Stressor cruise
27th April - 12th of May 2019

Edited by Sünnje L. Basedow

1. Aim and background

This was the first cruise of the Norwegian-Chinese collaborative effort to better understand how mesoscale physical, biogeochemical and biological processes are coupled in two contrasting shelf-slope-ocean ecosystems, as part of the Stressor project (2019-2021, financed jointly by the Norwegian Research Council and the National Natural Science Foundation of China). This year, we went to the shelf break area in the northern Norwegian Sea, outside the Lofoten-Vesterålen islands. This area was chosen firstly because it is known to be an area of high eddy activity, and secondly because very large surface aggregations of the copepod *Calanus finmarchicus* were observed here during previous research cruises. During our cruise we deployed two autonomous platforms, a Sailbuoy equipped with broadband acoustics, and a SeaGlider equipped with CTD and hydrophone, amongst other things. The gliders were partly financed and operated in cooperation with the Glider project (lead by Akvaplan-niva, financed by Conoco Phillips). These platforms surveyed our study area until the end of May, i.e. for about one month. In addition, our cruise was supported by satellite data, which were used to locate red surface patches of *Calanus* spp. (in cooperation with NEODAAS, U.K.), and to derive altimetry data for the modelling of Lagrangian Coherent Structures (in cooperation with the Chinese Academy of Sciences). By this extensive sampling we aim to determine how mesoscale processes and copepod behaviour interact to form these tremendously large surface aggregations. For public outreach, three artists joined the cruise, and we took pupils and teachers for sampling in Austnesfjorden for one day, in cooperation with Aust-Lofoten secondary school and the Northern Norwegian Artist Center.

2. Cruise Participants

Name	Main role during cruise	E-mail
1. Sünnje Basedow	cruise leader, MVP-LOPC	sunnje.basedow@uit.no
2. Stig Falk-Petersen	Multinet, pelagic trawl	stig.falk.petersen@akvaplan.niva.no
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6. Yisen Zhong	ADCP, LADCP	yisen.zhong@sjtu.edu.cn
7. Hans Dybvik	engineer, MVP, gliders	hans.dybvik@uit.no
8. John-Terje Eilertsen	engineer, MVP, gliders	john-terje.eilertsen@uit.no
9. Walker Smith*	Chlorophyll, nutrients	wos@vims.edu
10. Yonghui Gao	Flow-Through System	ygao80@sjtu.edu.cn
11. Kim Last	WP2 *Calanus* experiments	kim.last@sams.ac.uk
12. Jordan Grigor	WP2, *Calanus* experiments	jordan.grigor@sams.ac.uk
13. Hailong Liu	CTD	liuhailong@gmail.com
14. Rui Meng	Chlorophyll	mengrui0101@163.com
15. Sofia Aniceto	Whale observation	ana.s.aniceto@uit.no
16. Huizi Dong	LCS data	huizidong@sjtu.edu.cn
17. Ziquiang Su	LADCP, EK60	zhiqiangsu_sjtu@sjtu.edu.cn
18. Congwen Shan	LISST	shancongwen320@sjtu.edu.cn
19. Mathilde Servan	WP2, pigments	servanmathilde7@gmail.com
20. Paulina Urban*	eDNA	paulina.urban@mail.de
21. Guillaume Schuler	Multinet, pelagic trawl	schulergg@gmail.com
22. Yuan Yu	Flow-Through System	yuy1110@163.com
23. Michaela Casková	Blog, artist	eseleim@seznam.cz
24. Toril Johannessen**	Artist	toril.johannessen@gmail.com
25. Anna Naumann*	Artist	anna.i.naumann@gmail.com

*until 6th May **from 6th May

3. Study area

The Lofoten-Vesterålen marine ecosystem is extremely rich in biodiversity and is a key area for commercially and ecologically very important fish species (cod, herring). Many of the most vulnerable life stages are concentrated in this area, and it is an important breeding area for many seabirds. Also high numbers of marine mammals are observed here, and a system of cold water corals is found. Therefore the area has been designated as one of the seven 'especially valuable and vulnerable areas' by the Norwegian government. The high productivity is due the frontal system between the North Atlantic Current that flows along the shelf break and meets with the Norwegian Coastal current that flows along the coast. Off Lofoten-Vesterålen the shelf break is narrow such that the frontal system is found close to the coast. The area is also characterised by a high eddy activity. Deeper channels in the area can bring Atlantic Water and species closer to the coast, which is probably an important factor of replenishing the population of *Calanus finmarchicus* in Vestfjorden during winter. Cod eggs spawned inside Vestfjorden and developing larvae are eventually transported out of the fjord system and drift northwards into the Barents Sea with the prevailing currents. They feed mainly on nauplii of *C. finmarchicus* and are thus dependent on a match in time and space with high abundances of nauplii and hence on a large overwintering stock of *C. finmarchicus*.

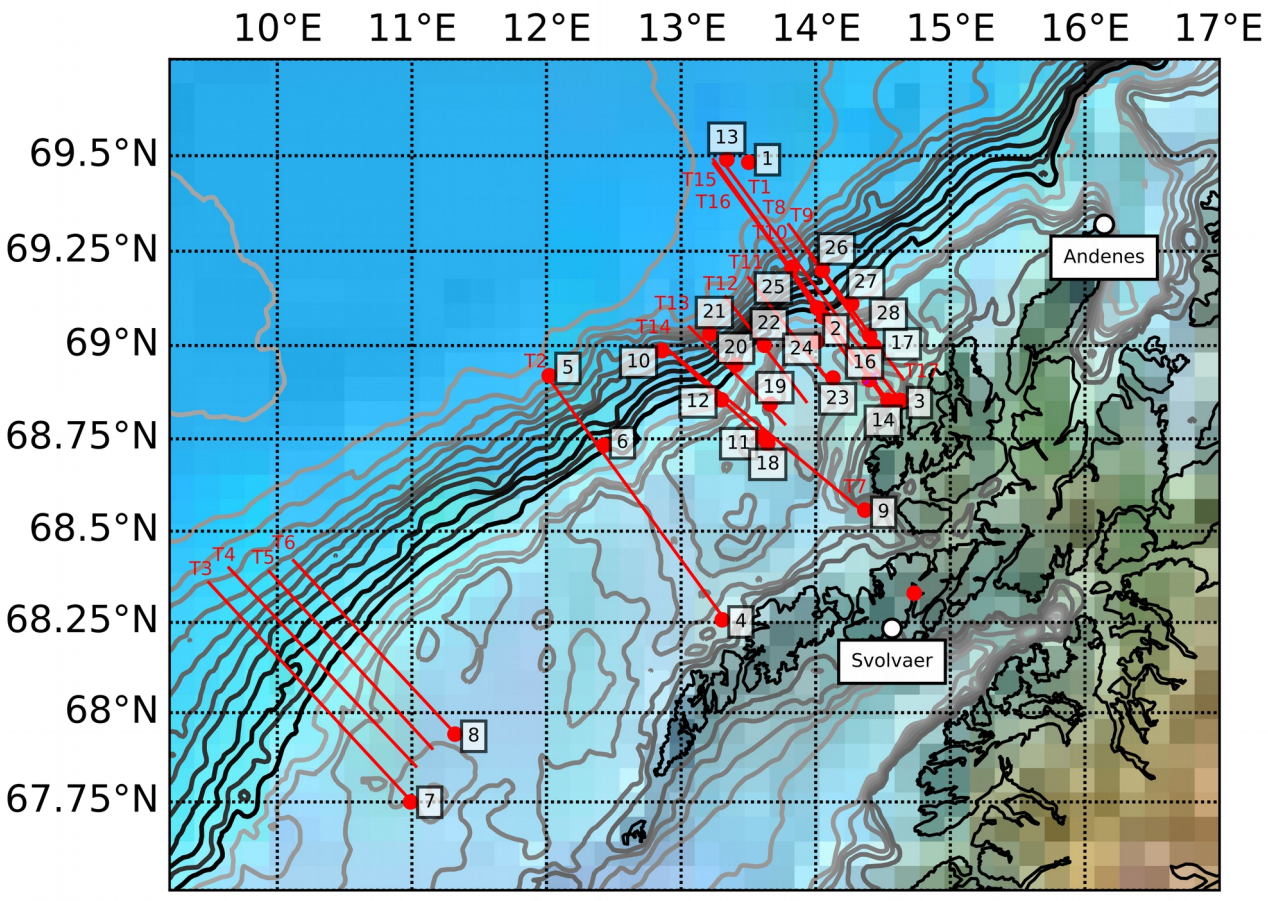


Fig. 1: Study area with sampled transects (T1-T17, red lines) and stations (St. 1 – St. 28, red dots).The red dot very close to station 2 is station 15. The red dot in the vicinity of Svolvær is our sampling station with the pupils, in Austnesfjorden.

4. Cruise narrative (all times UTC)

After cleaning the pipes of the seawater intake to inhibit bacterial growth, which would interfere with oxygen measurements of the underway flow-through system, we left Tromsø on **27 April** at 13:00 in calm and sunny weather, and arrived in our study area in the evening. At midnight we started sampling transect 1 (Fig. 1) with the MVP, from the coastal end towards the offshore end, through Hola canyon. A few problems with the MVP, hopefully nothing too bad. The transect was completed around 8 in the morning on **28 April**. We then set out the SeaGlider. which went very well, and sea conditions were really calm. After deploying the SeaGlider, we completed our first station (St. 1) at the offshore end of transect 1, then went back along the transect and sampled St. 2 in the middle of the line and St. 3 at the end, where there were high surface abundances of *C. finmarchcius*. St. 3 was completed around midnight of **29 April**.

While waiting for the first results from the LCS modelling and for satellite images, we sampled the canyon outside Vestvågøy island, starting with St. 4 at the coastal end, and then starting with transect 2 with the MVP. Lots of problems with the MVP, resulting from a broken cable. While detecting and luckily fixing the error, we sampled with the pelagic trawl (upper 30 m and at 105 m depth), and then completed transect 2, which was finished late evening. On **April 30** at midnight we sampled St. 5 at the offshore end of transect 2, and then St. 6 at the shelf break, also a pelagic trawl here. Weather was getting more windy.

Based on the LCS results we selected an area outside Røst island for further study, and placed four transects (T1-T4) such that eddies could be resolved (8 km apart, close to Rossby radius). Unfortunately, when we arrived in the area around 18:00, it was very windy, and the only instrument that could be deployed at St. 7 (coastal end of transect 3) was the CTD. With some difficulties due to rough seas, from the evening of the 30 April to midday **2 May**, we sampled the transects with the MVP, which went relatively well when using deployment mode 'continuous rpm' and we were able to complete all four transects. Weather conditions were still less than optimal, we could only deploy the CTD at St. 8 (coastal end of transect 6).

Because of the weather conditions we went to a wind-protected coastal station, St. 9, and started sampling there around 20:00 on 2 May. So far the coastal stations seemed to have the highest abundances of red copepods in the upper meter, somewhat contrasting satellite images that show red color at the shelf break. Afterwards weather conditions had improved somewhat. We sampled T7 from coast (St. 9) to offshore with the MVP, and then sampled three stations (St. 10 to St. 12) along the line. Locations of stations were selected based on physical features and copepod abundances as seen from the MVP data. This sampling was completed around midnight, finishing with a pelagic trawl.

For the remaining time before our trip to Svolvær for exchange of cruise participants, we decided to re-sample transect 1 (new sampling named transect 8) starting from the offshore end (St. 13) in the morning on **4 May** towards the coast (St. 14). We started sampling at the offshore end with a pelagic trawl, and sampling at the coastal end was finished in the morning of **5 May**. Based on the collected data along the transect we selected and sampled St. 15 and St. 16 along transect 8, finishing in the evening and then heading towards Svolvær through Raftsundet.

On **6 May**, three participants (Walker Smith, Pauline Urban and Anna Naumann) left the cruise in Svolvær. Most other cruise participants left the ship for half a day in Svolvær, apart from Sünnje Basedow, Kim Last and Mathilde Servan. In cooperation with the Northern Norwegian Artist Centre and with Aust-Lofoten Videregående Skole we then took a responsible from NNKS, and teachers and pupils from the school for basic sampling of nutrients, chlorophyll and zooplankton in Austnesfjorden. At 14:00 we delivered those back to Svolvær and picked up the cruise participants, plus one new artist (Toril Johannessen) and left around 16:00.

Based on data collected so far, and on satellite data and general considerations, we decided to sample a narrow part of the shelf break (T9 to T14) as a contrast to the wide part that was sampled earlier on (T3 to T6). We started sampling around midnight on May 6, with a station (St. 17) at the coastal end of T9 and then sampled parallel transects across the shelf break (T9 to T14) with the MVP. T10 was placed to re-sample part of T1/T8, and T14 re-sampled part of T7. This sampling was finished around midday on **May 8**. In that area we then sampled a large number of stations (St. 18 to St. 28) from **May 8 to May 10**, placed to cover varied conditions in abiotic and biotic factors. Weather conditions were favourable now.

We used the remaining cruise time to re-sample again T1/T8, from coast to offshore and return (T15/T16), and finalised by sampling T17 just to the north of it and including T9. Sampling was finished in the afternoon of **May 11**, and we then headed to Tromsø where we arrived in the morning.

5. Scientific program

5.1. Satellite ocean dynamics and LCS modelling

Huizi Dong (SJTU)

Aim

Combined with radar altimetry data, I want to understand the *C. finmarchicus* blooms from the perspective of the ocean physical process. Ocean surface geostrophic currents in our cruise region will be calculated using satellite sea surface height. Using Lagrangian coherent structure model to analyse the horizontal advection and variations during this cruise for 16 days. Under the background of coastal-open ocean Lagrangian latitudinal and longitudinal transport, we want to know how the *C. finmarchicus* moves during these days, and how they were influenced by ocean currents.

Methods: Lagrangian Coherent Structures (LCS) and FSLEs

The starting point of the Lagrangian Coherent Structures analysis presented in the remaining part of the work is: $\dot{x} = v(x, t)$, represents the trajectory of a particle seeded on the domain. In the equation, v is independent of t, we can find invariant manifolds. Backward-in-time FSLEs ridges approximate the so-called Lagrangian Coherent Structures (LCS) which are the generalization of stable hyperbolic trajectories of time independent flow. They are defined as the larger eigenvalues of the Cauchy-Green strain tensor of the flow map. FSLEs are strongly linked with the exponential rate λ of separation of two neighboring particles during a time advection t:

$$\Lambda(\boldsymbol{x}, \delta_0, \delta_f) = \frac{1}{|\tau|} \log\left(\frac{\delta_f}{\delta_0}\right)$$

The method was initiated by F. d'Ovidio (2004). LCS are widely used to characterize horizontal dynamics. Hyperbolic LCS are distinguished material lines that exert locally the strongest attraction and repulsion on nearby trajectories. Being material lines LCSs behave as transport barriers, not being crossed by tracers.

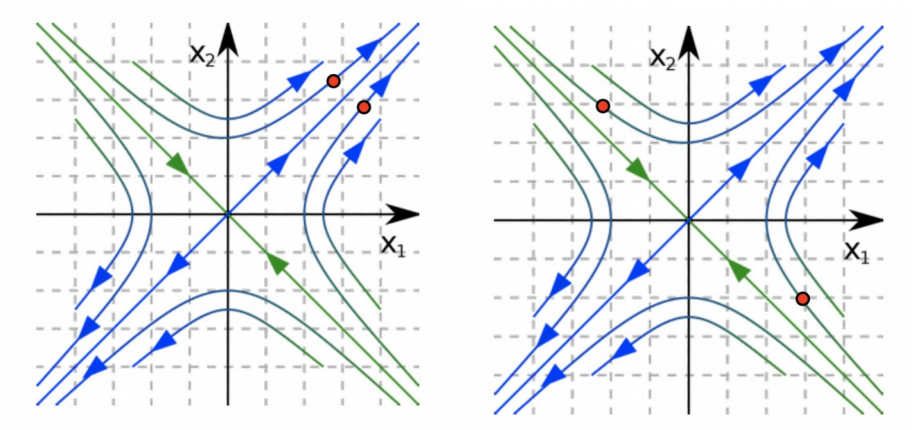


Fig. 2: LCS modelling

Preliminary results

Two relatively stable eddies can be found in the LCS results. One is on the shelf break region. Another one is located at 12°E 67°N or so, which may be induced by island. Our cruise transects T3- T6 were planned because of the fronts and relatively strong transports. From the latitude advection initial results, nutrients and primary production may be transported by cross slope transport during the bloom season.

