well as to ensure the data will be useful in a wider context.

Laboratories must put in place appropriate health and safety risk assessments to protect laboratory staff by minimising their exposure to presence of low levels of asbestos in samples.

Sediment samples should ideally be in the range of ~ 500ml to 2 litres in volume. The laboratory should visually assess the samples received, with ~500ml of sample taken forward for analysis. Where samples are considerably larger than 500ml and are homogenous (i.e. predominantly sand or very fine gravel size), it is acceptable to sub-sample the material, taking forward a minimum of 500ml for analysis. Where samples are heterogenous (e.g. including occasional coarser particles) this volume should, where possible, be increased. With very small samples that are clearly non-representative (e.g. 2 pebbles in a 500 ml pot) then analysis should be limited to a visual description. In such cases, samples should be kept but note that no data will be entered into the PSA results template.

The laboratory must provide evidence that results are representative of the field sample collected by performing analysis of a duplicate subsample, or the whole sample if the sample volume is between 500ml and 1000ml, for 1 in every 20 samples (5%).

The remainder of the sample must be retained and submitted as part of the external quality assurance procedure (3.2.6 Quality).

3.2.1 Sample storage

Prior to laboratory analysis the PSA sample should, where possible, be stored frozen in a sealed container, preferably in the dark.

3.2.2 Wet screening the sample into >2mm, <2mm >63µm and < 63µm sediment fractions

The sample should initially be wet screened at 2mm. The <2mm wet sediment should then be wet screened at 63µm to separate it into two fractions (<2mm to >63µm and <63µm). Care needs to be taken here, especially where samples contain mixtures of coarse gravel, sand and a lot of mud. The samples should be pre-dispersed by hand in a bowl if the mud is consolidated / partially consolidated. Screening at 2mm and 63µm will ensure that all the coarse (>2mm) sediment will be analysed. Practically, a range of meshes such as 4mm, 2mm, 500µm and

250µm sieves can be included in the overall screening process to prevent physical damage to the 63µm sieve mesh. This will also prevent overloading (where particles that are small enough to go through the mesh are unable to do so because the sieve mesh is clogged), ensuring water flow is maintained. Example methodology is provided in APPENDIX C PSA: Wet screening a sample into >2mm, <2mm >63µm and < 63µm sediment fractions – Fugro example.

For large and homogeneous samples it may be necessary to split the sample into batches, with each screened individually (see above text regarding subsampling).

The screening process may yield 3 different fractions (see below). The methodology for processing these fractions is detailed below.

- **>2mm**
  see **3.2.3 Analysis of the coarser fraction (>2 mm and <2 mm to >63 µm sediment fractions)** using a dry sieving process
- **<2mm >63µm**
  see **3.2.3 Analysis of the coarser fraction (>2 mm and <2 mm to >63 µm sediment fractions)** using a dry sieving process
- **<63µm**
  see **3.2.4 Analysis of the finer fraction**

3.2.3 Analysis of the coarser fraction (>2 mm and <2 mm to >63 µm sediment fractions) using a dry sieving process

The >2mm fraction, and the <2mm to >63µm fraction should be oven dried at between 80°C to 110°C for a period of 24 hours, or until completely dried. The weight of both of these dried fractions (>2mm fraction, and the <2mm to >63µm fraction) must be recorded prior to any sieving.

All the dried >2mm fraction must be sieved on a stack of sieves at 0.5 ϕ intervals from 2mm to 63mm (see Table 1) for a minimum period of 10 minutes. Any sediment passing through the 2mm sieve into the collecting pan at the bottom of the stack must be weighed, and then combined with the <2mm to >63µm fraction.

The <2 mm to >63µm fraction may be representatively subsampled, and this is recommended to avoid overloading of sieves. Ideally a sample splitter (example of the use of a sample divider is provided in Figure 24) should be used to obtain the test sub-sample. A minimum dried sample weight of 150g should be analysed, although if this sediment fraction is composed of particles with a narrow range of sizes then 75g is acceptable. Where possible, larger sieves (300mm diameter) are preferred. These can be half height (see sieves in use during wet splitting of sample in Appendix C).

This sediment fraction (<2mm to >63µm), for either all or the subsample, must be sieved on a stack of sieves at 0.5ϕ intervals from 2mm to 63µm (see Table 1) for a minimum period of 10 minutes. A collecting pan at the bottom of the stack retains the fraction passing through the 63µm sieve and the weight of the sediment in each sieve and bottom pan must be recorded in grammes to 2 decimal places.

If any subsampling is undertaken, then the laboratory must provide evidence that the result produced is representative of the entire <2mm to >63µm fraction by performing a duplicate analysis for 1 in every 20 samples (5%) if no sample splitter is available, or 1 in every 50 samples (2%) if a sample splitter is used.

Fig. 24. 1: Sample divider; 2: Sample being mixed prior to dividing, 3: Sample added to sample divider, 4: Subsample from sample divider (Fugro) (Cefas © Crown Copyright 2020).

Any <2mm to >63µm subsample sieve results must be reproportioned to the entire <2mm to >63µm fraction so this can be combined with the >2mm sieve results.

Sieve analysis results must be supplied as specified in the PSA results template, including any reproportioning calculations.

3.2.4 Analysis of the finer fraction

After wet screening (see section 3.2.2), the fine fraction is left to settle out for 24 hours, or until the water is clear (maximum of 48 hours). The overlying water is removed using a siphon pump, taking care not to lose any of the fines. The fine fraction should be dried (either by oven and/or freeze-drier), before weighing. Weight of the dried fine fraction sediment must be recorded in grammes to 2 decimal places in the PSA results template.

3.2.5 Particle size data reporting

The data generated from the analysis produces a particle size distribution for each sample on the basis of proportional weight of each fraction in the particle size scale as defined in Table 1.

