

ALKOR-Berichte

***Monitoring winter spawning activity of Western Baltic cod
(Gadus morhua) (2021-25)***

Cruise No. AL549

January 25th – February 1st 2021
Kiel (Germany) – Kiel (Germany)
Winter cod 2021-25

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2021

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1 Cruise Summary

1.1 Summary in English

The Western Baltic cod stock is currently in distress, which is largely associated with several years of only low recruitment success. The reasons for these several years of low recruitment are not understood sufficiently so far. However, there are indications for a (potentially climate-induced) shift in spawning phenology shifting spawning activity (peaking usually in March) to an earlier time, probably causing mismatch of cod larvae and zooplankton food and thus leading to a poor larval survival. This cruise was the first out of five proposed cruises in the framework of the winter cod 2021-25 cruises of the IMF, which aim to investigate the early winter spawning activity of Western Baltic cod.

For this purpose, ichthyoplankton samples and cod samples were taken on a for-defined station grid. Cod samples were used to investigate maturity stages and condition of adult cod. Plankton samples were analysed with a focus on the occurrence of cod eggs and larvae. The data should be used to identify whether there is an early-spawning activity of Western Baltic cod, and how spawning activity differs spatially between parts of the Belt Sea.

During the cruise AL549 spawning cod were found from the Kiel Bight to the Mecklenburg Bight. Moreover, first analyses of BONGO-net samples revealed the occurrence of cod larvae in all three of the investigated sub-areas of the Belt Sea. The observation of cod larvae in the Mecklenburg Bight is the first reported observation of cod larvae in this region in January and gave first evidence for the hypothesised shift in spawning phenology of cod in the Belt Sea.

1.2 Zusammenfassung

Der Dorschbestand der westlichen Ostsee befindet sich derzeit in einer Notlage, die mit dem geringen Rekrutierungserfolg über mehrere Jahre in Zusammenhang gebracht wird. Die Gründe für die mehrjährig auftretende geringe Rekrutierung sind bisher nicht ausreichend geklärt. Es gibt jedoch Hinweise auf eine (möglicherweise klimatisch bedingte) Verschiebung der Laichphänologie, die die Laichaktivität (die normalerweise im März ihren Höhepunkt erreicht) auf einen früheren Zeitpunkt verlagert. Dies führt wahrscheinlich zu einem Missverhältnis von Dorschlarven und Zooplanktonnahrung und damit konsequenterweise zu einem schlechten Überleben der Larven. Diese Fahrt war die erste von fünf vorgeschlagenen Fahrten im Rahmen der Winterdorsch 2021-25 Fahrten des IMF, die das Ziel haben, die frühe Winterlaichaktivität des westlichen Ostseedorsches zu untersuchen.

Zu diesem Zweck wurden Ichthyoplanktonproben und Dorschproben auf einem vorher festgelegten Stationsraster genommen. Die Dorschproben dienen der Untersuchung der Reifestadien und des Zustands der adulten Dorsche. Die Planktonproben wurden insbesondere auf das Vorkommen von Dorscheiern und -larven untersucht. Anhand der Beprobungsdaten sollte festgestellt werden, ob es eine frühe Laichaktivität des westlichen Ostseedorsches gibt, und ob es darüber hinaus räumliche Unterschiede in der Laichaktivität des westlichen Ostseedorsches zwischen den verschiedenen Teilen der Beltsee gibt.

Während der Fahrt AL549 wurden laichende Dorsche von der Kieler Bucht bis zur Mecklenburger Bucht gefunden. Darüber hinaus zeigten erste Analysen von BONGO-Netz-Proben das Vorkommen von Dorschlarven in allen drei untersuchten Teilgebieten der Beltsee. Die Beobachtung von Kabeljau-Larven in der Mecklenburger Bucht ist die erste gemeldete

Beobachtung von Kabeljau-Larven in dieser Region im Januar und lieferte erste Belege für die vermutete Verschiebung der Laichphänologie des Dorsches in der Beltsee.

2 Participants

2.1 Principal Investigators

Table 2.1. List of Principal Investigators of the Winter cod cruises 2021-25.

Name	Academic title	Institution
Möllmann, Christian	Prof., Dr. rer. nat.	IMF
Funk, Steffen	Dr. rer. nat.	IMF

2.2 Scientific Party

Table 2.2. List of scientific party of cruise AL549.

Name	Discipline	Institution
Funk, Steffen, Dr. rer. nat.	Chief scientist; PostDoc	IMF
Klinger, Richard	PhD student	IMF
Plonus, Rene-Marcel	PhD student	IMF
Hornetz, Peter	Scientific assistant, MSc student	IMF
Höper, Anton	BSc student	IMF
Kondratowicz, Stephanie	Technician	IMF

2.3 Participating Institutions

IMF Institute of Marine Ecosystem and Fisheries Science, University of Hamburg

3 Research Program

3.1 Description of the Work Area

The working area of AL459 was located in the Kiel Bight, 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) that together with the Arkona Sea (SD24), and the Sound (SD23) form the Western Baltic Sea (WBS) (Fig. 3.1). 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 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), mainly due to 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 is together with SD23 known as the distributional core area of the Western Baltic cod (*Gadus morhua*) stock and stock mixing with Eastern Baltic cod (*Gadus morhua callarias*) is considered negligible (ICES, 2019).

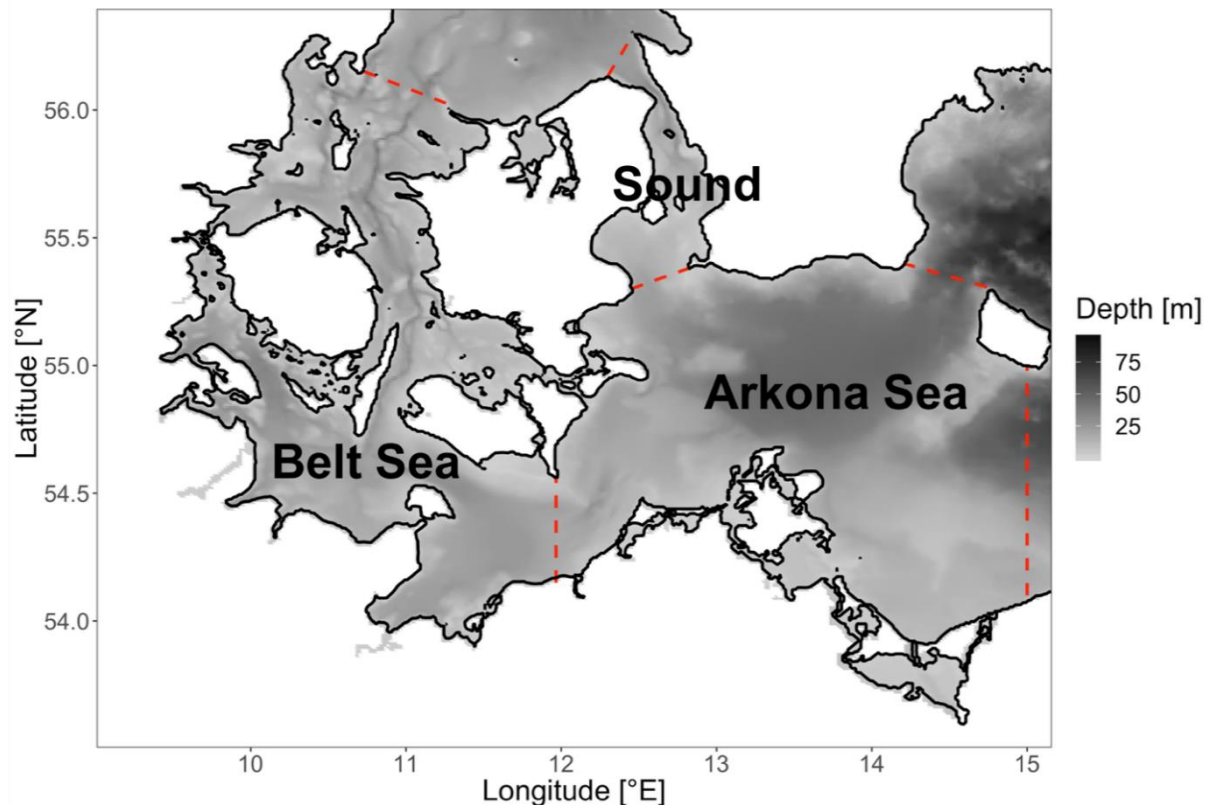


Figure 3.1. Bathymetry of the Western Baltic Sea. Dashed red lines indicate borders between ICES Subdivisions (SD22 – Belt Sea; SD23 – Sound, and SD24 – Arkona Sea). Figure was taken from Funk, 2020.