From previous papers, the overwintering population migrates from the hibernation depth of > 500 m into surface waters along the shelf slope area in spring, and is then carried by the Norwegian Atlantic Current (NAC) and the Norwegian Coastal Current northward. Populations intrude onto the shelf and into coastal fjords by this mesoscale currents (Zhu et al. 2009). So during the bloom season, the horizontal moving of *C. finmarchicus* may be highly induced by cross slope mesoscale eddies and currents. These initial results need to be verified by further calculations.

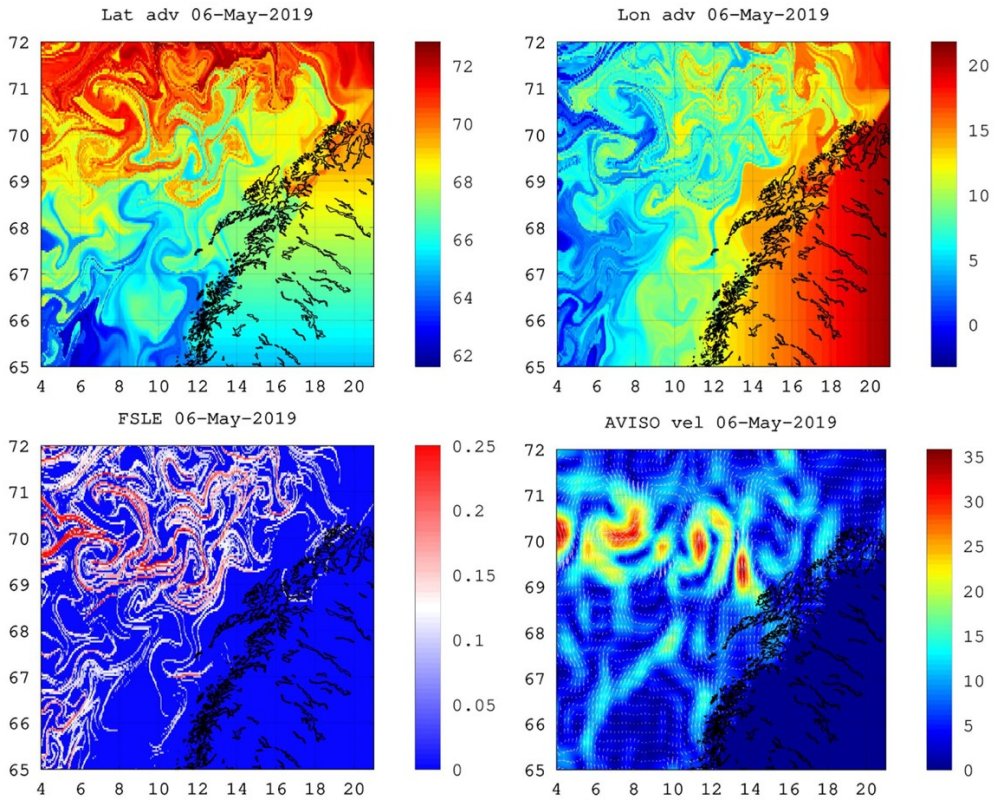


Fig. 3: LCS results from 6 May 2019

References
d'Ovidio F., V. Fernández, E. Hernández-García, C. López, 2004, “Mixing structures in the Mediterranean sea from Finite-Size Lyapunov Exponents”, Geophys. Res. Lett., 31, L17203.

Cotté C., F. d'Ovidio, A. Chaigneau, M. Lévy, I. Taupier-Letage, B. Mate, C. Guinet, 2011, "Scale dependant interactions of Mediterranean whales with marine dynamics", Lym. Ocean. 56(1), 219-232.

Zhu, Y., K.S. Tande, and M. Zhou, Mesoscale physical processes and zooplankton productivity in the northern Norwegian shelf region, Deep–Sea Research II, 56, 1922-1933, 2009.

5.2. Ocean current measurements

Yisen Zhong (SJTU)

5.2.1. Vessel-Mounted ADCP

A ship-mounted 75kHz RDI Ocean Surveyor ADCP was used to collect current data under the way. The ADCP recorded the data through the whole cruise path. The position and heading feed are from Seapath GPS and gyro. The basic parameters for ADCP setup included broadband mode for high resolution, 8 m bin size, 8 m blank distance, 100 layers, transducer angle -1.84 degree, salinity 34 psu, pinging triggered by EK60 to reduce the interference between the instruments. The ship draft is about 6.5 m. The drop keel where the ADCP is mounted was lowered by approximately 3.5 m at 16:15 on May 1, 2019 (UTC), in order to avoid the bubble layer due to the severe sea condition. The ADCP was restarted and the new data file starts from no. 35. The keel was lifted up at 17:45 on May 5 (UTC) and then lowered again at 12:31 on May 7 (UTC). These changes were not accompanied by changes of data file names. This needs to be taken into consideration when post-processing the data. The name of the ADCP data file is Stressor0XX_0000YY.ZZZ, where XX is deployment number from 29 to 36 in this cruise, YY is file sequence number and ZZZ is the file extension.

The preliminary processing of the ADCP data was conducted using CODAS during the cruise. The processing used LTA (300 s averaged) data files. The detailed single-pinging file (ENR) processing is left after the cruise. The tidal components were calculated using TPXO model and removed from the measured currents.

A total of 17 transects were planned to tow the MVP. The spacings between T3, 4, 5, 6 are around 8 km, approximately the Rossby deformation radius, which aims to investigating the mesoscale processes and their impacts on the biology in this region. The rest transects are located in a steeper slope region, where the current is much stronger.

Figures 4 and 5 show the currents at 30 m and 100 m depth respectively. The velocities are very similar at these two depths, indicating a vertically homogeneous flow in the shelf and the upper layer of the deep basin. In the T3-6 region, there are two branches of northeastward currents between 200 m and 1000 m isobaths (Figures 4 & 5 left panels). They merge into one stronger current when they arrive the steeper slope downstream, and then seemingly veer offshore with a much greater speed (Figure 4 & 5 right panels). The current on the shelf is to the opposite direction in the T3-6 region but is weak along T2 and T3 transects.

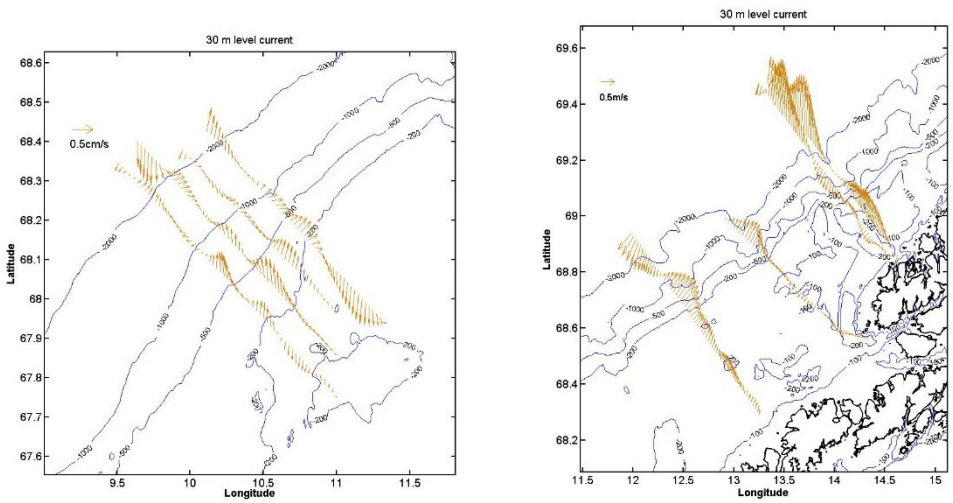


Fig. 4: The measured current at 30m depth along the transects

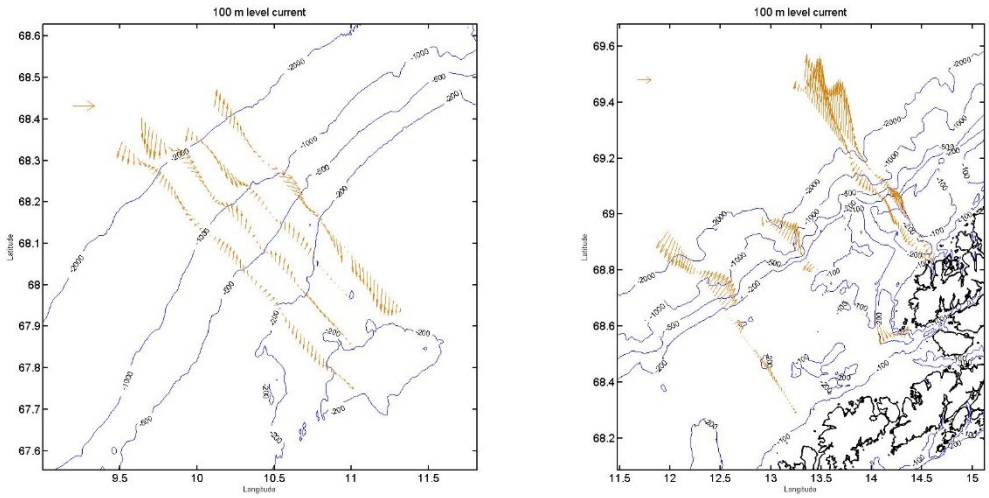


Fig. 5: The measured current at 100 m depth along the transects

Figures 6-13 show the across- and along-transect velocities at each transect. The currents are nearly barotropic in the upper 400 m at all transects. As presented above, currents with alternating direction can be seen at the T3-5 transects in the slope region, and finally they merge into one at the T6 transect. The slope current is more intense when the slope becomes steeper at the T2 transect.

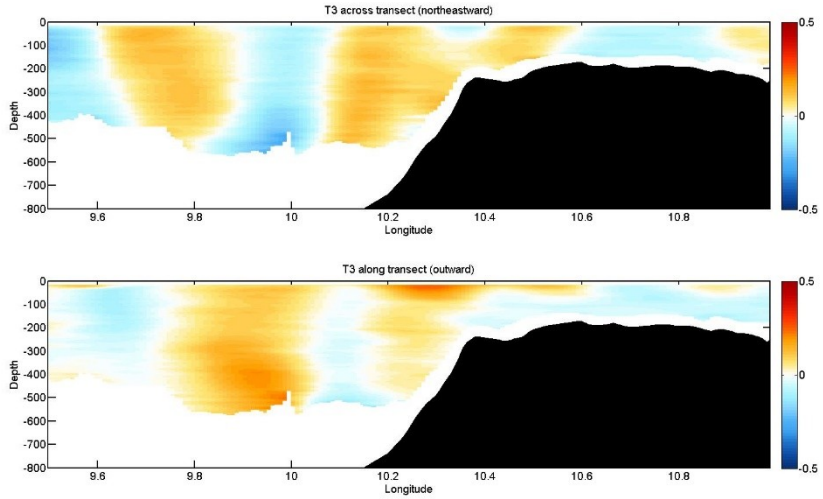


Figure 6: Across-transect velocity (top) and along-transect velocity (bottom) at Transect 3. Positive across-transect velocity indicates a northeastward direction. Positive along-transect indicates an offshore direction.

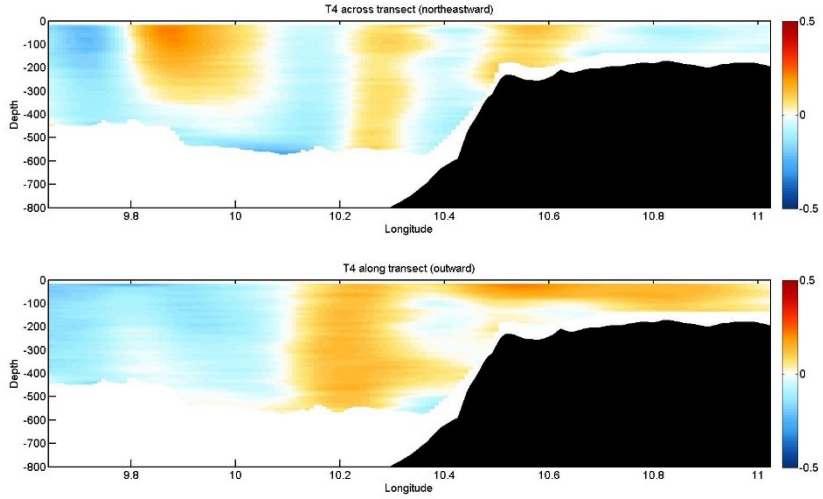


Figure 7: Same as Figure 6 but for Transect 4.

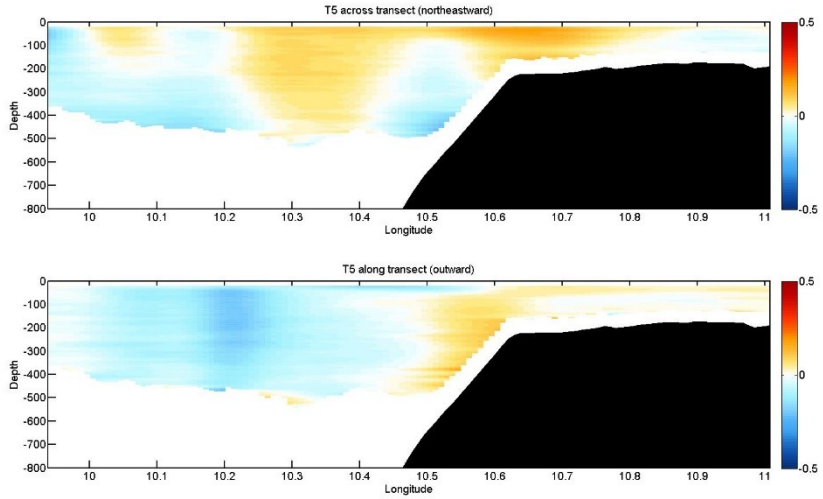


Fig. 8: Same as Figure 6 but for Transect 5.

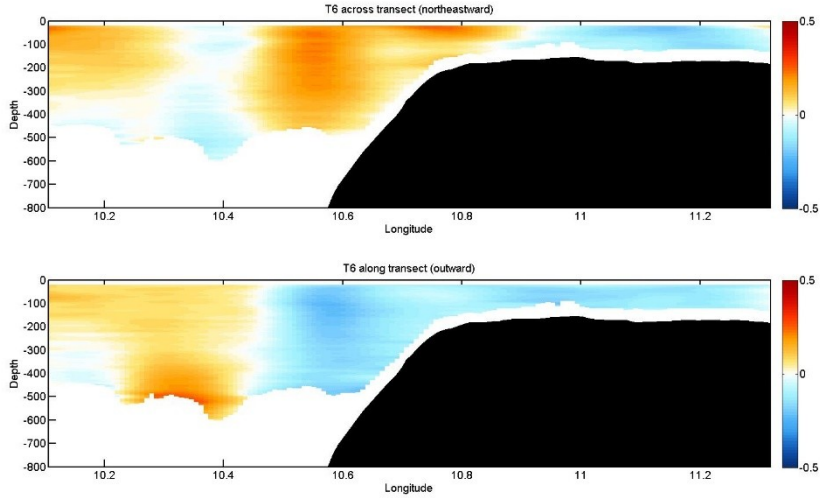


Fig. 9: Same as Figure 6 but for Transect 6.

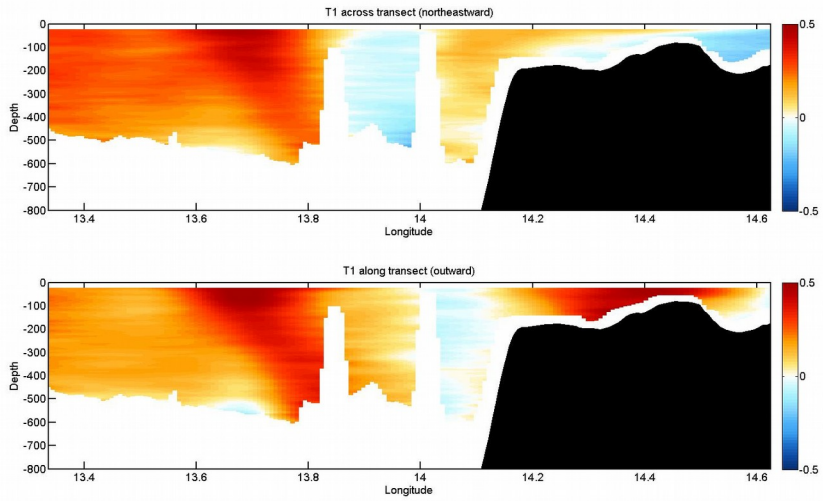


Fig. 10: Same as Figure 6 but for Transect 1.