Table 1: Particle size scale for RSMP PS methodology, including examples of breakdown of possible subsampling according to sediment type/sample volume size.

Particle diameter			Sediment fraction	Sample 500ml	Sample 2000ml	Sample 2000ml
μm	mm	ϕ	(RSMP)	All sediment types	Homogeneous sand/mud	Coarse or mixed (with gravel as a major component)
63000	63	-6	>2mm	ALL sample	Subsample	ALL sample
45000	45	-5.5		ALL sample	Subsample	ALL sample
31500	31.5	-5		ALL sample	Subsample	ALL sample
22400	22.4	-4.5		ALL sample	Subsample	ALL sample
16000	16	-4		ALL sample	Subsample	ALL sample
11200	11.2	-3.5		ALL sample	Subsample	ALL sample
8000	8	-3		ALL sample	Subsample	ALL sample
5600	5.6	-2.5		ALL sample	Subsample	ALL sample
4000	4	-2		ALL sample	Subsample	ALL sample
2800	2.8	-1.5		ALL sample	Subsample	ALL sample
2000	2	-1		ALL sample	Subsample	ALL sample
1400	1.4	-0.5	<2mm>63μm	ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
1000	1	0		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
710	0.71	0.5		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
500	0.5	1		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
355	0.355	1.5		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
250	0.25	2		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
180	0.18	2.5		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
125	0.125	3		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
90	0.09	3.5		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
63	0.063	4		ALL sample/ subsample	Subsample/subsample of subsample	ALL sample/ subsample
<63	<0.063	>4	<63μm	ALL sample	Subsample	ALL sample

All raw data, and associated calculations, must be reported as specified in the PSA results template.

3.2.6 Quality Management

Internal

A laboratory must have in place their own in-house quality control (QC) procedures to assure the quality of the resulting data. Evidence of quality control procedures, such as laboratory SOPs, quality control charts, and use of certified and/or in-house generated reference materials must be provided alongside PSA results presented in the PSA results template.

External

In addition to the 'in-house' QC measures described above, sample processing will be subject to external quality assurance (QA) checks by an independent, competent particle size analysis laboratory participant in the NMBAQC scheme (http://www.nmbaqcs.org/). This QA lab will be appointed by the RSMP processing lab. The process will work as follows: On completion of the PSA sample processing, a copy of the completed PSA results template workbook should be sent to Cefas (claire.mason@cefas.co.uk). Cefas will then randomly select 3 samples for QA. The processing laboratory will then send any sample material (see below) from each of the selected QA samples to the QA lab for reprocessing. On completion of the reprocessing of the 3 samples, the QA lab will email the results and comment on any issues that may need addressing. This may include analysis of whole sample if subsampling has taken place. Cefas will compare the original results with the AQC results. Cefas, with the QA lab and RSMP processing lab will need to work together to identify any discrepancies and define any required remedial action, which may be required on the entire sample batch. Remedial actions will be undertaken at the contractor's own expense.

Cefas will then confirm the data and associated AQC are acceptable. All sample material must be stored until confirmation that results have passed quality assurance checks.

Samples sent to the QA lab for an 'own sample' check should comprise of the >2mm fraction, <2mm >63µm fraction and the <63µm fraction. Note both the <2mm >63µm sieve fraction will include the pan sediment (both <2mm and <63 µm pans). If a sample has been subsampled either to reduce sample volume (if all homogeneous), or for sieve analysis, the unanalysed sample and/or the analysed subsample or subsamples as well as the un-sieved remainder of the sample must be submitted. All material should be double bagged separately and appropriately labelled.

All emails concerning the above external QA checks should be copied to Cefas (claire.mason@cefas.co.uk).

4. Final reporting

The following outputs will be required for each RSMP survey:

1. Cruise report providing a narrative on the survey work. The report should include tables and maps to show which of the planned stations have and have not been sampled. A table of any ad-hoc stations should also be included.
2. An Excel workbook detailing all relevant metadata for the samples collected (see relevant sections above for details of the required fields). The workbook should include separate sheets for each gear type (e.g. GRABS, TRAWLS, CAMERA).
3. A species/sample matrix for the macrofaunal data with separate sheets for abundance and biomass (see embedded template: *RSMP Macro template 2020_v1.xlsx*). Taxon names should be consistent with the World Register of Marine Species (http://www.marinespecies.org/aphia.php) and should be accompanied by a unique aphiaID code.
4. The completed PSA workbook (see embedded file: *RSMP PSA template 2020_v2.xlsx).*
5. A hard drive containing all image files from grabs, trawl and camera tows. Stills images should be provided as .jpeg files. Video files should be in .avi format. Files should be named using the following convention:
   RSMP REGION_YEAR_STATION CODE_STATION NUMBER_REP_IMAGE NUMBER

   e.g. HUMBER_ 2014_H_0001_001_A_001.jpeg
   SOUTH COAST_2014_SC_0007_023_A_001.avi

5. Acknowledgments

We gratefully acknowledge James Hutchinson (Fugro) for his input into the development of the sediment particle size processing methodology. We are also grateful to other experts who have commented on various drafts of this document. These contributions have undoubtedly helped in ensuring the production of quality data.

