ALKOR-Berichte

Bachelor-MARSYS education cruise in the Baltic Sea

Cruise No. AL588

March 1st – March 10th 2023,
Kiel (Germany) – Kiel (Germany)
BALTEACH – 1

Dr. Steffen Funk. Prof. Dr. Christian Möllmann

Dr. Steffen Funk
Institute of Marine Ecosystem and Fisheries Science.
University of Hamburg

2023

Table of Contents

1 Cruise Summary

1.1 Summary in English

This cruise was conducted as part of the teaching schedule of the Bachelor of marine ecosystem and fisheries science programme of the University of Hamburg. The cruise aimed to teach students in commonly used scientific methods, gears and working procedures of fisheries science and biological oceanography onboard of a research vessel. This included zooplankton and ichthyoplankton sampling using BONGO and multi-closing nets, investigation of size and species distribution of the fish fauna by using bottom trawl sampling and angling and investigating prevailing hydrographic conditions using CTD probes.

Initial sample analyses and subsequent sample archiving were taught to the students in the context of the continuation of the Belt Sea ichthyoplankton sampling time series of the University of Hamburg. This fish and ichthyoplankton sampling thereby served to investigate the late-winter spawning activity of western Baltic cod in the Belt Sea (ICES SD 22) and complemented internationally coordinated sampling efforts on the reproductive biology of western Baltic cod.

During cruise AL588, spawning cod were found in the Kiel Bight, the Mecklenburg Bight, the Fehmarn Belt, the Little Belt and the Great Belt. In addition, first analyses of BONGO net samples revealed the presence of cod larvae in all sampled subareas, with most larvae observed in the Kiel Bight and only a few cod larvae in the Mecklenburg Bight. The observation of a relatively high proportion of cod in the late spawning and post-spawning stages could be an indication that March, which in the past was designated as the main spawning season for western Baltic cod in the area, now tends to reflect the late spawning phase of cod.

1.2 Zusammenfassung

Diese Fahrt wurde im Rahmen des Lehrplans des Bachelor-Studiengangs Marine Ökosystem- und Fischereiwissenschaften der Universität Hamburg durchgeführt. Ziel der Fahrt war es, den Studenten an Bord eines Forschungsschiffes die gängigen wissenschaftlichen Methoden, Geräte und Arbeitsverfahren der Fischereiwissenschaft und der biologischen Ozeanographie zu vermitteln. Dazu gehörten die Beprobung von Zooplankton und Ichthyoplankton, die Untersuchung der Größen- und Artenverteilung der Fischfauna, sowie die Untersuchung der vorherrschenden hydrographischen Bedingungen mit CTD-Sonden.

Erste Probenanalysen und die anschließende Probenarchivierung wurden den Studenten im Rahmen der Fortführung einer Ichthyoplankton-Beprobungszeitreihe in der Beltsee. Diese dienen der Untersuchung der spätwinterlichen Laichaktivität des westlichen Ostseedorsches in der Beltsee und ergänzen international koordinierte Probenahmen zur Reproduktionsbiologie des westlichen Ostseedorsches.

Während der Fahrt AL588 wurden laichende Dorsche in der Kieler Bucht, der Mecklenburger Bucht, dem Fehmarnbelt, dem Kleinen Belt und dem Großen Belt gefunden. Erste Analysen ergaben, dass in allen beprobten Teilgebieten Dorschlarven vorhanden waren, mit höchsten Larvenanzahlen in der Kieler Bucht und nur wenigen in der Mecklenburger Bucht. Die Beobachtung eines relativ hohen Anteils von Dorschen im späten Laich- und Nachlaichstadium könnte ein Hinweis darauf sein, dass der März, der in der Vergangenheit als Hauptlaichzeit des

westlichen Ostseedorsches in diesem Gebiet bezeichnet wurde, nun eher die späte Laichphase des Dorsches widerspiegelt.

2 Participants

2.1 Scientific Party

Table 2.1.1 List of scientific party of cruise AL588 – Part A

Name	Discipline	Institution
Funk, Steffen, Dr. rer. nat.	Chief scientist; PostDoc	IMF
Klinger, Richard	PhD student	IMF
Dahlke, Flemming, Jun. Prof. Dr. rer.nat.	Professor	IMF
Höper, Anton	MSc student	IMF
Hauten, Elena	PhD student	IMF
Kondratowicz, Stephanie	Technician	IMF
Listmann, Luisa, Dr. rer. nat.	PostDoc	IMF
von Leesen, Gotje K.G., Dr. rer. nat.	PostDoc, Observer	AU
Dolling, Jasmin Isabel Maria	BSc Student	IMF
Hanft, Tabea	BSc Student	IMF
Winterhof, Carlotta	BSc Student	IMF
Madiraca, Frane	PhD student	IMF

Table 2.1.2 List of scientific party of cruise AL588 – Part B.

Name	Discipline	Institution
Funk, Steffen, Dr. rer. nat.	Chief scientist; PostDoc	IMF
Klinger, Richard	PhD student	IMF
Dahlke, Flemming, Jun. Prof. Dr. rer.nat.	Professor	IMF
Höper, Anton	MSc student	IMF
Hauten, Elena	PhD student	IMF
Kondratowicz, Stephanie	Technician	IMF
Listmann, Luisa, Dr. rer. nat.	PostDoc	IMF
von Leesen, Gotje K.G., Dr. rer. nat.	PostDoc, Observer	AU
Brändel, Dr. Markus	PostDoc	UHAM
Haves, Lisa	BSc student	IMF
Kretzchmar, Emilia	BSc student	IMF
Leistner, Viktoria	BSc student	IMF

Table 2.1.3 List of scientific party of cruise AL588 – Part C.

Name	Discipline	Institution
Funk, Steffen, Dr. rer. nat.	Chief scientist; PostDoc	IMF
Klinger, Richard	PhD student	IMF
Dahlke, Flemming, Jun. Prof. Dr. rer.nat.	Professor	IMF
Höper, Anton	MSc student	IMF
Hauten, Elena	PhD student	IMF
Kondratowicz, Stephanie	Technician	IMF
Dierking, Jan, Dr. rer. nat.	PostDoc	GEOMAR
von Leesen, Gotje K.G., Dr. rer. nat.	PostDoc, Observer	AU
Schramm, Lydia	BSc student	IMF
Stjepanovic, Lara	BSc student	IMF
Schleicher, Danny	BSc student	IMF
Funk, Steffen, Dr. rer. nat.	Chief scientist; PostDoc	IMF

2.3 Participating Institutions

IMF	Institute of Marine Ecosystem and Fisheries Science, University of Hamburg
AU	Aarhus University
GEOMAR	GEOMAR Helmholtz-Zentrum für Ozeanforschung Kiel
UHAM	University of Hamburg

3 Research Program

3.1 Description of the Work Area

The working area (Fig. 3.1.2) of AL588 was located in the Kiel Bight, Little Belt, Great Belt, Fehmarn Belt, and Mecklenburg Bight, which are all part of the Belt Sea (ICES subdivision (SD)22). The Belt Sea is a stratified, brackish-water area (common salinity range: 10 to 25 PSU), which together with the Arkona Sea (SD24) and the Sound (SD23) forms the Western Baltic Sea (WBS) (Fig. 3.1.1). The Western Baltic Sea is characterized by several shallow obstacles such as the Darss Sill, limiting inflows of water with high salinities from the Kattegat region to the eastern parts of the Baltic Sea. This limited saltwater inflow in combination with river runoffs results in a constant decrease of salinity from the western to the eastern parts of the Baltic Sea. The Belt Sea is microtidal (tidal range: ~ 10 cm) and characterized by wind-induced fluctuations in hydrographic conditions (Leppäranta and Myrberg, 2000; Snoeijs-Leijonmalm and Andrén, 2017). This is caused by changes in inflow of more saline bottom water from the Kattegat and surface outflow of less saline water from the central and southern Baltic Sea through the Danish Straits and the Darss sill. SD22 and SD23 are known as the distributional core area of the Western Baltic cod (*Gadus morhua*) stock. Here, stock mixing with the more easterly distributed Eastern Baltic cod (*Gadus morhua callarias*) is considered negligible (ICES, 2019).

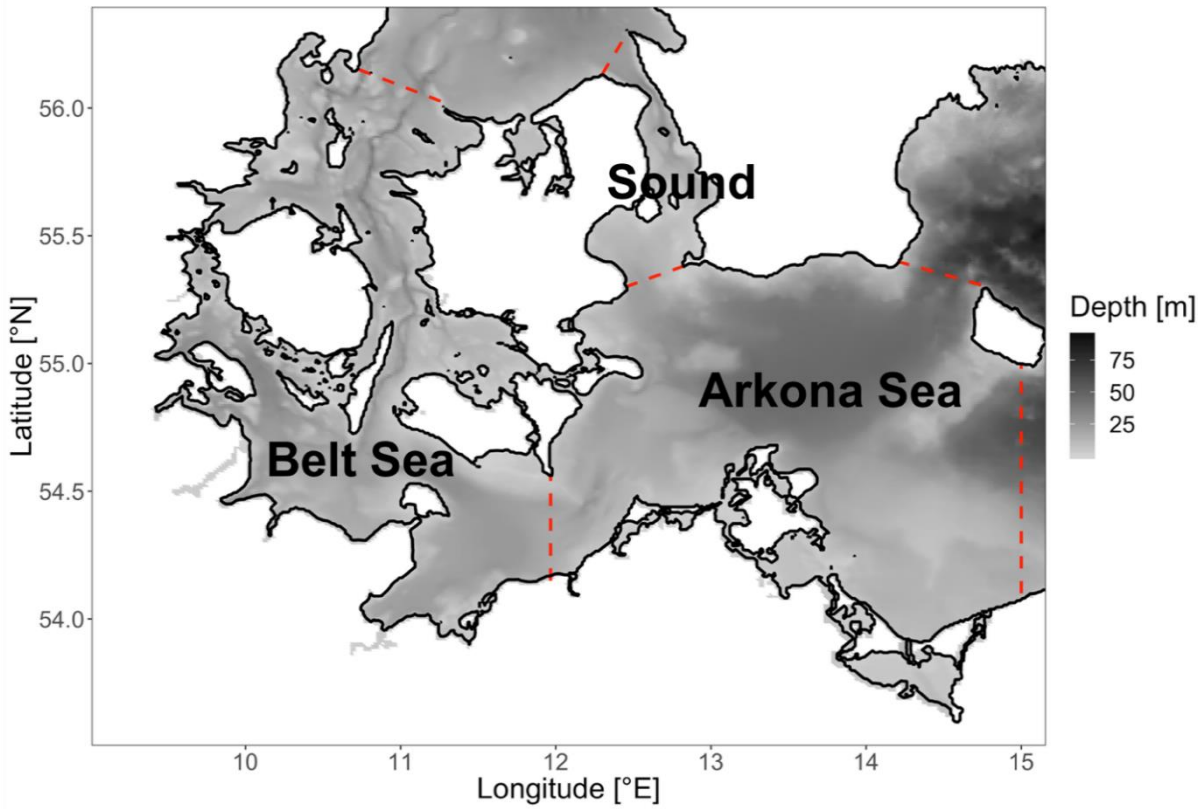

Fig. 3.1.1 Bathymetry of the Western Baltic Sea. Dashed red lines indicate borders between ICES Subdivisions (SD22 – Belt Sea; SD23 – Sound. and SD24 – Arkona Sea). Figure was taken from Funk. 2020.

