ALKOR–Berichte

Baltic Cod

Cruise No. AL594

13 May – 27 May 2023
Kiel (Germany) – Kiel (Germany)

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2024

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1 Cruise Summary

1.1 Summary in English

The cruise AL594 "Baltic Cod" focused on the status of the Eastern Baltic cod stock, along with its prey fields (zooplankton and pelagic fish prey) and hydrographic boundary conditions. The cruise extended a 38yr long-term data series on (eco-)system composition and functioning of the Baltic Sea, with a focus on the deeper basins. Collaborations included (i) sampling and experimentation on phytoplankton-virus and -grazer interactions (Uni HH, Dr. Luisa Listmann) (ii) cod gonad and liver sampling for fecundity and parasite studies (in collaboration with Dr. Jonna Tomkiewicz, DTU Aqua) (iii) the study of microbially mediated vitamin B1 (thiamine) dynamics in the Baltic Sea along a salinity gradient (Dr. Kristin Bergauer, GEOMAR). The cruise focused on the Bornholm Basin as most important remaining spawning area of Eastern Baltic cod, but also included the Western Baltic Sea (Kiel and Mecklenburg Bight) and the Arkona Basin. Detailed zoo- and ichthyoplankton sampling was conducted in the Western Baltic (Mecklenburg Bight, Arkona Basin) to contribute to spatially resolved recruitment data of Western Baltic cod via the "Winter cod 2021-2025" program in the BMBF-DAM funded Project SpaCeParti. Subsamples of cod (*Gadus morhua)*, whiting, and flatfish species were taken to determine stock structure, gonadal maturation, stomach contents, and egg production (sprat and cod), and to sample tissue and otolith samples for individual-level genomic and ecological analyses (cod). Here, we present the following first results (i) cod nutritional condition is no longer deteriorating, while individual growth rates have significantly decreased in the past 29 years (ii) the size structure of the stock is still not recovering towards larger individuals, with most individuals (>99%) smaller than 50 cm in length and (iii) Eastern Baltic cod shows moreover signs of recent fisheries induced evolution towards reduced growth rates that are mirrored in genomic changes.

1.2 Zusammenfassung

Die Forschungsfahrt AL594 "Baltic Cod" konzentrierte sich auf den Zustand des östlichen Ostseedorsches sowie dessen Beutefelder (Zooplankton und pelagische Fischbeute) und hydrografische Randbedingungen. Die Fahrt setzte eine 38-jährige Langzeit-Datenreihe zur Ökosystemzusammensetzung der Ostsee fort, mit Schwerpunkt auf die tieferen Becken. Die Zusammenarbeit umfasste (i) Probenahmen und Experimente zu Phytoplankton-Virus-Wechselwirkungen mit Fressfeinden (Uni HH, Dr. Luisa Listmann), (ii) die Entnahme von Dorschen-Gonaden und -Lebern für Fruchtbarkeits- und Parasitenstudien (Dr. Jonna Tomkiewicz, DTU Aqua), und (iii) die Untersuchung der mikrobiell vermittelten Vitamin B1 (Thiamin) Dynamik in der Ostsee entlang eines Salzgehaltsgradienten (Dr. Kristin Bergauer, GEOMAR). Die Fahrt konzentrierte sich auf das Bornholm-Becken als wichtigstes Laichgebiet des östlichen Ostseedorsches, umfasste aber auch die westliche Ostsee (Kieler und Mecklenburger Bucht) und das Arkona-Becken. Detaillierte Zoo- und Ichthyoplankton-Probenahmen in der westlichen Ostsee trugen zu den Rekrutierungsdaten des westlichen Ostseedorsches im Rahmen des "Winter cod 2021-2025" Programms bei. Unterproben von Dorsch (*Gadus morhua*), Wittling und Plattfischarten wurden entnommen, um die Bestandsstruktur, gonadale Reifung, Mageninhalt und Eiproduktion zu bestimmen und Proben für genomische und ökologische Analysen zu sammeln. Erste Ergebnisse zeigen, dass sich der Ernährungszustand des Dorsches nicht mehr verschlechtert, die individuellen Wachstumsraten aber in den letzten 29 Jahren signifikant abgenommen haben. Die Größenstruktur des Bestands erholt sich nicht, die meisten Individuen sind kleiner als 50 cm. Der östliche Ostseedorsch zeigt Anzeichen einer durch Fischerei induzierten Evolution mit reduzierten Wachstumsraten, die sich in genomischen Veränderungen widerspiegeln.

2 Participants

2.1. Principal Investigators

Prof. Thorsten Reusch
Dr. Felix Mittermayer
Dr. Kristin Bergauer
Dr. Christopher Monk

2.2. Scientific Party

Name	Function	institute*	leg
Prof. Thorsten Reusch	chief scientist	GEOMAR	entire cruise
Dr. Felix Mittermayer	zooplankton /fisheries (postdoc)	GEOMAR	entire cruise
Dr. Kristin Bergauer	microbial ecology (postdoc)	IMF-UHAM	1st leg
Dr. Christopher Monk	fish ecology (group leader)	GEOMAR	2nd leg
Hendrik Hampe	technician	GEOMAR	entire cruise
Jana Willim	doctoral student	GEOMAR	entire cruise
Hanna Rudnick	Msc student	GEOMAR	entire cruise
Nico Sievers	Msc student	IMF-UHAM	1st leg
Pernille Hagen Hoj	Msc student	DTU Aqua	entire cruise
Franziska Theising	Msc student	GEOMAR	1st leg
Femke Thoben	Msc student	GEOMAR	entire cruise
Hanna Gaber	Msc student	GEOMAR	2nd leg
Agne Jukneviciute	Bsc student	DTU Aqua	entire cruise
Leandra Weidenauer	Bsc student	GEOMAR	entire cruise
Sarah Kählert	media /outreach	GEOMAR	2nd leg
total	15		

*see abbrev Table 2.3.

2.3. Participating Institutions

Abbreviation	Full name
GEOMAR	Helmholtz-Centre for Ocean Research Kiel, Germany
DTU Aqua	Danish Technical University Aqua, Kopenhagen, DK

3 Research Program

3.1. Description of the work area

Cruise AL594 was part of a 38-year effort to collect long-term data series on hydrography, zooplankton and fish species composition along the salinity gradient of the Baltic Sea, with an emphasis on the central Baltic Sea. The cruise series is dating back to 1987 by the GEOMAR Helmholtz Centre for Ocean Research (and its predecessors IFM-GEOMAR Kiel and IFM Kiel). The rationale for the specific spatial focus “Bornholm Basin” results from the importance of this area as the only major remaining spawning ground of Eastern Baltic cod (EBC). However, the cruise also included the western Baltic Sea, Arkona Basin and Gdansk Deep (Fig. 3.1), thus covering ICES subdivisions (SD) 22, 24, 25, and 26 (Fig. 3.2).

3.2. Aims of cruise AL594

The objective of the cruise was to understand and where possible, quantify the interactions among major pelagic ecosystem components in the Western and central Baltic Sea. The primary components studied were the most abundant fish species in the area, their recruitment dynamics (by collecting ichthyoplankton) and their major prey fields, zooplankton in case of fish larvae, and prey fish in case of adult cod (*Gadus morhua*). These investigations were embedded into climatic forcing impinging on these populations, such as salinity, oxygen supply and temperature.

The cruise integrated oceanographic and biological sampling, permitting a later time series analysis as to how Baltic pelagic food webs and (fish) species across the environmental gradients of the Baltic Sea change in response to both, environmental forcing and human exploitation. Data sets and samples obtained during cruise AL573 are essential for a number of projects, including collaborations with the Technical University of Denmark, National Institute of Aquatic Resources (DTU Aqua), Stockholm University, and the University of Hamburg. Moreover, the cruise contributed to a data set on Western Baltic cod recruitment in the “Winter cod 2021-2025” program and analyses in the DAM funded SpaCeParti project (with member institutes CAU, GEOMAR and IMF-UHAM).

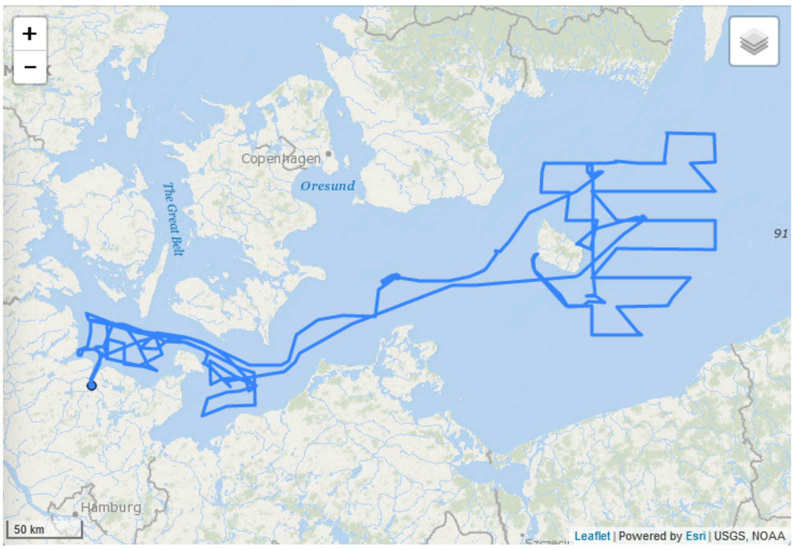

Fig. 3.1 Cruise track of AL594.