3.2 Aims of the Cruise

The Western Baltic cod (WBC) stock is currently in distress, which is largely associated with several years of only low recruitment success. The reasons for these several years of low recruitment are not understood sufficiently so far. However, there are indications for a (potentially climate-induced) shift in spawning phenology shifting spawning activity (peaking usually in March (Bleil and Oeberst, 1997; Bleil et al., 2009)) to an earlier time such as already observed for other stocks of Atlantic cod (McQueen and Marshall, 2017). The shift probably causes a mismatch of cod larvae and zooplankton food which can lead to a poor larval survival. There is an indication that accelerated gonad maturation is already an ongoing process in the study area where the proportions of post-spawning cod individuals are increasingly observed during the Baltic international trawl survey (BITS) Quarter 1 survey (pers. comm. Uwe Krumme, Thuenen Institute of Baltic Sea Fisheries, Rostock), which is conducted between end of February and mid-March each year. Furthermore, local gillnet fishers located in the harbours of Burgstaaken and Heiligenhafen (Schleswig-Holstein, Germany) report the occurrence of increasing numbers of spawning cod individuals on their traditional spawning grounds within the channels of the Kiel Bight, Mecklenburg Bight and Fehmarn Belt already in January (pers. comm. S. Funk with local gillnetters). In contrast former studies indicate a spawning migration towards these areas starting later within the year 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., 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. The proposed cruise will thus

provide important insights into the reproductive ecology of the WBC population, crucial for its sustainable management.

On the one hand, new insights into a potential shift in the spawning phenology of cod in the Western Baltic Sea may provide a better understanding of its recruitment dynamics and the interannual variability of recruitment success. On the other hand, these findings could be used to adapt management measures such as the spawning season accordingly (e.g., by extending the spawning season into January).

Therefore, cruise AL549 aimed to:

1. investigate spatial distribution of mature, adult cod on the traditional spawning grounds in the Belt Sea in late January including sampling positions in the channels of the Kiel Bight, Fehmarn Belt and Mecklenburg Bight.
2. investigate the spatial distribution of cod eggs and larvae in the Belt Sea in late January.

To realize these three goals, we defined a station grid of 35 sampling positions, which should be used for zooplankton and especially ichthyoplankton sampling using a BONGO net, including 16 positions in the Kiel Bight, 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 of the University of Hamburg. These previous plankton samples, dating back to 2016, were analysed in cooperation with the Danish Technical University (DTU) in the project FORTORSK. Data collected and analysed in this framework can be used as a kind of baseline for comparison of egg and larvae numbers observed in early winter (i.e., January) during the winter cod cruises with those observed during peak spawning periods (February and March of previous years). Furthermore, findings of cod eggs and larvae at several stations of the plankton station grid in previous years prove that at least occasionally cod eggs and larvae can be found at these stations.

In addition, we defined 10 trawl positions at known spawning grounds in the Belt Sea (Fig. 2), where we conducted trawl hauls using a young fish trawl (held at the bottom by weights). There it was planned to collect samples of mature, adult cod to investigate maturity stages, condition as well as size and age structure of spawning cod individuals at their early-winter spawning grounds. The 10 trawl positions were chosen based on catches of ripe individuals at previous winter and spring surveys of the University of Hamburg, dating back to 2016. The chosen trawl stations included four positions in the Kiel Bight, one position in the Fehmarn Belt and six positions in the Mecklenburg Bight. The limited number of trawl positions in the Fehmarn Belt was mainly due to the bottom structure of the Fehmarn Belt with rocky reef structures and hard ground posing a high risk of damaging the trawl gear. The chosen trawl station in the Fehmarn Belt represents the only trawlable position in the Fehmarn Belt known by Scientists of the University of Hamburg. However, we wanted to state that there are other well-known traditional spawning grounds of WBC in the Fehmarn Belt such as near to the Øjet, near the Fehmarn Belt fairway buoy 5, or near the former position of the Fehmarn Belt lightship (pers. comm. S. Funk with local gillnetters and recreational fishers; pers. observation S. Funk), which could not be covered during the cruise due to the earlier mentioned gear restrictions.

At the trawl positions additional multi net sampling (towed) was planned to give insights about egg and larvae vertical distributions on the spawning grounds and in relation to the number of adult cod at the corresponding spawning grounds.

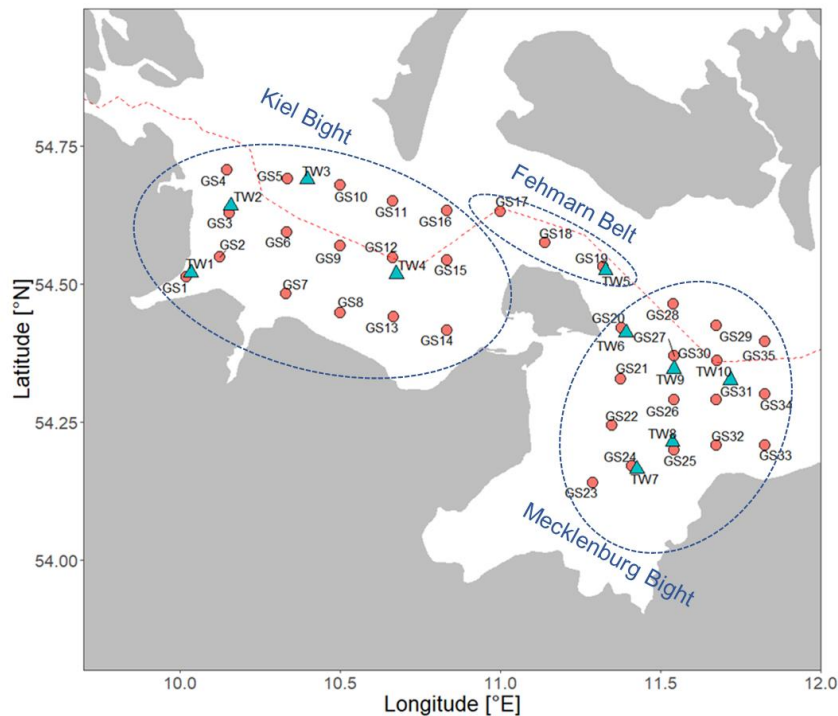


Figure 3.2. Planned zoo-plankton and trawl fishery stations for the winter cod cruise AL549. Red dots indicate CTD and BONGO net stations. Blue triangles indicate trawl and MULTINET stations. Red dashed line depicts EEZ borders and blue circles indicate stations allocated to a specific subregion in the work area, i.e., Kiel Bight, Fehmarn Belt, and Mecklenburg Bight.

3.3 Agenda of the Cruise

It was planned to realize a plankton grid sampling consisting of 35 BONGO net and CTD stations complemented by 10 stations with trawl fishery and MULTINET hauls including the following objectives:

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 MULTINET and 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 net 300 μm , were planned to be sieved over a 700 μm mesh size sieve to obtain a separate egg and ichthyoplankton sample. Egg-and ichthyoplankton samples as well as the rest of the 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 included the collection of individual fish data of cod and whiting (including full weight, gutted weight, liver weight, sex, maturity stage, gonad weight, stomach fullness, and otolith samples, as well as in the case of cod samples stomach, liver gonad samples and fin clip) and length and weight data of all remaining fish species. Furthermore, herring and sprat stomach samples were taken.

- Herring and sprat stomachs were sampled to supplement the longstanding stomach data base of these two species sampled by the University of Hamburg, as well as to provide insights on their predatory effects on the prevailing ichthyoplankton such as cod eggs and larvae.
- 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., 2020a).
- Cod fin clips were taken for potential cod stock discrimination analyses using genetics.
- Cod liver samples were taken in the framework of a running Bachelor thesis (Jannick Ehlers, Supervisors: Prof. Dr. Axel Temming, Jens-Peter Herrmann, and Richard Klinger) and a doctoral thesis (Richard Klinger, Supervisors: Prof. Dr. Axel Temming, and Dr. Uwe Krumme) at the University of Hamburg investigating the size-specific relations between cod liver size and weight and fat energy contents.
- Cod gonad samples (of maturity stages 4 to 6) were taken for later fecundity analyses.
- Cod and whiting otolith samples were taken for subsequent aging.
- Continuous recording of hydroacoustic data with four different echosounder frequencies (38, 70, 120 and 200 kHz) for biomass estimations

Limitations and adaptations of the cruise agenda due to the prevailing conditions and measures in terms of the Covid-19 pandemic

Due to the Covid-19 pandemic and the related restriction of the number of overnight participants aboard RV ALKOR during multiple-day cruises (6 or 7 instead of 12), the principal investigators adapted the work plan. Therefore, it was decided to not collect cod larvae out of the MULTINET samples, but only out of the BONGO net (500 µm). Further modifications and adjustments to the work programme (e.g., deletion of some work stations) were not made in advance but represented time reserves. They should be available for possible occurring time bottlenecks depending on the size of the trawl catches and the associated processing times, due to a lack of personnel.