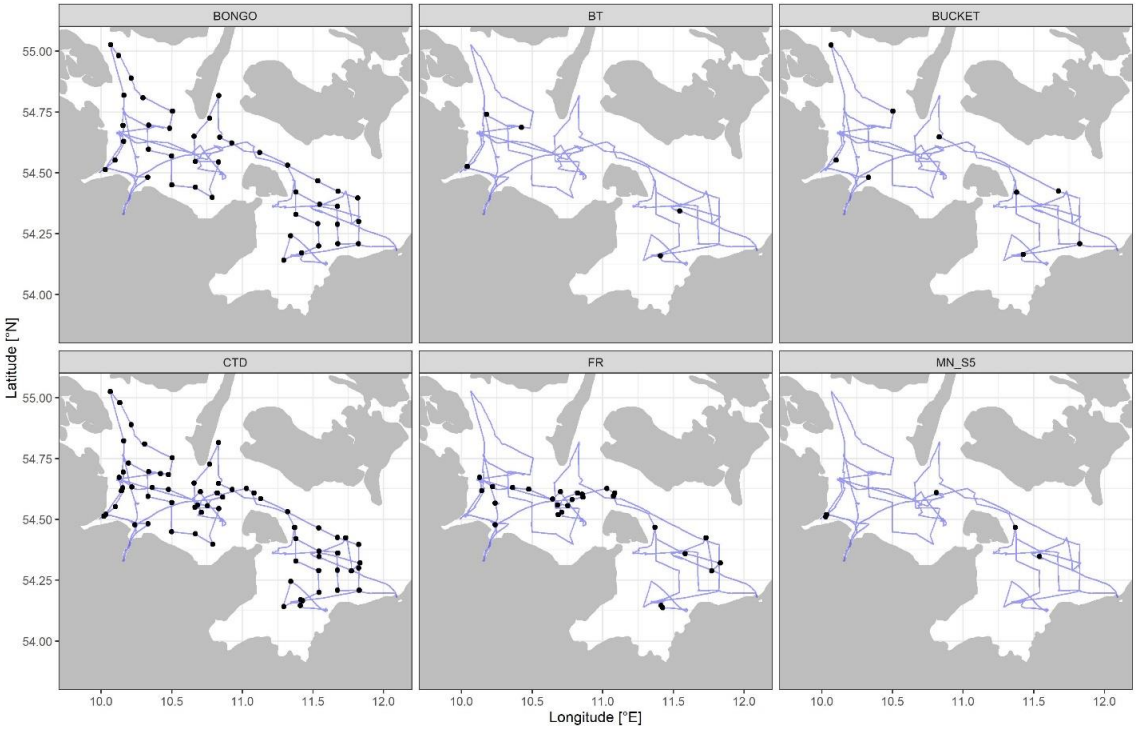

Fig. 3.1.2 Cruise track and gear deployments during AL588. Sampling positions are indicated with black dots (BONGO = Bongo net; BT = Bottom trawl TV3/50, Bucket = water sampler, CTD = CTD probe, FR =angling, and MN_S5 = Multinet midi towed)

3.2 Aims of the Cruise

This trip was planned as a teaching trip for MARSYS Bachelor students of the Institute of Marine Ecosystems and Fisheries Science (IMF, University of Hamburg) to train the students in various sampling techniques in marine ecology and fisheries science. The main feature is the integration of oceanographic and biological information to improve the understanding of the spatial distribution of pelagic fish eggs and larvae, phytoplankton and phytoplankton and zooplankton, and fish abundance in relation to climate change and anthropogenic stressors. Initial sample analyses and subsequent sample archiving were taught to the students in particular in the context of the continuation of the Belt Sea ichthyoplankton sampling time series of the University of Hamburg. This ichthyoplankton time series as well as supplementary sampling of adult cod at selected stations served to investigate the late-winter spawning activity of western Baltic cod in the Belt Sea (ICES SD 22) and complemented sampling efforts on the reproductive biology of western Baltic cod internationally coordinated by the University of Hamburg, GEOMAR, University of Aarhus and the Danish Technical University. The Western Baltic cod stock (WBC) is currently in distress. This is believed to be linked to the low level of recruitment success over several years. The reasons behind are not yet well understood. There are indications of a (potentially climate-induced) shift in the spawning phenology of the stock, with spawning activity shifting (peak spawning usually occurred in March [Bleil and Oeberst, 1997; Bleil et al., 2009]) to an earlier time period. This has already been observed for other stocks of Atlantic cod as well (e.g., McQueen and Marshall, 2017). The shift probably causes a mismatch situation between the cod larvae and its main prey (zooplankton), which can result in poor larval survival and consequently lower recruitment success. There is an indication that accelerated gonad maturation is already an ongoing process in the study area. Post-spawning cod individuals have been observed more frequently during the Baltic international trawl survey (BITS) conducted in the 1st quarter between the end of February and mid-March each year (pers. comm. U. Krumme, Thuenen Institute of Baltic Sea Fisheries, Rostock). Furthermore, local gillnet fishers located in the harbours of Burgstaaken and Heiligenhafen (Schleswig-Holstein, Germany) observed increasing numbers of spawning cod individuals already in January. Mature fish in spawning stages occur earlier on their traditional spawning grounds near to and within the channels of the Kiel Bight, Mecklenburg Bight and Fehmarn Belt (pers. comm. S. Funk with local gillnetters). In contrast, former studies indicate that spawning migrations towards these areas occur mainly in February and March. (Bleil and Oeberst, 1997; Bleil et al., 2009). Due to its internationally coordinated timing, the official monitoring programme (i.e., Baltic International Trawl Survey [BITS]) will continue to be carried out during the end of February to mid-March and is therefore likely to miss this potentially important early-winter stock dynamics of WBC. To evaluate the extent of spawning over the spawning season the University of Hamburg coordinates in cooperation with the GEOMAR, the University of Aarhus and the Danish Technical University sampling efforts aiming to cover the whole spawning period of cod.

Therefore, cruise AL588 aimed to:

1. Teach students in the use of commonly applied methods and gears in fisheries science and biological oceanography.
2. Teach students in biodiversity of the western Baltic (with special focus on fish fauna).

3. investigate spatial distribution of mature, adult cod inhabiting traditional spawning grounds in the Belt Sea in late January including sampling positions in the channels of the Kiel Bight, Little Belt, Great Belt (i.e., Langeland Belt), Fehmarn Belt and Mecklenburg Bight.
4. investigate the spatial distribution of cod eggs and larvae in the Belt Sea in late January.

To realize these goals, we sampled the station grid developed in the framework of the winter cod cruise 2021-2025 containing a total of 43 Bongo sampling positions, which should be used for zooplankton and especially ichthyoplankton sampling using a BONGO net (including 19 positions in the Kiel Bight, three positions in the Little Belt, two positions in the Great Belt, three positions in the Fehmarn Belt and 16 positions in the Mecklenburg Bight) (Fig. 3.2). This plankton station grid was based on a station grid sampled also during previous winter and spring cruises (including winter cod cruises in 2021, AL549; 2022, AL568b; 2023, AL585) of the University of Hamburg. Previous plankton samplings on former student teaching cruises of the IMF at parts of the Bongo station grid date back to 2016 and were analysed in cooperation with the Danish Technical University (DTU) in the project FORTORSK.

In addition, we defined a total number of 5 trawl positions at known spawning grounds of WBC in the Belt Sea (Fig. 3.2.1), where it was planned to sample cod using a bottom trawl net (TV3/520, the standard net used during the Baltic international trawl surveys of the ICES). For the cruise AL588 it was decided use additional angling sampling at hard-structured bottom areas (i.e., artificial reefs). This decision was made due to the comparably high cod catches resulting from angling during the IMF winter cod cruise AL585 in January 2023 and the considerably low cod catches obtained from trawling activities. Furthermore, angling sampling allowed a better area-coverage of the Fehmarn Belt area, where hard structured grounds with rocky reef structures strictly limited our range of activity during standard bottom trawling during previous cruises.