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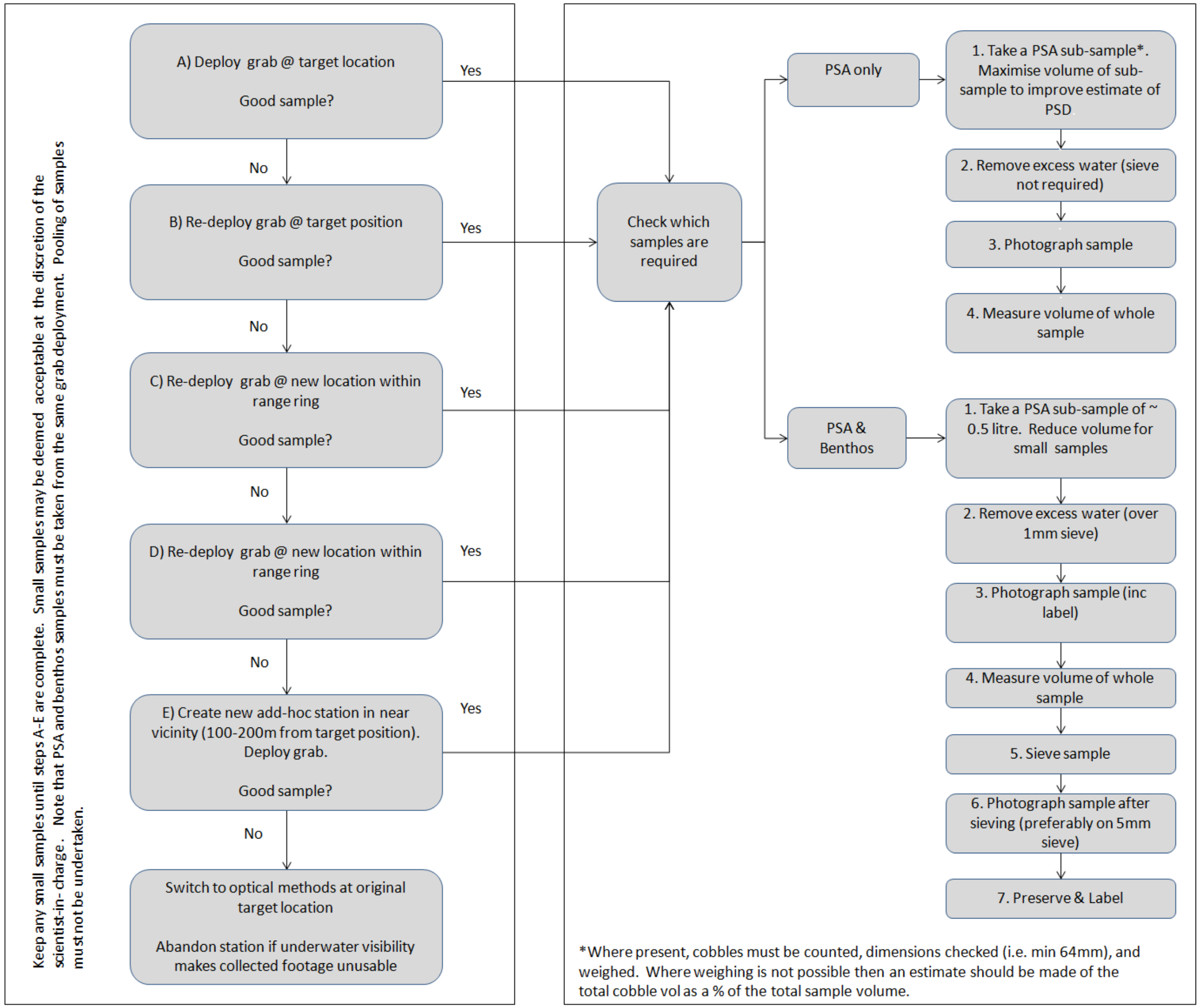
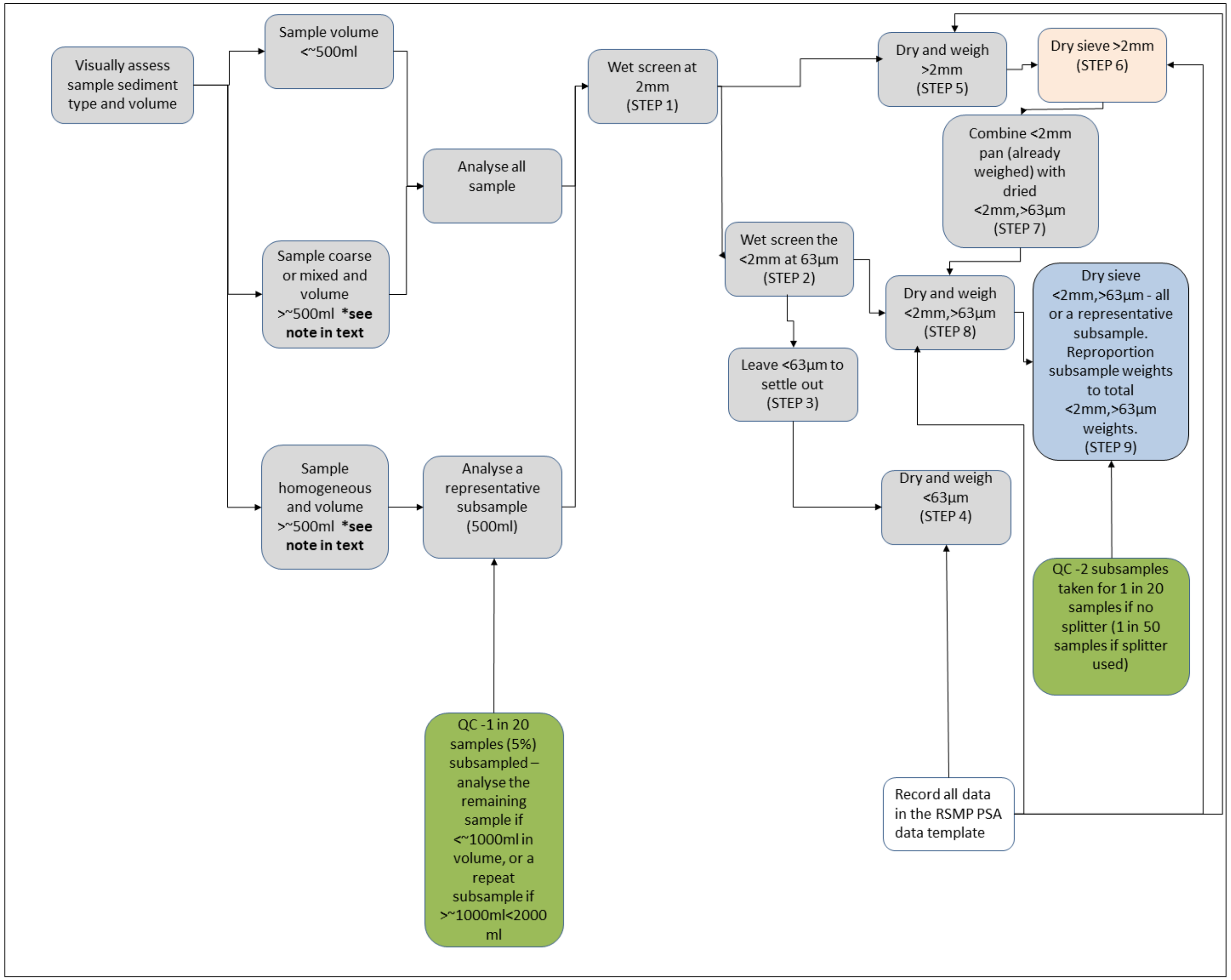
APPENDIX A Flow diagram for sample collection and processing in the field

