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Identification of suitable substrate and macroalgae observations for indicator improvement

Scientific Report from DCE – Danish Centre for Environment and Energy No. 647 2025

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Abstract: Locations for potential deeper occurrences of suitable hard substrate and macroalgae were identified using side scan sonar data and validated through ROV and diver field investigations in two Danish water bodies. The field investigations were conducted in late October and not compatible with ordinary monitoring data, but the study showed that it was possible to extend the depths ranges considerably and that more precise estimates of macroalgae indicators are possible. These results are useful for optimizing the marine monitoring program for macroalgae.

Keywords: Cumulative cover, macrophyte indicators, perennial species, water framework directive

Front page photo: Macroalgae at 14.5 m in Sejerø Bugt photographed by Emil Guddal Larsen

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Contents

Preface

This project was initiated by the Danish Environmental Protection Agency (Miljøstyrelsen) and carried out by Aarhus University/DCE, GEUS and WSP. The objective was to investigate the potential availability of hard substrate for macroalgae growth at deeper depths in three water bodies: Sejerø Bugt, Jammerland Bugt & Musholm Bugt, and Storebælt NV. Preferably, localities in the proximity of existing monitoring transects. Such observations have the potential to improve current macroalgae indicators (cumulative cover and number of perennial species), if depths with strong light limitation of the macroalgae community are included. The aim is also to assess the potential improvement in current macroalgae indicators for the three water bodies.

DCE managed the project and was responsible for the report with the main contribution on assessing potential improvement of macroalgae indicators. GEUS contributed analysis of side scan sonar data and identified potential locations for further investigations with Remotely Operated Vehicle (ROV) and drop camera. GEUS has contributed sub-sections 2.1 and 3.1 to the report. WSP contributed with ROV/drop camera survey data and description of visual observations. WSP has contributed sub-sections 2.2 and 3.2 to the report. The report has been reviewed by Miljøstyrelsen and revised after their comments.

Sammenfatning

Med den nuværende overvågningsstrategi kan makroalgeindikatorer udviklet til brug for Vandrammedirektivet kun bestemmes for 25 ud af 40 vandområder, hvor der udføres makroalgeovervågning. For de andre 15 vandområder er der ikke data fra større dybder, hvor makroalgesamfundet for alvor bliver reguleret af lyset. Potentielle dybere lokaliteter, hvor makroalger kan forventes, er bestemt ud fra analyse af side scan sonar data fra vandområderne Sejerø Bugt, Jammerland Bugt & Musholm Bugt og Storebælt NV. I dette studie er 10 dybere lokaliteter undersøgt med ROV (remotely operated vehicle) og tre af disse lokaliteter er yderligere undersøgt af professionel dykkere med kendskab til artsidentifikation af makroalger. Undersøgelsesdybden for makroalger blev dermed udvidet fra 12-13 m til 17 m i Sejerø Bugt og fra omkring 11 m til 22 m i Storebælt NV. Disse undersøgelser blev foretaget d. 29. oktober 2024, hvor ikke hele makroalgesamfundet er i vækst, og dækningsgrader er derfor ikke sammenlignelige med sommerens overvågningsdata. Studiet viser, at det er muligt at identificere egnet hårdt substrat på større dybder ved hjælp af side scan sonar data, og at der vokser makroalger på disse dybere lokaliteter. Selvom disse feltundersøgelser ikke direkte er sammenlignelige med overvågningsdata, så understreger de behovet for at inkludere dybere observationer til bestemmelse af makroalgeindikatorer, idet der opnås mere præcise estimater og i nogle tilfælde er de dybere observationer nødvendige for at kunne bestemme makroalgeindikatorer. Det anbefales, at der foretages tilsvarende analyser i de resterende vandområder, hvor der mangler observationer fra dybe lokaliteter, for at identificere dybere forekomster af egnet hårdt substrat og makroalger. Det bør også vurderes, om de eksisterende transekter kan overvåges mere effektivt som punktdyk i stedet for punktobservationer langs et kontinuert dykningstransekt. Endelig bør anvendelse af ROV til overvågning af makroalger på større dybder undersøges mere detaljeret. Specielt bør det undersøges, om og i hvilket omfang ROV kan erstatte eller supplere dykker observationer.

Summary

Macroalgae indicators developed for the European Water Framework Directive can only be estimated for 25 out of 40 water bodies with monitoring data due to the lack of observations at deeper depth, where the macroalgae community is regulated by light. Analyses of side scan sonar data from Sejerø Bugt, Jammerland Bugt & Musholm Bugt and Storebælt NV have identified several locations, where such deeper macroalgae community data could be obtained. In this study, 10 deep locations in Sejerø Bugt and Storebælt NV were surveyed with remotely operated vehicle (ROV) and three of these were surveyed by diver. Through these surveys the depth ranges for macroalgae data were extended from 12-13 m to 17 m in Sejerø Bugt and from around 11 m to 22 m in Storebælt NV. These surveys were conducted on 29 October 2024, when the macroalgae community is declining, and the observations are not strictly compatible with the ordinary monitoring data. However, the study demonstrates that it is possible to identify suitable hard substrate at deeper depths using side scan sonar data and that these deeper locations harbor macroalgae communities. Despite that the observations from the field survey do not comply with the monitoring guidelines, they clearly show the value of incorporating deeper observations for the estimation of the macroalgae indicators by improving the precision of the indicators and in some cases, allowing for their estimation where there is a lack of deeper observations in the regular monitoring data. It is recommended to examine other water bodies for potential deeper occurrences of hard substrate and macroalgae, and to evaluate if existing macroalgae transects can be monitored more efficiently by carrying out point observations as opposed to line transects. Finally, the use of ROV for macroalgae monitoring at deeper depths needs further exploration. Particularly, it should be investigated if, and if so how, ROV observations can substitute or complement diver observations.

1 Background

Aarhus University has developed macroalgae indicators intended for assessing ecological status in relation to the European Water Framework Directive (WFD) and assessing ecological potential according to the European Habitats Directive (HD). The two macroalgae indicators respond to the level of eutrophication, since light conditions are regulating macroalgae cumulative cover and the number of perennial species at deeper depths (Carstensen 2020a). However, these indicators can only be assessed for a limited number of water bodies (25 out of 40) and for some water bodies the indicators are estimated with considerable uncertainty (Carstensen 2020b). The main reason for this is the lack of macroalgae observations at deeper depths, where light limitation becomes prominent. The macroalgae indicators can potentially be estimated for additional water bodies and with greater precision, provided that deeper macroalgae observations are made available.

Current monitoring of macroalgae on hard substrate is partly limited by lack of suitable substrate at deeper depths in the immediate extension of diver transects. Consequently, many transects do not extend to depths where the macroalgae community is regulated by light. Dahl et al. (2024) successfully demonstrated the potential of using existing transects with side scan sonar data for identifying suitable substrate at deeper depth and validated the presence of hard substrate and macroalgae through ROV and drop camera in Flensborg Fjord and Little Belt. The identified locations were later monitored according to the technical guidelines for macroalgae monitoring and the inclusion of the data significantly improved the indicators (Carstensen 2024). This novel approach will be further investigated in three water bodies in the Northern Great Belt (Sejerø Bugt, Jammerland Bugt & Musholm Bugt, Storebælt NV), as described in this report.

2 Materials and methods

The potential improvement of macroalgae indicators for the three water bodies followed a 3-step procedure:

1. Identification of potential hard substrate from side scan sonar
2. Identification of macroalgae cover from field investigation
3. Assessing the effect of deeper observations on macroalgae indicators

These three tasks 1, 2 and 3 were carried out separately by GEUS, WSP and DCE, respectively.

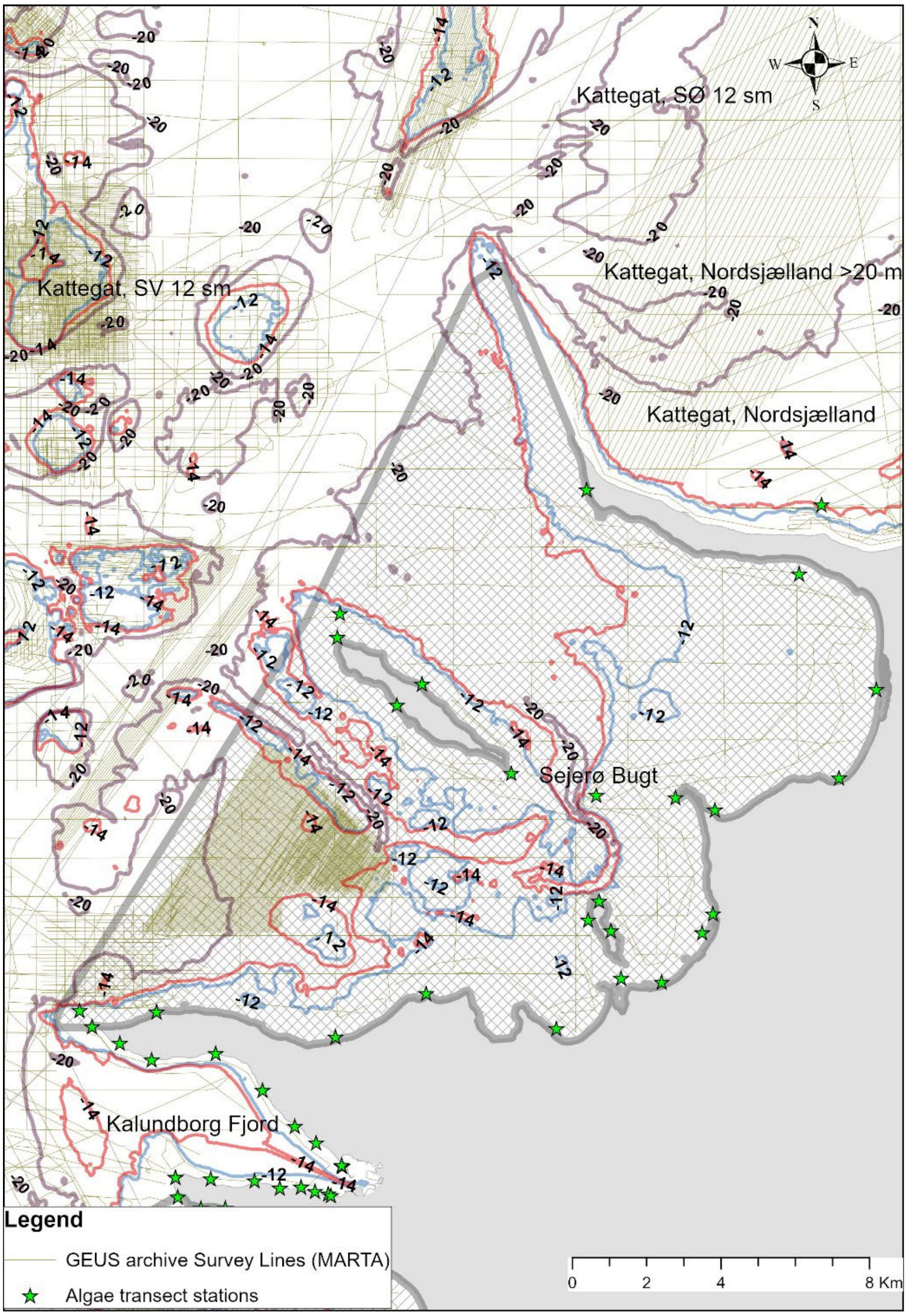
2.1 Identification of potential hard substrate from side scan sonar

Existing datasets from previously conducted geophysical surveys in the above-mentioned three areas were used to delineate areas of boulder accumulations on the seabed at different water depths. The surveys were carried out in different years and with different objectives.

The side scan image clarity, interpretability, and location accuracy were the main criteria that were used in choosing the side scan dataset that fulfilled the above-mentioned objectives. Only open access and free to publish datasets were used in this work. The restricted datasets were avoided, and alternative free data were used when available. A 12 m contour was set as the minimum depth, and 10% stones of > 25 cm as the minimum stone percentage were set as the criteria for designating the suitable areas for macroalgae monitoring at deeper waters.

The bathymetry map for the Danish waters (a digital terrain model (DTM) from EMODnet Bathymetry) was adopted for locating the required depth intervals. Contour lines along the 2 m curve were generated to aid the identification of suitable depths in which side scan sonar data were interpreted. The seabed sediment map of the Danish waters prepared by GEUS was used to identify potential areas for hard substrate at the seabed surface. The overlapping/interception of the potential hard substrate data from the sediment map and the depth contour yield the potential area of further investigation. The side scan sonar datasets at that location were processed and interpreted for boulder accumulation at the seabed surface and the percentage cover. Locations of macroalgae transect, both present and historically monitored, were also included for the purpose of selecting specific positions near existing transects within the water bodies with potential hard substrate.

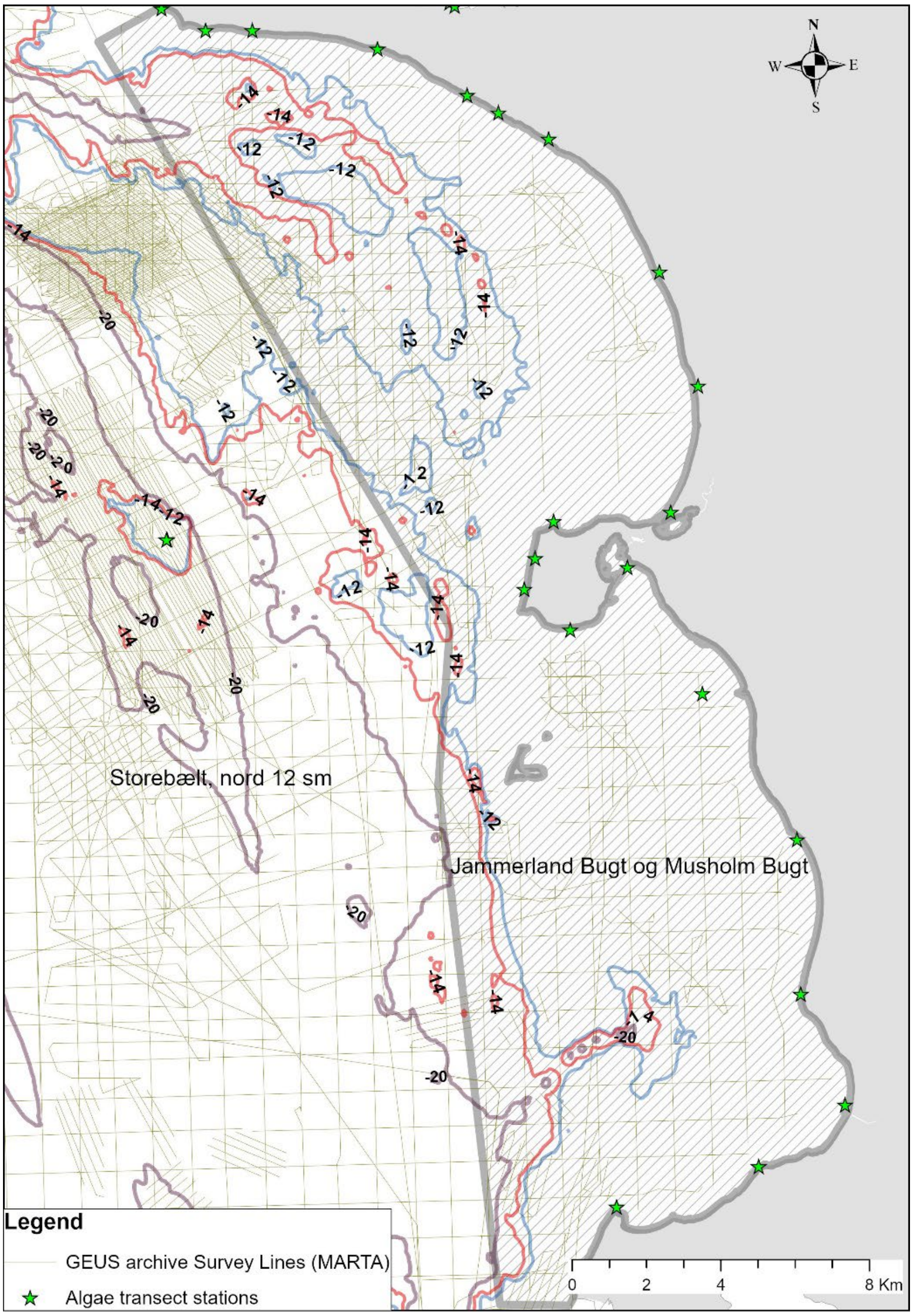
For Sejerø Bugt, dual frequency side scan sonar data from 2013 were used (Figure 2.1). The relevant survey lines with side scan sonar within the water body delineation were extracted from GEUS' Marine raw materials database (MARTA). Note that there were only survey lines south of Sejerø. Focus was on potential hard substrate at depths between 12 and 20 m, where macroalgae becomes strongly light limited in this area.



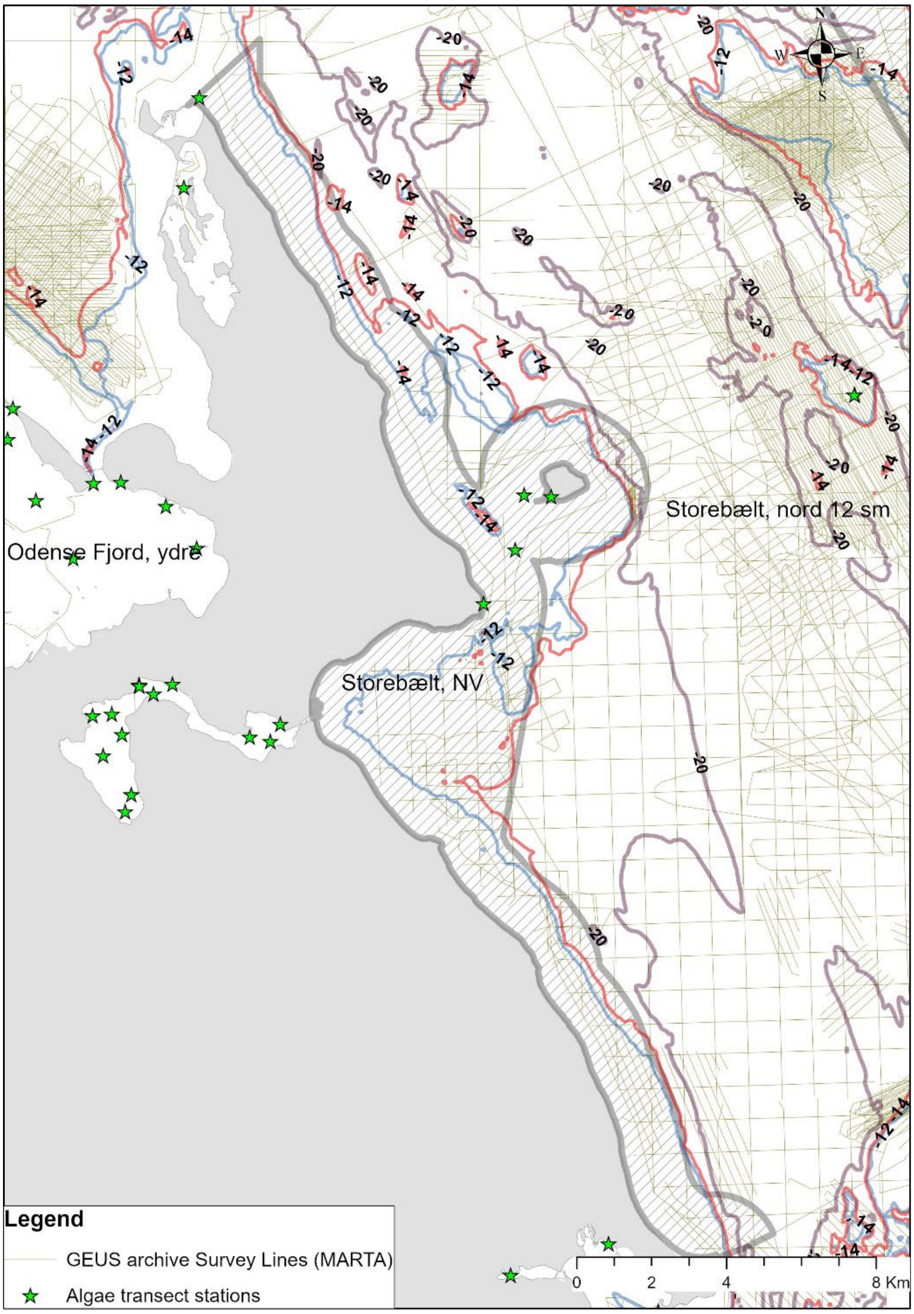
Figur 2.1. Sejerø Bugt water body area showing location, MARTA lines and three contour lines of 12, 14 and 20 m.