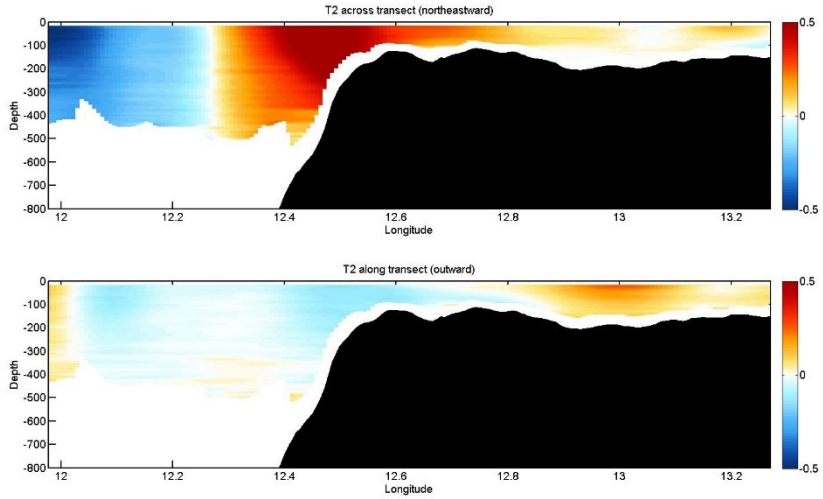


Fig. 11: Same as Figure 6 but for Transect 2.

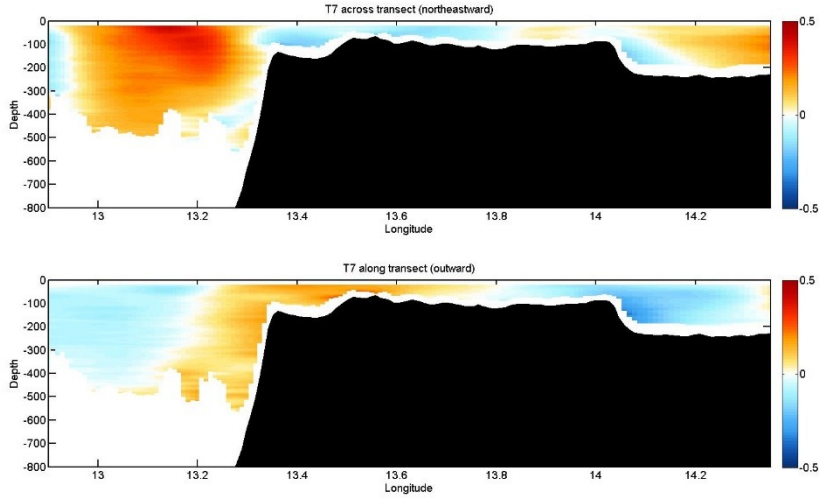


Fig. 12: Same as Figure 6 but for Transect 7.

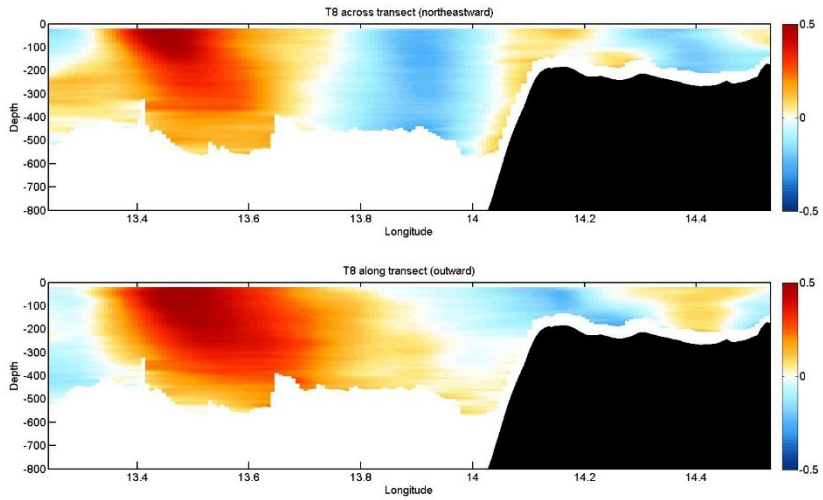


Fig. 13: Same as Figure 6but for Transect 8.

5.2.2. Lowered ADCP

A RDI 300 kHz Lowered ADCP was deployed together with the CTD. The data file is listed below.

Table 1: Overview over LADCP data files.

Station No.	File name	Notes
3	sta409_LADCPM.000.000	
3	sta409_LADCPM.001.000	Test data file
4	sta415_LADCPM.000.000	
5	sta426_LADCPM.000.000	
6	sta432_LADCPM.000.000	
8	sta443_LADCPM.000.000	
9	sta445_LADCPM.000.000	
10	sta460_LADCPM.000.000	
11	sta465_LADCPM.000.000	
12	sta470_LADCPM.000.000	
13	sta480_LADCPM.000.000	
14	sta485_LADCPM.000.000	
15	sta500_LADCPM.000.000	
16	sta502_LADCPM.000.000	
17	sta516_LADCPM.000.000	
18	sta522_LADCPM.000.000	
19	sta529_LADCPM.000.000	
20	sta530_LADCPM.000.000	
21	sta539_LADCPM.000.000	
22	sta544_LADCPM.000.000	
23	sta551_LADCPM.000.000	
24	sta552_LADCPM.000.000	
25	sta567_LADCPM.000.000	
26	sta568_LADCPM.000.000	
27	sta577_LADCPM.000.000	
28	sta581_LADCPM.000.000	

5.3. CTD-sampling & weather log

Sünnje Basedow (UiT)

CTD profiles were taken using the CTD onboard R/V Helmer Hanssen. The CTD consists of a Seabird Electronics (SBE) 911plus package with conductivity cell (SBE 4c, S/N 2666), temperature sensor (SBE 3plus, S/N 4497), pressure sensor (S/N 77984), dissolved oxygen (SBE 43, S/N 2557), a Seapoint fluorometer (S/N 3049) and turbidity meter (S/N 10894), and a Satlantic PAR sensor (S/N1060). All Seabird Electronics sensors were recently calibrated. The instruments were provided by UiT; details including maintenance calibration can be obtained from the UiT BFE technicians (John-Terje Eilertsen). The sensors are mounted on a rosette with 12 5l Niskin sampling bottles to collect water samples.

The CTD was controlled via the SBE Seasave software installed on a PC in the instrument room. GPS information (NMEA string) was added to the files automatically from the ship's Seapath positioning system. Surface irradiance was measured by a Biospherical/Licor PAR/irradiance sensor (S/N 6329) mounted on deck, and data was recorded together with the CTD profiles. Preliminary postprocessing was done after each cast using a SBE32 batch script written by the UiT technicians which calls the SBE data processing routines provided on the SBE website. Fine-calibration of the conductivity cell and final postprocessing will be done in Tromsø after the cruise.

28 stations were sampled with the CTD, an overview is given in Table 2. At most stations the CTD was deployed together with a LADCP, see section 5.2.2, Table 1. Salinity samples were taken at selected stations and depths (Table 2), and will be measured at UiT using an Guildline Portasal

salinometer for calbration of the conductivity cell. For other sampling from the Niskin bottles (nutrients, chlorophyll …) refer to later sections of this cruise report.

Table 2. CTD stations

Ship stn	Date DD/MM/YY	Start time UTC	Project station	Latitude (N)	Longitude (E)	Bottom depth (m)	Salinity sample depths (m)
392	28/04/19	09:14	St 1	69 28.61	13 20.41	2762	603
401	28/04/19	16:18	St 2	69 06.02	14 06.44	778	600
409	28/04/19	21:41	St 3	68 51.56	14 38.06	150	150
415	29/04/19	04:57	St 4	68 15.77	13 19.29	142	126
426	29/04/19	21:58	St 5	68 55.28	11 59.45	2704	600
432	30/04/19	03:42	St 6	68 44.07	12 23.92	739	600
441	30/04/19	17:58	St 7	67 44.83	10 59.92	226	217
443	02/05/19	10:45	St 8	67 58.47	11 19.16	185	175
445	02/05/19	20:06	St 9	68 33.05	14 21.75	224	211
460	03/05/19	12:26	St 10	68 59.28	12 54.93	1622	600
465	03/05/19	18:10	St 11	68 45.19	13 35.32	93	84
470	03/05/19	20:23	St 12	68 51.47	13 18.28	621	598
480	04/05/19	14:45	St 13	69 29.01	13 18.45	2772	600
485	05/05/19	05:25	St 14	68 51.02	14 32.54	175	166
500	05/05/19	12:34	St 15	69 05.57	13 58.51	725	600
502	05/05/19	16:27	St 16	68 54.54	14 23.86	266	250
516	06/05/19	23:55	St 17	69 00.44	14 25.84	86	76
522	08/05/19	12:00	St 18	68 44.26	13 38.61	85	75
529	08/05/19	15:40	St 19	68 50.59	13 39.69	108	95
530	08/05/19	17:07	St 20	68 56.93	13 24.33	765	601
539	09/05/19	01:07	St 21	69 01.88	13 12.73	2219	600
544	09/05/19	07:10	St 22	69 00.05	13 37.12	573	593
551	09/05/19	11:38	St 23	68 54.80	14 07.67	169	150
552	09/05/19	13:11	St 24	69 04.53	14 03.52	500	482
567	09/05/19	23:08	St 25	69 12.47	13 49.46	1750	601
568	10/05/19	00:31	St 26	69 11.99	14 02.96	1384	601
577	10/05/19	09:45	St 27	69 06.64	14 16.06	476	406
581	10/05/19	11:23	St 28	69 01.60	14 24.03	73	63

Weather log

Position, meteorological data from the DNMI weather station onboard (air temperature, air pressure, wind speed, wind direction, humidity) and depth from the EK60 echosounder were logged automatically every minute throughout the cruise.

5.4. Phytoplankton

5.4.1 Primary production and phytoplankton physiology

Yuan Yu (SJTU)

Aim

My work aims to find out the mechanism of how environmental factors will influence physiological status of phytoplankton and to figure out the component of phytoplankton community in Norwegian sea in this time period. These environmental factors include the variation of nutrients, predators and some physical factors, such as currents, sea water temperature, eddies and so on.

Method

Phyto-PAM, a multiple excitation wavelength phytoplankton photosynthesis analyzer was used to measure fluorescence of phytoplankton under different light conditions. Water samples were collected from CTD from different depth as well as underway water pump from ca. 5.5-meter depth along each transects. After 15 minutes dark adaption, we assume that all the reaction centers of PSII of

phytoplankton in water samples are closed. Then, a saturation pulse can excite its maximum quantum yield (F_V/F_M), which is an indicator of physiological status of phytoplankton. Actual quantum yield and non-photochemical quenching (NPQ), which indicated the potential ability of self-protection of phytoplankton were measured simultaneously. Phytoplankton photosynthesis fluorescence light curve (FLC) shows the fluorescence value of phytoplankton samples under gradient intensity of actinic light. So we can get α, E_k, I_{max} from each light curve, which indicate the ability of phytoplankton to adapt the variance of light during photosynthesis. E_k, α and I_{max} represent efficiency, maximum electron transport rate and saturating light intensity of phytoplankton, respectively. 81 records of fluorescence after dark adaption and 80 records of FLC were measured during this cruise.

Besides, 48 phytoplankton samples were fixed by Lugol's solution after filtering through a 150 μm mesh. These samples will be observed and calculated under microscope in order to figure out the component of phytoplankton community.

There were 305 filter samples collected, using 0.45μm pre-combusted GF/F filter. And primary production will be generally estimated by chlorophyll concentrations, using the following two equations (Harding, 2002):

$$\log PP(net) = 0.9460 + 0.6355 \log Chl\ a + 0.8611 \log tE_0 + 0.8133 \log Z_p + 0.2017 \log D_{irr} + 1.2638 \log SST + 0.5571 \log H$$

$$\log PP(gross) = 0.1619 + 0.7721 \log Chl\ a + 2.0344 \log tE_0 + 0.8115 \log Z_p + 0.0342 \log D_{irr} + 1.2817 \log SST$$

On May 7th, there were several transects run by the MVP. Along one of those transects, underway water was collected every 10 minutes (Table 3). Each sample was put in a dark bottle for 15 minutes in order to shut off all RC of PSII to get the maximum potential fluorescence of phytoplankton samples. Then samples were used to get F_V/F_M, NPQ and FLC, using PAM. Finally, physical, chemical and biological information along this transect will be analyzed comprehensively to figure out its interaction with each other.

Table 3. Samples collected 7th of May

No.	UTC time	Latitude	Longitude	No.	最高波长	F_V/F_M	No.LC
1	18:12:01	69,07.07	13,21.63	32	590	0.533	33
2	18:22:36	69,06.56	13,22.72	34	590	0.57	35
3	18:32:31	69,06.07	13,23.75	36	440	0.466	37
4	18:42:28	69,05.59	13,24.79	38	590	0.63	40
5	18:53:42	69,05.03	13,25.98	41	590	0.56	42
6	19:02:52	69,04.57	13,26.95	43	590	0.53	44
7	19:12:31	69,04.89	13,27.96	45	590	0.65	46
8	19:23:17	69,03.55	13,29.12	47	590	0.653	48
9	19:33:18	69,03.03	13,30.21	49	590	0.594	50
10	19:42:22	69,02.55	13,31.23	51	590	0.639	52
11	19:53:12	69,02.01	13,32.39	53	590	0.683	54
12	20:03:30	69,01.50	13,33.47	55	590	0.57	56
13	20:13:12	69,01.02	13,34.46	57	590	0.51	58
14	20:23:15	69,00.50	13,35.55	59	440	0.49	60
15	20:33:20	69,00.00	13,36.62	61	590	0.64	62
16	20:42:41	68,59,52	13,37.64	63	590	0.57	64
17	20:53:21	68,58.96	13,38.81	65	590	0.7	66
18	21:03:04	68,58.45	13,39.88	67	590	0.57	68
19	21:13:21	68,57.91	13,41.02	69	590	0.65	70
20	21:37:03	68,56.61	13,43.76	71	440	0.5	72

Table 4. Samples collected from different depth of 28 stations.