4 Narrative of the Cruise

RV ALKOR departed from GEOMAR pier in Kiel on Januar 25th at 07:00 heading to the first plankton grid station in the Kiel Bight near Eckernförde (GS 1, Fig. 3.2), where the station work started. Until Tuesday evening all planned plankton and trawl stations within the Kiel Bight were completed, with exception of the stations in the Bight of Hohwacht (i.e., stations TW4, GS8, GS13, and GS14) since naval exercises in the Todendorf shooting range made an approach to these sampling locations impossible. It was therefore decided to head to the Fehmarn Belt and Mecklenburg Bight first to continue station work and catch up for the missing stations in the Kiel

Bight at the weekend, when there was no naval shooting activity planned. Due to the reduced number of scientists (due to the current rules in terms of the corona pandemic), all station work were conducted during the day and no work was conducted during night-time hours. On Friday January 29th in the afternoon the last station work in Mecklenburg Bight was successfully accomplished and RV ALKOR headed to the stations GS18 and GS17 in the Fehmarn Belt. It should be noted that sampling positions of GS17 were changed prior to the cruise, since the principal investigators (PIs) got informed by the Danish Ministry of foreign affairs and the Danish Environmental Protection Agency that GS17 would be located in a Danish harbour porpoise protection area of importance status one. The PIs were given permission to take samples in this area, but under the restriction of not using echo sounder frequencies below 200 kHz. As it was planned to have continuous recordings of hydroacoustic data with four different echosounder frequencies (38, 70, 120 and 200 kHz) over the whole cruise track, the PIs decided to move the sampling position of station GS17 southwards into German territory. For all upcoming cruises in the framework of the winter cod project, this new position of GS17 will be adopted.

Until Saturday evening all work laid out in the original cruise program was accomplished including the missing stations in the Bight of Hohwacht as we were benefitting from the calm weather conditions leading to perfect working conditions. Due to the overall minor catches of adult cod during the 10 fishery hauls (in total $n < 30$), it was decided to conduct additional trawl hauls in the northern Kiel Bight (where highest cod catches were observed) in order to increase cod sample numbers. After consultations between the ship's command and the chief scientist, it was agreed to enter the port of Eckernförde on Saturday and Sunday evenings, since on the one hand there would be no work during the night hours anyway due to the reduced number of scientists, and on the other hand one more crew member would be available for station work during the day. On Saturday evening RV ALKOR headed to the port of Eckernförde.

On Sunday 31st January at 7 am RV ALKOR departed from the port of Eckernförde heading to the Vejsnæs channel (northern Kiel Bight) for additional trawl fishery. In total three additional trawl hauls were conducted partly extending 1h of fishing duration. For every additionally chosen trawl position an additional CTD cast was conducted. Furthermore, a CTD cast with water samplers was conducted and water samples were used for oxygen calibration of the CTD probe via Winkler method. In the afternoon station work was completed and RV ALKOR headed to GS30, where two additional BONGO hauls with two 500 μ m nets were conducted. At TW2 which was near to grid station GS30 mature, ripe whiting were observed in the trawl catches, and we wanted to exclude that caught cod larvae at GS30 were potentially whiting larvae. Visual differentiation between cod and whiting larvae is only hardly possible (pers. comm. B. Huwer). The occurrence of whiting larvae in the Baltic Sea has not yet been reported. However, to finally exclude this potential bias, it was decided to take additional larvae samples for genetic analyses (subsequent genetic analyses were coordinated by Dr. Luisa Listmann from University of Hamburg). After completing station work at GS30 RV ALKOR headed to the port of Eckenförde. On Monday 1st February RV ALKOR departed 7:45 am from the port of Eckenförde heading to an additional trawl sampling station in the Bight of Eckernförde. This additional sampling position was chosen due to the fact that cod larvae were found at Grid station GS1, but no adult cod were caught at trawl position TW1. A CTD cast was conducted prior to the trawl haul. First trawl haul resulted in no catch, since the cod end was accidentally opened. The haul was repeated but unfortunately the young fish trawl net got ripped and no catch was landed. Fishing-station work was finished. RV

ALKOR headed up to the Kiel Fjord, where two last BONGO hauls for calibration of flowmeters were conducted. In the afternoon RV ALKOR arrived at its homeport Kiel.

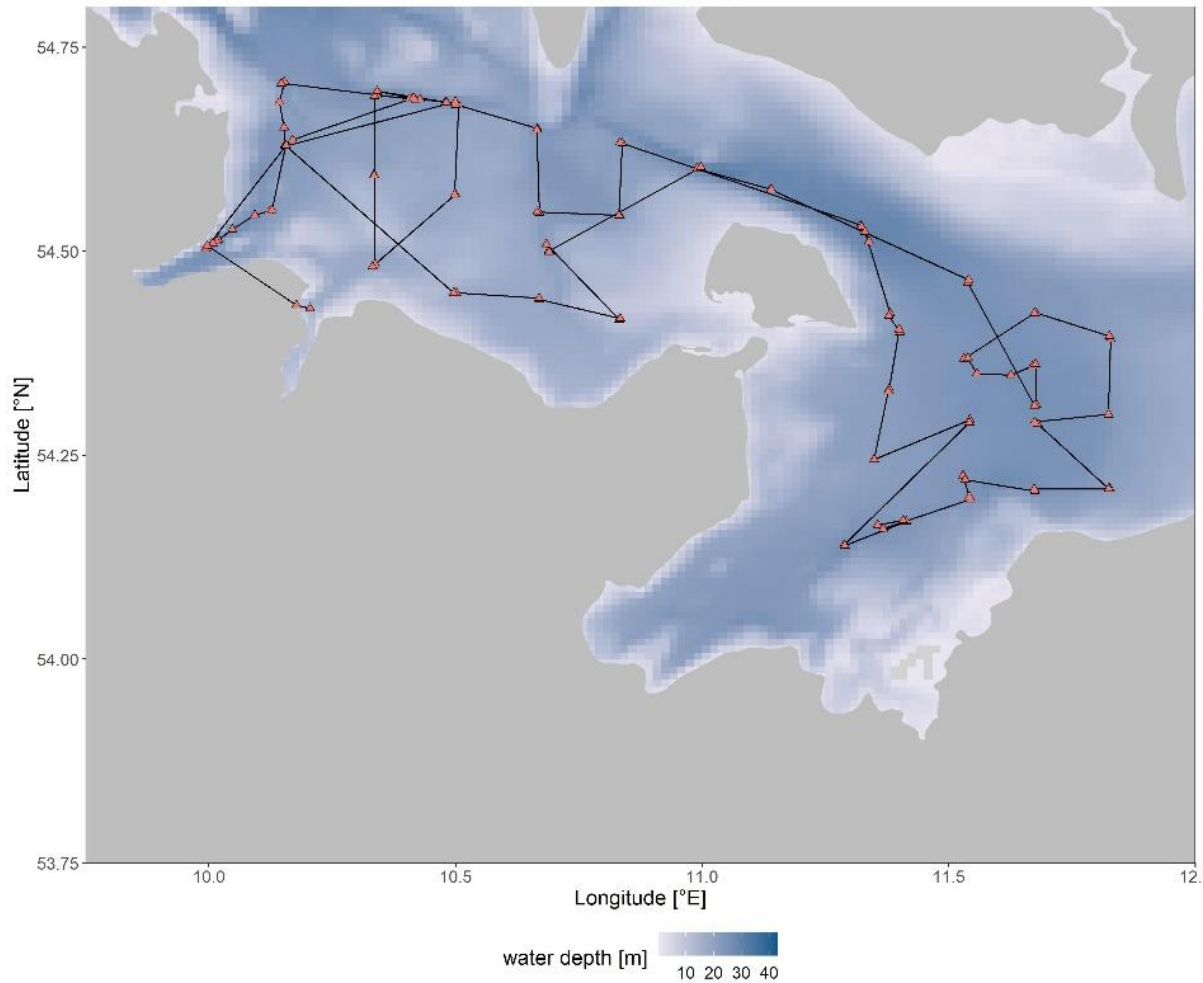


Figure 4.1. Cruise track of AL 549. Black line indicates cruise track between stations (linear distance) from the first station in the Bay of Eckernförde to the last station in the Kiel Fjord. Red triangles indicate working stations. A full list of which gear was deployed on which position is given in Tab. 5.

Table 4.1. Overview of gear deployment during AL 549. Numbers indicate number of deployments per gear (CTD = CTD probe, YFT = young fish trawl net, MSN = MULTINET midi towed, and BONGO = BONGO with 300, 500 and 150 μ m nets) and sub-area (KB = Kiel Bight, FB = Fehmarn Belt, and MB = Mecklenburg Bight). Number in brackets indicate number of gear deployments per sub-area planned in advance of the cruise.