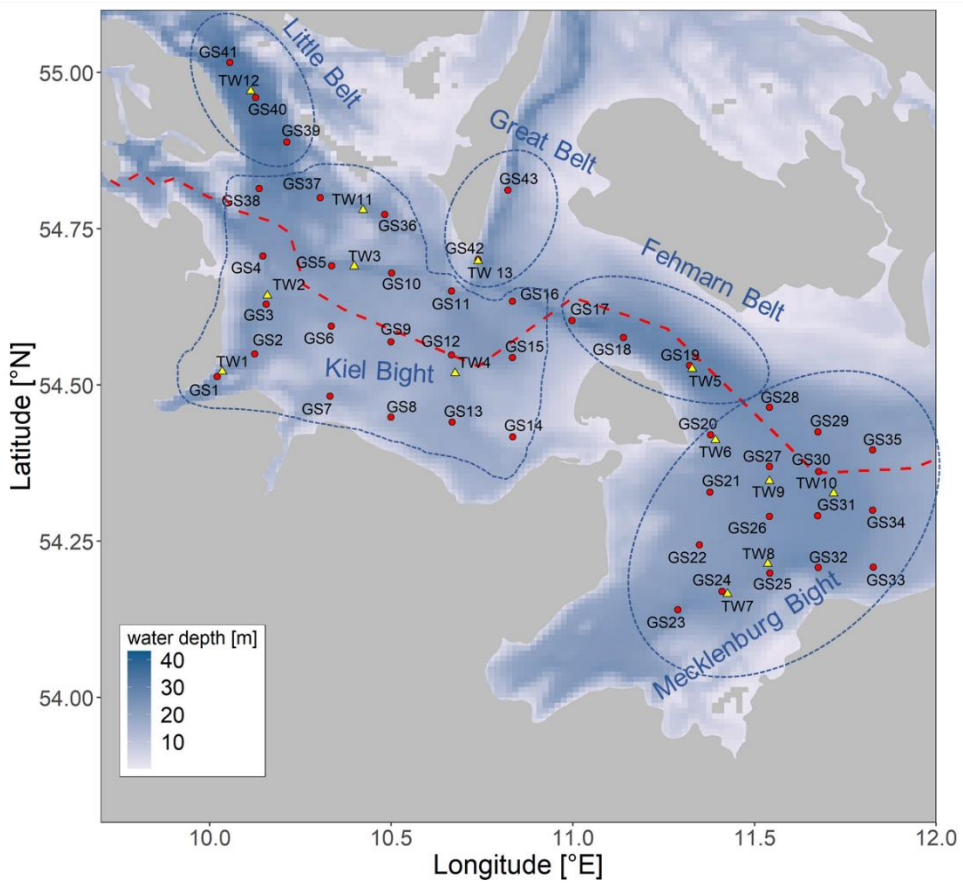

Fig. 3.2.1 Initially planned zooplankton and trawl fishery stations for the winter cod cruises. Red dots indicate CTD and BONGO net stations. Blue triangles indicate trawl and MULTINET stations. Red dashed line depicts EEZ borders and blue circles indicate stations allocated to a specific subregion in the work area. i.e., Kiel Bight, Fehmarn Belt, and Mecklenburg Bight, Great Belt, and Little Belt.

3.3 Agenda of the Cruise

It was planned to realize a plankton grid sampling consisting of 43 BONGO net and CTD stations complemented by 5 trawl hauls and angling sampling at selected wreck sites.

Hydrographic data

Detailed collection of the hydrographic conditions at the working area including fluorescence, oxygen, salinity, pH and temperature.

Zoo- and ichthyoplankton data

Cod larvae of BONGO net 500 µm should be collected directly out of the samples, and deep frozen at -80°C for subsequent condition analyses in the laboratory. BONGO- and MULTINET-samples should be preserved in formalin for later detailed zoo- and ichthyoplankton community and size composition analyses at the laboratory of the University of Hamburg.

Fishery data

Sampling of the occurring fish fauna at for-defined sampling stations at traditional cod spawning grounds including the collection of individual fish data of cod. In detail it was planned to record full weight, gutted weight, liver weight, sex, maturity stage, gonad weight, stomach fullness, and to take otolith, stomach, fin clip and muscle tissue samples.
Additionally, size distribution and total catch weight were recorded for all other fish species caught.

- Cod stomach samples were taken to supplement the Western Baltic cod stomach data base of the University of Hamburg dating back to 2016 (see Funk et al., 2021).
- Cod fin clips were taken for potential cod stock discrimination analyses using genetics.
- Cod muscle tissue samples were taken for stable isotope analysis.
- Cod samples were taken for subsequent aging.
- Continuous* recording of hydroacoustic data with four different echosounder frequency of 200 kHz for potential biomass estimations (echosounder was mainly used as fish finder during the cruise).

4 Narrative of the Cruise

RV ALKOR departed from GEOMAR pier in Kiel on March 1st at 08:00am heading to the first plankton grid station in the Kiel Bight (GS 1, Fig. 3.2.1), where the Bongo grid station work started.

Until Thursday evening all 43 planned Bongo samplings and one additional sampling at a wreck east of Fehmarn (close to the Fehmarn Belt entrance) were successfully conducted.

On Friday additional wreck sites in the southern Mecklenburg Bight were conducted as well as a bottom trawl haul (it has to be noted that the trawl haul resulted in zero catch since a twisted wire caused a malfunction of the net). At Friday afternoon RV ALKOR headed to the port of Warnemünde where a change of participants was made.

RV ALKOR departed from the port of Warnemünde on March 4th at 7:30 heading to continue trawl and wreck sampling in the central and eastern Mecklenburg Bight.

On Sunday RV ALKOR headed back from the Mecklenburg Bight to the Kiel Bight, with Wreck samplings conducted at the Fehmarn Belt area. On Monday two trawl hauls (one in the Vejsnæs channel and one northwest of Kappeln) as well as wreck samplings north of the Kiel fjord were conducted. At late Monday afternoon RV ALKOR headed to its home port Kiel where a second change of cruise participants was conducted.
Due to strong stormy weather conditions on March 7th it was decided to stay the day in the port of Kiel.

RV ALKOR departed from GEOMAR pier in Kiel on March 8st at 06:30am heading to continue station work at the Bay of Eckernförde, where multinet sampling and bottom trawling was conducted. From the Bay of Eckernförde AR ALKOR headed towards the central and the eastern parts of the Kiel Bight where several wracks were sampled.

On early moning of March 9th wreck samplings in the shooting range Bay of Hohwacht were conducted followed by additional wrack samplings near to the entrance of the Fehmarn Belt. At

Thursday afternoon RV ALKOR headed back to its homeport Kiel, where the cruises ended at 04:30pm.

5 Preliminary Results

5.1 Hydrography

(Steffen Funk)

CTD profiles were obtained from a total of 70 sampling stations during AL588. Highest bottom salinities with > 22 PSU were observed at sampling positions of the Little Belt and in the western Kiel Bight.

Surface salinities ranged between 9.2 PSU and 20.2 PSU with a decreasing spatial pattern from western to eastern parts of the sampling area. surface salinities occurring from west to east within the sampling area. Interestingly, even in the Fehmarn Belt considerably low surface salinities < 11 PSU were observed indicating freshwater surface outflows from the eastern parts of the Baltic, similar to observations made in January 2023. Bottom salinities ranged between 15.1 and more than 22.5 PSU, with lowest salinities observed in the eastern Mecklenburg Bight (Fig. 5.1.1), and highest salinities observed in the Little Belt

In the literature, salinities between 18 to 33 PSU are given as range for neutral egg buoyancy of Western Baltic cod with an optimum of 20-22 PSU (von Westernhagen, 1970; Westerberg, 1994; Nissling and Westin, 1997). Based on this salinity range conditions for cod egg buoyancy and thus conditions for a successful spawning could be found in the northern and central Kiel Bight as well as in the Fehmarn Belt, Great Belt and Little Belt but only partly in the Mecklenburg Bight, which was similar to our observations made in January 2022. Thus, as already mentioned in the last years' cruise reports (see Funk and Möllmann, 2021, 2022) the question can be raised, if any spawning activity in the central and eastern Mecklenburg Bight (see Figure 5.1.1D) during the survey period would have resulted in successful reproduction.

However, as also already mentioned in the last years' winter cod cruise report (see Funk and Möllmann, 2021, 2022) most of the cod egg buoyancy experiments were conducted with cod samples originating from the north-western Belt Sea and information from the Mecklenburg Bight are extremely limited. Since, in the Arkona Basin neutral cod egg buoyancy was already observed at a salinity of 13.7 PSU ± 1.3 PSU (Nissling and Westin, 1997), at least a potential for a lower salinity threshold for neutral egg buoyancy in Western Baltic cod might be considered. Further egg buoyancy experiments (for example in the framework of future winter cod cruises) may shed light on small scale difference in cod egg buoyancy requirements within the Belt Sea, and thus may provide valuable information on how successful observed spawning activities potentially are.

