Deep Scattering Layers at the Svalbard Gateway to the Arctic Ocean.

Peter Wiebe[1], Harald Gjøsæter[1], Tor Knutsen[1], and Randi Ingvaldsen[1]

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Abstract

As part of the Norwegian SI-ARCTIC Program, in late summer of 2014 and 2015 acoustic data (18, 38 and 120 kHz) for the estimation of the distribution and abundance of zooplankton and fish were collected from regions west and north of Svalbard, to examine high latitude epipelagic and mesopelagic scattering structures. The deep scattering layer biological constituents were determined from vertical and oblique hauls with zooplankton nets and pelagic trawls. There was strong patchy scattering in the upper part of the epipelagic zone (<50 m) throughout the area due to 0-group fish that were particularly abundant west of the Spitsbergen Archipelago and by copepods, krill, and amphipods. The distinct Off-shelf deep scattering layer (DSL) occurred between 200 and 600 m and contained a range of larger longer lived organisms (mesopelagic fish and macrozooplankton). In eastern Fram Strait, the DSL also included larger fish close to the shelf/slope break that were associated with Warm Atlantic Water moving north towards the Arctic Ocean, but switched to dominance by species having weaker scattering signatures further offshore. The Weighted Mean Depths of the DSL were deeper (WMD >440 m) in the Arctic habitat north of Svalbard compared to those south in the Fram Strait west of Svalbard (WMD ˜400 m) and the mesopelagic nautical area scattering coefficient was a factor of approximately 6-10 lower around Svalbard compared to the areas in the south-eastern part of the Norwegian Sea ˜62º30'N. The DSL displayed a clear ascending and descending diel movement. The high-light WMD with respect to backscattered energy was statistically deeper than the low-light WMD for the locations studied. This behavior of the DSL was consistent both when the sun was continuously above the horizon and after it started to set on 1 September, and both in open water and sea ice covered waters.

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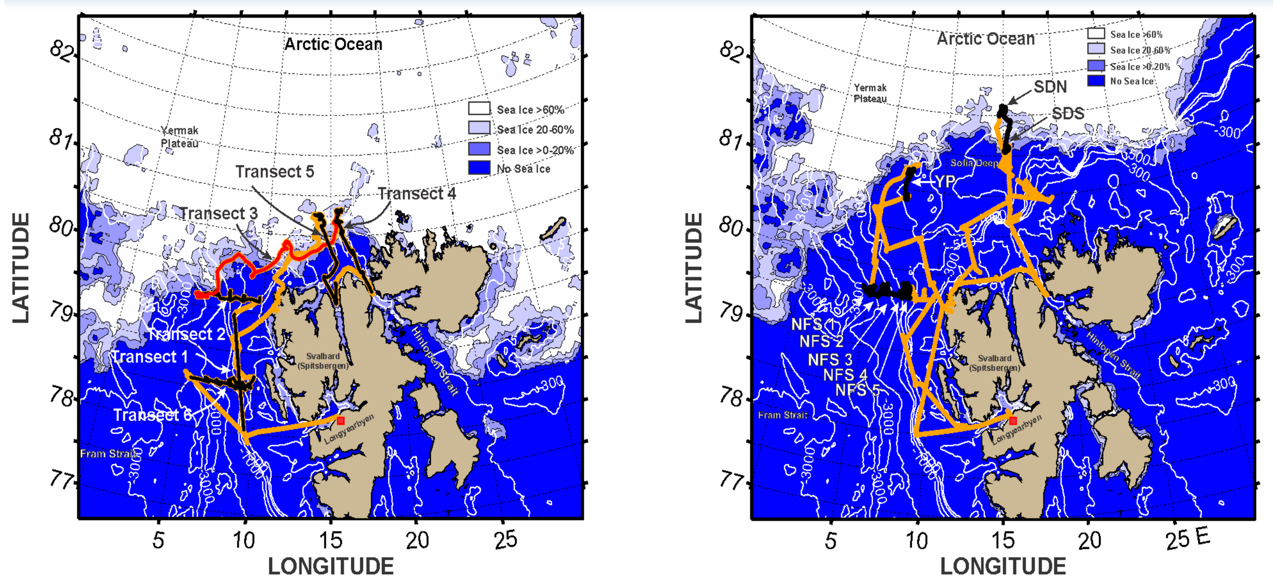
SI-ARCTIC Study Area



Tracks of the Helmer Hanssen cruises 2014806 and 2015843. Left: The orange track has the sections where the 38 kHz acoustic data were analyzed plotted in black, except for the Along Ice Edge transect that is red. Right: Locations, shown as black lines, where day/night differences in the WMD data in the mesopelagic layer were compared. Arrows point to eight locations: Sofia Deep N (SDN), Sofia Deep S (SDS), Yermak Plateau (YP), Northern Fram Strait 1 (NFS 1), Northern Fram Strait 2 (NFS 2), Northern Fram Strait 3 (NFS 3), Northern Fram Strait 4 (NFS 4), and Northern Fram Strait 5 (NFS 5).