Date	UTC	St.	Latitude	Longitude	Depth	Amount	Nutrient	Fixed phytoplankton	PAM record No.
4.28	17:20	S2	69 06.01	14 06.44	5		Y	Y	1
					10		Y	Y	
					30		Y	Y	
	22:07 :06	S3	68 51.31	14 37.66	5	4	Y		
					10	4	Y		
					30	4	Y		
4.29	5:11: 56	S4	68 15.63	13 19.15	5.5	/	/	/	2324
					9.8	1	Y	Y	1718
					19.4	2	Y	Y	1920
					29.6	2	Y	Y	2122
		S5	68 54	11 56	5	3	Y	Y	56
					30	3	Y		78
4.30	4:50	S6	68 44.07	12 24.39	5.3	4	Y	Y	911
					9.3	4	Y	Y	78
					19.9	2	Y	Y	56
					29.6	4	Y	Y	34
	18:40	S7	67 46.91	10 55.20	5	3	Y	Y	1819
					10	3	Y	Y	2021
					30	3	Y	Y	2324
5.2	11:04 :27	S8	67 56.53	11 19.03	5	2	Y	Y	1314
					10	3	Y	Y	567
					30	2	Y	Y	1112
					75	3	Y	Y	8910
	20:29 :33	S9	68 32.83	14 21.43	5.2	2	Y	/	2122
					10.9	2	Y	/	1920
					20.5	2	Y	Y	1718
					40.4	2	Y	/	1516
5.3	12:41 :21	S10	68 59.24	12 55.11	4.3	4	Y	Y	89
					10.5	4	Y	Y	1011
					20	2	Y	Y	1213
					49.8	3	Y	/	1415
	18:22 :46	S11	68 45.17	13 35.14	5.1	2	Y	/	/
					10	2	Y	/	2223
					30	2	Y	/	2021
					40	4	Y	Y	1819
	21:00 :00	S12	68 51.64	13 17.73	5	4	Y	/	3536
					10	4	Y	Y	3334
					30	4	Y	Y	2930
					50	4	Y	/	2728
5.4	15:02 :30	S13	69 28.49	13,17.20	4.1	4	Y	/	34
					10.8	4	Y	/	910
					21.5	4	Y	Y	78
					40.8	4	Y	/	56
5.5	6:02: 38	S14	68 50.97	14 32.58	5.8	2	Y	/	34
					10.2	2	Y	/	56
					19.9	2	Y	Y	78
					30.2	3	Y	/	910
	13:27 :55	S15	69 05.56	13 56.57	6.6	4	Y	/	1314
					9.7	4	Y	/	1516
					20	4	Y	/	1718
					30	4	Y	Y	1920
5.6	16:34 :12	S16	68 54.86	14 22.78	5		Y	/	282930
					10	4	Y	Y	2122
					41	4	Y	/	2627

					49	4	Y	/	2324
5.7	0:05	S17	69 00.62	14 26.02	4.7	2	Y	Y	89
					10.4	2	Y	/	67
					20.4	3	Y	/	45
					30.3	2	Y	/	123
5.8	9:34:17	S18	68 44.28	13 38.43	4.6	2	Y	/	34
					11.1	2	Y	/	567
					20.5	2	Y	/	1011
					30.2	2	Y	/	89
	15:48:13	S19	68 50.62	13 39.61	5.5	2	Y	/	1819
					10.5	2	Y	/	1617
					29.6	2	Y	Y	1514
					39.4	2	Y	/	1312
	17:05	S20	68 57.06	13 24.08	4	2	Y	/	2021
					12.6	2	Y	/	2223
					29.5	2	Y	Y	2425
					100	2	Y	Y	/
5.9	0:43:03	S21	69 01.89	13 12.58	3.4	2	Y	Y	910
					5.8	/	/	/	12
					10	4	Y	/	/
					20.9	4	Y	/	78
					31.1	/	/	/	34
					41.1	/	/	/	56
	7:46:14	S22	69 00.36	13 37.08	3.4	/	/	/	1112
					4.5	2	Y	/	2324
					10.7	2	Y	/	2122
					20.9	/	/	/	1314
					40.4	3	Y	/	1920
					51.4	/	/	/	1718
					74.6	4	Y	Y	1516
	11:54:51	S23	68 54.87	14 08.00	3.6	/	/	/	2526
					5.8	2	Y	/	3738
					11.5	2	Y	/	3536
					19.9	2	Y	/	3334
					30.6	3	Y	Y	3132
					40.8	/	/	/	2930
					50.2	/	/	/	2728
	14:06:26	S24	69 04.28	14 03.70	5	2	Y	/	4546
					10.6	/	/	/	3940
					20.4	2	Y	Y	4344
					30.4	/	/	/	4142
	23:30:48	S25	69 12.69	13 49.20	3.4	/	/	/	56
					5.3	2	Y	/	1112
					11.1	2	Y	/	/
					20.4	/	/	/	34
					29.9	2	Y	/	910
					39.4	2	Y	Y	78
					51	/	Y	/	12
5.10	10:24:50	S26	69 12.04	14 02.38	3.8	/	/	/	1314
					7	2	Y	/	1819
					10.4	/	/	/	1516
					20.2	2	Y	/	2021
					29.6	2	Y	/	2223
					39.5	2	Y	/	17
	10:11:26	S27	69 06.82	14 16.68	3.7	/	/	/	2425
					5.4	2	Y	/	3233
					10.3	1	Y	/	3031

					20.3	2	Y	Y	3536
					30.4	2	Y	/	/
					40.5	/	/	/	26272829
5.11	11:33 :56	S28	69 01.72	14 24.12	3.8	/	/	/	3940
					4.9	2			4748
					10.5	/	/	/	4142
					20.8	2	Y	Y	4950
					30.3	/	/	/	4344
					40.7	/	/	/	4546

5.4.2. Phytoplankton distribution and phytoplankton – grazer interactions

Walker Smith and Meng Rui (SJTU)

Aim

The objectives of the phytoplankton group were to understand the distributions of phytoplankton biomass over the continental shelf/slope system, and to analyze the physical-biological coupling in the region. We also want to understand the carbon dynamics within the phytoplankton-zooplankton interactions by estimating primary production and comparing it to crude assessments of zooplankton growth and ingestion.

Methods

The phytoplankton group from Shanghai Jiao Tong University conducted measurements on all CTD casts (n = 28, Table 2) conducted during the cruise. The variables measured included chlorophyll *a*, particulate organic carbon (POC) and nitrogen (PON), and biogenic silica (BSi). A total of 28 stations were completed, and generally ten depths were sampled at each station for each variable. All chlorophyll samples were frozen and will be analyzed at the University of Tromso, but POC/PON and BSi samples were dried at 60^{o}C and returned to SJTU for analysis. Sampling methodology for all three variables is well documented in the literature (e.g., JGOFS 1996; Smith et al. 2011a). Additional samples were taken to help other groups to understand the elemental fluxes of this unusual system (e.g., POC/PON samples of individual copepods, chlorophyll *a* samples to calibrate fluorescence measured by gliders and the moving vessel profiler).

A bio-optical model designed to predict phytoplankton primary production will be generated using the vertical temperature and chlorophyll distributions, known temperature-photosynthetic relationships, and the ambient incident irradiance (e.g., Behrenfeld and Falkowski 1997). As such, the primary production of the entire shelf-slope can be assessed and analyzed in conjunction not only with zooplankton distributions but physical processes occurring.

Results

While the samples will be analyzed after the cruise, a number of patterns of phytoplankton were discerned from the fluorescence and plankton composition. For example, phytoplankton biomass as determined from fluorescence and chlorophyll was greater in waters off the continental shelf when compared to that on the continental shelf. This suggests that the canonical “spring bloom” had occurred earlier in the season (prior to the cruise) on the shelf, likely due to enhanced stratification induced by freshwater inputs from land. Second, the waters off the shelf appeared to be diatoms, whereas patches of the haptophyte *Phaeocystis* sp. were found on the shelf. Understanding the relationship of copepods and other zooplankton to phytoplankton composition will require further analysis.

References

JGOFS, 1996. Protocols for the Joint Global Ocean Flux Study (JGOFS) core measurements, IOC SCOR Rpt. 19, Bergen, Norway.

Smith, W.O. Jr., V. Asper, S. Tozzi, X. Liu and S.E. Stammerjohn. 2011a. Surface layer variability in the Ross Sea, Antarctica as assessed by in situ fluorescence measurements. Prog. Oceanogr. 88: 28-45 (doi: 10.1016/j.pocean.2010.08.002).

Behrenfeld, M.J. and P.G. Falkowski. 1997. Photosynthetic rates derived from satellite-based chlorophyll concentration. Limnol. Oceanogr. 42: 1-20.

5.5. Satellite image support from NEODAAS

Sünnje Basedow (UiT)

Through cooperation with David McKee (University Strathclyde), the people at NEODAAS provided daily support of fully processed AVHRR-SST, MODIS and VIIRS CHLA, Kd490 and, not the least, RGB images, as well as weekly averages of VIIRS RGB, for the period 1st April to 28th May. These images were very useful in selecting lines for transects and stations, and for the cruise tracks of the Gliders. Unfortunately, cloud cover was pronounced at times. However, towards the end of the study period, clear skies were common.

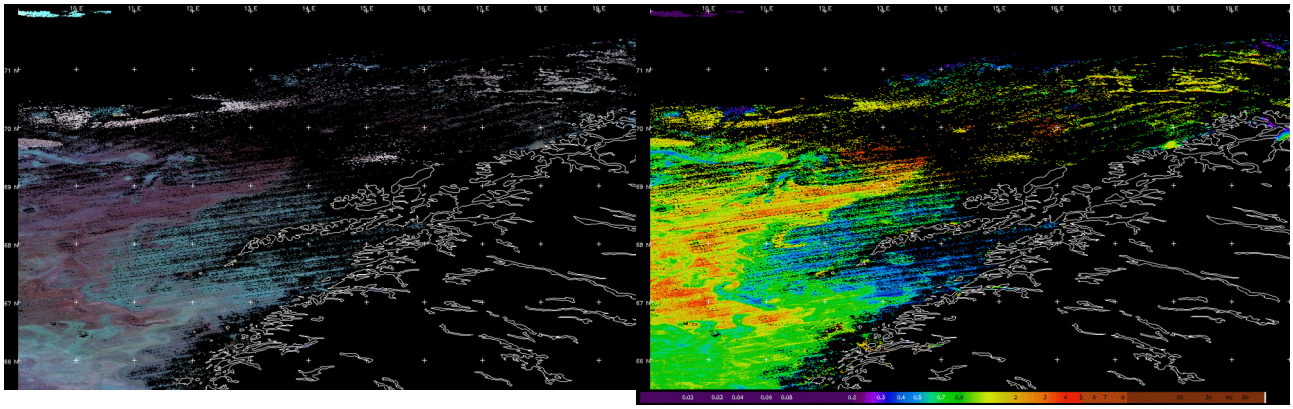


Fig. 14. Example of VIIRS RGB image (left) and VIIRS chlorophyll a image (right), for 28th April.

5.6. Size spectrum and distribution of plankton measured by LISST

Yiwu Zhu & Congwen Shan (SJTU)

Aim

Plankton community structures and abundances, their spatial distributions, temporal evolutions, and their correlations to the physical fields, are of critical information for understanding the response of the ecosystem to the environment pressure. We aim to obtain those information on shelf, slope, and oceanic regions of northern Norway to analyze distributions and population changes, provide plankton linkages between microbes and fishes, and to have a deep understanding on the plankton population dynamics in various ecosystems in changing environment.

Methods

A Laser In-Situ Scattering and Transmissometry (LISST, Sequoia Scientific) was mounted on a ringed frame and powered by a battery pack (Brooke Ocean). The LISST uses the light diffraction theory to measure sizes and volume concentration of small particles from 1 to 250 µm (Agrawal & Pottsmith, 2000, Karp-Boss et al. 2007). Together on the frame was a package of a Laser Optical Plankton Counter (LOPC), which measures the particle size from 100 µm to 35 mm, and a Seabird19plus CTD. This suite of instruments was deployed at stations for vertical casts. With 1 Hz sampling frequency and 32 size classes, the LISST provides high resolution measurements of plankton concentration on vertical and size distribution. A total of 26 LISST casts have been conducted during 14 days of the STRESSOR cruise (Table 5).

All data went through primary quality check and data processing. Size classed vertical profiles and size spectrum are calculated from the LISST raw data. Primary data analysis are done to compare the

size structure, the vertical distributions and abundances between slope, shelf and oceanic regions, and temporal evolution at the same location. The LISST data are also integrated into different depth intervals to see vertical variations of bio-volume concentrations.

Table 5: Overview over LISST profiles.

GMT=Local - 2

Date	Time(local)		Latitude	Longitude	Station	Code Op	LISST	Cast Depth	Bottom
	start	end	(N)	(E)			raw File	(m)	(m)
4/28/ 2019	14:28	15:02	69°28.93′	13°20.23′	1	400	L1531238	600	2762
4/28/ 2019	20:46	21:20	69°05.73′	14°06.85′	2	403	L1531232	600	727
4/29/ 2019	1:57	2:14	68°51.18′	14°37.85′	3	414	L1771905	151	142
4/29/ 2019	7:51	8:14	68°15.41′	13°18.02′	4	418	L1531340	140	148
4/30/ 2019	2:00	2:32	68°54.88′	12°00.64′	5	428	L1531232	600	2674
4/30/ 2019	8:31	8:59	68°43.96′	12°25.52′	6	436	L1531232	600	738
5/2/ 2019	23:13	23:48	68°34.43′	12°22.91′	9	450	L1531232	220	235
5/3/ 2019	16:51	17:25	68°59.18′	12°59.65′	10	463	L1531340	600	1595
5/3/ 2019	19:46	19:54	68°45.16′	13°35.60′	11	464	L1531232	90	96
5/3/ 2019	23:50	0:18	68°51.29′	13°17.97′	12	471	L1531234	520	572
5/4/ 2019	14:25	14:56	69°29.23′	13°19.57′	13	478	L1531234	600	2762
5/5/ 2019	8:55	9:24	68°51.21′	14°32.18′	14	487	L1531232	177	188
5/5/ 2019	13:05	13:33	69°6.013′	14°00.77′	15	498	L1531232	600	845
5/5/ 2019	19:53	20:18	68°54.86′	14°22.73′	16	504	L1531232 L1531252	255	265
5/7/ 2019	1:06	1:24	68°59.95′	14°26.08′	17	513	L1531232	75	86
5/8/ 2019	15:22	15:43	68°44.75′	13°37.23′	18	526	L1531238	80	90
5/8/ 2019	17:04	17:27	68°50.35′	13°40.04′	19	528	Li531234	90	102
5/8/ 2019	22:14	22:51	68°56.90′	13°23.93′	20	532	Li531232	600	785
5/9/ 2019	1:31		69°01.82′	13°12.09′	21	538	L1531234	600	2260
5/9/ 2019	10:36		69°00.31′	13°37.29′	22	545	L1531232	550	603
5/9/ 2019	12:50	13:13	69°54.64′	14°06.75′	23	547	L1531232 L1531234 L1531244	150	157
5/9/ 2019	16:28	13:13	69°04.434′	14°03.73′	24	547	L1531232 L1531234 L1531244	452	465
5/9/ 2019	23:40	0:11	69°11.57′	13°50.72′	25	561	L1531232	600	1673

5/10/ 2019	4:01	4:33	69°12.04′	14°01.70′	26	569	L1531232	600	1500
5/10/ 2019	10:42	11:10	69°06.10′	14°14.86′	27	574	L1531340	600	640
5/10/ 2019	14:22	14:45	69°22.44′	14°24.71′	28	582	L15313235	600	640

Preliminary results

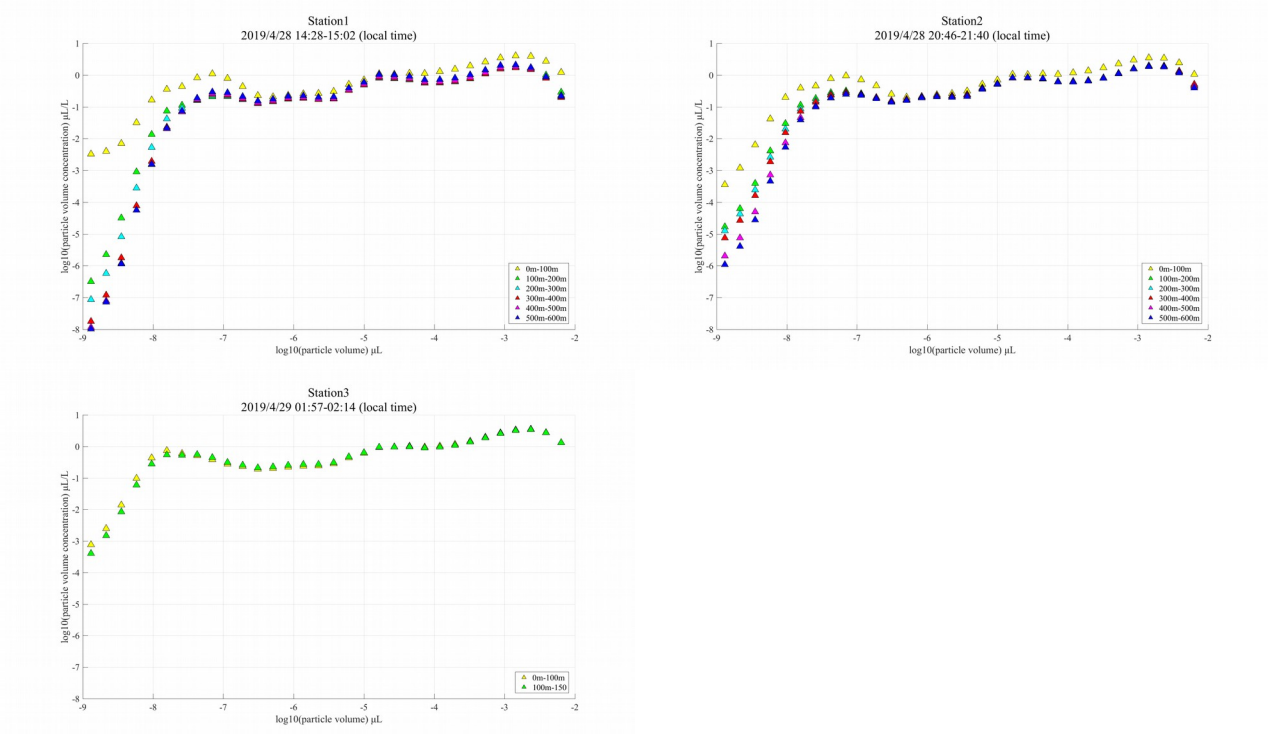
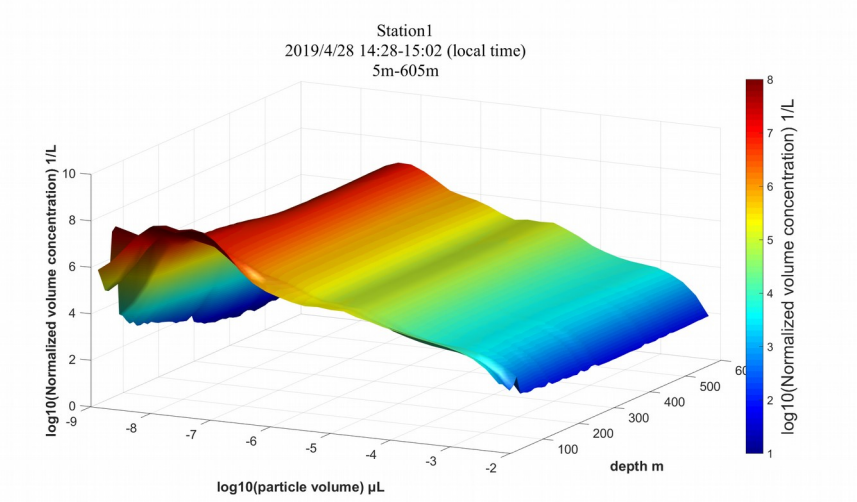


Fig. 15. Station 1, 2, and 3 represent oceanic, slope and shelf regions respectively.