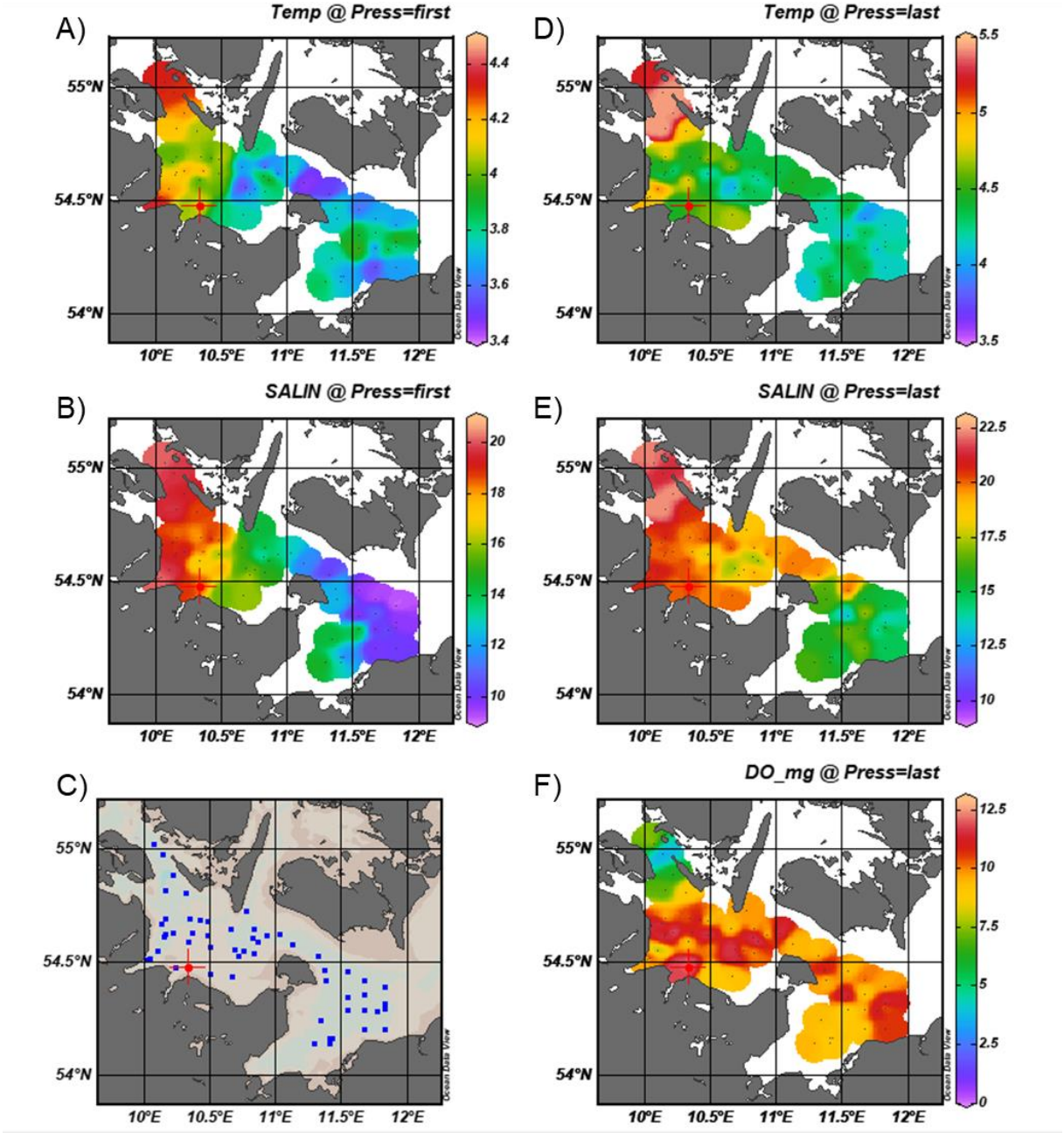

Fig. 5.1.1 Interpolated hydrographic conditions in the Belt Sea in March 2023 obtained from CTD casts (A: Temperature at surface [°C]; B: Salinity at surface [PSU]; C: Map displaying CTD stations, D: temperature at bottom [°C]; E: Salinity [PSU] at bottom; and F: dissolved oxygen at bottom [mg/L]). Graphical visualization was made using the software tool Ocean Data View (Schlitzer. 2018).

5.2 Fishery

(Steffen Funk)

Angling

A total of 33 angling hauls were conducted in Kiel Bight (n = 21), Fehmarn Belt (n = 5) and Mecklenburg Bight (n = 7) (see Fig. 4.1.1).

During angling 336 cod individuals were caught with a total wet weight of 242.435 kg. Lengths of cod caught during angling varied between 20 and 79 cm. Total cod catches per angling station varied between 0 and 41 individuals (Fig. 5.2.1).

Trawling

During AL588, a total of five trawl hauls were conducted in Kiel Bight (n = 3) and in Mecklenburg Bight (n = 2). Due to malfunction during the first haul, this haul yielded a zero catch.

A total of 27 different fish species were recorded in the trawl catches. In total 1127.476 kg of fish had been caught with plaice clearly dominating the catch compositions of all four trawl hauls (Tab. 5.2.2). Cod contributed only to minor fractions of the trawl catches. In total 57 cod individuals with a total weight of 8.367 kg were caught during trawling, with small cod < 20 cm clearly dominating the catches (Tab. 5.2.2).

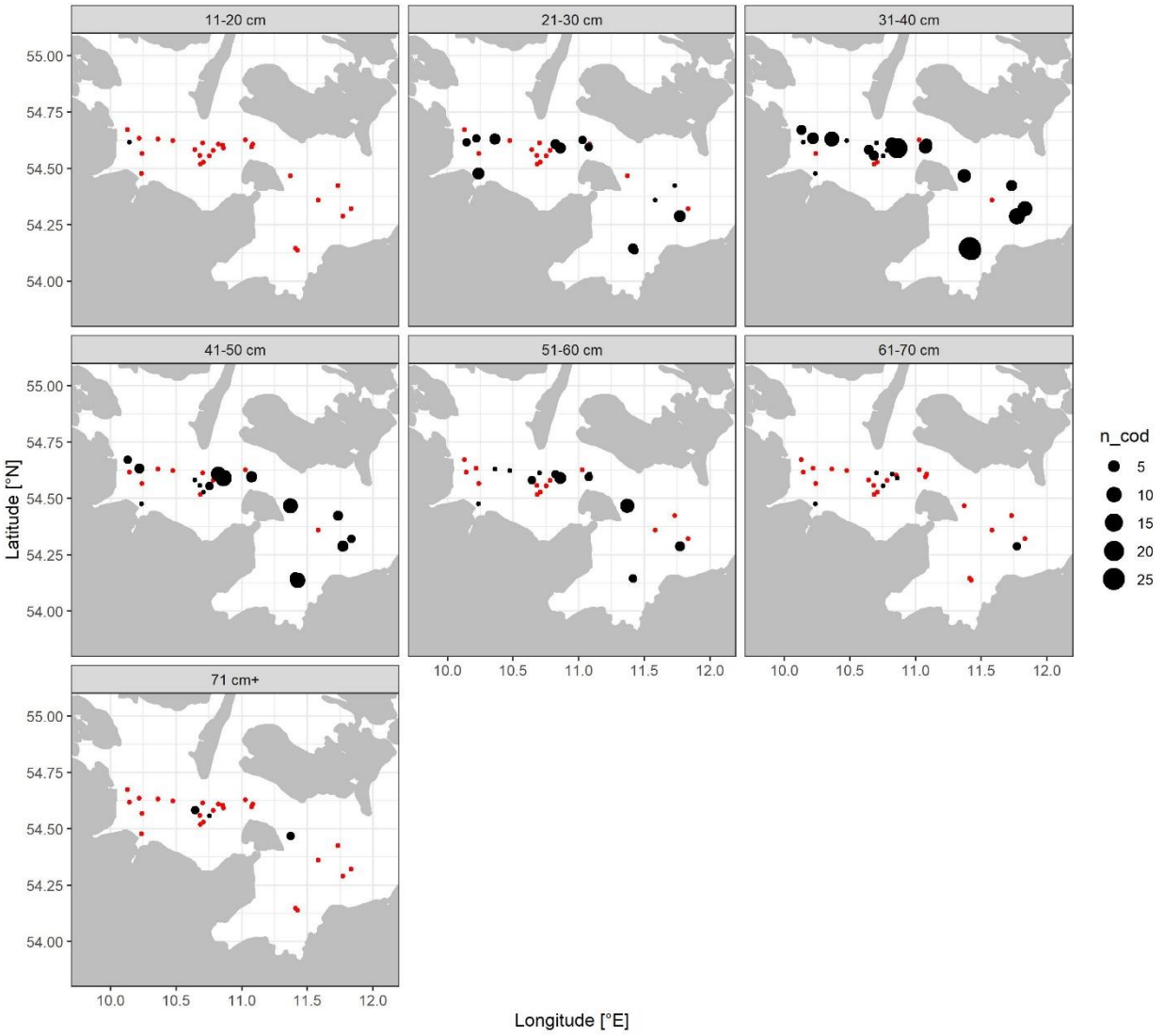

Fig. 5.2.1 Total cod catches per angling station and 10 cm-length class of cod (*two test fishing stations at structured grounds in the western Kiel Bight are not displayed on the map). Sizes of dots correspond to total catches (n_cod). Red dots denote zero catches.

Table 5.2.2 Total catch obtained from trawl fishing during AL588.

Cruise	Year	Month	Day	Gear	Station	Haul	Species	Weight	Numbers
AL588	2023	3	4	TV3_520	48-3	2	*Clupea harengus*	0.04	5
AL588	2023	3	4	TV3_520	48-3	2	*Sprattus sprattus*	58.15	147
AL588	2023	3	4	TV3_520	48-3	2	*Scomber scombrus*	0.62	1
AL588	2023	3	4	TV3_520	48-3	2	*Gadus morhua*	0.806	7
AL588	2023	3	4	TV3_520	48-3	2	*Merlangius merlangus*	252	3
AL588	2023	3	4	TV3_520	48-3	2	*Platichthys flesus*	7.6	35
AL588	2023	3	4	TV3_520	48-3	2	*Limanda limanda*	26.9	315
AL588	2023	3	4	TV3_520	48-3	2	*Pleuronectes platessa*	128.9	2368
AL588	2023	3	4	TV3_520	48-3	2	*Pestta maximus*	0.181	1
AL588	2023	3	4	TV3_520	48-3	2	*Myoxocephalus scorpius*	0.46	7
AL588	2023	3	4	TV3_520	48-3	2	*Lumpenus lampretaeformis*	0.023	3
AL588	2023	3	4	TV3_520	48-3	2	*Zoarces viviparus*	0.068	2
AL588	2023	3	4	TV3_520	48-3	2	*Callionymus lyra*	0.036	1
AL588	2023	3	6	TV3_520	58-2	3	*Engraulis encrasicolus*	0.016	4
AL588	2023	3	6	TV3_520	58-2	3	*Scomber scombrus*	0.846	12
AL588	2023	3	6	TV3_520	58-2	3	*Clupea harengus*	0.015	110
AL588	2023	3	6	TV3_520	58-2	3	*Sprattus sprattus*	0.017	365
AL588	2023	3	6	TV3_520	58-2	3	*Gadus morhua*	6.817	35
AL588	2023	3	6	TV3_520	58-2	3	*Merlangius merlangus*	10.332	170
AL588	2023	3	6	TV3_520	58-2	3	*Arnoglossus laterna*	0.008	1
AL588	2023	3	6	TV3_520	58-2	3	*Microstomus kitt*	0.544	1
AL588	2023	3	6	TV3_520	58-2	3	*Myoxocephalus scorpius*	0.114	1
AL588	2023	3	6	TV3_520	58-2	3	*Callionymus lyra*	0.032	1
AL588	2023	3	6	TV3_520	58-2	3	*Enchelyopus cimbrius*	0.224	4
AL588	2023	3	6	TV3_520	58-2	3	*Rhinonemus cimbrius*	0.049	7
AL588	2023	3	6	TV3_520	58-2	3	*Zoarces viviparus*	0.019	42
AL588	2023	3	6	TV3_520	58-2	3	*Platichthys flesus*	0.21	306
AL588	2023	3	6	TV3_520	58-2	3	*Limanda limanda*	0.057	261
AL588	2023	3	6	TV3_520	58-2	3	*Pleuronectes platessa*	0.061	560
AL588	2023	3	6	TV3_520	58-2	3	*Solea solea*	0.159	16
AL588	2023	3	6	TV3_520	58-2	3	*Hippoglossoides platessoides*	0.033	163
AL588	2023	3	6	TV3_520	58-2	3	*Pomatoschistus sp.*	0.002	1
AL588	2023	3	6	TV3_520	58-2	3	*Neogobius melanostomus*	0.012	1
AL588	2023	3	6	TV3_520	58-2	3	*Agonus cataphractus*	0.02	2
AL588	2023	3	6	TV3_520	59-2	4	*Clupea harengus*	2.756	302
AL588	2023	3	6	TV3_520	59-2	4	*Sprattus sprattus*	5.742	725
AL588	2023	3	6	TV3_520	59-2	4	*Engraulis encrasicolus*	0.014	3
AL588	2023	3	6	TV3_520	59-2	4	*Gadus morhua*	0.744	15
AL588	2023	3	6	TV3_520	59-2	4	*Merlangius merlangus*	2.738	36