Methods

Acoustic data for distribution and abundance estimation of water column plankton and fish were collected with calibrated EK60 echo sounder systems. The acoustic data were scrutinized during the two cruises, using LSSS (the Large Scale Survey System). The main tool for identifying plankton / mesopelagics / micronekton (PMM) and fish was the frequency response. Trawl and net data were used to corroborate the interpretation of the acoustic data. The acoustic backscattering data in the reports were in the form of s_A - Nautical area scattering coefficient (NASC) in units of m² nmi⁻² (MacLennan et al. 2002).

38 kHz acoustic records were summarized in 10 meter depth bins from the below the hull mounted transducers to below 700 m and stored in Excel spreadsheets. Matlab m-files were used to make plots of NASC data as a function of time and space. The weighted mean Depth of the backscattering (WMD) was computed using the following equation:

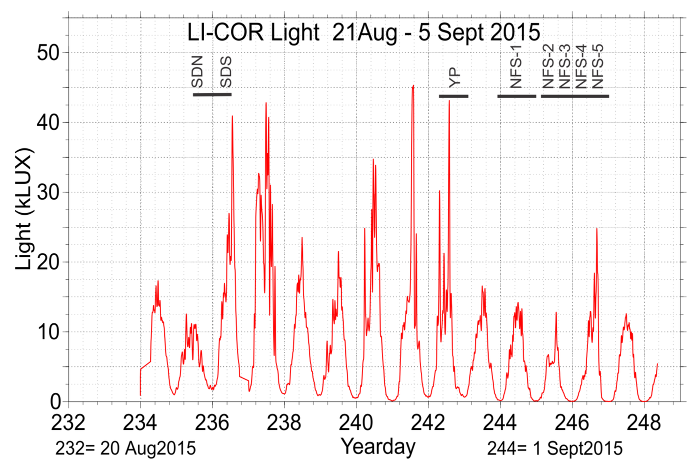
$$WMD = \sum_{j=1}^{N} z_j s_{A_j} \Big/ \sum_{j=1}^{N} s_{A_j}$$

where z is the depth of interval j, S_A is the NASC value for that depth interval, and N is the number of depth intervals.

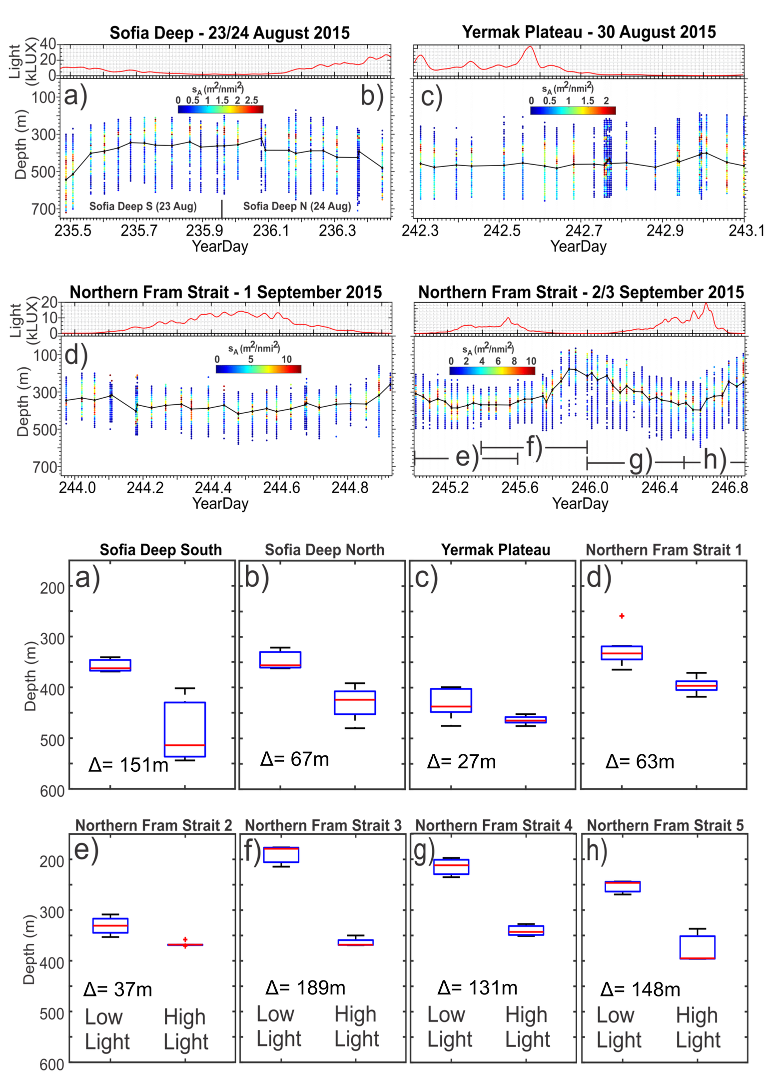
On SI-ARCTIC cruise 2014806, sequential thresholding was used to differentiate strong scatterers from weak scatterers. Total backscatter was allotted to the stronger scattering target categories 0-group fish, cod, capelin, redfish, and others, then lumped to the category Strong_SC. The remaining backscatter including the micronekton krill, amphipods, and mesopelagic fish were lumped into the category Weak_SC.

