Cruise Report FK Littorina
Cruise L10-22a
4th – 8th of July 2022

Areas of Research: Marine Geophysics, Remote Sensing, Biology, Oceanography

Port Calls: Kiel (GEOMAR East shore) – Eckernförde – Kiel (GEOMAR East shore)

Institute: Institute of Geoscience (CAU) – Marine Geophysics; Kiel Marine Science (KMS) – Center for Ocean and Society (CeOS)

Chief Scientist: Jenny Friedrich

Number of Scientists: 3

Project: CDRmare - sea4soCiety

Objective: Hydroacoustic mapping of submerged aquatic vegetation in the coastal area of the Western Baltic Sea

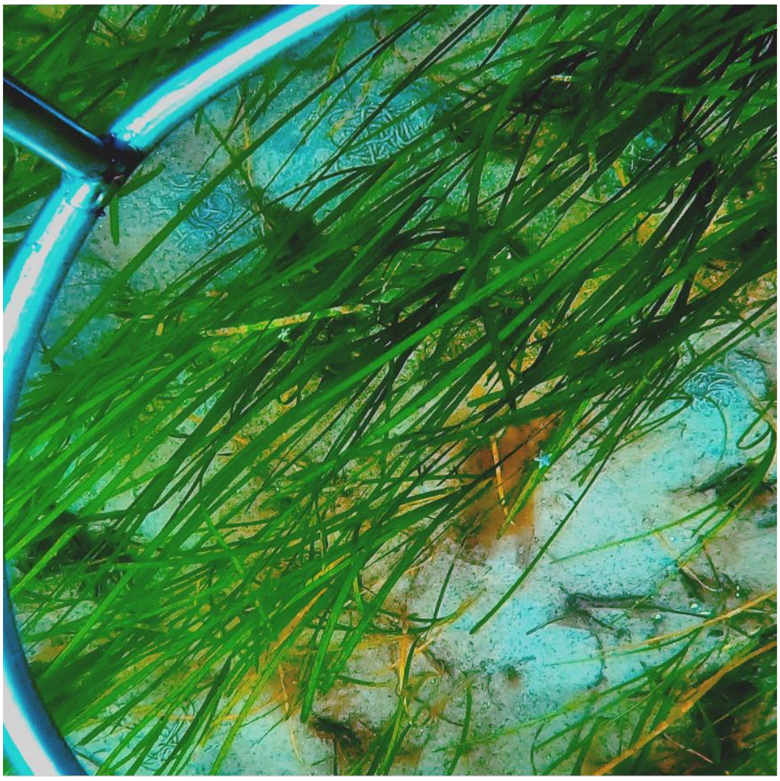

Figure 1: Eelgrass Zostera marina observed in a video in Eckernförde Bay

1. Scientific Crew

Name	Function	Institute
Friedrich, Jenny	Chief Scientist Marine Geophysics, PhD candidate	CAU - IfG
Karstens, Svenja, Dr.	Ecologist, PostDoc	CAU – KMS
Held, Philipp, Dr.	Marine Geophysics, PostDoc	CAU – IfG
Wittig, Amelie	Marine Geophysics, Student assistant	CAU – IfG

M.Sc. Jenny Friedrich
Institute of Geosciences
Christian-Albrechts-Universität zu Kiel Otto-Hahn-Platz 1 Room 112
24118 Kiel, Germany
Phone: +49 431 880-3912
E-Mail: jenny.friedrich@ifg.uni-kiel.de
https://www.marinegeophysik.ifg.uni-kiel.de/

2. Research Programme

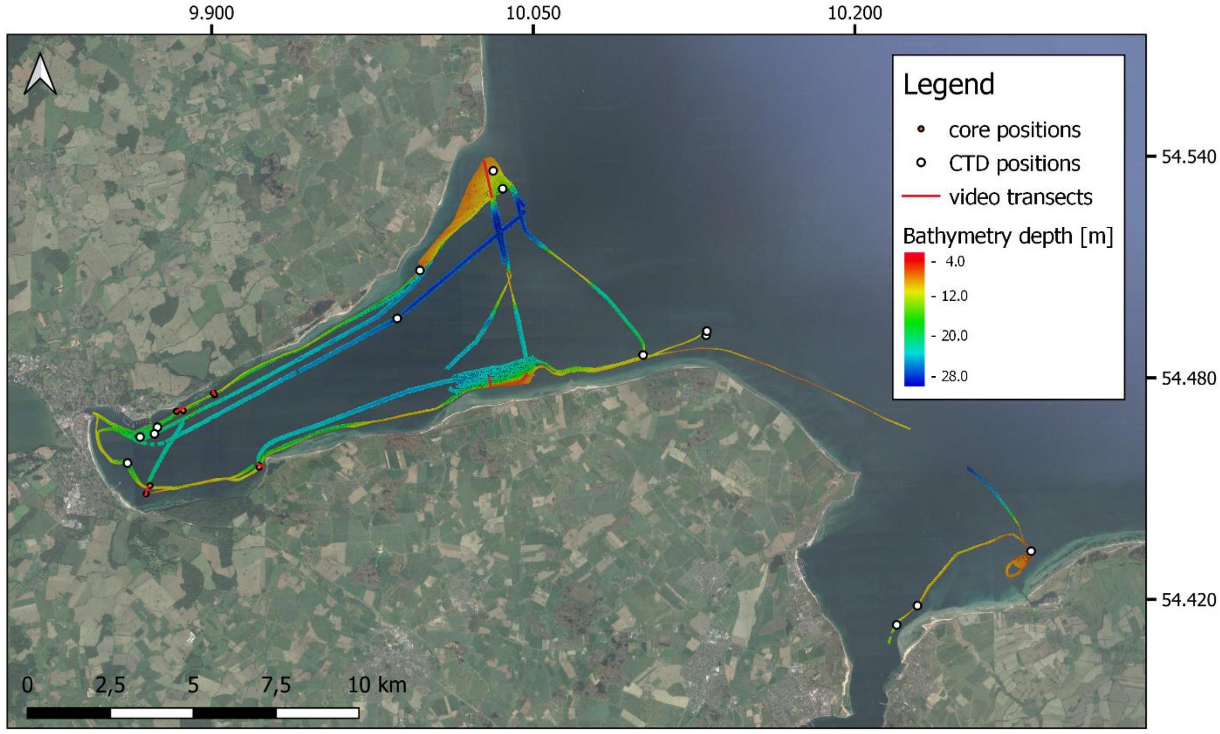

Figure 2: Overview of the surveyed area of cruise L10-22a, including CTD positions, video transects and coring locations.

Within the framework of the DAM mission sea4soCiety, so-called SAV (submerged aquatic vegetation) is being investigated by the Remote Sensing team of Kiel University. The core objectives are an inventory of SAV of the Western Baltic Sea, the development of suitable monitoring methods and an improved understanding of these habitats for their conservation and potential restoration. In the Western Baltic Sea region, seagrass is the most widespread representative of SAV (Boström et al., 2014), which was to be investigated thoroughly by means of Hydroacoustics on cruise L10-22a in Eckernförde Bay (fig. 2). Seagrass acts as a local carbon sink, as a coastal protector due to its ability to attenuate wave energy, as a sediment trap and as a nursery for many fish species (Duarte, 2002). Globally, stocks are declining due to increasing environmental stressors such as water turbidity caused by human activities, rising temperatures and the expansion of marine (infra-)structures, marine traffic and fishing activities (Reusch et al., 2005). So far, there are no comprehensive population maps of the native seagrass species *Zostera marina* and *Zostera noltii* in the Western Baltic Sea, only selective data records derived from camera recordings conducted by divers and ship-borne camera transects, which are extrapolated to larger areas using species distribution models (SDM; Schubert et al., 2015), thus neglecting local, structural features. Hence, currently available modelled maps often contradict regional geology and topography. Temporal developments can only be monitored selectively, physical stressors can only be identified to a limited extent. This data gap is commonly referred to as the "white band of coastal research" (Carvalho et al., 2017) and based on the fact that so far no feasible, large-scale monitoring approach exists to map the shallow water area (< 8 m in the Baltic Sea), an area that is difficult to access. In order to close this data gap and to enable a habitat classification that is true to detail and accurate to location, the Kiel Earth Observation and Modelling (EOM) and Marine Geophysics working groups are cooperating within sea4society's WP3 to generate an opto-acoustic map of the western Baltic Sea. Eckernförde Bay is an ideal training area for this approach due to its known seagrass occurrences at greater depths (> 5 m) and its morphological and sedimentary diversity. Hydroacoustically acquired, high-resolution bathymetry and snippet data from our modern NORBIT multi beam echo sounder are combined with equally close-meshed Pleiades Neo satellite data, LiDAR and drone images and analysed and classified using AI, in order to deliver a realistic image of the SAV distribution in the Western Baltic Sea.