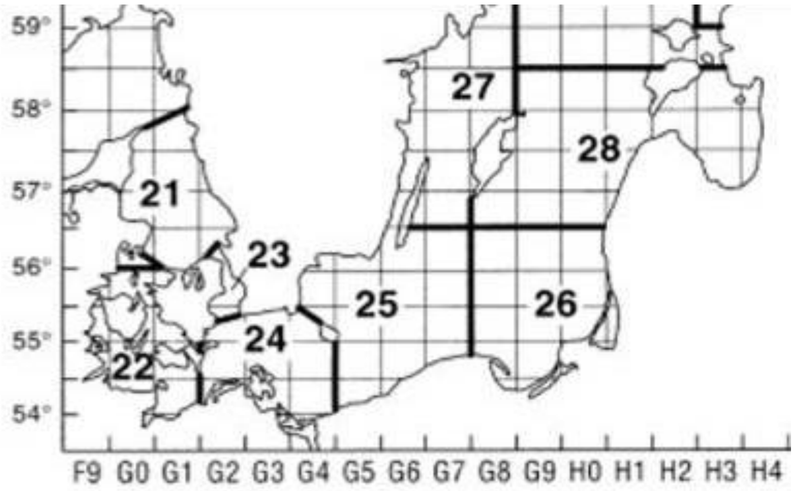

Fig. 3.2 ICES subdivisions in the cruise area (Source: ICES). ICES SD22 corresponds to Kiel Bight = KB, SD24 to Arkona Basin = AB, SD25 to Bornholm Basin = BB and Stolpe Trench = SR, SD26 to Gdansk Deep = GD and Southern Gotland Basin (GB).

3.3. Agenda of the Cruise

Specific investigations during AL594 included (1) a detailed hydrographic survey (oxygen, salinity, temperature) (2) zoo- and ichthyoplankton surveys to determine the composition, abundance, vertical and horizontal distribution and nutritional status of species as well as patterns of plankton phenology (3) sampling of important food web components including nutrients, seston, phyto-, zoo- (including jellyfish) and ichthyoplankton, (4) benthic (Mecklenburg Bight/Arkona basin) and pelagic (Bornholm basin) fishery hauls.

Fisheries hauls served to determine size distributions, maturity status, and length – weight relationships of the three dominant fish species in the pelagic system of the Baltic, cod (*Gadus morhua*), herring (*Clupea harengus*) and sprat (*Sprattus sprattus*) as well as flatfishes including flounder (*Plathichthys flesus*). Secondly, various samples for more detailed analyses back on land were obtained, including cod gonads, livers and otoliths, herring and sprat stomachs and whole samples for dietary analyses, and tissue samples of cod, flounder, whiting, plaice and other species for genetic and stable isotope analysis. In addition, hydroacoustic data were collected continuously along the cruise track for later analysis of fish abundance and distribution. Additional work lines carried out in the context of collaborations with external groups included sampling and on-board experiments on photosynthesis and respiration rates of different phytoplankton fractions.

All measures for responsible marine research were taken. In particular, diplomatic permits were obtained for all countries whose EEZ was covered by the cruise track. For all biological samples intended for genetic analyses, permissions were obtained under the legislation required to meet the Convention for Biological Diversity ("Nagoya protocol"). Care was also taken to only trawl as short as possible to obtain the required number of specimens for later laboratory, isotopic, histological and genomic analysis. Evidently, no non-destructive sampling is possible here that would not sacrifice the individuals.

4 Cruise Narrative

RV ALKOR was loaded on the days prior to the onset of the cruise. ALKOR then departed from the GEOMAR Westshore pier on 13 May 2023 at 9:00h (all times board time). We fished in the Kiel and Mecklenburg Bays until 14 May using bottom trawl nets (a total of 5 hauls). The goal was to sample populations of the western cod stock in cooperation with the IMF (Hamburg University), focusing on one-year-old cod (<15 cm length), of which we caught 41 individuals.

We then transited to the Bornholm Basin, where on 15 May, we sampled the central long-term station BB23 using various plankton nets and water samplers. Different plankton fractions (phytoplankton, meso- and microzooplankton) were collected in collaboration with IFO (Dr. Jörg Dutz, Dr. Caroline Paul) to document long-term changes. Additionally, large volumes of nano-plankton and viroplankton were collected using McLane water samplers and in-situ pumps (project by Dr. Kristin Bergauer, GEOMAR). From 15-16 May, we conducted depth-resolved sampling of zooplankton and fish larvae using the Maxi multinet. Samples were taken every 5 meters over 24 hours in three 8-hour intervals with a 335 µm plankton net, and counted onboard under a stereoscope. Some fish larvae were frozen for later biochemical and genetic analyses. Due to bad weather (wind gusts up to 8), we had to weather off east of Nexö/Bornholm from May 16-17.

Starting at 4 PM on 17 May, we conducted quasi-synoptic sampling of 45 stations in the Bornholm Basin with nets of 150/335/500 µm mesh size to assess zooplankton and fish larvae across the basin on a 10 nm grid. This was completed successfully on 19 May at 21:00 h, and we docked in Rönne, Bornholm that evening. A crew change took place in Rönne/Bornholm on 20 May, and we departed on the morning of 21 May. Near stations BB41/BB42, two bottom trawls were conducted to intensively sample cod in the only remaining core spawning area of the EBC. Blood samples for high-quality DNA extraction for long-read sequencing were taken from 28 cod to study structural genomic variations between western and eastern stocks. Additional samples were taken from 200 cod for otoliths, genomics (fin clips), and stable isotopes. We selected 40 spawning females across all size classes for later fertility analyses (collaboration with Dr. Jonna Tomkiewicz, DTU Aqua, Copenhagen) and collected liver samples to quantify parasitic nematode burdens (collaboration with Dr. Jane Behrens, DTU Aqua).

Parallel phytoplankton and marine virus sampling in the mixed surface layer were conducted at one station each in Kiel Bay, Arkona Basin, and Bornholm Basin (collaboration with Dr. Luisa Listmann, IMF, Uni HH) using the Kranz water sampler. From 22-24 May, Bongo-CTD station sampling for ichthyoplankton and fish larvae was conducted in the Arkona Basin and Mecklenburg Bay (24 May). At the end of the trip, cod were caught by angling on 25-26 May in the western Baltic Sea (Kiel and Mecklenburg Bight) for comparison with genomic analyses of individuals from the Bornholm Basin, followed by thorough tissue-specific sampling and organ analysis.

The trip concluded successfully with our arrival in Kiel harbor on 27 May 2023, one day ahead of time.

5 Preliminary Results

5.1 Gear Deployments and Hydrography

An overview of all gear deployments is given in Table 4.1. During the AL594 cruise a CTD profile was taken at every station, recording salinity, temperature and dissolved oxygen from surface to 1 m above sea floor. The salinity gradient of the Baltic Sea was as expected (Figure 5.1a) with high salinity near the bottom of the Kiel and Mecklenburg Bight with medium saline water above. The oxygen situation in the Baltic Sea remains to be one of the major problems. Our data shows that, in addition the anoxic areas in the Bornholm Basin, certain areas in the Kiel and Mecklenburg Bight already in mid-may show depleted dissolved oxygen below 20m (Figure 5.1b). A situation that should not arise as early in the year and will cause severe problem for deeper benthic communities and demersal fish relying on cold water refugia during high summer. The rising spring temperatures lead to warming surface temperature in the South West (Figure 5.1c)

Gear	Number_of_deployments
CTD	107
Bottom trawl	8
WS-CTS	6
In-Situ pump	4
Apstein	3
Multinetz Maxi	8
Bongo	99
JFT	1
Angling	7
Mooring(Fishtrap)	4
WP2-100	3

Table 4.1 Overview of all gear deployments during AL594. Contrary to former years, fewer deployments of pelagic trawls were done to avoid excessive bycatch of clupeids.

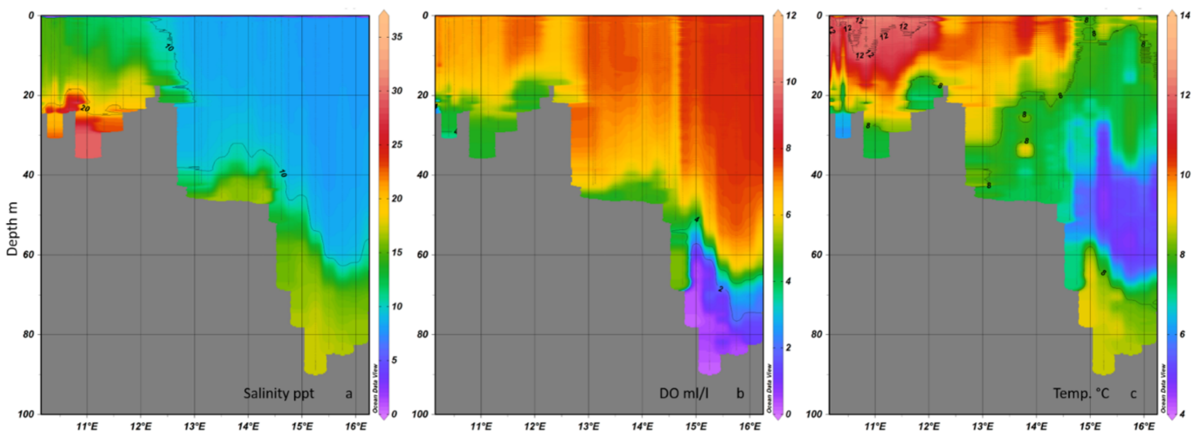

Fig. 5.1a-c Hydrography of the SW and Central along a longitudinal transect from 10° E to 16.5°E during the AL594 cruise in May 2023 a) salinity (ppt), b) dissolved oxygen (ml/l) and c) temperature (°C).

The hydrographic situation in the Bornholm Basin is relatively unchanged in comparison to prior years, the dissolved oxygen (Figure 5.2a,b) concentration below 70m depth is lower than 2 ml/l with anoxic conditions below approximately 80m. These anoxic conditions cover large volumes of the reproductive volume of EBC, e.g. water with a salinity of above 11 psu, which is found below 60 m (Figure 5.2c). This water body was warmer than the above laying waterbody illustrating the stratification in this area (Figure 5.2d).