In Jammerland Bugt & Musholm Bugt (Figure 2.2), side scan sonar data from three survey projects were utilized: 1) raw material survey in 2021, 2) mapping survey in 2014 for habitat area H100 in Storebælt, and 3) raw material survey conducted in 2018. Focus was on potential hard substrate at depths between 12 and 20 m, where macroalgae becomes strongly light limited in this area.

Figur 2.2. Jammerland Bugt & Musholm Bugt water body area showing location, MARTA lines and three contour lines of 12, 14 and 20 m.



For Storebælt NV area (Figure 2.3), side scan sonar data were extracted from three different surveys: 1) Raw material survey in 2021, 2) seabed habitat survey from 2014, 3) raw material and habitat survey in 2011. In all these surveys, a dual frequency side scan sonar system was used for collecting data. Focus was on potential hard substrate at depths between 12 and 20 m, where macroalgae becomes strongly light limited in this area.



Figur 2.3. Storebælt NV water body area showing location, MARTA lines and three contour lines of 12, 14 and 20 m.

The high-frequency raw side scan sonar data for each potential location were processed in SonarWiz software, where boulders of >25 cm can be clearly identified. The highest boulder density at the specifically required depth was delineated. A 25 m x 25 m grid was used as a unit cell in which the boulder density was estimated. The chosen boulder distribution areas were manually delineated with a polygon, and if more than one area fulfilled the depth/boulder density criteria, then that nearest to existing macroalgae monitoring transect was chosen. The reported coordinates of the chosen position points were located at the center of the boulder accumulation while the polygon covered a larger area of boulder distributions, as will be shown in the results chapter. These selected survey areas of potential hard substrate were further explored in field investigations.

2.2 Field investigations

Field investigations were carried out on 29 October 2024 (Sejerø Bugt and Storebælt NV) and 4 November 2024 (Jammerland Bugt & Musholm Bugt) with the diving vessel *Sephia*, where 15 survey areas in the water bodies of the northern parts of Storebælt (Great Belt) were studied with a Remotely Operated Vehicle (ROV). Drop video was not employed. The GPS positions of the selected survey areas were plotted in the boat's navigation system, and anchoring was done at all locations. The surveys covered smaller areas identified as consisting of lesser or larger percentages of hard substrate, suitable for macroalgal growth in depths varying from 10.5 to 22.5 meters. It should be noted that the survey was conducted almost two months after the official NOVANA monitoring window for macroalgae, most likely typifying a declining macroalgae community.

Visual verification of macroalgae was performed using WSP's ROV (Blue Robotics), equipped with powerful LED lights and an HD video camera. After anchoring at the positions, a 20 kg weight was used as a drifting anchor at a suitable depth for the ROV, providing a free radius of approximately 10 m, covering approximately 314 m^2. The ROV was lowered to the bottom at each position, and a video recording of about 5 minutes was made. During the video, descriptions of the seabed conditions and biological observations were continuously narrated. These videos, along with the logbook, form the basis of the survey results. A detailed description of the survey results is found in Annex A.

For each ROV dive, a logbook was prepared with various abiotic support information: GPS position, depth, weather, and wind conditions, etc. Additionally, several pieces of information related to the visual verification task were recorded. This could include (as in the present task) specific cover of suitable hard substrate, cover of soft substrate, information on approximate boulder sizes, and various specific details about the cover of different species, either substrate-specific, used for flora cover, or overall cover, used for fauna cover. The substrate-specific cover is the 2D cover of the potential substrate for macroalgae, i.e., on small stones <10 cm and large boulders >10 cm, but not gravel and sand. The overall cover is the 2D cover of the entire seabed.

Depth data from the ROV verifications come from the ROV's dive computer, which records the depth using the measured pressure at the given depth. The depth is measured at the lowest point at the position. The data is then corrected for water level relative to DVR.

ROV videos and accompanying log files were quality assured on land after the survey. Unfortunately, species-specific coverage estimates assessed with ROV were associated with greater uncertainty, which is why coverage estimates of macroalgae were only registered as a total. With ROV, it is possible to estimate the broader picture, such as the general coverage of hard substrate, vegetation, and fauna. In contrast, assessing the coverage of smaller species, requires closer inspection as these are more likely to be overseen between the larger species of macroalgae as well as bryozoans. Therefore, the largest species can perhaps be estimated with percentage coverage, but this would be based on the overall image and not what lies within the layers. With ROV, one can dive down the sides of the boulders and record species as they appear on the screen. However, it is quite challenging to use ROV to estimate coverage for individual species when they need to be estimated overall for an entire 25 m^2 frame.

2.2.1 Additional survey by diver

As a supplement to the ROV survey, three of the 15 locations were additionally surveyed by a professional diver with qualified knowledge of macroalgae species. The diver, experienced in macroalgae surveys in connection with NOVANA, examined three frames (~25 m^2 around position) in the location's specific depth range in accordance with the technical guidelines (Høgslund et al. 2014). The bottom conditions were described, macroalgae species were recorded, and cover rates for the individual species in the relevant depth range were estimated. The diver's results were recorded in a field form adapted to the survey.

2.3 Effect on macroalgae indicators

First, observations from the ROV were compared with the diver observations by considering the cumulative cover and number of perennial species. For the ROV observations, it was not possible to investigate multi-layered structures, but the macroalgae cover was overall low (maximum of 80%) and hence, it was assumed that macroalgae communities at monitored depths (10.5 -22.5 m) were primarily single-layered structures. However, it should be noted that multi-layered communities typically establish when the total cover is around 40-50% (Karsten Dahl, pers. comm.), which included 2 of the 10 positions. Thus, the total cover assessed from the ROV was compared with the cumulative cover from diver observations. Similarly, the number of perennial species were compared between ROV and diver observations. Noteworthy, only three stations (depths between 10.6 and 14.5 m) were monitored by diver, resulting in few and relatively shallow diver observations for this comparison.

Therefore, for assessing the potential effect of the additional deeper observations on the macroalgae indicators, both ROV and diver observations were included, both methods (albeit different) assumed to represent replicate samples of cumulative cover and number of perennial species. It should be noted that ROV observations follow a different protocol than regular diver observations carried out according to NOVANA guidelines. This may affect the number of perennial species, as species richness depends on monitoring effort, i.e. more perennial species will be identified with longer video recordings. Nevertheless, all video recordings were of similar length (~5 min) underlining that the numbers of perennial species assessed by ROV are similar, at least.

For comparison, the macroalgae indicators (k_{bio} for cumulative cover and number of perennial species) were calculated with and without the additional macroalgae observations from 29 October 2024. The potential improvement of the precision of the macroalgae indicators was assessed by comparing the standard errors of estimated k_{bio} with and without the additional macroalgae observations. Note that data from the boulder reef station DMU260 (Ryggen) was not included for Storebælt NV, as this station is located further offshore from the water body. However, it would be worth considering including this station covering depths at 11-13 m for the macroalgae indicators, despite that it is not located within the water body.

Estimates of k_{bio} and C_{max} were compared with the estimates provided in Carstensen (2020a) to investigate whether the parameter estimates were consistent with the overall pattern, linking k_{bio} with k_d and C_{max} with salinity.

3 Results and discussion

This section reports the outcomes of the screening for potential hard substrate using side scan sonar data, the potential validation of hard substrate and macroalgae presence during field investigation and the effect that the additional data have on the macroalgae indicators.

3.1 Screening based on side scan sonar data

For the three investigated water bodies, high-frequency side scan sonar datasets were used for identifying positions of boulders located at the seabed. For each water body, a couple of side scan sonar examples, a table with information on the chosen positions, and a map showing their location are shown. A spread sheet with all required information and side scan examples from the three chosen positions were provided so that ground truth sampling using ROV could take place.

3.1.1 Sejerø Bugt

Three positions were identified that fulfilled the requirements, two at ~14 m and one at 16.5 m depth (Table 3.1, Figure 3.1 and 3.2).

Table 3.1. Identified positions in Sejerø Bugt.

Position	Depth (m)	Long	Lat	Easting	Northing	Nearest transect	Distance to transect	Remarks
SJ01	14.2	11° 01.63716´ (11.0273)	55° 51.65018´ (55.8608)	626881.58	6192449.46	2820- 19, sejerø	9.4km	>25% boulders >25 cm
SJ02	14.2	11° 02.9678´ (11.0495)	55° 50.9886´ (55.8491)	628307.9	6191189.7	2820- 19, sejerø	6.9km	>20% boulders >25 cm
SJ03	16.5	11° 01.40062´ (11.0233)	55° 49.55849´ (55.826)	626748	6188560	2820- 19, sejerø	6.4km	>10% boulders >25 cm

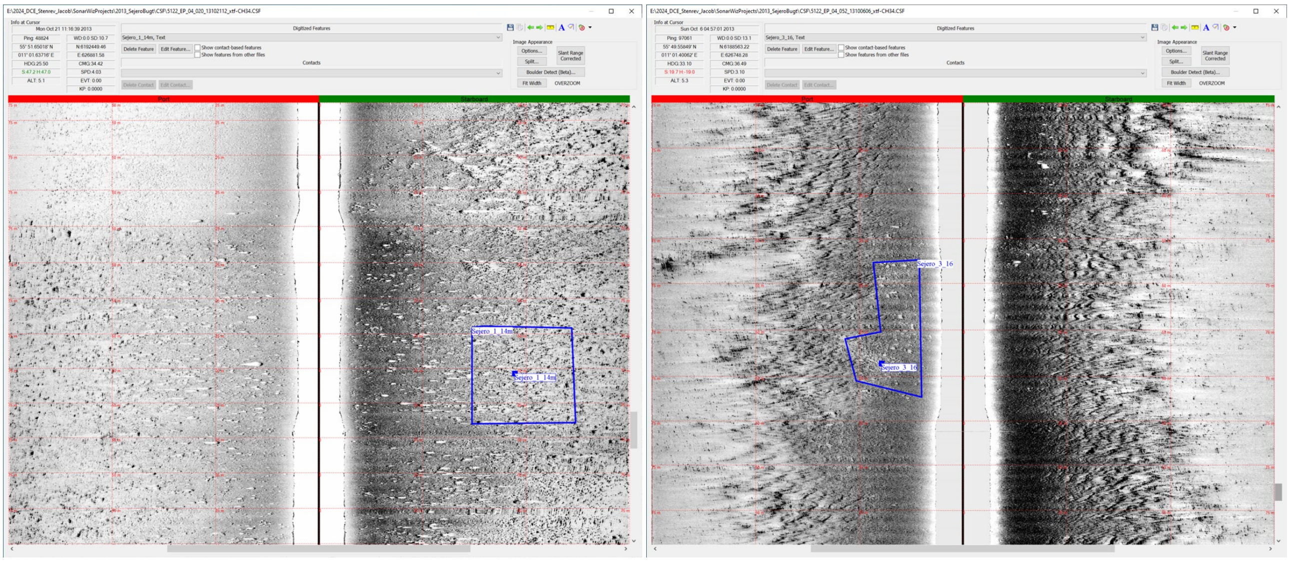
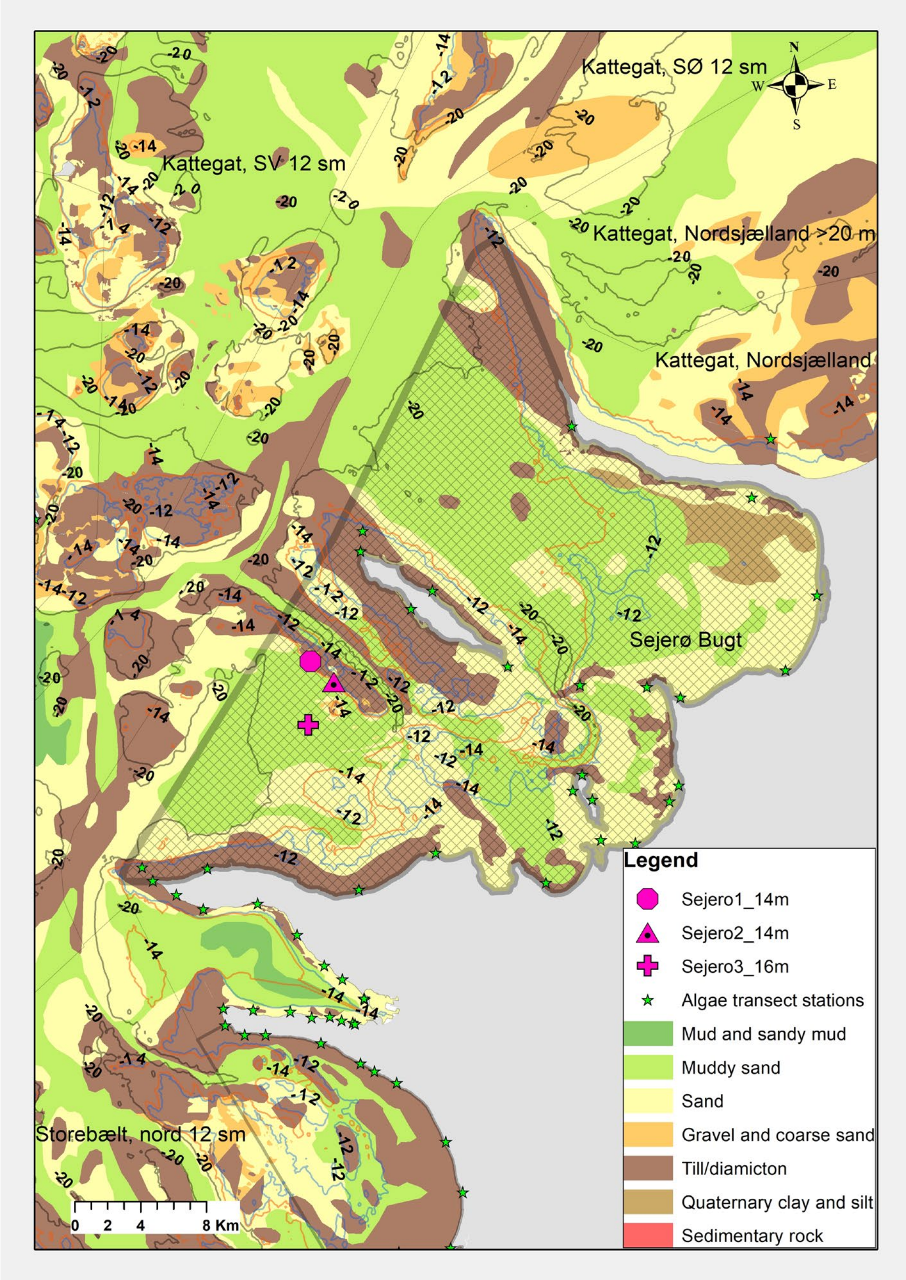


Figure 3.1. Examples from the 14 m (left) and the 16 m depth (right) side scan sonar images, where positions SJ01 and SJ03 point are located (cf. Table 3.1). The chosen positions are located where the highest concentration of boulders occurred, while the polygon covers the extent of boulder distribution.



Figur 3.2. The three identified positions in Sejerø Bugt with depth contours for 12, 14 and 16 m overlaying the sediment map. Positions are labelled with their number and depth (cf. Table 3.1). Note that SJ03 has a small-scale feature with till/diamicton that is overlaid by the symbol.

3.1.2 Jammerland Bugt & Musholm Bugt

Five potential locations were identified from the side scan sonar images that contain boulders of different density and size (Table 3.2, Figure 3.3 and 3.4). Two positions were at 12.8-13 m, two at 14 m and 14.9 m, and one at 16.6 m. For JM05, two nearby transects were identified.

Table 3.2. Identified positions in Jammerland Bugt & Musholm Bugt.

Position	Depth (m)	Long	Lat	Easting	Northing	Nearest Transect	Distance to transect	Remarks
JM01	14.9	11° 03.58403' (11.0597)	55° 27.70208' (55.4617)	630230.89	6148099.66	1201002 DRgSSEL-BJERG	8.5km	20% boulders >25 cm
JM02	16.6	11° 03.91361' (11.0652)	55° 22.28219' (55.3714)	630876.51	6138060	1201003 LEJE ODDE	3km	25% boulders >25 cm
JM03	13	11° 05.32127' (11.0887)	55° 23.49375' (55.3916)	632295.61	6140350.58	1201003 LEJE ODDE	2.8km	10% boulders >25 cm
JM04	14	11° 05.09850' (11.08498)	55° 23.85968' (55.39766)	632040.1	6141022	1201003 LEJE ODDE	3.5	10% boulders >25 cm
JM05	12.8	11° 02.07276´ (11.03454)	55° 31.85723´ (55.53095)	628412.9	6155758	12, JAMMERLAND BUGT	3.36km	25% boulders >25 cm
						1201014 Reersg tr.01 1998	3.2km	Another tran-sect

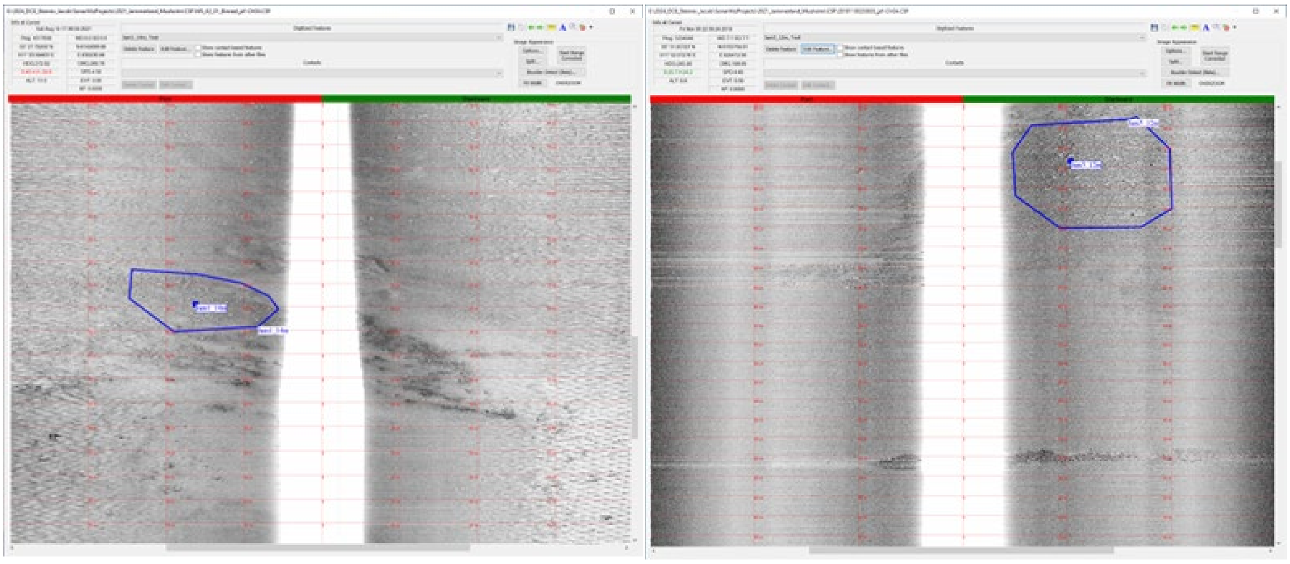
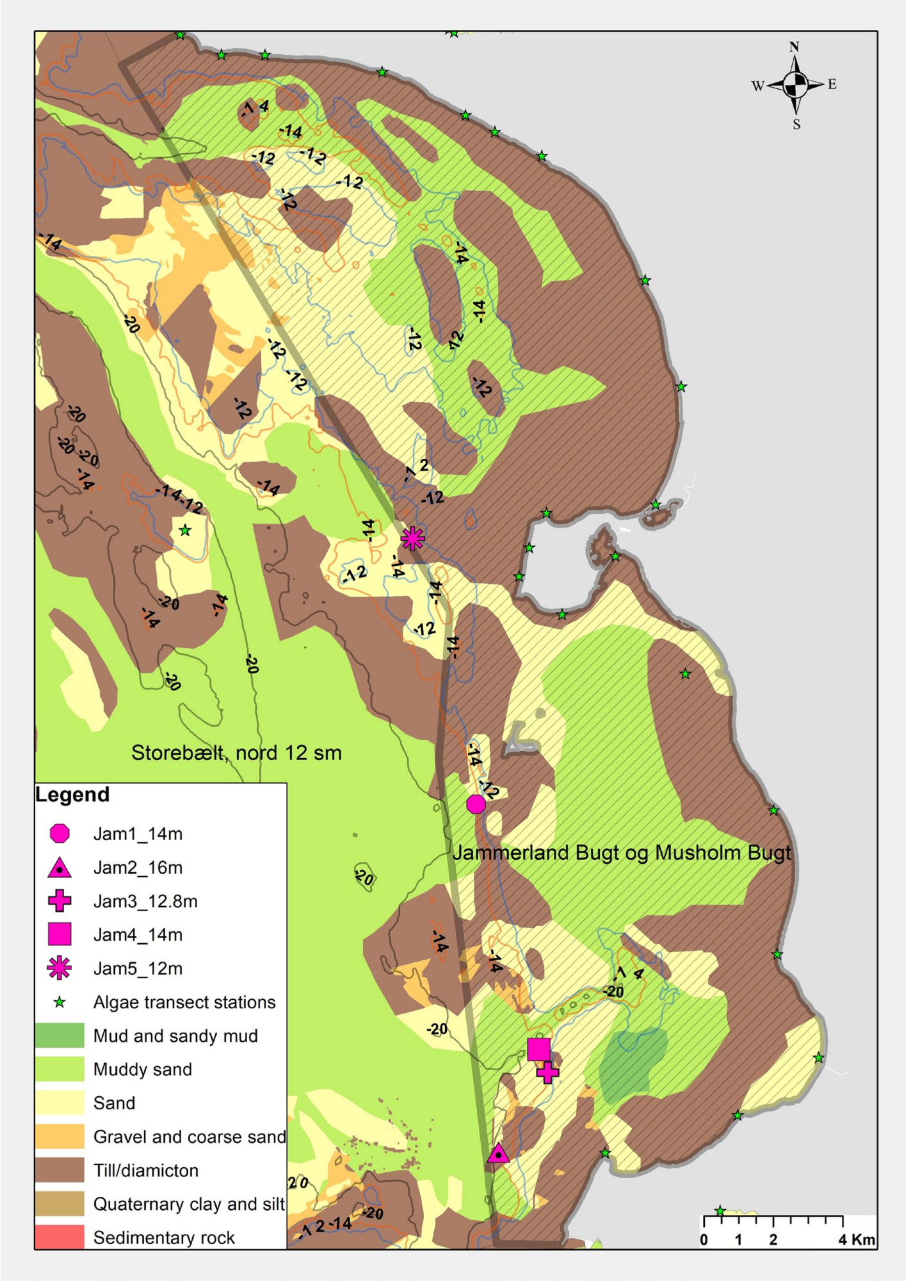