AL588	2023	3	6	TV3_520	59-2	4	*Enchelyopus cimbrius*	0.054	1
AL588	2023	3	6	TV3_520	59-2	4	*Platichthys flesus*	16.34	70
AL588	2023	3	6	TV3_520	59-2	4	*Limanda limanda*	57.94	903
AL588	2023	3	6	TV3_520	59-2	4	*Pleuronectes platessa*	232.82	4358
AL588	2023	3	6	TV3_520	59-2	4	*Scophthalmus maximus*	1.94	2
AL588	2023	3	6	TV3_520	59-2	4	*Myoxocephalus scorpius*	0.208	5
AL588	2023	3	6	TV3_520	59-2	4	*Hyperoplus lanceolatus*	0.002	1
AL588	2023	3	6	TV3_520	59-2	4	*Lumpenus lampretaeformis*	0.036	4
AL588	2023	3	6	TV3_520	59-2	4	*Zoarces viviparus*	0.17	6
AL588	2023	3	8	TV3_520	62-3	5	*Clupea harengus*	0.801	169
AL588	2023	3	8	TV3_520	62-3	5	*Sprattus sprattus*	0.19	15
AL588	2023	3	8	TV3_520	62-3	5	*Engraulis encrasicolus*	0.263	48
AL588	2023	3	8	TV3_520	62-3	5	*Merlangius merlangus*	0.11	6
AL588	2023	3	8	TV3_520	62-3	5	*Melannogrammus aeglefinus*	0.417	6
AL588	2023	3	8	TV3_520	62-3	5	*Platichthys flesus*	5.81	27
AL588	2023	3	8	TV3_520	62-3	5	*Limanda limanda*	130.86	2093
AL588	2023	3	8	TV3_520	62-3	5	*Pleuronectes platessa*	171.73	2553
AL588	2023	3	8	TV3_520	62-3	5	*Myoxocephalus scorpius*	0.299	5
AL588	2023	3	8	TV3_520	62-3	5	*Pomatoschistus sp.*	0.045	28
AL588	2023	3	8	TV3_520	62-3	5	*Neogobius melanostomus*	0.035	2
AL588	2023	3	8	TV3_520	62-3	5	*Glyptocephalus cynoglossus*	0.041	1

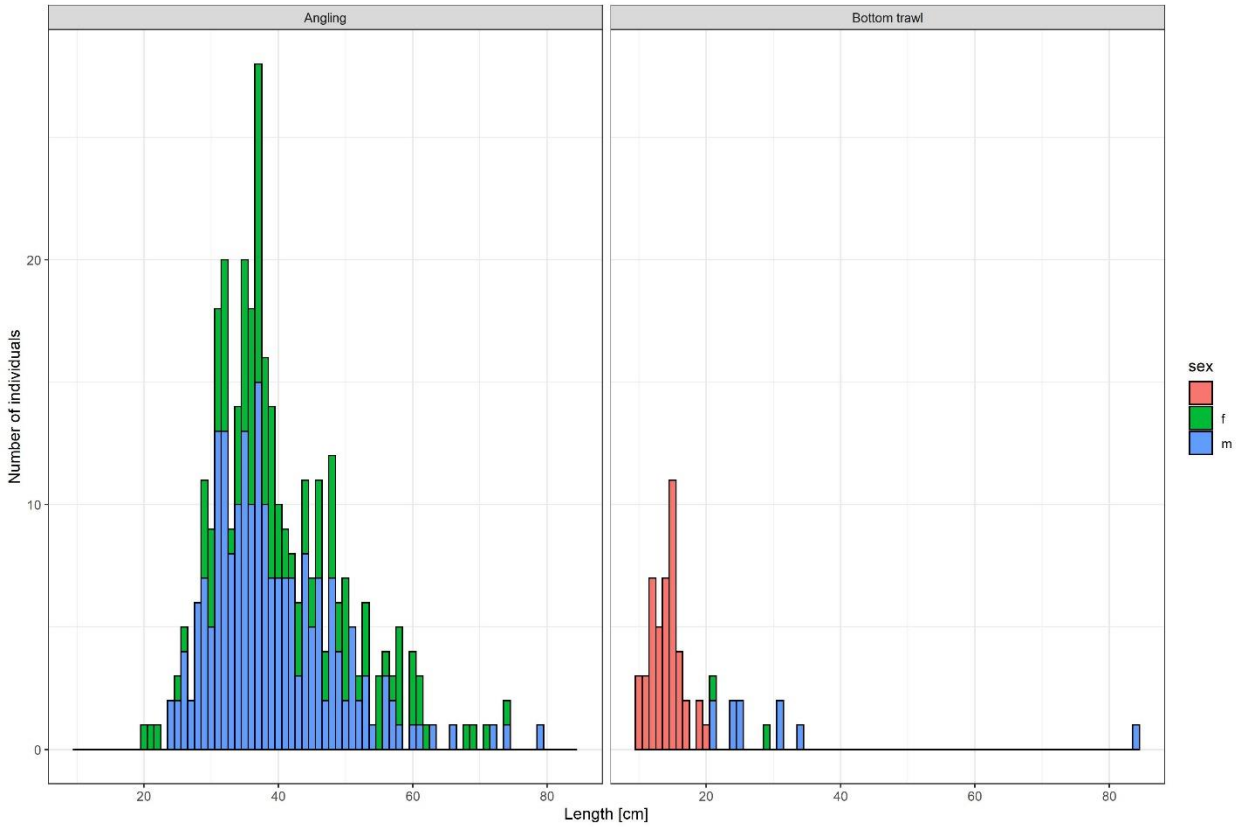

Fig. 5.2.3 Length distribution of cod catches during AL588 from angling (left panel) and bottom trawling (right panel). Colours denote cod sexed (blue = male, green = female, red = unsexed individuals which will be sexed during later analysis in the laboratory of the UHAM).

Catch comparison

Overall, our angling activities can be seen as highly cod selective fishing activities especially when comparing the total catches with those obtained from our trawling activities with the standard BITS trawl TV3/520.

The minor cod catches resulting from trawling stand in line with our results from AL568b and AL585 where we also struggled to catch cod at soft bottom substrates during angling and trawling, while wreck and reef sides yielded comparable good catches. In 2022 we already hypothesized that soft bottom habitat use of cod might be driven by overall cod density and thus stock biomass. With soft bottom being rather unfavoured habitats for cod (Funk and Möllmann, 2022). Our catches suggest that cod favour structured habitats also during spawning time.

Interestingly, similar to our observation during AL585 in January 2023, cod < 20 cm were absent in our angling samplings during AL588.

Results from test fishing at the GEOMAR pier, where we caught cod < 15 cm with the same bait we used for wreck fishing, showed that smaller cod can also be caught with these baits. Therefore, it seems unlikely that the absence of cod catches < 20 cm can be explained by size selectivity of the gear we used. Rather, a general absence of cod at these wreck sites could be considered, most likely to minimise the risk of predation by larger conspecifics.

Cod maturity stages

In all areas ripe cod individuals were found (Fig. 5.2.4), which means cod in maturity stages in 5 to 7 (“early spawning stage”, “main spawning stage”, and “late spawning stage”). All cod staging was determined following the guidelines of Tomkiewicz et al. (2002). Mature female individuals were mostly found in maturity stages five to eight (i.e., from “early spawning stage” to “post-spawning stage”) while mature male individuals were found mostly in stages six and seven (i.e., “main spawning stage” and “late spawning stage”). Our results suggest that female spawning activity was more advanced at the beginning of March 2023 than at the end of January 2023. Furthermore, the observation of several individuals in post-spawning stage suggests that beginning of march rather reflects the end of peak-spawning activity than the beginning of the peak spawning activity of WBC in the area. However, in the literature peak spawning activity was reported to be happen in the area between March and April (see Bleil and Oeberst, 1997; Bleil et al., 2009).