Various video transects with RTK-GPS positioning were recorded to validate the acoustic data obtained on FK Littorina and to determine the maximum distribution depth of seagrass in Eckernförde Bay. To conduct geochemical investigations, sediment samples were retrieved from different depths using van-Veen grab and Frahm lot in order to follow carbon resettlement processes from the shallow to the deep.

Once the data has been processed, features can be identified that provide a habitable base for seagrass and other SAV prevalent in the western Baltic Sea. This will result in identification of potentially habitable areas to exploit the carbon sequestration potential, as well as other benefits that SAV can provide to their ecosystem. The coupled processing of optical and hydroacoustic data will be time and capacity consuming, generating several terabytes of data that will require further analysis.

3. Cruise Narrative

Figure 3 (left): Securing the antenna mount in the harbour in Eckernförde. (top right): The research cutter near the coast in Eckernförde Bay braves navigational obstacles such as fishing equipment and windsurfers in search of seagrass; © Dailydose – 4th of July 2022 - Lindhöft. (bottom right): View of Laboe as the vessel leaves the Kiel Fjord.

We left Kiel at GEOMAR East shore with FK Littorina on the 4th of July at 08:20 am with the first two scientists and headed to GEOMAR West shore to pick up empty Zargesboxes and the two remaining scientists. The equipment setup could be retained from the previous cruise L10-22, only the MBES pole and the RTK antennas had to be reinstalled (fig. 3). All scientists had a PCR tests carried out in laboratory Erichsen prior to the start of the cruise and were tested for a corona infection by means of a rapid test before boarding the research cutter. As all participants were healthy, we were able to set off from the west shore at 11:40 am with fine weather. On the way to Eckernförde Bay, we acquired a CTD profile and a hydroacoustic line using the INNOMAR sub-bottom profiler (SBP) and our NORBIT multi beam echo sounder (MBES) for our project partners from sea4soCiety on the eastern shore of the fjord off Wendtorf and first hints of seagrass presented themselves. In Eckernförde Bay, based on the BSH (Federal Maritime and Hydrographic Agency) chart, the 10 m depth line was surveyed, which was to serve as the deep limit for the forthcoming surveys. However, the discrepancy between the BSH chart and the nautical chart became clear already on the first day: coast-parallel sandbanks caused restricted navigation in many areas, especially in the southern part of the bay. The original plan to first follow the 10 m contour, then the 5 m contour, in order to map out areas that opened up in between, was limited to only two larger areas within the bay in the forthcoming days: Boknis Eck and a section between Lindhöft and Noer. In the evenings, Littorina docked in the port of Eckernförde, where one scientist disembarked on the 1st evening. In the following days, the work focussed on hydroacoustic mapping, starting with

Boknis Eck, later Lindhöft to Noer, sediment sampling by means of Frahm-lot and van-Veen grab off Hemmelmark, Goossee and Aschau, as well as video validation of areas where hydroacoustic indicators of SAV could be observed. Eventually, on the 6th of July, the first successful RTK-video validation was carried out on seagrass off Lindhöft in water depths of 5 – 7 m. With three scientists and the crew, we arrived at GEOMAR East shore at 5.30 pm on the 7th of July to disassemble and stow our equipment the following day and finish the cruise at 1 pm. Altogether, the weather and equipment played along with our scientific programme and all work could be carried out successfully except for a few minor restraints.

4. Scientific Report & Preliminary Results

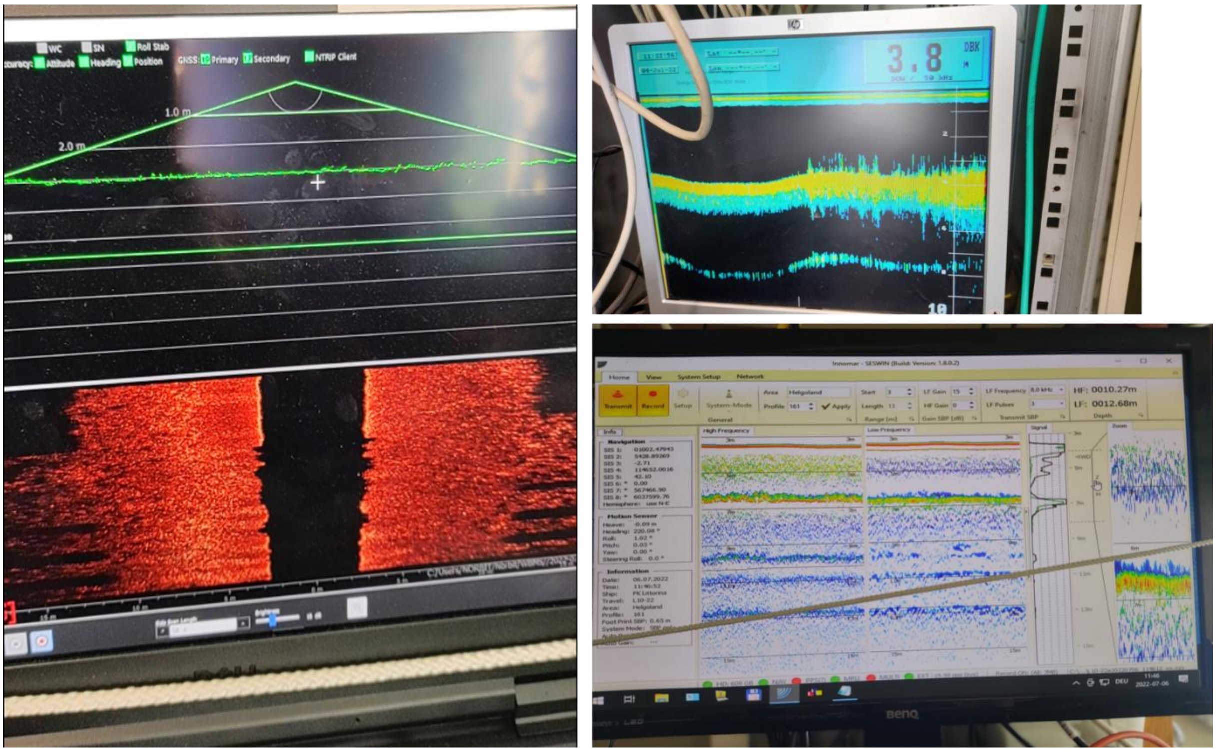

Figure 4 (left): Sidescan-like snippet MBES image capture of our NORBIT Multi beam Echo sounder. When traversing seagrass meadows, the bottom detection algorithm (BDA) is responsive to the top of seagrass canopy, resulting in a "fuzzy", uneven image of the bottom. (upper right): Recording of the ship's own single-beam echo sounder above a seagrass meadow. The transition from unvegetated to vegetated ground is clearly visible. (bottom right): The INNOMAR SES also shows a similar picture when traversing seagrass meadows: vegetation-induced echoes above the bottom are recognisable, weaker than the bottom signals themselves.

<u>Multi beam Echosounding</u>

Our NORBIT iWBMS multi beam echo sounder was mounted fore on the massive Littorina side mast mount in front of the INNOMAR SES (fig. 5). It obtained its position via a dual antenna; whose primary antenna transmits the GPS position directly into the sonar head and is also attached to the pole (fig. 3). The positions are written to the s7k-files generated by the MBES. All systems were mounted on starboard side of the vessel to leave sufficient space for operating the heavy equipment on port side. The GPS signal was received via 15 – 20 satellites on each antenna, whose measurements were kindly corrected by Axio-Net using the NTRIP protocol and Mountpoint #07 (GPS + GLONASS, VRS, ETRS89, ellipsoidal). Thus, we achieved an RTK "fixed" status and height and positioning accuracies ranging between 2 – 4 cm. To measure acceleration and angular velocities, the MBES was coupled to an Applanix Wavemaster inertial measurement unit (MRU). The installation distances between NORBIT, MRU and the antennas are known and the offsets are corrected for. The MRU system was calibrated on the previous cruise L10-22 and performed flawlessly.