Figure 3.3. Examples of side scan images used for identifying the required positions. The left is for position JM01 at 14.9 m, and the right is for position JM05 at 12.8 m (cf. Table 3.2).

Figur 3.4. The five identified positions in Jammerland Bugt & Musholm Bugt with depth contours for 12, 14 and 16 m overlaying the sediment map. Positions are labelled with their number and depth (cf. Table 3.2).



3.1.3 Storebælt NV

Seven suitable positions that fulfilled the requirements of depth and boulder density were identified from the existing side scan sonar images within the water body (Table 3.3, Figure 3.5 and 3.6). The shallowest is at 11.7 m and the deepest is at 21.4 m. Some of the identified locations are located outside the WFD water body.

Table 3.3. Identified positions in Storebælt NV.

Position	Depth (m)	Long	Lat	Easting	Northing	Nearest Transect	Distance to transect	Remarks
SB01	12.8	10° 47.76766' (10.7961)	55° 31.87347' (55.5312)	613366.5	6155370.3	Romse A, Roms8 tr. 3.1	2.5km	25% boulders >25 cm
SB02	11.7	10° 49.91514' (10.8319)	55° 20.46660' (55.3411)	616181.9	6134280.9	Nyborg Fjord 3	4.5km	10% boulders >25 cm
SB03	14.9	10° 50.28411' (10.8381)	55° 20.38570' (55.3398)	616575.9	6134140	Nyborg Fjord 3	4.5km	15% boulders >25 cm
SB04	21.4	10° 51.46295' (10.8577)	55° 18.94652' (55.3158)	617893	6131500.4	Nyborg Fjord 3	3.8km	10% boul-der>25 cm
SB05	13.5	10° 51.49301' (10.8582)	55° 18.24452' (55.3041)	617959.5	6130200.4	Nyborg Fjord 3	3.4km	10% boulders >25 cm
						Nyborg Fjord 9	2.9km	Southern Al-gaeStation
SB06 (Out-side NV)	15.7	10° 44.35480' (10.7392)	55° 36.72711' (55.6121)	609550.8	6164280.1	FYNSHOVED TR. 02	7.7km	20% boulders >25 cm
SB07 (Out-side NV)	15	10° 44.71203' (10.7452)	55° 35.02517' (55.5838)	610005.2	6161140.4	LILLESTRAND 9	8.6km	25% boulders >25 cm

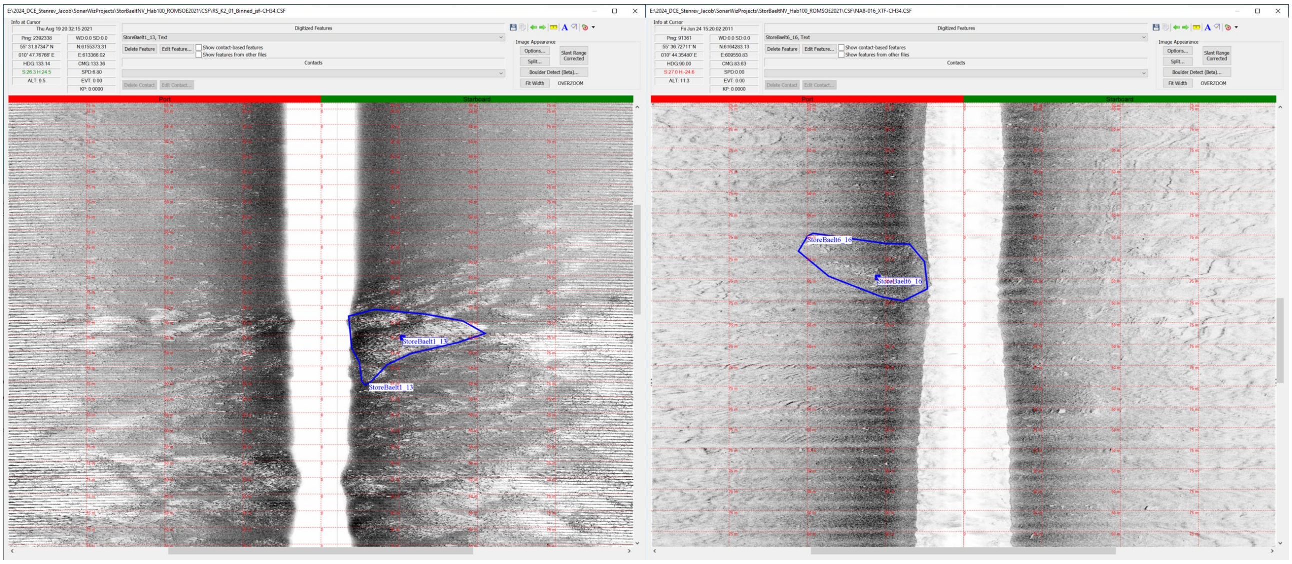
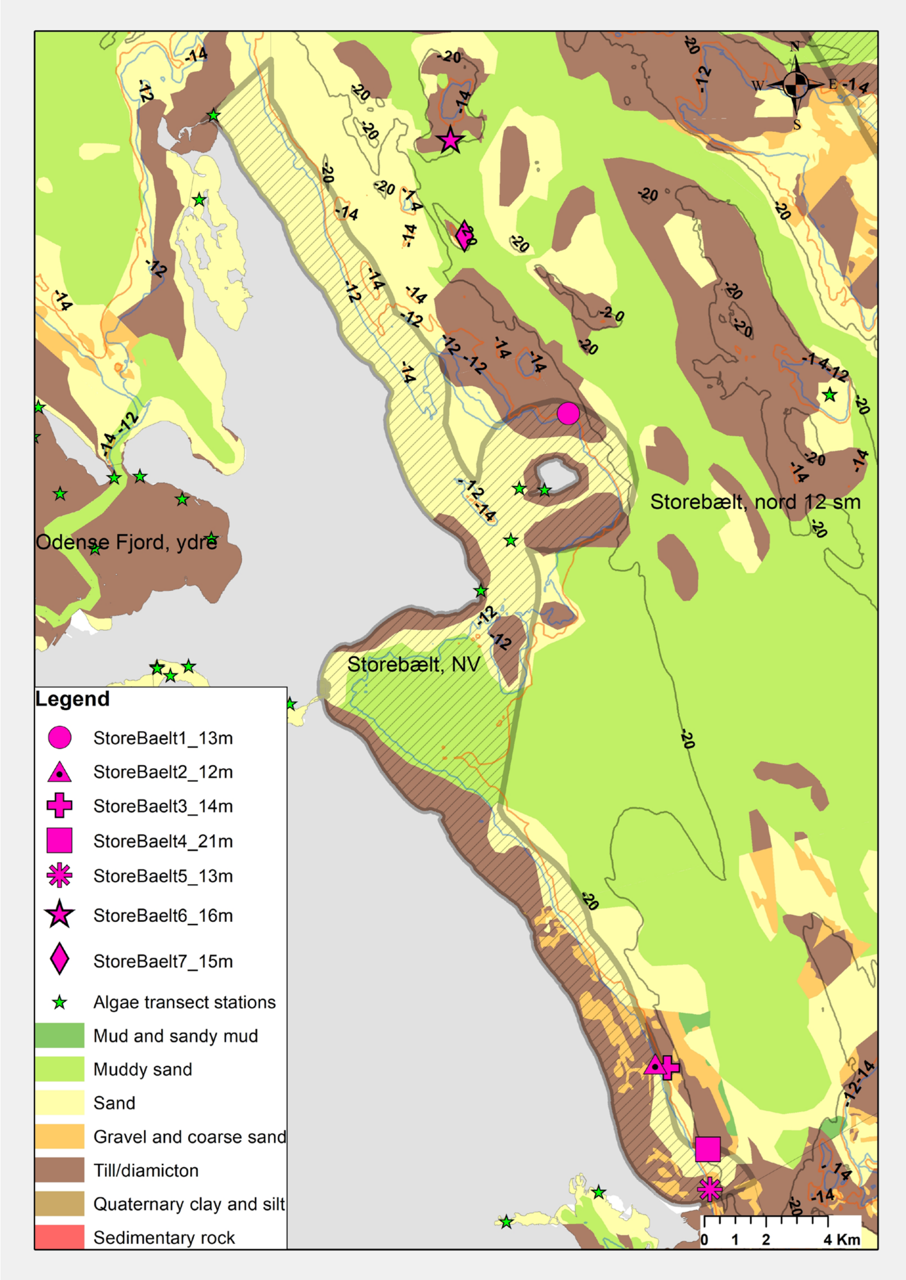


Figure 3.5. Examples of side scan images used for identifying the required positions in Storebælt NV. The left is for SB01 at 13 m and the right is for SB06 at 16 m (cf. Table 3.3).

Figur 3.6. The seven identified positions in Storebælt NV with depth contours for 12, 14 and 16 m overlaying the sediment map. Positions are labelled with their number and depth (cf. Table 3.3).



3.2 Field investigations

It was possible to conduct surveys with ROV at the 15 identified locations within the water bodies of Sejerø Bugt, Storebælt NV, Jammerland Bugt & Musholm Bugt.

The positional deviation of the ROV surveys from the designated locations was acceptable, with an average of only 12 meters (range 11-23 meters).

At three of the stations, the ROV survey was complemented by diver survey conducted in accordance with the technical guidelines at same position as the ROV.

3.2.1 Substrate and depth conditions

The 15 surveyed locations were distributed at depths ranging from 10.5 m to 22.5 m (Table 3.4; Figure 3.7). All locations could be classified as substrate type 3 (sand, gravel and pebbles, and larger boulders) or 4 (stony area and boulder reefs). The fraction of large boulders (>10 cm) varied from 5% to 95%, with an average of 24%. All locations, except SB05, had at least 10% large boulders, whereas SB05 was dominated by many smaller stones (80%). Four locations (SJ01,SB02, JM02 and JM03) had relatively low fractions of both small stones and large boulders (≤25%) and none of these represented the deepest locations. Overall, the ROV survey confirmed the presence of hard substrate at the locations identified from the analysis of side scan sonar data.

Table 3.4. Overview of substrate and depth distribution across the 15 ROV-surveyed locations for the three water bodies.

Water body	Location ID	Mud/silt [%]	Sand [%]	Gravel [%]	Stones <10 cm [%]	Boulders >10 cm [%]	Depth [m]	Substrate type	Description of bottom
Sejerø Bugt	SJ01	0	77	0	3	20	14.5	3	Sandy bottom with larger and smaller boulders.
	SJ02	0	5	5	80	10	15.0	3	Stony, cobblestone-like bottom dominated by smaller and larger boulders, with sand, shell fragments, and gravel.
	SJ03	0	10	30	40	20	17.0	3	Gravelly bottom with larger and smaller boulders.
Storebælt NV	SB01	0	5	5	10	80	10.5	4	Hard bottom with primarily larger but also smaller boulders. Large depth variation in the area. Locally type 2a (coarse sand, gravel and pebbles), but overall type 4.
	SB02	0	73	2	15	10	12.0	3	Mixed bottom with sand, gravel, and larger and smaller boulders.
	SB03	0	0	20	70	10	16.0	4	Hard bottom with small and large boulders.
	SB04	0	25	15	50	10	22.5	4	Firm bottom with many small stones and a few larger boulders covered with loose material.
	SB05	0	5	10	80	5	14.2	4	Gravelly, pebbly bottom with a few large boulders.
	SB06	0	15	15	30	40	15.0	4	Densely vegetated small stones and large boulders with gravel and shell fragments between the boulders.
	SB07	0	0	2	3	95	15.0	4	Boulder reef with large boulders dominated by bryozoans.
Jammerland & Musholm Bugt	JM01	0	68	2	20	10	15,0	4	Mixed bottom, sandy with scattered larger stones
	JM02	0	70	5	15	10	16,4	3	Scattered larger stones.
	JM03	0	80	0	10	10	13,8	3	Finegrained sand with few larger rocks
	JM04	0	50	5	30	15	15,5	4	Mixed sand, gravel, small and large rocks
	JM05	0	55	10	20	15	14,5	3	Mixed sand, gravel, shell fragments, small and few larger rocks

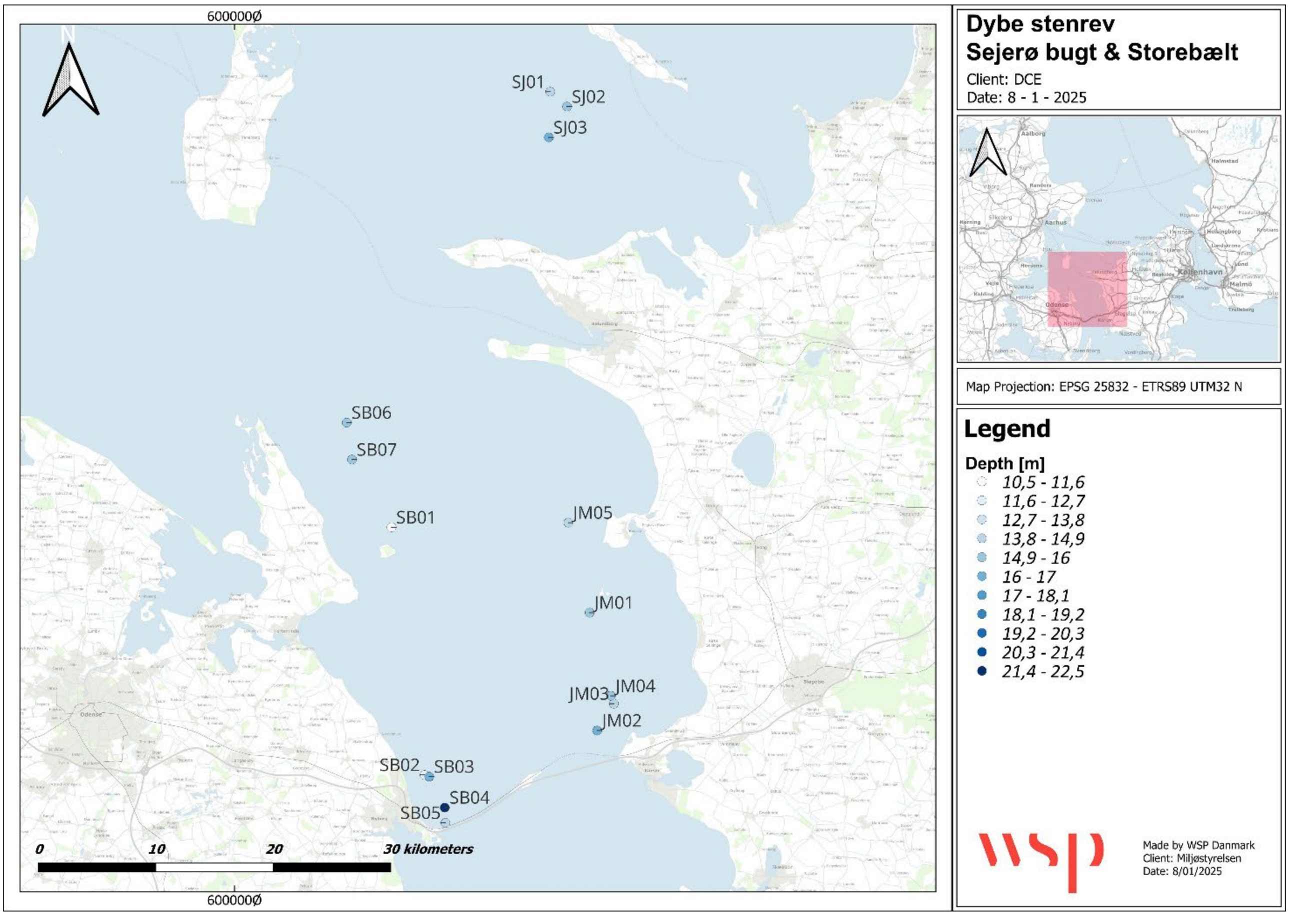


Figure 3.7. Distribution of observed depth at surveyed locations in Sejerø Bugt,Storebælt NV and Jammerland & Musholm bugt.

3.2.2 Vegetation and fauna

A total of 12 macroalgae species were observed across the 15 designated locations. The three most frequently observed species were *Phycodrys rubens*, *Delesseria sanguinea*, and *Saccharina latissima*. Macroalgae cover was low at greater depths reaching 2% at 22.5 m for SB04 (Table 3.5; Figures 3.8 & 3.9). Generally, it was observed that macroalgae cover transitioned from multi-layered and relatively well-developed at approximately 15 m depth to more single-layered and open vegetation at greater depths, where bryozoans largely dominated and outcompeted the vegetation. Sea urchins were observed at JM02, JM03, JM04, SB03, SB05 and SB06. Their cover was not reported (see methods) but for the calculation of macroalgae indicators it was set to 1%.

Table 3.5. Cover and species richness assessed at the ROV-surveyed locations. Details of flora and invertebrate fauna species are found in Annex A. Table explanation: s.c.= substrate-specific cover, o.c.= overall cover.