	KB	FB	MB	total
CTD	22 (16)	3 (3)	16 (16)	41 (35)
YFT	9 (4)	1 (1)	5 (5)	10 (10)
MSN	4 (4)	1 (1)	5 (5)	10 (10)
BONGO	21 (16)	3 (3)	16 (16)	36 (35)

Note: Given number of gear deployments differ from those given in the station and haul table (Tab. 6.1). In detail: Number of BONGO net hauls shown in Tab. 4.1 does not include two calibration hauls, and number of Multi net hauls and CTD casts do not include one haul each which were repeated due to malfunctions of the devices.

5 Preliminary Results

5.1 Hydrography

(Steffen Funk, Jens-Peter Herrmann, Christian Möllmann)

CTD profiles were obtained from a total of 41 sampling stations. In general, we observed a nearly completely vertically mixed water body throughout the working area (Fig. 4). Highest salinities were observed in the bottom water layers at the deepest sampling positions (> 30 m depth) in the Vejsnæs channel and in the Fehmarn Belt with 22 PSU. Surface salinities ranged between 18 and 12 PSU from the western to the eastern parts of the sampling area. Bottom salinities ranged between 16 and 22 PSU, with lowest salinities observed in the Mecklenburg Bight. 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 Kiel Bight and Fehmarn Belt, but not for the Mecklenburg Bight. Thus, the question can be raised, if any spawning activity in the Mecklenburg Bight during the survey periods would have been possible to result in successful reproduction. However, most of the cod egg buoyancy experiments were conducted with cod samples from the north western Belt Sea only and information from the Mecklenburg Bight are extremely limited. In the Arkona Basin neutral cod egg buoyancy was already observed at a salinity of $13.7 \text{ PSU} \pm 1.3 \text{ PSU}$ (Nissling and Westin, 1997). Hence, there is at least a potential for a lower salinity threshold for neutral egg buoyancy in Western Baltic cod. 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.

Temperature at bottom layers were in the range of the optimal values (4-8.5 °C) for successful egg development of Western Baltic cod eggs at all sampling stations (von Westernhagen, 1970; Bleil, 1995) (Fig. 5.1).

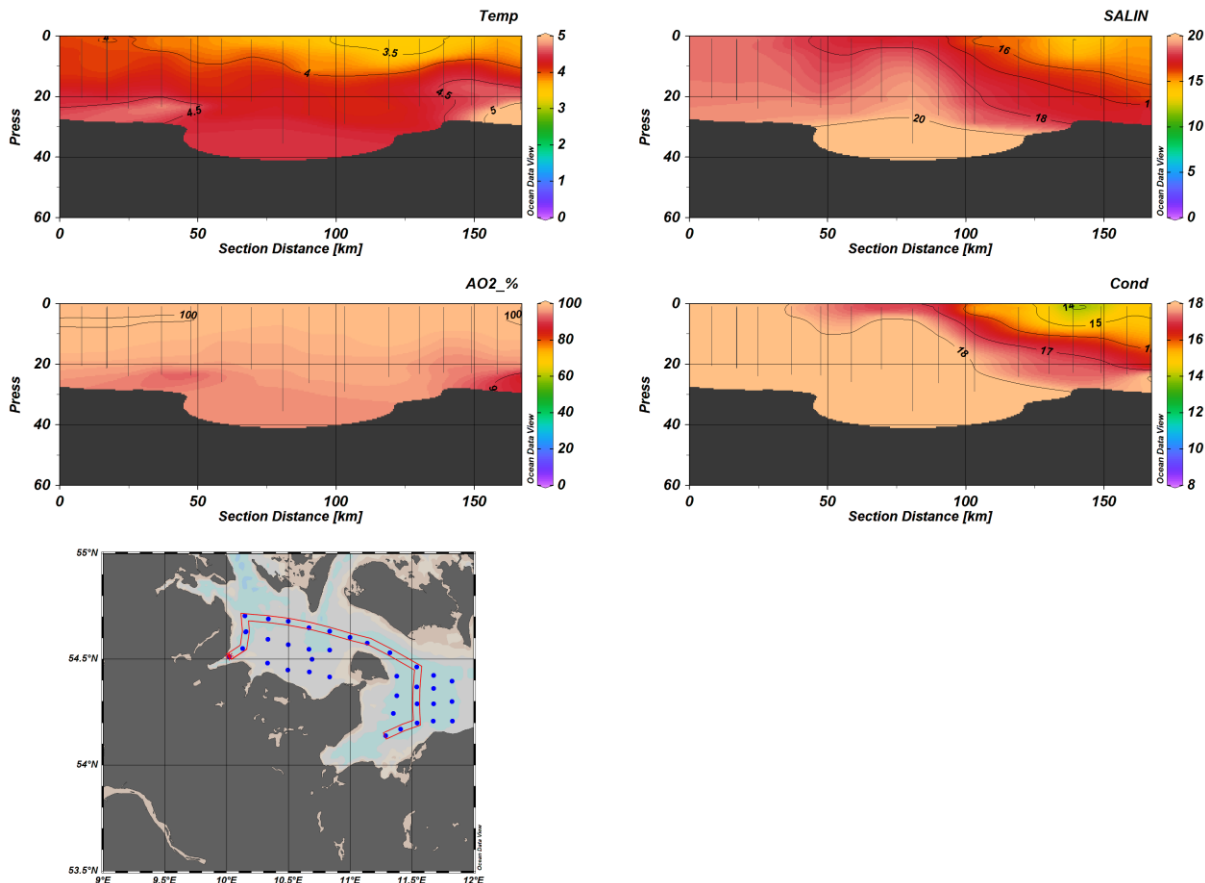


Figure 5.1. Hydrographic conditions during AL549 obtained from CTD casts along a transect from the Bight of Eckernförde (southwestern Kiel Bight) to Lübeck Bight (southern Mecklenburg Bight).

5.2 Fishery

(Steffen Funk, Richard Klinger, Christian Möllmann)

A total of 15 fishery hauls (using pelagic young fish trawl net fished with weights and fished close to the bottom, i.e., distance between footrope and bottom = 0 m, and distance between headrope and bottom ~ 2 m) were conducted in Kiel Bight ($n = 9$), Fehmarn Belt ($n = 1$) and Mecklenburg Bight ($n = 5$) (see Tab. 4.1).

In total we caught 22 different fish species, a total of 170,739 fish individuals with a total weight of 3127 kg (Tab. 5.1).

Our main target were adult cod for subsequent staging of the individuals as well as to collect further single fish data. However, overall cod catches were surprisingly low, with a total catch of 35 cod individuals only. For further information of the cod sampling see sub-section “Cod catches”.

We caught a total of 485 whiting, with highest catches in the northern Kiel Bight. 116 individuals were processed individually including measurements of total length, weight and gutted weight, liver weight, gonad weight, determination of sex and maturity stage, and taking otolith samples. Whiting is one of the species which is planned to be collected in a rolling scheme together with cod and flounder in the Baltic Sea as part of the planned internationally coordinated fish Pi2 stomach sampling project. Otoliths and individual fish data of whiting will be shared within the

framework of preliminary analyses of fish Pi2 with partners in the fish Pi2 project, such as the DTU and the Thuenen Institute of Baltic Sea Fisheries Rostock (Thuenen-OF). The remaining individuals were processed within a reduced single fish programme, including measurements of total length, weight and determination of sex. In case of the whiting in the Kiel Bight, we observed some spawning individuals (ripe females, i.e., ovaries filled most of body cavity, very distended and soft, appeared reddish-grey with a mixture of opaque and glassy oocytes and lumen contained viscous fluid in excess). From 2015 on we observed several times ripe whiting individuals during different times of the year and different regions of the Baltic Sea. First observation of ripe males and females were made during the IMF summer cruise AL461 (chief scientist Jens-Peter Herrmann) in the Arkona Sea (ICES subdivision 24), where we conducted additionally in vitro fertilisation and egg buoyancy experiments (in collaboration with Dr. Christoph Petereit from GEOMAR). Since eggs floated at salinities corresponding to the prevailing salinities at bottom water layers in the Arkona basin, these experiments gave first indication of potentially successful spawning activity of whiting in the Baltic Sea, which was not confirmed so far. In winter 2016 we observed additional spawning whiting individuals in the Mecklenburg Bight and Arkona Sea during the IMF winter cruise HE457 (chief scientist: Jens-Peter Herrmann). The observed spawning whiting individuals in the Kiel Bight during AL549, were however, as far as we know the first of ripe, spawning whiting in the western part of the Belt Sea and give further indication for regular whiting spawning in the Baltic Sea. In addition, the question can be raised if the Baltic Sea whiting is at least a partly self-sustaining stock as hypothesized by Ross (2016) and not completely relying on juvenile individuals migrating from the North Sea and the Kattegat as postulated by Arntz and Weber (1972).

