NORTH SEA ECOSYSTEM SURVEY

Report_2025002005

Cruise leader(s): Gayantonia Franze (IMR)

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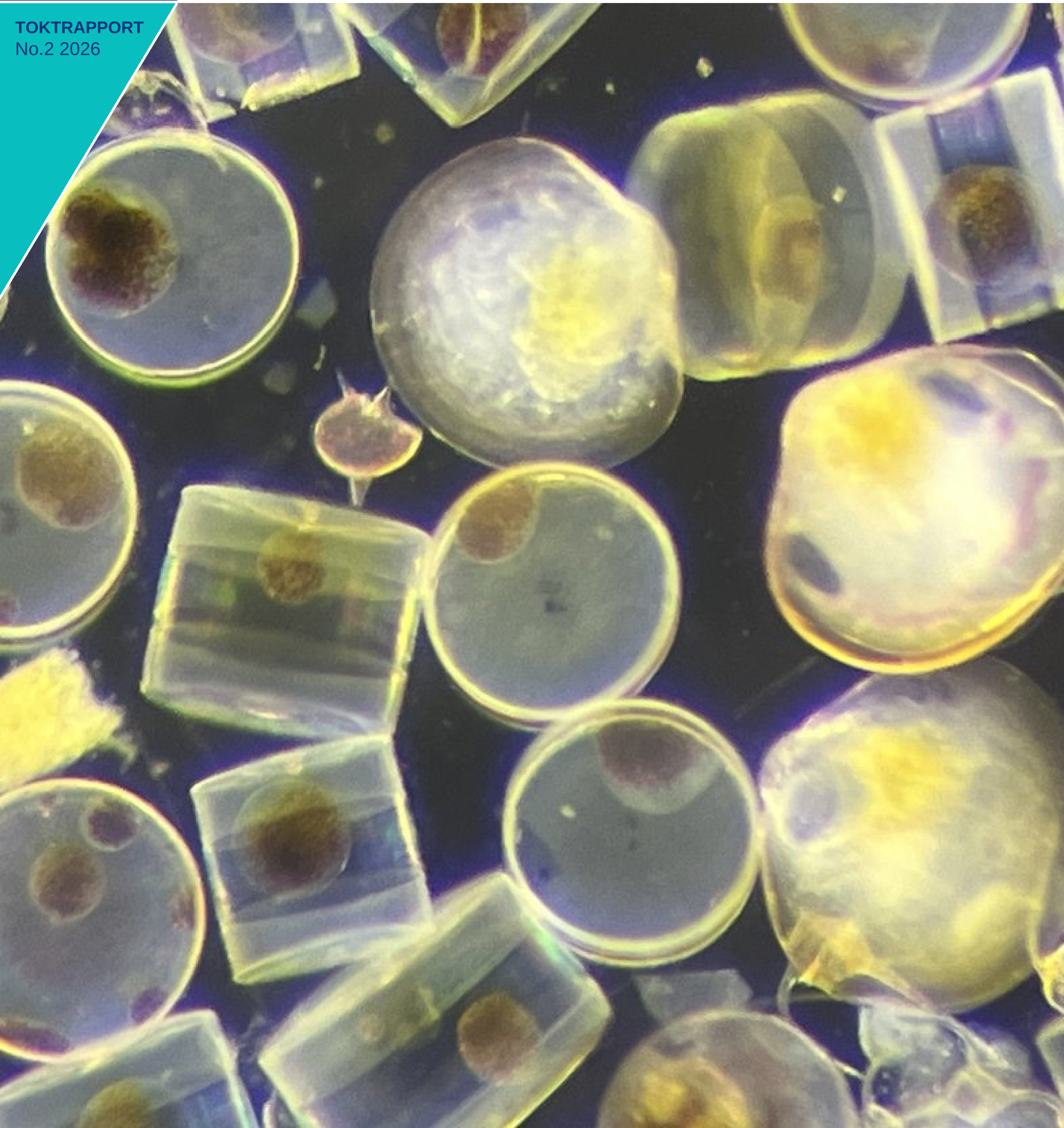

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Summary (English):

The 2025 North Sea Ecosystem Cruise provided an integrated assessment of physical, chemical and biological conditions across the northern North Sea and Skagerrak. Hydrographic observations revealed a clear expression of the Norwegian Coastal Current, low surface salinities in the Skagerrak, and unusually warm Atlantic water, reflecting the late timing of the cruise relative to the long-term series. Phytoplankton communities, quantified through microscopy and FlowCam imaging, displayed strong spatial variability. Small nano- and microplankton dominated the central basin, while large chain-forming diatoms were concentrated in the southeastern North Sea and the Norwegian Trench. Mixotrophic and heterotrophic protists were associated with Atlantic-influenced waters, highlighting links between water mass structure and microbial communities. Mesozooplankton biomass and community structure showed equally distinct regional patterns. High biomass in the central basin was largely composed of small copepods and juvenile stages, supported by abundant microplankton prey. In contrast, the Norwegian Trench sustained lower biomass but proportionally larger zooplankton, including Calanus and euphausiids. Depth-stratified sampling revealed a strong concentration of biomass in the upper 100 m, with larger species occupying deeper layers. Macroplankton trawls added information on gelatinous zooplankton and micronekton in the trench, while ichthyoplankton sampling documented broad distributions of fish eggs and larvae, with the western survey area being the most productive of the basin.

Summary (Norwegian):

Økosystemtoktet i Nordsjøen 2025 ga en samlet vurdering av de fysiske, kjemiske og biologiske forholdene i nordlige deler av Nordsjøen og Skagerrak. De hydrografiske observasjonene viste en tydelig Norsk kyststrøm, lave overflatesaliniteter i Skagerrak og uvanlig varmt atlantisk vann . Dette er forhold som reflekterer at toktet ble gjennomført senere på året sammenlignet med tidligere (år i tidsserien). Planktonsamfunnene ble kvantifisert gjennom både mikroskopi og FlowCam-analyser, og viste tydelig romlig variasjon. Små nano- og mikroplankton dominerte i den sentrale områdene, mens store kjededannende diatomeer var konsentrert i den sørøstlige delen av Nordsjøen og i Norskerenna. Mixotrofe og heterotrofe protister var knyttet til atlantisk påvirkede vannmasser, noe som understreker sammenhengen mellom vannmassesstruktur og mikrobiell samfunnsdynamikk. Mesozooplankton viste tilsvarende tydelige regionale mønstre. Den høye biomassen i de sentrale områdene bestod i hovedsak av små hoppekreps og juvenile stadier, opprettholdt av høye konsentrasjoner av mikroplankton. Derimot hadde Norskerenna lavere total biomasse av zooplankton, men en større andel store zooplankton, inkludert *Calanus* og krill. Dybdestratifiserte prøver viste en opphopning av zooplanktonbiomasse i de øverste 100 meterne, mens større arter i større grad forekom dypere i vannsøylen. Prøvetaking med Makroplanktontrål bidro med informasjon om geleplankton og mikronekton i Norskerenna, mens egg- og larveprøvene viste brede utbredelsesmønstre av fiskeegg og fiskelarver, med de vestlige delene av toktområdet som det mest produktive området.

Content

1 - Introduction

The North Sea Ecosystem Spring Cruise (NSEC) has been carried out annually since 2010 by the Institute of Marine Research (IMR) as a multi-purpose survey. The cruise is typically conducted from mid-April to mid-May to investigate the horizontal and vertical distribution of hydrography, chemistry, phytoplankton, zooplankton, and ichthyoplankton (fish eggs and larvae). The 2025 NSEC delivered data and samples to the following projects: *Climate and plankton in the North Sea and Skagerrak* (IMR 16006), *Early life history dynamics of North Sea fishes* (IMR 16003), *Monitoring of radioactivity in Norwegian waters* (IMR 15595), *Monitoring of environment and plankton in coastal waters* (IMR 15593), and *CoastRisk* (15507-05). Additionally, samples for molecular analysis of zooplankton communities were collected in support of a submitted NFR proposal.

The objectives of the North Sea Ecosystem Cruise 2025 were:

1. To sample pre-selected stations along standard transects for physical, chemical, and biological parameters in the northern North Sea and Skagerrak (IMR 16006, IMR 16003, IMR 15593).
2. To map the abundance, distribution, and species composition of phytoplankton, microzooplankton, mesozooplankton, and the early life stages of fish (eggs and larvae) (IMR 16006, IMR 16003).
3. To monitor radioactive contamination in Skagerrak (IMR 15595).
4. To acquire samples for the development of standard metabarcoding analyses for plankton monitoring (IMR 16006, IMR 15507-05).

1.1 - Monitoring of plankton, biogeochemistry and hydrography in the North Sea and Skagerrak (IMR 16006)

The IMR monitoring project *Climate and plankton in the North Sea and Skagerrak* aims (1) to collect and analyze biological, chemical, and physical data to characterize and understand the causes of variability in the region on seasonal and interannual scales, and (2) to provide multidisciplinary datasets for studying relationships among biological, chemical, and physical variability.

The monitoring program includes one regional survey each year (the spring cruise in April/May) and additional sampling along standard transects: four times per year at Utsira–Start Point and Hanstholm–Aberdeen, and—since 2021—Scotland East Coast and Fair Isle–Pentland; and 12 times per year at the Torungen–Hirtshals transect. Due to budget constraints, the seasonal coverage of these transects has been significantly reduced. In 2025, with substantially less ship time available, the seasonal monitoring was shifted toward the northern boundary of the North Sea. The Utsira transect—our highest priority for plankton monitoring—was maintained, while the Hanstholm–Aberdeen transect was replaced by the Fedje–Shetland transect. The latter defines the northern boundary with the Norwegian Sea and serves as an entry point for planktonic organisms moving toward higher latitudes, supporting the development of higher trophic levels and ecologically and economically important species.

The spring survey on plankton and hydrography in the North Sea–Skagerrak has been carried out by IMR since 2006. Between 2006 and 2014, the work was conducted through two parallel surveys: the *Environmental Cruise* (Miljøtoktet on RV G.M. Dannevig) in the Skagerrak and *The North Sea Plankton Survey* (typically on RV Johan Hjort) in the northern North Sea. In 2010, sampling of fish eggs and larvae was incorporated, and the survey was renamed the *North Sea Ecosystem Cruise* (NSEC). Since 2015, the two surveys have been merged into a single spring cruise covering both the northern North Sea and the Skagerrak.

The spring survey also serves as a platform for developing and testing metabarcoding approaches for marine plankton monitoring. This methodology has the potential to expand monitoring capabilities by enabling more comprehensive community assessments from a larger number of samples than can be processed visually. Metabarcoding can also support early detection of invasive species or distributional shifts, helping to inform management strategies.

1.2 - Early life history dynamics of North Sea fishes (IMR 16003)

The IMR project *Early life history dynamics of North Sea fishes* aims to determine the distribution and abundance of fish eggs and larvae in the northern North Sea and to link these observations to biotic and abiotic environmental conditions. Depth-integrated distributions of ichthyoplankton are obtained from Gulf VII hauls, complemented by zooplankton and oceanographic measurements. A Multinet Mammoth is available to investigate vertical and diel distributions of ichthyoplankton and their predators and prey.

1.3 - Monitoring of radioactivity in Norwegian waters (IMR 15595)

Water samples are collected annually by IMR from the Skagerrak for analysis of radioactive contamination (cesium-137). This project contributes to the national monitoring program *Radioactivity in the Marine Environment (RAME)* , coordinated by the Norwegian Radiation Protection Authority.

2 - Materials and Methods

An overview of the total number of stations sampled during the North Sea Ecosystem cruise 2025 is presented in Figure 1.

Figure 1. Map of the stations sampled during the North Sea Ecosystem cruise 2025.

A list of the personnel participating in the cruise, along with dates and their primary responsibilities, is presented in Table 1 while all the sampling equipment on board the ship is presented in Table 2.

Table 1. Cruise participants.

Name	Role	Dates
Gayantonia Franzè	Cruise Leader	07-20.05.2025
Terje Berge	Plankton	07-20.05.2025
Mona Ring Kleiven,	Plankton	07-20.05.2025
Marianne Petersen	Fish Eggs and Larvae	07-20.05.2025
Magnus Reeve	Fish Eggs and Larvae	07-20.05.2025
Jane Stromstad Møgster	Plankton	07-20.05.2025
Trond Bjordal	Instrument	07-20.05.2025
Sebastian Grieg Pedersen	Instrument	07-20.05.2025
Jarle Kristiansen	Instrument	07-20.05.2025

Table 2. Sampling equipment.

Instruments/Gears	**Data/samples**
SeaBird Electronics SBE911 CTD profiles	Temp, Salinity, Conductivity, Oxygen, light
Water bottle rosette (on CTD)	Nutrients (NO3, Si, PO4, TotN,TotP) Chlorophyll a Phytoplankton (cell counts) Microzooplankton (cell counts/species id)
Phytoplankton net (10µm)	Phytoplankton
WP2 (0.25 m^2, 180µm) ring net	Zooplankton biomass Zooplankton fixed samples (enumeration/species)
WP3 (1 m^2, 1000 µm) ring net	Gelatinous zooplankton
Gulf VII (280 µm)	Fish larvae and eggs
PUP (80µm) attached on Gulf VII	Prey items for fish larvae
MultiNet MAMMOTH (180µm)	Mesozooplankton (depth stratified samples)
Macroplankton Trawl	Krill
Continuous measurements	
Echosounder	
ADCP	Water current velocities
Thermosalinograph	Temp, Salinity, Fluorescence (surface)
Light sensor on deck	PAR (Photosynthetically active radiation)

2.1 - Hydrography

Seawater temperature and salinity were measured at all stations with a SeaBird Electronics SBE911 CTD profiler fitted with a water bottle rosette.

2.2 - Biogeochemistry

Water samples for nutrient analysis (nitrate, nitrite, phosphate, silicate) were sampled from all CTD stations at all depths. From each depth 20 mL aliquots of sample water were collected in clean polyethylene bottles and added 0.2 mL chloroform, before storage at +4 ºC until further analysis at the *Plankton Chemistry Laboratory* at the Institute of Marine Research (IMR) in Bergen. Chlorophyll pigment samples (268 mL) were taken from eight depths between the surface and 100 m and collected on GF/F fiber glass filters. The filters were stored at -20 ºC to be analyzed for Chlorophyll- *a* and Phaeopigments (Chl *-a* , Phaeo) at the *Plankton Chemistry Laboratory* in Bergen.

2.3 - Phytoplankton Analysis

Samples used to characterize phytoplankton community composition and abundance were collected from a total of 211 stations. All samples were collected during the May ecosystem cruise (2025002005) except for four microscopy samples collected during the Torungen-Hirtshals transect cruise on April 30th. Microscopy was used to identify and quantify taxa in 20 preselected stations along the transects, covering multiple WGINOSE sub-regions (Figure 1). Algae-net and metabarcoding samples were also collected, which can be used to qualitatively assess community composition. In total, 32 Algae-net and 110 metabarcoding samples were collected.

Samples for algal cell counts (100 ml) were taken from 10 m CTD collected water and fixed in Neutral Lugol. Microscope counts were performed following the Utermöhl (1958) method on CTD samples to quantify abundance and community composition at the *Flødevigen Plankton Laboratory* . Qualitative Algae-net samples were collected using a vertical net tow (10 µm mesh; 0.1 m^2 opening; 30-0 m), fixed with 2 ml 20% formalin and stored for future use. Metabarcoding samples were collected by filtering approximately 2000 ml of seawater, pre-filtered with 180 µm mesh, on to 25 mm filters with a pore size of 5 µm. Samples were then frozen at -20°C and ultimately stored at -80°C for future DNA extraction and sequencing.

Microscopy algal counts include heterotrophic and autotrophic groups; these communities will therefore be referred to as microplankton in the summarized results below.

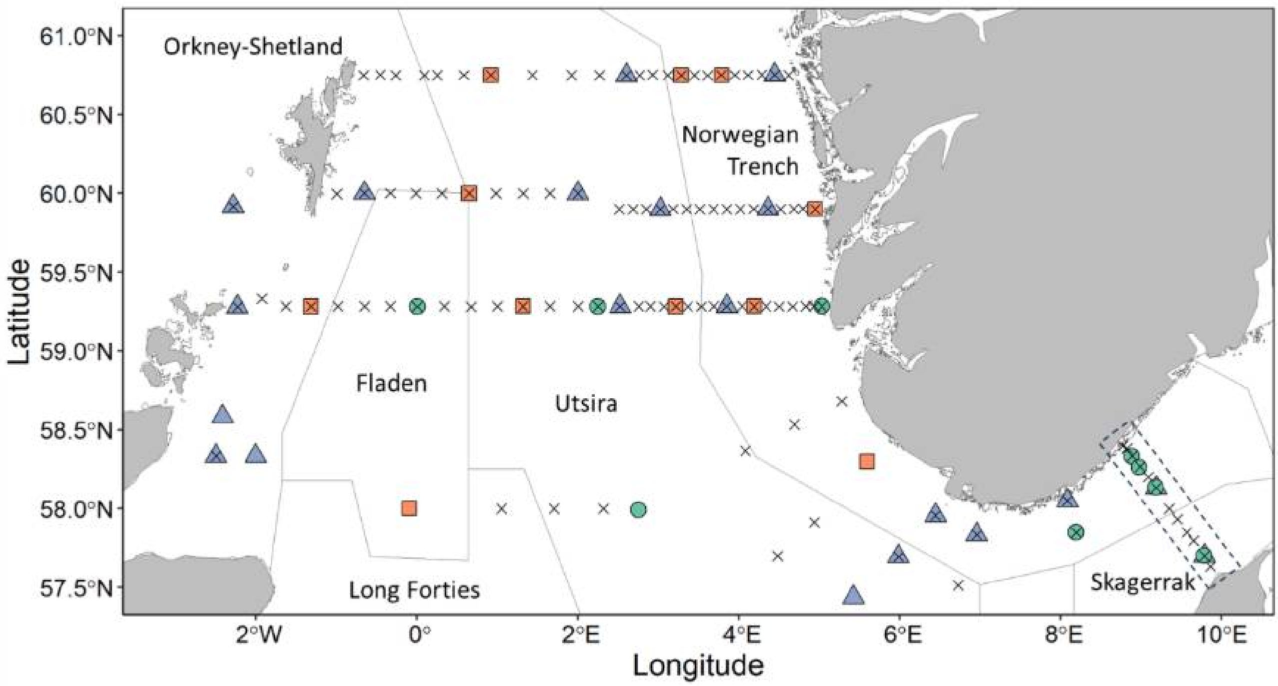

Figure 2. Map showing stations where phytoplankton samples were collected and analyzed. Shapes indicate sampling activities at a given station: cross- metabarcoding sample collection, square- algae net sample collection and microscopy analysis, triangle- algae net sample collection, circle- microscopy analysis. Outlined and labeled areas indicate WGINOSE sub-regions. Torungen-Hirtshals transect where microscopy samples were collected on a separate transect cruise is outlined with dashed-lines.