Water body	Station ID	Macroalgae total cover [%] (s.c.)	Macroalgae # species	Fauna total cover [%] (o.c.)	Fauna # species	Depth [m]	Substrate type
Sejerø Bugt	SJ01	80	6	20	10	14,5	3
	SJ02	55	7	4	3	15,0	3
	SJ03	15	6	25	10	17,0	3
Storebælt NV	SB01	30	7	65	8	10,5	4
	SB02	25	8	20	7	12,0	3
	SB03	10	3	20	10	16,0	4
	SB04	2	4	10	11	22,5	4
	SB05	10	6	55	7	14,2	4
	SB06	35	6	60	10	15,0	4
	SB07	15	7	75	10	15,0	4
Jammerland & Musholm Bugt	JM01	30	4	10	10	15,0	4
	JM02	20	3	15	12	16,4	3
	JM03	50	6	15	10	13,8	3
	JM04	10	7	40	7	15,5	4
	JM05	40	3	10	6	14,5	3

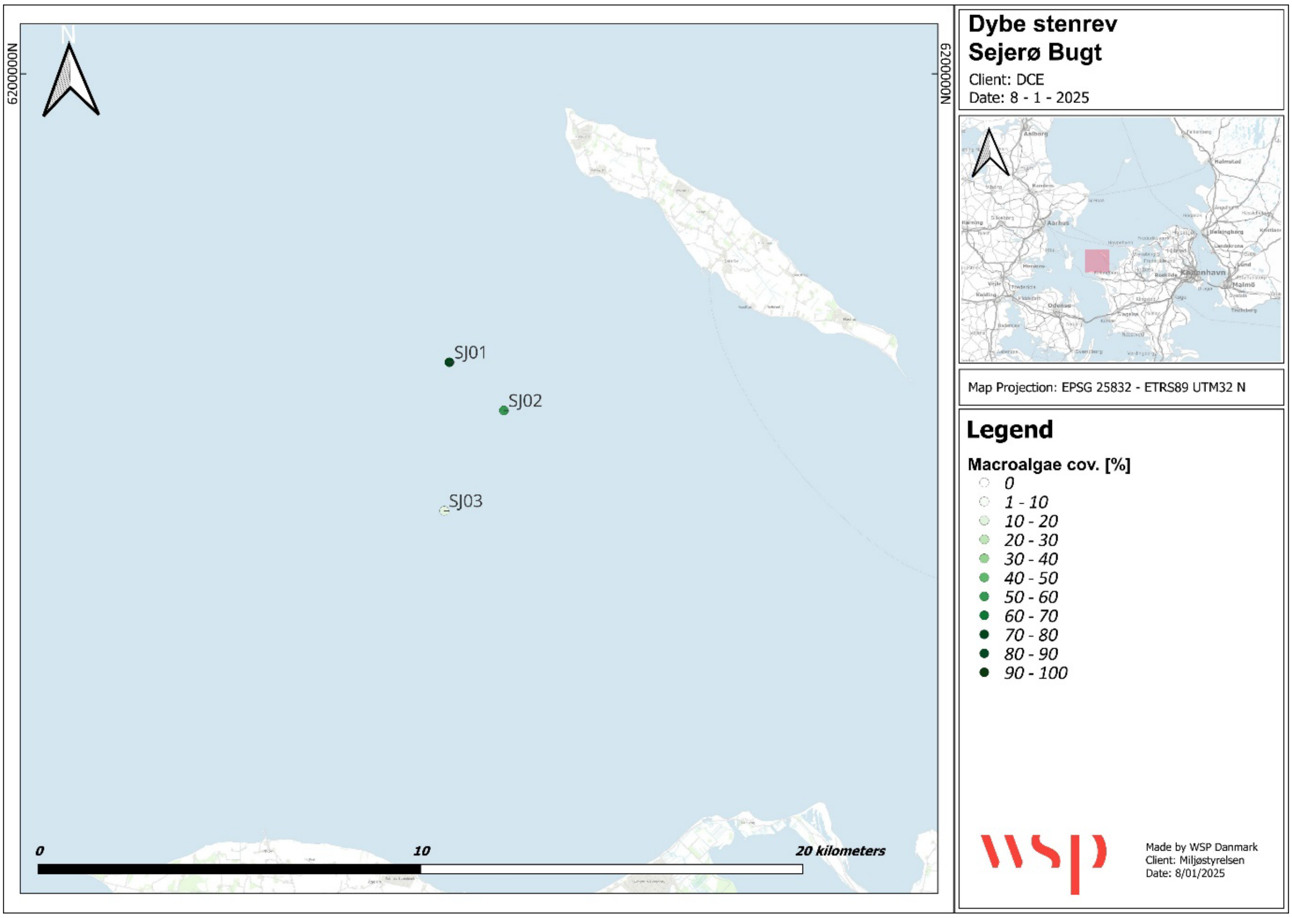


Figure 3.8. Overall substrate-specific macroalgae cover at the surveyed locations in Sejerø Bugt.

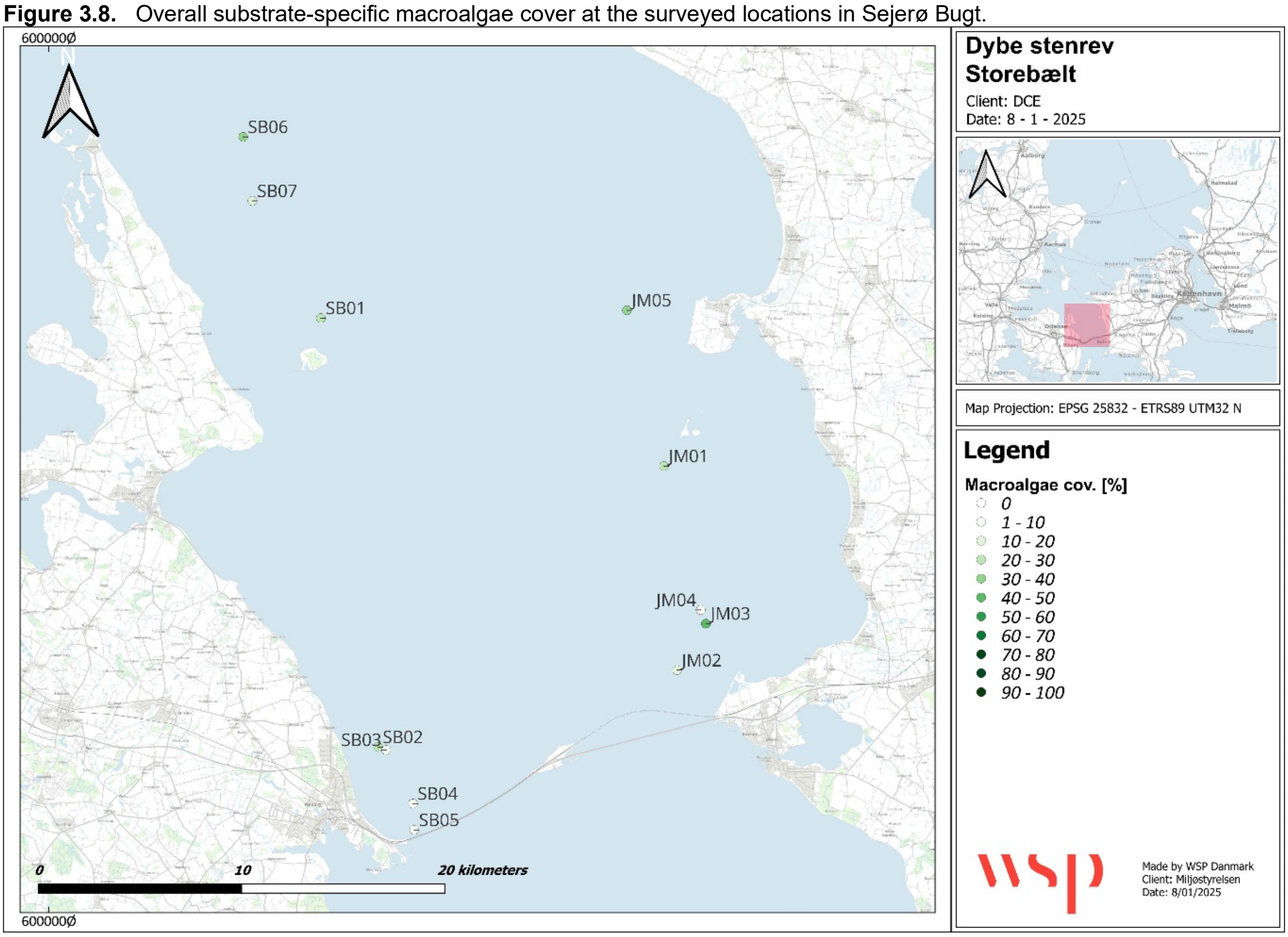


Figure 3.9. .Overall substrate-specific macroalgae cover at the surveyed locations in Storebælt NV, Jammerland Bugt & Musholm Bugt.

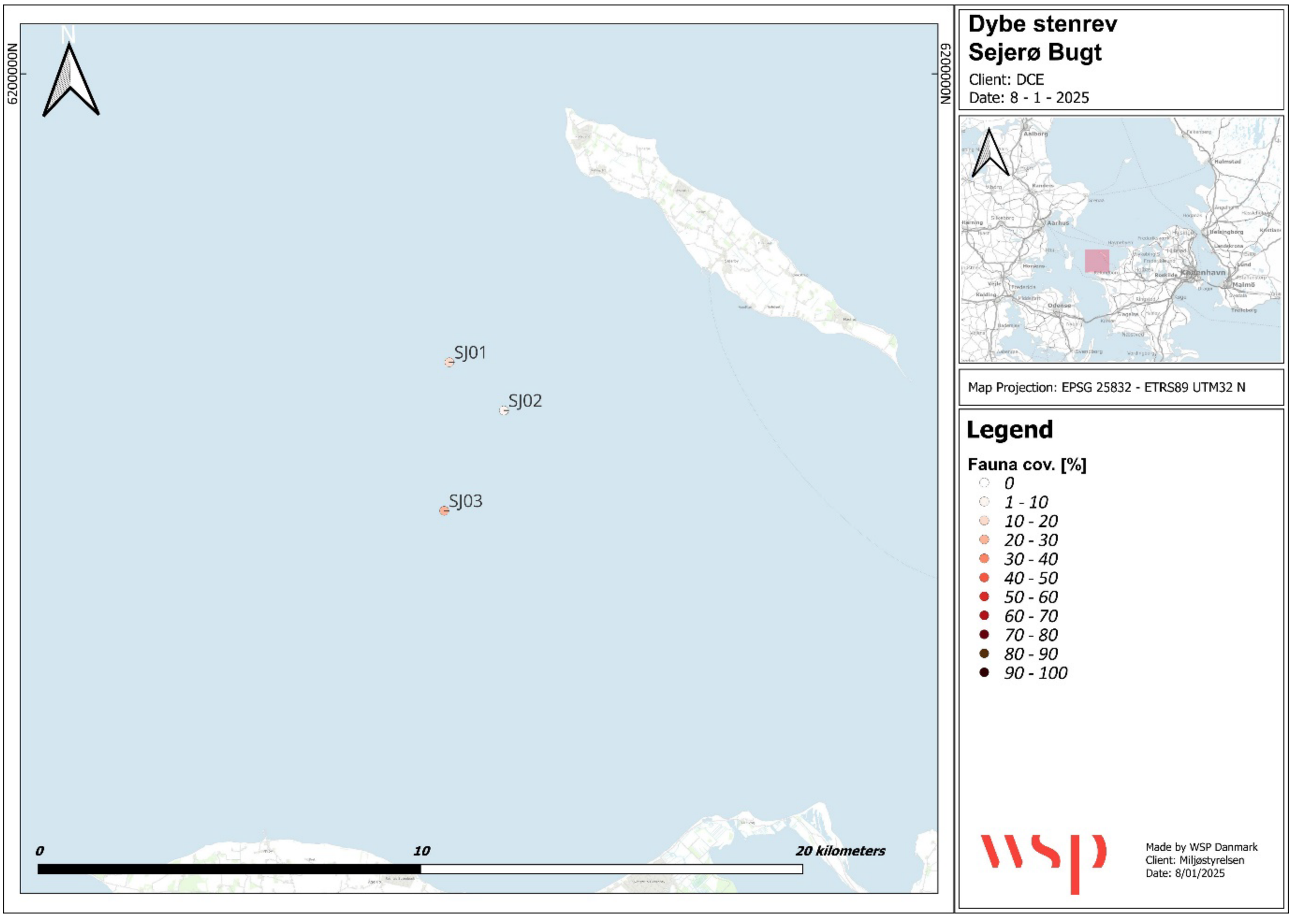


Figure 3.10. Overall fauna cover for the entire bottom at the surveyed locations in Sejerø Bugt.

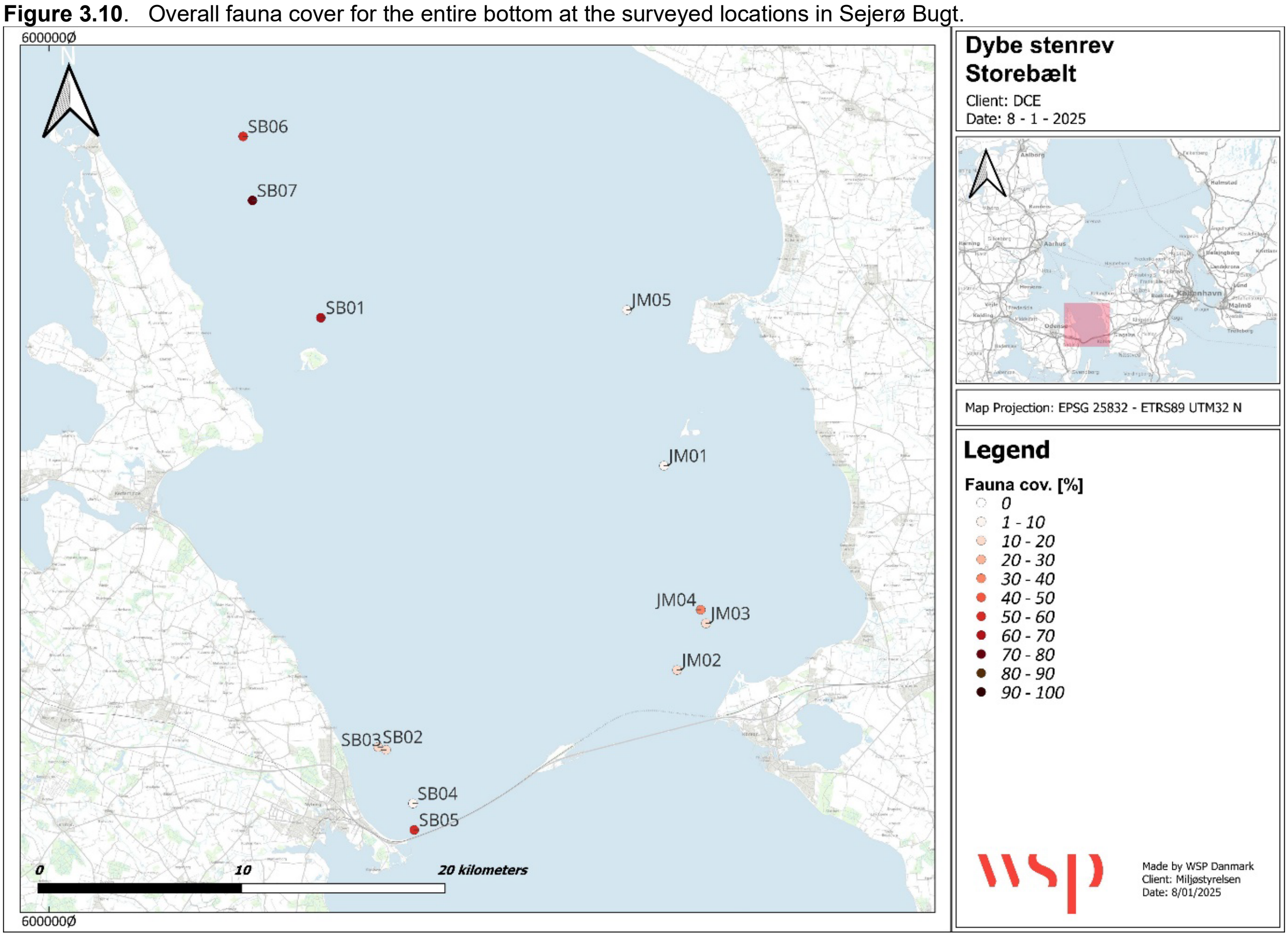


Figure 3.11. Overall fauna cover for the entire bottom at the surveyed locations in Storebælt NV, Jammerland Bugt & Musholm Bugt.

A total of 25 invertebrate species were observed. The most frequently observed species belonged to the phyla bryozoans (*Bryozoa*) and sponges (*Porifera*), as well as common starfish (*Asterias rubens*). In addition to the invertebrate species, a total of nine fish species were also observed, with goldsinny wrasse (*Ctenolabrus rupestris*) being the most frequent. The faunal richness was generally higher at deeper depths with most locations harboring around 10 different species (Table 3.5). The faunal cover on hard substrate ranged from 4 to 25% in Sejerø Bugt,from 10 to 75% in Storebælt NV and from 10 to 40% in Jammerland & Musholm Bugt (Table 3.5; Figure 3.10 & 3.11). Further details on the species found at the different locations are found in Annex A.

3.2.3 Additional survey by diver

In addition to ROV field registrations, three of the 15 locations were complemented by diver registrations: SJ01 in Sejerø Bugt and SB01 and SB02 in Storebælt NV.

Figur 3.12. *Carradoriella elongata* along with *Vertebrata fucoides* photographed by diver in Sejerø Bugt (SJ01).

Observations from the diver included 14 species of macroalgae (Table 3.6). Similar to ROV registrations, the dominating species were *Delesseria sanguinea*, *Phycodrys rubens* and *Saccharina latissima*. By diving, however, it was possible to sample and distinguish between red species of macroalgae *Rhodophyta* in more detail than possible with the ROV. Certain "red bushes" registered with the ROV, were further specified into species such as *Ceramium virgatum*, *Vertebrata fucoides* and *Carradoriella elongata* (Figure 3.12).

Table 3.6. Comparison of registered species of diver and ROV on the three stations SJ01, SB01 and SB02. (X) shows species registered as "red bushes" through ROV. Growth strategies associated with the species are listed (C=crust, O=opportunist, P=perennial).

Species	Growth strategy	SJ01		SB01		SB02	
		ROV	Diver	ROV	Diver	ROV	Diver
Ceramium virgatum	O		X	(X)	X		X
Coccotylus truncatus	P			X	X		X
Delesseria sanguinea	P	X	X	X	X	X	X
Furcellaria lumbricalis	P		X				X
Phycodrys rubens	P	X	X	X	X	X	X
Carradoriella elongata	P		X				
Vertebrata fucoides	P			(X)	X		
Rhodomela confervoides	P					X	X
Red calcified crust	C	X	X	X	X	X	X
Hildenbrandia sp	C	X	X			X	X
Desmerestia aculeata	P		X	X	X	X	X
Saccharina latissima	P	X	X	X	X	X	X
Battersia arctica	P			X	X		
Brown crust	C	X	X			X	X

3.2.4 Comparison of ROV and diver observations

Only three stations were monitored by diver, although each with three replicates totaling nine diver observations. These were combined with the three ROV observations from the three stations (one per station) to assess if ROV and diver observations were similar (Figure 3.13).

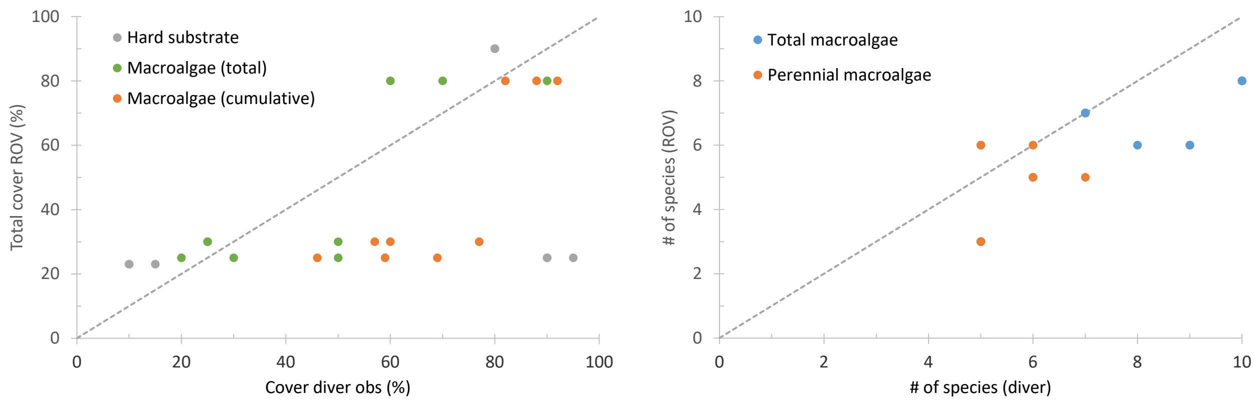


Figure 3.13. ROV versus diver observations of a) hard substrate and macroalgae total and cumulative cover and b) total number and number of perennial species. Dashed lines are identity (1:1) lines.