Table 5.1. Catch composition in young fish trawl net hauls during AL549 with species composition, and total catch per species in numbers and weight [kg].

Species name	Common name	Total number	Total weight [kg]
<i>Sprattus sprattus</i>	sprat	141133	2558.594
<i>Clupea harengus</i>	herring	27831	298.501
<i>Limanda limanda</i>	common dab	781	77.972
<i>Merlangius merlangus</i>	whiting	485	45.999
<i>Pleuronectes platessa</i>	plaice	414	71.060
<i>Gadus morhua</i>	cod	35	65.128
<i>Platichthys flesus</i>	flounder	16	6.224
<i>Engraulis encrasicolus</i>	anchovy	10	0.050
<i>Eutrigla gurnardus</i>	grey gurnard	9	0.702
<i>Solea solea</i>	sole	7	0.812
<i>Cyclopterus lumpus</i>	lumpsucker	3	1.120
<i>Arnoglossus laterna</i>	Mediterranean sculdfish	3	0.014
<i>Melanogrammus aeglefinus</i>	haddock	2	0.376
<i>Scomber scombrus</i>	mackerel	2	0.131
<i>Callionymus lyra</i>	common dragonet	2	0.078
<i>Hippoglossoides platessoides</i>	American plaice	1	0.030
<i>Trisopterus esmarkii</i>	Norway pout	1	0.025

<i>Zoarces viviparus</i>	viviparous eelpout	1	0.018
<i>Glyptocephalus cynoglossus</i>	witch	1	0.010
<i>Neogobius melanostomus</i>	round goby	1	0.005
<i>Pomatoschistus minutus</i>	sand goby	1	0.002

Cod catches

During the cruise AL549 a total of 35 cod individuals only were caught during the trawl fishery (Fig. 5.2). All cod caught were processed individuals and single fish data (total length, weight, gutted weight, sex maturity, liver weight, gonad weight and number of nematodes in the livers) as well as samples (otoliths, fin clips for genetics, female gonads, non-infested livers, and stomachs) were obtained. In case of individuals with total length smaller than 21 cm ($n = 8$) only total length and weight were measured on board and individuals were deep frozen and taken as a whole sample for later analysis in the laboratory at the University of Hamburg (this decision was made since accuracy range (~ 0.1 g) of the scales onboard would have made accurate weight measurements of the small livers and gonads of the cod < 21 cm hardly possible).

The total catch numbers of cod were surprisingly low, especially since a large trawl activity by Danish and German commercial fishers at the chosen trawl positions was observed by the scientists throughout the cruise AL549.

Mean catch of cod per 60-minute haul was slightly lower in the Kiel Bight than in Mecklenburg Bight, with 4 individuals $\cdot h^{-1}$ and 5 individuals $\cdot h^{-1}$, respectively. Highest total number of cod samples, where obtained from the Kiel Bight ($n = 18$), followed by the Mecklenburg Bight ($n = 15$) and the Fehmarn Belt ($n = 2$) (Fig. 5; Fig. 5.3A). In Kiel Bight average total length of caught cod was with 50.17 cm (± 28.11 cm) considerably higher than in Mecklenburg Bight with 38.50 cm (± 27.58 cm) (Fig. 5.3B). In both areas ripe males were found (Fig. 5.3C) with maturity stages in five and six (“early spawning stage” and “main spawning stage”). All cod staging was determined following the guidelines of Tomkiewicz et al. (2002). Mature female individuals were mostly found in maturity stage five (“early spawning stage”) (Fig. 5.3C). In the Kiel Bight we observed furthermore a female individual in stage seven (“late spawning stage”), indicating that this individual had already spawned. Overall, we observed a higher percentage of male individuals at the spawning grounds. We had only minor catches of cod compared to catches from previous winter and spring surveys of the University of Hamburg since 2016. Even in these larger catches in previous years the total numbers of females caught had been considerably lower than the number of male individuals. This phenomenon was also observed for cod stocks from other ecosystems and was explained by the fact that male cod tend to stay on the spawning ground throughout the spawning season, while females only gradually enter the spawning grounds and leave soon after releasing their eggs to return to shallower areas presumably to feed (Morgan and Trippel, 1996; Funk et al., 2020b). Hence, there is a higher number of males on the spawning ground throughout the spawning season, resulting in an overall higher catchability for male individuals in spawning ground trawl fishery.

However, this specific spawning behaviour of cod may inflict the risk that the internationally coordinated Baltic international trawl survey conducted in the first quarter each year, which mainly samples the spawning grounds of cod (Funk et al., 2020b), potentially miss shifts in spawning phenology of cod. As long as the survey period is at least partly covered by the spawning time of

cod, the survey will find spawning cod male individuals on the spawning ground. Since post-spawning females but also post-spawning males will not remain on the spawning grounds proportions of maturity stages of individuals on the spawning grounds would remain nearly similar throughout the whole spawning period with always high percentage of ripe males and a few females from early to late spawning stage. Thus, to shed light on the temporal occurrence of post-spawning females it might be a prerequisite to sample also on the shallower feeding grounds of cod off the traditional spawning grounds. A first attempt of investigating Western Baltic cod maturity outside from its spawning ground was made in winter to spring 2020 and recently published by Froese et al., (2020). Froese et al. (2020) reported high shares of post spawning cod in gillnet catches from depth < 20 m in the Kiel Bight already from early February on, giving strong indication for a considerably large early winter spawning activity of cod in this area.

While spawning activity of cod in the Kiel Bight in January have been already reported in studies of the 1940s and the 1960s (Kändler, 1944; Kändler, 1961) which were based on ichthyoplankton samplings, these results have not been confirmed by later studies from the 1990s and 2000s by Bleil and Oeberst (1997) and Bleil et al. (2007), which were based on the sampling and staging of adult cod individuals as well as spawning experiments. In contrast, our observation of spawning individuals in the Kiel Bight supports the findings of Kändler (1944), that cod spawning in the Kiel Bight takes already place from January on. Furthermore, the observation of spawning cod in the Mecklenburg Bight is the first report of cod spawning activity in January from the eastern part of the Belt Sea and thus gives first evidence for the hypothesized shift in spawning phenology of cod in this area.