2.4 - Automated Imaging Analysis of Plankton

Plankton samples for imaging analysis were collected at 49 selected stations along the standard North Sea transects. Samples were collected in parallel with phytoplankton and zooplankton microscopy samples to acquire a better understanding of North Sea plankton community structure. Water samples from microplankton enumeration, identification, and size structure analysis (500 ml) were collected from the 10m CTD sampler bottle, fixed in 2% (final conc.) acidic Lugol and stored in a dark refrigerated room (4 ° C). Samples for the zooplankton analysis were collected with a WPII net and fixed with 4% formaldehyde. Post cruise analyses were performed at the *Plankton Laboratory* either in Flødevigen or Bergen. Sampled were analyzed using a flowcam 8400 laser equipped with a 10x objective lens and a 100µm deep field-of-view flowcell (magnification = 100), a f lowcam VS-1 quipped with a 2x objective lens and a 800µm deep non-field-of-view flowcell (magnification = 20) and a flowcam Macro with a 0.5x objective lens and a 5000µm deep field of view flowcell (magnification = 12).

During the 2025 cruise, live plankton samples were analyzed using a FlowCam Macro. Five-liter samples were collected from the 10 m Niskin bottle and analyzed immediately without preservation. The primary objective was to explore potential new approaches for detecting larger, less abundant planktonic forms that are often overlooked in microscopy counts due to their low occurrence.

2.5 - Zooplankton

Mesozooplankton were collected at 68 stations, comprising 88 vertical tows with WP2 plankton nets (0.25 m^2 opening; 180 µm mesh size) from the bottom to the surface, and from 200-0 m, bottom depth permitting (Figure 3). Additional stratified sampling of zooplankton was carried out on 11 stations by Multinet MAMMOTH (Hydrobios, 180µm, 1 m^2 mouth opening, soft cod-ends). Oblique tows were made from 5 m above bottom while releasing nets at standard depths (Table 3).

Table 3. MultiNet standard depth of the IMR zooplankton monitoring in the North Sea-Skagerrak.

Strata Depth	Multinet Number
0-bottom	0
bottom-400	1
400-300	2
300-200	3
200-150	4
150-100	5
100-50	6
50-25	7
25-0	8

Large medusae and ctenophores were removed from whole samples, and the displacement volume of each species was recorded. The remaining zooplankton sample was split into two parts by a Motoda plankton splitter: one part was fixed in 4% borax buffered formaldehyde for species identification and enumeration. The other half was used for estimation of biomass (dry weight): samples were fractionated into three fractions (180-1000µm, 1000-2000µm and >2000µm) and placed on pre-weighted aluminum trays, dried at 60°C for 24 hours and kept in a freezer until return to Bergen. From the >2000 µm size fraction euphausiids, shrimps, amphipods, fish and fish larvae were counted, and their lengths measured separately before drying. In addition, Chaetognaths, *Pareuchaeta* sp. and *Calanus hyperboreus* from the >2000 µm size fraction were counted and dried separately (but sizes not measured). Biomass was estimated for all zooplankton samples collected during the survey (68 WP2 net hauls and 11 Multinet hauls).

For species identification and enumeration, a subset of samples from seven preselected stations was analyzed in detail (Figure 3). These stations were located along two transects, Utsira–StartPoint and Torungen–Hirtshals, chosen to represent contrasting hydrographic regions and to provide continuity with previous surveys. Species identification and quantification were performed by light microscopy following standard IMR procedures (Hassel et al., 2023). Samples were split into appropriate subsample sizes and examined under a stereomicroscope. Individuals were identified to the lowest possible taxonomic level, typically to species or genus for copepods, and to broader groups for less distinctive taxa. Counts were made for each taxon and subsequently standardized to numbers per square meter of sea surface.

Dry weight determination and microscopic analyzes were performed at the IMR plankton laboratory in Bergen after the cruise. Details on the sampling procedures and analysis are found in the IMR Plankton Manual (Hassel et al., 2023).

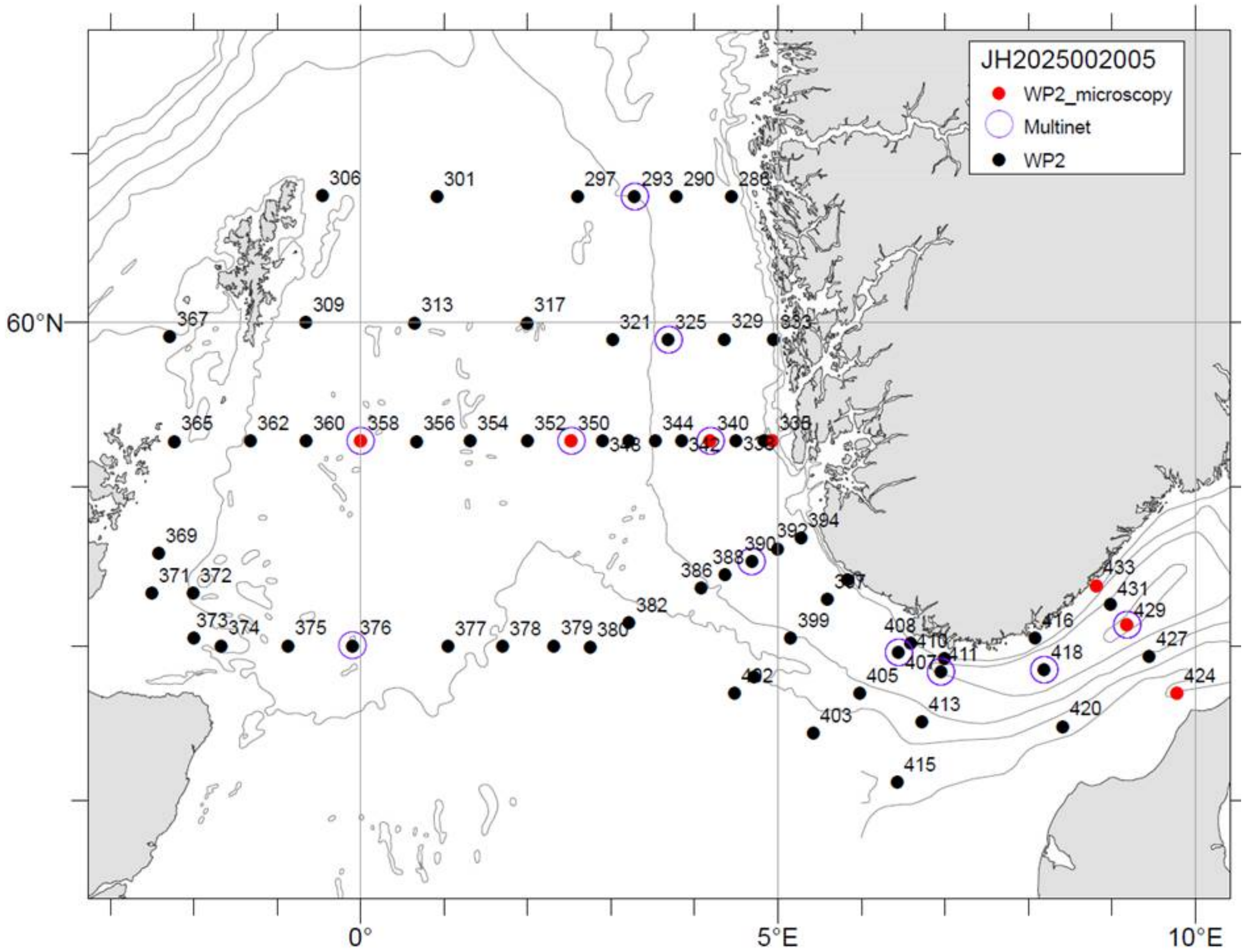

Figure 3. North Sea Ecosystem cruise 7-19 May 2025. Stations where mesozooplankton were collected and analyzed. Black points: WP2 samples for biomass estimates. Red points: WP2 sample for both biomass estimates and microscopic analysis. Blue circles: Multinet (biomass estimates). Numbers refer to the CTD station numbers.

2.6 - Macroplankton trawl

Macroplankton and micronekton (>2 mm) was sampled with the macroplankton trawl in the deeper regions of the Norwegian Trench. This trawl is a fine-meshed plankton trawl with an approximate 36 m^2 mouth opening and 3 mm stretched meshes from the trawl-opening to the rear end (Wenneck et al., 2008; Heino et al., 2011). A total of 9 stations were completed with the Macroplankton trawl in the Norwegian trench (Figure 4), along a transect following the bathymetry from Feie in the north (60.751N; 3.949E) to Skagerrak in the southeast (58.115N; 9.186E).

Trawl stations were located in the deepest point in the trench, with bottom depth ranging from 275 to 634 m. The trawl was lowered vertically from surface to approx. 15 to 30 m above bottom and then hauled obliquely to the surface at ~2.5 knots. The lower sampling depth of the trawl varied between 250 - 603 m. Upon completion of trawl hauls the catches were weighed, and either the entire catch or a representative subsample was sorted. Species identification was made to the lowest possible taxonomic level, usually to genus or species level.

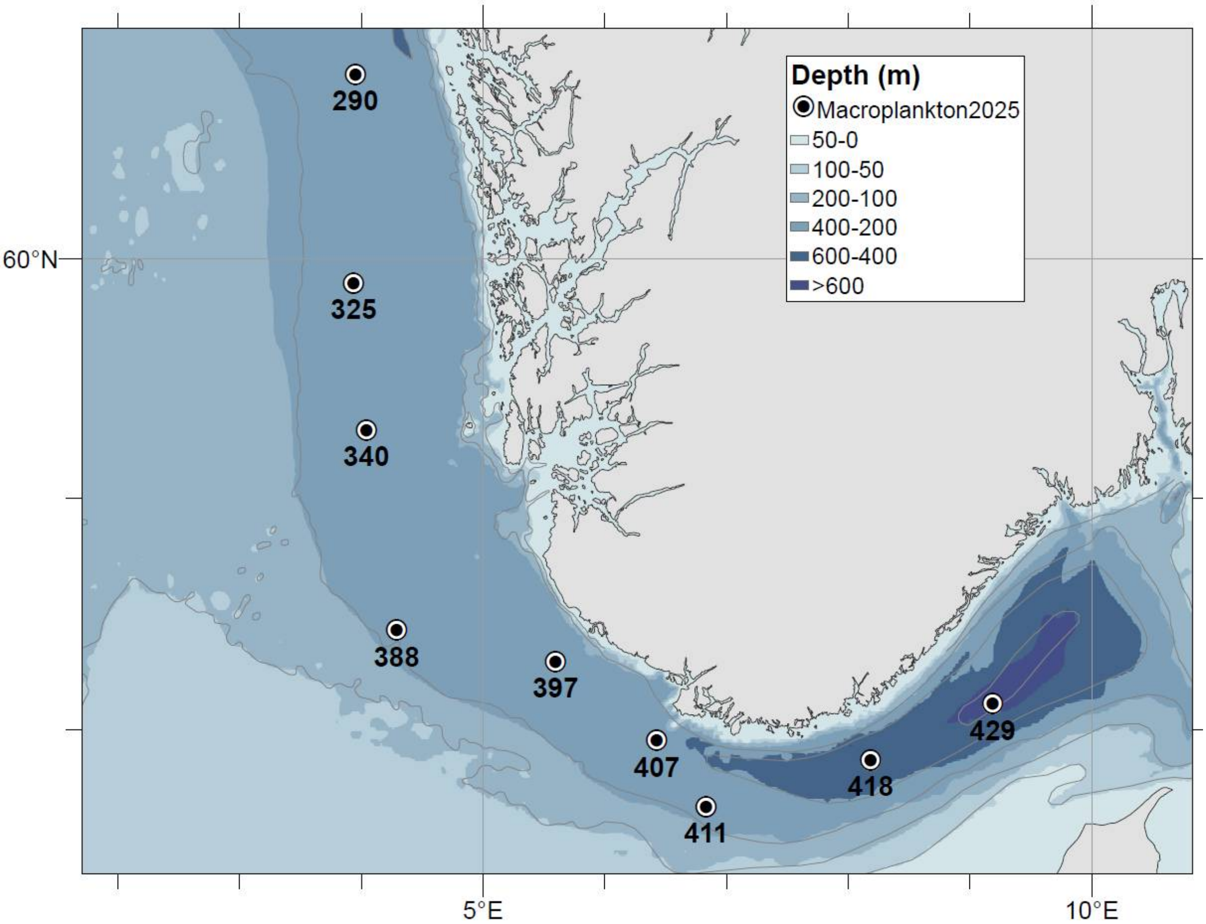

Figure 4. Stations sampled with the Macroplankton trawl in the Norwegian Trench. (36 m 2 , 3 mm mesh, oblique hauls bottom-0m). Bottom depth along the transect ranged from 275 to 634 m.

2.7 - Ichthyoplankton

All GULF VII hauls were associated with a CTD station in close proximity. Temperature data in °C was extracted from the CTD records and used to interpolate temperature in the surface layer down to 5 m, and for the lowest point of each CTD station, representing near-bottom temperatures. The interpolation was performed in R 4.5.0 (R Core Team 2025), using the autokrige function in the automap-package (Hiemstra et al. 2008).

Ichthyoplankton was sampled with a Gulf VII high-speed sampler with a 76 cm frame and a 40 cm nose cone (Nash, Dickey-Collas, and Milligan 1998) at pre-determined stations along each of the standard transects (Figure 5). The net mounted on the GULF had a 280 µm mesh, and a General Oceanics flow meter was fitted, slightly off center, in the nosecone, measuring the volume of water filtered. The sampler was deployed in double oblique hauls at 5 knots, down to a 100 m depth or within 10 m of the bottom. Fish eggs and larvae were sorted from the samples, or sub-samples thereof. Fish larvae were sorted into large taxonomic groups, whilst the eggs were preserved pooled. Starting with the 2025 survey, *Ammodytidae* , *Argentinidae* and *Gobidae* were separated from the category of other larvae, as well as *Lotidae* from the *Gadioformes* . Therefore, there is no direct comparison with previous years possible for these taxa. Preservation was done in 4% seawater and Borax buffered formalin. A PUP sampler, equipped with a 5 cm diameter nosecone and a 80 µm mesh, was fitted on top of the GULF VII to provide samples of the fish larvae’s prey fields. The PUP-sampler was fitted with a separate General Oceanics flow meter. PUP-samples were preserved in the same way as the GULF samples.

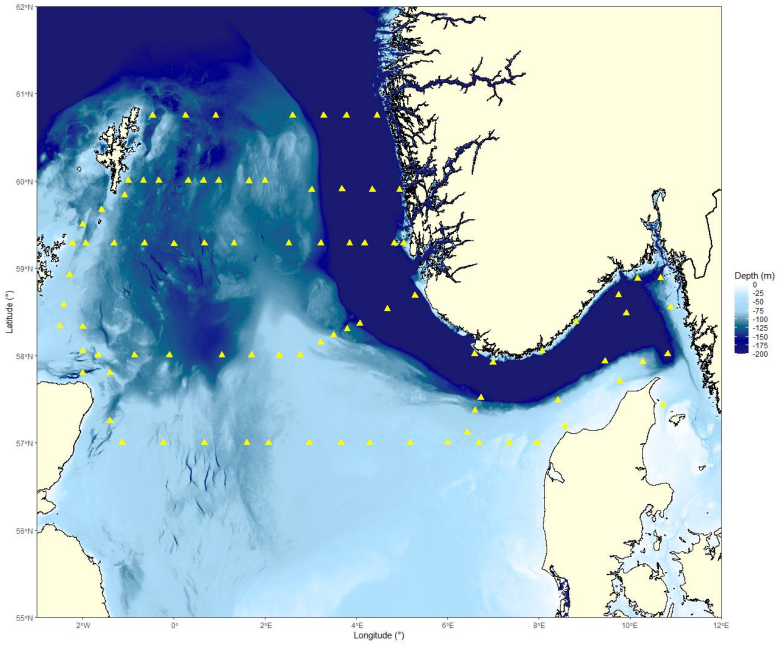

Figure 5. Executed GULF VII tows during the 2025 North Sea Ecosystem Survey. A total of 61 tows were conducted across the survey area. The underlying map shows the bathygraphy of the northern North Sea, with depths deeper than 200 m depicted in the same color.

To examine how the number and taxonomic composition of the larvae-samples relate to the abiotic environment we constructed a simple Generalized Linear Mixed Model (GLMM) in glmmTMB (Brooks et al. 2017), using taxonomic group, bottom depth, extracted from the 2023 GEBOC 15’’ grid (GEBCO Compilation Group 2023), and temperature as independent variables, with numbers raised to the complete sample as response and the filtered volume in m^3 as offset. Separate models were constructed for either surface or near-bottom temperature, with the other variables being the same. As there was a low number of zero stations a Gaussian probability distribution with an identity link was appropriate.

2.8 - Metabarcoding

Genetic samples were collected from 44 WPII net tows. A ¼ fraction of the sample was rinsed with fresh water onto a sieve and transferred to the cup of a 1000W blender. The volume was topped up to 125 mL with MilliQ water and the sample was blended for ca. 1 minute until completely homogenous. 3 cryovials were filled with 4.5ml sample using a clean 5mL pipette tip and frozen at -20C. The remainder of the sample was discarded. Samples were stored at -20C till further analysis once funding becomes available.

2.9 - Radioactivity

Water samples are collected annually from 10 designated stations in the Skagerrak (refer to Table 4 and Figure 6) for the analysis of the radionuclide cesium-137 (Cs-137) under project number 15595. However, in 2024 and 2025, reduced survey time resulted in sampling being restricted to four of the ten designated stations, with the southern Skagerrak stations omitted from the program. A detailed list of the samples collected in 2025 can be found in Table 4. To compensate for the samples that were not collected, six additional samples were collected from sections in the North Sea (also detailed in Table 4).