The cover of hard substrate matched well at two of the three stations (SJ01 and SB01), but there was a large discrepancy at station SB02 (25% for ROV versus 90-95% for diver observations). This station was dominated by sand and gravel (75%) according to the ROV survey and with larger boulders comprising 10%. It is possible that the diver examined frames with higher presence of larger boulders, causing this discrepancy. However, the discrepancy does not affect the macroalgae cover observations that are assessed as substrate-specific.

There was a larger agreement between ROV and diver observations of total cover that were within ±10% for 6 out of 9 observations (Figure 3.13). The three diver replicates of total cover were both higher and lower than the total cover assessed by ROV, suggesting that the variation around the line represented variability among replicates. Hence, this suggests that ROV surveys in this case and relative late time of year can reproduce diver assessment of total macroalgae cover without systematic bias.

However, the diver's assessment of cumulative cover was generally higher than that of total cover, causing a substantial difference between cumulative cover by diver versus total cover by ROV. Surprisingly, this difference was most pronounced when the total cover was low, whereas there was a better agreement for higher total cover (Figure 3.13). If the disagreement was due to multi-layered macroalgae communities, the difference would be expected to be larger for more developed and diverse communities. This is not the case, and this could suggest that cumulative cover might be overestimated when several summing across many species that all have low cover. Another explanation is that the relative importance of small filamentous macroalgae (mostly red macroalgae) typically increase with depth, but these species are harder to identify with ROV and often, the diver needs to remove detritus particles to be able to see them. Hence, ROV surveys might underestimate cumulative cover at deeper depths. However, these assertions are based on only nine diver observations, which are too few to evaluate a potential systematic bias between diver and ROV. Furthermore, this analysis is based on observations that are not conforming to the official monitoring guidelines, as the macroalgae community was surveyed two months after the official monitoring window. Nevertheless, a more detailed analysis of this potential discrepancy could be warranted.

For the total number of species and the number of perennial species there was a reasonable agreement between diver and ROV observations, although with a tendency for 1-2 fewer species in the majority of ROV observations (Figure 3.13). Particularly, four species were recorded by divers but not observed from the ROV (Table 3.6), and these species mostly covered less than 5% of the hard substrate. It could be argued that this apparent bias (lower number of species, both total and perennial) is related to the effort, such that additional species would have been recorded if the ROV survey were extended. However, the identification of species from ROV surveys does not appear to be a random subset of the diver recordings (Table 3.6), underscoring that the fewer species in ROV surveys is not related to the sampling effort. Hence, it is more likely that fewer species are observed with ROV in general, as the larger and most characteristic macroalgae species are primarily identified. The diver has the possibility of removing detritus particles and place reference material to achieve better visual contrast, enabling the identification of species, which is not possible with the ROV at present. It should also be stressed that it is not possible to assess the species-specific cover from the ROV video (see methods). A more detailed analysis of the differences between the two methods is also warranted.

Instead, it appears that certain species are more difficult to identify from the ROV, particularly when their cover is low. For instance, *Ceramium virgatum* and *Vertebrata fucoides* were most likely recorded as "red bushes" (Table 3.6), and *Rhodomela confervoides* can be difficult to distinguish from *Vertebrata fucoides* on ROV. *Rhodomela* and *Furcellaria lumbricalis* can be hidden underneath other macroalgae species (Karsten Dahl and Peter Stæhr, pers. comm.) and species like *Phyllophora truncata* and *Phyllophora pseudoceranoides* often form substrate for other epiphytic algae species in multilayered vegetation making it difficult to identify without physical handling the vegetation. Noteworthy, two species were recorded from the ROV surveys at other stations without diver monitoring (*Phyllophora pseudoceranoides* and *Dilsea carnosa*), suggesting that species that are not always present, are also recorded with the ROV. Thus, it is possible to identify large characteristic macroalgae species with reasonable cover from ROV surveys, but there is a risk of underestimating the number of perennial species. However, more detailed analyses of comparing ROV with diver observations are needed to fully determine the magnitude of this potential bias.

3.3 Potential improvement of macroalgae indicators

The ROV surveys documented that suitable hard substrate could be found at deeper locations in Sejerø Bugt and Storebælt NV (Figure 3.14). In Sejerø Bugt and Storebælt NV, the observational depths were extended to 17 m and 22.5 m, respectively, with most of the observations inside the borders of the WFD areas. Importantly, most of the surveyed locations had relatively high substrate cover as opposed to regular NOVANA monitoring, where substrate cover generally decreases with depth along the transects. The ROV and diver surveys further confirmed that these deeper locations with suitable substrate were inhabited by macroalgae communities. These results are in line with Dahl et al. 2023) recommending the use of side scan sonar data for identification of deep locations with hard substrate. Examining the depth gradient along existing macroalgae transects with side scan sonar could be a favorable strategy for optimizing macroalgae transects to focus on those positions with the highest substrate cover and avoid longer stretches with too little suitable substrate.

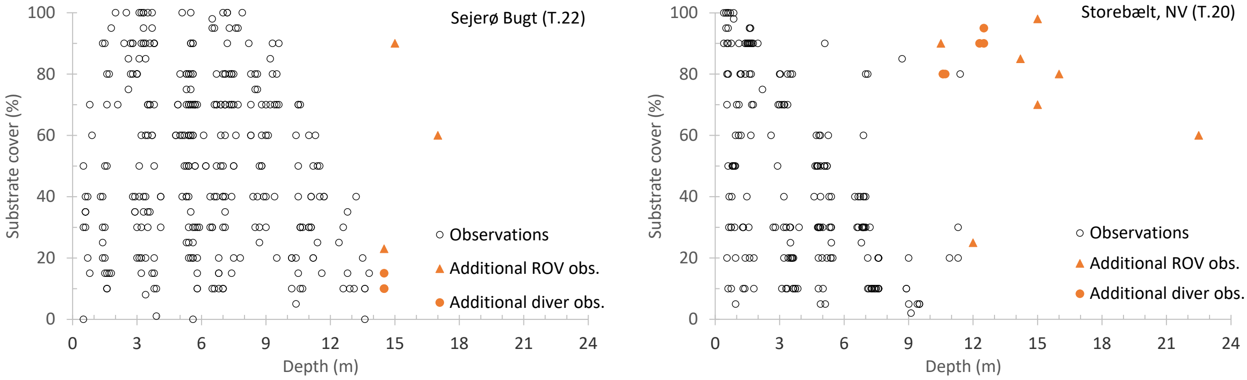


Figure 3.14. Cover of suitable substrate versus depth for Sejerø Bugt and Storebælt NV (2013-2024). Additional data from ROV and diver surveys in October 2024 are highlighted.

3.3.1 Cumulative cover estimation

Sejerø Bugt:

Four NOVANA transects were investigated in the two 6-year periods reaching depths of 13.8 m in 2013-2018 and 11.4 m in 2019-2024 (Figure 3.15). Fewer depth-specific observations were available for the second period. The additional survey included depths from 14.5 to 17 m with cumulative cover estimates from 15% to 92%. For the second period it was not possible to estimate k_{bio} with NOVANA data only, as there were not sufficient deeper observations to characterize the light limited phase of the macroalgae community. Extending the depth range allowed for estimating k_{bio} with a standard error similar to k_{bio} for the first period, despite that the latter was estimated on substantially more observations. The additional observations from the ROV and diver appeared to follow the expected depth relationship for cumulative cover.

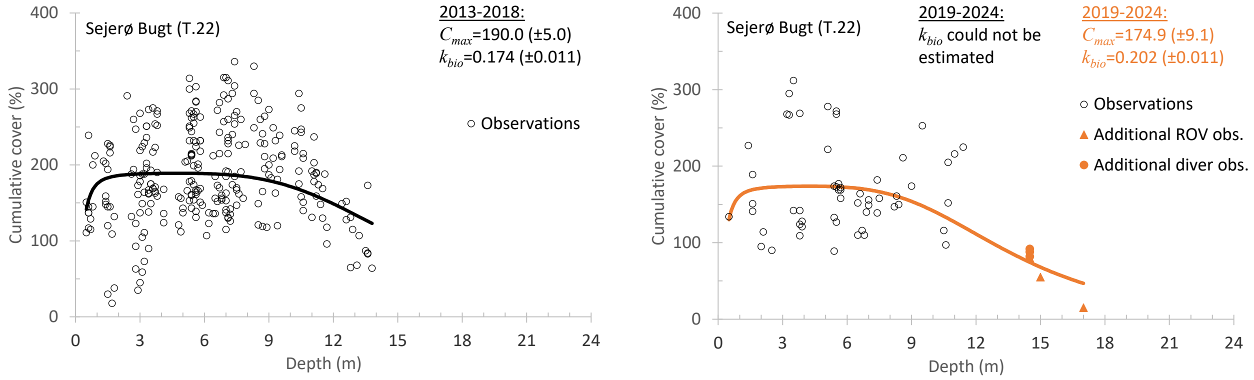


Figure 3.15. Cumulative cover across the depth gradient for Sejerø Bugt for two assessment periods. Additional data are highlighted, and their effects on parameter estimates are shown as inserts.

Jammerland Bugt & Musholm Bugt:

Three NOVANA transects were investigated in the two 6-year periods reaching depths of 9.5 m in 2013-2018 and 9.0 m in 2019-2024 (Figure 3.16). Fewer depth-specific observations were available for the second period. The additional survey included depths from 13.8 to 16.4 m with cumulative cover estimates from 10% to 50%. For the second period it was not possible to estimate k_{bio} with NOVANA data only, as there were not sufficient deeper observations to characterize the light limited phase of the macroalgae community. Extending the depth range allowed for estimating k_{bio} with a standard error about half of the estimate for the first period, despite that the latter was estimated on substantially more observations. The additional observations from the ROV appeared to follow the expected depth relationship for cumulative cover.

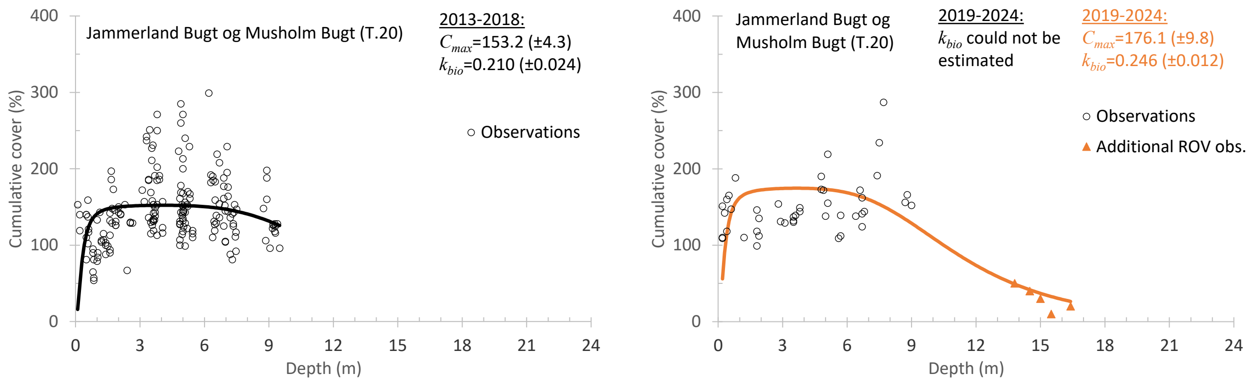


Figure 3.16. Cumulative cover across the depth gradient for Jammerland Bugt & Musholm Bugt for two assessment periods. Additional data are highlighted, and their effects on parameter estimates are shown as inserts.

Storebælt, NV:

Three NOVANA transects were investigated in the two 6-year periods reaching depths of 11.4 m in 2013-2018 and 11.3 m in 2019-2024 (Figure 3.17). The additional survey included depths from 10.5 to 22.5 m with cumulative cover estimates between 2% and 77%. Cumulative cover was relatively low for the additional surveys in 2024, which resulted in a relatively high estimate for k_{bio}. Cumulative cover was around 100-120% at 10 m depth in the NOVANA observations (and similar 11 m depth at the boulder reef station DMU260), whereas cumulative cover in the additional surveys from October 2024 was 10-70% with ROV observations being the lowest. These observations also had a high faunal cover (10-75%, cf. Table 3.5), indicating competition for space between macroalgae and benthic fauna.

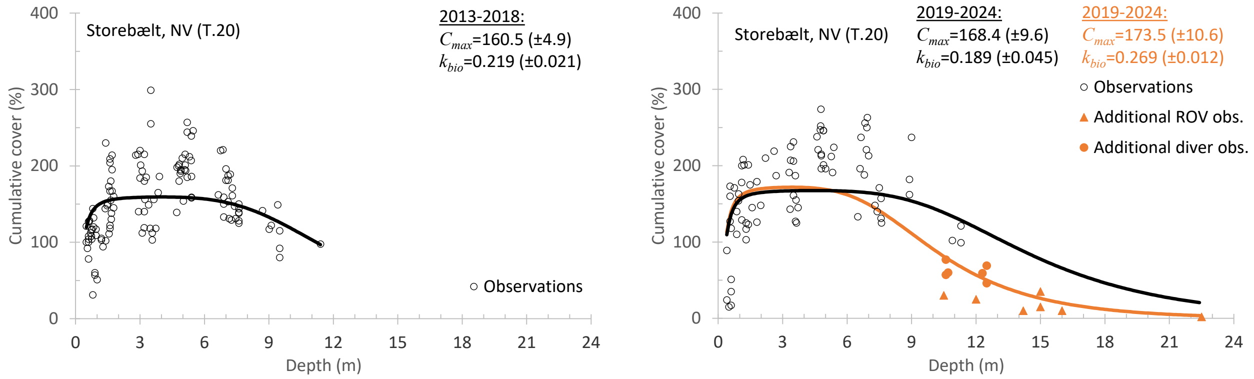


Figure 3.17. Cumulative cover across the depth gradient for Storebælt NV for two assessment periods. Additional data are highlighted, and their effects on parameter estimates are shown as inserts.

The faunal cover in Storebælt NV was generally higher than in Sejerø Bugt (4-25%) and Jammerland Bugt & Musholm Bugt (10-40%), which could be caused by higher currents in Storebælt NV. However, <u>further investigations are needed to assess if the relatively low cumulative cover observations at deeper depths in Storebælt NV are also observed during the NOVANA monitoring window</u> (June-August). This could include observations from the boulder reef monitoring at Ryggen (station DMU260), which is located further offshore and outside of the water body.

Comparison with all water bodies:

The model estimates for C_{max} and k_{bio} compared well with the broad-scale relationships in Carstensen (2020a) (Fig. 3.18). Including data from the additional survey increased the C_{max} estimate in Storebælt NV slightly, but still within the overall trend against salinity (Fig. 3.18a). The estimate for k_{bio} in Storebælt NV with additional observations was slightly higher than expected from the overall relationship, whereas the k_{bio} estimate without the additional observations was somewhat lower (Fig. 3.18b). It is likely that the inclusion of cumulative cover observations from October may increase k_{bio} more than if k_{bio} was estimated on data from the monitoring window only, due to the possible decline of cumulative cover during the autumn. Importantly, however, inclusion of deeper observations made the estimation of k_{bio} possible for Sejerø Bugt as well as Jammerland Bugt & Musholm Bugt and improved the precision of the k_{bio} estimate for Storebælt NV.

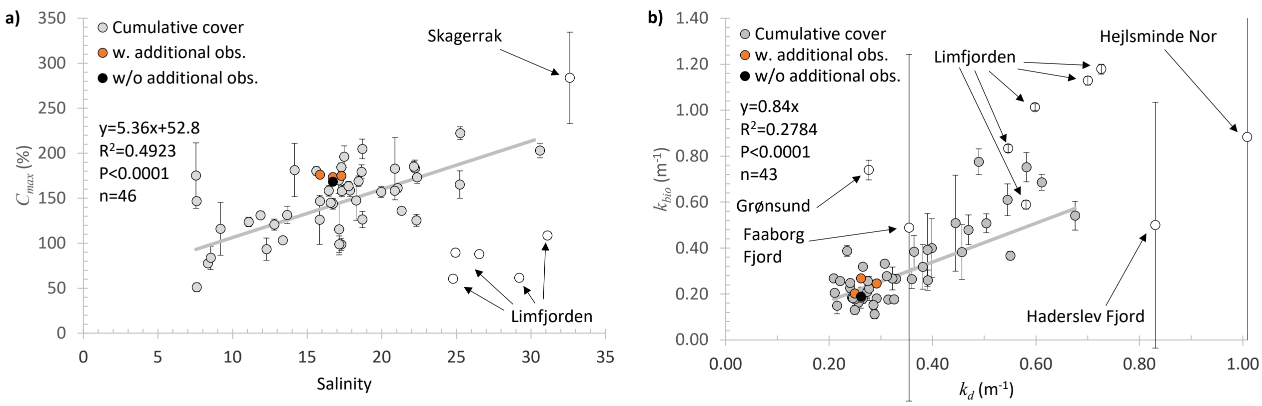


Figure 3.18. Estimates for cumulative cover of C_{max} versus salinity (a) and k_{bio} versus k_d (b) for different water bodies. Estimates from the second assessment period (2019-2024) with (orange) and without (black) the additional observations are overlaid the estimates (grey) from Carstensen (2020a).

3.3.2 Number of perennial species

Sejerø Bugt:

The additional observations from October were few but still had a substantial impact as they made it possible to estimate k_{bio} for the second 6-year period (Figure 3.19). The additional observations were mainly lower than expected from the estimated relationship, supporting that ROV observations might underestimate the number of perennial species. The standard error of k_{bio} was similar to that from the first 6-year period, despite it was estimated on substantially fewer observations. Hence, including deeper observations improves the precision of k_{bio}.

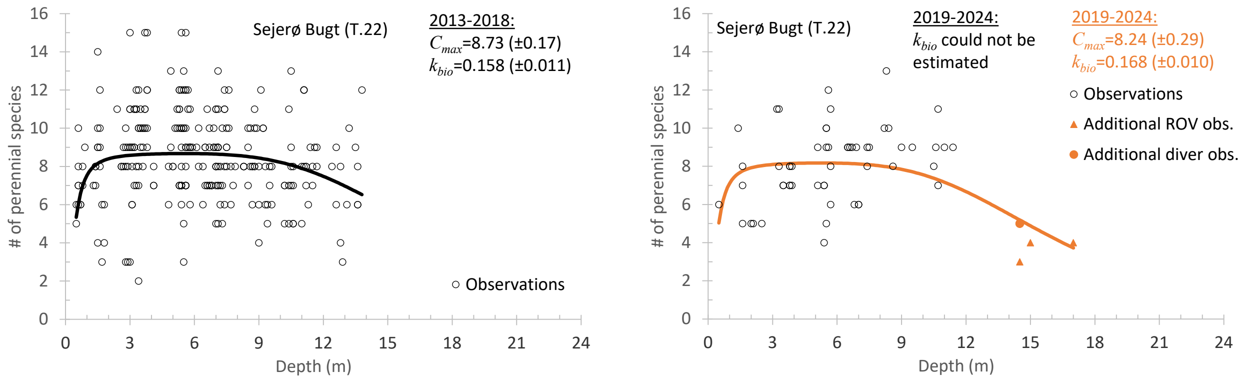


Figure 3.19. Number of perennial species across the depth gradient for Sejerø Bugt for two assessment periods. Additional data are highlighted, and their effects on parameter estimates are shown as inserts.

Jammerland Bugt & Musholm Bugt:

The additional observations from October were few but still had a substantial impact as they made it possible to estimate k_{bio} for the second 6-year period (Figure 3.19). The additional observations were slightly lower than expected from the estimated relationship, supporting that ROV observations might underestimate the number of perennial species. The standard error of k_{bio} was similar to the standard errors estimated for the other two water bodies when including additional deeper observations. Importantly, including deeper observations for this water allowed for the estimation of k_{bio}.