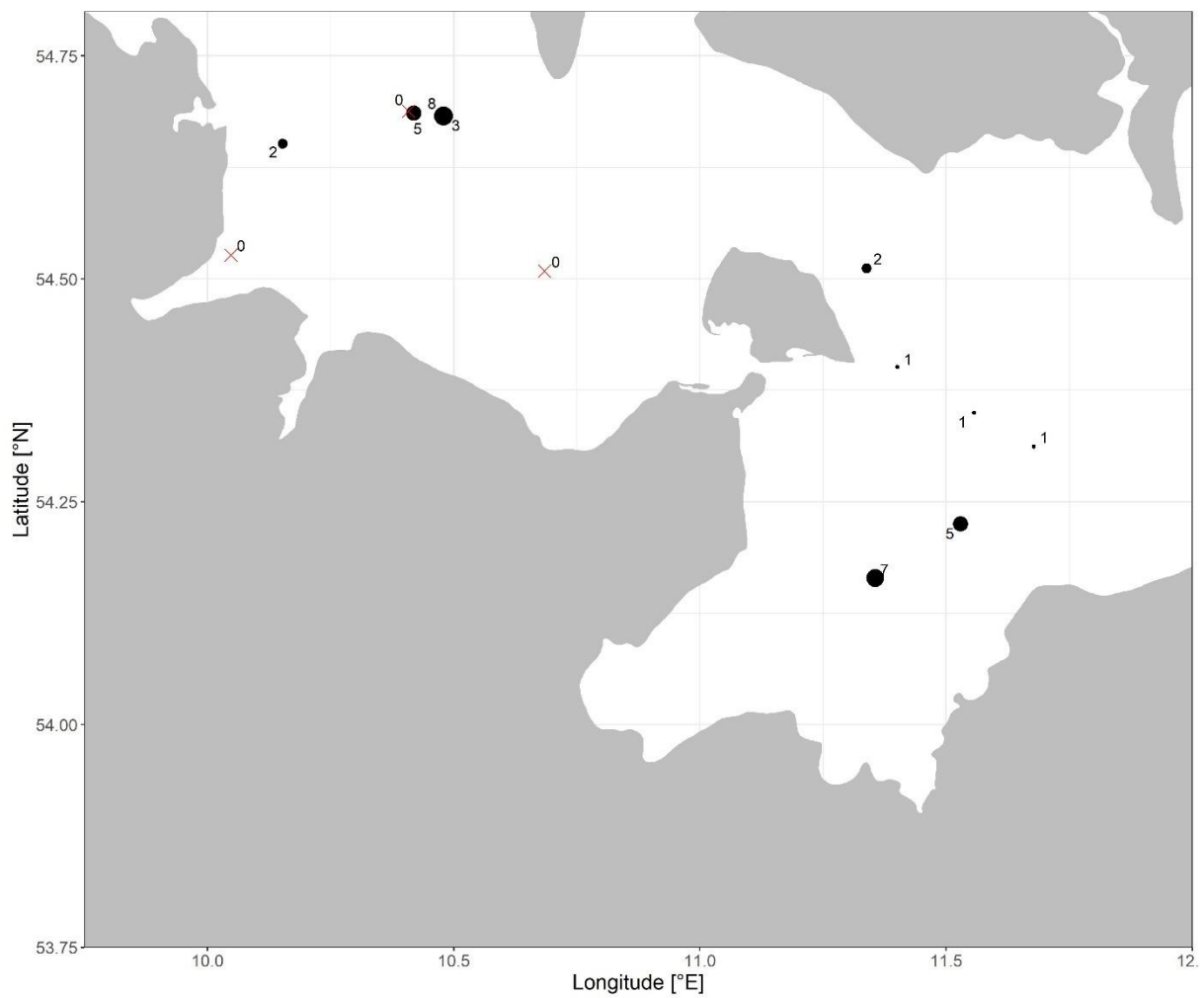


Figure 5.2. Total cod *Gadus morhua* catches per haul (not standardized on haul duration). Size of points and numbers indicate numbers of caught cod individuals. Red crosses and zeros indicate hauls with no cod catch. Haul 14 and 15 were excluded from the map, since there was no catch in these hauls due to malfunctions (open cod end and rip in the net).

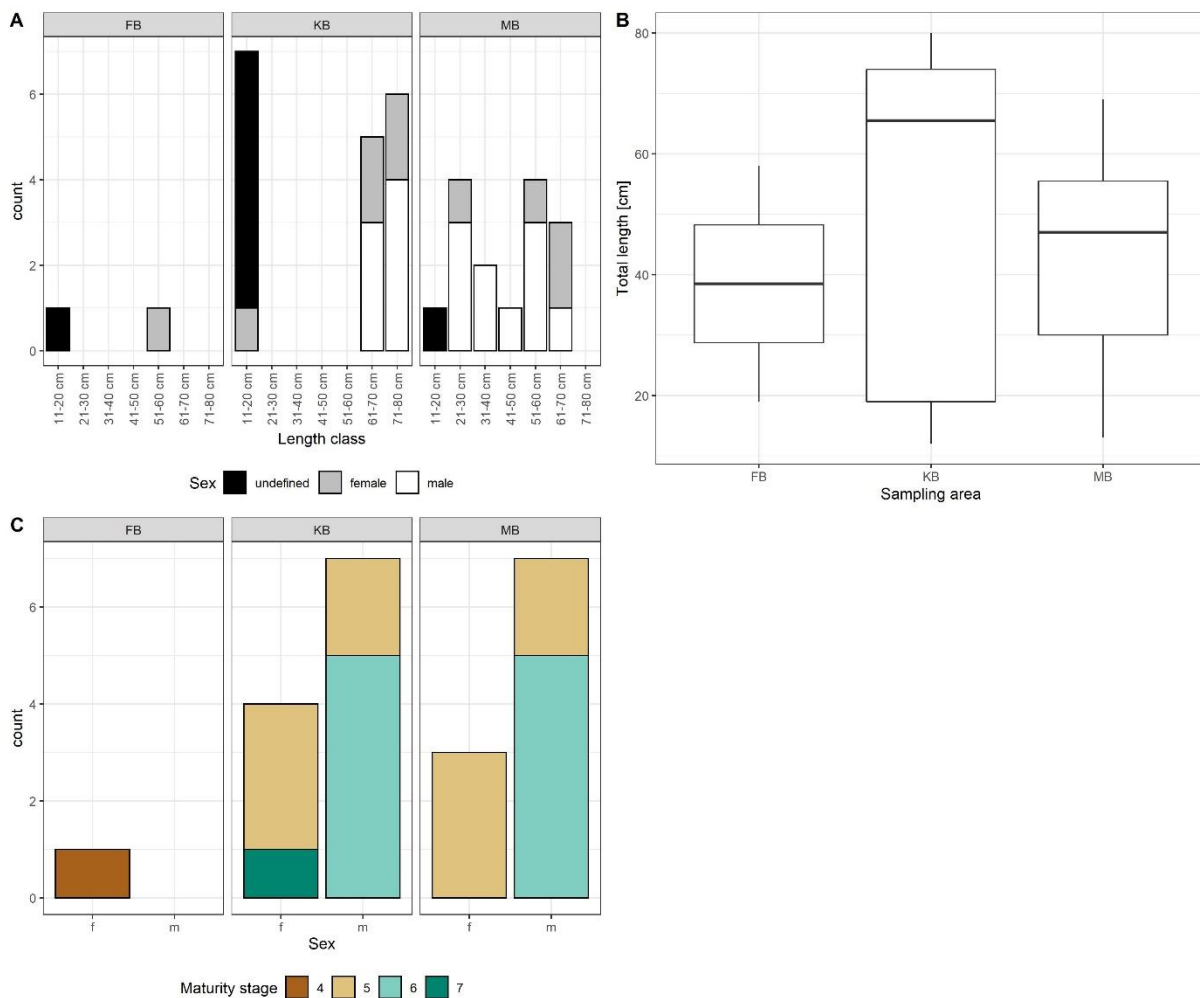


Figure 5.3. Size, sex and stage distribution of caught cod during AL549. In A: total cod catch per sampled sub-area (FB – Fehmarn Belt, KB – Kiel Bight, and MB – Mecklenburg Bight and per sex (unidentified sex correspond to the individuals < 21 cm, which were deep frozen and which will be processed later in the laboratory of the University of Hamburg). In B: Boxplots of length distribution of cod samples caught in each subarea. In C: Number of caught cod > 21 cm (n = 27) per maturity stage, sex and subarea.

5.3 Ichthyo- and Zooplankton Sampling

(Steffen Funk, Richard Klinger, Luisa Listmann, Christian Möllmann)

Zoo- and ichthyoplankton samples were obtained from a total of 35 BONGO (not including additional hauls at GS3) and 10 MULTINET stations. During the whole cruise we observed extremely high numbers of Ctenophora in the plankton samples, with highest numbers (with several 100 individuals in a single BONGO net 500 µm sample) in the Kiel Bight, and lower abundancies in the eastern parts of the working area.

BONGO net 500 µm samples were also checked directly on board for occurrence of cod larvae by Richard Klinger. Cod larvae were picked out of the samples and deep frozen for later condition analysis. The rest of the plankton samples were conserved in formalin for later species- and size-composition analysis in the laboratory.

In total we found a number of 13 cod larvae in the BONGO net 500 µm samples, clearly indicating a spawning activity and a successful hatch of cod in January 2021. We observed cod larvae not only in the Kiel Bight ($n = 11$), but also in the Fehmarn Belt ($n = 1$) and Mecklenburg Bight ($n = 1$). As far as we know, these are the first reports on the observation of cod larvae from the Fehmarn Belt and Mecklenburg Bight from January. Together with our observation of spawning individuals in the Mecklenburg Bight, these results clearly point towards an early spawning activity of cod also in these areas and thus towards the hypothesized shift in cod spawning phenology in the Belt Sea. Further cruises in the framework of the proposed winter cod cruises can give further insights in this early-winter spawning activity of cod in the Belt Sea.

Given the development times at the prevailing temperature conditions of 4 to 5 °C provided in the literature (Geffen et al., 2006) it can be assumed that cod larvae needed nearly 20 days from spawning to hatching. This indicates that the cod larvae found had been spawned potentially already at the beginning of January 2021. Further analysis will be made in near future including length measurements of cod larvae via imageJ and potential back calculations of hatch dates for the different cod larvae.

Near to the BONGO and CTD sampling station GS3 at TW2 we observed spawning whiting individuals. Since visual distinguishment between whiting and cod larvae is hardly possible (pers. comm. B. Huwer), we decided to take two additional BONGO samples (using two 500 µm nets) at station GS3 and to use larvae subsamples obtained from these additional hauls for a DNA analysis. These DNA analyses (coordinated by Dr. Luisa Listmann from the University of Hamburg) were performed to identify a potential bias by the occurrence of whiting larvae, but revealed that all analysed larvae were without exception cod individuals (see section “DNA analysis of larvae subsample” for further details).