The vertical structure of particle size distribution showed that smaller particles had higher volume concentration in oceanic region than on the shelf.

3D biomass spectrum from station 1, 2 and 3 also revealed variations of volume concentration on different sizes and depths for different regions.



The LISST data will be further analyzed with LOPC data and CTD data to study population dynamics over a larger range of the plankton community and to look at physical-biological coupled processes.

Fig. 16. 3D visualisation of LISST data from station 1.

5.7. Physical-biological measurements by MVP

Sünnje Basedow (UiT) & Zhaoru Zhang (SJTU)

Aim & Method

The aim of the project is to analyse biophysical interactions, to enable this we deployed a moving vessel profiler (MVP) equipped with a CTD (Micro CTD, Applied Microsystems Ltd.), fluorescence sensor (WET Labs FLRT Chl a fluorometer) and laser optical plankton counter (LOPC; ODIM-Brooke Ocean Rolls Royce Canada Ltd., Herman et al. 2004) to collect physical and biological data with the same, high spatio-temporal resolution. The instruments collected data with 2 Hz (LOPC) or higher frequencies, and were towed along 17 transects (Table 6). All data are stored, have been pre-processed and will be processed at UiT, in cooperation with SJTU. The fluorescence sensor will be calibrated against filtered chlorophyll, for which samples were collected by the phytoplankton group (SJTU) when the sensor was at the surface (see section 5.4.2).

Table 6. Deployments of the MVP

Transect ID	Start Date	Start Time	Start Lat	Start Lon	End Date	End Time	End Lat	End Lon
T1	27/04/19	21:59	68.85 N	14.63 E	28/04/19	05:55	69.47 N	13.34 E
T2	29/04/19	12:56	68.26 N	13.32 E	29/04/19	21:15	68.92 N	12.00 E
T3	30/04/19	18:32	67.75 N	11.00 E	01/05/19	05:02	68.36 N	9.49 E
T4	01/05/19	06:04	68.40 N	9.64 E	01/05/19	14:51	67.85 N	11.03 E
T5	01/05/19	15:43	67.90 N	11.15 E	02/05/19	0:09	68.58 N	9.94 E
T6	02/05/19	01:26	68.42 N	10.12 E	02/05/19	10:37	67.95 N	11.30 E
T7	02/05/19	22:43	68.56 N	14.33 E	03/05/19	08:30	68.99 N	12.90 E
T8	04/05/19	16:07	69.49 N	13.24 E	05/05/19	05:10	68.85 N	14.52 E
T9	07/05/19	00:46	69.00 N	14.42 E	07/05/19	04:55	69.26 N	13.92 E
T10	07/05/19	06:01	69.24 N	13.73 E	07/05/19	10:49	68.95 N	14.27 E
T11	07/05/19	11:52	68.90 N	14.11 E	07/05/19	16:34	69.18 N	13.50 E
T12	07/05/19	17:52	69.13 N	13.33 E	07/05/19	23:12	68.85 N	13.93 E
T13	08/05/19	01:19	68.79 N	13.77 E	08/05/19	05:05	69.05 N	13.06 E
T14	08/05/19	06:22	68.99 N	12.90 E	08/05/19	11:32	68.74 N	13.64 E
T15	10/05/19	14:26	68.87 N	14.50 E	10/05/19	23:25	69.48 N	13.24 E
T16	10/05/19	23:39	69.48 N	13.24 E	11/05/19	08:53	68.87 N	14.50 E
T17	11/05/19	09:42	68.91 N	14.65 E	11/05/19	15:53	69.32 N	13.80 E

Preliminary results

The common trend along all transects was the extension of relatively low saline coastal water in the upper layer, that stretched far offshore (Fig. 17, 18). Below, Atlantic Water dominated. The distribution of both chlorophyll a (from the fluorescence sensor) and zooplankton (from the laser optical plankton counter, particles with characteristics of *Calanus* CIV and older are shown below (Fig. 19), processed as in Basedow et al. 2013) was centered in the upper 100 m, but with large differences in concentrations/abundances along the transects. Fluorescence is not shown here, because the concentrations are off and meaningless before calibration against filtered chlorophyll.

References

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Herman, A.W., Beanlands, B., Phillips, E.F. (2004) The next generation of Optical Plankton Counter: the Laser-OPC. *J. Plankton Res*. 26, 1135-1145.

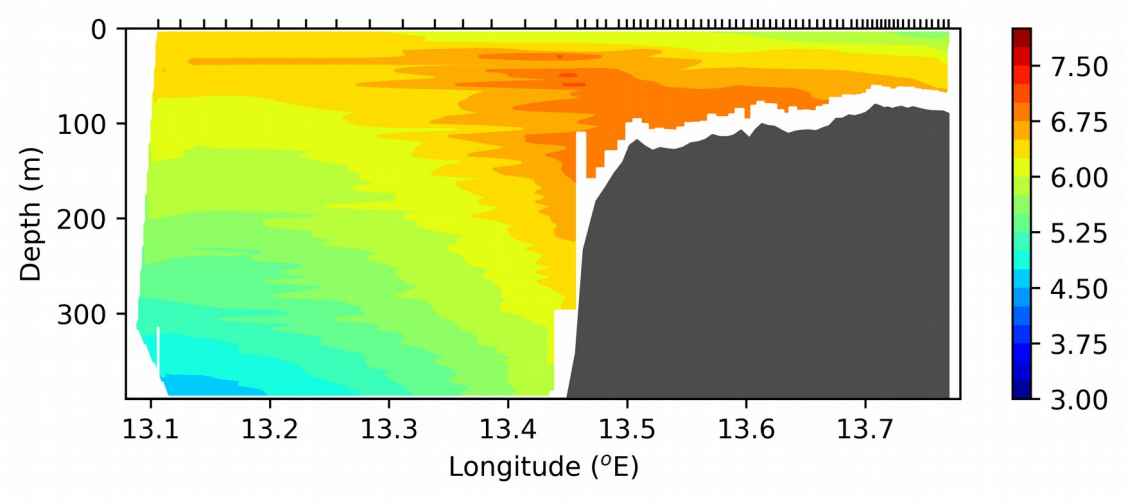

Fig. 17. Temperature along transect 13 with the warmest water at the shelf edge.

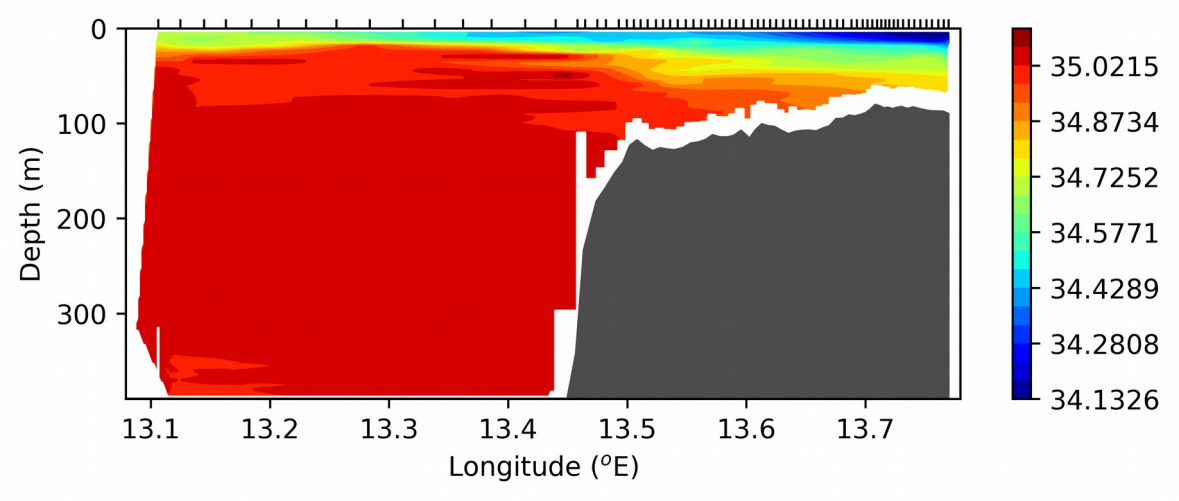

Fig. 18. Salinity along transect 13. Relatively fresh water in the upper tens of metres, and water with salinity characteristics of Atlantic water below.

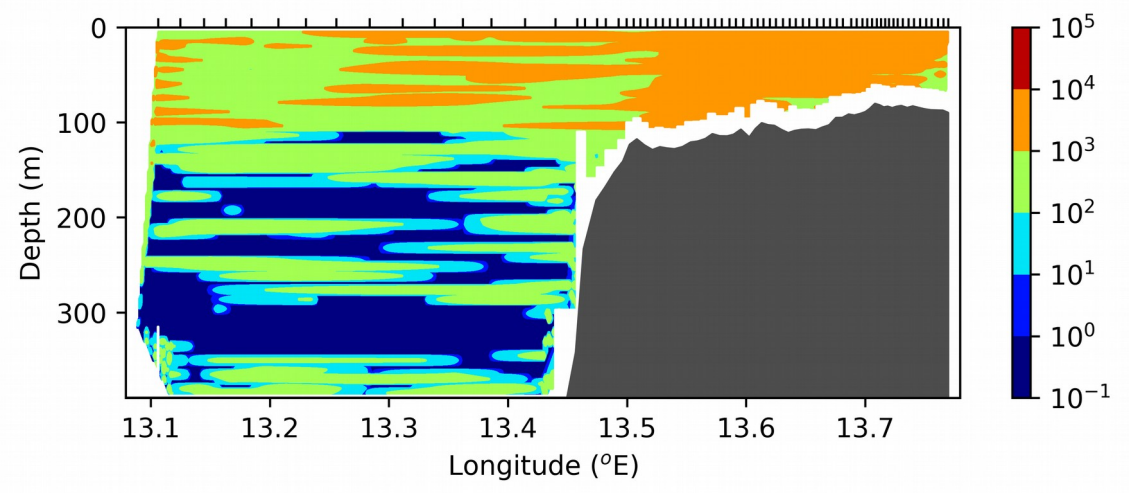

Fig. 19. Patches of older stages of C. finmarchicus. Few below 100 m, various abundances above.

5.7. Zooplankton

5.7.1. Multinet

Nicholas Weidberg (UiT)

A total of 123 samples, all preserved in 4% formaline buffered with hexamine, were taken all over the study area (Table 7). At stations 7, 8 and 19 no net could be deployed due to bad weather or because these were only CTD stations. At stations 12 and 18 the WP2 replaced the Multinet due to bad weather. 5 depths were always taken with the Multinet down to 600 when possible, usually off the shelf, while the on the shelf the deepest simple was taken 20-50 m above the bottom. With the WP2 three depths were sampled down to 100. Samples were taken back to UiT and will be analysed at IOPAS in Poland by Kasia Dmoch.

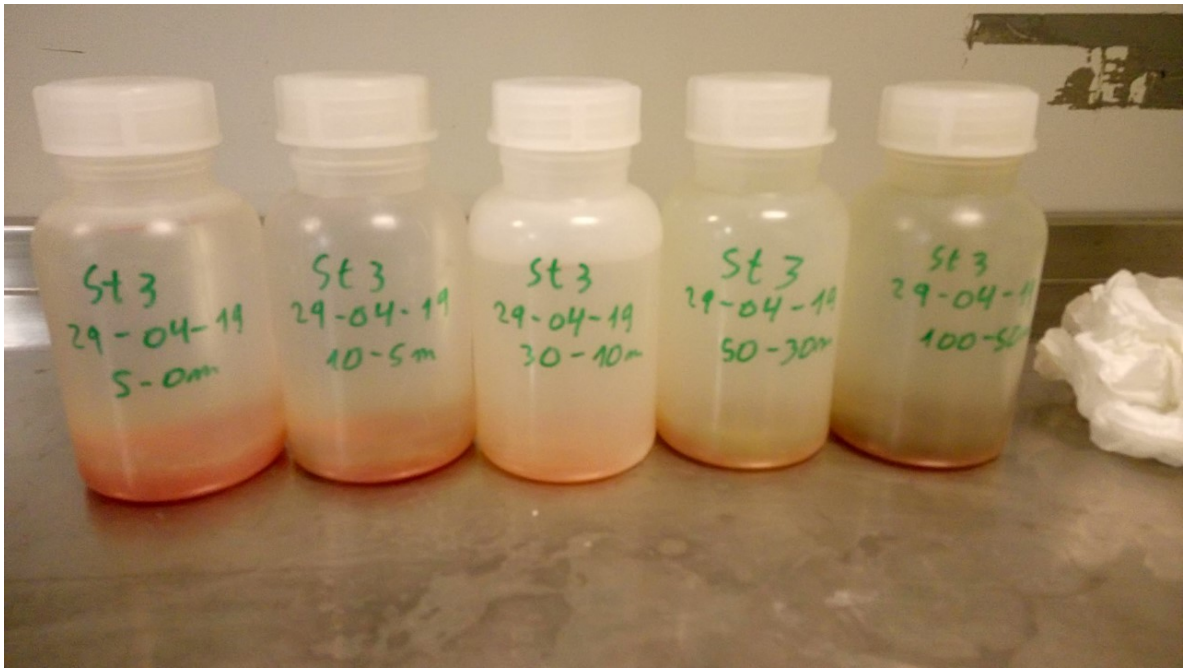

Fig. 20. Example of Station 3.

Table 7: Stations sampled by the Multinet

Station	Day	Depths	Remarks
1	28-04-2019	0-5-10-30-100-600	
2	28-04-2019	0-5-10-30-100-600	
3	29-04-2019	0-5-10-30-50-100	
4	29-04-2019	0-5-10-30-50-100	3 depths not to be trusted: codends 3, 4 and 5 broken and opened and had to be replaced
5	30-04-2019	0-5-10-30-100-600	
6	30-04-2019	0-5-10-30-100-600	
9	02-05-2019	0-5-10-30-100-180	
10	03-05-2019	0-5-10-30-100-600	
11	03-05-2019	0-5-10-30-50-65	
12	04-05-2019	0-10-30-100	WP2 used due to bad weather
13	04-05-2019	0-5-10-30-100-600	
14	05-05-2019	0-5-10-30-100-145	
15	05-05-2019	0-5-10-30-100-600	

16	05-05-2019	0-5-10-30-100-220	
17	07-05-2019	0-5-10-30-40-50	Codend for first depth (0-5) opened when the net was out of the water, according to crew, it might be trusted
18	08-05-2019	0-10-30-70	WP2 used instead due to bad weather
20	09-05-2019	0-5-10-30-100-490	
21	09-05-2019	0-5-10-30-100-600	
22	09-05-2019	0-5-10-30-100-490	
23	09-05-2019	0-5-10-30-50-100	
24	09-05-2019	0-5-10-30-100-480	
25	10-05-2019	0-5-10-30-100-600	
26	10-05-2019	0-5-10-30-100-600	
27	10-05-2019	0-5-10-30-100-490	
28	10-05-2019	0-5-10-30-40-50	One codend broke due to impact with the boat before getting into the water, it was replaced before deployment

5.7.2. CHASE project - Chronobiology in Arctic Sea Ecosystems

Kim Last & Jordan Grigor (SAMS)

Aim

Experiments were carried out to investigate the response of copepods to photoperiod and to determine changes in respiration rate and gene expression with season. Experiments were also carried out to investigate buoyancy control in copepods found in surface swarms.