Sample collection Sample processing



This decision tree is intended to help surveyors decide what actions to take in the event of a 'no-sample' under ideal conditions. However, it is recognised that surveyors may, on occasion, need to exercise their own judgement, taking into account factors such as weather, overall progress etc.

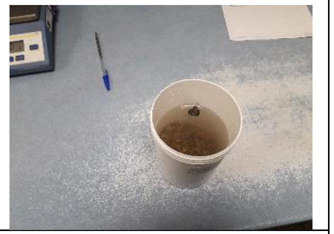
APPENDIX B Flow diagram for PSA laboratory sample methodology



APPENDIX C PSA: Wet screening a sample into >2mm, <2mm >63µm and < 63µm sediment fractions – Fugro example

1	2	3	4	5	6
					

1. The sample is carefully tipped out of the sample pot onto the sieve stack (2mm sieve on top of a 63µm sieve). Sediment is gently removed from the sample pot (2), and care is taken to make sure all sediment is washed into the sieve stack (3). A gentle flow of water is used to wash sediment finer than 2mm through the 2mm sieve (4). The 2mm sieve is lifted to check the 63µm sieve is not overfilling and stop a vacuum building up between the 2mm and 63µm sieve (5 and 6).

7	8	9	10	11	12
					

Any large particles >2mm are placed into the labelled sample container (>2mm) (7). The labelled sample container (>2mm) is placed in the sink (8). A funnel is placed into the labelled sample container (>2mm) (9). The 2mm sieve is gently tipped over the funnel with the mesh on top and the sediment >2mm able to fall directly into the sample container (>2mm) (10). The 2mm sieve is gently washed from the top of the sieve using as little water as possible to avoid overfilling the sample container (>2mm) with lots of water (the analyst makes sure the sample container is not overfilling and can add a new container if required (11). The >2mm sediment with water is taken out of the sink (water can be tipped off but care must be taken not to lose any of the >2mm sediment if doing this) (12).

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<tr><td colspan="6">Continue to wet screen the sediment on the 63µm sieve (13). The 63µm sieve and funnel are lifted to check the bucket underneath does not need replacing (14) before continuing to wash the <63µm fraction through this sieve (15). Washing is continued (16) and then the bucket replaced (17). Washing is continued until the water runs clear (18).</td></tr>
<tr><td>19
</td><td>20
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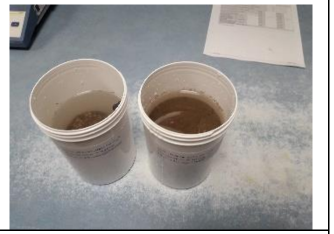
</td><td>24
</td></tr>
<tr><td colspan="6">The water is running clear from under the 6 µm sieve showing there is no more <63µm sediment present in the 63µm sieve (19). Two buckets of water with <63µm for this sample are produced and these will be left to settle out, before removal of overlying water, transfer to a container and drying (20). The <2mm >63µm sediment on the 63µm sieve is scooped into a second labelled sample container (21) (with a collection pot under the funnel to catch any potential escaped sediment). The remaining <2mm >63µm sediment is centralised using water from a water bottle to one area of the 63µm sieve (22). The remaining <2mm >6 µm sediment is washed into the sample pot (23). At the end of this process, one sample container of >2mm sediment, one sample container of <2mm >63µm sediment (24) and two buckets of <63µm sediment (20). The whole process took 30 minutes for this example, but this will be sample dependant.</td></tr>
</table>

APPENDIX D: SIZ JUSTIFICATION (REGIONS: HUMBER, ANGLIAN, THAMES, EAST CHANNEL, SOUTH COAST, NORTH-WEST)

The monitoring of dredging footprints on the seabed is divided into two main zones: the Primary Impact Zone (PIZ) corresponding to the boundary of the Licence area and the Secondary Impact Zone (SIZ), an area adjacent to the PIZ in which changes in sediment composition could potentially occur as a result of the fallout of suspended sediment from dredge plumes.