DNA analysis of larvae subsamples

Upon returning to the IMF in Hamburg the DNA of each larvae sample was extracted using the ReliaPrep gDNA® kit of Promega. Then a region of the 5' end of cytochrome b sequence of all larvae and a DNA sample of a muscle sample of an adult cod were amplified using the primers and reaction parameters described in Carr et al., (1999). The amplification was successful for all 5 larvae and the muscle sample (Fig. 5.4A) upon which, all samples were cleaned up and sent to Sanger sequence at Eurofinsgenomics®. All 6 sequences were clear and aligned with a 99.9% match (Fig. 5.4B) to an NCBI sequence of *Gadus morhua*. An NCBI Blast search also revealed a 99% match to *Gadus morhua*. Based on these analyses it can be stated that all 5 larvae assessed via cytochrome b sequence were identified as *Gadus morhua*. Since, the threat of a bias caused by the occurrence of whiting larvae can be assumed to be greatest at GS3 (only plankton station close to trawl stations with ripe whiting individuals) and since this bias was not confirmed by the subsequent DNA analysis, an overall bias of the number of cod larvae due to the occurrence of whiting larvae during AL549 might be considered negligible.

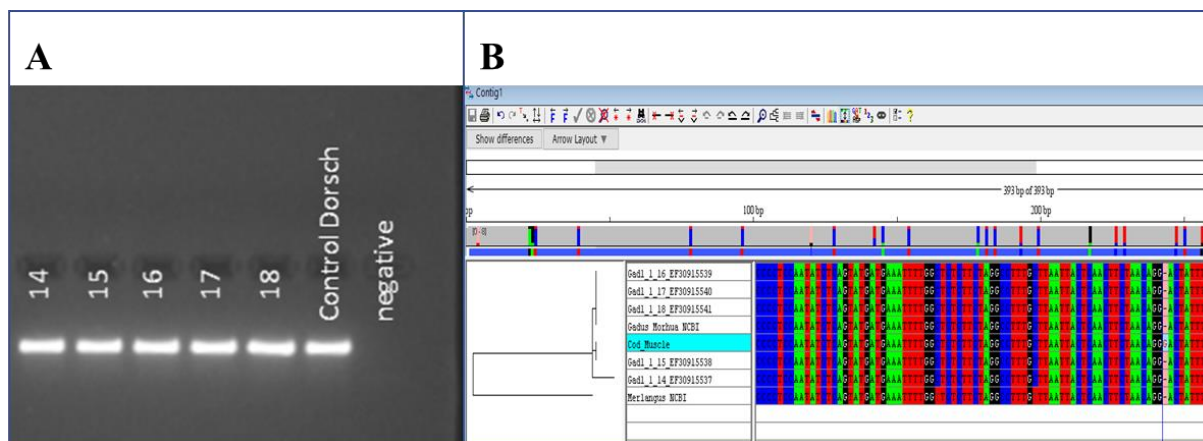


Figure 5.4. PCR results of the five gadoid larvae samples (14-18) and cod muscle sample (Control Dorsch) (A) and alignment of the five gadoid larvae samples, cod muscle and NCBI controls of cod (*Gadus morhua*) and whiting (*Merlangius merlangus*), clearly indicating that all five larvae samples are of the species *Gadus morhua* (B).

6 Station List

In total 108 gear deployments were conducted during the cruise AL549 (see Tab. 4.1 for an overview per subarea and Tab. 6.1 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 of the University of Hamburg and are available on request. Furthermore, it is planned to make additional cruise data of AL549 (including for example station data, catch data and individual fish data of whiting and cod, as well as cod stomach content data) publicly available via public data repository PANGEA (for further details see also section 7 “Data and Sample Storage and Availability” and Tab. 7.1).

Table 6.1. Station List with all gear deployments during AL549 with CTD = CTD probe, BONGO = BONGO net with 150, 300 and 500 μm nets, YFT = young fish trawl with weights, MULTINET = MULTINET midi and CTD-WS = CTD with water sampler, Stat. = Station number, Stat. Id. = internal station name (see also section 3.2. Aims of the Cruise), and SD = ICES subdivision.

Gear	AL549 Stat.	Haul	Stat. Id	Stat. SD	Lat. deg.	Lat. min.	Lon. deg.	Lon. min.	Date 2021	Time	Depth [m]	Duration [min]
CTD	1-1	1	GS1	22	54	30.82	10	1.14	25.1	9:41	28	0:03
BONGO	1-2	1	GS1	22	54	30.73	10	0.93	25.1	9:51	28	0:05
YFT	2-1	1	TW1	22	54	31.61	10	2.85	25.1	10:16	28	0:40
MULTINET	2-2	1	TW1	22	54	32.67	10	5.58	25.1	12:22	28	0:29
BONGO	3-1	2	GS2	22	54	32.97	10	7.31	25.1	13:14	23	0:04
CTD	3-2	2	GS2	22	54	33.04	10	7.68	25.1	13:23	22	0:02
CTD	4-1	3	GS3	22	54	37.80	10	9.33	25.1	13:58	23	0:02
BONGO*	4-2	3	GS3	22	54	37.76	10	9.23	25.1	14:04	23	0:04
YFT	5-1	2	TW2	22	54	39.10	10	9.15	25.1	14:27	23	0:30
MULTINET	5-2	2	TW2	22	54	40.99	10	8.55	25.1	15:20	23	0:22
BONGO	6-1	4	GS4	22	54	42.44	10	9.19	25.1	16:00	26	0:05
CTD	6-2	4	GS4	22	54	42.35	10	8.80	25.1	16:09	26	0:03

YFT	7-1	3	TW3	22	54	41.16	10	25.11	26.1	8:11	30	0:40
MULTINET	7-2	3	TW3	22	54	41.19	10	25.67	26.1	9:23	31	0:22
BONGO	8-1	5	GS5	22	54	41.44	10	20.46	26.1	9:59	26	0:04
CTD	8-2	5	GS5	22	54	41.40	10	20.16	26.1	10:07	25	0:02
CTD	9-1	6	GS6	22	54	35.64	10	20.10	26.1	10:44	16	0:02
BONGO	9-2	6	GS6	22	54	35.58	10	20.08	26.1	10:49	16	0:03
BONGO	10-1	7	GS7	22	54	29.03	10	20.24	26.1	11:55	20	0:05
CTD	10-2	7	GS7	22	54	28.88	10	19.90	26.1	12:04	20	0:03
CTD	11-1	8	GS9	22	54	34.20	10	29.99	26.1	13:02	19	0:03
BONGO	11-2	8	GS9	22	54	34.15	10	29.90	26.1	13:09	19	0:03
BONGO	12-1	9	GS10	22	54	40.72	10	30.38	26.1	13:56	25	0:04
CTD	12-2	9	GS10	22	54	40.78	10	29.99	26.1	14:03	25	0:03
CTD*	13-1	10	GS11	22	54	39.04	10	39.97	26.1	14:43	25	0:02
CTD	13-2	11	GS11	22	54	38.99	10	39.90	26.1	14:48	27	0:02
BONGO	13-3	10	GS11	22	54	38.94	10	39.88	26.1	14:53	29	0:05
BONGO	14-1	11	GS12	22	54	32.81	10	40.21	26.1	15:31	21	0:04
CTD	14-2	12	GS12	22	54	32.88	10	39.94	26.1	15:38	21	0:05
CTD	15-1	13	GS15	22	54	32.63	10	50.00	26.1	16:18	21	0:03
BONGO	15-2	12	GS15	22	54	32.63	10	49.88	26.1	16:24	21	0:03
BONGO	16-1	13	GS16	22	54	37.94	10	50.26	26.1	17:00	23	0:04
CTD	16-2	14	GS16	22	54	38.00	10	49.97	26.1	17:07	23	0:03
CTD	17-1	15	GS19	22	54	31.92	11	19.27	27.1	7:59	30	0:02
BONGO	17-2	14	GS19	22	54	31.81	11	19.34	27.1	8:06	31	0:04
YFT	18-1	4	TW5	22	54	30.72	11	20.28	27.1	8:29	29	0:30
MULTINET	18-2	4	TW5	22	54	31.41	11	19.80	27.1	9:35	30	0:20
BONGO	19-1	15	GS20	22	54	25.43	11	22.89	27.1	10:30	22	0:03
CTD	19-2	16	GS20	22	54	25.26	11	22.72	27.1	10:37	20	0:01
YFT	20-1	5	TW6	22	54	24.06	11	24.06	27.1	11:37	23	0:33
MULTINET	20-2	5	TW6	22	54	24.26	11	23.99	27.1	12:43	23	0:22
BONGO	21-1	16	GS21	22	54	19.88	11	22.75	27.1	13:34	22	0:03
CTD	21-2	17	GS21	22	54	19.69	11	22.63	27.1	13:40	22	0:03
CTD	22-1	18	GS22	22	54	14.66	11	20.91	27.1	14:19	21	0:03
BONGO	22-2	17	GS22	22	54	14.69	11	20.94	27.1	14:25	21	0:04
BONGO	23-1	18	GS26	22	54	17.59	11	32.56	27.1	15:12	25	0:04
CTD	23-2	19	GS26	22	54	17.40	11	32.50	27.1	15:19	25	0:03
CTD	24-1	20	GS23	22	54	8.40	11	17.26	27.1	16:37	23	0:03
BONGO	24-2	19	GS23	22	54	8.34	11	17.32	27.1	16:44	27	0:04
BONGO	25-1	20	GS24	22	54	10.13	11	24.87	28.1	7:57	24	0:03
CTD	25-2	21	GS24	22	54	10.21	11	24.45	28.1	8:05	24	0:02
YFT	26-1	6	TW7	22	54	9.87	11	21.36	28.1	8:37	24	0:30
MULTINET	26-2	6	TW7	22	54	9.58	11	22.03	28.1	9:38	25	0:22
BONGO	27-1	21	GS25	22	54	11.74	11	32.63	28.1	10:42	24	0:04
CTD	27-2	22	GS25	22	54	11.96	11	32.51	28.1	10:50	25	0:02
YFT	28-1	7	TW8	22	54	13.51	11	31.76	28.1	11:41	24	0:40
MULTINET	28-2	7	TW8	22	54	13.18	11	32.01	28.1	13:01	25	0:21
BONGO	29-1	22	GS32	22	54	12.35	11	40.49	28.1	14:00	25	0:04
CTD	29-2	23	GS32	22	54	12.51	11	40.39	28.1	14:07	26	0:03