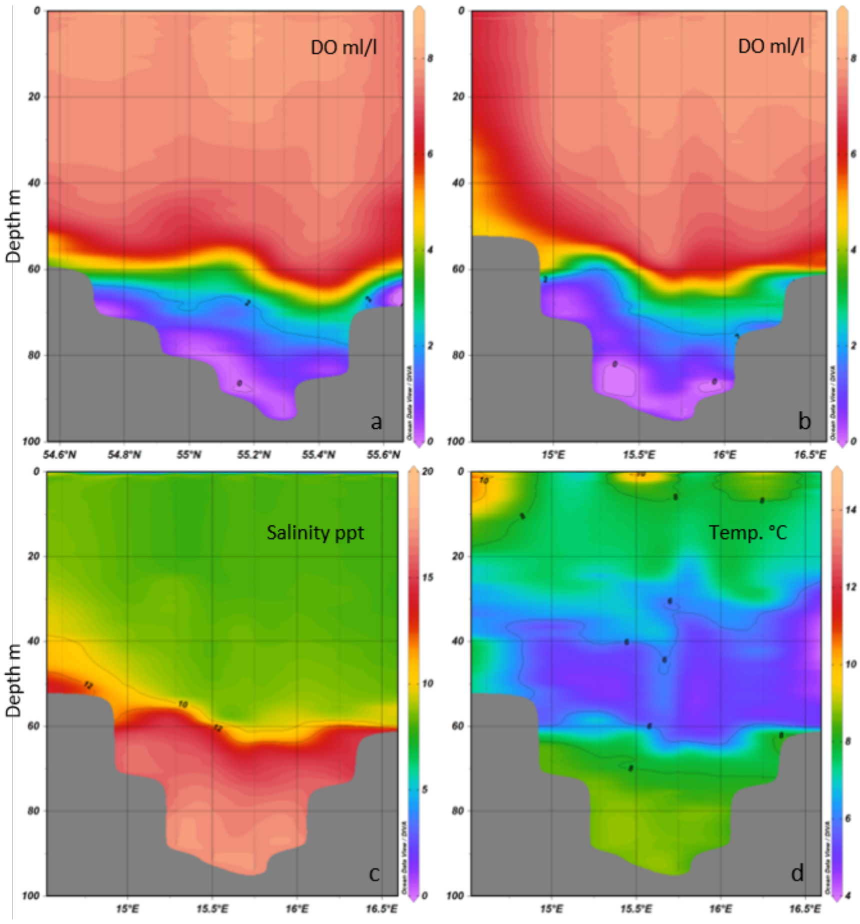

Fig. 5.2a-d Hydrography of the Bornholm Basin during the AL594 cruise in May 2023 a) dissolved oxygen (ml/l) along a latitudinal transect b) dissolved oxygen (ml/l) along a longitudinal transect, b) dissolved oxygen (ml/l) along a longitudinal transect, c) salinity (ppt) along a longitudinal transect and d) temperature (°C) along a longitudinal transect.

During the cruise the on-board underway thermosalinograph (TSG) together with a SBE38 Thermometer collected temperature and salinity date. While temperature is taken at the water inlet in about 4 m depth, salinity is estimated within the interior TSG from conductivity and interior temperature. No temperature calibration was performed. Salinity was calibrated with independent water samples taken at the water inlet. Data has been published here https://doi.pangaea.de/10.1594/PANGAEA.962717.

5.2. Fish Larvae Abundance

Zooplankton samples including fish larvae were taken along a salinity gradient from Kiel Bight to the Bornholm Basin using Bongo nets. The sampling effort west of the Arkona Basin was enhanced for collecting spatially resolved data within the “Winter cod 2021-2025” program in the SpaCePari project (DAM funded, "Küstenfischerei, Biodiversität, räumliche Nutzung und Klimawandel") that addresses as one of the major objectives the regionally resolved status of the Western Baltic cod stock.

Traditionally, fish larvae as one major indicator of fish recruitment are the focus of ALKOR cruises "Baltic Cod". During the cruise AL594, five fish species were identified to the species level in the Bongo 500µm catches. In addition to *Gadus morhua*, this included *Taurulus bubalis*, *Myoxocephalus scorpius, Liparis liparis,* and *Platichthys flesus.* In addition, larva of certain species were only identifiable to lower taxonomic groups, including flatfish, sandeel, clupeidae and gobies. A total of 1957 larva were samples and frozen at -70°C for later genetic, biochemical and ecological analysis. All sample information has been deposited together with their meta data in the BIS system, have been assigned persistent identifiers and are available under https://biosamples.geomar.de/.

During the "Bornholm-Bongo-Grid" only two cod larvae were found in the central Bornholm Basin (Figure 5.3.), which aligned with expectations considering the timing of the cruise coninciding with the early spawning season. The "Bongo-Grid-West" (Figure 5.4) on the other hand coincidedwith the end of the larval season in the Kiel and Mecklenburg Bight and larval catches were substantially higher, with fewer larvae in the Kiel Bight compared to the Mecklenburg Bight. This finding reflects those of previous cruises in this area (cf. cruise report AL571 and AL573 of 2022). A second sampling of the grid in the Kiel Bight during night did not lead to higher catches, indicating that low numbers during day were not related to vertical migration of settled cod post larva to the bottom (where they are hard to catch) during daylight.

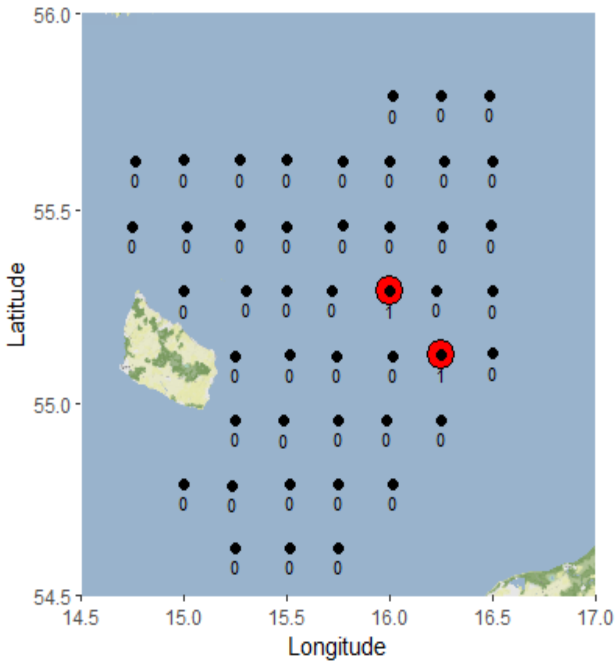

Fig. 5.3 Catch of larval cod (*Gadus morhua*) in the Bornholm Basin, black spots are the 45 Bongo stations the size of the red circle and the number indicates the number of caught larvae.

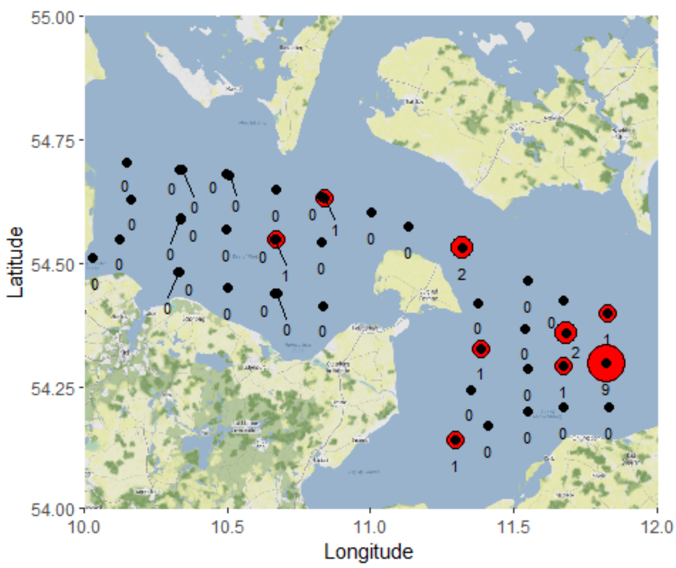

Fig. 5.4 Catch of larval cod (*Gadus morhua*) in the Western Baltic Sea, black spots are the 35 Bongo stations the size of the red circle and the number indicates the number of caught larvae.

5.3 Fisheries and Status of Baltic Cod Stocks

5.3.1. General Catches and Environmental Conditions

As oxygen conditions near the bottom were generally low to sustain higher life including fish at water depth >70m, one haul in Bornholm Basin was done within or slightly above the halocline, i.e. in the pelagic zone, using a juvenile fish trawl (JFT). All remaining hauls wereconducted with a small bottom trawl (in total 8 hauls) deployed at the bottom, after previously checking that >2 mL O_2 saturation were present (checked with a CTD before catch). This way, the bycatch of clupeids could be minimized in favour of our target species cod (*Gadus morhua*). Fishery hauls were conducted in Kiel Bight (1 haul), Mecklenburg Bight (2 hauls) Arkona Basin (3 hauls) and Bornholm Basin (3 hauls). The overall catch composition is shown in Table 5.1.

Table 5.1. Overview on species catch composition of fish catches, all numbers are kg, separate for the 3 ICES subdivision (cf. Fig. 3.2). Single fish measurement and samples were taken for 2954 cod and 393 whiting individuals. For dab, flounder and plaice up to 400 and 50 individuals per species were sampled for length, weight and finclips respectively for each ICES subdivision. For herring and sprat, sub-samples were taken. measured and samples at each station.