We used a chirp around 400 kHz and an 80 kHz bandwidth with an 1x1° array and operated with an aperture angle of 150°, apart from a few exceptions. The MBES was operated with a prototype firmware (10.7.0.43.e1da69f) kindly provided by NORBIT. Pulse length, bandwidth, gains, and filter settings were kept constant to ensure comparability of the data as recommended by Lamarche & Lurton (2018). The MBES data were tide corrected with RTK-GPS and the German Combined Quasigeoid (GCG2016) and gridded to 0.25 x 0.25 m with the QPS software Qimera.

Figure 5 (left): Research cutter Littorina in the harbour of Eckernförde Bay. (right): The pole for the hydroacoustic systems is mounted to starboard.

Parametric Echosounding

To complement our hydroacoustic investigations, a parametric sediment echo sounder, in this case an INNOMAR SES-2000 Standard, was used during the cruise (see fig. 5). This device records two frequencies, a primary frequency around 100 kHz with a corresponding wavelength of 0.1 m (assuming an average sound velocity of 1,500 m/s and 15 kHz signal) and a secondary frequency that can be adjusted between 4 kHz and 15 kHz. Depending on sedimentary conditions, the lower frequency allows penetration of the seabed by several tens of metres and depiction of sedimentary stratification, if present. The aperture angle of the emitted sound pulse is 3.6°, which, in combination with its high ping- rate, results in a small but high-resolution footprint. For the work on SAV, the simultaneous visualisation of the water column is particularly beneficial, as acoustic scattering bodies such as fish but also vegetation can be detected. To prevent signal interference, the INNOMAR SES was triggered externally by our NORBIT MBES. The INNOMAR SES captures full waveform data that is transcribed in

SEG-Y format and can be analysed using Kingdom. The high and low frequency data could be viewed live in the INNOMAR-SESWIN software. Also, the INNOMAR SES was fed by the Applanix Wavemaster MRU. The motion was recorded and compensated for by a Seatex motion sensor installed directly on the pole frame. The forward lever arm offset between the antenna and the INNOMAR transducer is 25 cm, and the positioning accuracy should be equivalent to that of the MBES data. The time setting of the INNOMAR computer was unfortunately incorrect, resulting in an offset of 24h.

Technically, the INNOMAR worked perfectly, but unfortunately there were frequent problems with the SESWIN software, which required several computer restarts.

<u>Acoustic detection feasibility of submerged aquatic vegetation (SAV) in Eckernförde Bay</u>

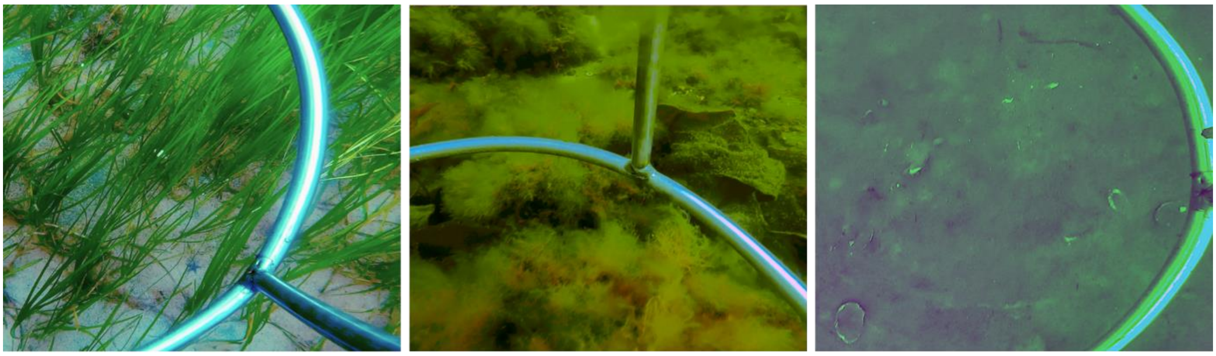

Figure 6: Three types of habitats that could be differentiated hydroacoustically and were verified by video validation in the research area, (left): seagrass vegetation off Noer, (middle): algae growth off Boknis Eck, (right): bare sediment with mussel shells off Hemmelmark.

During the cruise, the bathymetry and snippet imagery could be viewed live in NORBIT's proprietary software NORBIT WBMS-GUI and DCT. In combination with the live data from the ship' s own single beam echo sounder and the parametric INNOMAR SES, areas with SAV could be identified, which could later be validated via video recordings. Already in the live-view a distinction could be made between seagrass cover and other SAV, whereby mainly the recordings of the WBMS GUI and INNOMAR SESWIN were decisive: on the one hand, only seagrass beds produce the typical "fuzzy" image in the snippet imagery, at the same time as the bouncy bottom finder in the swatch view appears to be settling on the top of the seagrass canopy (fig. 4). The INNOMAR data provided information on the seafloor conditions, which is an indirect indicator for the possible presence of seagrass: sandy substrate (stratification visible) provides a possible habitable substrate, while stony and silty substrate (only one bottom reflector, no penetration into deeper layers) do not allow dense seagrass growth. However, the height of the SAV-signals above the seabed has been the decisive factor: seagrass causes acoustic signals between 0.4 – 0.6 m above the ground, while other native SAV produce echoes much lower (up to max. 0.3 m) over a larger area. Even during the cruise, it was thus possible to reliably distinguish between unvegetated substrate, seagrass covered areas and vegetated areas with other SAV, as could be validated by considering the video data (fig. 6): at all positions where there were suspicions of eelgrass in the hydroacoustic data, turned out to be indeed seagrass sites. Other positions where no deflections could be observed, but where it was known that seagrass grows in shallower water inaccessible to

Littorina and were thus selected as core locations, turned out to be actually seagrass-free, which could be shown by video validation. Finally, the region 5 – 10 m deep off Boknis Eck, which clearly showed vegetation-induced signals in the hydroacoustic data but were not interpreted as seagrass signals, could be investigated by video recordings: here, dense, mixed algal growth was found on a gravelly substrate, the species diversity of which still has to be determined. Seagrass, on the other hand, could not be found. The extent to which it is possible to distinguish species hydroacoustically still needs to be investigated, however, the use of hydroacoustics proved to be clearly beneficial for distinguishing between SAV, seagrass cover and no vegetation.

<u>Hydrography</u>

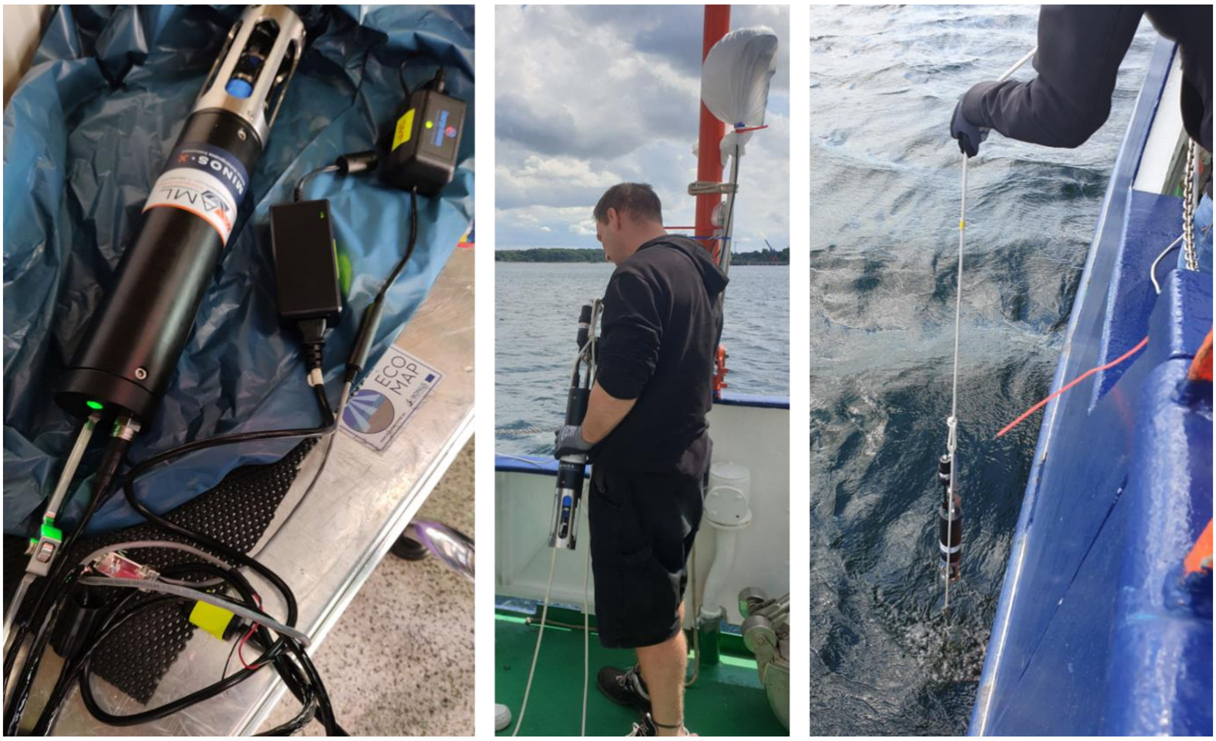

Figure 7 (left): AML Sea Cast probe with wireless transponder. (middle): Sound velocity probe prepared with plunger weight and rope. (right): Sound probe in use with live GPS positioning.