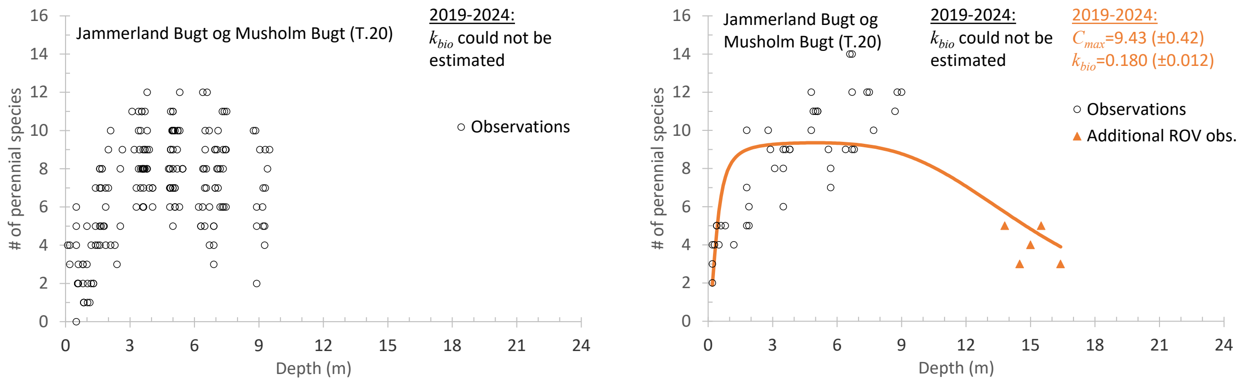


Figure 3.20. Number of perennial species across the depth gradient for Jammerland Bugt & Musholm Bugt for two assessment periods. Additional data are highlighted, and their effects on parameter estimates are shown as inserts.

Storebælt, NV:
Despite the relatively low cumulative cover (Figure 3.17), the number of perennial species was relatively high in the additional data (Figure 3.21). Since the additional surveys were conducted in October, it is likely that the cover of annual species, and maybe also perennial species, declined and lowered the cumulative cover assessment, whereas the number perennial species was unaffected by the late monitoring of the additional data

Moreover, it is possible that the number of perennial species could be overestimated by the ROV observations that did not assess the species-specific cover. For the calculation of number of perennial species indicator, only perennial species with at least 1% cover are included to avoid sporadically occurring species that do not contribute to the macroalgae community. For example, station SB04 with a depth of 22.5 m had 2% cover and 2 perennial species, although the specific cover of the two species is not known with the ROV surveys. Thus, this analysis may include perennial species with less than 1% cover from the ROV surveys, which would overestimate the number of perennial species at deeper depths and thereby underestimate k_{bio}.

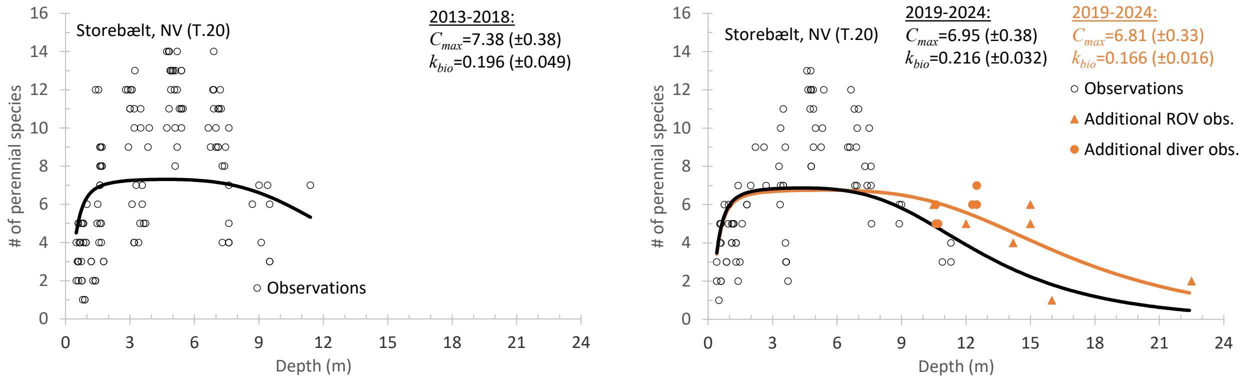


Figure 3.21. Cumulative cover across the depth gradient for Storebælt NV for two assessment periods. Additional data are highlighted, and their effects on parameter estimates are shown as inserts.

Comparison with all water bodies:
The model estimates for C_{max} and k_{bio} compared well with the broad-scale relationships in Carstensen (2020a), whether including the additional observations or not (Figure 3.22). The C_{max} estimate for Storebælt NV only changed marginally, whereas the k_{bio} estimates were slightly lower when estimated with additional observations. It is possible that the k_{bio} estimates are too low, given that the assessment of the number of perennial species might include species with less than 1% cover. Importantly, although the inclusion of the additional data, not strictly comparable with NOVANA data, may produce bias, they do allow for estimation of k_{bio} as well as reduce the standard error of the k_{bio} estimate.

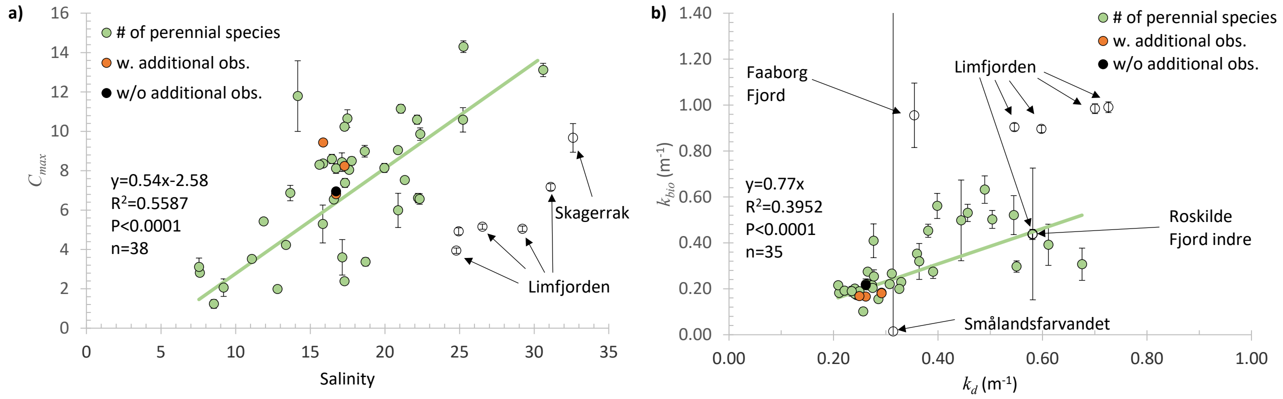


Figure 3.22. Estimates for cumulative cover of C_{max} versus salinity (a) and k_{bio} versus k_d (b) for different water bodies. Estimates from the second assessment period (2019-2024) with (orange) and without (black) the additional observations are overlaid the estimates (grey) from Carstensen (2020a). Note that C_{max} estimates for Storebælt NV (w. and w/o additional observations) overlay each other.

4 Conclusion and recommendations

This feasibility study confirmed that it is possible to identify suitable hard substrate at deeper depths using side scan sonar data for the water bodies Sejerø Bugt, Jammerland Bugt & Musholm Bugt, and Storebælt NV as it was done in in other areas e.g. Lillebælt (Dahl et al. 2023) and in N2000 areas in general. The presence of hard substrate harboring macroalgae was confirmed by field investigations using ROV and diver assessment in Sejerø Bugt and Storebælt NV. It should be noted that these field investigations produced observations that were not strictly compatible with ordinary NOVANA monitoring data, which may affect estimates of the macroalgae indicators. Nevertheless, including these observations, extending the depth range, allowed for estimating macroalgae indicators in Sejerø Bugt and improved the precision of macroalgae indicators in Storebælt NV.

Based on the outcome of this feasibility study it is recommended:

- To extend the analyses to other water bodies where the lack of macroalgae observations at deeper depths has large impact on the estimation of macroalgae indicators.
- To optimize existing macroalgae monitoring transects by identifying nearby locations with higher cover of hard substrate. Instead of a continuous transect, monitoring could be carried out as discrete observation points.
- To initiate further investigations, focusing on the summer period, on how (or if) ROV surveys can replace diver surveys at deeper depth. Particularly, to assess the potential bias introduced by ROV on cumulative cover and number of perennial species.

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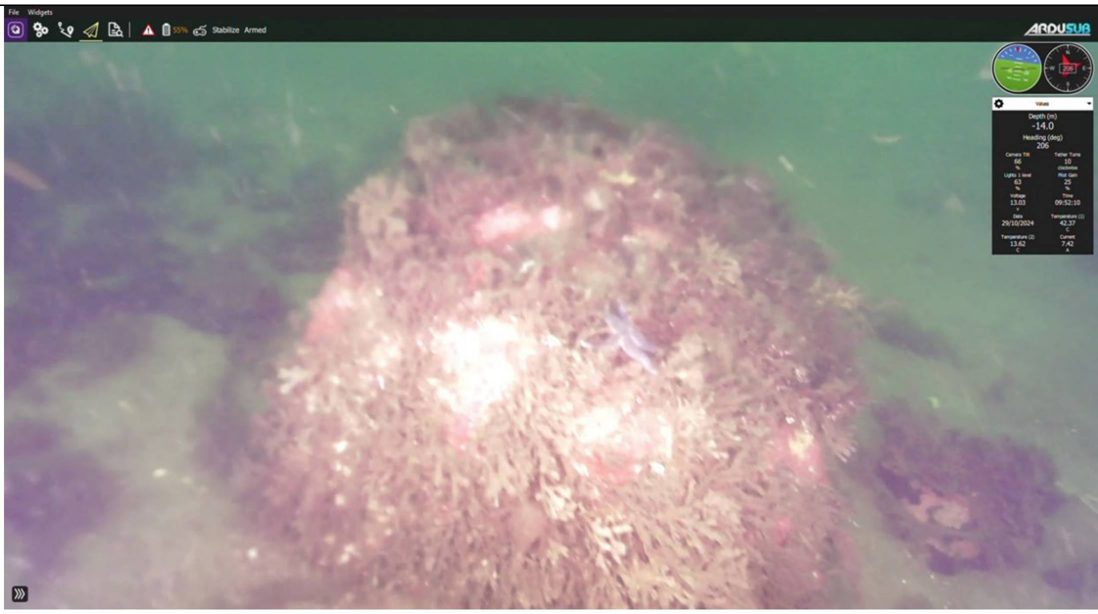
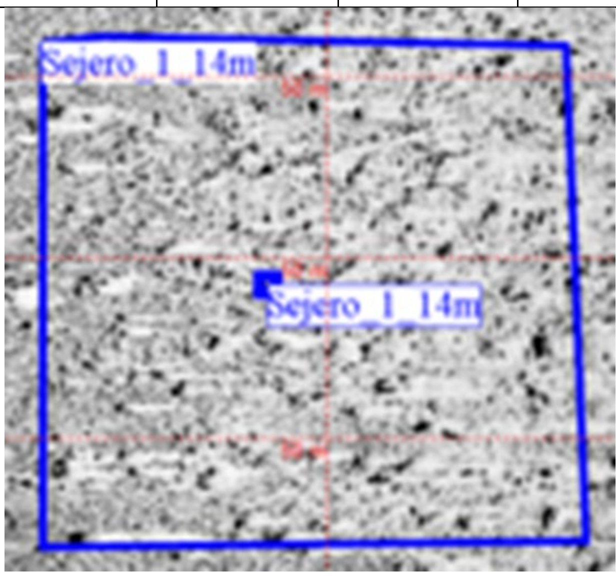
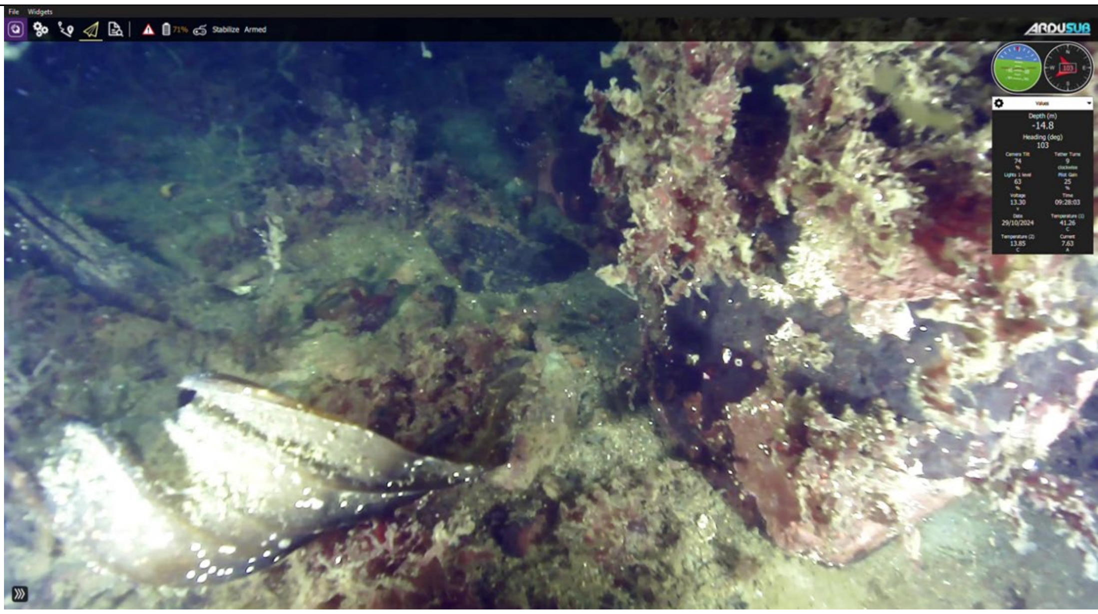
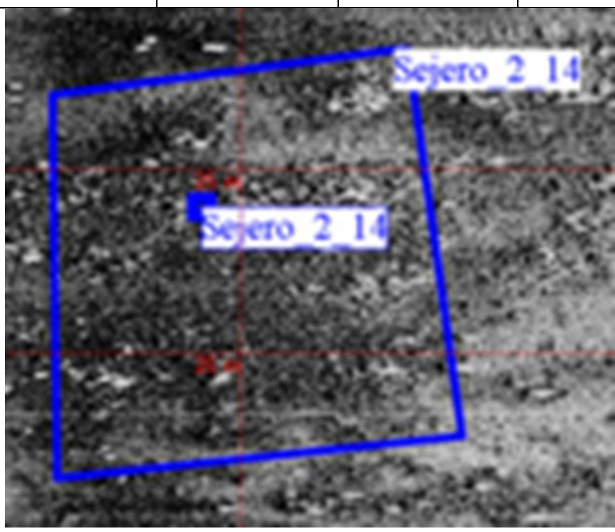
Annex A: Details of ROV surveys

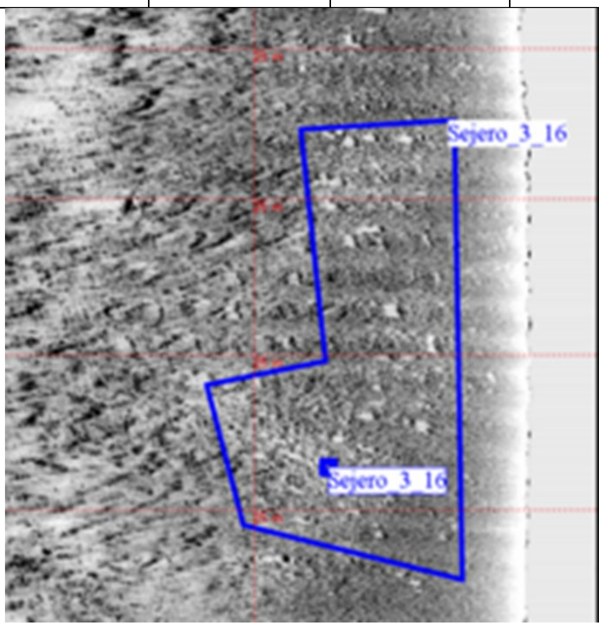
Sejerø Bugt, SJ01, station Sejero_1_14m

Bundtype	Type 3. Sandbund med større og mindre sten.					
Dybde	14,5 meter					
Flora	Sten: Rød kalkskorpe, brun kødskorpe, rød kødskorpe, blodrød ribbeblad, bugtet ribbeblad, sukkertang. Substrat-specifik floradækning: 80 %.					
Fauna	Invertebrater: Skallus, almindelig søstjerne, slangestjerne, stor polypdyr, smal bladmosdyr, havsvamp, glat hindemosdyr, sildebenspolypper, posthornsorm, pigget hindemosdyr, skaller af molboøsters, rurer. Fisk: Sandkutling, havkarusse, fløjfisk, toplettet kutling					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	77	0	3	20	0
Sidescan (SSS)						

Sejerø Bugt, SJ02, station Sejero_2_14m

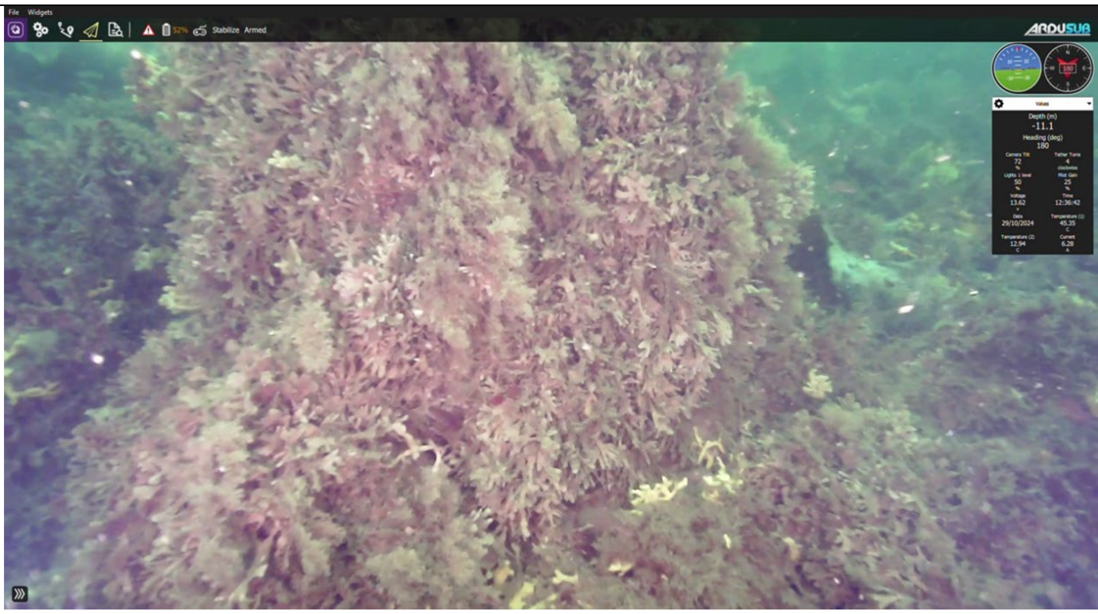
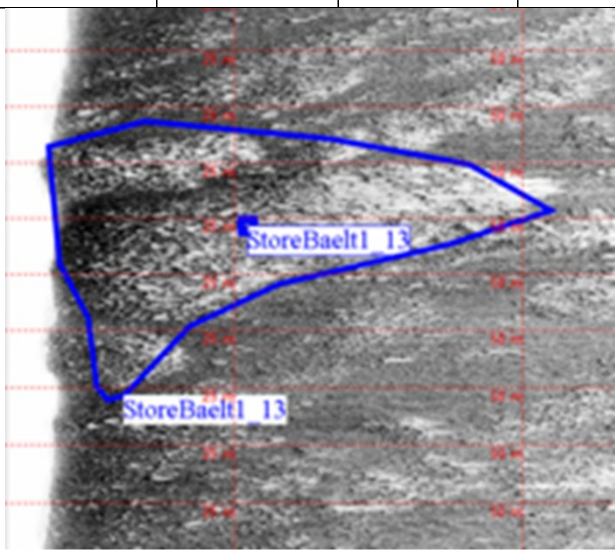
Bundtype	Type 3. Stenet brolægningsagtig bund domineret af mindre og større sten, med sand, skalfragmenter og grus.					
Dybde	15 meter					
Flora	Sten: Sukkertang, *Hildenbrandia*, rød kalkskorpe, brun kødskorpe, blodrød ribbeblad, bugtet ribbeblad, ulvehaletang. Substratspecifik floradækning: 55 %.					
Fauna	Invertebrater: Skallus, små polypdyr, posthornsorm Fisk: Sortmundet kutling, juv. torskefisk sp., havkarusse.					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	5	5	80	10	0
Sidescan (SSS)						

Sejerø Bugt, SJ03, station Sejero_3_16m

Bundtype	Type 3. Gruset bund med større og mindre sten.					
Dybde	17 meter					
Flora	Sten: domineret af fliget rødblad, kile-rødblad, blodrød ribbeblad, rød kalkskorpe, sukkertang, brun kødskorpe Substratspecifik floradækning: 15 %.					
Fauna	Invertebrater: Bladmosdyr, polypdyr, alm. Søstjerne, granpolypper, søanemone, stor strandkrabbe med gammelt exoskelet med rurer, taskekrabbe, havsvamp, hindemosdyr, få levende muslinger, hydroider Fisk: Havkarusser, sortmundet kutling, toplettet kutlinger					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	10	30	40	20	0
Sidescan (SSS)						

Storebælt NV, SB01, station Storebaelt1_13

<table>
<tr><td>Bundtype</td><td colspan="6">Type 4. Hård bund med primært større men også mindre sten. Stor dybdevariation i området. Lokalt type 2a bund med grus, men overordnet type 4.</td></tr>
<tr><td>Dybde</td><td colspan="6">10,5 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Sten: Blodrød ribbeblad, sukkertang, ishavs totalge, bugtet ribbeblad, røde buske (dykker observerede Ceramium sp. og almindelig ledtang), almindelig kællingehår, rød kalkskorpe, kilerødblad. Substratspecifik floradækning: 30 %.</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Bladmosdyr, havsvamp, polypdyr, almindelig søstjerne, finknæet klokkepolyp, posthornsorm, glat og pigget hindemosdyr.