The SIZS used in the RSMP were, for the majority of sites, supplied from the MAREA studies (EMU Ltd, 2012a; EMU ltd, 2012b; ERM, 2010; ERM, 2012). The MAREA SIZ extents were produced by merging separate polygons for modelled zones of i) potential bedform formation, ii) changes in sediment particle size composition and iii) plume extent. These studies suggest that the maximum distance over which the effects of dredging have been shown to cause changes in sediment composition on the seabed surface in the UK is up to 4 km from the licence area boundary (i.e. PIZ) and up to 2.5 km for changes in bedforms. For this reason, RSMP SIZs typically extend to 4 km from the PIZ in line with the direction of sediment transport. Note that cross tide extents may be substantially less. For sites not included in the MAREA process, SIZs are typically based on a local tidal ellipse, clipped, if necessary, to 4 km. Smaller SIZ extents may be accepted where there is supporting evidence. This is the case for licences in the Bristol Channel, where high natural levels of turbidity mean dredge plumes are not detectable beyond 500 m (see EMU Ltd, 2004 and APPENDIX E).

The RSMP approach is based on detection of significant changes in sediment composition. A review of the literature regarding the distance at which changes in sediment composition have been observed following aggregate dredging suggests the area of 4 km is conservative, with significant change mostly restricted to between 0 and 2.6 km from the PIZ (Table D1). Furthermore, a recent review of physical impacts of sediment dispersion from aggregate dredging (Spearman, 2015) showed that the distance of 4 km observed by Newell et al. (2002) at area 408 in the Humber Region is not supported by more recent validated flow models and *in-situ* suspended sediment transport measurements. This new evidence suggests that the patch of well sorted sand found to the SE of the dredge site is a coincidence and the only zone of impact which can be identified is less than 500 m from the dredge site (Spearman, 2015).

Based on our understanding of the extent of sediment change outside licence areas, it seems therefore sensible to base the SIZs only on the bedform and particle size distribution (PSD) polygons (i.e. to not include the plume extent). Indeed, it is in the interest of the RSMP to keep the extent of the SIZ restricted to maintain a suitable density of sampling points per surface area and therefore to be able to detect significant change on the seabed.

Table D2: Results from various studies identifying the distance (km) from the dredger at which a significant change in sediment composition on the seabed has been detected.

Region	Area	Distance (km)	Reference
Humber	106*	<0.45 (N) & 0.25 (S)	Andrews Survey (2004) Newell et al. (2004)
	408*	0.5 (SE)	Newell et al. (2002)
Anglian	430*	1.75 (N) & 0.5 (S)	Andrews Survey (2004) Newell et al. (2004)
	222*	1.5 to 2.5	Boyd et al. (2003)
Thames	447	None	Pearce et al. (2011)
	222 (498)	2.3 (NNE)	Cooper et al. (2013a)
Eastern Channel	473/2	2.6	ECA (2011)
	Off Dieppe*	2 (E-NE)	Desprez et al. (2010)
	Area 473*	2.6	East Channel Association, (2011)
South Coast	122/3	0.3 (SW)	Hitchcock & Bell (2004)
	Area 351*	<0.5	Boyd and Rees (2002)

*Details found in a review of the physical impacts of sediment dispersion from aggregate dredging by Spearman (2015)

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APPENDIX E: SIZ JUSTIFICATION (REGION: BRISTOL CHANNEL/SEVERN ESTUARY)

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Consideration of Evidence in Respect of Defining Realistic Secondary Impact Zones in the Bristol Channel and Severn Estuary

Summary

- Studies within the ECR of fine sediment dispersion, deposition and seabed transport have significantly improved understanding of secondary impacts and their extent.
- Sediment plumes in the ECR have been found to be detectable at a maximum of 3.5-4km in line with the tidal axis and a maximum of 1km across the tidal axis. Beyond this suspended sediment concentrations are indistinguishable from natural, background levels.
- The deposition of sediment from dredging operations in the ECR and subsequent transport of sediment on the seabed, have been shown to produce detectable changes to seabed sediment character for a maximum of 2.5-3km in line with the tidal axis and 0.5km across the tidal axis.
- The HR Wallingford (2010) work in the Bristol Channel and Severn Estuary to support the renewal of Coast Protection Act consents for existing marine aggregate sites indicate that secondary effects would largely be negligible and in any event not detectable beyond a few hundred metres from the area of dredging activity.
- Specific monitoring studies at Area 472 Culver Sands of the seabed sediments and benthic fauna support the CPA study findings showing that there are limited effects of dredging activities observable beyond the area directly impacted by dredging activities. Indeed, there have not been any significant detectable effects beyond the licence boundary, with secondary impact zone sampling sites reflecting conditions observed at reference areas.
- Review of the hydrodynamic processes observed in the Severn Estuary region reveal a highly dynamic environment, continuously altered by tides and wave action. As a result the constantly shifting sand targeted for extraction is quickly reworked and the effects of dredging are not seen to be significant beyond the immediate dredging zone.
- The natural turbidity within the Severn estuary and Bristol Channel is high and therefore any plumes resulting from dredging are masked by the background suspended sediment concentrations beyond the licence boundary.
- Modelling undertaken for Area 472 Culver Sands indicated that, due to the high tidal flow observed within the Severn Estuary, significant dredging related variations to current speed were not expected beyond the area directly impacted by dredging.
- Due to the expected highly limited spatial extent and negligible impact of dredging on the seabed sediment structure, faunal communities and hydrodynamic process within the area surrounding aggregate licences, it is suggested that a maximum secondary impact zone of 500m is scientifically justifiable for monitoring works in the Bristol Channel and Severn Estuary Region; this suggested maximum extent being indicative of an area which may potentially experience short term smothering effects from overspill or screened sediments.

Consideration of Evidence

This briefing has been created to inform discussions between Mark Russell (BMAPA) and Keith Cooper (Cefas) regarding the definition of secondary impact zones around marine aggregate dredging areas in the Bristol Channel and Severn Estuary for the purposes of compliance monitoring. Definition of secondary impact zones (SIZ) is required to inform planning of regional seabed monitoring programme (RSMP) surveys. A number of sources of evidence have been used to inform this briefing, specifically;

- Findings of investigations of secondary impacts resulting from dredging in the Eastern English Channel;
- Work completed to inform Coast Protection Act consent issues;
- The results of monitoring completed at Culver Sand (Area 472);
- General contextual information regarding the natural environment of the Bristol Channel and Severn Estuary.