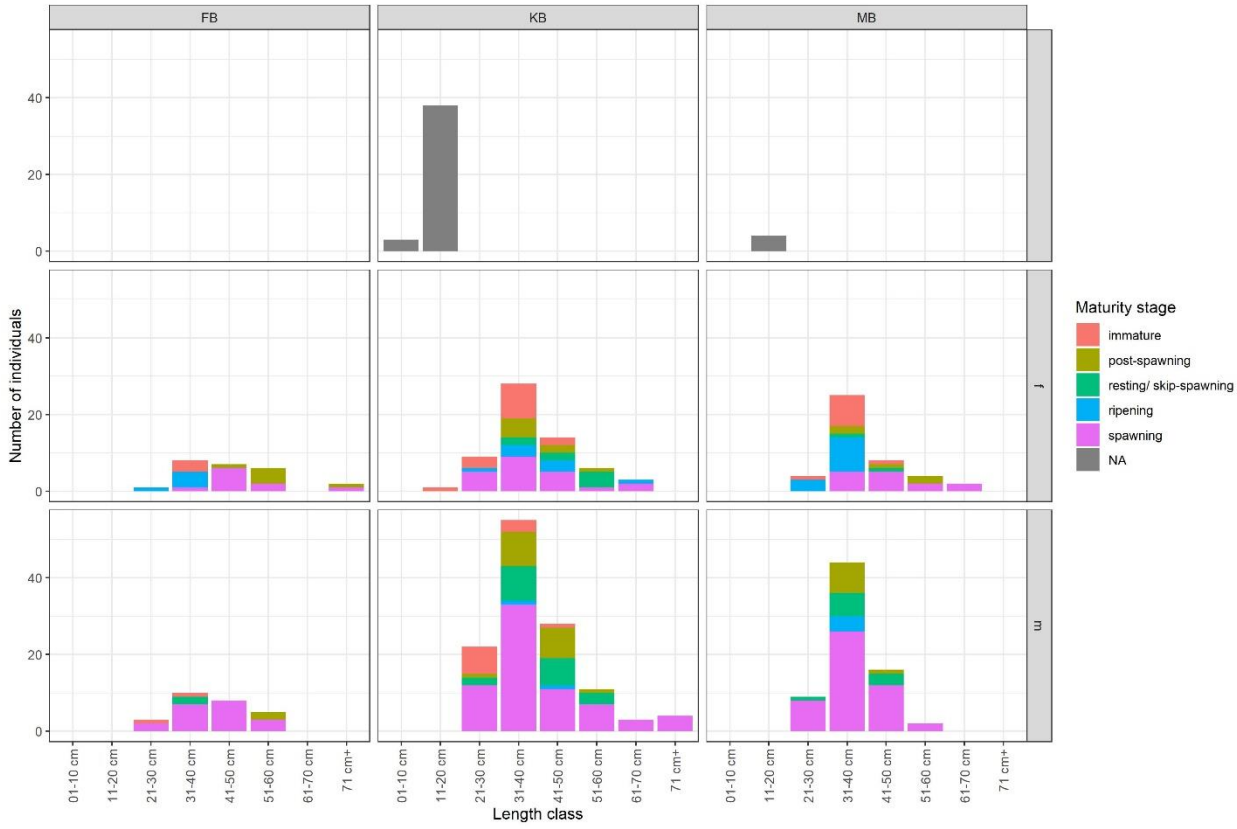

Fig. 5.2.5 Maturity stage distribution of cod caught during AL588 per sex and 10 cm-length class (f = females, m = males) and subarea (FB = Fehmarn Belt, KB = Kiel Bight, MB = Mecklenburg Bight). Colours denote maturity stages (upper panel with NAs = unsexed small cod which will be sexed during later analysis in the laboratory of the UHAM).

5.3 Ichthyo- and Zooplankton Sampling

(Steffen Funk)

Zoo- and ichthyoplankton samples were obtained from a total of 43 BONGO stations. BONGO net 500 µm samples were also checked directly on board for occurrence of cod larvae by trained scientists (Richard Klinger and Anton Höper). Cod larvae were picked out of the samples and

deep frozen for later condition and otolith microstructure analysis. The rest of the plankton samples were conserved in formalin for later species- and size-composition analysis in the laboratory.

Cod larvae

In total we found a total number of 96 cod larvae in the BONGO net 500 µm samples, with most larvae per area observed in the Kiel Bight. Highest total number of cod larvae per Bongo haul was observed in the Little Belt with a total of 17 at GS 41 (Fig. 5.3.1).

In the Mecklenburg Bight a relatively low total number of cod larvae was observed with 5. Whether this relatively low number can be explained by low spawning activity in the area, by a transport of larvae from eastern to western areas of the Belt Sea due to wind-driven water currents, or by the low salinity levels (which either caused neutral egg emergence only in water layers close to the bottom and thus in areas that were only partially sampled with the Bongo net, as we used a safety distance of about 2 m to the bottom, or which possibly caused the eggs to sink and die) can only be speculated. Most likely it is a combination of several of these possible explanations.

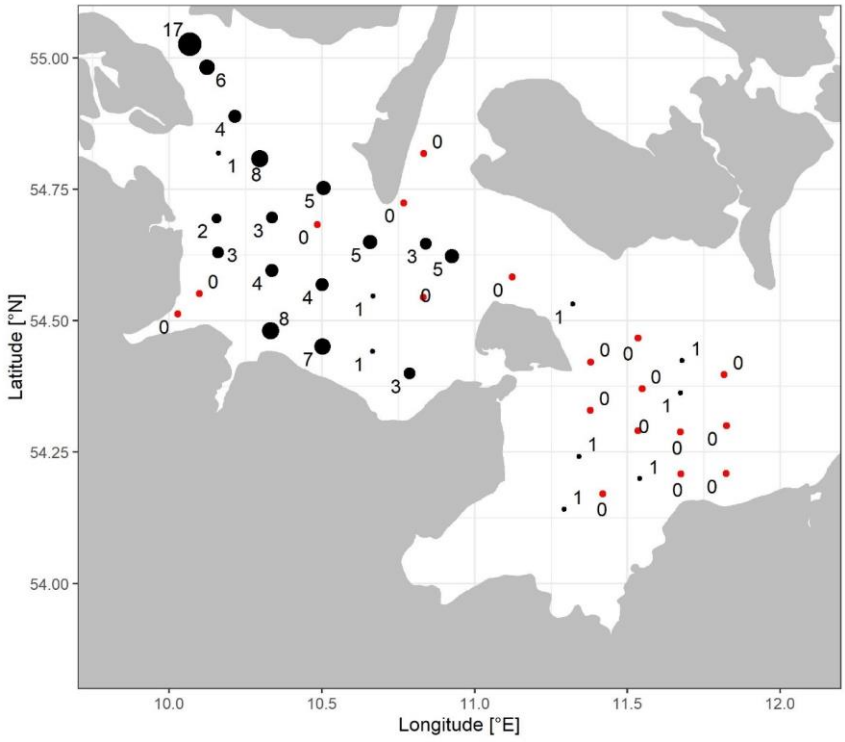

Fig. 5.3.1 Number of cod larvae observed in BONGO 500 µm net samples during AL588 (black dots and numbers). Red dots denote BONGO stations where no cod larvae were caught.

Other fish larvae

Despite larvae of cod, we also found a variety of other fish larvae such as for example flatfish larvae (i.e., plaice [*Pleuronectes platessa*] and flounder [*Platichthys flesus*]), larvae of hooknose (*Agonus cataphractus*), longspined bullhead (*Taurulus bubalis*), butterfish (*Pholis gunnellus*) and clupeids.

Cacthes of flatfish larvae from our Bongo 500 µm net samples, showed a spatial distribution pattern similar to those of cod with in general higher total numbers observed in the western parts of the study area. Highest total numbers per flatfish larvae and haul were observed at the western entrance to the Fehmarn Belt at GS 17 with a total number of 88 larvae (Fig. 5.3.2).

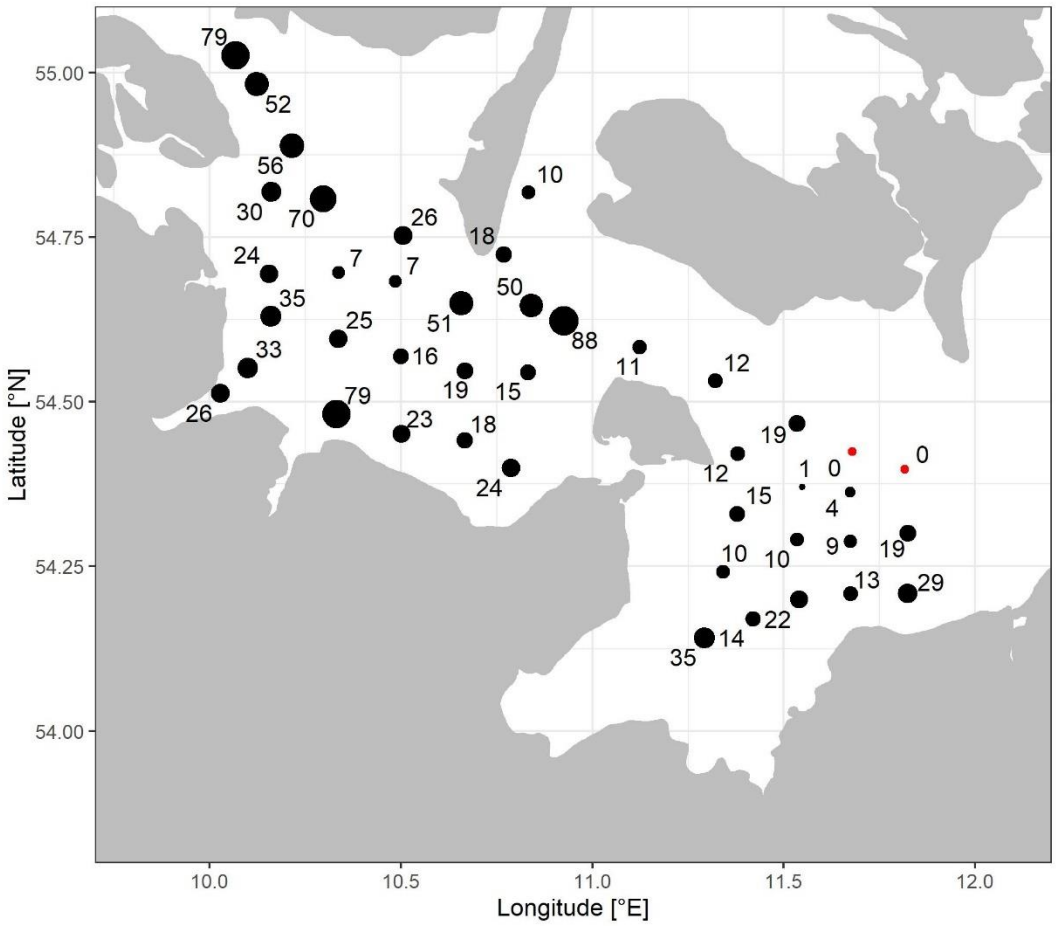

Fig. 5.3.2 Number of flatfish (i.e., plaice *Pleuronectes platessa*, flounder *Platichthys flesus* and common dab *Limanda limanda* larvae observed in BONGO 500 µm net samples during AL588 (black dots and numbers). Red dots denote BONGO stations where no flatfish larvae were caught.

6 Station List AL588

In total 165 gear deployments were conducted during the cruise AL588 (see Tab. 6.1.1 for the full station list). The electronic version of the station list as well as additional cruise data are permanently stored at the field data server of the Institute of Marine Ecosystem and Fisheries Science (IMF) of the University of Hamburg and are available on request. Furthermore, it is planned to make additional cruise data of AL588 (including for example station data, catch data and individual fish data of cod, as well as cod stomach content data) publicly available via the public data repository PANGEA (for further details see also section 7 “Data, Sample Storage and Availability” and Tab. 7.1.1).