CTD	30-1	24	GS33	22	54	12.53	11	49.61	28.1	14:45	21	0:03
BONGO	30-2	23	GS33	22	54	12.53	11	49.46	28.1	14:50	21	0:05
BONGO	31-1	24	GS31	22	54	17.29	11	40.84	28.1	15:34	26	0:05
CTD	31-2	25	GS31	22	54	17.44	11	40.45	28.1	15:41	26	0:03
CTD	32-1	26	GS34	22	54	18.00	11	49.46	28.1	16:16	24	0:02
BONGO	32-2	25	GS34	22	54	18.01	11	49.43	28.1	16:21	24	0:04
BONGO	33-1	26	GS35	22	54	23.55	11	49.71	28.1	16:58	22	0:04
CTD	33-2	27	GS35	22	54	23.76	11	49.53	28.1	17:05	22	0:03
CTD	34-1	28	GS29	22	54	25.47	11	40.58	28.1	17:45	25	0:02
BONGO	34-2	27	GS29	22	54	25.45	11	40.42	28.1	17:50	25	0:04
BONGO	35-1	28	GS27	22	54	22.09	11	31.88	29.1	7:59	25	0:03
CTD	35-2	29	GS27	22	54	22.14	11	32.36	29.1	8:07	25	0:02
YFT	36-1	8	TW9	22	54	20.99	11	33.39	29.1	8:34	25	0:45
MULTINET	36-2	8	TW9	22	54	20.90	11	37.56	29.1	9:41	26	0:22
BONGO	37-1	29	GS30	22	54	21.57	11	40.21	29.1	10:19	26	0:04
CTD	37-2	30	GS30	22	54	21.70	11	40.56	29.1	10:27	26	0:03
YFT	38-1	9	TW10	22	54	18.70	11	40.68	29.1	11:35	26	0:45
MULTINET	38-2	9	TW10	22	54	18.65	11	40.43	29.1	12:56	26	0:21
BONGO	39-1	30	GS28	22	54	27.71	11	32.29	29.1	14:25	26	0:04
CTD	39-2	31	GS28	22	54	27.89	11	32.41	29.1	14:32	26	0:03
CTD	40-1	32	GS18	22	54	34.55	11	8.34	29.1	16:05	28	0:03
BONGO	40-2	31	GS18	22	54	34.56	11	8.39	29.1	16:10	28	0:05
BONGO	41-1	32	GS17	22	54	36.06	10	59.36	29.1	16:48	28	0:05
CTD	41-2	33	GS17	22	54	36.19	10	59.85	29.1	16:55	28	0:04
CTD	42-1	34	TW4	22	54	30.02	10	41.38	30.1	7:59	23	0:03
MULTINET*	42-2	10	TW4	22	54	30.10	10	41.36	30.1	8:06	23	0:08
MULTINET	42-3	11	TW4	22	54	29.95	10	41.37	30.1	8:23	22	0:20
YFT	42-4	10	TW4	22	54	30.52	10	41.06	30.1	9:07	22	0:30
BONGO	43-1	33	GS14	22	54	24.99	10	49.91	30.1	11:08	13	0:02
CTD	43-2	35	GS14	22	54	25.06	10	50.02	30.1	11:13	13	0:02
CTD	44-1	36	GS13	22	54	26.46	10	40.22	30.1	11:54	19	0:01
BONGO	44-2	34	GS13	22	54	26.55	10	40.15	30.1	12:00	19	0:02
BONGO	45-1	35	GS8	22	54	26.93	10	30.09	30.1	12:48	17	0:03
CTD	45-2	37	GS8	22	54	26.93	10	29.78	30.1	12:54	17	0:02
CTD	46-1	38	GS3	22	54	37.78	10	9.31	30.1	14:33	23	0:05
BONGO	46-2	36	GS3	22	54	37.74	10	9.27	30.1	14:39	23	0:04
CTD	47-1	39	NONE	22	54	40.99	10	29.95	31.1	9:18	28	0:02
YFT	47-2	11	NONE	22	54	40.97	10	28.74	31.1	9:34	32	0:35
YFT	48-1	12	NONE	22	54	41.29	10	24.47	31.1	10:46	32	1:00
CTD	48-2	40	NONE	22	54	41.78	10	20.45	31.1	12:13	32	0:02
YFT	49-1	13	NONE	22	54	40.96	10	28.88	31.1	13:03	32	1:00
CTD-WS	49-2	2	NONE	22	54	41.28	10	24.88	31.1	14:42	32	0:10
BONGO**	50-1	37	GS3	22	54	38.19	10	10.16	31.1	15:51	23	0:04
BONGO**	50-2	38	GS3	22	54	37.79	10	9.37	31.1	16:04	23	0:03
CTD	51-1	41	NONE	22	54	30.16	9	59.60	1.2	8:16	26	0:02
YFT	51-2	14	NONE	22	54	30.57	10	0.49	1.2	8:30	28	0:30
YFT	51-3	15	NONE	22	54	30.41	9	59.81	1.2	9:43	28	0:26

BONGO***	52-1	39	NONE	22	54	26.04	10	10.64	1.2	12:17	14	0:20
BONGO***	53-1	40	NONE	22	54	25.79	10	12.29	1.2	12:43	17	0:20

CTD* – measurement error, CTD cast was repeated; BONGO* – spilt sample, haul was repeated; MULTINET* – failure of device, haul was repeated, BONGO** – additional hauls with two 500 µm nets; BONGO*** – BONGO calibration hauls.

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 AL549 publicly available. Hydrographic data (CTD) will be submitted to the ICES Oceanographic database within one year from the cruise. Furthermore, it is planned to upload fishery data (including cod and whiting single fish data) in the public data repository PANGAEA.

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 in near future.

All plankton as well as sprat and herring samples obtained during the cruise AL549 and preserved in formalin were labelled directly on board using a barcoding scheme, and were achieved at the IMF. Please contact the responsible persons for a corresponding data set (see Tab. 5) 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)	ICES database	Publicly by January 2022, earlier on request	By January 2022	steffen.funk@uni-hamburg.de
Fishery data	PANGAEA	Publicly at time of publishing of the underlying peer- reviewed publication; earlier upon request (see contact)		steffen.funk@uni-hamburg.de
Cod stomach content data	PANGAEA	Publicly at time of publishing of the underlying peer- reviewed publication; earlier upon request (see contact)		steffen.funk@uni-hamburg.de
Ichthyoplankton	PANGAEA	Publicly at time of publishing of the underlying peer- reviewed publication; earlier upon request (see contact)		christian.moellmann@uni- hamburg.de

Zooplankton	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)		christian.moellmann@uni-hamburg.de
Hydroacoustic data	PANGEA	Publicly at time of publishing of the underlying peer-reviewed publication; earlier upon request (see contact)		christian.moellmann@uni-hamburg.de

8 Acknowledgement

We thank Captain Jan Lass and the entire crew of RV ALKOR for their outstanding support throughout the cruise and the excellent and constructive working atmosphere during the cruise AL549. Our grateful thanks are also extended to Richard Klinger for his support in planning and logistics prior and during the cruise also including all technical matters. We also thank the whole scientific staff Rene-Marcel Plonus, Peter Hornetz, Anton Höper and Stephanie Kondratowicz for their unwavering support during the cruise, their motivation and enthusiasm bringing this cruise to a scientific success despite the difficult conditions of reduced crew number due to the corona measures.

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10 Abbreviations

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