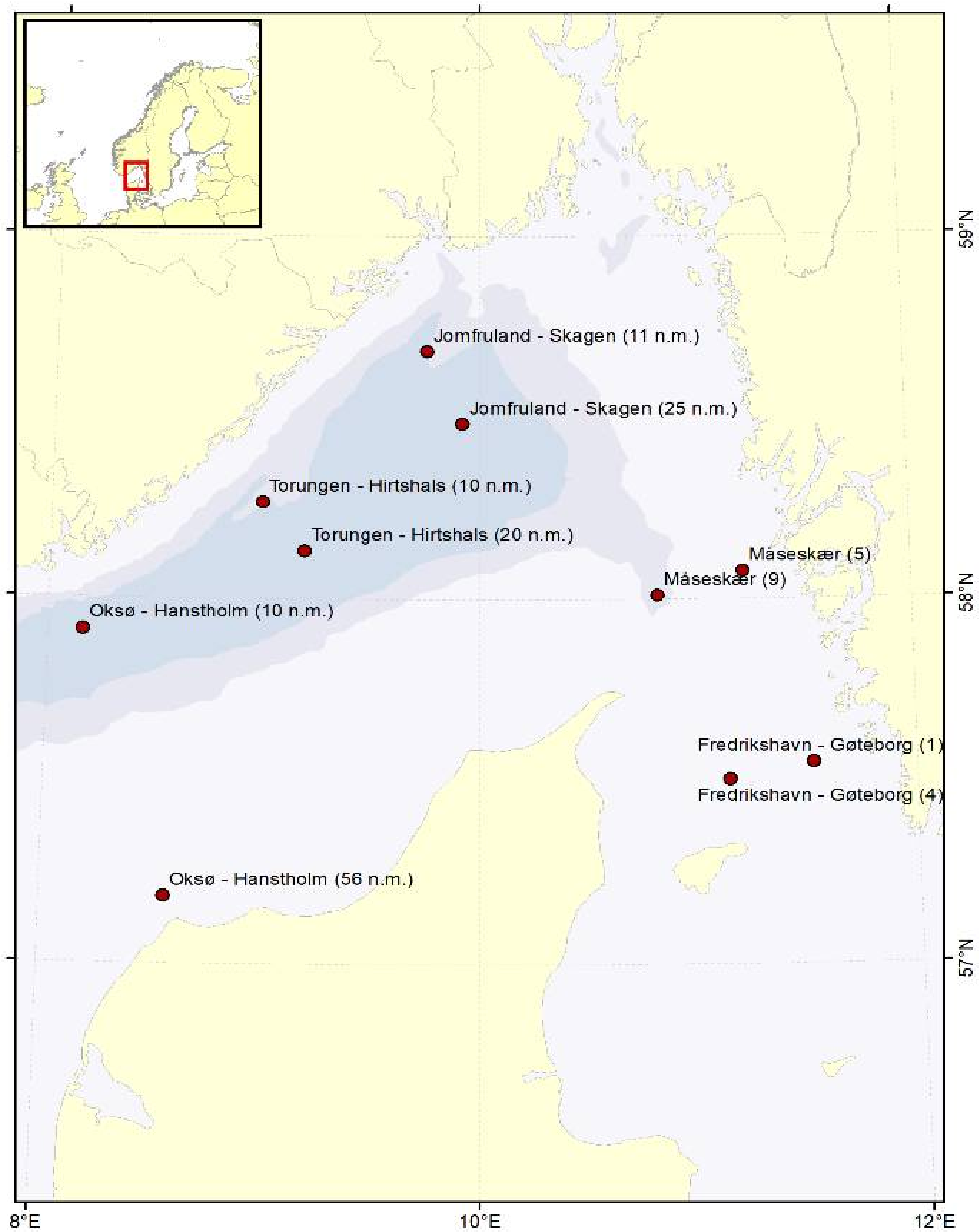

Figure 6 . Stations where seawater has been collected yearly since 2008 for analyses of Cs-137.

At each station, 50 liters of seawater is collected from the ship's seawater intake and filled directly into 25 L plastic containers. These samples are subsequently analyzed for Cs-137 at the Laboratory for inorganic chemistry at IMR, Bergen, following to the internal method "460 - Bestemmelse av Cs-137 i sjøvann" (MET.UORG.01-17). This is a modified version of the analytical procedure described by Roos et al. (1994).

Monitoring of radioactive contamination in the Skagerrak is part of the national monitoring program Radioactivity in the Marine Environment (RAME), which is coordinated by the Norwegian Radiation and Nuclear Safety Authority (DSA) (e.g. Skjerdal et al., 2017; Skjerdal et al., 2020).

Table 4 Station list. Samples collected in May 2025 for monitoring of Cs-137.

Transect	CTD Station	Fix Station	Lat	Long	Date	Temp	Salinity
Feir Isle -Pentland (2/2)	369	11	58.583	-2.417	13/05/2025	10.94	34.8326
Jærens rev mot sw og w	374	30	58.000	-1.667	13/05/2025	10.66	34.8032
Lista	403	10	58.017	6.583	16/05/2025	10.91	32.1944
Lista	408	1	57.433	5.433	16/05/2025	10.31	30.9570
Lindesnes	409	1	57.967	7.033	17/05/2025	11.67	27.2351
Lindesnes	415	10	57.117	6.433	17/05/2025	12.02	31.9444
Fredrikshavn - Gøteborg	Not collected	1	-	-	-	-	-
Fredrikshavn - Gøteborg	Not collected	4	-	-	-	-	-
Måseskær	Not collected	5	-	-	-	-	-
Måseskær	Not collected	9	-	-	-	-	-
Jomfruland - Skagen (11 n.m.)	Not collected	3	-	-	-	-	-
Jomfruland - Skagen (25 n.m.)	Not collected	5	-	-	-	-	-
Oksø - Hanstholm (10 n.m.)	417	3	57.917	8.167	17/05/2025	11.86	30.4291
Oksø - Hanstholm (56 n.m.)	422	12	57.183	8.567	18/05/2025	12.25	32.6361
Torungen - Hirtshals (20 n.m.)	429	6	58.133	9.183	18/05/2025	12.13	29.3164
Torungen - Hirtshals (10 n.m.)	431	4	58.267	8.983	19/05/2025	12.35	25.9877

Table 5 . Summary of the overall samples collected on the transects covered by the North Sea Ecosystem Cruise 2025.

Transect	Nutrients	Chlorophyll a	TOT NP	Phytopl. Net 30-0m	Phytopl. Abund.	Flowcam Micropl.	Phytopl. Metabarc.	Zoopl. Metabarc.	WP2	WP3	Multinet	Gulf	[illegible]
Fedje-Shetland	224	176	0	6	5	5	23	6	9	3	1	6	
Slotterøy mot w	244	207	0	7	7	7	26	5	8	3	0	9	
Utsira mot vest	272	256	0	10	10	10	32	13	17	2	3	11	
Fair Isle-Pentland	36	42	0	3	3	3	2	2	3	0	0	3	
Scotland east coast	14	16	0	2	1	2	0	2	2	0	0	2	
Jærens rev	184	166	0	3	8	8	6	4	11	3	1	8	
Egerøya	61	55	0	1	1	1	2	1	6	1	0	1	
Lista	58	47	0	3	3	2	2	1	5	3	1	4	
Lindesnes	63	54	0	1	1	1	2	4	7	3	1	2	

Oksø-Hanstholm	52	48	28	2	4	4	3	3	4	0	1	3
Hirtshals-Torungen	101	85	57	3	12	4	12	3	6	0	1	2
TOTAL	1309	1152	85	41	55	47	110	44	78	18	9	51

3 - Results

3.1 - Hydrography

The hydrographic coverage of the survey area provides information on the main characteristics of the water masses in the northern North Sea and Skagerrak. The lowest surface salinities are typically found in the Skagerrak due to the outflow of low-salinity Baltic water through the Kattegat, combined with freshwater input from local rivers along the Skagerrak coast. The resulting low-salinity surface waters then follow the Norwegian coast westward out of the Skagerrak and northward along the coast as the Norwegian Coastal Current (NCC). The shelf area in the northern North Sea is generally dominated by inflow of Atlantic water from the north (from the Tampen area) and from the west between the Orkneys and Shetland as the Fair Isle Current.

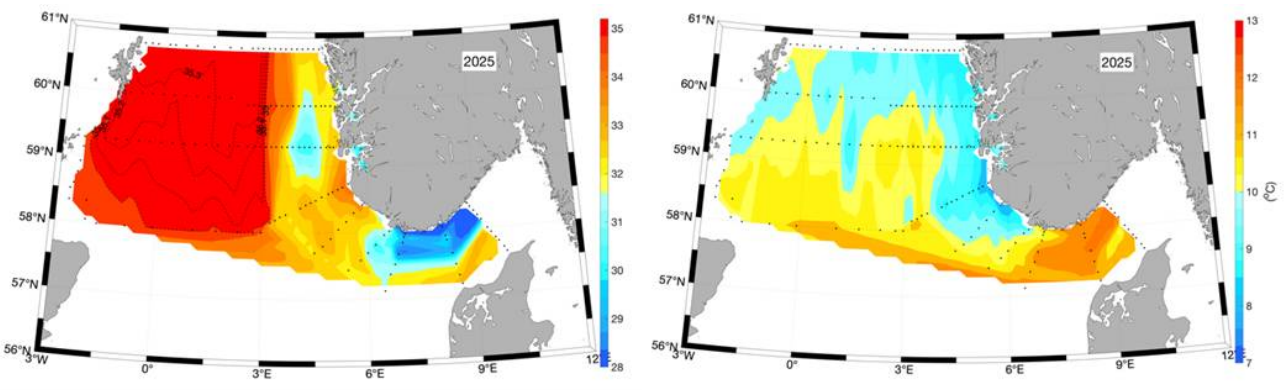

Figure 7. Salinity (left panel) and temperature (right panel, in o C) at 10m depth based on the hydrographic stations (marked with black dots) sampled between 7 and 19 May 2025.

Based on the hydrographic measurements from the Ecosystem Cruise (7–19 May 2025), the NCC can be identified in the surface salinity map in the areas with minimum values (Figure 7, left panel; blue and yellow colors). The low-salinity areas in the Skagerrak extend relatively far south towards Denmark, indicating winds from the northeast and/or east. We also observed relatively low temperatures, between 7.5 and 9.0 °C, in the NCC off the west coast of Norway, likely linked to the prevailing wind regime and associated upwelling. In contrast, temperatures in the coastal areas of the Skagerrak, east of the southern tip of Norway, were above 11 °C (Figure 7, right panel).

Compared with the long-term average from the 20-year time series (2005–2025), the Atlantic water in the northern North Sea and the Skagerrak was considerably warmer in April/May 2024 and 2025 (Figure 8). The elevated temperatures observed in 2024 and 2025 are likely influenced by the timing of the ecosystem cruise, which in these two years was conducted in May rather than April, as is normally the case.

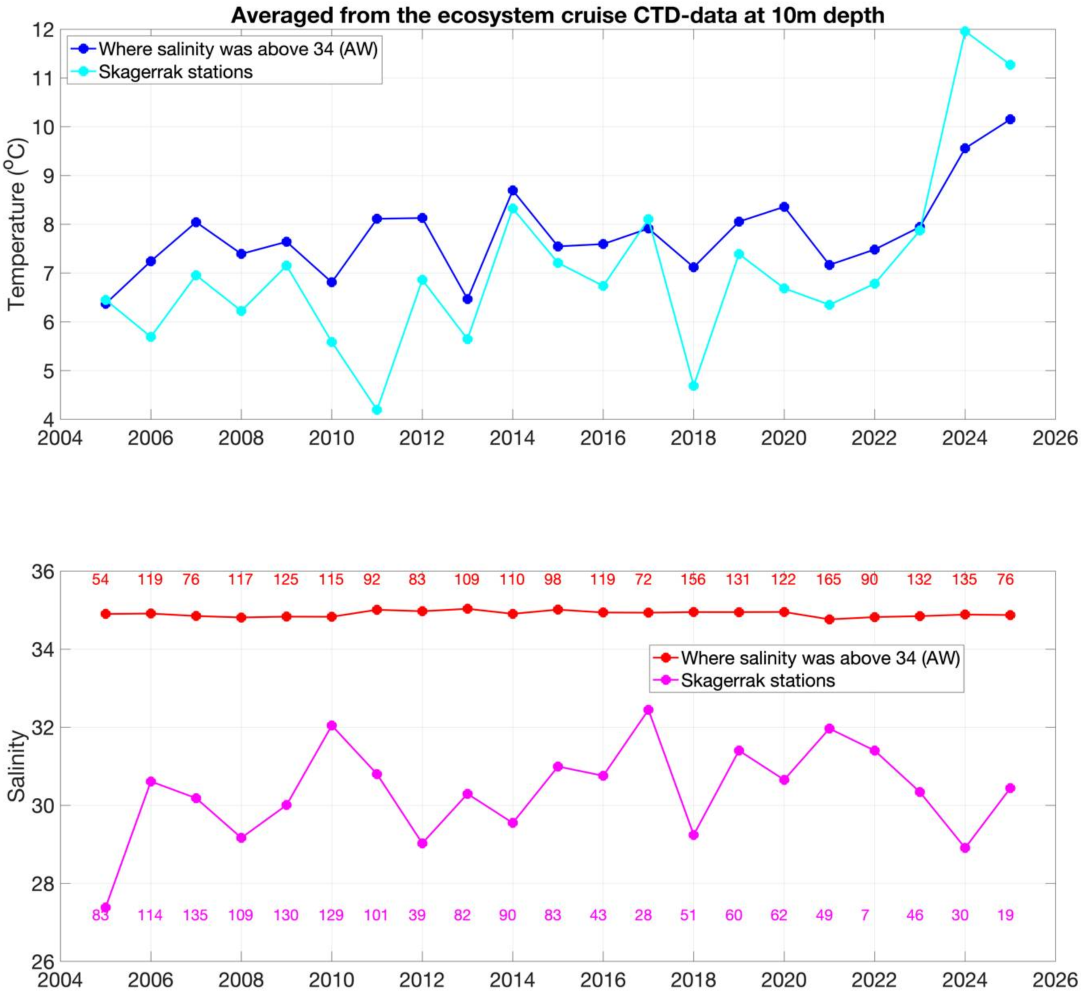

Figure 8. Based on the hydrographic measurements from the Ecosystem Cruise (7–19 May 2025), the NCC can be identified in the surface salinity map in the areas with minimum values (Figure 7, left panel; blue and yellow colors). The low-salinity areas in the Skagerrak extend relatively far south towards Denmark, indicating winds from the northeast and/or east. We also observed relatively low temperatures, between 7.5 and 9.0 °C, in the NCC off the west coast of Norway, likely linked to the prevailing wind regime and associated upwelling. In contrast, temperatures in the coastal areas of the Skagerrak, east of the southern tip of Norway, were above 11 °C (Figure 7, right panel).

Photosynthetic organisms in the ocean, such as phytoplankton, use sunlight as their primary source of energy and therefore must live in the well-lit surface layer, the euphotic zone. Light attenuation is an important parameter for determining the depth of the euphotic zone and can be influenced by both biotic and abiotic particles in the water. The depth of the 1% light irradiance level provides an indication of the amount of particles in the water and the light available to phytoplankton.

During the 2025 survey, the central area along the Utsira transect, as well as waters just outside the Norwegian Trench where temperatures were relatively high, were characterized by the deepest 1% irradiance depths (Figure 9), suggesting a deeper mixed layer and low particle concentrations. In fact, these areas correspond well with the lowest chlorophyll a concentrations measured during our survey (Figure 10a).

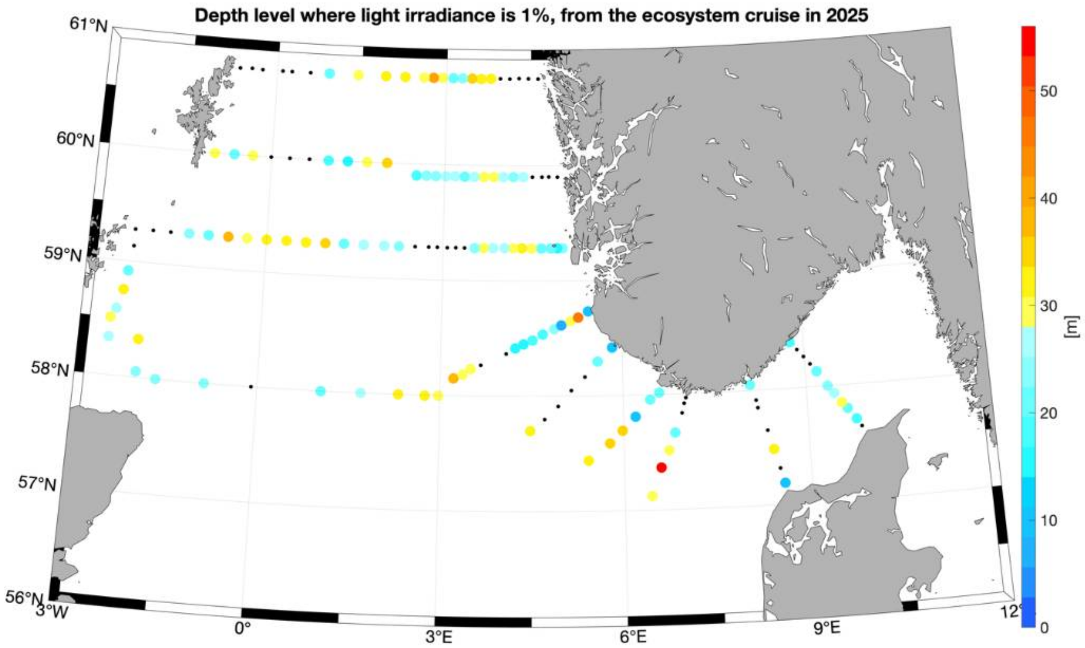

Figure 9. Areal distribution of the 1% light irradiance depth. Warmer colors indicate that light reaches deeper layers, suggesting lower particle concentrations in the water.

3.2 - Biogeochemestry

During the 2025 North Sea ecosystem survey, chlorophyll a concentrations ranged from 0.31 to 11.13 µg L^{-1}, with the highest values recorded at the westernmost stations along the Fedje–Shetland transect (Figure 10a). In general, elevated chlorophyll a concentrations were observed in the northern part of the North Sea, with several localized hotspots along the Utsira transect. A patch of higher concentrations was also detected along the west coast of Norway on the Jærens transect. These elevated chlorophyll a values indicate areas of recent or ongoing phytoplankton growth, which is also reflected in the associated lower nutrient concentrations in the same areas.