Fisk: Havkarusser</td></tr>
<tr><td>Foto</td><td colspan="6"></td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>5</td><td>5</td><td>10</td><td>80</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6">
</td></tr>
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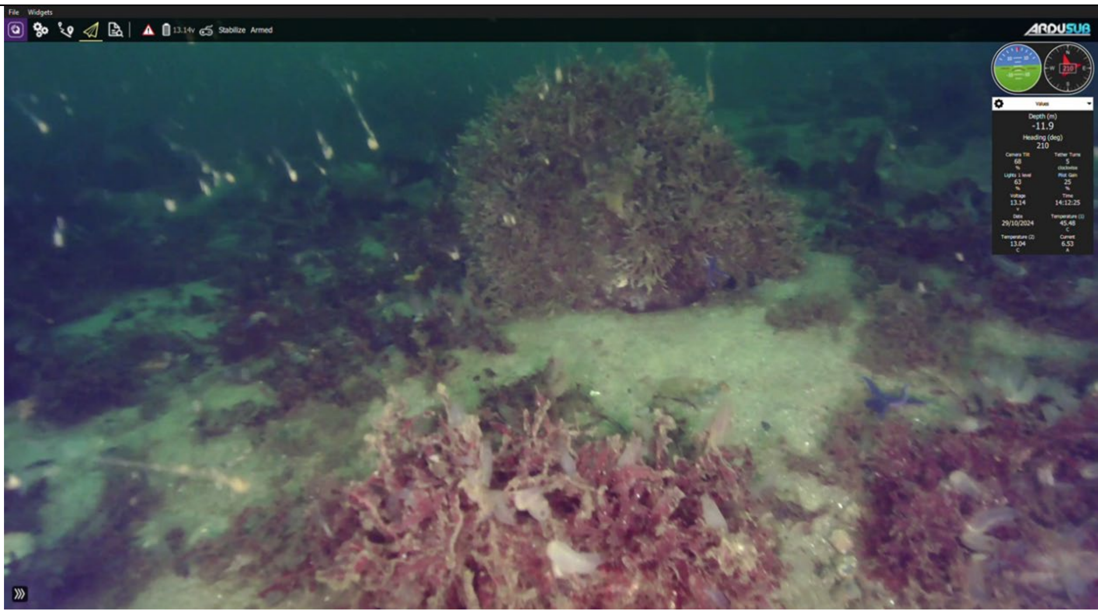
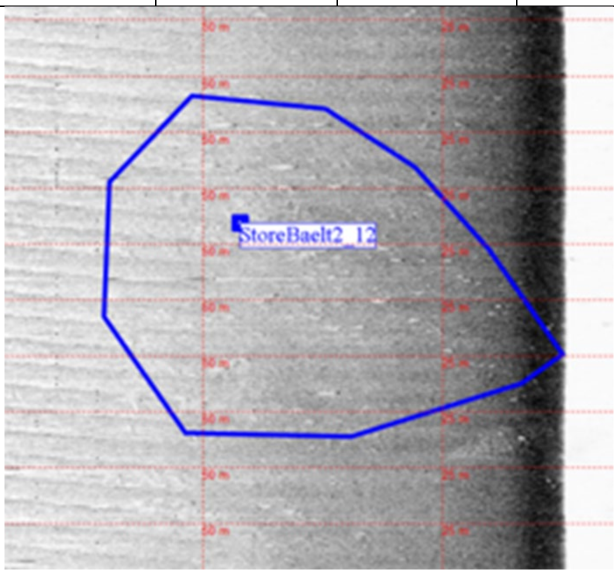
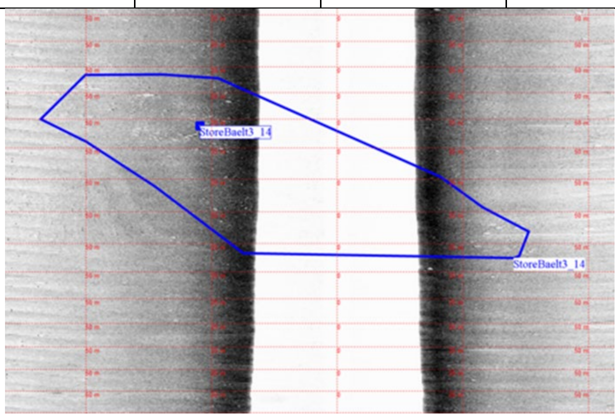
Storebælt NV, SB02, station Storebaelt2_12

<table>
<tr><td>Bundtype</td><td colspan="6">Type 3. Blandet bund med sand, grus og større og mindre sten.</td></tr>
<tr><td>Dybde</td><td colspan="6">12 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Sten: Sukkertang, blodrød ribbeblad, almindelig kællingehår, rød kalkskorpe, bugtet ribbeblad, brun kødskorpe, Hildenbrandia, ulvehaletang, Coccotylus. Substratspecifik floradækning: 25 %.</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Alm søstjerne, søpunge, smal bladmosdyr, sandormehobe, glat hindemosdyr, polypdyr (klokkepolyp), eremitkrebs.

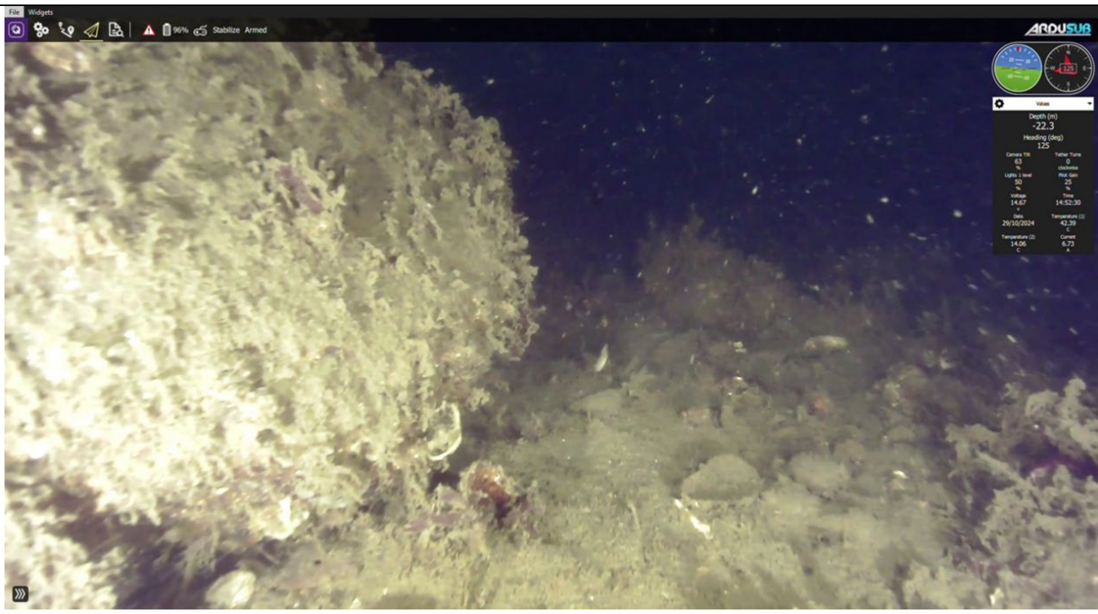
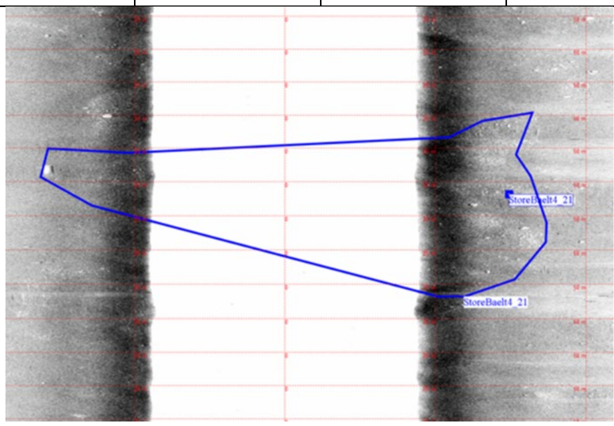
Fisk: Havkarusse, kutling sp., sandkutling</td></tr>
<tr><td>Foto</td><td colspan="6"></td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>73</td><td>2</td><td>15</td><td>10</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6">
</td></tr>
</table>

Storebælt NV, SB03, station Storebaelt3_14

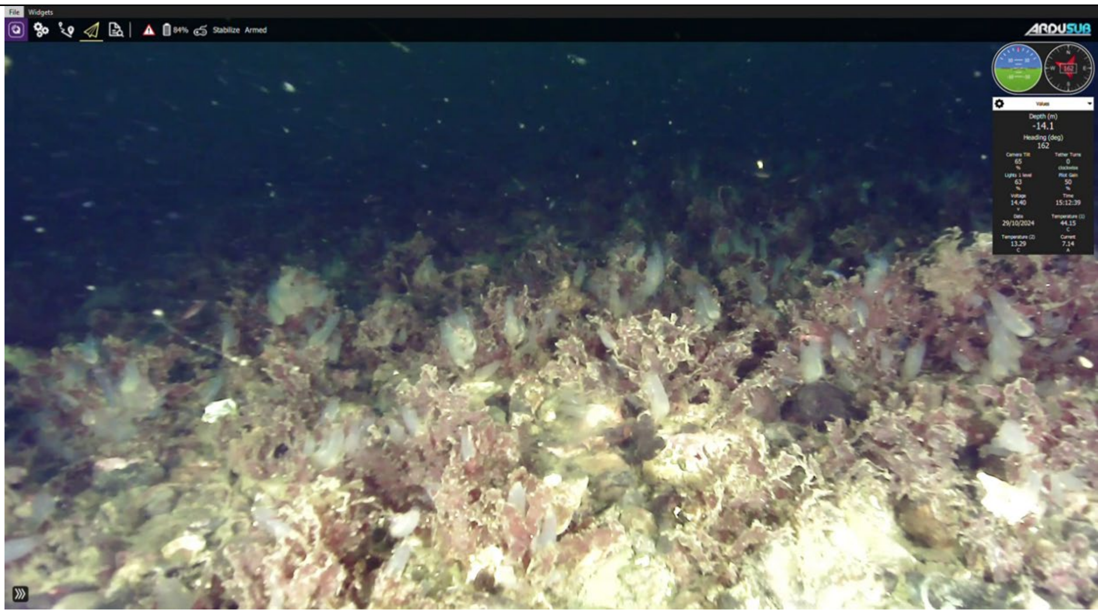
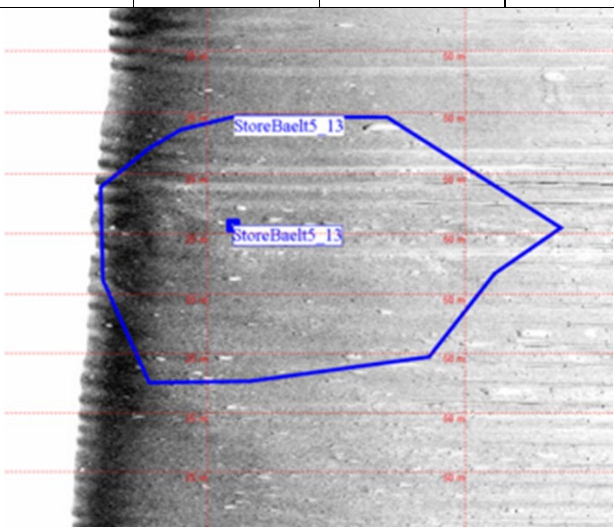
<table>
<tr><td>Bundtype</td><td colspan="6">Type 4. Hårdbund med små og store sten.</td></tr>
<tr><td>Dybde</td><td colspan="6">16 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Sten: Rød kalkskorpe, brun kødskorpe, bugtet ribbeblad. Substratspecifik floradækning: 100 %.</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Havsvampe, søanemone, søpindsvin, bladmosdyr, posthornsorm, sildebenspolyp, alm. søstjerne, skal-lus, eremitkrebs, slangestjerne.

Fisk: Savgylte, havkarusse, sandkutling, torsk</td></tr>
<tr><td>Foto</td><td colspan="6"></td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>0</td><td>20</td><td>70</td><td>10</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6">
</td></tr>
</table>

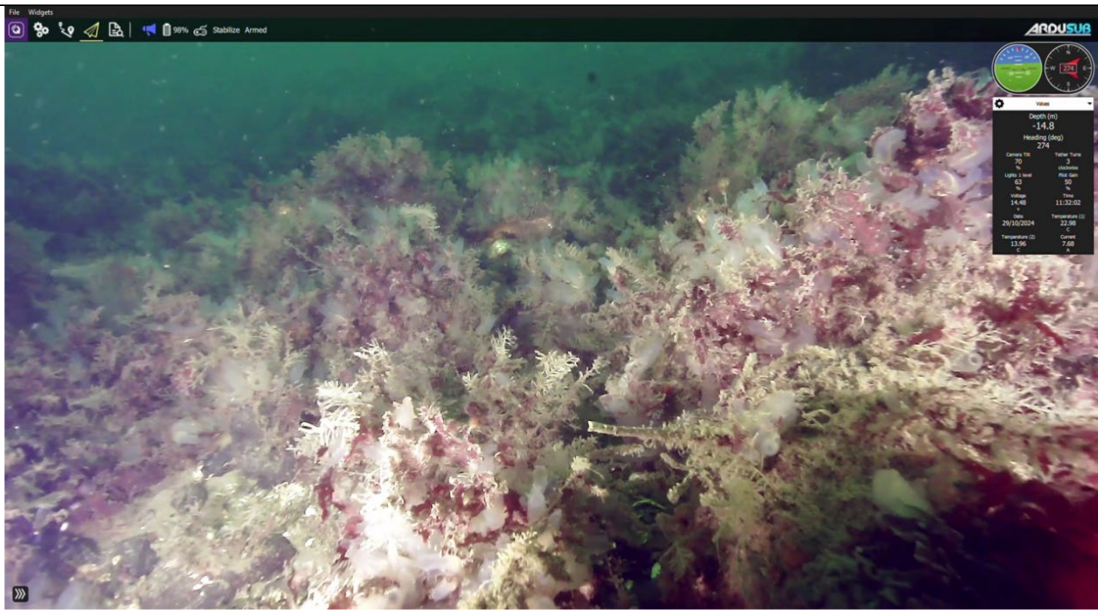
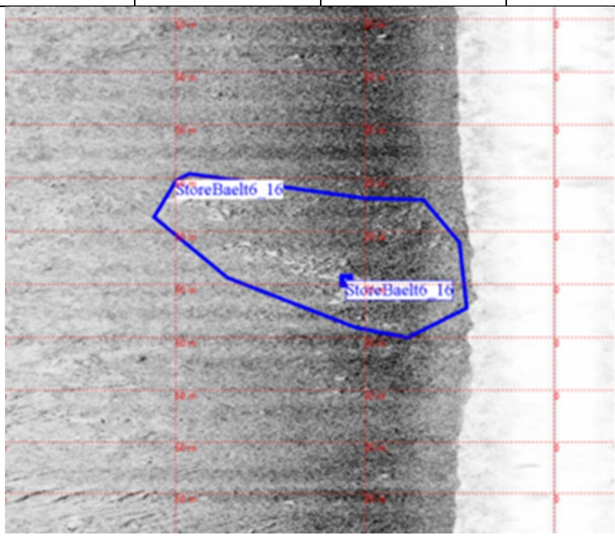
Storebælt NV, SB04, station Storebaelt4_21

Bundtype	Type 4. Fast bund af mange små sten og få større sten dækket af løst materiale.					
Dybde	22,5 meter					
Flora	Sten: Rød kalkskorpe, rød kødskorpe, bugtet ribbeblad, blodrød ribbeblad. Alt er dækket til af sediment. Substrat-specifik floradækning: (2%).					
Fauna	Invertebrater: Konksnegle, slangestjerner, hydroider, sildebenspolypper, hindemosdyr, havsvamp, søpunge, strand-krabbe, store rurer, taskekrabbe, søsol. Fisk: Havkarusser, sortmundet kutling, ising.					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	25	15	50	10	**0**
Sidescan (SSS)						

Storebælt NV, SB05, station Storebaelt5_13

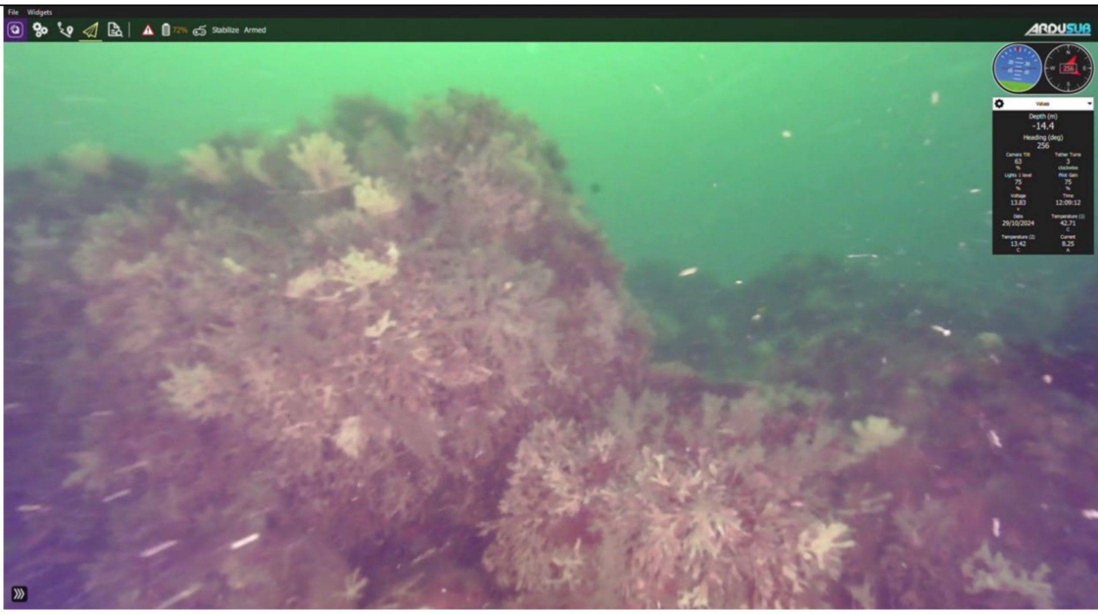
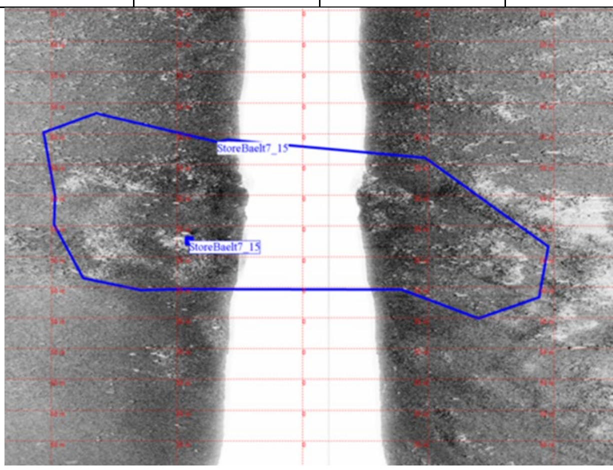
Bundtype	Type 4. Gruset, småstenet bund med enkelte store sten.					
Dybde	14,2 meter					
Flora	Sten: domineret af bugtet - og blodrød ribbeblad, almindelig kællingehår, sukkertang, rød kalkskorpe og brun kødskorpe. Substratspecifik floradækning: 10 %					
Fauna	Invertebrater: Søpunge, søpindsvin, alm. søstjerne, posthornsorm, konksnegl, sildebenspolypper, strandkrabbe, skaller fra molboøsters, bladmosdyr. Fisk: Havkarusse, lille torskefisk, savgylte.					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	5	10	80	5	0
Sidescan (SSS)						

Storebælt NV, SB06, station Storebaelt6_16

Bundtype	Type 4. Tætbevoksede små og store sten med grus og skalfragmenter imellem stenene.					
Dybde	15 meter					
Flora	Sten: Bugtet ribbeblad, Coccotylus, blodrød ribbeblad, kødblad, almindelig kællingehår, brun kødskorpe, rød kalkskorpe. Substratspecifik floradækning: 35 %					
Fauna	Invertebrater: Søpunge, store polypdyr, rød konk, sildebenspolyp, skallus, alm. søstjerne, strandkrabbe, slangestjerner, havsvamp, skaller fra molboøsters og hestemuslinger, blåmuslinger, rurer, granpolyp, søpindsvin, søsol. Fisk: Havkarusser, tangspræl.					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	15	15	30	40	0
Sidescan (SSS)						

Storebælt NV, SB07, station Storebaelt7_15

<table>
<tr><td>Bundtype</td><td colspan="6">Type 4. Stenrev med store sten domineret af bladmosdyr.</td></tr>
<tr><td>Dybde</td><td colspan="6">21,0 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Bugtet ribbeblad, Coccotylus, rød kalkskorpe, sukkertang, alm. kællingehår, blodrød ribbeblad, ulvehaletang. Substratspecifik floradækning: 15 %</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Smal bladmosdyr, havsvampe, polypdyr, alm. søstjerne, granpolyp, sildebenspolyp, posthornsorm, glat hindemosdyr, blåmuslinger, rurer.