	ICES Subdivision (SD)					
	22		23		25	
Species	**n**	**Mass (kg)**	**n**	**Mass (kg)**	**n**	**Mass (kg)**
Ammodytidae	2	0.04	1	0.02		
Clupea harengus	2	0.13	739*	40.9	15	0.75
Enchelyopus cimbrius	19	0.38	2	0.1	6	0.1
Gadus morhua	59	505	73	5.6	2822	18.5
Glyptocephalus cynoglossus	2	1.67				
Hippoglossoides platessoides	5	0.13	2	0.1		
Limanda limande	2891*	199.5	364*	33.8		
Lumpenus lampretaeformis	108	6.6	1	0.01		
Melanogrammus aeglefinus	2	0.29				
Merlangius merlangus	51	4.3	342	59.8		
Microstomus kitt	3	0.93				
Myoxocephalus scorpius	29	2.18				
Pholis gunnellus	1	0				
Platichthys flesus	10	2.3	275*	46.3	147	22.4
Pleuronectes platessa	3279*	264	368*	31.2	8	0.74
Scophthalmus maximus	3	2.3	4	10.3		
Scophthalmus rhombus	1	0.11				
Solea solea	1	0.1	1	0.1		
Sprattus sprattus	8721*	123.64	4367*	73.8	38131*	423.2
Zoares viviparus	20	1113.6				
**calculated via extrapolation*						

In the Arkona Basin, but also in western parts of the Bornholm Basin, the whiting population seems to further increase in abundance compared to earlier years. Approximately twice the biomass /number of individuals were caught in 2023 compared to 4 yrs before, despite slightly less catch effort. Individualized samples of whiting (otoliths, fin clips for genetic analysis) were taken from a total of 394 individuals. This year, due to the increase in abundance of flatfish, individualized data and finclips for later genetic analyses were also take from dab (N=41), plaice (N= 435) and flounder (N=60). For cod, single fish data (length, weight, sex and maturity stage) and samples (otoliths, fin clips for genetic analysis, gonads and livers) were obtained for 327 individuals in total, while length /weight data were obtained for a total of 2957 individuals. The first set of samples will be subjected to a variety of methods later, including age readings (otoliths), parasite investigations (livers), and genetic analyses (finclips, see below). Stable isotope analyses are also being conducted at the moment to reconstruct the trophic level and past prey (i.e. pelagic fish or benthic prey). Length and weight were measured for additional individuals. The condition of animals, assessed as Fulton's K, has not significantly improved compared to previous years, but is also not further declining.

5.3.2. Cod Population Structure in the Bornholm Basin

In Bornholm Basin, the main remaining spawning area of the Eastern Baltic cod (EBC) stock, the mean standard length of individuals caught in 2023 was still very small (Figure 5.5a), and larger individuals >50 cm, which were frequently observed in past decades, were mostly absent from the population, similar to the previous years. However, the condition of cod does not seem to deteriorate further which is a hopeful sign (Fig. 5.5b). Further analyses, including full genome sequencing of a random samples spanning time has now identified putative causes for the dramatic decline in fish size, in particular the hypothesis that ongoing strong size selective fishing "bred" small individuals owing to fisheries induced selection, which will be briefly summarized in the next section.

5.3.3. Temporal Changes in Genomic Composition and Growth Rate of the Eastern Baltic Cod Population

One key goal of the past and previous cruises of the 38-yr time series is to detect demographic and conditional changes in the EBC population. Eastern Baltic cod population is facing worsening of the body size, condition, population size structure and abundance under heavy and persistent and/or size-selective trawling over the last decades. We hypothesized that evolutionary responses are detectable in a temporal population genomic data set that reflect the observed phenotypic changes. To test this, we took a full advantage of the Baltic Sea Integrative Long-Term Data Series of EBC in Bornholm Basin archived with otoliths, finclips and individual phenotype records. We conducted a growth modelling and whole-genome resequencing of the 152 archived samples spanning five time points between 1996 and 2019, investigating whether or not changes in a heritable trait under selection translates to a detectable response of the genomes.

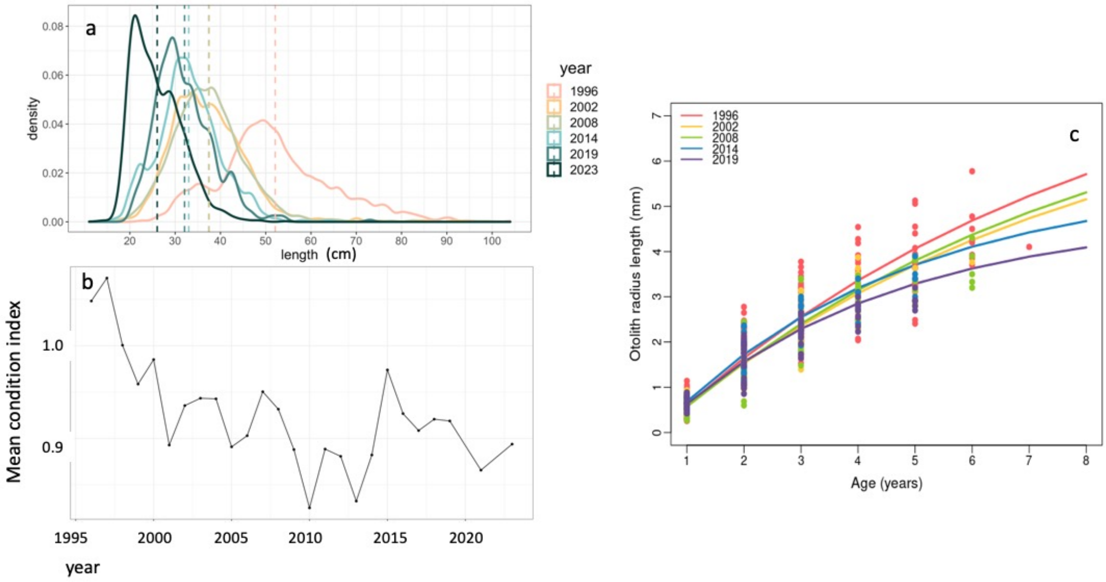

Fig. 5.5a-c Status of Eastern Baltic cod population. (a) Modelled density frequency diagrams of cod individual size distribution since 1996 (in cm standard length) compared to AL594 collected in May 2023. Note that in 2022 <1% of individuals had a standard length of >50 cm. (b) Mean condition of cod individuals caught in Bornholm Basin over time (same sample set as (a). The Fulton's condition index was calculated as 100*(weight in g)/(body length in mm)^3. (c) Estimated von Bertalanffy growth curves for each catch year. The von Bertalanffy growth curves are based on otolith readings and were plotted using estimated sets of parameters for each temporal population. Each point depicts observed otolith radius to chemical annuli at age coloured based on the individuals' catch year.

A von Bertalanffy growth model using phenotype data, age, body length and chemical annuli of otoliths, of the sequenced individuals showed markedly impaired growth for the study period (Figure 5.5c). A genotype-phenotype association study (GWAS) identified pronounced peaks of outlier loci near genes linked to growth and maturity, which in turn showed signals of selection (Fig. 5.6). It showcases the strength of combining temporal genomics of wild population with its phenotype data for the first time. The evolutionary consequences of intense size-selective fishing pressure presented in this study implies the persistent impact of fisheries over multiple generations, limiting the recovery potential of the population and underscores the imperative for the informed fisheries management to mitigate long-term repercussions and conserve the adaptive potential of marine populations. This work has been published as a preprint (Han et al. al 2024; https://doi.org/10.1101/2024.06.27.601002).

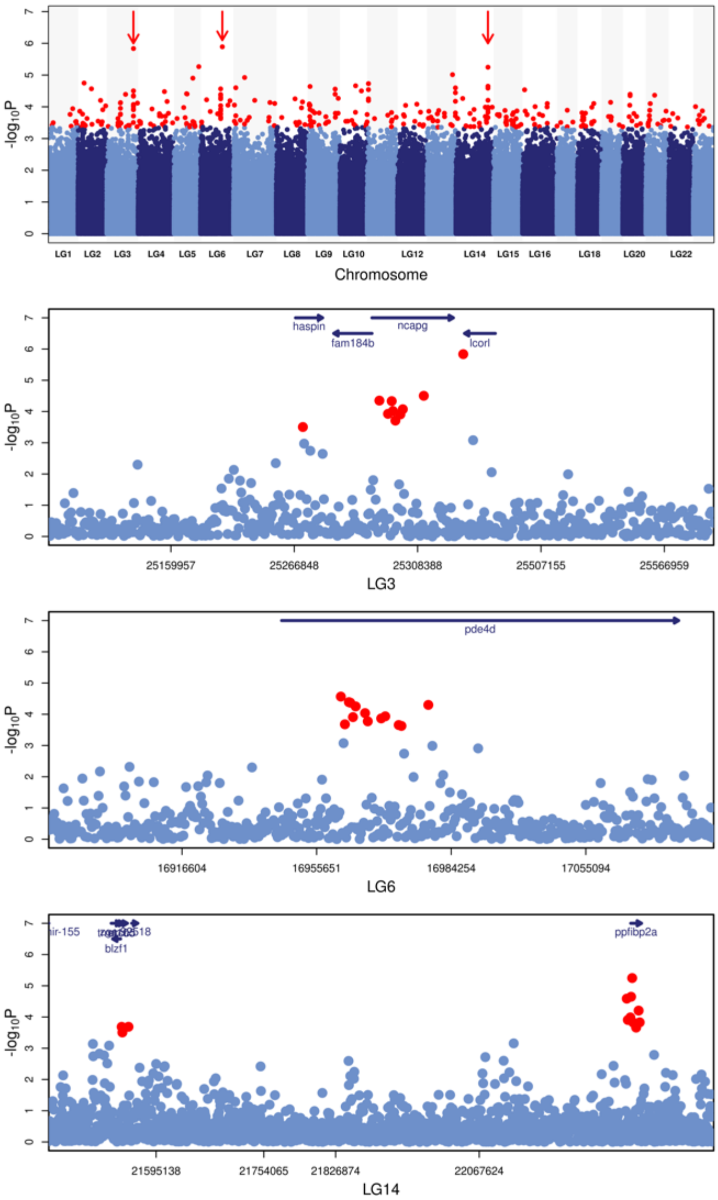

Fig. 5.6 Genomic signals of selection in the genome of EBC. A Manhattan plot of -logP values in genome-wide association (GWA) analysis. A total of 152 samples were subjected to GWA using the sequenced genotypes, 679,584 SNPs (>0.05 MAF), and estimated growth performance index as phenotype. Negative log transformed Wald test p-values for each SNP were plotted along the genome. Outlier status was assigned for 338 SNPs with lowest 0.05% p-values (in red circles). The cutoff for outliers were selected based on the visual examination of the Manhattan plot in the first panel, so as to include distinctive peaks with clustering outliers and at the same time exclude spurious outliers consisting of single SNPs only. Each arrow indicates regions with such peaks, which are zoomed in panels. In panels 2-4, genes residing at or near the outlier SNPs which showed biological relevance to growth were shown in arrows. In linkage group 3 lie ncapg, which is differentially expressed in puberty in salmon (Crespo et al. 2019) and fam184b, which is associated with body weight at first egg in chicken (Fan et al. 2017), linkage group 6 included pde4d gene which showed response in the transcriptome of fast growth line in a rainbow trout, and in linkage group 14 lie mettl21e which was linked to growth in pupfishes and intramuscular fat deposition in cattle.