Higher nutrient concentrations, on the other hand, were measured in the northeastern sector of the survey area, as well as along the coastal region outside Stavanger. Silicate concentrations were generally low, with 15% of the stations presenting surface silicate concentrations <2 µM. However, concentrations above 4 µM were measured on the west coast of Norway outside Stavanger and along the Torungen–Hirtshals transect on the

Danish coast (Figure 10b). Low silicate concentrations are most likely the combined result of low initial values and/or previous diatom growth. Diatoms are the main users of silica; thus, low values suggest that silica was depleted to support diatom growth.

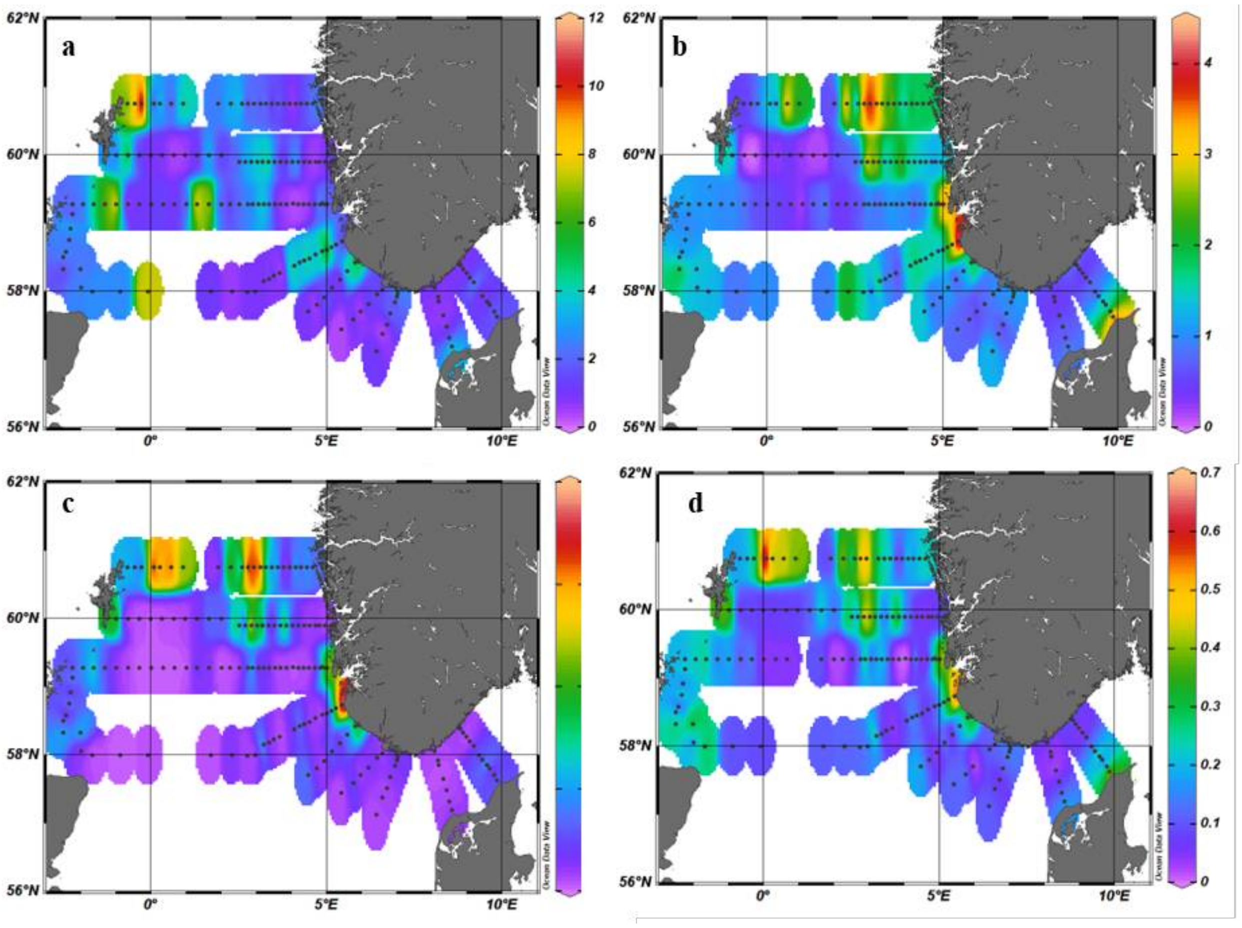

Figure 10. Chlorophyll a and nutrient concentrations during the North Sea spring survey 2025: a) chlorophyll a, b) silicate, c) dissolved Inorganic Nitrogen (DIN, nitrite + nitrate) d) phosphate.

Overall, the stations sampled during the 2025 survey showed an N:P relationship lower than 16 for most parts of the North Sea (Figure 11a), suggesting that phosphate was in excess relative to DIN (nitrite + nitrate). Phytoplankton had less access to silicate than to DIN (Figure 11b), indicating that primary producers were likely co-limited by silicate and nitrogen (P > N > Si) in these areas.

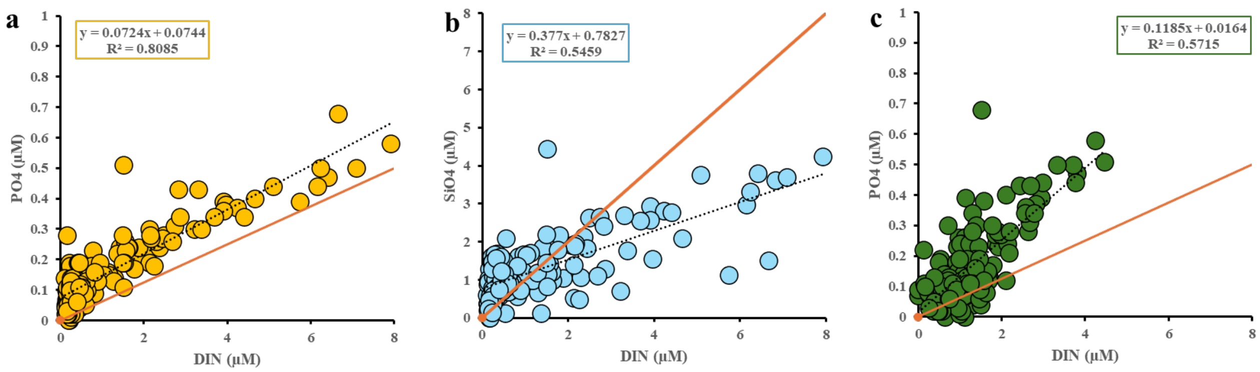

Figure 11. Dissolved inorganic nutrients measured in surface waters. Phosphate (a) and silicate (b) were plotted as a function of dissolved, combined nitrogen (DIN= NO2+NO3), and phosphate (c) is plotted as a function of silicate. The solid lines indicate the Redfield N:P relationship and other molar relationships (N:Si, Si:P) necessary for balanced cellular synthesis and growth in phytoplankton.

3.3 - Phytoplankton taxa

Based on microscopy counts, the North Sea microplankton community at an average station was numerically dominated by flagellates (34%, $3.98\times10^5 \pm 4.87\times10^5$ cells L^{-1}) and diatoms (27%, $3.15\times10^5 \pm 5.91\times10^5$ cells L^{-1}), with lesser contributions from haptophytes (16%, $1.84\times10^5 \pm 1.78\times10^5$ cells L^{-1}), and cryptophytes (9%, $1.07\times10^5 \pm 1.09\times10^5$ cells L^{-1}). It should be noted that the standard deviation is high on all of these means due to large variations in taxon abundance between stations.

Microplankton abundances and communities varied spatially within the North Sea (Figure 2). Cell concentrations varied by more than an order of magnitude between stations, with a minimum concentration of 1.78×10^5 cells L^{-1} and maximum of 4.55×10^6 cells L^{-1}. The two highest abundance stations were found at the southern end of the Norwegian trench, otherwise abundances were variable without clear spatial patterns across the sampled region. Similarly, there were no obvious spatial patterns in community composition. Notably though, many stations were quite diverse relative to previous years and had relatively large proportions of taxa from multiple different broad taxonomic groups.

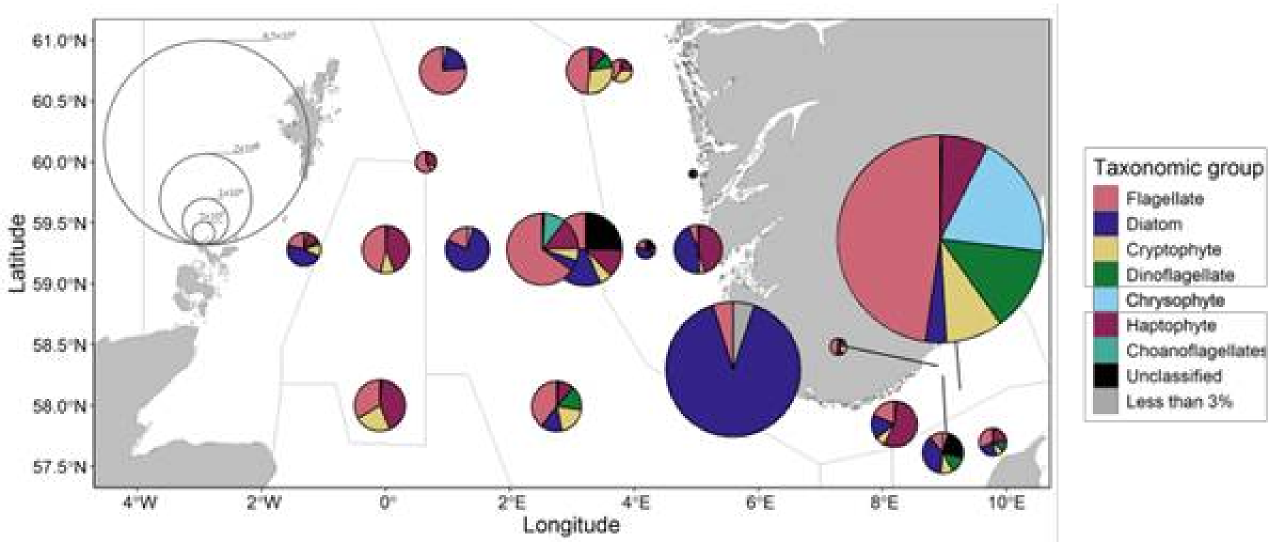

Figure 12. Map showing microplankton community composition and abundance. Divisions within pie charts show the contributions from broad taxonomic groups. Pie chart radii scale to average cell concentrations in cells per liter. Groups accounting for less than 3% of a community at a given station are summed.

Within these data diatoms are the only purely photosynthetic group described at a high taxonomic level. Diatom abundance was greatest (2.67×10^{6} cells L^{-1}) at one station in the Norwegian trench where the diatom community was almost entirely comprised of the genus *Skeletonema* (Figure 13) . Other stations in the trench were also dominated by *Skeletonema,* although abundances were lower. Outside of the trench a diverse group of diatoms were seen including the genera *Dactylisoloen, Cerataulina, Chaetoceros,* and *Guinardia.* The diversity in diatom taxa, distributed over multiple stations, may be related to the late timing of the ecosystem cruise relative to the typical spring bloom period in the North Sea.

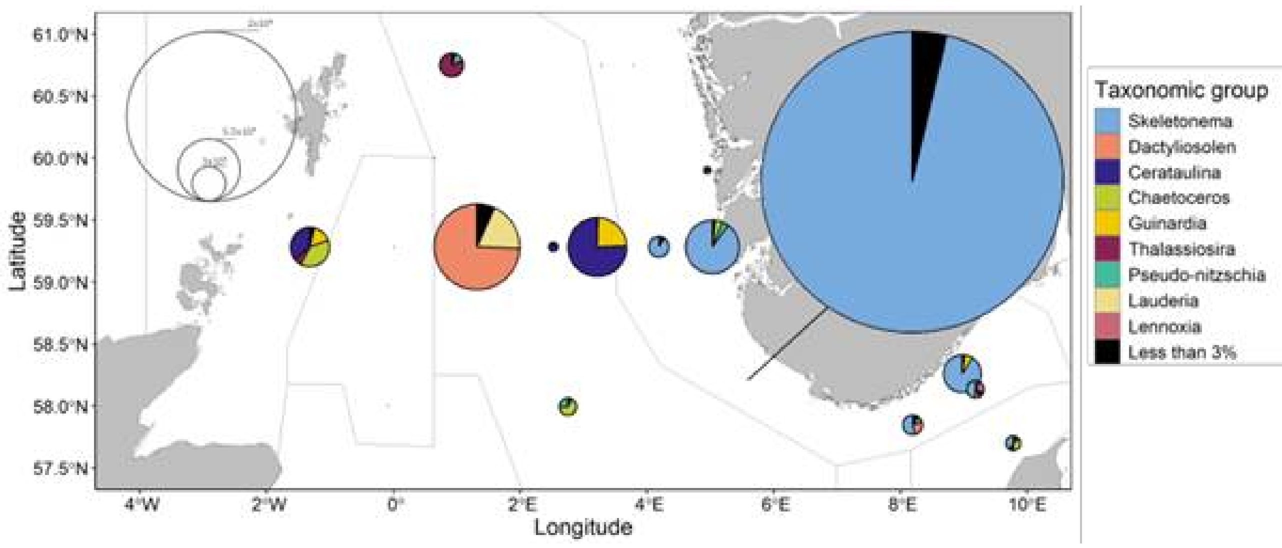

Figure 13 . Map showing diatom community composition and abundance at sampled stations. Pie chart radii scale to average cell concentrations in cells per liter. Divisions within pie charts show the contributions from different diatom genera. Groups accounting for less than 3% of a community at a given station are summed.

3.4 - Plankton through imaging analysis

Plankton communities were also analyzed using the FlowCam flow-imaging system. By integrating observations from three complementary instruments, we were able to generate a comprehensive overview of plankton community composition and size structure across the 5–2000 µm size spectrum. This approach enables rapid assessment at high spatial resolution, although the level of taxonomic detail is lower than what can be achieved through traditional microscopy.

The spatial distribution of the nano- and microplankton community observed during the 2025 North Sea ecosystem survey is shown in Figure 14. The central basin was largely dominated by the smallest cells (5–15 µm), with abundances reaching up to 300 000 cells L^{-1} (Figure 14a). This pattern is consistent with the early stages of the spring bloom, when small, fast-growing phytoplankton are favored under increasing light availability and developing stratification.

Diatoms were most abundant in the southeastern sector of the North Sea, particularly along the Norwegian Trench, where large chain-forming species dominated (Figure 14b). Elevated concentrations of smaller diatoms were also detected along the shelf break and the northern coast of Denmark, likely associated with frontal mixing zones and enhanced nutrient supply. These patterns reflect typical spring bloom dynamics in the region, where diatoms rapidly exploit high nutrient concentrations before stratification strengthens later in the season.

Dinoflagellates and ciliates exhibited broadly similar spatial distributions (Figure 14c,d), although at markedly different abundance levels. Elevated concentrations of these mixotrophic and heterotrophic protists overlapped with areas influenced by Atlantic-derived water masses entering the North Sea, suggesting tight coupling between microbial grazers and nutrient-rich inflows.

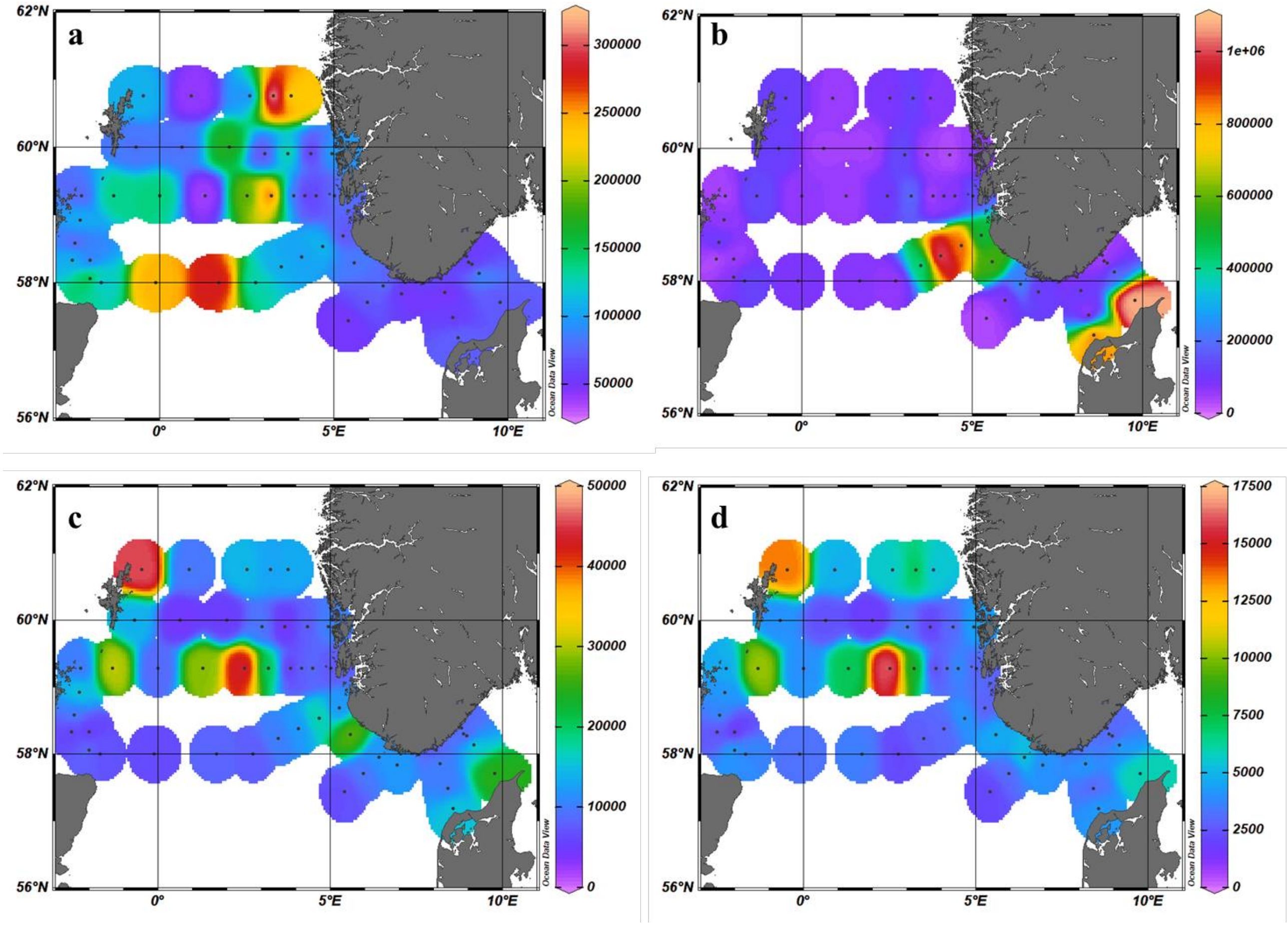

Figure 14. Spatial distribution of nano- and microplankton abundances during the 2025 North Sea ecosystem survey derived from FlowCam analyses. (a) nanoplankton (5–15 µm), (b) diatoms, (c) dinoflagellates, and (d) ciliates. Warmer colors indicate higher abundances (cells L^{-1}).