East Channel Region Results of Monitoring

Investigations of impacts resulting from dredging in the East Channel Region (ECR) (The East Channel Association, 2011) have significantly improved understanding of the nature and extent of secondary impacts arising from dispersion, deposition and transport on the seabed of fine sediment, specifically sand and silt/clay, released during the dredging process. The relevance of the East Channel Region studies in informing decision making in other regions lies in the fact that the impacts of dredging in the ECR can realistically be considered to represent a maximum case, on the basis that turbidity in the region is typically low, seabed habitats are considered very stable and there is very limited naturally occurring mobile seabed sediment.

The results of water column monitoring in the ECR indicate that sediment plumes resulting from dredging are detectable a maximum of 3.5-4km in line with the tidal axis and a maximum of 1km across the tidal axis before turbidity levels fall to natural background levels. The results of monitoring also indicate that deposition of sediment from dredging operations, and subsequent transport of sediment on the seabed, result in detectable changes to seabed sediment character a maximum of 2.5-3km in line with the tidal axis and 0.5km across the tidal axis.

The results of monitoring in the ECR augment the findings of previous similar studies (Hithcock *et al.*, 1998) and were ultimately used to define maximum extents of SIZ for RSMP survey plans for the Humber, Anglian, Thames, ECR and South Coast regions.

Coastal Protection Act Consent Studies

In 2010, HR Wallingford completed work to inform the renewal of Coastal Protection Act (CPA) consents for existing marine aggregate sites. The scope of the works completed included consideration of the extent of secondary effects arising from marine aggregate dredging, with specific works completed for the Bristol Channel and Severn Estuary. The report applied the results of modelling in the context of historic dredging activity to determine how future dredging might influence physical processes and the wider environment of the Region. The report made the following specific conclusions in respect of the potential secondary/indirect impacts of future dredging:

- *'There is no reason to believe that the proposed dredging from Areas considered in this report to 2013* [NB the report considered all current and potential future dredging areas in the region] *will change the existing sediment regime in the Severn Estuary*.'
- *'The sediment regime of the Severn Estuary is such that the expected changes to sediment caused by the proposed dredging will be negligible except very close (no more than a few hundred metres) to the dredging. The strong currents in the area which winnow fine sediments from the banks to maintain them as sand dominated environments, will also winnow any fine sediment deposits created by dredging.'*

- *'Changes to the nature of the seabed from sediment released from the aggregate dredging process in the Severn (Areas 377, 385 and 391) are likely to the negligible throughout the identified indirect footprints.'*

Results of Licence Specific Monitoring in the Bristol Channel and Severn Estuary

Dredging activities have been occurring at Licence Area 472 Culver Sands since 2008, and monitoring of the seabed sediments and benthic ecology at the site is a requirement of the Marine Licence. As such, prior to the five year substantive review (MESL, 2013), seabed sampling occurred annually across the site and the surrounding area. It was seen that the seabed sediment composition around the licence remained statistically similar throughout the study period. It was therefore determined that there were no detectable effects of dredging on the seabed sediment composition recorded outside the Licence Area.

In addition to monitoring the seabed sediment composition, the benthic fauna present across the site and surrounding seabed was investigated. The study observed a decrease in overall abundance of organisms, species diversity, and the biomass of the main taxonomic groups within the licence area, along with slight variation to the community structure. However when the sample sites immediately outside the licence area (indicative of the SIZ) were compared to those sites further afield (indicative of unimpacted/reference areas) no significant differences were observed between the faunal communities and their composition. It was therefore determined that there were no detectable effects of dredging on the composition of the benthic faunal communities outside the Licence Area.

For both the seabed sediments composition and the benthic ecology at Area 472 Culver Sands it was suggested in the 5 Year Substantive Review (MESL, 2013) that there were no detectable effects of dredging within the SIZ. Any secondary effects that may have been manifesting were masked by the natural variability of the area which is driven by the highly dynamic environmental conditions present across the Bristol Channel and Severn Estuary.

Other Evidence Relevant to Definition of Secondary Impact Zones in the Bristol Channel and Severn Estuary

A number of other factors have a bearing on the extent of secondary impact zones around dredging areas in the Bristol Channel and Severn Estuary Region. Proper consideration of this further evidence in the context of the impacts resulting from dredging in the Region, is required to ensure that any secondary impact zones established for RSMP works are realistic and suitably targeted.

A consideration of further evidence is presented below, specifically focusing on:

- Dredging and monitoring practices as defined by licence conditions for existing dredging licence areas;
- The nature of resources targeted for extraction in the region;
- Hydrodynamic processes that maintain the sand resources;
- Natural turbidity in the Region; and
- The ecology of benthic communities that exist within and around dredging area.

Dredging and Monitoring Practices for Existing Dredging Licence Areas

According to operators of the North Bristol Deep and Middle Ground dredging licence areas, conditions attached to the licences for these areas no longer require monitoring of seabed sediments. The powerful hydrodynamic forces and natural mobility of the seabed sediment within and surrounding these areas results in extensive morphological changes over a single tidal cycle. In recognition of these factors, regulatory authorities (Natural Resources Wales) have accepted that monitoring of seabed sediments both within the primary impact zone and secondary impact zone by conventional grab surveys is not required. Rather, a programme of sediment character assessment is undertaken by taking sub-samples of dredged cargos for particle size analysis (Dr Andrew Bellamy, pers. Comm). The current licence conditions and operational procedures for dredging management and monitoring of the seabed are therefore indicative of the limited scientific value that would result from undertaking conventional grab surveys at these locations for the purposes of monitoring changes in sediment character.