Swimming behavior

We conducted on-board activity experiments on the swimming behavior of copepods in relation to species stage and day-length (photoperiod). All measurements were made on individual copepods using Trikinetics Locomotor Activity Monitors (LAMS). Activity measurements using the LAMS yield activity as a proxy for swimming, quantified as the number of beam breaks across the experimental chamber per specified unit of time. Activity screens were carried out with various ontogenetic stages of the copepod *Calanus finmarchicus.* All experimental runs and their conditions are annotated in Table 8.

Table 8: Summary of swimming behaviour experiments (note all animals collected with 200 um WP2 net). Total animals screened behaviorally: 626.

Station	Depth (m)	Experiment and photo. treatment	N	Species	Salinity (psu)	Temp (tinytag)	LAMS	UTC + 1hStart	UTC + 1hEnd	Notes
S1	100-40	LL Water 602m	32	*C. fin CV, AM, AF*	Check ctd	6.5	1	28/4/19 17:42	1/6/19 08:10	Images taken
S1	100-40	LD 18:6 (on: 03:00, off: 21:0) Water 602 m	64	*C. fin CV, AM, AF*	Check ctd	6.5	2+4	28/4/19 17:42	1/6/19 08:10	Lights on but v dim until 07:40 29/4/19
S1	100-40	LD 12:12 (on: 06:00, off: 18:00)	32	*C. fin CV, AM, AF*	Check ctd	6.5	3	28/4/19 17:42	1/6/19 08:10	Images taken
S1	100-40	LD 6:18 (on: 09:00, off: 15:00) Water 602m	32	*C. fin CV, AM, AF*	Check ctd	6.5	5	28/4/19 17:42	1/6/19 08:10	Images taken

S1	100-40	DD Water 602m	32	*C. fin CV, AM, AF*	Check ctd	6.5	9	28/4/19 17:42	1/6/19 08:10	Images taken
S2	100-40	Stacked LAM DD Water 50-0	31	*C. fin CV, AM, AF*	Check ctd	6.5	6 (top) 7 (bot.)	28/4/19 23:37	30/4/19 15:00	Images taken
S6	150-50 m	Stacked LAM DD Water 100-0 Stat. 3/4	31	*C. fin CV, AM, AF*	Check ctd	6.5	6 (top) 7 (bot.)	30/4/19 20:47	2/5/19 20:10	Images taken
S9	40-20	LL Water from S9 3m + bottom	32	*C.f.* CIII, CIV	33 (1-16) 35 (17-32) 1-8 CIII 9-16 CIV		1 + 3	3/5/19 11:30	5/5/19 ~17:00	Swarm Camera broken – animals discarded
S9	40-20	LD 18:6 Water from S9 3m + bottom	32	*C.f.* CIII, CIV	33 (1-16) 35 (17-32) 1-8 CIII 9-16 CIV		2 + 4	3/5/19 11:30	5/5/19 ~17:00	Swarm Camera broken – animals discarded
S9	40-20	DD Water from S9 3m + bottom	32	*C.f.* CIII, CIV	33 (1-16) 35 (17-32) 1-8 CIII 9-16 CIV		5 + 9	3/5/19 11:30	5/5/19 ~17:00	Swarm Camera broken – animals discarded
S9	40-20 m	Stacked LAM DD Water from S9 200m and 3m	31 + 11	*C.f.* CIII, CIV	33 (1-16) 35 (17-32) 1-8 CIII 9-16 CIV		6 (top) 7 (bot) 8 (top) 10 (bot)	3/5/19 01:00	5/5/19 ~18:00	Swarm. Data just noise from poor weather Animals not photo and discarded
S16	5-0 m	Stacked LAM	31 + 11	*C.f.* CV	33 (1-16) 35 (17-32)	6.5	6 (top) 7 (bot) 8 (top) 10 (bot)	6/5/19 00:30	6/5/19 After 22:30 data unusable	Set up right after collection and take advantage of being in port/shelter for 24 hours Animals not photo and discarded
S16	5-0 m	LL Water 7m	32	*C. fin CV*	33	6.5	1+2	7/5/19 23:07	11/9/19 11:30	Buoyancy test on all animals prior to exp.
6	5-0 m	LD 18:6 (on: 03:00, off: 21:0) Water 7m	64	*C. fin CV*	33	6.5	4+10	7/5/19 23:07	11/9/19 11:30	Buoyancy test on all animals prior to exp.
S16	5-0 m	LD 12:12 (on: 06:00, off: 18:00) Water 7m	32	*C. fin CV*	33	6.5	5+6	7/5/19 23:07	11/9/1111:30	Buoyancy test on all animals prior to exp.
S16	5-0 m	LD 6:18 (on: 09:00, off: 15:00) Water 7m	32	*C. fin CV*	33	6.5	7+8	7/5/19 23:07	11/9/19 11:30	Buoyancy test on all animals prior to exp.
S16	5-0 m	DD Water 7m	32	*C. fin CV*	33	6.5	3+9	7/5/19 23:07	11/9/19 11:30	Buoyancy test on all animals prior to exp.

Preliminary analysis of animals collected from station S1 reveal marked differences in swimming activity between *C. finmarchicus* adult females and CV and in response to light treatment.

Lipid and genetic samples

Animals were also frozen for lipid analysis in order to understand the principle food source for these animals, summarized in Table 9.

Buoyancy experiments

Further experiments were carried out focusing on the dominant stages at this time of year (CIII, CIV and CV) especially in relation to the occurrence of copepod 'super swarms' in order to determine if loss of buoyancy control is a contributing factor in the occurrence of these animals at the sea surface. Copepods were anaesthetized and allowed to sink in a column tank (length: 500 mm, diameter: 50 mm) as shown in Figure 21.

Table 9: Animals collected for lipid analysis (note all animals collected with 200 µm WP2 net).
Individuals picked: 226

Stressor cruise station	**Lat/Long**	**Depth (m)**	**Stage**	**Sample No**	**Vial location**	**Notes**
S2		100 - 40	*C. f.* adult females	3x 10 ind. 3 vials	A1-A3	
S4		100 - 40	*C. f.* CV	3x 10 ind. 3 vials	A4-A6	
S6		150 - 50	*C. f.* CV	3x 10 ind. 3 vials	A7-A9	
S9		10 - 0	*C. f.* CIII	3x 30 ind. 3 vials	B1-B3	Swarm
S9		10 - 0	*C. f.* CIV	3x 30 ind. 3 vials	B4-B6	Swarm
S9		10 - 0	*C. f.* CV	3x 10 ind. 3 vials	B7-B9	Swarm
S9		10 - 0	Community sample	1	1	Swarm
S10	68 59.34N 12 54.52E	50 - 5	*C. f.* CIII	3x 10 ind. 3 vials	C1-C3	
S10	68 59.34N 12 54.52E	50 - 5	*C. f.* CIV	3x 10 ind. 3 vials	C4-C6	
S11		10 - 0	*C. f.* CV	3x 10 ind. 3 vials	C7-C9	
S11		10 - 0	Community sample	2	2	
S14		40 - 20	*C. f.* CV	3x 10 ind. 3 vials	D1-D3	
S14		40 - 20	Community sample	3	3	
S16		5 - 0	*C. f.* CV	3x 10 ind. 3 vials	D4-D6	Swarm
S16		5 - 0	Community sample	4	4	Swarm
S17		20 - 0	*C.f.* CV	3x 10 ind. 3 vials	D7-D9	Swarm
S17		20 – 0	*C.f.* CIV	3x 12 ind. 3 vials	E1-E3	Swarm
S17		20 - 0	Community sample	5	5	Swarm
S25		250 - 150	*C.f.* CV	3x 10 ind. 3 vials	E4-E6	
S25		250 - 150	Community sample	6	6	
S27	69 06.37N 14 15.43E	50 – 0	*C.f.* CV	3x 10 ind. 3 vials	E7-E9	
S27	69 06.37N 14 15.43E	150 – 50	*C.f.* CV	3x 10 ind. 3 vials	F1-F3	
S27	69 06.37N 14 15.43E	50 – 0	Community sample	7	7	Swarm
S27	69 06.37N 14 15.43E	150 – 50	Community sample	8	8	Swarm

Table 10: summary of samples collected for seasonal gene expression analysis

Stressor cruise station	**Lat/Long**	**Depth (m)**	**Time (UTC)**
S10	68 59.34N 12 54.52E	50-0	12:00
S10	68 59.34N 12 54.52E	150-50	12:09
S15	69 05.25N 14.01.74E	150-50	10:17
S15	69 05.25N 14.01.74E	50-0	10:36
S27	69 06.37N 14 15.43E	150-50	09:11
S27	69 06.37N 14 15.43E	50-0	0939

Preliminary results reveal that all stages are negatively buoyant at the range of salinity and temperature found in their habitat and a working hypothesis is that behavior, not hydrography, result in the animals swarming near the ocean surface. Sinking rate was higher at the lower salinity, especially in stages CIV and CV. This difference between stages was not apparent at the higher salinity, with overall sinking decreased especially at the CIV and CV stages compared to the lower salinity treatment. The effect of temperature on buoyancy was not apparent.

Gene expression

Community samples were also collected for seasonal gene expression analysis where cruise plan allowed for a near midday net stratified between deep (150 – 50 m) and shallow (50-0 m) as summarized in Table 10.

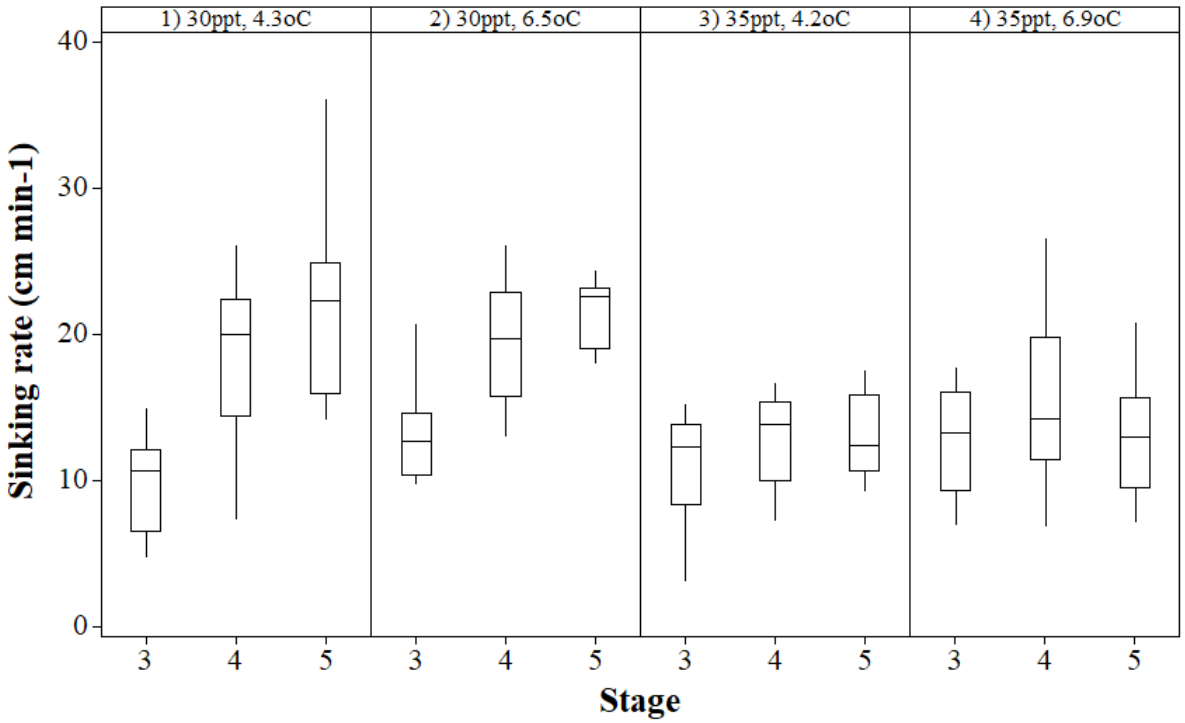

Fig. 21: Sinking rate of anaesthetized copepod stages (CIII, CIV and CV) at two salinities (30 ppt and 35 ppt) and two temperatures (4.3C and 6.9C).

Respiration

We conducted oxygen consumption experiments to provide a physiological correlate to rhythmic activity measurements made on copepods from the same field collections. All measurements were made on individual copepods using a 24-well Loligo microplate respirometry system. Experimental runs are annotated in Table 11. Temperature was 6.5 ºC and salinity treatments varied between 34-35 psu, barometric pressure at the start of each run is noted. After each run, species and stage of individual copepods was confirmed, each was photographed for later measurement of prosome length and area (to be converted to dry weight) and lipid sac volume (where applicable). Failure of camera system on the Oxygen consumption data will be processed to calculate respiration rates and critical partial pressures (Pcrit). These values will be compared among stations, species, stage, sex, energetic status as measured by lipid reserves, and time of day to test whether respiration rates reflect periods of increased activity observed in the LAM experiments.

Table 11: Summary of respiration experiments (note all animals collected with 200 um WP2 net). Total animals respiration: 180

Species	Depth	(event No)Station	Run Start (UTC +1)	Run stop (UTC+2)	(µl)Well size	Pressure (hPa)	Temp / Sal	Control	File name
C.f. CV, AF, AM	100 - 40	S1	29/4/19 16:41	30/4/19 07:53	500	1025	7 / 34	A1-D1	File: AF_CV_29042019_1639_S1 Image: yes
C.f. CV, AF, AM	50 - 0	S6	30/4/19 14:10	30/4/19 20:00	500	1018	7 / 35	A1-D1	File: AF_AM_CV_30042019_1409_S6 Image: yes
C.f. CV, AF, AM	150 - 50	S6	30/4/19 22:28	1/5/19 07:37	500	1013	6.5 / 34	A1-D1	File: AF_AM_CV_30042019_2228_S6 Image: yes
C. f. CIII + CIV	10 - 0	S9	3/5/19 00:40	3/5/19 13:55	500	1004	6.3 / 33_35	A1-D1	CIII: A2_A6, C2_C6 (33, 35 psu) CIV: B2_B6, D2_D6 (33, 35 psu) File: C3_C4_03052019_0037_S9 Image: no, but measured
C. f. CIII + CIV	10 - 0	S9	3/5/19 17:52	4/19 08:47	500	1001	6 / 33_35	A1-D1	CIII: A2_A6, C2_C6 (33, 35 psu) CIV: B2_B6, D2_D6 (33, 35 psu) File: C3_C4_03052019_S9_1750 Image: no, but measured
C. f. CIII + CIV	10 - 0	S11	4/5/19 11:01	5/5/19 08:13	500	999	6 / 33_35	A1-D1	CIII: A2_A6, C2_C6 (33, 35 psu) CIV: B2_B6, D2_D6 (33, 35 psu) File: C3_C4_05052019_1100_S11 Image: no, but measured
C.f. CV	5-0	S16	6/5/19 23:50	7/5/19 08:32	500	1012	6.3 / 33_35	A1-D1	CV: A2_A6, C2_C6 (33, 35 psu) CV: B2_B6, D2_D6 (33, 35 psu) File: CV_06052019_2350_S16 Image: no, but measured
C.f. CV	5-0	S16	7/5/19 23:29	8/5/19 10:44	500	10??	6.3 / 33_35	A1-D1	CV: A2_A6, C2_C6 (33, 35 psu) CV: B2_B6, D2_D6 (33, 35 psu) File: CV_07052019_2330_S16 Image: no, but measured
C.f. CIV	40 - 20	S18	8/5/19 22:30	9/8/19 08:30	500	10??	33	A1-D1	CIV: A2_A6, B2_B6, C2_C6, D2_D6. File: CV_07052019_2330_S16 Image: no, but measured

5.7.3. Zooplankton and phytoplankton pigments

Mathilde Servan (Nord)

Aim

The copepod *Calanus* contains varying amounts of pigmentation. The pigment, astaxanthin, is synthesized by the copepods from precursors from their algal diet. The differences in pigmentation could therefore be thought of as originating from different diets. Remote sensing of *Calanus* surface swarms is possible because of the copepods red coloration. The aim is to compare the phytoplankton community and *Calanus* pigmentation in the surface layers, to better understand pigment dynamics.