14 CTD profiles were obtained (11 in Eckernförde Bay and three in Wendtorf) with an AML Oceanographic Minos X instrument with installed XchangeTM sensors, measuring conductivity, temperature and pressure (fig. 7). Additionally, the sound velocity was measured directly by an integrated SV XchangeTM sensor. The profiles varied greatly; in some cases, the water column was well mixed, in others it was clearly stratified and thermoclines could be identified that influenced the sound velocity profile (see Appendices – B).

<u>Sediment Sampling</u>

Figure 8 (left): Retrieval of the Frahm lot with seafloor material. (middle): Transferring the sediment core to plugs to secure the specimen. (right): Sediment sampling with Van Veen grab corer.

During our cruise, sediment samples were taken on behalf of the project partners in sea4soCiety, on the one hand, to identify metabolites in its organic matter, and on the other hand, samples were taken by Dr. Svenja Karstens to determine total concentrations of carbon (C), nitrogen (N) and phosphorus (P).

Ratios of carbon, nitrogen and phosphorus have been widely used as source indicators of organic matter in a variety of coastal waters with salinity gradients (e.g. Yamamuro & Kamiya 2014; de la Lanza-Espino et al. 2011; Nasir et al. 2016; Meng et al. 2021). Redfield et al. (1963) showed that marine phytoplankton has a C:P ratio of 106:1 and a C:N ratio of 6.6:1. In contrast to this, C:P ratios for terrestrial plants with soft tissue range from 300-1300:1 and C:N from 10-110:1 (Ruttenberg & Goni 1997). Phytoplankton, macroalgae, seagrass and freshwater angiosperms have relatively constant C:N and C:P atomic ratios (Duarte 1992). Thus, information on nutrient concentrations in sediments and their ratio can support the identification of possible origins of the organic matter along land-to-sea transect in the Eckernförde Bay.

Surface sediment samples were taken along land-to-sea gradients in the Eckernförde Bay at three sites (with three replicates): (1) drainage Hemmelmark lake, (2) drainage Goossee; (3) drainage Aschau lagoon (Fig. 9 & 10). Ship-based sediment samples during Littorina cruise L10-22a were taken with a Van Veen grab on the 6^{th} of July 2022 (Fig. 8). For land-based sampling, a stainless-steel corer with 7 cm diameter (Hydrobios, Kiel, Germany) was used. Sediment samples were dried at 40 °C, sieved and grinded. Total carbon and total nitrogen will be quantified by combustion in a CN Analyzer (Euro EA 3000). Total phosphorus will be analysed by photometric determination (Specord 50 Plus) of phosphorus after acid (HNO3) microwave digestion (MARS 6).

Figure 9: Sampling sites at land (left): drainage Hemmelmark lake, (middle): drainage Goossee; (right): drainage Aschau lagoon. Land-based sampling took place after L10-22a cruise on the 10th of July 2022.

Additional cores (0 – 10 cm depth, no replicates) were taken for metabolite analysis by Dr. Jana Geuer with a Frahm-Lot (MacArtney Underwater Technology, Esbjerg, Denmark). Sediment and pore water were split by centrifugation. Pore water samples will be derivatised before measurements (Sogin et al. 2019). Sediment samples will be extracted by soxhlet extraction with a methanol-water (4:1) mixture. Metabolites will subsequently be identified in both sample types using gas chromatography coupled with mass spectrometry (GC-MS, Agilent 7890B with Agilent 59977A).

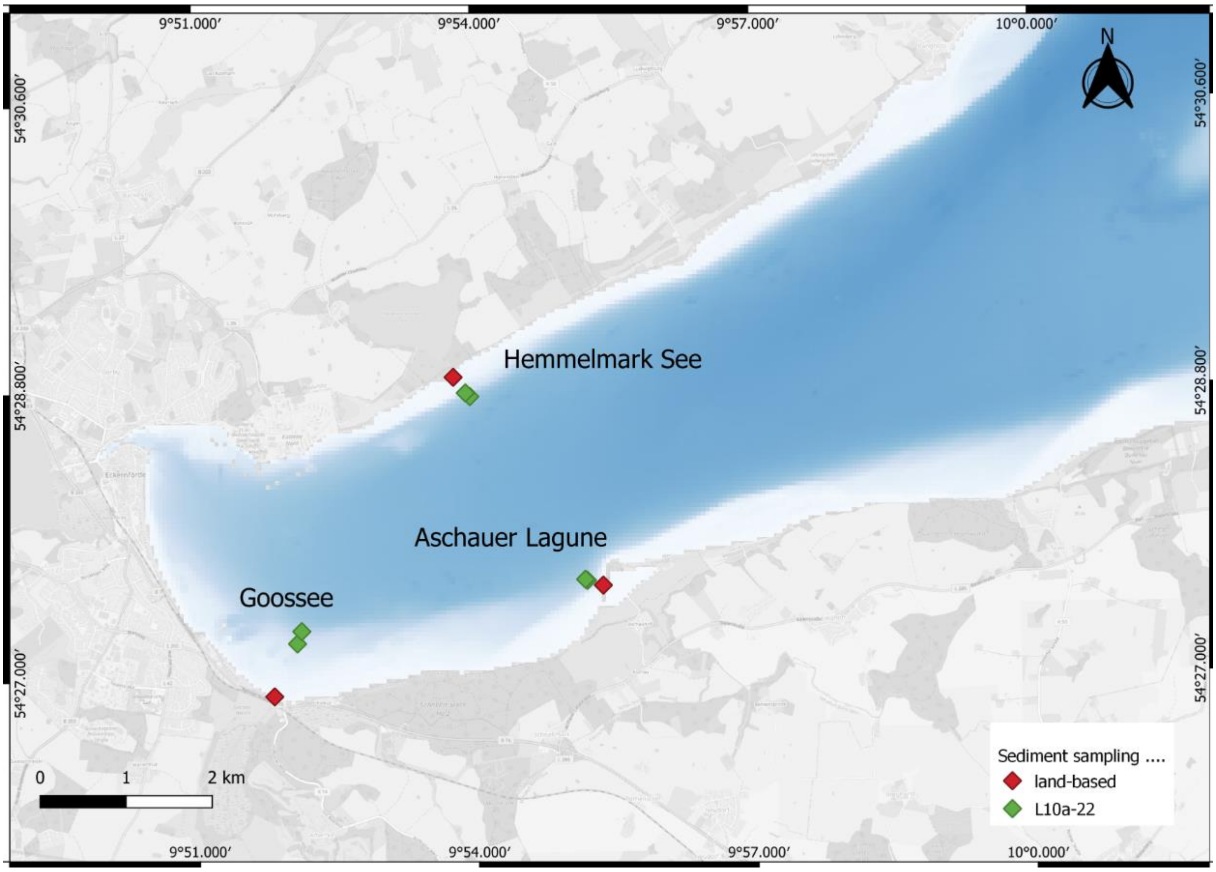

Figure 10: Sampling sites along the Eckernförde Bay: drainage Hemmelmark lake, drainage Goossee and drainage Aschau lagoon. Bathymetry provided by BSH.