The spatial patterns emerging from the mesozooplankton biovolume (Figure 16a) and the corresponding size-spectrum slopes (Figure 16b) reveal two distinct trophic configurations across the survey area. In the central basin, biovolume is relatively high and is predominantly composed of smaller zooplankton, as indicated by steeper (more negative) size-spectrum slopes. This region was also characterized by elevated abundances of mixotrophic and heterotrophic protists, which represent high-quality prey for small zooplankton but imply a longer and more microbially driven food chain. Although such pathways efficiently recycle primary production within the planktonic community, they may reduce the energy ultimately available to higher trophic levels.

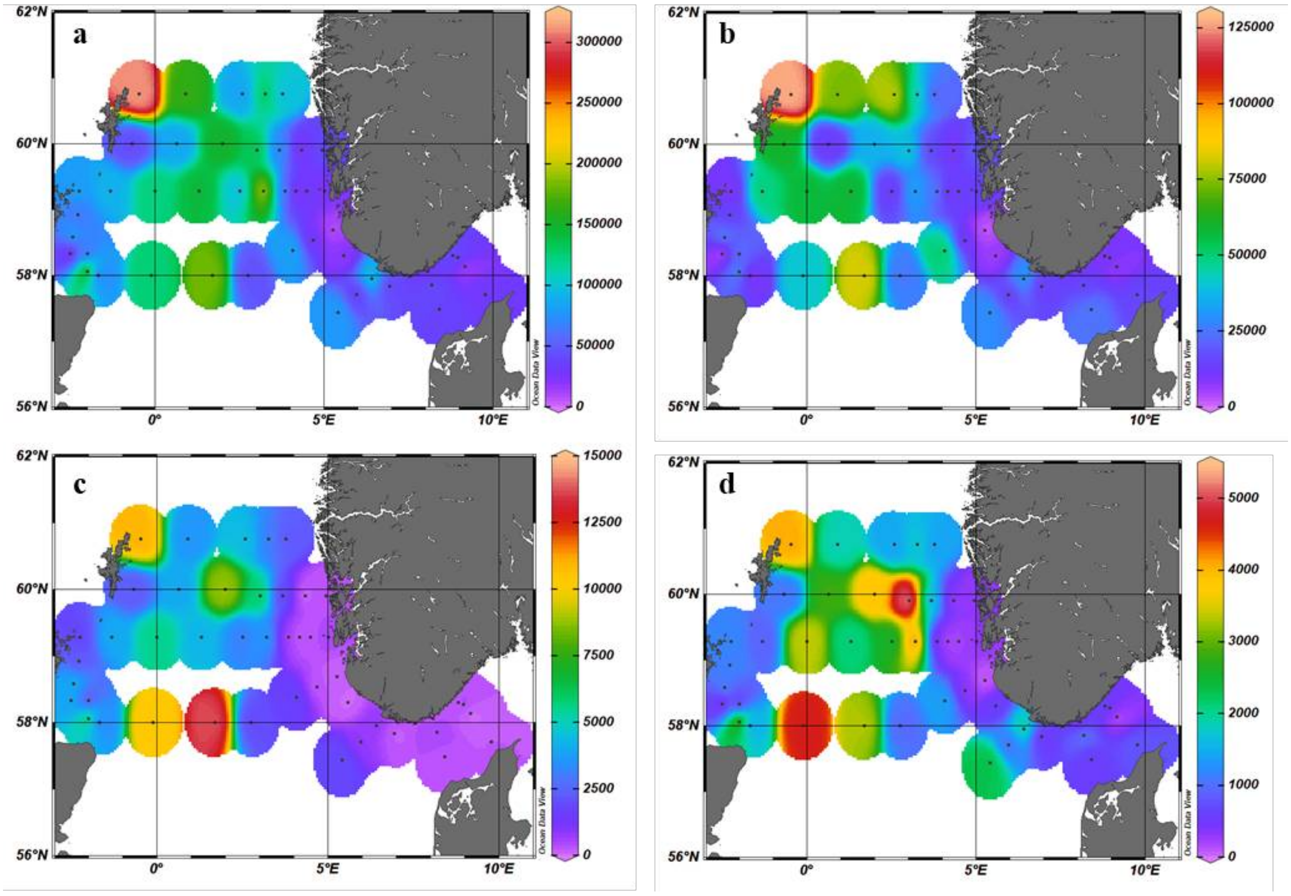

Figure 15. Spatial distribution of mesozooplankton abundance (individuals m^{-2}) during the 2025 North Sea ecosystem survey for (a) Calanoida, (b) Oithona spp., (c) Centropages spp., and (d) euphausiids. Warmer colors indicate higher abundances; dots mark sampling stations.

In contrast, the Norwegian Trench exhibits lower total biovolume but comparatively flatter size-spectrum slopes, indicating a greater contribution of larger zooplankton. This pattern co-occurs with elevated concentrations of large chain-forming diatoms, suggesting a productive environment with a shorter and more direct food chain. Such conditions are typically favorable for fish larvae, which rely on larger mesozooplankton prey during early development.

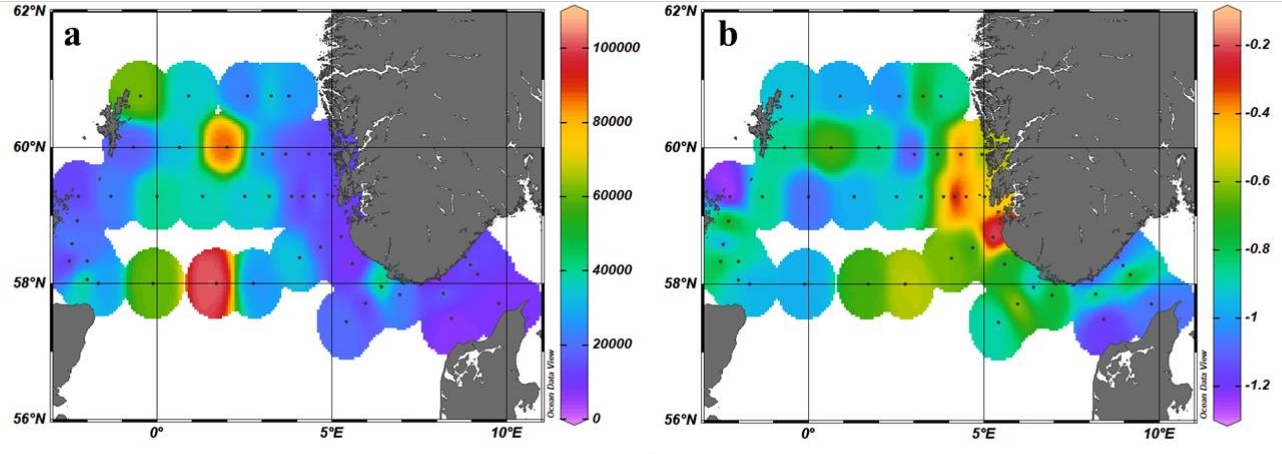

Figure 16. Spatial distribution of (a) mesozooplankton biovolume (individuals m⁻²) and (b) size-spectrum slopes derived from the relationship between organism abundance and body volume during the 2025 North Sea ecosystem survey. Warmer colors indicate higher values. Flatter (less negative) slopes reflect a greater contribution of larger-bodied mesozooplankton, whereas steeper slopes indicate dominance by smaller forms. Dots mark sampling stations.

Taken together, these results highlight marked spatial variation in zooplankton community structure and trophic transfer efficiency across the North Sea during spring. Regions dominated by small zooplankton reflect microbially mediated food webs with potentially reduced energy export to higher trophic levels, while areas supporting larger zooplankton point to more efficient pathways linking primary production to fish recruitment. This contrast underscores the importance of size-structured analyses when assessing the ecological functioning and productivity of North Sea plankton communities.

3.5 - Mesozooplankton

3.5.1 - Zooplankton biomass

Mesozooplankton were sampled at 68 stations, comprising 88 vertical WP2 net tows and 11 depth-stratified Multinet hauls (Figure 17). The spatial distribution of total mesozooplankton biomass (dry weight) based on WP2 hauls from bottom to surface is shown in Figure 17. Overall, the average zooplankton biomass across the survey area was 7.3 g m^{-2}, which is higher than the long-term mean (2005–2024) of 5.7 g m^{-2}. This elevated biomass is likely linked to the later timing of the cruise (7–19 May), coinciding with the seasonal increase in zooplankton populations, and may also reflect the smaller survey area covered compared to previous years.

The distribution of zooplankton biomass showed marked spatial variability. High biomass values (>8 g dry weight m^{-2}) were concentrated mainly in the central part of the area, where several stations exceeded 15 g dry weight m^{-2}. In contrast, biomass levels were generally low (<2 g dry weight m^{-2}) at the westernmost stations (Orkney–Shetland), over the Norwegian Trench, and in the Skagerrak.

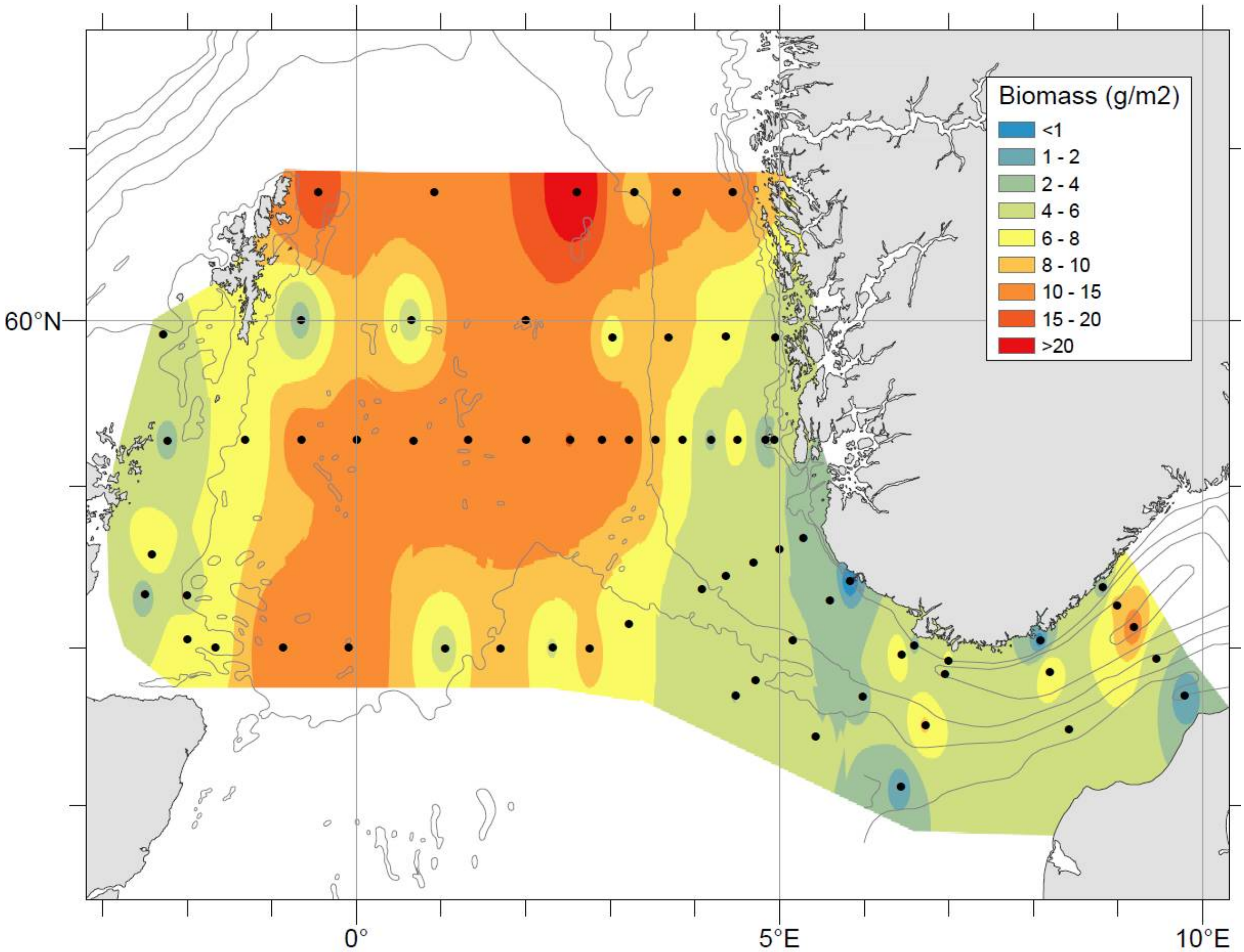

Figure 17. Distribution of total zooplankton biomass (g dry weight m⁻²) from near-bottom to surface in the North Sea during the NSEC, 7–19 May 2025 (WP2, 180 µm). Interpolation was carried out in ArcGIS v.10.8.1, Spatial Analyst, using inverse distance weighting (IDW).

In general, zooplankton biomass was dominated by the smallest size fraction (180–1000 µm), particularly in the western and central parts of the area, where this fraction contributed >60% of the total biomass at most stations (Figure 18). This size range includes small copepods (*Oithona* spp., *Pseudocalanus* spp.), juvenile stages of larger copepods (*Calanus* spp.), and benthic larvae. However, this fraction may also contain phytoplankton, which could lead to an overestimation of zooplankton biomass.

The 1000–2000 µm size fraction, dominated by *Calanus* spp., was more prominent on the Norwegian (eastern) side of the survey area (Figure 18). Larger zooplankton (>2000 µm), including large copepods (*Calanus hyperboreus* , *Paraeuchaeta norvegica*), amphipods, decapod shrimps, and chaetognaths, were associated with deeper stations in the Norwegian Trench.

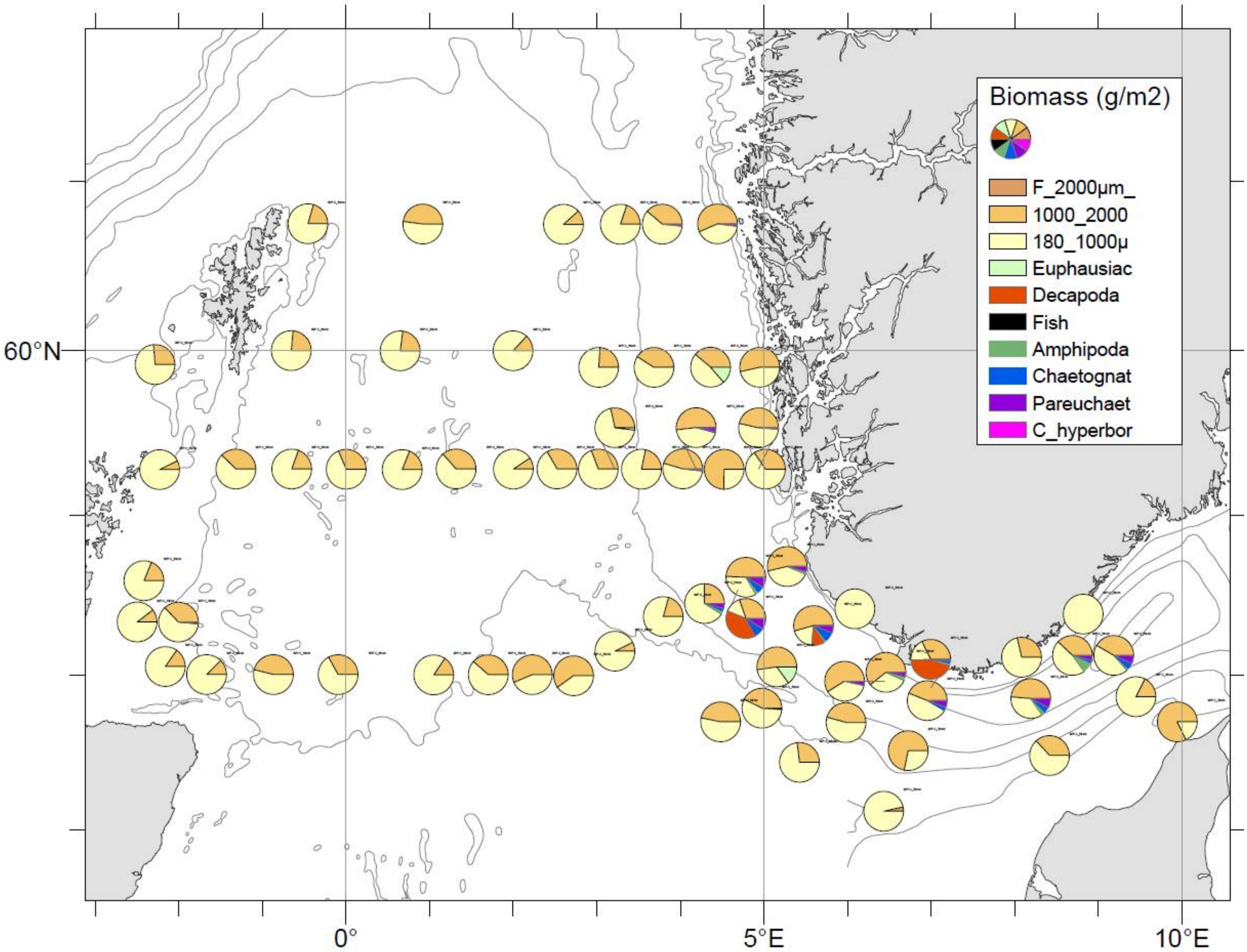

Figure 18 . Relative proportions of zooplankton size fractions in WP2 net tows (180 µm, bottom-surface) on the NSEC 7-19 May 2025

Vertical distribution: The vertical distribution of zooplankton biomass was obtained from depth-stratified Multinet sampling (Figures 19 and 20). The major proportion of zooplankton biomass was found in the upper layers at all stations, with 50–90% of the total biomass distributed in the water column above 100 m, regardless of time of day. Larger zooplankton (>2000 µm) had a deeper distribution, and pelagic decapods, euphausiids, and large copepods (*Paraeuchaeta* and *C. hyperboreus*) were located below 150 m in the Norwegian Trench (Figure 20). These taxa may require a habitat where the water column exceeds 150–200 m, which is consistent with the spatial distribution of macroplankton associated with the Norwegian Trench (Figure 18).