Method

Secchi depth and Forel Ule scale

The secchi depth was measured at each station with daylight, unless waves were too high to determine accurate depth. A Forel Ule scale was used to determine ocean color. The secchi depth was noted down as the depth were the disk disappeared. It was then raised to half this depth, and the color on the disk was matched to the color on the scale (Table 12).

Phytoplankton pigments

Water from 5 and 30 m were filtrated through 25 mm GF/F filters. Volume ranged from 0.15 to 1.7 L depending on amount of particles in the water. Filters were folded, placed in aluminum foil, and placed in zip lock plastic bags. They were frozen immediately at -80˚C.

Table 12. Deployment and results of the Secchi disk and Forel-Ule scale.

Station	Secchi depth (m)	Forel-Ule	Time
1	5	13	11:18
2	6	7	19:17
4	9	6	07:17
6	10	13	08:23
9	10	7	22:05
13	12	7	16:57
14	20	6	09:30
15	20	6	13:00
16	21	7	20:11
18	10	7	13:45
19	10	7	16:58
23	13	7	13:17
24	10	9	17:00
28	12	7	13:11
Ausnesfjorden	12	7	11:45

Table 13. Overview over samples taken for pigment analyses.

Station	Time	WP2 10-0 m	WP2 40-20 m	Filtration 5 m (L)	Filtration 30 m (L)	Experiment
1	09:36	0	0	1	1,4	
2	19:25	0	0	0.68	0.78	
3	23:21	3x30 CIV	3x30 CIV	1	0.8	
4	06:23	0	0	1	0.8	
5	00:40	3x30 AF	NA	0.15	0.57	
6	06:02	0	30 + 22 AF	0.3	0.6	
9	20:30	3x30 CV	3x30 CV	1.6	1.6	20 CV from 10-0m. 12h light/dark
10	11:08	0	0	0	0	
11	19:02	2x30 CV. 3x30 CIV. 60 CIIV	3x30 CV	1.35	0.8	20 CV from 10-0m. 12h light/dark
13	15:23	3x30 CIV	NA	0.6	0.6	
14	07:30	3x30 CV	3x30 CIV	1.7	1.4	20 CV from 10-0m. 12h light/dark
15	18:19	3x30 CIV	26 CIV	1	0.6	
16	09:46	3x30 CV	3x30 CV	NA	NA	20 CV from 10-0m. 24h dark
17	23:24	3x30 CV	3x30 CV	1.8	1.6	20 CV from 10-0m. 24h dark
18	11:44	3x30 CV	3x30 CV	1	1	20 CV from 10-0m. 24h light
19	12:34	0	0	0	0	

20	20:46	3x30 CIV	3x30 CIV	2.2	1.4	
21	23:06	NA	30 AF	0.75	0.75	
23	11:20	30 CV. 2x30 CIV	3x30 CV	1	1	20 CV from 10-0m. 24h light
24	15:04	3x30 CV	3x30 CV	0.8	1	20 CV from 10-0m. 24h light
25	22:11	30 CV	30 AF. 2x30 CV	1.2	0.8	
28	11:12	3x30 CIV	3x30 CV	1.6	1.4	20 CV from 40-20m. 24h dark

Zooplankton pigments

Copepods were collected from 40-20 m and 10-0 m with the WP2. 3 replicates of 30 *Calanus* CV were collected from each depth. If CV were not present in desired quantity, the most abundant stage was collected. This was either CIV or AF. At some stations, CV were only present in 40-20 m while younger stages were found in 10-0 m. The copepods were placed in aluminum foil, dried with a paper tissue to remove excess water, and stored in zip lock plastic bags. They were frozen immediately at -80˚C and will be kept frozen until pigment extraction.

Pigment degradation experiment

At 9 different stations 20 *Calanus* CV were put in individual containers with 100 ml of filtered seawater. They were put in a cold room (4˚C) with controlled light conditions. Three replicates with 12h light/darkness, three replicates with 24h darkness and three replicates with 24 h light. After 24 h of starvation they were collected and frozen in the same manner as above. Pigment amount will be compared to controls of the same stage collected form the same depth.

Zooplankton and phytoplankton pigments will be analyzed by Mathilde using HPLC at the university in Bodø. One sample was taken for genetics at station 27 and will also be analyzed at Nord university.

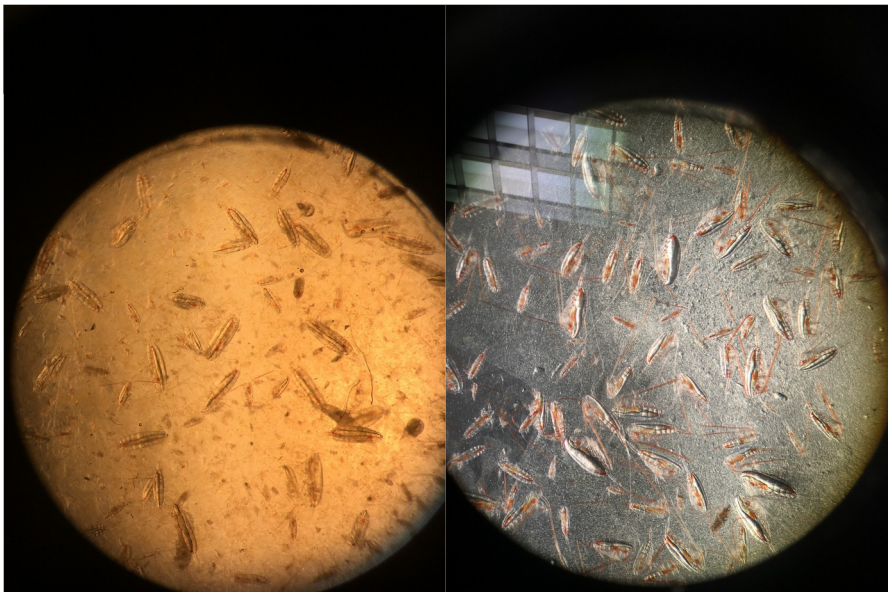

Fig. 22. Difference between off-shelf (left) and on-shelf (right) stations.

Observations

Huge surface swarms were observed at on-shelf stations. The off-shelf plankton community was dominated by *Phaeocystis*, and few copepods were found in the upper layers. On-shelf copepods appeared to contain more lipids and pigment than the copepods offshore. Did not observe the same

degree of redness as some of the stations in June 2018, which could indicate that the copepods accumulate astaxanthin throughout the season. Pigment appeared to disappear slightly after starvation, especially in the antennules (Figure 22).

5.7.4. Echo strength and biomass measurements from ADCP

Zhiqiang Su (SJTU)

Aim

In order to research the abundance, distribution and biomass of krill with different spatial scales, the echo return signal of ADCP data is used to calculate the volume backscattering strength and biomass of krill.

Materials and methods

The previously calibrated 75KHz ADCP hull-mounted on R/V Helmer recorded acoustic data continuously from April 27 to May 12 (see section 5.2.1). Data were processed along the transects that were sampled by the moving vessel profiler. In order to validate the acoustic data, pelagic trawls were taken at selected stations along the acoustic transects. Further processing of both net samples and acoustic data will enable the estimation of the composition, abundance and biomass of the krill patches together with the total relative biomass and abundance of the targeted species in the studied area. Unfortunately, the data from sea surface to 30 m can't be recorded due to the mounting of ADCP. In addition, the CTD stations taken along the cruise track will enable the calculation of the sound speed and coefficient of absorption necessary for the acoustic calculations.

Preliminary results

The 75 kHz frequencies data from the ADCP echo signal revealed a wide range sound scattering layer from the surface to approximate 1000 m. Thus, it could reflect the biomass distribution and variance from on-shore to off-shore, an example is shown for transect 1 (Fig. 23). The white thick line represents the bottom of the sea and the data below white thick line is unavailable.

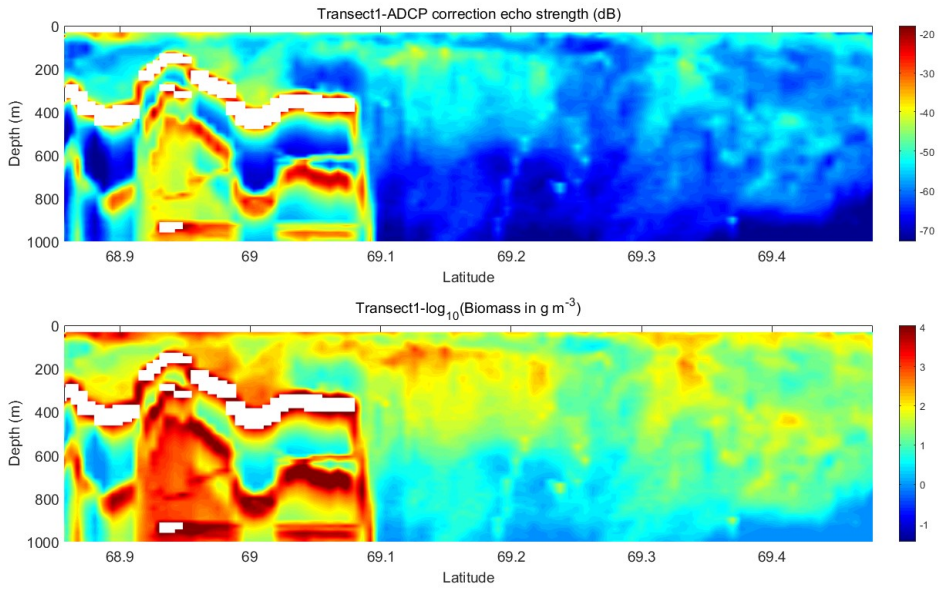

Fig. 23. The upper panel represents the correction echo strength (dB) from the echo return signal of ADCP and the lower panel represents the biomass of krill mainly (including other biology species) in transect 1.

References

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Zhou, M., & Dorland, R. D. (2004). Aggregation and vertical migration behavior of euphausia superba. Deep Sea Research Part II Topical Studies in Oceanography, 51(17–19), 2119-2137.
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5.8. Fish and Macrozooplankton sampling

Guillaume Schuler (UiT), Stig Falk-Petersen (APN), Nicolas Weidberg (UiT)

Objectives

1) To study the abundance of predators, mostly in the mesopelagic layer (200-400 m), and measure morphometrics (length, weight and volume) of each individual.
2) To analyse the stomach contents to establish each species' position in the mesopelagic trophic web.

Materials and Methods

A Harstad pelagic trawl was deployed 16 times in the offshore areas of North Norway (table 14), from offshore South Lofoten to North Vesterålen, using an 8 mm mesh size with an opening area of 96 m². Each trawl collected fish from roughly less than 180 000 m^3 of seawater: trawl height 8 m, trawl width 30 m, boat speed 3 knots = 9.26 m/min, sampling time 20 min → volume sampled = 177 792 m^3.

Table 14 : Overview of trawls sampled during the 2019 STRESSOR cruise

Date	Time (UTC)	Number	Location	St Nr Bridge	Lat	Lon	Echo Depth	Gear	Depth (m)
29/04/2019	10:47	1	Trawl start	423 start	68 16.85 N	13 20.16 E	131	Pelagic trawl start	15
29/04/2019	11:07		Trawl end	423 end	68 17.74 N	13 18.81 E	151	Pelagic trawl end	
29/04/2019	11:42	2	Trawl start	424 start	68 16.96 N	13 17.31 E	151	Pelagic trawl start	135
29/04/2019	12:00		Trawl stop	424 stop	68 17.63 N	13 15.62 E	157	Pelagic trawl end	
30/04/2019	01:29	3	S5	431	68 54.28 N	012 04.89 E		Pelagic Trawl	290
30/04/2019	08:26	4	S6	439	68 44.95 N	12 26.30 E	306	Pelagic trawl	200
30/04/2019	09:39	5	S6	440	68 45.43 N	12 29.53 E	306	Pelagic trawl	600
05/03/2019	10:05	6	S10	453	69 01.11 N	12 55.07 E	1953	Pelagic trawl start	230
05/03/2019	10:25		S10	453	69 02.05 N	12 55.81 E		Pelagic trawl end	
05/03/2019	23:11	7	S12	476	68 52.01 N	13 18.95 E	587	Pelagic trawl start	20
05/03/2019	23:30		S12	476	68 30.06 N	13 20.35 E	461	Pelagic trawl end	
05/04/2019	08:42	8	S13	477	69 30.06 N	13 20.35 E	2771	Pelagic trawl start	280
05/04/2019	09:03		S13	477	69 31.19 N	13 19.94 E	2776	Pelagic trawl end	
05/05/2019	13:57	9	S15	501	69 06.39 N	14 02.15 E	908	Pelagic trawl start	220
05/05/2019	14:21		S15	501	69 06.75 N	14 02.15 E	1133	Pelagic trawl end	
05/08/2019	18:35	10	S20	531	68 59.03 N	13 27.78 E	443	Pelagic trawl start	200
05/08/2019	18:55		S20	531	69 00.10 N	13 29.29 E	681	Pelagic trawl stop	
05/09/2019	03:38	11	S21	541	69 03.21 N	13 14.25 E	2390	Pelagic trawl	260-270
05/09/2019	05:16	12	S22	542	69 01.28 N	13 36.90 E	718	Pelagic trawl	200
05/09/2019	15:48	13	S24	557	69 05.87 N	14 04.14 E	797	Pelagic trawl start	280-320
05/09/2019	16:18		S24	557	69 07.21 N	14 06.52 E	925	Pelagic trawl stop	
05/09/2019	20:35	14	S25	560	69 12.85 N	13 55.01 E	1995	Pelagic trawl	300
05/10/2019	03:03	15	S26	570	69 12.45 N	69 12.71 E	1203	Pelagic trawl	400-350
05/10/2019	07:38	16	S27	573	69 06.98 N	14 14.99 E	597	Pelagic trawl start	300
05/10/2019	08:04		S27	573	69 08.27 N	14 14.89 E	576	Pelagic trawl stop	

The trawl depth was planned to match the depth of the strongest soundscatter layer measured by the echosounder. After each trawl, the catch contents were processed in the fish-lab on board. For each fish and invertebrate species, every captured specimen was measured and counted, in order to record the abundance (number of individuals) and biomass (total weight). In case that too many individuals of one species were caught, sub-samples were taken. Ten individuals of each major species (or species of interest), along with flesh pieces, were frozen for further analyses back in Tromsø. The stomach of each predator was opened on board in order to identify, count and weight prey species to the lowest taxonomic level possible. If too many predators were caught, some stomachs were put in alcohol for

further processing at the UiT laboratory. Later, the size distribution of the prey species contained in the stomachs will be compared to the size distribution of the same prey species in the environment, to infer potential prey selectivity of the mesopelagic predators. In addition, fatty acid analyses of the frozen predator flesh samples will be performed for further long term information on diets.