6.1 Overall Station List

Table 6.1.1 Station List with all gear deployments during AL585 with CTD = CTD probe. BONGO = BONGO net with 150. 300 and 500 µm nets. RF = rod and reel fishery. Bucket = surface water sampler. AL 585 Stat. = Station number. Depth = water depth at station. and duration = duration of gear deployment.

Station AL588	Date 2023	Gear	Latitude	Longitude	Depth (m)	Duration [min]
1-1	1.3	CTD	54° 28.937' N	010° 19.932' E	19	5
1-2	1.3	BUCKET	54° 28.924' N	010° 19.867' E	19	2
1-3	1.3	BONGO	54° 28.895' N	010° 19.851' E	19	5
2-1	1.3	BONGO	54° 30.758' N	010° 01.717' E	27	5
2-2	1.3	CTD	54° 30.776' N	010° 01.256' E	27	3
3-1	1.3	CTD	54° 33.130' N	010° 06.024' E	27	3
3-2	1.3	BUCKET	54° 33.136' N	010° 05.996' E	28	2
3-3	1.3	BONGO	54° 33.107' N	010° 05.906' E	28	4
4-1	1.3	BONGO	54° 37.773' N	010° 09.623' E	22	3
4-2	1.3	CTD	54° 37.793' N	010° 09.207' E	23	2
5-1	1.3	CTD	54° 41.701' N	010° 09.402' E	31	2
5-2	1.3	BONGO	54° 41.692' N	010° 09.249' E	28	3
6-1	1.3	BONGO	54° 49.141' N	010° 09.654' E	31	3
6-2	1.3	CTD	54° 49.364' N	010° 09.584' E	31	3
7-1	1.3	CTD	55° 01.505' N	010° 03.976' E	36	3
7-2	1.3	BUCKET	55° 01.523' N	010° 03.971' E	36	3
7-3	1.3	BONGO	55° 01.552' N	010° 04.024' E	36	7
8-1	1.3	BONGO	54° 58.933' N	010° 07.390' E	37	6
8-2	1.3	CTD	54° 58.748' N	010° 07.935' E	38	3
9-1	1.3	CTD	54° 53.332' N	010° 12.788' E	30	2
9-2	1.3	BONGO	54° 53.328' N	010° 12.853' E	30	5
10-1	1.3	BONGO	54° 48.494' N	010° 17.756' E	30	6
10-2	1.3	CTD	54° 48.538' N	010° 18.419' E	33	3
11-1	1.3	CTD	54° 45.199' N	010° 30.214' E	28	2
11-2	1.3	BUCKET	54° 45.195' N	010° 30.194' E	28	2
11-3	1.3	BONGO	54° 45.158' N	010° 30.300' E	28	4
12-1	1.3	BONGO	54° 40.990' N	010° 29.128' E	32	6
12-2	1.3	CTD	54° 41.040' N	010° 28.548' E	31	3
13-1	1.3	CTD	54° 41.723' N	010° 20.258' E	32	2
13-2	1.3	BONGO	54° 41.755' N	010° 20.227' E	32	3
14-1	1.3	BONGO	54° 35.757' N	010° 20.098' E	16	2
14-2	1.3	CTD	54° 35.603' N	010° 20.020' E	16	2
15-1	1.3	CTD	54° 34.176' N	010° 30.029' E	19	2
15-2	1.3	BONGO	54° 34.132' N	010° 29.969' E	19	4
16-1	1.3	BONGO	54° 27.059' N	010° 30.051' E	17	3
16-2	1.3	CTD	54° 26.908' N	010° 29.942' E	17	2

17-1	1.3	CTD	54° 26.470' N	010° 39.968' E	18	3
17-2	1.3	BONGO	54° 26.494' N	010° 39.975' E	18	2
18-1	1.3	BONGO	54° 23.967' N	010° 47.190' E	18	2
18-2	1.3	CTD	54° 23.876' N	010° 47.408' E	18	2
19-1	1.3	CTD	54° 32.684' N	010° 50.030' E	22	2
19-2	1.3	BONGO	54° 32.667' N	010° 49.891' E	21	3
20-1	2.3	BONGO	54° 32.804' N	010° 40.029' E	20	3
20-2	2.3	CTD	54° 32.962' N	010° 39.869' E	20	2
21-1	2.3	CTD	54° 38.965' N	010° 39.560' E	32	3
21-2	2.3	BONGO	54° 38.969' N	010° 39.465' E	33	4
22-1	2.3	BONGO	54° 43.444' N	010° 46.035' E	33	3
22-2	2.3	CTD	54° 43.657' N	010° 46.070' E	34	3
23-1	2.3	CTD	54° 48.983' N	010° 49.867' E	37	3
23-2	2.3	BONGO	54° 49.064' N	010° 49.954' E	38	6
24-1	2.3	BONGO	54° 38.787' N	010° 50.378' E	33	3
24-2	2.3	CTD	54° 38.871' N	010° 49.869' E	37	3
24-3	2.3	BUCKET	54° 38.837' N	010° 49.840' E	37	2
25-1	2.3	CTD	54° 37.340' N	010° 55.643' E	36	3
25-2	2.3	BONGO	54° 37.374' N	010° 55.511' E	37	6
26-1	2.3	BONGO	54° 35.007' N	011° 07.324' E	28	5
26-2	2.3	CTD	54° 35.068' N	011° 07.737' E	29	2
27-1	2.3	CTD	54° 31.883' N	011° 19.246' E	30	2
27-2	2.3	BONGO	54° 31.890' N	011° 19.293' E	30	5
28-1	2.3	BONGO	54° 28.027' N	011° 32.100' E	25	4
28-2	2.3	CTD	54° 27.848' N	011° 32.438' E	25	2
29-1	2.3	CTD	54° 25.526' N	011° 40.428' E	24	3
29-2	2.3	BUCKET	54° 25.503' N	011° 40.501' E	24	1
29-3	2.3	BONGO	54° 25.482' N	011° 40.734' E	24	5
30-1	2.3	BONGO	54° 23.848' N	011° 49.005' E	22	4
30-2	2.3	CTD	54° 23.779' N	011° 49.465' E	21	2
31-1	2.3	CTD	54° 17.983' N	011° 49.414' E	23	3
31-2	2.3	BONGO	54° 17.997' N	011° 49.451' E	23	5
32-1	2.3	BONGO	54° 12.566' N	011° 49.342' E	21	3
32-2	2.3	CTD	54° 12.496' N	011° 49.641' E	21	2
33-1	2.3	CTD	54° 12.492' N	011° 40.405' E	25	2
33-2	2.3	BONGO	54° 12.527' N	011° 40.489' E	25	3
34-1	2.3	BONGO	54° 17.292' N	011° 40.372' E	25	2
34-2	2.3	CTD	54° 17.492' N	011° 40.371' E	25	2
35-1	2.3	CTD	54° 21.675' N	011° 40.567' E	25	3
35-2	2.3	BONGO	54° 21.772' N	011° 40.388' E	25	3
36-1	2.3	BONGO	54° 22.252' N	011° 32.875' E	25	4
36-2	2.3	CTD	54° 22.178' N	011° 32.534' E	25	2
37-1	2.3	CTD	54° 25.239' N	011° 22.738' E	20	1

37-2	2.3	BUCKET	54° 25.246' N	011° 22.755' E	20	2
37-3	2.3	BONGO	54° 25.285' N	011° 22.763' E	22	3
38-1	2.3	FR	54° 28.052' N	011° 22.242' E	22	66
38-2	2.3	CTD	54° 28.055' N	011° 22.259' E	24	3
39-1	2.3	CTD	54° 19.720' N	011° 22.692' E	22	2
39-2	2.3	BONGO	54° 19.763' N	011° 22.689' E	22	3
40-1	2.3	BONGO	54° 17.464' N	011° 32.111' E	24	3
40-2	2.3	CTD	54° 17.381' N	011° 32.482' E	24	2
41-1	2.3	CTD	54° 11.971' N	011° 32.534' E	24	2
41-2	2.3	BONGO	54° 11.966' N	011° 32.433' E	24	3
42-1	2.3	BONGO	54° 10.241' N	011° 25.162' E	23	4
42-2	2.3	CTD	54° 10.173' N	011° 24.713' E	23	2
43-1	2.3	CTD	54° 08.509' N	011° 17.606' E	26	2
43-2	2.3	BONGO	54° 08.489' N	011° 17.588' E	26	4
44-1	2.3	BONGO	54° 14.522' N	011° 20.485' E	21	3
44-2	2.3	CTD	54° 14.697' N	011° 20.608' E	21	2
45-1	3.3	FR	54° 08.242' N	011° 25.463' E	22	59
45-2	3.3	FR	54° 08.791' N	011° 24.700' E	22	77
45-3	3.3	CTD	54° 08.806' N	011° 24.701' E	22	2
46-1	3.3	CTD	54° 09.912' N	011° 25.619' E	23	3
46-2	3.3	BUCKET	54° 09.888' N	011° 25.595' E	23	3
46-3	3.3	BT	54° 09.527' N	011° 24.431' E	23	30
47-1	3.3	CTD	54° 12.515' N	011° 49.596' E	21	2
47-2	3.3	BUCKET	54° 12.504' N	011° 49.592' E	21	2
48-1	4.3	CTD	54° 20.802' N	011° 32.532' E	25	3
48-2	4.3	MN_S5	54° 20.816' N	011° 32.396' E	25	25
48-3	4.3	BT	54° 20.576' N	011° 32.730' E	25	15
48-4	4.3	FR	54° 21.575' N	011° 35.017' E	26	24
49-1	4.3	FR	54° 19.276' N	011° 49.979' E	24	29
49-2	4.3	CTD	54° 19.284' N	011° 49.996' E	23	3
50-1	4.3	FR	54° 17.339' N	011° 46.258' E	25	39
50-2	4.3	CTD	54° 17.345' N	011° 46.275' E	26	2
51-1	4.3	FR	54° 25.462' N	011° 43.957' E	24	38
51-2	4.3	CTD	54° 25.460' N	011° 43.959' E	25	4
52-1	5.3	CTD	54° 27.990' N	011° 22.242' E	24	3
52-2	5.3	MN_S5	54° 28.006' N	011° 22.171' E	23	14
52-3	5.3	FR	54° 28.042' N	011° 22.256' E	24	28
53-1	5.3	FR	54° 35.749' N	011° 04.569' E	31	39
53-2	5.3	FR	54° 36.476' N	011° 05.071' E	27	20
53-3	5.3	CTD	54° 36.511' N	011° 05.025' E	26	5
54-1	5.3	FR	54° 37.619' N	011° 01.759' E	17	15
54-2	5.3	CTD	54° 37.605' N	011° 01.746' E	17	1
55-1	5.3	FR	54° 36.211' N	010° 51.323' E	21	31