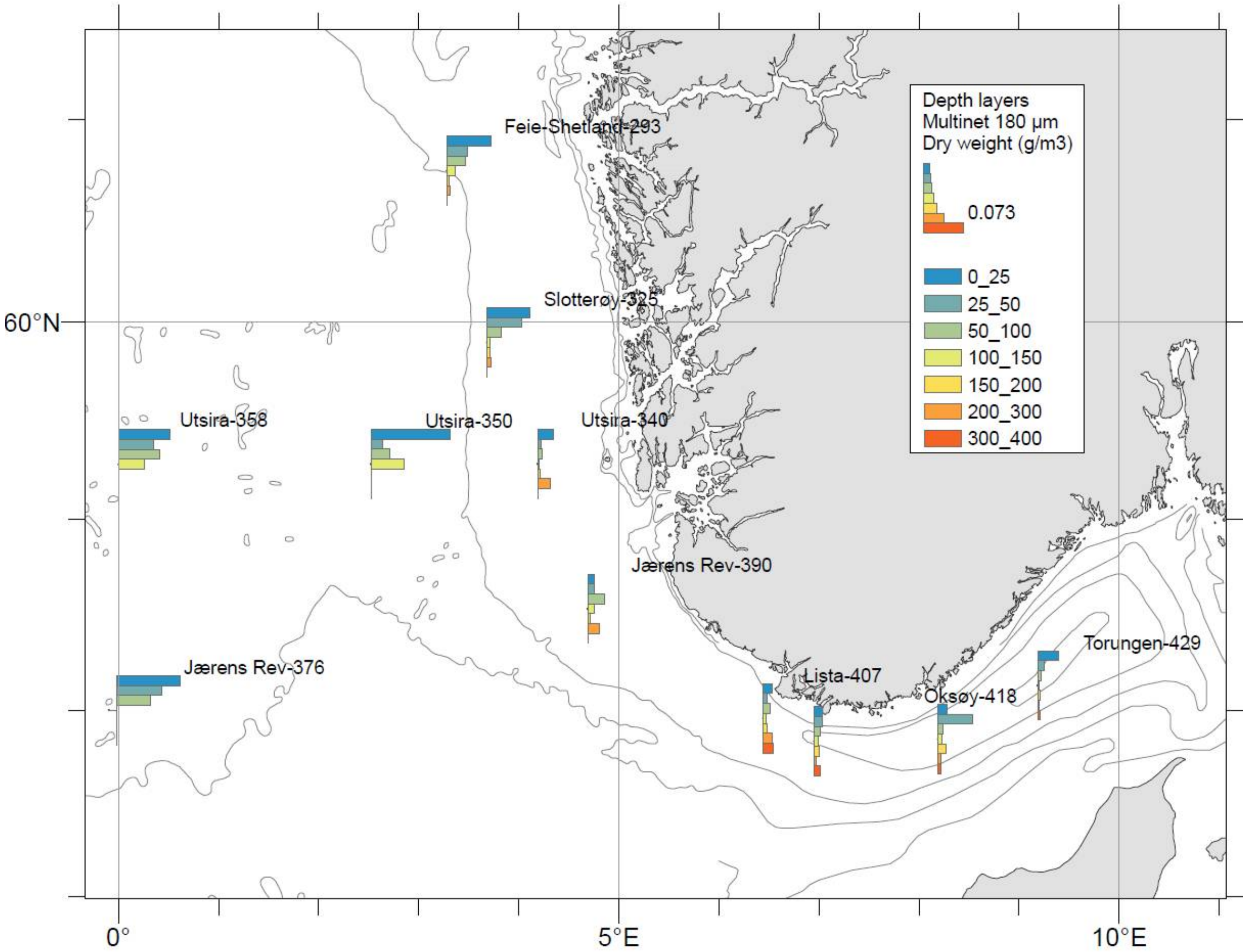

Figure 19. Depth stratified sampling with Multinet (180µm) at the NSEC 7-19 May 2025. The vertical distribution of total zooplankton biomass is indicated by bars (g dry weight m-3).

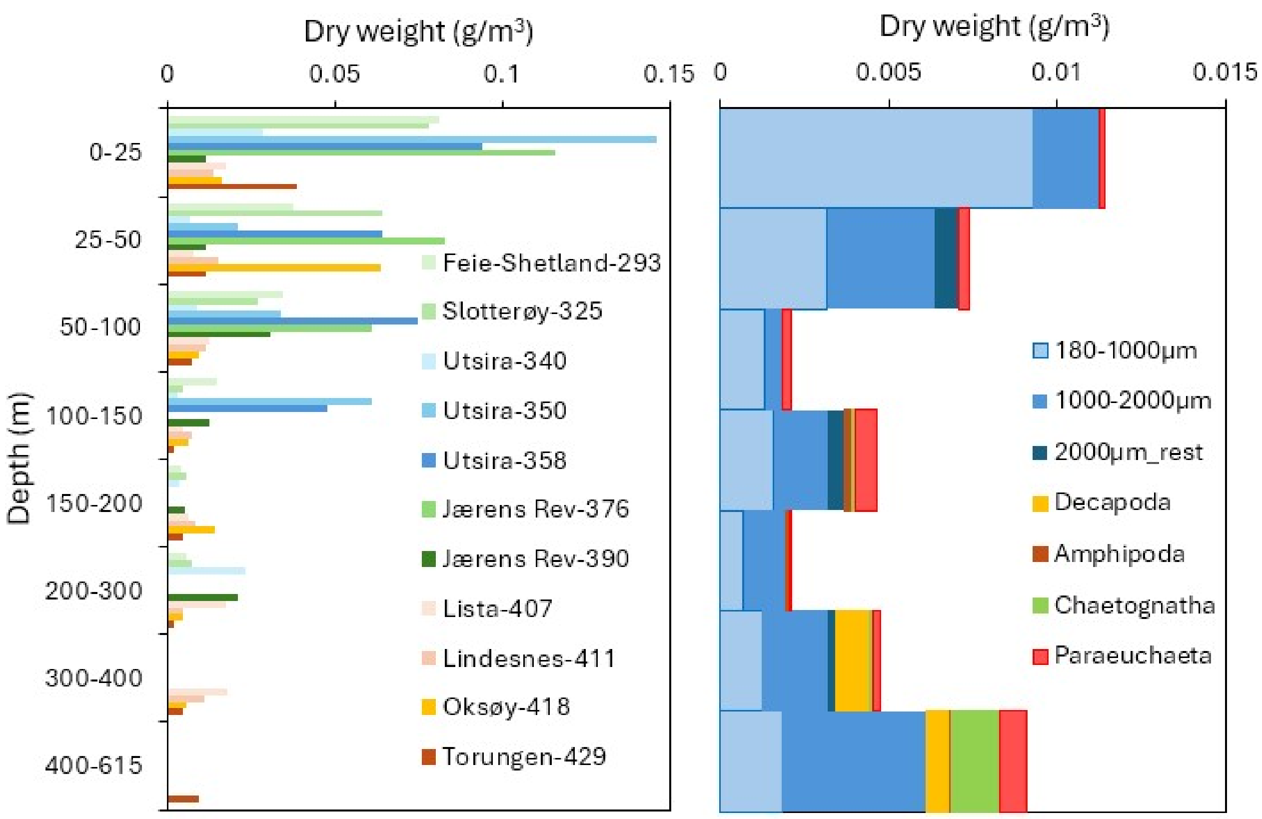

Figure 20. Vertical distribution of zooplankton biomass (g dry weight m-3 , Multinet, 180 µm) on the NSEC 2025. Left panel: Vertical distributions of total biomass on all stations . Right panel: Vertical distribution of zooplankton size fractions in the Norwegian Trench, at station Torungen-429. Positions shown in Figure 19 .

3.5.2 - Zooplankton taxonomic composition

Species identification and enumeration of zooplankton (WP2 tows) were carried out at selected stations along two transects: Utsira–Start Point and Torungen–Hirtshals (Figure 3). Zooplankton community composition differed markedly between the two transects (Figure 21). Along Utsira–Start Point, total abundances were generally higher and dominated by calanoid copepods, particularly at the westernmost stations (358 and 350), where they accounted for 50–70% of total numbers. In contrast, lower overall abundances were recorded along the Torungen–Hirtshals transect, with a more diverse contribution from other groups, such as cladocerans and meroplanktonic larvae, especially at the coastal station 433.

Copepods: Overall, 18 different copepod taxa (species or genera) were identified, with *Oithona* spp., *Para/Pseudocalanus* , *Microcalanus* and *Calanus* spp. being the most abundant (Figure 21). The copepod communities further emphasized the contrasts between the two transects: early developmental stages of *Calanus* spp. (CI–CIV) and *C. finmarchicus* (CV–CVI) were more abundant along the Utsira–Start Point transect, whereas the Torungen–Hirtshals transect had higher proportions of smaller copepod taxa such as *Temora longicornis* , *Centropages typicus* , *Metridia* spp. and cyclopoids (*Oithona* , *Oncaea*). This pattern suggests a spatial difference in zooplankton community structure, with high abundances of large calanoids in the northwestern region and a more mixed community with increased representation of smaller taxa in the Skagerrak.

The deepest station in the Norwegian Trench (643 m, station 429; Figure 21) comprised a diverse assemblage of Arctic–boreal and mesopelagic copepod species, although in low numbers: *Paraeuchaeta norvegica* , *Aetideopsis armata* , *Gaetanus brevispinus* and *Candacia armata* . In contrast to previous years, no occurrences of *Calanus hyperboreus* were recorded at any stations in the Norwegian Trench during this cruise.

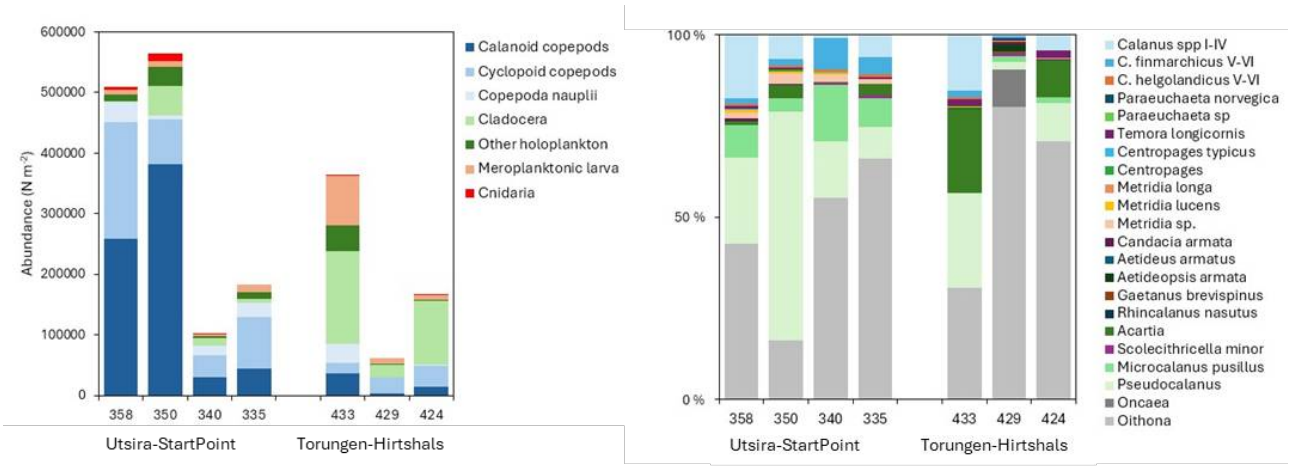

Figure 21. Zooplankton taxonomic composition along two transects at the NSEC 7-19 May 2025 : Utsira-StartPoint and Torungen-Hirtshals. Positions shown in Figure 3 . Left panel: Major taxonomic groups of zooplankton (numbers/m 2), Right panel: Relative abundance (%) of copepod taxa.

The sibling species *Calanus finmarchicus* and *C. helgolandicus* co-occurred across the survey area. However, *C. finmarchicus* was the dominant species, typically comprising >80% of *Calanus* CV–CVI at all stations (Figure 22). *Calanus* spp. were most abundant at the northwestern station on the Utsira–Start Point transect (>80 000 ind. m^{-2}), while abundances were below 10 000 ind. m^{-2} in the Skagerrak (Torungen–Hirtshals).

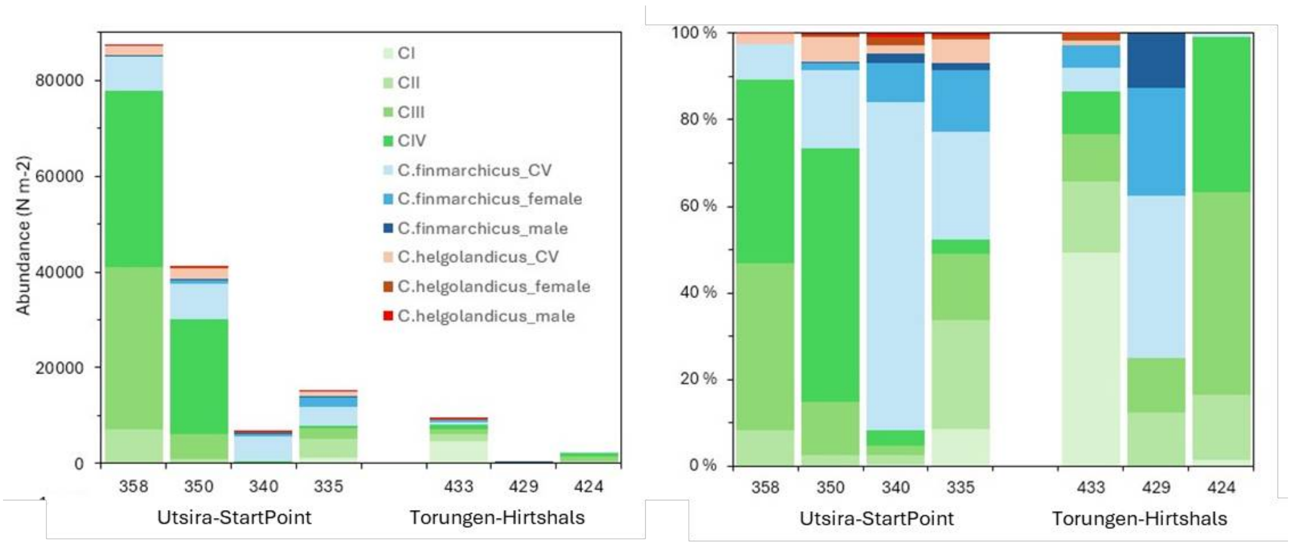

Figure 22. Copepodite stages and species composition of Calanus finmarchicus and C. helgolandicus on two transects at the NSEC 7-19 May 2025 : Utsira-StartPoint and Torungen-Hirtshals. Station positions shown in Figure 3. Left panel : Abundances of Calanus spp (Numbers m -2). Right panel: Relative abundances of Calanus species and copepodite stages.

3.6 - Macroplankton

A total of 23 different taxa were recorded in the macroplankton trawl hauls, including fish (10 taxa), crustaceans (7) and gelatinous plankton (6) (Figure 23). The highest densities were registered at station 418 in the Norwegian Trench (0.09 g m^{-3}, equivalent to 48 g m^{-2}) at a bottom depth of 520 m. Considerably lower densities were found in the western and northern parts of the trench, where biomass was below 0.01 g m^{-3}.

The macroplankton community was dominated by decapods and euphausiids, which together accounted for 50–80% of total biomass. Decapods (*Pasiphaea* sp.) were more abundant at the easternmost stations, whereas euphausiids (mainly *Meganyctiphanes norvegica*) were the dominant taxon at the western and northern stations. The gelatinous plankton community also showed clear spatial differences and was more abundant in the southeastern area, mainly *Cyanea capillata* and, to a lesser extent, *C. lamarckii* . The macroplankton trawl samples the entire water column, and the vertical distributions of the different taxa are therefore not directly resolved. However, based on Multinet catches (Figure 20), euphausiids and decapods were most likely distributed below 150 m.

The Macroplankton trawl was developed specifically for quantitative sampling of macroplankton and micronekton, but is less suited for larger fish species. Fish catches from the trawl were generally low but nevertheless revealed a diverse list of 10 taxa (Table 6). *Maurolicus muelleri* was the numerically most abundant fish species at the northern stations, followed by *Melanogrammus aeglefinus* at the eastern stations in the Skagerrak. By weight, the most abundant fish species were *Cyclopterus lumpus* and *Pollachius pollachius* .