Aggregate Resource Characteristics on the Bristol Channel and Severn Estuary Region

The marine aggregate industry in the Region differs from other parts of the UK insofar as the resources targeted for extraction are exclusively sand. As there is no established market for marine won gravel in the region at present, and because only limited economically viable gravel deposits exist on the seabed, the aggregate dredging industry in the Region only targets sand resources to supply the requirements of the local market.

To fulfil the demand for sand resources, the industry targets a number of sand deposits including large sand bodies in the upper Estuary, isolated sand bank features and extensive sand wave fields further offshore in the Outer Bristol Channel. By virtue of their mode of formation, whereby the sand has been extensively reworked by natural marine processes into the present day deposits, the sand is clean and has very little extraneous sediment such as gravel or silt/clay. Therefore, during extraction operations, there is very little unwanted sediment returned to the seabed and any sediment that is returned during dredging has an almost identical character to that which exists on the seabed. To ensure sand-only cargoes are loaded, the dredged sediment passes over fine-mesh screens before entering the ship's hold. Any rejected sediment will consist of gravel clasts and shell fragments, neither of which would contribute to secondary effects beyond the dredging area as they settle back to the seabed rapidly. A relatively small proportion of sand will inevitably be lost over board during screening and through over-spill as water drains off the cargo.

Therefore, marine aggregate dredging operations in the Bristol Channel have a far lesser potential to alter the natural character of the seabed sediment, either within the dredging area or immediately surrounding the dredging area, as any sediment returned to the seabed is very similar to the sediment *in situ* on the seabed.

Hydrodynamic Processes

The sand resources in the Region were established in their current position by hydrodynamic processes that are still acting upon the resources today. In the upper Estuary, these processes result in large scale bathymetric changes occurring across licence areas on a continuous basis, as the sand deposits are influenced by the effects of tide and wave – making it almost impossible to determine any direct effects of extraction, let alone indirect effects. Therefore, assuming only a small proportion of the total sand resource is removed from any deposit, and hydrodynamic processes remain similar, then the sand deposit will be maintained in a similar condition without any significant change in character or extent. As such, impacts resulting from removal of sand from the surface of a deposit will not have any significant effect beyond the immediate vicinity of the location of the dredging.

Natural Turbidity

The Bristol Channel and Severn Estuary is a naturally turbid ecosystem, predominantly driven by the high tidal flows found here. According to information contained in the Area 472 Culver Sands Environmental Statement (EMU Ltd, 2004), the highest recorded natural turbidity in the region ranges from 500 mg/l to 1000 mg/l between Avonmouth and Bridgewater Bay in the Severn Estuary. Further to the west, along the Bristol Channel, this is expected to reduce significantly as the channel widens and flow diminishes, however the suspended sediment concentrations observed here are still much higher than in open water environments.

It has been shown through the development of a model of tidal currents around Area 472 Culver Sands that dredging activity in parts of the Severn estuary is not expected to significantly affect flow speed. The study by HR Wallingford (2002) indicated virtually no change in either peak flood or peak ebb current speeds beyond the boundaries of the proposed dredging zones. It should be pointed out that due to the variability of the Severn Estuary the results of this study can only reliably inform on the areas in the vicinity of the area modelled. As a result of this study it would be unlikely for any variation to the natural turbidity within the SIZ or beyond to occur as a result of dredging activities acting on tidal flow.

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Appendix C. BMAPA Fisheries Code of Practice

MARINE AGGREGATE EXTRACTION AND THE FISHING INDUSTRY

Operational Code of Practice

This code has been developed by the British Marine Aggregate Producers Association (BMAPA), the Marine Management Organisation (MMO) and The Crown Estate for the marine aggregate industry, in order to minimise operational conflicts between aggregate dredging vessels and fishing vessels/activity – particularly the loss or damage of fishing gear. This code defines best practice for communication between marine aggregate operators and fisheries interests both in advance of dredging operations commencing and while dredging operations are taking place.

The following procedures should be adopted by the marine aggregate industry.

<u>In advance of dredging operations:</u>

1. Regional Active Dredge Area (RADA) charts will be produced by BMAPA and The Crown Estate on a bi-annual basis (charts are dated 31 January and 31 July) to show where dredging is currently permitted within existing production licences. Areas where dredging is permitted is monitored by the MMO through the approved Electronic Monitoring Systems (EMS) located on each vessel. The need for working areas within production licences may be defined through existing licence conditions or through operators' voluntary management arrangements. Any changes to active dredge areas between issues of each RADA chart will be clearly highlighted.

2. Dredging operators will ensure that the limits of their active dredge areas are up to date and coincide with the EMS boundaries so they can be accurately presented through the RADA charts that are routinely issued.

3. The RADA charts will include up to date contact details for all marine aggregate operators with licensed interests in the region.

4. Laminated versions of the RADA charts will be produced by BMAPA on a bi-annual basis and circulated to local fisheries interests (charts may be made available via the relevant MMO coastal office or direct from BMAPA). The latest RADA chart issued will also be flagged via the Marine Aggregate Kingfisher Fortnightly Bulletin service, http://www.seafish.org/industry-support/kingfisher-information-services/kingfisher-bulletins and will be available to be downloaded at http://www.bmapa.org/issues/other_sea_users.php

5. Where changes to active dredge areas are required (including the commencement of operations on a newly licensed production licence area), dredging operators will normally be required to provide a minimum of four weeks' notice prior to commencing operations in any new working areas that are defined. Details of the proposed changes will be flagged via the Marine Aggregate Kingfisher Fortnightly Bulletin service, and operators may also be required to directly notify local fishing associations, using where necessary the assistance of the MMO and regional Inshore Fisheries and Conservation Authorities (IFCA) offices.