5.4. Microbially Mediated Vitamin B1 (Thiamine) Dynamics

Dr. Kristin Bergauer, GEOMAR

In the marine environment microbes engage in synergistic interactions to mediate the cycling of major and trace nutrients, including vitamins. Vitamin B1 is essential for the viability of living cells. And yet, it appears that many marine microbes are unable to produce B1 *de novo*, and our understanding of how B1 is exchanged in aquatic systems is limited (Fig. 5.7). Phytoplankton, Bacteria, and Archaea are the primary producers of this important metabolite in the world's oceans and play a crucial role in transmitting B1 to higher trophic levels through grazing and predation. During the AL594 cruise, we collected vertical profiles of seawater along the different basins covered by the cruise track to 1) quantify *in situ* particulate (cellular quotas of microbes and zooplankton) and dissolved B1 and precursor concentrations, 2) detect changes in the composition of the microbial community using eDNA analysis, and 3) evaluate how environmental factors (such as dissolved oxygen and macronutrients) and abiotic factors regulate the cycling of B1 (Fig. 5.7). The particle size distribution was obtained with the Underwater Vision Profiler 6 mounted onto the water sampler. In addition, we collected large volumes of seawater to analyze the endo- and exoproteomes of the natural microbial community to ultimately determine the activity of major B1 synthesizers and consumers. The seasonal and circadian regulation of B1 biosynthesis gene expression and their potential impact on microbial interactions and water column concentrations are part of a project where monthly sampling at Boknis Eck and culture experiments will be combined.

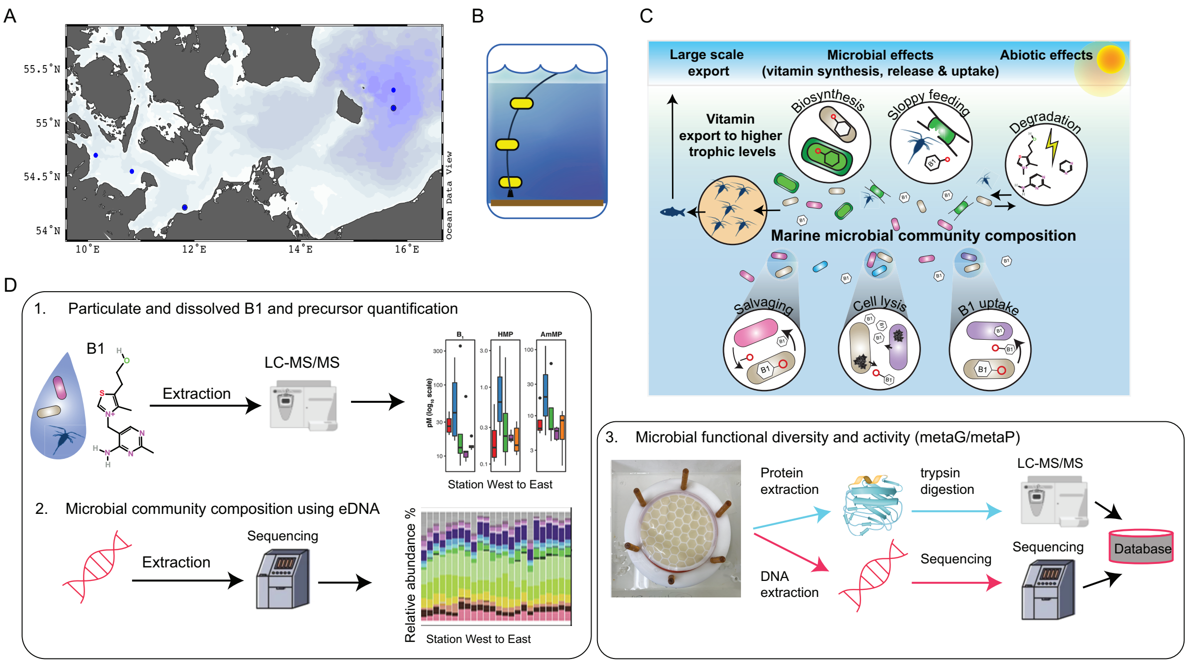

Fig. 5.7 Sampling strategy during AL594 Baltic sea cruise. (A) Location of the study sites (circles) occupied. (B) Schematics of the vertical sampling strategy. (C) Conceptual sketch of B1 cycling in the pelagic ocean, illustrating abiotic factors that can affect the stability of B1 (e.g., solar radiation). Microbial processes describing biosynthesis and salvaging as well as release and uptake are shown. Potential routes of large-scale export are depicted in the left section including transfer up the marine food web.

6 Station List

The list and additional cruise data are also permanently available via the GEOMAR OSIS data portal under the link: https://osis.geomar.de/app/expeditions/364225.

Station	Device	Event Time	Latitude	Longitude	Depth (m)
AL594_0_Underway-1	Thermosalinograph	2023/05/13 07:09:37	54° 30,149' N	010° 15,362' E	10
AL594_1-1	CTD	2023/05/13 07:32:10	54° 33,192' N	010° 13,082' E	19
AL594_1-2	Fish Net (Bottom Trawl)	2023/05/13 07:37:32	54° 33,192' N	010° 13,117' E	19
AL594_2-1	CTD	2023/05/13 10:17:54	54° 41,395' N	010° 23,845' E	31
AL594_2-2	Fish Net (Bottom Trawl)	2023/05/13 10:36:59	54° 41,525' N	010° 22,667' E	30
AL594_2-3	In Situ Pump	2023/05/13 13:37:40	54° 41,353' N	010° 23,899' E	31
AL594_2-4	CTD with water sampler	2023/05/13 14:53:17	54° 41,332' N	010° 23,940' E	31
AL594_3-1	CTD	2023/05/14 06:00:06	54° 25,608' N	011° 23,712' E	21
AL594_3-2	Fish Net (Bottom Trawl)	2023/05/14 06:07:53	54° 25,540' N	011° 23,809' E	21
AL594_4-1	CTD	2023/05/14 10:27:56	54° 20,835' N	011° 32,472' E	24
AL594_4-2	Fish Net (Bottom Trawl)	2023/05/14 10:36:24	54° 20,722' N	011° 32,567' E	24
AL594_4-3	In Situ Pump	2023/05/14 12:20:50	54° 20,823' N	011° 32,544' E	24
AL594_4-4	CTD with water sampler	2023/05/14 13:04:23	54° 20,850' N	011° 32,513' E	24
AL594_5-1	CTD	2023/05/15 06:02:41	55° 17,497' N	015° 44,981' E	96
AL594_5-2	Apstein Net	2023/05/15 06:11:25	55° 17,493' N	015° 44,985' E	96
AL594_5-3	Apstein Net	2023/05/15 06:31:13	55° 17,497' N	015° 44,989' E	96
AL594_5-4	Apstein Net	2023/05/15 06:48:02	55° 17,495' N	015° 44,993' E	96
AL594_5-5	WP-2 Plankton Net	2023/05/15 07:06:25	55° 17,498' N	015° 44,994' E	96
AL594_5-6	WP-2 Plankton Net	2023/05/15 07:16:12	55° 17,491' N	015° 44,988' E	96
AL594_5-7	WP-2 Plankton Net	2023/05/15 07:25:12	55° 17,502' N	015° 44,971' E	96
AL594_5-8	CTD with water sampler	2023/05/15 07:51:29	55° 17,497' N	015° 44,971' E	96
AL594_5-9	CTD with water sampler	2023/05/15 07:59:24	55° 17,488' N	015° 44,965' E	96
AL594_5-10	In Situ Pump	2023/05/15 08:29:06	55° 17,500' N	015° 44,998' E	96
AL594_5-11	Multinet MAXI (9 Netze)	2023/05/15 11:06:45	55° 17,518' N	015° 45,395' E	96
AL594_5-12	Multinet MAXI (9 Netze)	2023/05/15 13:15:03	55° 17,478' N	015° 44,980' E	96
AL594_5-13	Multinet MAXI (9 Netze)	2023/05/15 14:14:33	55° 17,470' N	015° 45,040' E	96
AL594_5-14	Multinet MAXI (9 Netze)	2023/05/15 20:58:48	55° 17,539' N	015° 45,035' E	96
AL594_5-14	Multinet MAXI (9 Netze)	2023/05/15 21:43:24	55° 17,522' N	015° 45,026' E	96
AL594_5-15	Multinet MAXI (9 Netze)	2023/05/15 22:45:57	55° 17,366' N	015° 44,934' E	96
AL594_5-16	Multinet MAXI (9 Netze)	2023/05/16 04:59:22	55° 17,570' N	015° 45,044' E	96
AL594_5-17	Multinet MAXI (9 Netze)	2023/05/16 06:02:38	55° 17,514' N	015° 45,010' E	96
AL594_6-1	CTD with water sampler	2023/05/17 11:01:00	55° 07,496' N	015° 15,064' E	61
AL594_6-2	In Situ Pump	2023/05/17 11:25:24	55° 07,504' N	015° 15,008' E	62
AL594_7-1	CTD	2023/05/17 13:55:53	55° 07,513' N	015° 15,156' E	61
AL594_7-2	Bongo Net	2023/05/17 14:02:46	55° 07,489' N	015° 15,115' E	61
AL594_8-1	Bongo Net	2023/05/17 15:11:22	55° 17,538' N	015° 18,337' E	92
AL594_8-2	CTD	2023/05/17 15:25:34	55° 17,522' N	015° 17,239' E	90
AL594_9-1	CTD	2023/05/17 16:31:40	55° 17,509' N	014° 59,974' E	72
AL594_9-2	Bongo Net	2023/05/17 16:39:04	55° 17,443' N	014° 59,900' E	72
AL594_10-1	Bongo Net	2023/05/17 17:47:41	55° 27,401' N	015° 00,929' E	79
AL594_10-2	CTD	2023/05/17 18:02:41	55° 27,511' N	014° 59,937' E	78