Samples of fish, micronekton, zooplankton, and phytoplankton were collected with a variety of net systems. These included the Harstad Trawl, the Macroplankton Trawl, the Åkra trawl, the MIK-Ring Net, the Multinet, the WP2/Juday net, and a 10 µm phytoplankton net.

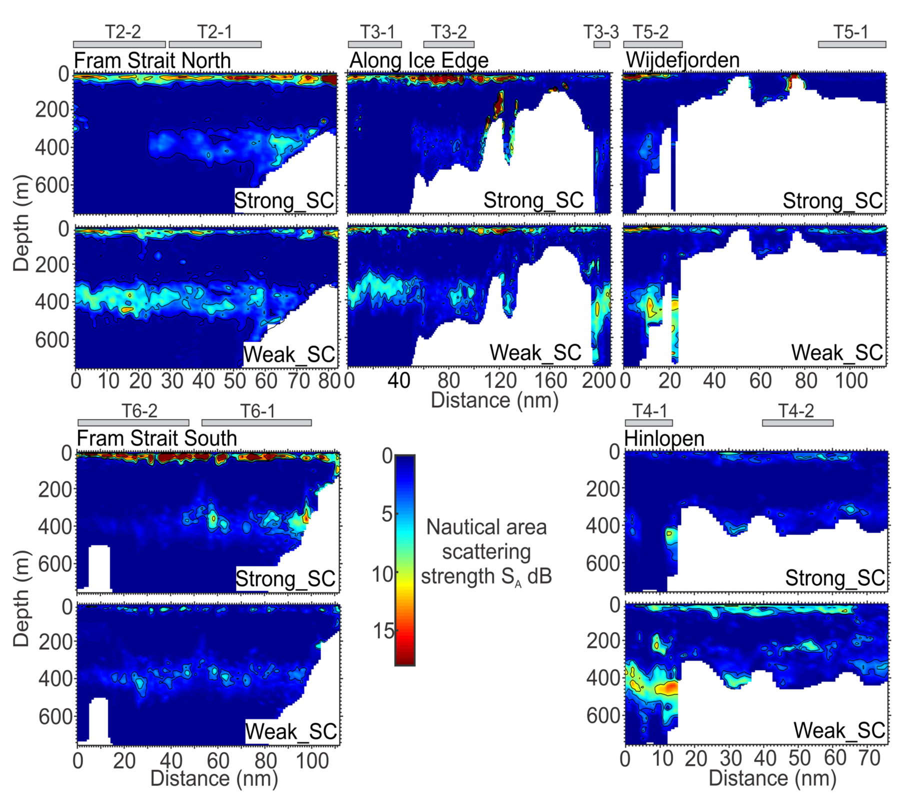
Results



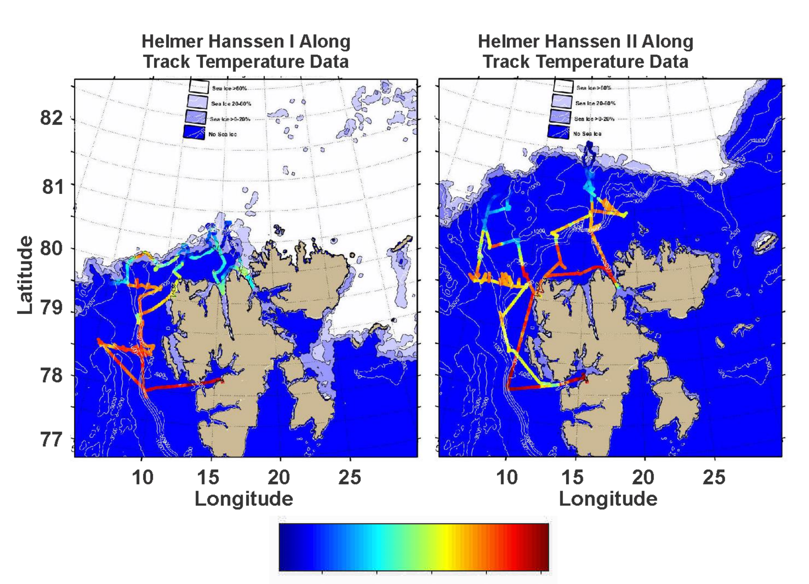
Light levels determined from a LI-COR LI-COR Model LI-1400 data logger with a LI-210SA Photometric Sensor recorded during SI-ARCTIC Cruise 2015843.



Light levels and vertical distribution of scrutinized acoustic DSL NASC data assessed as originating from mesopelagic organisms (two upper panels). The light data determined the times used to select the NASC data for