Camera

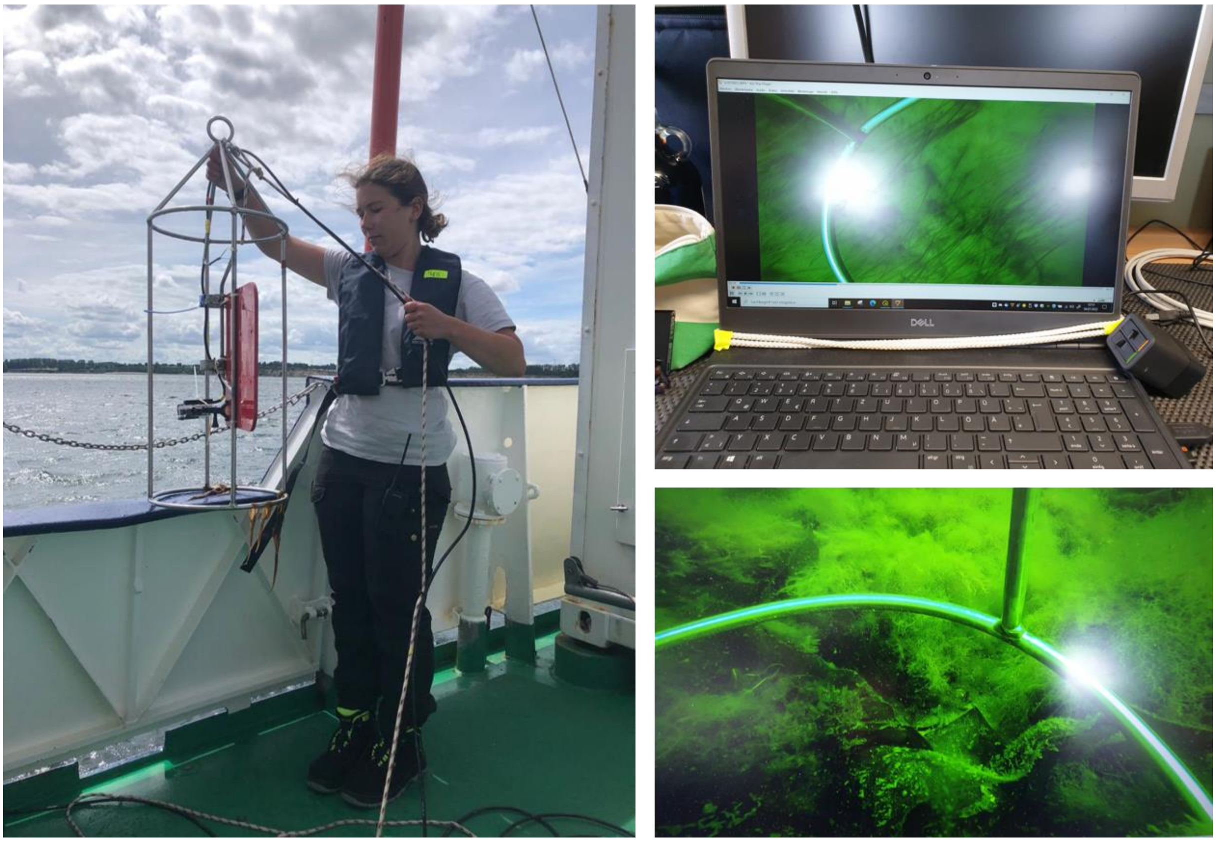

Figure 11 (left): Camera frame with GoPro 8 attached, rope and data cable for live broadcast of the video footage. (top right): live video on seagrass with the GoPro 8. (bottom right): Close-up on local SAV (presumably Laminaria saccharina and Pylaiella littoralis) off Boknis Eck.

We used a camera rig with a 60 cm high frame, a stabilising fin and a GoPro Hero8 mounted inside to observe the seabed and validate our hydroacoustic data (fig. 11). Beforehand, the camera lens was calibrated with a checkerboard. The apparatus was manually manoeuvred with a rope while the vessel was drifting with a maximum speed of 1 kn, a wireless LAN cable enabled live transmission of the video footage to the deck. Positioning was provided by a STONEX RTK-GPS, with the antenna mounted about 60 cm from the camera's drop position.

The visibility was acceptable, the weather conditions were not ideal (overcast sky and partly rain). Nevertheless, it is possible to clearly distinguish between vegetation and bare sediment; species identification is therefore possible. It is also possible to identify the type of substrate and potential acoustic signal sources (mussel beds, stones, etc.). In general, a very variable seabed was found, ranging from silty, fine-grained texture in the inner bay with sparse vegetation, to coarse sediment at the north-eastern end of the bay with diverse algal growth, as well as sandy sediment on the southern shore, which allows for seagrass growth down to depths of > 5 m.

5. Acknowledgements

We would like to thank the crew of FK Littorina for a very pleasant cruise, their patience with the research requests of us scientists in waters that were challenging for navigation, and their welcoming hospitality on board. We would also like to thank our " on-land team" of the Marine Geophysics Working Group for their willingness to help with scientific, technical and organisational questions, often even late in the day. In particular, we would like to express our gratitude to Philipp Held for his support on board on the first day of research. Finally, we would like to thank our colleagues from the Coastal Geology, Applied Geophysics Divisions from Kiel University and AWI Sylt for the trustful loan of their equipment.

6. Appendices

A) Station protocol

L10-22a Protocol Eckernförde Bay

- **Time in UTC**

sea4soCiety station format:

- The INNOMAR Computer was offset throughout to one day before, the UTC time itself roughly fits
- CTD offset 1 hour

04.07.2022

Start in Kiel at 06:20 UTC at GEOMAR East shore, transit to West shore

09:40 UTC start transit from GEOMAR West shore to Wendtorf

Station 1: 08:27 UTC test multi beam (MBES)

Station 2: 08:30 UTC CTD 1 Wendtorf, 54° 24.84458' N, 10° 12.88130' E, Wendtorf, on deck 08:34 UTC

File: WNT_CTD1_20220704_...csv

Station 3: 08:35 UTC start track NORBIT and INNOMAR transect Wendtorf, 09:27 UTC stop tracking, transit to Eckernförde Bay (Ebay)

Station 4: 10:34 UTC, CTD 1 54° 29.62037' N, 10° 7.71400' E, EBay SO, on deck 10:35 UTC

File: ECK_CTD01_....csv

Station 5: start record at 10:38 UTC, MBES & INNOMAR EBay SO at 10 m contour

Station 6: CTD 2, 12:41 UTC, 54° 27.67797' N, 9° 51.21260' E, inner bay, 12:45 on deck

File: ECK_CTD02_...csv

Station 7: CTD 3, 14:12 UTC, 54° 32.04608' N, 10° 2.09390' E, EBay NO, 14:14 on deck

CTD stands off at 40° angle

File: ECK_CTD03_...csv

Station 8: profile Ercan profile1

Files: 2022-07-04-14_38_40, 2022-04-07-14_49_27; start: 14:38 UTC,

Stop at 15:33 UTC

Station 9: CTD 4, 15.35 UTC, inner bay, 54° 28.25537' N, 9° 52.39040' E, on deck 15:36 UTC

File: ECK_CTD04_...csv

Station 10: transit to harbour with INNOMAR & MBES record, start: 15:36; end: 15:48 UTC

05.07.2022

Left harbour at 05:20 UTC

Station 11: start recording MBES at 05:22 UTC, from harbour to SO EBay shallow line, INNOMAR start

at 05:29 UTC

Station 12: CTD 5, 05:37 UTC, inner bay, 54° 27.67338' N, 9° 51.49010' E, on deck 05:41 UTC

File: ECK_CTD05_....csv

Station 13: CTD 6, 07:27 UTC, 54° 29.30247' N, 10° 5.94800' E, SO EBay, on deck: 07:30

File: ECK_CTD06_...csv

Station 14: transit to NO EBay, record INNOMAR & MBES, start: 07:30 UTC, mapping Boknis

Eck, starting at 08:02 UTC, stop 13:45 UTC

Station 15: CTD 7, 10:22 UTC, 54° 30.73288' N, 9° 59.73960' E (Boknis Eck), on deck 10:24 UTC

File: ECK_CTD07_....csv

Station 16: Profile_9 Ercan, start 13: 55 UTC, 54° 31.67347' N, 10° 2.68520' E

File: 2022-07-05-13_55_52

Station 17: CTD 8, 14:26 UTC, 54° 29.95967' N, 9° 59.08549' E, inner bay, on deck 14:29 UTC

File: ECK_CTD08_...csv

Station 18: Profile_8 Ercan, start 14:31 UTC, 54° 29.94107' N, 9° 59.07350' E, end: 15:19 UTC

File: 2022-04-07-14_31_51, 2022-04-07-14_52_59

DCT caused problems, GUI became very slow and stopped working at some point, bug: Error no incoming data, started recording and drawing again after few seconds.