AL594_11-1	CTD	2023/05/17 19:01:01	55° 27,471' N	014° 44,983' E	69
AL594_11-2	Bongo Net	2023/05/17 19:08:49	55° 27,458' N	014° 44,916' E	69
AL594_12-1	Bongo Net	2023/05/17 20:19:50	55° 37,487' N	014° 45,998' E	69
AL594_12-2	CTD	2023/05/17 20:32:04	55° 37,488' N	014° 45,074' E	68
AL594_13-1	CTD	2023/05/17 21:31:17	55° 37,544' N	015° 00,005' E	75
AL594_13-2	Bongo Net	2023/05/17 21:38:08	55° 37,594' N	014° 59,827' E	75
AL594_14-1	Bongo Net	2023/05/17 22:46:55	55° 37,648' N	015° 16,160' E	72
AL594_14-2	CTD	2023/05/17 23:00:33	55° 37,515' N	015° 15,086' E	72
AL594_15-1	CTD	2023/05/17 23:56:14	55° 37,496' N	015° 30,018' E	67
AL594_15-2	Bongo Net	2023/05/18 00:03:13	55° 37,581' N	015° 29,921' E	67
AL594_16-1	Bongo Net	2023/05/18 01:09:05	55° 37,514' N	015° 46,220' E	69
AL594_16-2	CTD	2023/05/18 01:22:05	55° 37,481' N	015° 45,205' E	69
AL594_17-1	CTD	2023/05/18 02:16:29	55° 37,463' N	016° 00,081' E	74
AL594_17-2	Bongo Net	2023/05/18 02:23:18	55° 37,523' N	015° 59,910' E	74
AL594_18-1	Bongo Net	2023/05/18 03:30:40	55° 47,380' N	016° 00,868' E	62
AL594_18-2	CTD	2023/05/18 03:40:03	55° 47,483' N	016° 00,131' E	61
AL594_19-1	CTD	2023/05/18 04:34:31	55° 47,502' N	016° 14,998' E	60
AL594_19-2	Bongo Net	2023/05/18 04:41:14	55° 47,497' N	016° 14,980' E	60
AL594_20-1	Bongo Net	2023/05/18 05:32:29	55° 47,431' N	016° 29,216' E	57
AL594_20-2	CTD	2023/05/18 05:43:19	55° 47,518' N	016° 29,987' E	56
AL594_21-1	CTD	2023/05/18 06:51:57	55° 37,530' N	016° 29,982' E	62
AL594_21-2	Bongo Net	2023/05/18 06:58:21	55° 37,491' N	016° 29,902' E	62
AL594_22-1	Bongo Net	2023/05/18 07:49:19	55° 37,543' N	016° 16,096' E	74
AL594_22-2	CTD	2023/05/18 08:02:03	55° 37,475' N	016° 15,088' E	74
AL594_23-1	CTD	2023/05/18 09:20:46	55° 27,508' N	016° 30,007' E	58
AL594_23-2	Bongo Net	2023/05/18 09:30:44	55° 27,512' N	016° 29,859' E	58
AL594_24-1	Bongo Net	2023/05/18 10:25:31	55° 27,427' N	016° 15,754' E	74
AL594_24-2	CTD	2023/05/18 10:38:56	55° 27,513' N	016° 14,967' E	74
AL594_25-1	CTD	2023/05/18 11:35:21	55° 27,470' N	016° 00,042' E	83
AL594_25-2	Bongo Net	2023/05/18 11:42:31	55° 27,487' N	015° 59,981' E	83
AL594_26-1	Bongo Net	2023/05/18 12:36:42	55° 27,531' N	015° 46,219' E	85
AL594_26-2	CTD	2023/05/18 12:52:25	55° 27,468' N	015° 45,073' E	85
AL594_27-1	CTD	2023/05/18 13:49:33	55° 27,506' N	015° 30,066' E	85
AL594_27-2	Bongo Net	2023/05/18 13:56:21	55° 27,495' N	015° 29,980' E	85
AL594_28-1	Bongo Net	2023/05/18 14:50:10	55° 27,573' N	015° 16,293' E	88
AL594_28-2	CTD	2023/05/18 15:05:19	55° 27,511' N	015° 15,009' E	90
AL594_29-1	CTD	2023/05/18 16:28:10	55° 17,489' N	015° 29,923' E	93
AL594_29-2	Bongo Net	2023/05/18 16:35:06	55° 17,520' N	015° 30,121' E	93
AL594_30-1	Bongo Net	2023/05/18 17:29:12	55° 17,505' N	015° 43,350' E	95
AL594_30-2	CTD	2023/05/18 17:46:34	55° 17,489' N	015° 44,911' E	95
AL594_31-1	CTD	2023/05/18 18:43:56	55° 17,474' N	016° 00,029' E	89
AL594_31-2	Bongo Net	2023/05/18 18:51:12	55° 17,454' N	016° 00,185' E	88
AL594_32-1	Bongo Net	2023/05/18 19:44:12	55° 17,518' N	016° 13,732' E	75
AL594_32-2	CTD	2023/05/18 19:58:32	55° 17,482' N	016° 14,945' E	74
AL594_33-1	CTD	2023/05/18 20:54:50	55° 17,484' N	016° 29,949' E	61
AL594_33-2	Bongo Net	2023/05/18 21:00:38	55° 17,427' N	016° 29,933' E	62

AL594_34-1	Bongo Net	2023/05/18 21:59:53	55° 07,871' N	016° 30,069' E	51
AL594_34-2	CTD	2023/05/18 22:09:31	55° 07,508' N	016° 30,026' E	51
AL594_35-1	CTD	2023/05/18 23:07:23	55° 07,487' N	016° 15,083' E	79
AL594_35-2	Bongo Net	2023/05/18 23:15:12	55° 07,548' N	016° 14,850' E	79
AL594_36-1	Bongo Net	2023/05/19 00:09:15	55° 07,475' N	016° 01,010' E	86
AL594_36-2	CTD	2023/05/19 00:22:56	55° 07,493' N	016° 00,000' E	86
AL594_37-1	CTD	2023/05/19 01:21:09	55° 07,496' N	015° 45,010' E	89
AL594_37-2	Bongo Net	2023/05/19 01:28:59	55° 07,507' N	015° 44,773' E	89
AL594_38-1	Bongo Net	2023/05/19 02:22:41	55° 07,560' N	015° 30,871' E	68
AL594_38-2	CTD	2023/05/19 02:35:22	55° 07,520' N	015° 29,967' E	67
AL594_39-1	CTD	2023/05/19 03:55:34	54° 57,496' N	015° 15,010' E	43
AL594_39-2	Bongo Net	2023/05/19 04:00:31	54° 57,512' N	015° 15,098' E	43
AL594_40-1	Bongo Net	2023/05/19 04:49:54	54° 57,426' N	015° 29,016' E	77
AL594_40-2	CTD	2023/05/19 05:01:56	54° 57,503' N	015° 29,939' E	76
AL594_41-1	CTD	2023/05/19 05:58:25	54° 57,485' N	015° 45,013' E	81
AL594_41-2	Bongo Net	2023/05/19 06:05:25	54° 57,482' N	015° 45,165' E	80
AL594_42-1	Bongo Net	2023/05/19 07:00:35	54° 57,486' N	015° 59,249' E	74
AL594_42-2	CTD	2023/05/19 07:13:19	54° 57,490' N	016° 00,047' E	73
AL594_43-1	CTD	2023/05/19 08:08:08	54° 57,540' N	016° 14,905' E	50
AL594_43-2	Bongo Net	2023/05/19 08:12:49	54° 57,515' N	016° 14,888' E	50
AL594_44-1	Bongo Net	2023/05/19 09:28:38	54° 47,529' N	016° 00,894' E	49
AL594_44-2	CTD	2023/05/19 09:38:32	54° 47,515' N	016° 00,029' E	51
AL594_45-1	CTD	2023/05/19 10:31:08	54° 47,505' N	015° 44,987' E	71
AL594_45-2	Bongo Net	2023/05/19 10:37:46	54° 47,559' N	015° 44,863' E	72
AL594_46-1	Bongo Net	2023/05/19 11:31:08	54° 47,483' N	015° 30,925' E	73
AL594_46-2	CTD	2023/05/19 11:43:33	54° 47,462' N	015° 29,998' E	73
AL594_47-1	CTD	2023/05/19 12:57:27	54° 37,509' N	015° 44,955' E	59
AL594_47-2	Bongo Net	2023/05/19 13:03:28	54° 37,482' N	015° 44,928' E	59
AL594_48-1	Bongo Net	2023/05/19 13:51:00	54° 37,495' N	015° 30,725' E	63
AL594_48-2	CTD	2023/05/19 14:01:10	54° 37,478' N	015° 29,970' E	63
AL594_49-1	CTD	2023/05/19 14:52:24	54° 37,502' N	015° 14,917' E	58
AL594_49-2	Bongo Net	2023/05/19 14:57:14	54° 37,541' N	015° 14,929' E	58
AL594_50-1	Bongo Net	2023/05/19 15:52:47	54° 47,258' N	015° 14,242' E	67
AL594_50-2	CTD	2023/05/19 16:03:57	54° 47,510' N	015° 14,932' E	67
AL594_51-1	CTD	2023/05/19 16:54:52	54° 47,526' N	015° 00,042' E	60
AL594_51-2	Bongo Net	2023/05/19 17:02:34	54° 47,594' N	015° 00,106' E	60
AL594_52-1	Fish Net (Bottom Trawl)	2023/05/21 08:00:33	54° 47,422' N	015° 09,453' E	65
AL594_53-1	Fish Net (Bottom Trawl)	2023/05/21 13:00:07	54° 51,008' N	015° 11,829' E	67
AL594_54-1	CTD	2023/05/22 06:46:23	55° 32,837' N	015° 14,198' E	76
AL594_54-2	Fish Net (Jungfisch-Trawl)	2023/05/22 06:56:33	55° 32,840' N	015° 14,230' E	76
AL594_55-1	CTD	2023/05/22 11:21:58	55° 20,012' N	014° 36,960' E	52
AL594_55-2	Bongo Net	2023/05/22 11:28:41	55° 20,073' N	014° 37,121' E	52
AL594_56-1	Bongo Net	2023/05/22 12:17:45	55° 14,691' N	014° 29,659' E	44
AL594_56-2	CTD	2023/05/22 12:25:58	55° 14,977' N	014° 29,927' E	44
AL594_57-1	CTD	2023/05/22 13:03:08	55° 10,484' N	014° 24,983' E	45
AL594_57-2	Bongo Net	2023/05/22 13:08:15	55° 10,493' N	014° 25,010' E	45