comparison of the vertical distribution between low-light levels and high-light levels. Box plots of the depths of the high-light and low-light depths of WMD of the DSL backscattering at 38 kHz (two lower panels) showed that there was a marked difference between them. The WMDs for high-light periods were significantly deeper than for low-light periods. The median differences varied from 27.8 m to 189.3 m.

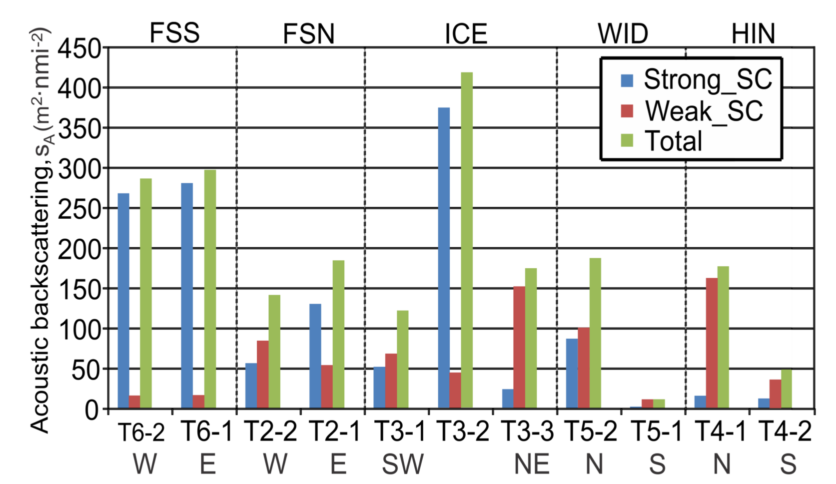


Distribution of the Strong_SC (Upper) and Weak_SC (Lower) for the transects on SI-ARCTIC cruise 2014806, Fram Strait South (T6), Fram Strait North (T2), Along Ice Edge (T3), Wijdefjorden (T5), and Hinlopen (T4). Gray rectangles above transects indicate position of subsections.