Back at harbour 15:39 UTC

06.07.2022

4 tests at 04:48 UTC with NORBIT, DCT GUI erroneous

05:20 UTC start from harbour, tests with NORBIT but DCT still not working properly

Station 19: Hemmelmark Video, 06:16 UTC, 06:24 on deck, BoSi (ground visible)

Station 20: Hemmelmark core deep 1, 06:37 UTC, 54° 28.76477' N, 9° 53.95209' E, 17 m depth, core was taken; cores had lots of mussels (Mytilidae) on top of sediments that were carefully removed from core

Hemmelmark core deep 2, 06:46 UTC, 54° 28.76217' N, 9° 53.95570' E , core was taken

Hemmelmark core deep 3, 06:50 UTC, 54° 28.76757' N, 9° 53.95620' E, core was taken

Hemmelmark core deep 4, 06:55 UTC, 54° 28.77348' N, 9° 53.95040' E, core was taken

Station 21: Hemmelmark shallow

Core shallow 1, 07:01 UTC, 54° 28.79077' N, 9° 53.92240' E, 3.5 m depth, corer empty

Core shallow 2, 07:04 UTC, 54° 28.79048' N, 9° 53.91659' E, 3.3 m depth, corer empty

More weights on Frahm lot used (2 weights)

Core shallow 3, 07:06 UTC, 54° 28.78188' N, 9° 53.91469' E, 7 m depth, not triggered

Core shallow 4, 07:08 UTC, 54° 28.78608' N, 9° 53.91400' E, 7 m depth, core was taken

Core shallow 5, 07:12 UTC, 54° 28.77998' N, 9° 53.90739' E , 7.6 m depth, core empty

3 weights on Frahm lot

Core shallow 5, 07:15 UTC, 54° 28.78298' N, 9° 53.90750' E, 4.7 m depth, core was taken

Core shallow 6, 07:19 UTC, 54° 28.79048' N, 9° 53.91030' E, 3.3 m depth, core was taken

Core shallow 7, 07:22 UTC, 54° 28.78768' N, 9° 53.91280' E, 4.2 m depth, not triggered

Core shallow 8, 07:24 UTC, 54° 28.79157' N, 9° 53.91090' E, 3.3 m depth, core was taken

Station 22: Ercan Video Hemmelmark (position 2 at Hemmelmark)

07:31 UTC record MBES & INNOMAR, RTK GPS connection started at middle of transect

Station 23: Ercan K2, 07:38, 54° 28.50108' N, 9° 52.88950' E, core empty

08:10 UTC, few centimetres core on deck (Ercan_K2)

Station 24: Ercan K1, 08:21 UTC, 54° 28.51257' N, 9° 53.07120' E, 1 core few cm,

Station 25: Record MBES & INNOMAR transect to Goossee 08:24 UTC start

Station 26: Video Goossee, RTK GPS track start at 08:36 UTC,

Video transect start: 08:38 UTC, 54° 27.28998' N, 9° 52.06330' E, end 08:52 UTC

Station 27: Goossee deep

After several attempts with all cores empty, switch to crab corer

Corer 1 deep: 09:19 UTC on deck, 54° 27.30398' N, 9° 52.11949' E, sampling ok

Station 28: Goossee shallow

Corer 1 shallow: 09:24 UTC on deck

Station 29: transit to Aschau MBES record 09:25 UTC, INNOMAR start 09:26 UTC, stop: 9:54 UTC

Station 30: start RTK GPS log at: 09:54 UTC, 54° 27.63608' N, 9° 55.02959' E, video start 09:59 UTC

Station 31: Aschau grab & core shallow (11 m, to close at shore),

Grab 1: 10:18 UTC, 54° 27.58038' N, 9° 55.17260' E,

Core 1: 10:21 UTC

Station 32: Aschau deep

Core 1: 12:28 UTC, corer down, 54° 27.60887' N, 9° 55.17580' E, core on deck: 12:29 UTC

Grab 1: 10:36 UTC, 54° 27.60018' N, 9° 55.19440' E, seagrass roots in core!

Station 33: transit to video position SE EBay inner (Jenny_video1), MBES & INNOMAR record 10:38 UTC, 7 kn

Station 34: Video_Jenny_1 SE EBay inner bay, start 11:16 UTC GPS log, 54° 28.98848' N, 10° 1.60240' E; video transit starts 11:23 UTC ; Video Stop 11:41 UTC

Station 35: transit to video position SE EBay outer (Jenny_video2), MBES & INNOMAR record

Station 36: Video_Jenny_2 SE EBay outer bay, 54° 28.96947' N, 10° 2.62030' E; video transit start: 11:54 UTC; camera on deck and video stop 12:02 UTC, GPS log file Video_Jenny_1 unfortunately, overwritten, **no GPS log for Station Video_Jenny_1**

Station 37: transit to Boknis Eck, start INNOMAR & MBES 12:04 UTC, 7kn

Station 38: Video Boknis, 54° 31.89877' N, 10° 1.77010' E; video transit starts 12:33 UTC; reaching ground 12:35 UTC; camera on deck to check battery at 13:09 UTC at 54° 32.26117' N, 10° 1.67860' E; back into water and on ground 13:13 UTC at 54° 32.27067' N, 10° 1.65730' E; camera on deck and stop 13:39, 54° 32.49587' N, 10° 1.61330' E

07.07.2022

Start from harbour at 05:19 UTC, start recording 05:23 UTC MBES & INNOMAR

Station 39: Patch Test: start 07:28 UTC record MBES, 54° 28.27987' N, 9° 51.14970' E

Central File: 2022-07-07-05_29_06

Pitch File: 2022-07-07-05_34_27

Yaw File: 2022-07-07-05_41_18

Roll File 1: 2022-07-07-05_47_20

Roll File 2: 2022-07-07-05_53_36

Station 40: CTD 09; 05:57 UTC; 9, 54° 28.08987' N, 9° 51.88970' E; on deck 06:00 UTC

File: ECK_CTD09_...csv

Station 41: transit to Boknis, recording MBES & INNOMAR, start: 06:01 UTC, end 07:53 UTC

Station 42: CTD 10, 07:11 UTC, 54° 32.35338' N, 10° 1.86740' E, on deck 07:12 UTC

File: ECK_CTD10_...csv

Station 43: transit to Noer, start 07:54 UTC, record MBES & INNOMAR

Station 44: mapping Noer seagrass area, start: 08:28 UTC, 54° 28.78007' N, 10° 0.94190' E,

end: 11:28 UTC, 54° 29.24358' N, 10° 2.64950' E

Station 45: CTD 11, 10:07 UTC, 54° 29.21048' N, 10° 2.93850' E, on deck 10:09 UTC

File: ECK_CTD11_...csv

Station 46: transit to Wendtorf, recording MBES & INNOMAR, 11:30 UTC

Station 47: Wendtorf MBES line, 12:46 UTC, 54° 26.28827' N, 10° 16.41350' E, stop 14:35 UTC,

54° 25.17347' N, 10° 13.48580' E

Station 48: CTD 2 Wendtorf, 13:05 UTC, 54° 26.01977' N, 10° 16.67959' E, on deck 13:06 UTC

File: WNT_CTD02_...csv

Station 49: CTD 3 Wendtorf, 14:36 UTC, 54° 25.16428' N, 10° 13.47910' E, on deck 14:38 UTC

File: WNT_CTD03_...csv

Station 50: transit to Kiel, start 14:40 UTC, 54° 25.10108' N, 10° 13.34659' E, at Kiel GEOMAR