55-2	5.3	FR	54° 36.494' N	010° 49.366' E	21	33
55-3	5.3	CTD	54° 36.508' N	010° 49.361' E	22	2
55-4	5.3	MN_S5	54° 36.552' N	010° 48.677' E	22	9
56-1	5.3	FR	54° 35.491' N	010° 51.598' E	20	50
56-2	5.3	CTD	54° 35.494' N	010° 51.577' E	20	2
57-1	5.3	FR	54° 34.863' N	010° 47.001' E	23	25
57-2	5.3	FR	54° 33.352' N	010° 45.166' E	23	11
57-3	5.3	CTD	54° 33.346' N	010° 45.120' E	23	2
58-1	6.3	CTD	54° 41.251' N	010° 25.213' E	31	2
58-2	6.3	BT	54° 41.207' N	010° 25.481' E	31	24
59-1	6.3	CTD	54° 43.896' N	010° 11.650' E	24	3
59-2	6.3	BT	54° 44.384' N	010° 10.669' E	24	27
60-1	6.3	FR	54° 33.980' N	010° 14.307' E	19	14
61-1	6.3	FR	54° 28.643' N	010° 14.275' E	19	41
61-2	6.3	CTD	54° 28.642' N	010° 14.262' E	19	3
62-1	8.3	CTD	54° 31.273' N	010° 02.070' E	28	3
62-2	8.3	MN_S5	54° 31.202' N	010° 02.007' E	28	3
62-2	8.3	MN_S5	54° 30.650' N	010° 01.605' E	26	11
62-3	8.3	BT	54° 31.597' N	010° 02.478' E	28	30
63-1	8.3	FR	54° 37.065' N	010° 08.611' E	18	21
63-2	8.3	CTD	54° 37.069' N	010° 08.586' E	23	2
64-1	8.3	FR	54° 40.341' N	010° 07.717' E	17	31
64-2	8.3	CTD	54° 40.320' N	010° 07.687' E	19	2
65-1	8.3	FR	54° 38.037' N	010° 13.171' E	21	34
65-2	8.3	CTD	54° 37.999' N	010° 13.149' E	22	2
66-1	8.3	FR	54° 37.842' N	010° 21.657' E	20	32
66-2	8.3	CTD	54° 37.830' N	010° 21.669' E	21	1
67-1	8.3	FR	54° 37.403' N	010° 28.564' E	19	18
67-2	8.3	CTD	54° 37.399' N	010° 28.569' E	19	2
68-1	8.3	FR	54° 34.994' N	010° 38.630' E	22	35
68-2	8.3	FR	54° 36.811' N	010° 42.094' E	25	43
68-3	8.3	CTD	54° 36.810' N	010° 42.129' E	25	2
69-1	9.3	FR	54° 31.137' N	010° 41.052' E	20	23
69-2	9.3	FR	54° 31.719' N	010° 42.565' E	19	17
69-3	9.3	CTD	54° 31.716' N	010° 42.547' E	19	2
70-1	9.3	FR	54° 33.501' N	010° 40.863' E	21	19
70-2	9.3	CTD	54° 33.494' N	010° 40.919' E	22	2
71-1	9.3	FR	54° 36.498' N	010° 49.357' E	22	42
71-2	9.3	FR	54° 36.217' N	010° 51.330' E	21	23
71-3	9.3	FR	54° 35.491' N	010° 51.595' E	20	28
71-4	9.3	FR	54° 35.501' N	010° 51.598' E	20	25
71-5	9.3	CTD	54° 35.514' N	010° 51.620' E	20	2
72-1	9.3	FR	54° 34.858' N	010° 46.996' E	22	13

7 Data and Sample Storage and Availability

All data obtained during the cruise have been backed up on the field data server of the IMF of the University of Hamburg. In addition, data have been backed up and stored on different hard drives at different locations. Paper protocols filled out during the cruise were entered electronically and thus already felt under the back-up scheme, applied for the rest of the cruise data (including all cruise meta data such as the output of the onboard DSHIP-System). In addition, paper protocols were also conserved as hard copy at the IMF.

Furthermore, we aim to make all data obtained during the cruise AL588 publicly available. Hydrographic data (CTD) will be submitted to PANGEA (also planned to be uploaded on the ICES Oceanographic database) within one year from the cruise. Furthermore, it is planned to upload fishery data (including cod single fish data) in the public data repository PANGEA.
Depending on the data set, some of the data (especially including all zooplankton & ichthyoplankton data) are intended for specific publications. In the context of publication these data will be made publicly available. Right after analysing the taken cod stomach samples, stomach data will be added to the cod stomach data base of the IMF and Thuenen-OF. It is planned to make the whole Belt Sea cod stomach data publicly available.

All plankton samples obtained during the cruise AL588 and preserved in formalin were labelled directly on board using a barcoding scheme and were archived at the IMF. Please contact the responsible persons for a corresponding data set (see Tab. 7.1.1) if earlier access to the data is desired.

Table 7.1 Overview of data. data availability and corresponding contact persons (responsible for the specific data sets).

Data	Database	Available	Free Access	Contact
Hydrography (CTD data)	PANGEA/ ICES database	Publicly by March 2024. earlier on request	By March 2024	steffen.funk@uni-hamburg.de
Fishery data	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)	at time of publishing of the underlying peer-reviewed publication	steffen.funk@uni-hamburg.de
Cod stomach content data	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)	at time of publishing of the underlying peer-reviewed publication	steffen.funk@uni-hamburg.de
Ichthyoplankton	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)	at time of publishing of the underlying peer-reviewed publication	christian.moellmann@uni-hamburg.de
Zooplankton	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)	at time of publishing of the underlying peer-reviewed publication	christian.moellmann@uni-hamburg.de
Hydroacoustic data	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)	at time of publishing of the underlying peer-reviewed publication	christian.moellmann@uni-hamburg.de

8 Acknowledgements

We thank Captain Jan Lass and the entire crew of RV ALKOR for their outstanding support and the excellent and constructive working atmosphere during the cruise AL588. We also thank the whole scientific staff of the IMF our colleague Jan Dierking from the GEOMAR our colleague Gotje von Leesen (who took part in the role of a Danish observer) from the University of Aarhus for their unwavering support during the cruise, their motivation and enthusiasm bringing this cruise to a scientific success.

9 References

Bleil, M., and Oeberst, R., 1997. The timing of the reproduction of cod (*Gadus morhua morhua*) in the western Baltic and adjacent areas. ICES CM 1997/CC: 02.

Bleil, M., Oeberst, R., and Urrutia, P., 2009. Seasonal maturity development of Baltic cod in different spawning areas: importance of the Arkona Sea for the summer spawning stock. Journal of Applied Ichthyology, 25: 10-17.

Funk, S., 2020. Spatio-temporal distribution, food intake and growth of cod (*Gadus morhua* L.) in the Western Baltic Sea. Doctoral Dissertation, University of Hamburg, Hamburg, Germany. 211pp.

Funk, S., Frelat, R., Möllmann, C., Temming, A., and Krumme, U., 2021b. The forgotten feeding ground: patterns in seasonal and depth-specific food intake of adult cod *Gadus morhua* in the western Baltic Sea. Journal of Fish Biology, 98(3): 707-722.

Funk, S., and Möllmann, C. 2021. Monitoring winter spawning activity of Western Baltic cod (*Gadus morhua*) (2021-2025) – Cruise No. AL549. ALKOR Berichte, 24pp.

Funk, S., and Möllmann, C. 2022. Monitoring winter spawning activity of Western Baltic cod (*Gadus morhua*) (2021-2025) – Cruise No. AL568b. ALKOR Berichte, 30pp.

ICES, 2019. Benchmark Workshop on Baltic Cod Stocks (WKBALTCOD2). ICES Scientific Reports. 1:9. 310 pp. Available at: http://doi.org/10.17895/ices.pub.4984 (last accessed 4 May 2020)

Leppäranta, M., and Myrberg, K., 2000. Physical Oceanography of the Baltic Sea. Berlin – Heidelberg – New York, Springer

McQueen, K., and Marshall, C.T., 2017. Shifts in spawning phenology of cod linked to rising sea temperatures. ICES Journal of Marine Science, 74(6): 1561-1573.

Nissling, A., and Westin, L., 1997. Salinity requirements for successful spawning of Baltic and Belt Sea cod and the potential for cod stock interactions in the Baltic Sea. Marine Ecology Progress Series, 152: 261-271.

Schlitzer, R. 2018. Ocean Data View, https://odv.awi.de

Snoeijs-Leijonmalm, P., and Andrén, E., 2017. Why is the Baltic Sea so special to live in? In P. Snoeijs-Leijonmalm, H. Schubert, & T. Radziejewska (Eds.) Biological Oceanography of the Baltic Sea (pp. 23-84). Dordrecht, Springer

Tomkiewicz, J., Tybjerg, L., Holm, N., Hansen, A., Broberg, C., and Hansen, E., 2002 Manual to determine gonadal maturity of Baltic cod. Charlottenlund: Danish Institute for Fisheries Research, DFU-116-02. 49pp.

von Westernhagen, H., 1970. Erbrüten der Eier von Dorsch (*Gadus morhua*), Flunder (*Pleuronectes flesus*) and Scholle (*Pleuronectes platessa*) unter kombinierten Temperatur-

und Salzgehaltsbedingungen. Helogoländer Wissenschaftliche Meeresuntersuchungen, 21: 21-102.

Westerberg, H. 1994. The transport of cod eggs and larvae through Öresund. ICES CM 1994/Q: 4.

10 Abbreviations

AU – Aarhus University
BITS – Baltic international trawl survey
DTU – Danish Technical University
ICES – International Council for the Exploration of the Sea
IMF – Institute of Marine Ecosystem and Fisheries Science
UHAM – University of Hamburg
Thuenen-OF – Thuenen Institute of Baltic Sea Fisheries Rostock
WBC – Western Baltic cod