AL594_58-1	Bongo Net	2023/05/22 13:53:39	55° 06,661' N	014° 16,215' E	47
AL594_58-2	CTD	2023/05/22 14:01:54	55° 06,924' N	014° 16,275' E	47
AL594_59-1	CTD	2023/05/22 15:13:42	54° 59,005' N	014° 04,460' E	47
AL594_59-2	Bongo Net	2023/05/22 15:19:52	54° 58,978' N	014° 04,527' E	47
AL594_60-1	Bongo Net	2023/05/22 16:24:50	54° 56,494' N	013° 47,242' E	46
AL594_60-2	CTD	2023/05/22 16:33:00	54° 56,632' N	013° 47,714' E	47
AL594_61-1	CTD	2023/05/22 17:34:35	54° 56,496' N	013° 30,091' E	46
AL594_61-2	Bongo Net	2023/05/22 17:40:20	54° 56,520' N	013° 29,972' E	46
AL594_62-1	Bongo Net	2023/05/22 18:32:17	54° 57,350' N	013° 15,618' E	46
AL594_62-2	CTD	2023/05/22 18:43:00	54° 57,479' N	013° 14,972' E	46
AL594_63-1	CTD	2023/05/23 06:09:49	54° 56,552' N	013° 07,584' E	43
AL594_63-2	Fish Net (Bottom Trawl)	2023/05/23 06:16:21	54° 56,503' N	013° 07,588' E	43
AL594_64-1	Fish Net (Bottom Trawl)	2023/05/23 10:32:06	54° 57,421' N	013° 11,565' E	45
AL594_65-1	CTD	2023/05/23 14:00:48	54° 53,499' N	013° 05,021' E	43
AL594_65-2	Bongo Net	2023/05/23 14:06:06	54° 53,482' N	013° 04,973' E	43
AL594_66-1	Bongo Net	2023/05/23 15:03:41	54° 44,023' N	013° 02,950' E	23
AL594_66-2	CTD	2023/05/23 15:09:42	54° 44,011' N	013° 02,588' E	24
AL594_67-1	CTD	2023/05/23 16:09:27	54° 44,018' N	012° 47,538' E	22
AL594_67-2	Bongo Net	2023/05/23 16:14:18	54° 44,090' N	012° 47,348' E	22
AL594_68-1	Bongo Net	2023/05/23 17:16:44	54° 42,894' N	012° 29,621' E	18
AL594_68-2	CTD	2023/05/23 17:21:00	54° 42,915' N	012° 29,384' E	18
AL594_69-1	CTD	2023/05/24 06:00:19	54° 38,040' N	010° 49,960' E	22
AL594_69-2	Bongo Net	2023/05/24 06:05:20	54° 38,078' N	010° 49,829' E	22
AL594_70-1	Bongo Net	2023/05/24 06:40:44	54° 39,018' N	010° 40,105' E	25
AL594_70-2	CTD	2023/05/24 06:46:42	54° 39,045' N	010° 39,826' E	24
AL594_71-1	CTD	2023/05/24 07:26:07	54° 40,791' N	010° 29,994' E	25
AL594_71-2	Bongo Net	2023/05/24 07:30:37	54° 40,852' N	010° 29,880' E	25
AL594_72-1	Bongo Net	2023/05/24 08:05:12	54° 41,362' N	010° 20,647' E	24
AL594_72-2	CTD	2023/05/24 08:11:16	54° 41,411' N	010° 20,236' E	24
AL594_72-3	CTD with water sampler	2023/05/24 08:16:52	54° 41,415' N	010° 20,206' E	25
AL594_73-1	CTD	2023/05/24 09:04:37	54° 42,367' N	010° 08,813' E	25
AL594_73-2	Bongo Net	2023/05/24 09:08:41	54° 42,379' N	010° 08,863' E	25
AL594_74-1	Bongo Net	2023/05/24 09:44:32	54° 37,812' N	010° 09,673' E	22
AL594_74-2	CTD	2023/05/24 09:50:07	54° 37,774' N	010° 09,362' E	22
AL594_75-1	CTD	2023/05/24 10:24:15	54° 32,980' N	010° 07,474' E	22
AL594_75-2	Bongo Net	2023/05/24 10:29:22	54° 33,061' N	010° 07,411' E	22
AL594_76-1	Bongo Net	2023/05/24 11:02:27	54° 30,761' N	010° 01,621' E	27
AL594_76-2	CTD	2023/05/24 11:08:16	54° 30,795' N	010° 01,212' E	27
AL594_77-1	CTD	2023/05/24 12:31:30	54° 28,911' N	010° 19,863' E	19
AL594_77-2	Bongo Net	2023/05/24 12:36:09	54° 28,953' N	010° 19,874' E	19
AL594_78-1	Bongo Net	2023/05/24 13:19:04	54° 35,400' N	010° 20,102' E	15
AL594_78-2	CTD	2023/05/24 13:25:39	54° 35,692' N	010° 20,024' E	16
AL594_79-1	CTD	2023/05/24 14:06:26	54° 34,177' N	010° 29,959' E	18
AL594_79-2	Bongo Net	2023/05/24 14:10:34	54° 34,179' N	010° 29,807' E	18
AL594_80-1	Bongo Net	2023/05/24 14:55:53	54° 27,143' N	010° 29,964' E	16
AL594_80-2	CTD	2023/05/24 15:01:25	54° 26,912' N	010° 29,995' E	16