East shore at 15:36 UTC

08.07.2022

Equipment de-installation

END OF CRUISE

B) CTD Data

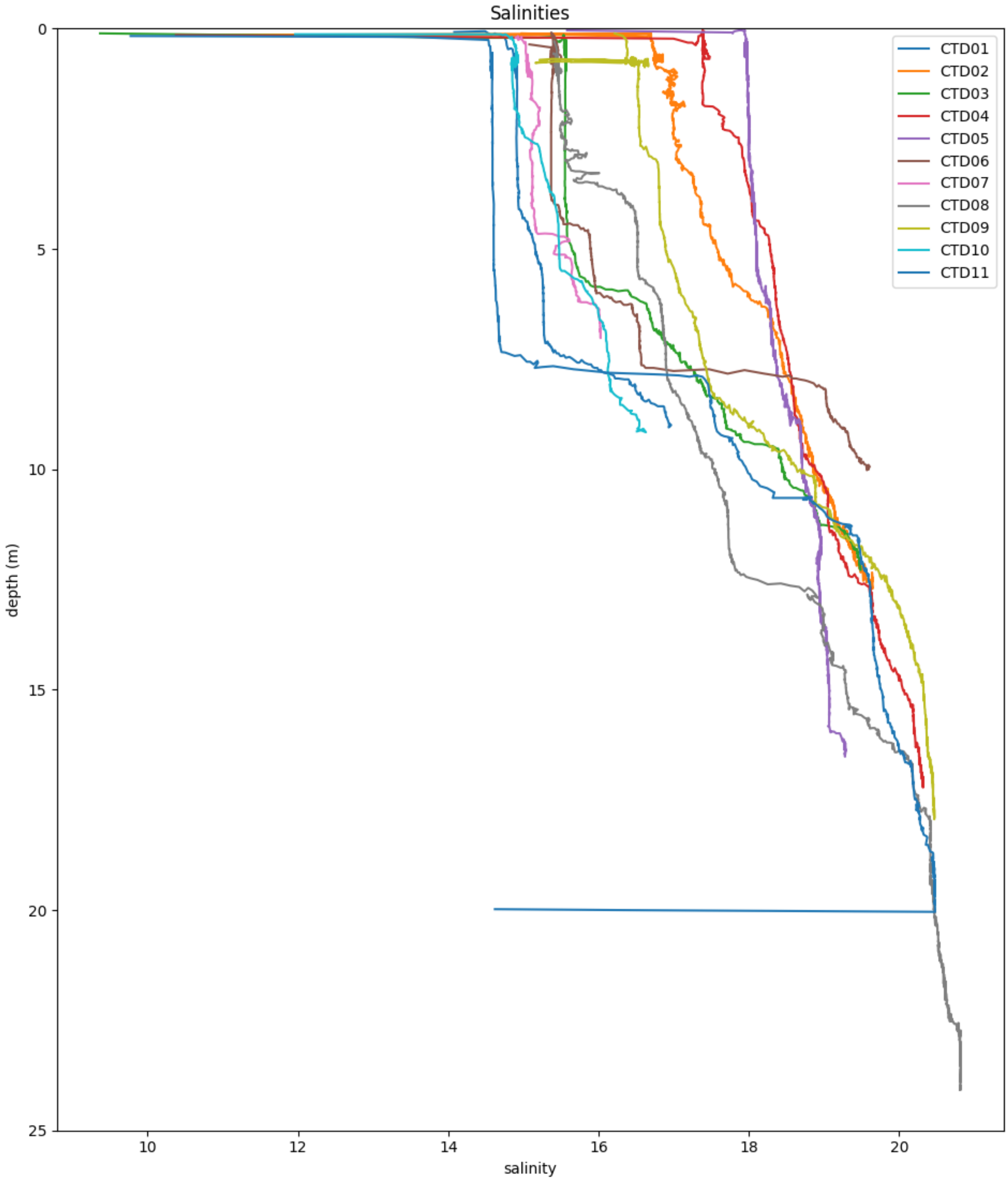

Figure 9: Salinity gradients of the CTD profiles in the Eckernförde Bay.

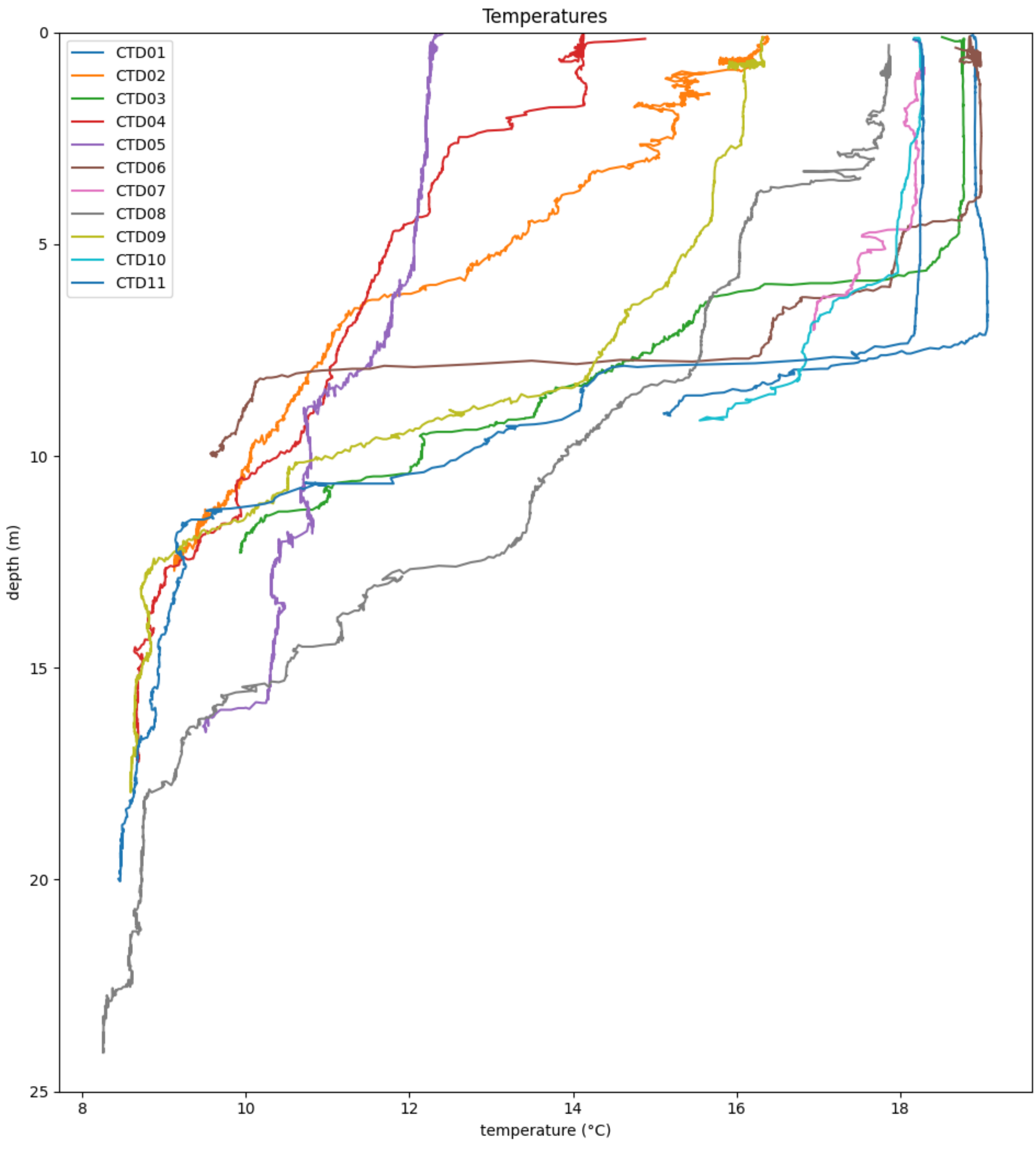

Figure 10: Temperature gradients of the CTD profiles in the Eckernförde Bay.