6. Under exceptional operational circumstances, changes to working areas may be required inside of the standard four week notice period. Should this situation occur, operators are required to liaise directly with the MMO, regional IFCA offices and local fishing associations in order to determine any particular conflicts that could exist and any additional mitigation measures that may be required.

<u>During dredging operations:</u>

7. Dredging and fishing vessels to maintain listening watch on VHF Channel 16.

8. Masters of dredgers to call up on VHF Channel 16 when approaching a dredging area at a range of 10 nautical miles (approximately one hour before operations are to commence). They should provide an estimated time of arrival on the area and position of operation.

9. On hearing a dredging vessel's notification any fishing vessels in the area should respond giving their position and the gear being worked. A VHF working channel should be established between the dredger and the fishing vessel (s).

10. Once communications have been established liaison can take place to allow time for the removal of fishing gear as may be necessary. Dredging should commence clear of fishing gear until it is removed.

11. Masters of fishing vessels approaching an area where an aggregate dredging vessel is operating should call up the dredger on VHF Channel 16 to establish lines of communication.

12. The MMO, regional IFCA offices and local fishing associations can be used to establish communications depending upon the area being worked, such as in cases where direct communication between dredging vessels/operators and fishing vessels/activities is proving difficult.

<u>During survey operations:</u>

13. A range of survey activities may be taken by marine aggregate operators in order to investigate a new area of seabed for potential resources (prospecting) or to obtain environmental data to allow environmental impact assessment to inform a new application. Once an area has been consented, various survey activities will be required during its operation to demonstrate compliance with marine licence conditions and for the operators own resource management purposes. In all cases, it is recognised that such survey works have the potential to interact with other marine users, including fisheries interests.

14. Survey activities comprise of two principal types.

Sampling activities involve a grab or vibrocore being deployed to the seabed from a vessel at a number of sample stations across a given area. Each sample will take between 10 minutes and one hour to obtain, depending on whether the vessel is required to anchor. During the sampling activities, the vessel will display the appropriate lights/shapes for a vessel restricted in its ability to manoeuvre which may create a temporary obstruction for other marine users, including mobile fishing activity. If the vessel is not required to anchor, then the potential for the sampling activities to interfere with static fishing gear is considered to be limited. However, if the vessel is required to anchor before undertaking the sampling works the potential for interaction with static fishing gear will be far greater.

Acoustic and geophysical surveys involve a vessel repeatedly transiting across a defined area in a grid pattern. The equipment for bathymetric surveys will typically be mounted on the hull of the vessel, so the potential for such works to interact with either mobile or static fishing activity is considered to be limited. However, survey works which require equipment to be towed behind the vessel (such as seismic, magnetometer or side scan sonar equipment) – either on the surface or submerged – clearly have far greater potential to interact with static fishing gear, although the cost of the equipment and importance of obtaining the data will mean that contractors will look to avoid this.

In both cases, the survey works are not expected to have any primacy over other activities that may be taking place.

15. Given the range of survey activity associated with marine aggregate interests that may take place throughout its lifetime, it is essential operators provide sufficient notice to other marine users, including local fisheries interests, to ensure that any potential conflicts can be minimised. Notices should include the type of works being undertaken, the geographical location, the start date and the estimated duration. Contact details for the vessel undertaking the works and the operator (or the operator’s agent) should also be provided.

16. Similar to the notice required for the commencement of dredging in a new area (paragraph 5 above), a minimum of four weeks’ notice should be provided before any survey works begin outside of the active dredge zone(s) of licence areas. Details of the proposed works should be flagged via the Marine Aggregate Kingfisher Fortnightly Bulletin service, and operators may also choose to directly notify local fishing associations, using where necessary the assistance of the MMO and regional IFCA offices. In some cases, it may be advantageous to appoint a local fisheries liaison officer to assist

with the local notifications. Should the commencement date for planned survey works change, on account of inclement weather or because of vessel availability for example, further updates should be provided.

17. The variables associated with suitable weather windows and vessel availability required to undertake offshore survey works mean there may be occasions where it is not possible to provide four weeks' notice. Should this situation occur, operators are required to liaise directly with the MMO, regional IFCA offices and local fishing associations in order to determine any particular conflicts that could exist and any additional mitigation measures that may be required. In all bar the most exceptional circumstances, a minimum of two weeks' notice should be provided before any works commence outside active licence areas.

18. Unless there are exceptional circumstances, a minimum of five working days' notice will be provided for surveys undertaken within the active dredge zone(s) of licence areas.

19. It is the responsibility of the dredging operator to ensure the risks of any conflicts with fisheries interests are minimised while survey works are being undertaken on their behalf. Operators will require survey contractors to be mindful of fishing interests and to take appropriate action to avoid or minimise interaction with fishing gear whilst surveying. Where appropriate, regular broadcasts by survey vessels, giving updates on the survey programme, will be made.

20. Where the notice of an offshore survey identifies the potential for conflict or interaction with existing fisheries interests, the operator should consider what additional mitigation measures may be possible. These may include excluding survey work in defined areas where high densities of fishing activity have been identified, only working during daylight hours to reduce the risk of interacting with static gear, appointing a fisheries liaison officer on board the survey vessel to liaise directly with fisheries interests, or delaying the commencement of works to allow time for fishing gear to be relocated. With careful advanced planning, it may be possible to arrange for temporary removal of static gear at a time that is mutually acceptable.

21. Where it has been established that specific interaction is likely to occur, throughout the survey, operators should provide regular update notices on progress with the works to local interests. Where the survey area is large, this may include defining the specific areas where works are underway over a given period of time. Any delays to the works, such as through inclement weather, should be clearly signalled along with the potential impact on the end date of the works. Where particular site-specific interactions with local fisheries interests have been identified, confirmation should be provided once the survey works have ended.

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