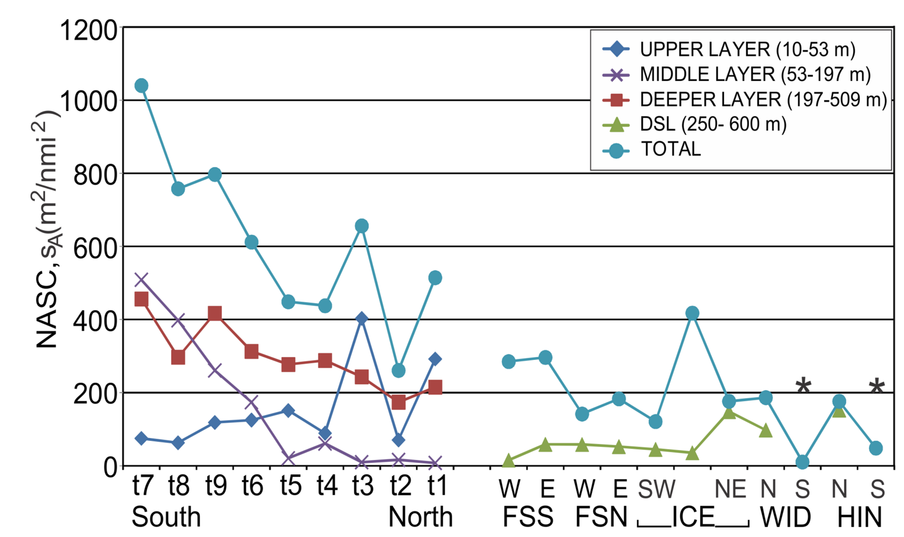


Sea surface temperature [C] in 2014 (left) and 2015 (right) Helmer Hanssen cruises. Warm Atlantic water flowed up along the continental Svalbard shelf and turned northeast into the Arctic Ocean. There was considerable variation in the extent of the pack ice in the late Summer Period.

Macroplankton trawl.



Integrated water column acoustic backscattering s_A for the categories Weak_SC, Strong_SC and Total s_A by subsection within the transects FSS (T6), FSN (T2), ICE (T3), WID (T5), and HIN (T4).



Left: Integrated s_A in layers 10–53, 53–197, and 197–509m, averaged over individual transects t1–t9 in the eastern Norwegian Sea where bottom depth exceeded 509 m from ~62 to 68°33'N during the period June/July 1991, modified from Melle et al. (1993). Right: Integrated s_A for subsections of FSS, FSN, ICE, WID, and HIN. *Water column too shallow for DSL formation.

Taxa	Station	St2	St20	St22
Copepods	Calanus hyperboreus	0.101	0.004	
	Paraeuchaeta barbata		0.070	0.046
	Paraeuchaeta norvegica		0.026	0.046
Euphausiids	Thysanoessa inermis	5.848	2.473	4.942
	Meganyctiphanes norvegica	5.129	0.626	3.525
	Nematoscelis megalops	0.020		
	Thysanoessa longicaudata	0.015	0.000	0.031
Amphipods	Themisto libellula	0.153	0.600	1.493
	Themisto abyssorum	0.076	0.091	0.123
	Amphipoda	0.012	0.002	0.034
Shrimp	Hymenodora glacialis	0.656		
Chaetognaths	Chaetognatha	0.101	1.071	
Pteropod	Clione limacina		0.009	0.062
Ctenophore	Ctenophora		0.343	1.270
Hydromedusae	Aglantha	1.823	0.793	1.270
Cephalopods	Cephalopoda		0.021	
Fish	Benthosema glaciale		0.054	0.132
	Arctozenus risso		0.105	
	Myctophidae		0.017	
	Reinhardtius hippoglossoides	0.003	0.003	
	Lumpenus lampretaeformis		0.002	
	Sebastes, 0-group	0.229	0.001	
	Total catch (kg)	1.541	2.91	2.32
	Depth of sampling (m)	0-450	0-1185	0-408

Macroplankton trawl wet weight catch composition (g·1000 m-3). Trawls taken on Cruise 2014806. St2 at start of transect 1, St 20 and St22 taken at northern end of Transect 4.

Conclusions

- In 2014, the surveyed area to the west and northwest of Svalbard was dominated by two prominent layers of organisms: a near-surface layer of strong scatterers, consisting of young-of-the-year fish species and mesozooplankton, and a DSL at 250–600m, consisting of mesopelagic fishes and various zooplankton forms (e.g. krill and amphipods, and various gelatinous forms) off-shelf and larger fish close to the shelf.
- Mesopelagic fish and other micronekton that have a more southern origin were still a significant component of the DSL found as far north as ~81◦N, during a period with a 24-h light regime.
- In 2015, small but significant differences among estimated WMDs of the DSL, consisting of various mesopelagic fishes, large zooplankton were observed in the study area situated west and northwest of Svalbard (latitude 79° 40' N - 82° N) during the two surveys.
- These vertical differences were probably caused by the small but clearly visible differences between high-light and low-light periods observed.
- These SI-ARCTIC data sets provide a reference for future ecosystem change.

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