Fisk: Havkarusse, savgylte.</td></tr>
<tr><td>Foto</td><td colspan="6"></td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>0</td><td>2</td><td>3</td><td>95</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6">
</td></tr>
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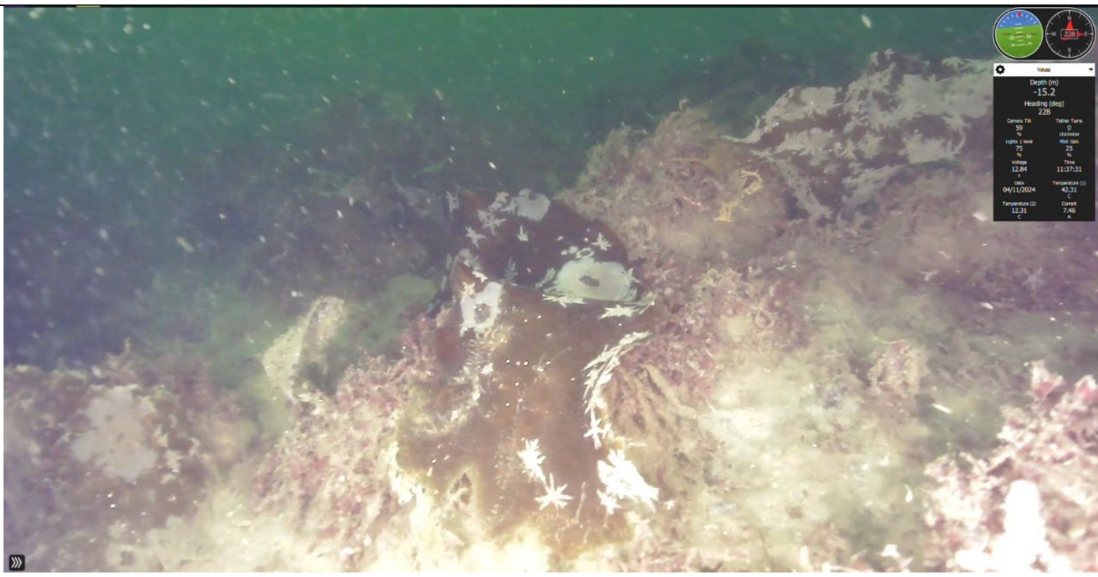
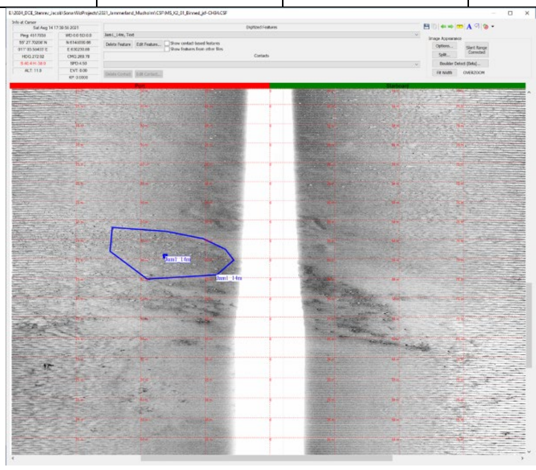
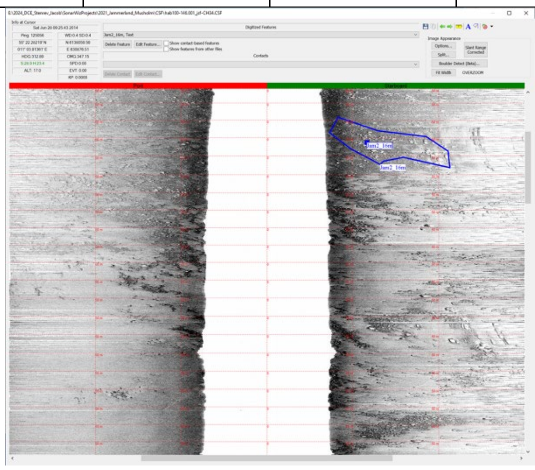
Jammerland Bugt & Musholm Bugt, JM01, station Jam1_14 m

<table>
<tr><td>Bundtype</td><td colspan="6">Type 4. Blandet bund, sandet med spredte sten</td></tr>
<tr><td>Dybde</td><td colspan="6">15,0 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Bugtet ribbeblad, blodrød ribbeblad, sukkertang, ulvehaletang. Substratspecifik floradækning: 30 %</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Glat- og pigget hindemosdyr, knæet klokkepolyp, posthornsorm, havsvampe, sildebenspolyp, søpunge, alm søstjerne, rurer, bladmosdyr.

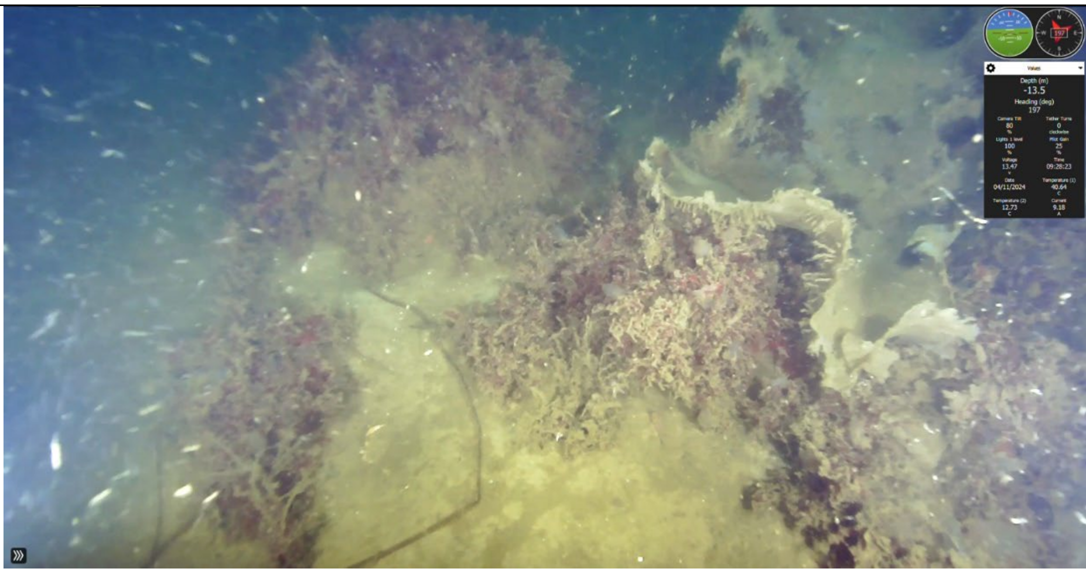
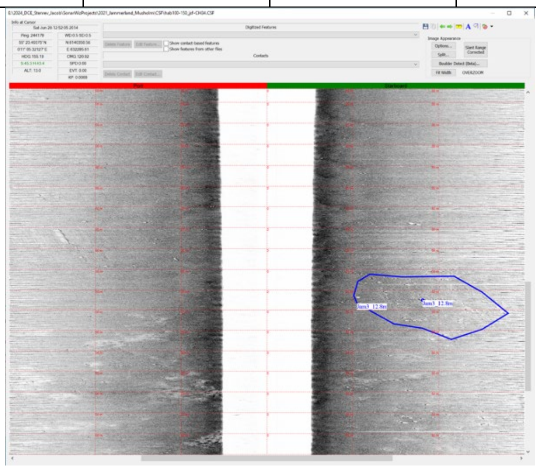
Fisk: Havkarusse, sandkutling.</td></tr>
<tr><td>Foto</td><td colspan="6"></td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>68</td><td>2</td><td>20</td><td>10</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6"></td></tr>
</table>

Jammerland Bugt & Musholm Bugt, JM02, station Jam2_16 m

<table>
<tr><td>Bundtype</td><td colspan="6">Type 3. Spredte sten, marint sne i vandsøjlen</td></tr>
<tr><td>Dybde</td><td colspan="6">16,4 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Bugtet ribbeblad, blodrød ribbeblad, sukkertang. Substratspecifik floradækning: 20 %</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Havsvampe, søpunge og glat- og pigget hildemosdyr, alm søstjerne. Sandkrabbe, polypdyr, slangestjerner, posthornsorm, rurer, bladmosdyr, strandkrabbe.

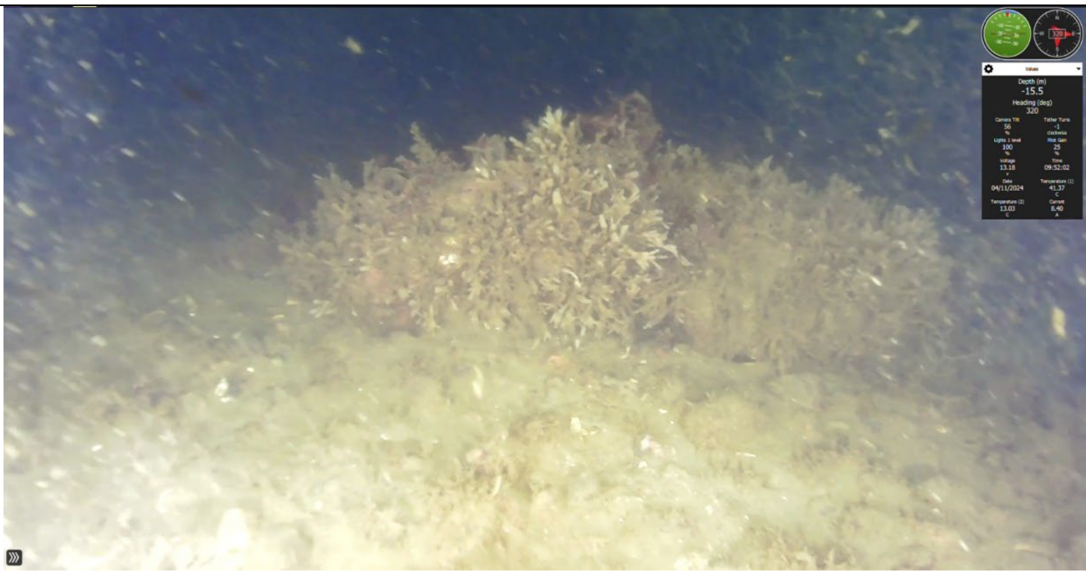
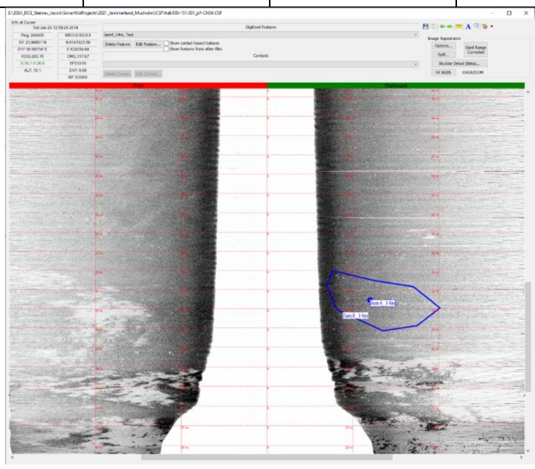
Fisk: Havkarusse, fløjfisk, sortmundet kutling.</td></tr>
<tr><td>Foto</td><td colspan="6"></td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>70</td><td>5</td><td>15</td><td>10</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6"></td></tr>
</table>

Jammerland Bugt & Musholm Bugt, JM03, station Jam3_12,8 m

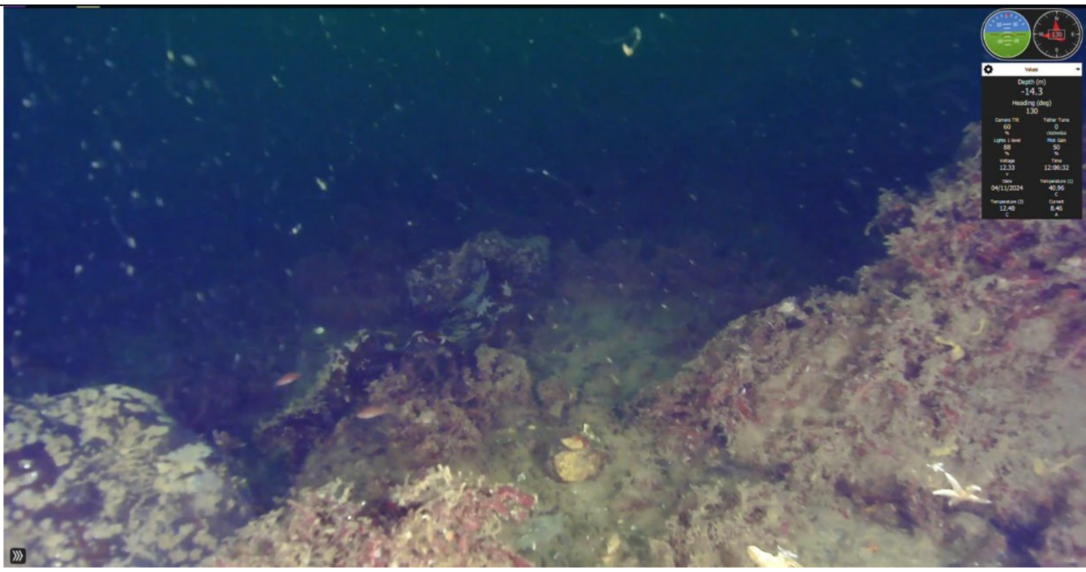
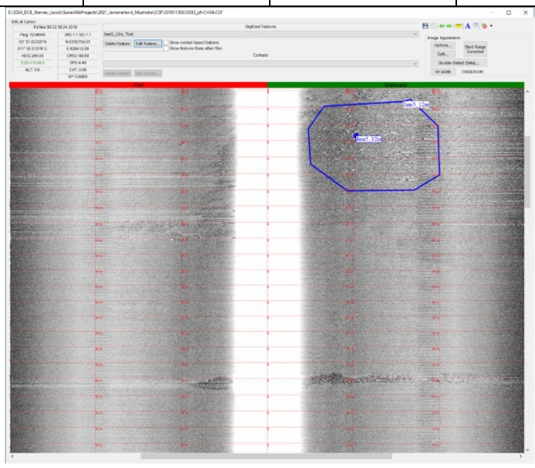
Bundtype	Type 3. Finkornet sand med få sten					
Dybde	13,8 meter					
Flora	Bugtet ribbeblad, blodrød ribbeblad, sukkertang, ulvehaletang, *Polysiphonia* sp., Kødskorpe på sten. Substratspecifik floradækning: 50 %					
Fauna	Invertebrater: Søpunge, havsvampe, sandormehobe, alm søstjerne, glat og pigget hindemosdyr, knæet klokkepolyp, alm søstjerne, posthornsorm, sandormehob. Fisk: Sandkutlinger, havkarusse, savgylte.					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	80	0	10	10	0
Sidescan (SSS)						

Jammerland Bugt & Musholm Bugt, JM04, station Jam4_14 m

<table>
<tr><td>Bundtype</td><td colspan="6">Type 4. Blandet bund af sand, grus, små og store sten.</td></tr>
<tr><td>Dybde</td><td colspan="6">15,5 meter</td></tr>
<tr><td>Flora</td><td colspan="6">Bugtet ribbeblad, blodrød ribbeblad, sukkertang, ulvehaletang, Polysiphonia sp., Brun og rød kødskorpe, rød kalk-skorpe, Coccotylus truncatus.
Substratspecifik floradækning: 10 %</td></tr>
<tr><td>Fauna</td><td colspan="6">Invertebrater: Bladmosdyr, sildebenspolyp, glat- og pigget hindemosdyr, havsvampe, søpunge, alm søstjerne.

Fisk: Sort kutling, sortmundet kutling, havkarusse.</td></tr>
<tr><td>Foto</td><td colspan="6">
</td></tr>
<tr><td>Stendækning</td><td>% mudder/silt</td><td>% sand</td><td>% grus</td><td>% sten <10 cm</td><td>% sten >10 cm</td><td>% rest:</td></tr>
<tr><td></td><td>0</td><td>50</td><td>5</td><td>30</td><td>15</td><td>0</td></tr>
<tr><td>Sidescan (SSS)</td><td colspan="6"></td></tr>
</table>

Jammerland Bugt & Musholm Bugt, JM05, station Jam5_12 m

Bundtype	Type 3. Blandet bund af sand, grus, små og store sten, samt skalfragmenter					
Dybde	14,5 meter					
Flora	Bugtet ribbeblad, blodrød ribbeblad, sukkertang. Substratspecifik floradækning: 40 %					
Fauna	Invertebrater: Pigget- og glat hindemosdyr, knæet klokkepolyp og posthornsorme, havsvampe. Fisk: Sandkutling, havkarusse.					
Foto						
Stendækning	% mudder/silt	% sand	% grus	% sten <10 cm	% sten >10 cm	% rest:
	0	55	10	20	15	0
Sidescan (SSS)						

VALIDATION OF MACROALGAE INDICATORS THROUGH DEEPER SAMPLING

Identification of suitable substrate and macroalgae observations for indicator improvement

Locations for potential deeper occurrences of suitable hard substrate and macroalgae were identified using side scan sonar data and validated through ROV and diver field investigations in two Danish water bodies. The field investigations were conducted in late October and not compatible with ordinary monitoring data, but the study showed that it was possible to extend the depths ranges considerably and that more precise estimates of macroalgae indicators are possible. These results are useful for optimizing the marine monitoring program for macroalgae.

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