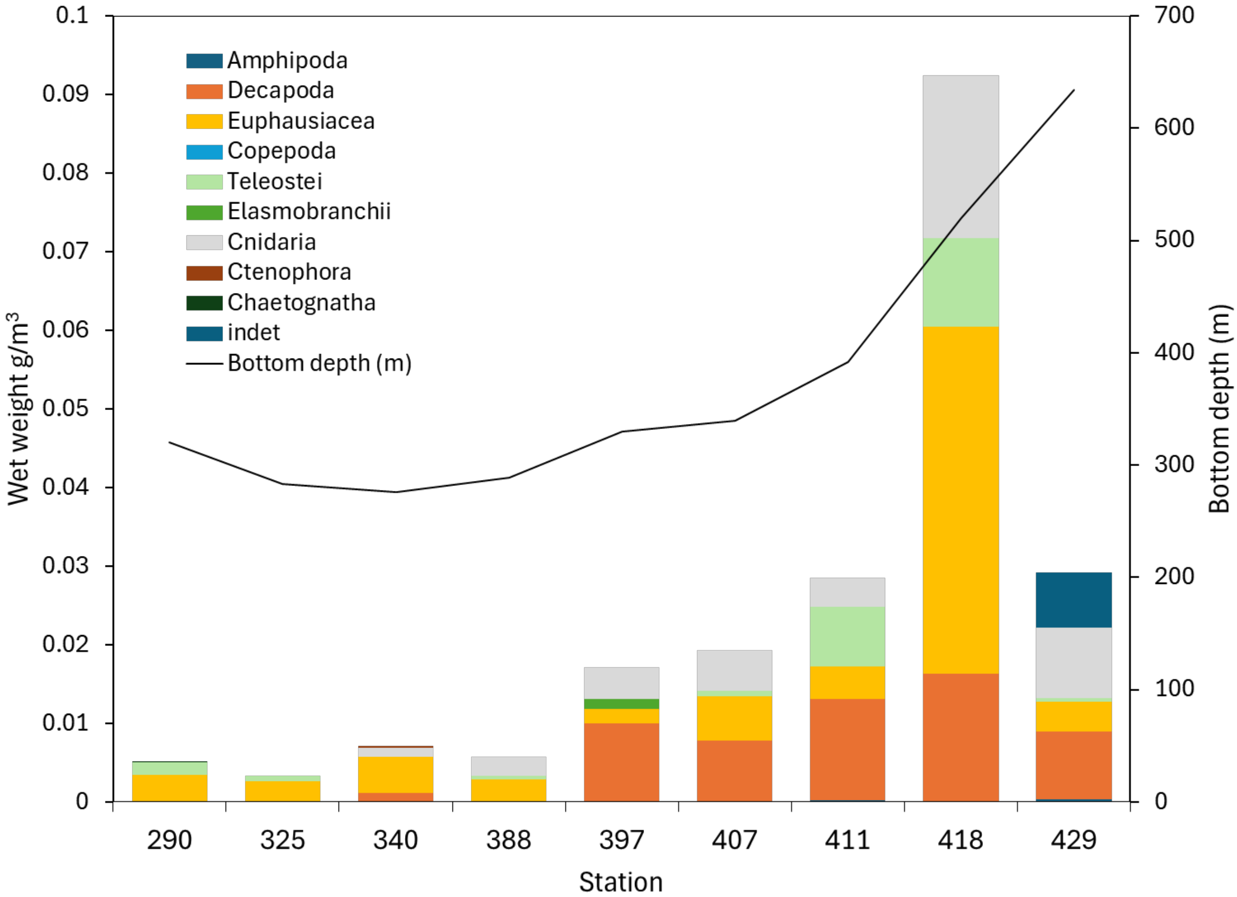

Figure 23. Taxonomic composition of Macroplankton (g wet weight m -3) sampled with the Macroplankton trawl (36 m 2 , 3 mm mesh, oblique hauls bottom-0m). Bottom depth shown on right axis. Station positions shown in Figure 4.

.Table 6. Taxa registered in Macroplankton trawl, NSEC 2025. Densities as wet weight (10^{-4} g/m^3). Station positions shown in Figure 4.

	Serial number	**24056**	**24057**	**24058**	**24059**	**24060**	**24061**	**24062**	**24063**
	Station number	**290**	**325**	**340**	**388**	**397**	**407**	**411**	**418**
Amphipoda	*Themisto abyssorum*	0.00	0.00	0.00	0.52	0.93	1.60	1.90	0.00
Decapoda	Pasiphaea sp.	0.00	0.00	0.00	0.00	60.40	0.00	128.89	163.25
	Pasiphaea multidentata	0.00	0.00	0.00	0.00	0.00	22.45	0.00	0.00
	Pasiphaea sivado	0.00	0.00	11.67	0.60	38.10	11.22	0.00	0.00
	Pasiphaea tarda	0.00	0.00	0.00	0.00	0.00	43.29	0.00	0.00
Euphausiacea	*Meganyctiphanes norvegica*	34.98	25.98	45.77	27.48	18.58	56.12	41.70	440.77
	Nematoscelis megalops	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.98
Copepoda	*Paraeuchaeta sp.*	0.00	0.00	0.00	0.52	0.00	0.16	0.00	0.00
Teleostei	Argentinidae	0.00	0.00	0.00	0.00	0.00	1.60	0.00	0.00
	Maurolicus muelleri	6.63	7.61	0.00	4.40	0.55	4.35	0.56	0.38
	Coryphaenoides rupestris	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.06
	Cyclopterus lumpus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	109.66
	Melanogrammus aeglefinus	0.00	0.00	0.12	0.00	0.00	0.97	0.69	1.76
	Micromesistius poutassou	9.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Pollachius pollachius	0.00	0.00	0.00	0.00	0.00	0.00	74.37	0.00
	Trisopterus esmarkii	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.88
	Gadidae	0.00	0.00	0.00	0.00	0.11	0.00	0.00	0.00

Elasmobranchii	*Squalus acanthias*	0.00	0.00	0.00	0.00	12.13	0.00	0.00	0.00
Cnidaria	*Cyanea capillata*	0.00	0.00	0.00	0.00	31.10	27.68	16.44	196.62
	Cyanea lamarcki	0.00	0.00	0.46	0.00	9.37	23.42	20.12	10.08
	Aurelia aurita	0.00	0.00	10.96	0.00	0.00	0.00	0.00	0.00
	Hydromedusae	0.00	0.00	0.00	23.85	0.00	0.00	0.00	0.00
Ctenophora	*Pleurobrachia pileus*	0.00	0.00	2.42	0.00	0.00	0.00	0.00	0.00
Chaetognatha	Chaetognatha	0.17	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Indet		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Bottom depth (m)	320	283	276	289	330	339	392	520
	Max sampling depth (m)	390	250	250	257	302	313	350	516
	Latitude	60.75	59.90	59.29	58.43	58.30	57.95	57.67	57.87
	Longitude	3.95	3.94	4.04	4.29	5.59	6.43	6.83	8.18
	Date	45785	45787	45788	45792	45792	45793	45794	45794
	Time (UTC)	0.22	0.71	0.61	0.16	0.85	0.69	0.15	0.92

3.7 - Ichthyoplankton

A total of 61 Gulf VII hauls were conducted during the survey. Results presented here are preliminary, as fish larvae could only be identified to higher taxonomic groups at sea due to time constraints; identification to species level and quality assurance remain pending.

3.7.1 - Fish eggs

Fish eggs were found at all but four stations, with the highest densities per m² (420 ind. m^{-2}) observed off the southern tip of Norway along the edge of the Norwegian Trench. Egg densities were generally highest in the southeastern part of the survey area, declining somewhat northwards and then decreasing westwards, with densities along the western edge of the North Sea largely below 100 ind. m^{-2}. Three of the four stations without eggs were located on the southernmost transect along the 58th parallel (Figure 24).

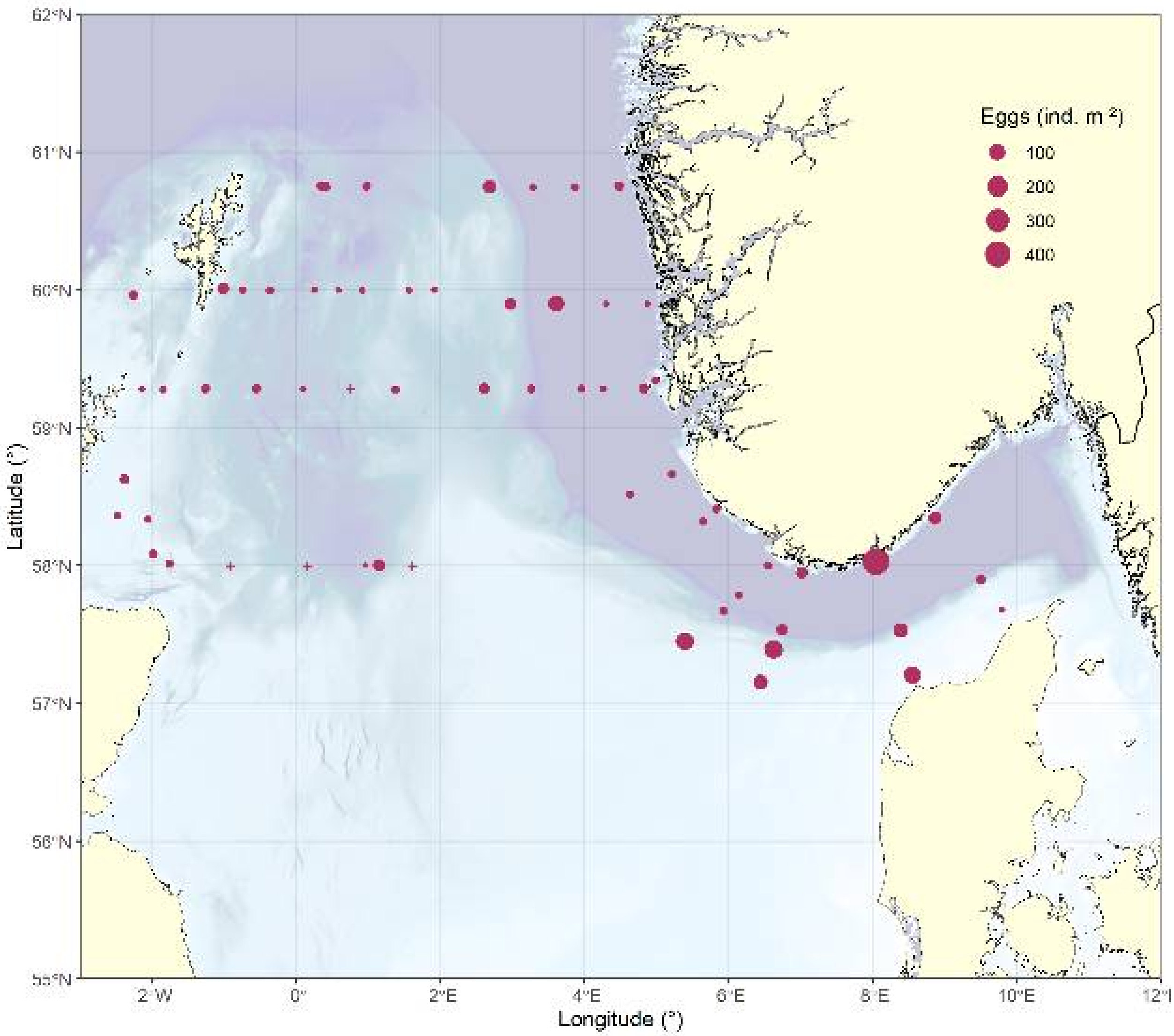

Figure 24. Distribution of fish eggs during the survey, raised to numbers per square meter (ind. m -2). Highest densities were found in the Southeast of the survey area, off the southern tip of Norway.

3.7.2 - Fish larvae

In contrast to the pattern for fish eggs, the highest densities of fish larvae were observed in the western North Sea (Figures 25 and 26a). Peak larval densities were 60.2 ind. m^{-2} southeast of Shetland for Gadidae and for the composite group “other larvae”. The distribution of Lotidae showed a high degree of co-occurrence with Gadoids, with a peak density of 16.9 ind. m^{-2} occurring further east and slightly south of the peak for Gadidae.

Densities of other taxonomic groups were generally low. Pleuronectiformes peaked at 34.1 ind. m^{-2}, with their distribution centered mostly in the western North Sea, and many zero stations in the eastern part. Clupeidae exhibited a peak of 20.5 ind. m^{-2} outside the Moray Firth, with other high densities found northwards from there, while densities off the Norwegian and Danish coasts were very low.

The newly separated categories Ammodytidae and Argentinidae exhibited complementary distributions: Ammodytidae were confined to the western edge of the North Sea, peaking at 15.1 ind. m⁻² southeast of Shetland, while Argentinidae were nearly absent near the British Isles and peaked at 8.2 ind. m⁻² on the Fladen Ground. Ammodytidae were completely absent from the eastern part of the North Sea, whereas Argentinidae occurred only offshore of the Skagerrak and at one station inside the Skagerrak. Very few Gobiidae were found, with a peak density of 1.9 ind. m⁻² and no clear distribution pattern. The distribution of “other larvae” was similar to that of Gadidae, although higher densities were more concentrated along the western edge of the North Sea.

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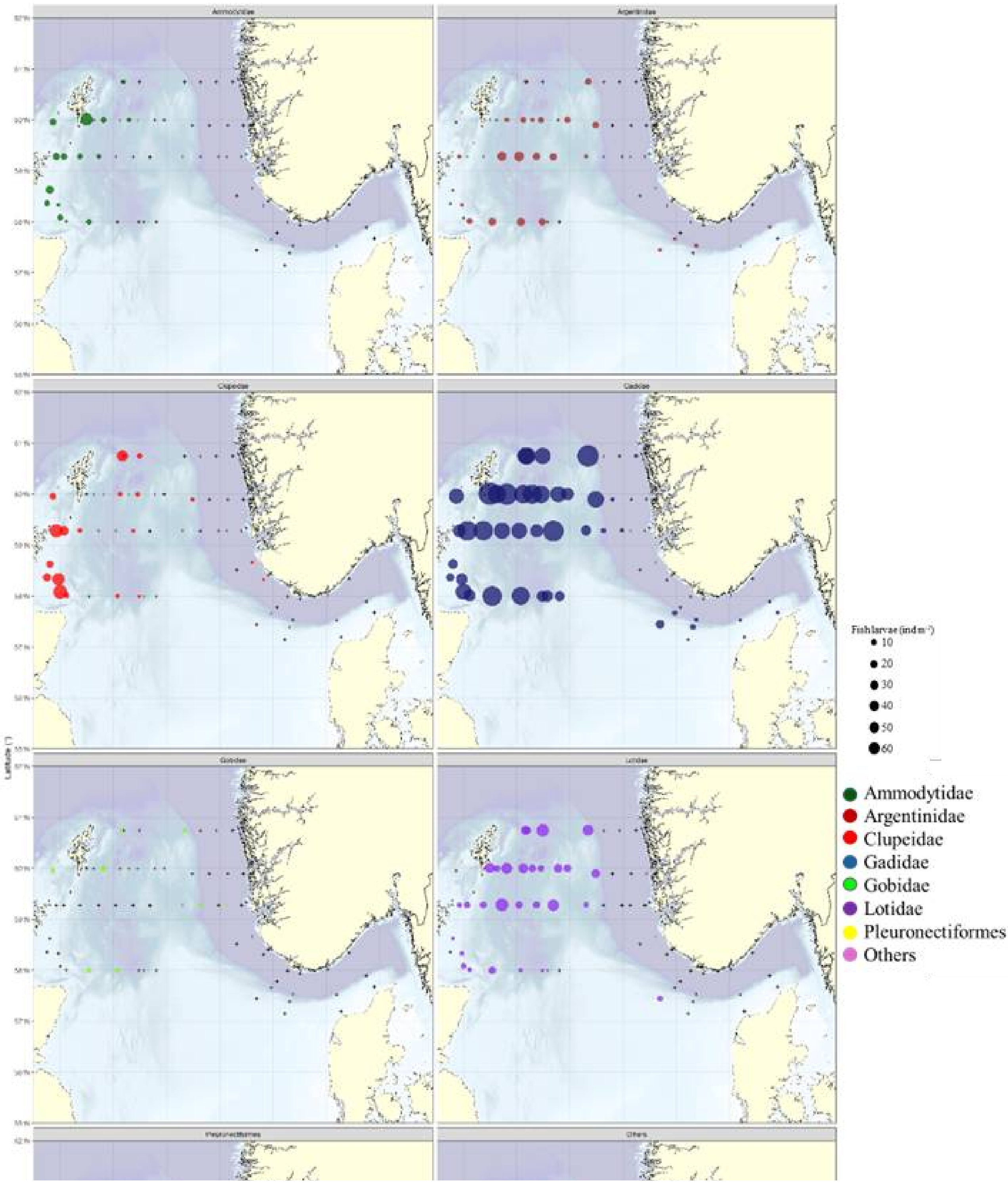

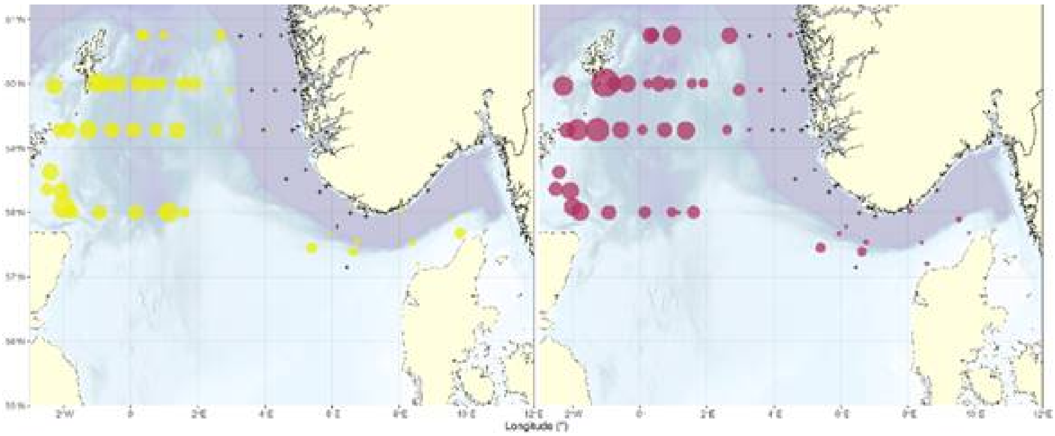

Figure 25. Distribution of fish larvae separated by major taxonomic groups. Gadoids dominated the assemblage, being found almost everywhere and exhibiting the highest densities. Clupeids were most common along the western edge of the North Sea, with densities about one third of those of Gadoids. The group "Others" comprises a wide range of species, including e.g. dragonets. Argentines, sandeel and gobies were separated out from this group in the 2025 survey.

When aggregated to ICES rectangles (Figure 26), Gadidae were most prominent in the larval assemblage in the northeast and west of the Skagerrak. Pleuronectiformes dominated the assemblage towards the Skagerrak, although they also contributed substantially in rectangles further north and west. Clupeidae contributed noticeably to the assemblage only along the western edge of the North Sea, from the Orkneys south to the Moray Firth, with the exception of two rectangles with single stations off the southwestern tip of Norway where only Clupeids were found. Lotidae were most prominent in rectangles over the Norwegian Trench, otherwise making up a small percentage of rectangles in which Gadidae were dominant.

Neither Ammodytidae nor Argentinidae dominated the assemblage in any rectangle, and Gobiidae were so rare that they always comprised <0.5% of the assemblage. Other larvae were most prominent on the eastern edge of the North Sea, particularly directly west of and inside the Skagerrak. A similar, though weaker, effect of influx from adjacent seas was also noticeable along the western edge of the North Sea.