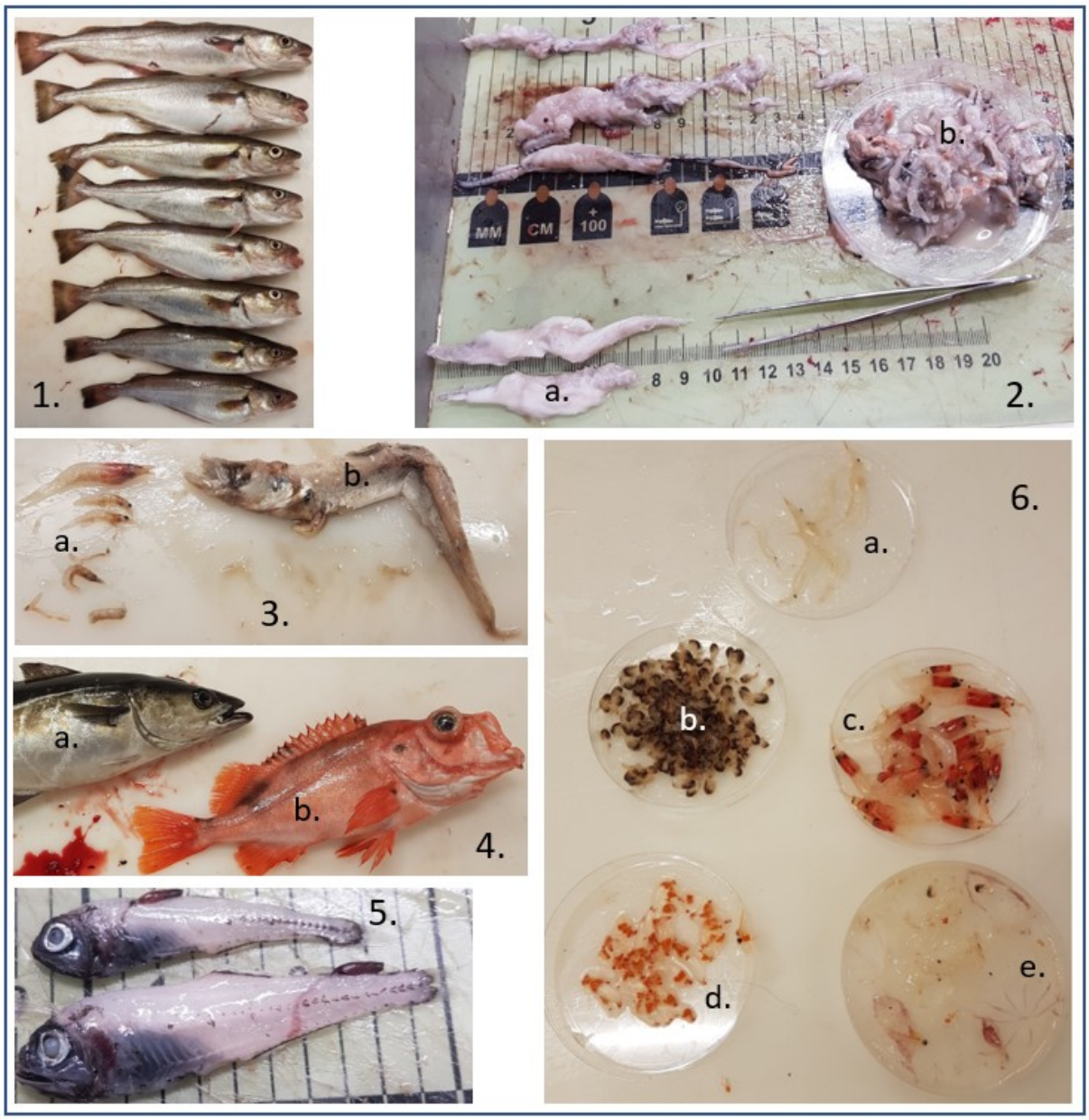

Fig. 24: 1) Whitings. 2) Saithe's stomach content. a) Likely blue whitings. b) Krill. 3) Whiting's stomach content (trawl 13). a) A Pandalus *and krill b) Blue whiting. 4) a) Saithe. b) Deepwater redfish. 5) Myctophids* Benthosema *sp. with parasites. 6) a) All white shrimps. b) Themistos. c) Shrimps. d)* Clione limacina*. e) Jellyfish.*

Preliminary results

Regardless of the species, a lot of individuals have been found with empty stomachs. The following organisms were found in the trawls (figure 24): krill (mostly *Meganyctiphanes norvegica*, but also *Thysanoessa raschii*), *Clione limacina*, Chaetognaths, *Themisto*, squids, jellyfishes, but also shrimps (*Pandalus* red ones, red headed with white body ones and all whites) and two big copepods at trawl 9 (*Paraeuchaeta*).The following fishes were caught as well (figure 24): blue whitings, saithes, myctophids (both *Maurolicus* sp. and *Benthosema* sp.), a white barracudina and a greenland halibut (trawl 5), herrings (*Clupea harengus*), Atlantic cods (*Gadus morhua*), haddocks (*Melanogrammus*

aeglefinus), whitings (*Merlangius merlangus*) and a deepwater redfish at the last trawl. Regarding the stomach analyses, several different results were obtained (figure 24). At trawl 5, a greenland halibut and a saithe have been caught (among others). By opening their stomachs, two different diets were found. The saithe had a full stomach (90-100% estimated fullness) of krill, almost only *Thysanoessa raschii*, whereas the greenland halibut only fed on *Pandalus* shrimps, which fed on krill. At trawl 13, 8 whitings were caught. In the second biggest whiting's stomach, there were krill (both *Meganyctiphanes norvegica* and *Thysanoessa raschii*), a *Pandalus* and even a blue whiting. At other trawls, blue whitings were found with krill in their stomachs, so it is possible to establish both species' position in the trophic web.

5.9. Marine mammal research

Sofia Aniceto (UiT)

Background

The Lofoten-Vesterålen region is an area with high commercial interest to both the petroleum and fishing, where marine mammals have economic importance (tourism) as well as conservation interest. Current survey methodology in sea mammal research relies primarily on visual observation at a limited spatial and temporal scale. Such surveys are often time demanding and require the deployment of research vessels and manpower, which are costly. Marine mammals spend a considerable time under water often vocalizing, and the use of acoustic equipment and suitable methods to interpret the recordings are increasingly important. During this research cruise, we evaluate marine mammal distribution during the spring bloom and in relation to copepod super swarms.

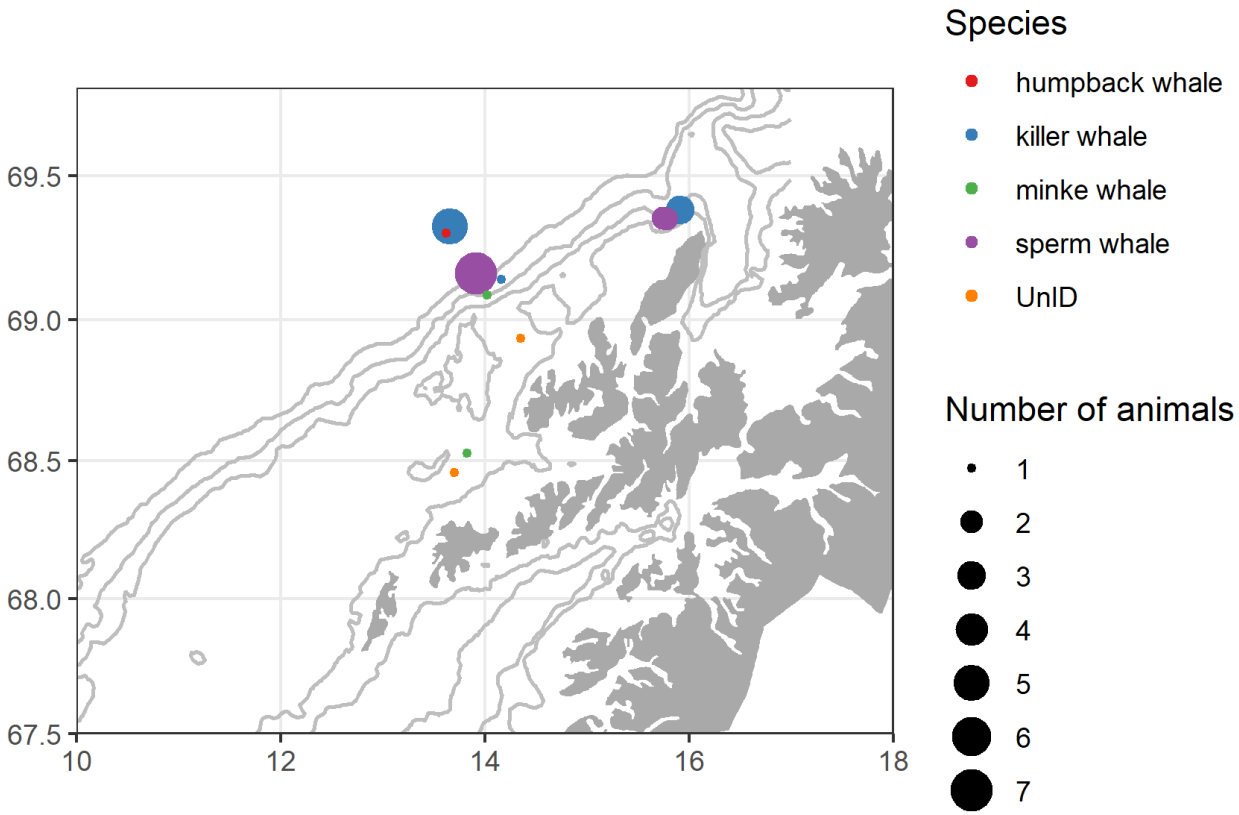

Fig. 25. Whale observations during the cruise.

Methods

Visual observations were made from FF Helmer Hansen bridge using the naked eye and validation was made with binoculars. The observations were recorded always facing ahead of the ship, covering

approximately 180 degrees. To cover several parts of the day, in case distribution is based on time of day, observations were made for two hours and every four hours, from sunrise to sunset. Upon detection the species, number of individuals, and position were recorded. Observations collected by other people outside of the observation period were also noted. However, there is a degree of uncertainty in these detections as observer expertise in species identification and group size estimates is not known. Given the distance to horizon provided by the crew (12 km) and given that distance sampling is not part of the goals of this expedition (for abundance estimates), range to animals sighted was not calculated. Furthermore, a threshold for sea state (Beaufort scale) conditions was established. No observations were to be made above sea state 4. Observations collected during periods with higher sea state conditions are often underestimates of the true number of animals, given the effect of swell, wind, and visibility conditions on observer performance. For the purpose of this expedition, and to provide a minimum number of animals recorded, sporadic detections recorded under such conditions were considered for analysis. Furthermore, we deployed a Seaglider (Kongsberg), which operated in the region of the LoVe Cabled Ocean Observatory (led by the Institute of Marine Research and Equinor) and collected environmental, echosounder, and hydrophone data. We combine the results from visual and acoustic surveys to estimate marine mammal distribution during the spring bloom, and assess changes in vocal behavior of the animals.

Preliminary results

Ten animals were detected during the surveys, two of which were unidentified species observed by members of the crew of Helmer Hansen. The species most detected was the sperm whale, primarily sighted in the Bleik canyon region (Fig. 22). No whales were visually detected during super swarm events. The low number of sightings was connected with the harsh winds and swell encountered during the surveys. Additionally, reports from the local whale hunting efforts showed that the numbers of minke whales in this region are considerably lower than previous years, and whalers were moving further north towards Finnmark in search for more animals (Nikolaisen 2019).

Data collected by the acoustic sensors will be provided at a later stage, as this requires access and download of data files from local servers. Though the effects of weather should be evident in hydrophone data and cause an increase in background noise, it is expected more whale detections than visually. Deep diving species such as sperm whales spend significantly more time underwater than at the surface in search for prey, whilst other species will often have different foraging strategies and are therefore less predictable in terms of their underwater behavior and distribution.

References

Nikolaisen K., 2019. Laber uke for hvalfangerne. Lofotposten [available online at https://www.lofotposten.no/kval/fiskeri/norges-rafisklag/laber-uke-for-kvalfangerne/s/5-29-485313]

6. Impressions from the artists

Michaela Casková

The curatorial team of Lofoten International Art Festival (LIAF) 2019 have been invited to collaborate with UiT The Arctic University of Norway and their research project Stressor. Liaf has been offered 2 spaces on the cruise and I am happy I could be one of invited artists-on-board, together with Toril Johanessen. I was part of international group of scientists who were willing to share their knowledge and also let me get involved during samplings in many stations. Being an editor of Stressor blog was also important task allowing me to be in touch with many and kept me updated on different stages of research on daily bases.

I have long term special interest in the intersection between art, science, and sustainable practices relating to food, travel, and energy. I therefore intended to learn a lot about a specialised strand of research during this expedition. My previous and ongoing collaborations aims to promote critical thinking, skills and enquiry-based and projects focused on sustainable values and lifestyle, ecological

and cultural diversity. The opportunity to learn more about ancient marine organisms, research practice, individual attitudes, role of science in geopolitical means as well as local questions, were definitely some of main valuable points of trip for me.

I feel like I have learned more than I can at the moment reflect and that some time for settling all impressions and grounding new information is needed.

During the cruise I concentrated on observing and collecting material and data on weather that definitely was a significant factor on life on board. Weather in times of climate change is one of my biggest themes. Observing how numbers and data really feel and how they affect our behavior and action interested me also on Helmer Hanssen.

I envision that my weather notes based on life on boat will transform into temporary weather observation space and will be presented during LIAF main exhibition venue in Svolvær in Lofoten between 30thof August and 27thof September 2019.

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Toril Johannessen

I joined the STRESSOR cruise halfway when Helmer Hanssen was docking in Svolvær Monday 6th of May. My participation happened on invitation from the curators of Lofoten International Art Festival (LIAF). For the LIAF exhibition in Svolvær in September I am invited to show already existing works from a series of graphs entitled “Words and Years”, and to do a performance or oral presentation within their program of lectures and events on the topic of statistics. The objective of my participation on the cruise was to get acquainted with the scientific research onboard and possibly make use of this experience in the preparations for my presentation at LIAF.

Through informal conversations, roaming around the labs, and the daily lectures by the researchers onboard, I learned about *Calanus finmarchicus* and the various research methods carried out. The range of modes of observation involved in the process of collecting data was wide, from sophisticated technologies including autonomous vessels, satellites and machine learning, to basic observation methods like eye observation only aided by binoculars. This interests me as an artist and a citizen, because the observations involved in scientific research - and the technological and institutional aspects that enables the research to be made - are so fundamental for our society: What I see when I look at the screens onboard with numbers and graphs that I only understand a fraction of, is that ultimately, the painstakingly collected data will add to the knowledge on which future decisions might be based - such as decisions on environmental policy, industry and quotas.

Artistic research can be a long and squiggly process, and less systematic than what the word research may suggest in other fields. As an artist on a scientific research cruise, I was in good company with my colleague Michaela Casková. We attempted to unpack the “mystery” of artists-onboard a bit by giving short presentations on our work. I presented a selection of three projects from the past 10 years, giving a brief outline of work methods and interests. The works I presented included the graphs from the series “Words and Years”; a film with marine micro-organisms entitled “Reclaiming Vision”, and a current project with AI generated images of trees entitled “Skogsaken”. By speaking about these works I wanted to give an impression of what my work process can be like, for instance through how I make use of history, facts and collected data in combination with idiosyncratic methods and fiction.

7. Talks presented during the cruise:

1. Guillaume Schuler
2. Jordan Grigor: Unravelling the mysteries of the zooplankton.
3. Kim S. Last: The Moon, the Clock and the Fat Copepod.
4. Mathilde Servan: Seasonal variation in astaxanthin pigmentation of a North Atlantic copepod.
5. Michaela Casková: Weather in me.
6. Nicholas Weidberg: Spatial assemblages and patch formation mechanisms in *C. finmarchicus* populations off Northern Norway.
7. Stig Falk-Petersen: Mesopelagic layers in the European Arctic: seasonal migrations and trophic interactions.
8. Sünnje Basedow: Fishing for *Calanus*.
9. Toril Johannessen: Artistic Research.
10. Walker Smith: Biological Oceanography in the Ross Sea, Antarctica: A brief story.
11. Yisen Zhong: A first glance of ADCP data.
12. Yonghui Gao: Preliminary data summary of net community production during STRESSOR.
13. Zhaoru Zhang: Physical control on the biogeochemical processes in the Yangtze River estuary.

8. Planned publications, as of now

1. Falk-Petersen S, Pedersen G, Geoffroy M, Basedow S et al.: Trophic structure and biomass of the mesopelagic layers off Lofoten.
2. Smith W et al.: Grazing impacts on phytoplankton distributions in the Lofoten region of coastal Norway.
3. Servan M et al.: Seasonal variation in astaxanthin pigmentation of copepods in relation to phytoplankton.
4. Aniceto S. et al.: Assessing Norwegian cetacean distribution from marine bioacoustics systems and visual observations.
5. Zhong Y. et al.: Symmetric instability on the Norwegian Slope Current
6. Grigor J, Last K et al.: Lipid and buoyancy control of *Calanus* super swarms in the sub-arctic.
7. Gao Y. et al.: Net community production in the spring of the Norwegian Sea.
8. Basedow SL et al: Surface patches of *Calanus* revisited: the role of physical mechanisms and behaviour.

9. In the media [in Norwegian]

liaf.no, 12th April: LIAF på tokt med forskningsfartøyet Helmer Hanssen.

Lofotposten 14th April. Knut Johansen: Supersvermer av raudåte utenfor Lofoten og Vesterålen.

Bladet Vesterålen 10th May. Mareno Leonhardsen: Jakter på raudåtas hemmelige liv.

forskning.no 12th May. Stig Falk-Petersen, Sünnje Basedow, Geir Pedersen: Et kart fra 1539 kan skjule hemmeligheten bak de gode fiskeområdene utenfor Lofoten.

Bladet Vesterålen 21st May. Stig Falk-Petersen, Sünnje Basedow, Geir Pedersen: Kart fra 1539 kan skjule en hemmelighet utenfor Lofoten.

www.stressor.lofoten-research.no