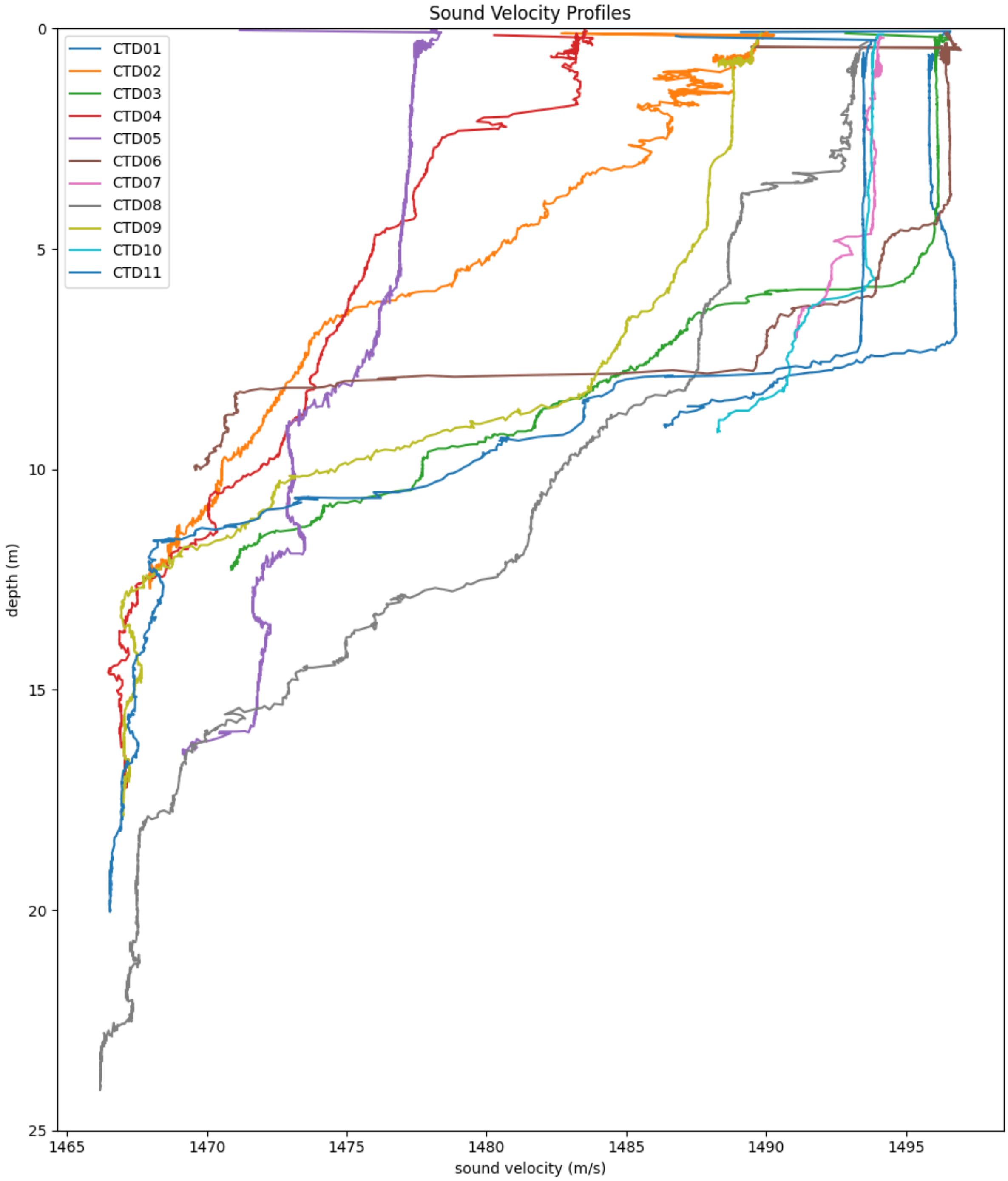

Figure 11: Course of the sound velocity profiles in Eckernförde Bay at the individual CTD stations.

7. References

Boström, C., Baden, S., Bockelmann, A. C., Dromph, K., Fredriksen, S., Gustafsson, C., ... & Rinde, E. (2014). Distribution, structure and function of Nordic eelgrass (Zostera marina) ecosystems: implications for coastal management and conservation. *Aquatic conservation: marine and freshwater ecosystems*, *24*(3), 410-434.

Carvalho, R. C., Hamylton, S., & Woodroffe, C. D. (2017, July). Filling the 'white ribbon'in temperate Australia: a multi-approach method to map the terrestrial-marine interface. In *2017 IEEE/OES Acoustics in Underwater Geosciences Symposium (RIO Acoustics)* (pp. 1-5). IEEE.

de la Lanza-Espino, G., Flores-Verdugo, F. J., Hernandez-Pulido, S., & Penié-Rodríguez, I. (2011). Concentration of nutrients and C: N: P rations in surface sediments of a tropical coastal lagoon complex affected by agricultural runoff. *Universidad y ciencia, 27*(2), 145-155.

Duarte, C. M. (2002). The future of seagrass meadows. *Environmental conservation, 29*(2), 192-206.

Gumusay, M. U., Bakirman, T., Tuney Kizilkaya, I., & Aykut, N. O. (2019). A review of seagrass detection, mapping and monitoring applications using acoustic systems. *European Journal of Remote Sensing*, 52(1), 1-29.

Held, P., & Schneider von Deimling, J. (2019). New feature classes for acoustic habitat mapping—A multibeam echosounder point cloud analysis for mapping submerged aquatic vegetation (SAV). *Geosciences, 9*(5), 235.

Krull, E., Haynes, D., Lamontagne, S., Gell, P., McKirdy, D., Hancock, G., ... & Smernik, R. (2009). Changes in the chemistry of sedimentary organic matter within the Coorong over space and time. *Biogeochemistry, 92*(1), 9-25.

Kuhwald, K., Schneider von Deimling, J., Schubert, P., & Oppelt, N. (2021). How can Sentinel-2 contribute to seagrass mapping in shallow, turbid Baltic Sea waters?. *Remote Sensing in Ecology and Conservation.*

Lamarche, G., & Lurton, X. (2018). Introduction to the Special Issue "Seafloor backscatter data from swath mapping echo sounders: from technological development to novel applications". *Marine Geophysical Research*, *39*(1), 1-3.

Lübmann, 2018. Hydroakustische Untersuchung der Seegraswiesen in der Kolberger Heide. M.Sc. Thesis Geophysics, Kiel University

Meng, L., Qu, F., Bi, X., Xia, J., Li, Y., Wang, X., & Yu, J. (2021). Elemental stoichiometry (C, N, P) of soil in the Yellow River Delta nature reserve: Understanding N and P status of soil in the coastal estuary. *Science of The Total Environment*, *751,* 141737.

Nasir, A., Lukman, M., Tuwo, A., Hatta, M., & Tambaru, R. (2016). The use of C/N ratio in assessing the influence of land-based material in Coastal Water of South Sulawesi and Spermonde Archipelago, Indonesia. *Frontiers in Marine Science, 3,* 266.

Qin, L. Z., Suonan, Z., Kim, S. H., & Lee, K. S. (2021). Coastal Sediment Nutrient Enrichment Alters Seagrass Blue Carbon Sink Capacity. *Environmental Science & Technology, 55*(22), 15466-15475.

Redfield, A. C. (1963). The influence of organisms on the composition of seawater. *The sea, 2,* 26-77.

Reusch, T. B., Ehlers, A., Hämmerli, A., & Worm, B. (2005). Ecosystem recovery after climatic extremes enhanced by genotypic diversity. *Proceedings of the National Academy of Sciences*, *102*(8), 2826-2831.

Ruttenberg, K. C., & Goni, M. A. (1997). Phosphorus distribution, C: N: P ratios, and δ13Coc in arctic, temperate, and tropical coastal sediments: tools for characterizing bulk sedimentary organic matter. *Marine Geology, 139*(1-4), 123-145

Schubert, P. R., Hukriede, W., Karez, R., & Reusch, T. B. (2015). Mapping and modeling eelgrass Zostera marina distribution in the western Baltic Sea. *Marine Ecology Progress Series*, *522*, 79-95.

Schneider von Deimling, J., & Feldens, P. (2021). ECOMAP Habitatkartierung mittels innovativer optischer und akustischer Fernerkundungs-und Auswerteverfahren. *HN 120*

Schneider von Deimling, J., & Weinberger, F. (2020). Spatial assessment of Zostera marina in the western Baltic Sea. *BONUS deliverable*.

Sogin, E. M., Puskás, E., Dubilier, N., & Liebeke, M. (2019). Marine metabolomics: a method for nontargeted measurement of metabolites in seawater by gas chromatography–mass spectrometry. *Msystems, 4*(6), e00638-19.

Yamamuro, M., & Kamiya, H. (2014). Elemental (C, N, P) and isotopic (δ13C, δ15N) signature of primary producers and their contribution to the organic matter in coastal lagoon sediment. *Landscape and ecological engineering, 10*(1), 65-75.

Yamamuro, M. (2000). Chemical tracers of sediment organic matter origins in two coastal lagoons. *Journal of Marine Systems, 26*(2), 127-134.