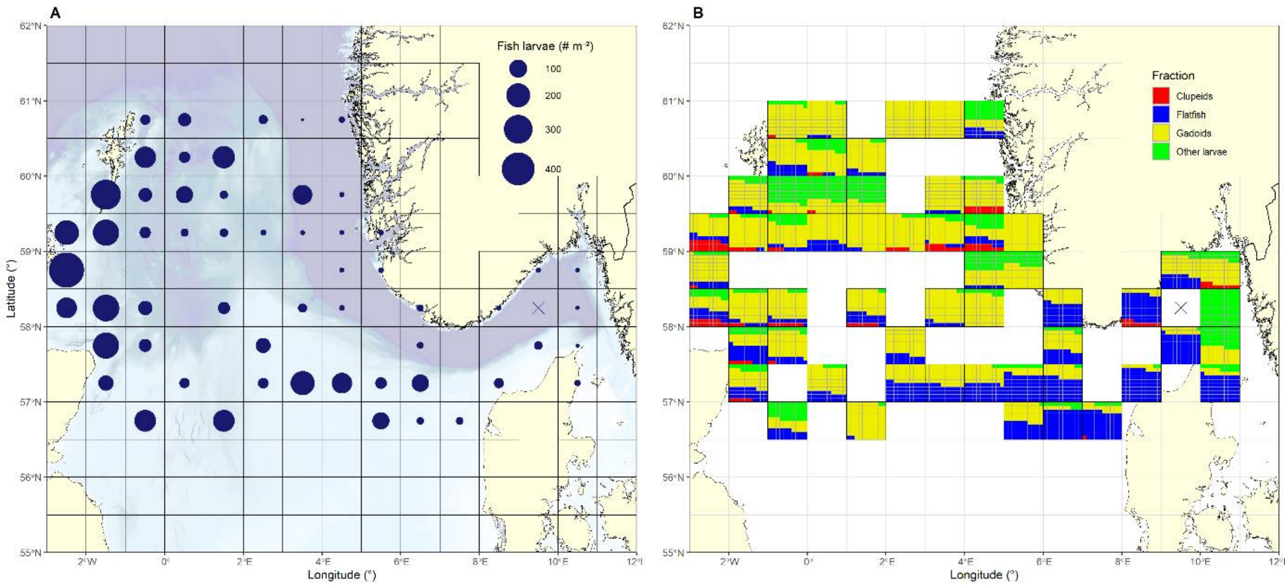

Figure 26. Total abundance of fish larvae (a) and proportional composition of the larval assemblage (b), aggregated by ICES rectangles. Gadoids dominated the assemblage and total abundance from around 59°N northwards and partly also in the northwest of the survey area. Flatfish were most prominent in the assemblage in the east and south, dominating in the Skagerrak.

3.7.3 - Relationships to the abiotic environment and earlier years

The GLMM using near-bottom temperature had a lower AIC than the model using surface temperature (6304 vs. 6320). Although salinity was included in the initial model, it did not contribute significantly and was excluded from the final model. In contrast, depth and bottom temperature were both highly significant ($p < 0.001$) in the bottom-temperature model, whereas only depth was significant in the model using surface hydrography.

All taxa exhibited similar relationships to depth and temperature (Figure 27), with declining abundances at greater depths and increasing abundances with higher temperatures. Gadidae differed significantly from other taxa ($p = 0.03$).

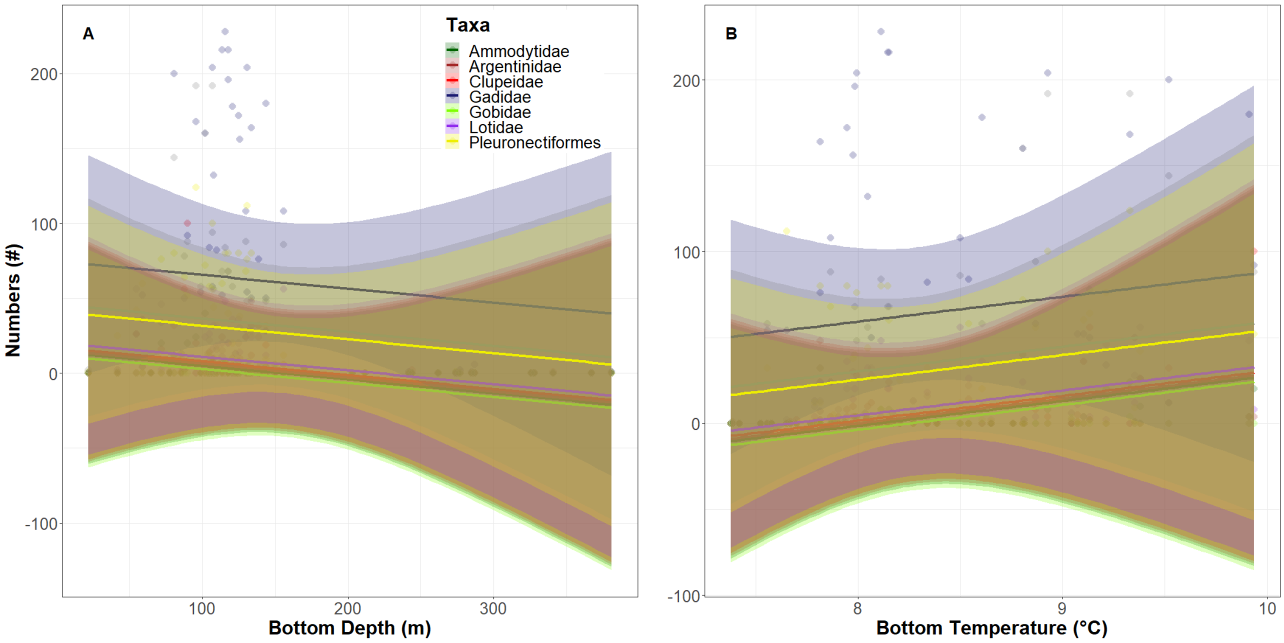

Figure 27. GLMM results for the relationship between larval abundance and depth (A) and near-bottom temperature (B). Trends indicate higher abundances at shallower depths, peaking around 100 m, and higher abundances at warmer temperatures, with peak values around 8 °C. While trends were similar for all groups, slopes differed notably for flatfish, and Gadoids differed significantly from other groups.

As in earlier years, Clupeidae were most commonly found along the western edge of the North Sea, but were even less common on the eastern side than in 2023 and 2024. Densities were intermediate between previous years, being slightly more than twice the 2024 peak (7.7 ind. m^{-2}) but only about one third of the 2023 peak (59 ind. m^{-2}).

A major feature of Gadidae in 2025 was their much lower abundance compared with the two previous years, with peak densities one-fifth and one-tenth of those in 2024 (344.1 ind. m^{-2}) and 2023 (600 ind. m^{-2}), respectively. However, the distribution pattern was very similar to that in 2024, albeit at much lower densities overall. In earlier years, Gadidae and Lotidae were counted together as Gadiformes; even when combined for 2025, densities (77.1 ind. m^{-2}) were much lower than in previous years.

Pleuronectiformes abundance was also much lower than in earlier years—about one-fifth and one-half of the 2023 (159 ind. m^{-2}) and 2024 (80.4 ind. m^{-2}) peaks, respectively. The distribution pattern also differed, with most flatfish occurring in the western North Sea. However, Pleuronectiformes still dominated the assemblage in the southeastern part of the survey area, where overall larval densities were low.

Peak densities of “other larvae” were about two-thirds of the 2023 and 2024 peaks, while mean densities (8.7 ind. m^{-2}) were similar to those in the early 2024 survey. As for flatfish, they were most prominent in the assemblage in the southeastern part of the survey area, and the dominance of high densities along the western edge of the North Sea was even more pronounced than in 2024. However, because three taxa were separated out of this group for 2025, numbers are not directly comparable with earlier years.

3.8 - Radioactivity

The Baltic Sea is currently the largest source of radioactive contamination in Norwegian waters. This is because the land areas surrounding the Baltic Sea received significant fallout from the Chernobyl accident in 1986.

Runoff from these contaminated land areas is transported with ocean currents from the Baltic Sea to Norwegian waters. To monitor the supply of cesium-137 (Cs-137) to Norwegian waters, we aim to sample seawater annually from 10 stations in the Skagerrak (Table 4, Figure 6).

Results from 2008 to 2024 are presented in Figure 28. Samples collected in 2025 have not yet been analyzed. Typically, the highest activity concentrations of Cs-137 are observed along the Fredrikshavn–Gøteborg section, which is close to the outlet of the Baltic Sea. In 2024, two samples were collected on the Våderø section at fixed stations 5 and 8, with activity concentrations of 10.8 and 3.3 Bq m^{-3}, respectively (not shown in Figure 28). Conversely, the lowest activity concentrations are consistently recorded at station Oksø–Hanstholm (56 n.m.), where levels have remained relatively stable at around 1–2 Bq m^{-3} during 2008–2024. This stability is expected, as seawater at this station has characteristics more similar to the North Sea. Generally, activity concentrations of Cs-137 in open Norwegian sea areas range from 1 to 2 Bq m^{-3}, with slightly higher values in coastal areas.

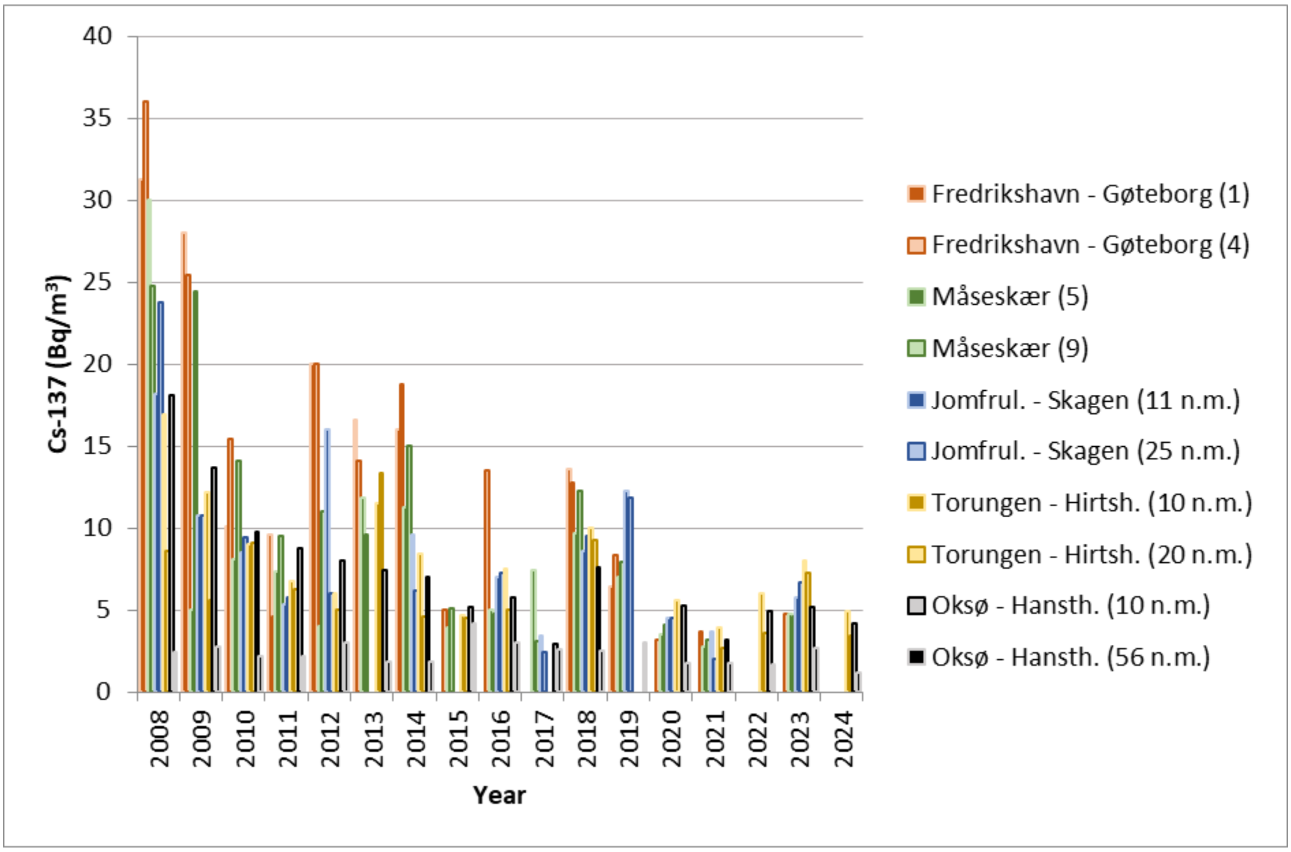

Figure 28. Activity concentrations of cesium-137 (Cs-137) (Bq/m^3) in samples of seawater collected yearly in the period 2008 – 2024 at the stations shown in Figure 6. In 2024, samples were only collected from the Torungen-Hirtshals and Oksø-Hanstholm sections.

Figure 29 shows Cs-137 acticity concnetrations (Bq m^{-3}) at each station potted against salinity. There is a clear negative correlation between salinity and Cs-137 activity. The Baltic Sea has brackish water, with surface salinity ranging from1-2 in the northernmost Bothnian Bay to around 20 in the Kattegat, compared to ca. 35 in the NOrth Sea. Thus, low salinity implaies a stronger "Baltic Sea influence", while higher salinity reflects more "North Sea Characteristics". This pattern is consistent with the Cs-137 results.

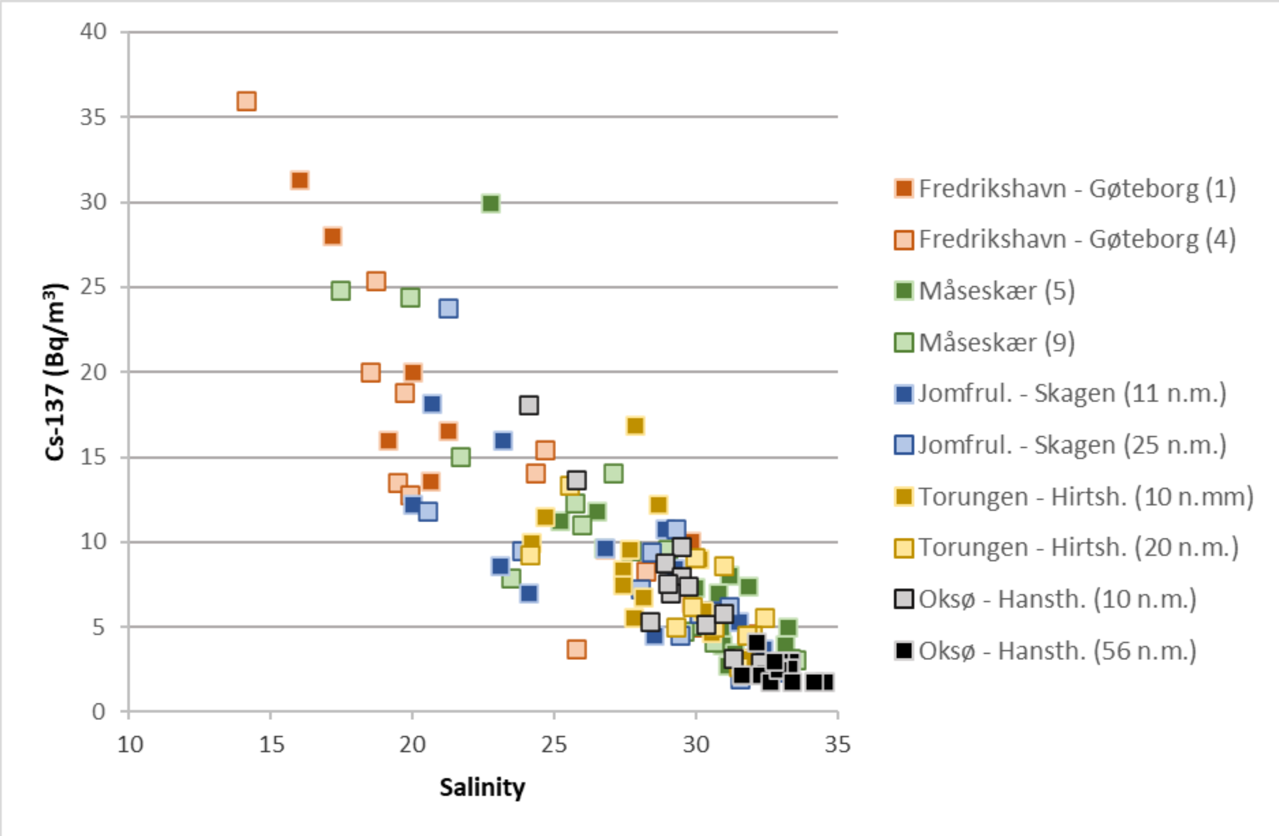

Figure 29. Activity concentrations of cesium-137 (Cs-137) (Bq/m 3) in samples of seawater collected yearly in the period 2008 – 2024 at the stations shown in Figure A plotted against salinity.

4 - Conclusions

Taken together, the 2025 observations reveal a North Sea ecosystem characterized by pronounced spatial heterogeneity in productivity, size structure, and trophic pathways. The central basin emerged as a region dominated by microbial processes: small phytoplankton and protists formed dense populations that supported large numbers of small copepods. This community structure suggests a longer, microbially mediated food chain , with much of the primary production recycled within the plankton before reaching higher trophic levels. Such systems can sustain high zooplankton abundance, but they typically transfer energy less efficiently to fish larvae and pelagic predators.

In contrast, the Norwegian Trench represented a shorter and more efficient food chain , driven by the presence of large chain-forming diatoms and correspondingly larger mesozooplankton. These areas, though lower in total biomass, concentrate high-quality prey for early fish life stages and may act as important recruitment zones. The co-occurrence of large-bodied zooplankton with elevated diatom biomass indicates a more direct coupling between primary and secondary production, allowing rapid energy transfer to higher trophic levels.

The survey also highlights the critical influence of physical forcing—such as water mass boundaries, nutrient supply routes, and stratification—on plankton community composition. Atlantic inflows shaped microbial grazer distributions, while local hydrodynamics structured light and nutrient conditions that governed the spatial mosaic of phytoplankton and zooplankton communities.

From an ecosystem perspective, these findings underscore the importance of maintaining long-term, size-structured monitoring. Shifts in the balance between microbially dominated regions and diatom-based food webs will have direct consequences for fish recruitment, carbon export, and overall trophic efficiency in the North Sea. The 2025 cruise provides essential context for detecting such changes and for understanding how physical variability and climate-related shifts propagate through the ecosystem.

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