AL594_81-1	CTD	2023/05/24 15:39:09	54° 26,419' N	010° 40,025' E	18
AL594_81-2	Bongo Net	2023/05/24 15:43:03	54° 26,440' N	010° 39,877' E	18
AL594_82-1	Bongo Net	2023/05/24 16:22:33	54° 24,900' N	010° 49,958' E	12
AL594_82-2	CTD	2023/05/24 16:26:35	54° 24,957' N	010° 50,149' E	12
AL594_83-1	CTD	2023/05/24 17:31:34	54° 32,899' N	010° 39,911' E	20
AL594_83-2	Bongo Net	2023/05/24 17:35:10	54° 32,909' N	010° 40,083' E	20
AL594_84-1	Bongo Net	2023/05/24 18:10:21	54° 32,549' N	010° 49,795' E	20
AL594_84-2	CTD	2023/05/24 18:15:03	54° 32,649' N	010° 50,008' E	21
AL594_85-1	CTD	2023/05/24 19:00:14	54° 36,217' N	010° 59,876' E	35
AL594_85-2	Bongo Net	2023/05/24 19:04:56	54° 36,230' N	011° 00,033' E	36
AL594_86-1	Bongo Net	2023/05/24 19:36:15	54° 34,522' N	011° 07,955' E	27
AL594_86-2	CTD	2023/05/24 19:42:25	54° 34,537' N	011° 08,279' E	27
AL594_87-1	CTD	2023/05/24 20:26:38	54° 31,913' N	011° 19,274' E	29
AL594_87-2	Bongo Net	2023/05/24 20:30:49	54° 31,936' N	011° 19,189' E	29
AL594_88-1	Bongo Net	2023/05/24 21:27:14	54° 27,967' N	011° 32,827' E	25
AL594_88-2	CTD	2023/05/24 21:33:42	54° 27,852' N	011° 32,531' E	25
AL594_89-1	CTD	2023/05/24 22:10:33	54° 25,549' N	011° 40,460' E	24
AL594_89-2	Bongo Net	2023/05/24 22:14:30	54° 25,499' N	011° 40,349' E	24
AL594_90-1	Bongo Net	2023/05/24 22:52:23	54° 23,975' N	011° 49,505' E	21
AL594_90-2	CTD	2023/05/24 22:57:26	54° 23,822' N	011° 49,509' E	21
AL594_91-1	CTD	2023/05/24 23:36:27	54° 17,972' N	011° 49,531' E	22
AL594_91-2	Bongo Net	2023/05/24 23:41:46	54° 17,919' N	011° 49,416' E	23
AL594_92-1	Bongo Net	2023/05/25 00:19:32	54° 12,517' N	011° 49,950' E	20
AL594_92-2	CTD	2023/05/25 00:25:21	54° 12,526' N	011° 49,713' E	20
AL594_93-1	CTD	2023/05/25 01:05:17	54° 12,506' N	011° 40,636' E	25
AL594_93-2	Bongo Net	2023/05/25 01:09:42	54° 12,466' N	011° 40,508' E	25
AL594_94-1	Bongo Net	2023/05/25 01:44:01	54° 11,981' N	011° 32,913' E	24
AL594_94-2	CTD	2023/05/25 01:50:02	54° 11,956' N	011° 32,581' E	24
AL594_95-1	CTD	2023/05/25 02:30:26	54° 10,197' N	011° 24,723' E	23
AL594_95-2	Bongo Net	2023/05/25 02:35:11	54° 10,143' N	011° 24,584' E	23
AL594_96-1	Bongo Net	2023/05/25 03:06:12	54° 08,485' N	011° 17,692' E	26
AL594_96-2	CTD	2023/05/25 03:12:40	54° 08,404' N	011° 17,386' E	26
AL594_97-1	CTD	2023/05/25 03:55:39	54° 14,633' N	011° 20,925' E	21
AL594_97-2	Bongo Net	2023/05/25 03:58:55	54° 14,638' N	011° 20,868' E	20
AL594_98-1	Bongo Net	2023/05/25 04:43:51	54° 17,204' N	011° 32,814' E	24
AL594_98-2	CTD	2023/05/25 04:49:26	54° 17,376' N	011° 32,564' E	24
AL594_99-1	CTD	2023/05/25 05:19:01	54° 17,450' N	011° 40,431' E	25
AL594_99-2	Bongo Net	2023/05/25 05:23:59	54° 17,521' N	011° 40,445' E	25
AL594_100-1	Mooring (Fish Trap)	2023/05/25 06:12:23	54° 19,244' N	011° 49,974' E	22
AL594_100-2	Mooring (Fish Trap)	2023/05/25 06:21:46	54° 19,300' N	011° 50,004' E	22
AL594_101-1	Bongo Net	2023/05/25 06:57:56	54° 21,611' N	011° 40,952' E	25
AL594_101-2	CTD	2023/05/25 07:04:10	54° 21,644' N	011° 40,593' E	25
AL594_102-1	CTD	2023/05/25 07:37:30	54° 22,128' N	011° 32,480' E	24
AL594_102-2	Bongo Net	2023/05/25 07:44:52	54° 22,140' N	011° 32,482' E	24
AL594_103-1	Bongo Net	2023/05/25 08:24:44	54° 19,682' N	011° 23,032' E	21
AL594_103-2	CTD	2023/05/25 08:30:14	54° 19,705' N	011° 22,682' E	21

AL594_104-1	CTD	2023/05/25 09:09:03	54° 25,221' N	011° 22,759' E	19
AL594_104-2	Bongo Net	2023/05/25 09:13:52	54° 25,248' N	011° 22,629' E	20
AL594_105-1	Fishing Rod	2023/05/25 09:49:57	54° 28,042' N	011° 22,255' E	23
AL594_106-1	Fishing Rod	2023/05/25 13:00:00	54° 17,340' N	011° 46,280' E	25
AL594_107-1	Mooring (Fish Trap)	2023/05/25 14:45:26	54° 19,239' N	011° 49,992' E	22
AL594_107-2	Mooring (Fish Trap)	2023/05/25 14:56:17	54° 19,291' N	011° 50,017' E	22
AL594_108-1	Fishing Rod	2023/05/25 15:00:58	54° 19,279' N	011° 50,007' E	21
AL594_109-1	Bongo Net	2023/05/25 20:01:39	54° 37,959' N	010° 50,305' E	22
AL594_109-2	CTD	2023/05/25 20:10:32	54° 38,118' N	010° 50,157' E	22
AL594_110-1	CTD	2023/05/25 21:01:18	54° 32,844' N	010° 39,874' E	20
AL594_110-2	Bongo Net	2023/05/25 21:05:38	54° 32,929' N	010° 39,806' E	20
AL594_111-1	Bongo Net	2023/05/25 22:08:12	54° 40,740' N	010° 30,391' E	24
AL594_111-2	CTD	2023/05/25 22:16:06	54° 40,756' N	010° 30,074' E	24
AL594_112-1	CTD	2023/05/25 23:00:51	54° 41,419' N	010° 20,237' E	24
AL594_112-2	Bongo Net	2023/05/25 23:05:08	54° 41,407' N	010° 20,047' E	24
AL594_113-1	Bongo Net	2023/05/25 23:44:51	54° 35,597' N	010° 20,329' E	16
AL594_113-2	CTD	2023/05/25 23:50:10	54° 35,640' N	010° 20,120' E	16
AL594_114-1	CTD	2023/05/26 00:35:12	54° 28,887' N	010° 19,917' E	19
AL594_114-2	Bongo Net	2023/05/26 00:40:22	54° 28,948' N	010° 19,699' E	19
AL594_115-1	Bongo Net	2023/05/26 01:57:48	54° 26,389' N	010° 40,390' E	18
AL594_115-2	CTD	2023/05/26 02:06:46	54° 26,466' N	010° 40,214' E	18
AL594_116-1	Mooring (Fish Trap)	2023/05/26 06:00:42	54° 36,478' N	010° 49,392' E	21
AL594_116-2	Mooring (Fish Trap)	2023/05/26 06:15:36	54° 36,514' N	010° 49,354' E	21
AL594_117-1	Fishing Rod	2023/05/26 06:40:52	54° 36,212' N	010° 51,341' E	20
AL594_118-1	Fishing Rod	2023/05/26 09:57:04	54° 42,893' N	010° 08,231' E	24
AL594_119-1	Fishing Rod	2023/05/26 10:44:11	54° 44,895' N	010° 07,017' E	23
AL594_120-1	Mooring (Fish Trap)	2023/05/26 14:16:09	54° 36,452' N	010° 49,411' E	21
AL594_120-2	Mooring (Fish Trap)	2023/05/26 14:23:21	54° 36,497' N	010° 49,362' E	22
AL594_121-1	Fishing Rod	2023/05/26 14:44:19	54° 36,500' N	010° 49,358' E	21

7 Data Availability and Sample Storage

All data are available immediately upon request if not otherwise stated.

7.1 Data Availability and Storage

All data obtained during the cruise have been backed up on a GEOMAR virtual drive that is backed up daily. In addition, data are stored on different hard drives in different locations. Paper protocols filled out during the cruise were entered electronically continuously throughout the cruise, and thus fall under the electronic back-up scheme, but have also been conserved as hard copies to resolve possible data entry errors later on if needed.

All cruise meta-data – including output of the on board DSHIP-System - have been entered in the GEOMAR Ocean Science Information System (OSIS), managed by the Kiel Data Management Team (KDMT), and intended for permanent archiving of such data. The data are freely available via the link https://osis.geomar.de/app/expeditions/364225 (keyword "AL594").

We aim to ultimately make all data accumulated during the cruise publicly available.

All hydrographic (CTD) data will be submitted to the ICES database within one year from the cruise. Moreover, the KDMT team will assist with the publication of data in the public data repository PANGAEA to provide long-term archival and access. Some of the data are intended for specific publications, and will be published openly with the appearance of the underlying peer-review article. In these cases, please contact the person responsible for the data in case earlier access to the data is desired (Table 7.1).

Genetic /genomic data have been submitted to the relevant data archives (Genbank /NCBI) during the process of publication.

Table 7.1 Overview of data availability and persons responsible for specific data sets of AL594.

Type	**Database**	**Available**	**Free Access**	**Contact**
Hydrography (CTD data)	ICES database	Publicly by April 2025, earlier on request (see contact e-mail).	yes	Dr. Jan Dierking jdierking@geomar.de
Food web sampling data	PANGAEA	Publicly at time of acceptance of the underlying peer-reviewed publication; or via request (see contact e-mail).	yes	Dr. Jan Dierking jdierking@geomar.de
Fish individual data (*Gadus morhua*, others)	PANGAEA	work in progress; we are finalizing steps to publish a database containing 30 years of individual cod data via Pangaea, expected to be available open access by end of 2024	yes	Dr. Jan Dierking jdierking@geomar.de
Fish genetic data (*Gadus morhua*, others)	NCBI /Genbank; see NCBI BioProject PRJNA1128 530	Publicly at time of acceptance of the underlying peer-reviewed publication; or via request (see contact e-mail).	yes	Kwi Yong Han khan@geomar.de
Zooplankton metadata	GEOMAR internal /biodiversity storage centre	Publicly at time of acceptance of the underlying peer-reviewed publication; or via request (see contact e-mail).	yes	Dr. Felix Mittermayer fmittermayer@geomar.de
Ichthyoplankton data	PANGAEA	Publicly at time of acceptance of the underlying peer-reviewed publication; or via request (see contact e-mail).	yes	Dr. Felix Mittermayer fmittermayer@geomar.de
Phytoplankton community sampling	PANGAEA	Inquire with collaboration partner (see contact e-mail).	yes	Dr. Luisa Listmann luisa.listmann@uni-hamburg.de

7.2 Sample Availability and Storage

All samples obtained during the cruise were labelled on board with a barcoding scheme, and all samples intended for longer-term storage at GEOMAR were professionally archived immediately after the cruise. This includes formalin conserved samples for long-term storage, and frozen samples (-20°C and -80°C) currently conserved in freezer rooms at GEOMAR. A selection of samples has been deposited together with their meta data in the developing BIS system and has been assigned persistent identifiers and are available here (https://biosamples.geomar.de/). Additional samples will be deposited during the ongoing development of the data base being set up under the umbrella Mare Data Hub to contain all sample metadata of all zooplankton, fin-clip and other preserved biological samples. Please send further inquiries to fmittermayer@geomar.de

8 Acknowledgements

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