

Lower trophic levels and seabirds

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The purpose of this study was to get insight into factors governing the distribution of migrating seabird in the Davis Strait in autumn. Some preliminary results are presented below.

In September 2009, a ship-based study was carried out in the Davis Strait/southern Baffin Bay along a number of transects covering the area between the west coast of Greenland and Baffin Island (Canada) from 68° - 72° N (Figure 1). Water temperature, salinity and *in situ* chlorophyll *a* (chl. *a*) measured in the 0-500 m depth range followed the general hydrographical characteristics of the late summer situation (Figure 2). Surface chl. *a* concentration based on remote sensing satellite data from September 2009 (Figure 3) supported these findings. Measurement of *in situ* chl. *a* concentrations revealed a maximum in the subsurface (30-50 m water depths). Thus, spatial distribution of the phytoplankton bloom was often restricted to subsurface rather than the surface waters and therefore not detected by the remote sensing during September.

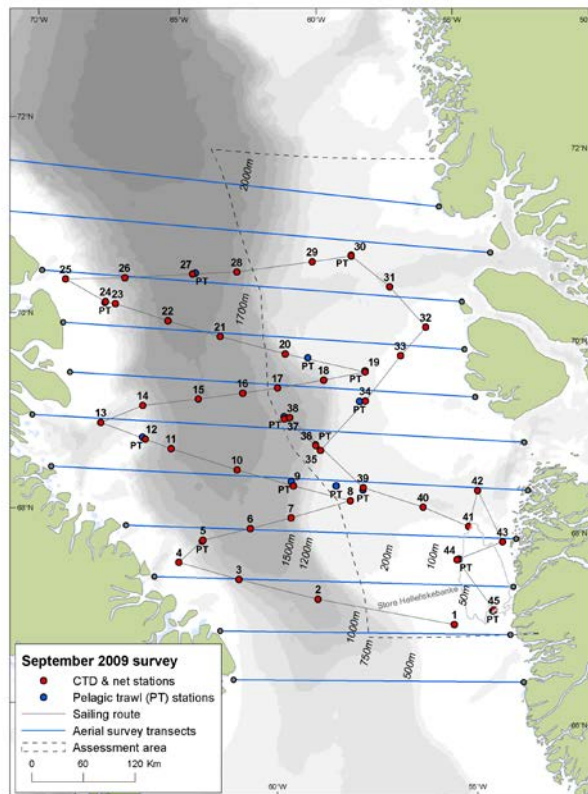


Figure 1. Map showing the ship-based transects (red line) and the aerial transects (blue line) during the survey in September 2009. Station numbers and positions of CTD measures and zooplankton samples (red dots, $n=45$), pelagic trawls- PT (blue dots, $n=15$).

Zooplankton communities, their distribution and link to higher trophic levels

The zooplankton assemblage was represented by copepod taxa characteristic for the marine Arctic environment and was mainly composed of the following large copepod species (importance in terms of biomass): *Calanus hyperboreus*, *C. glacialis* and *C. finmarchicus* and *Metridia longa*, and non-copepod species such as *Chaetognatha* spp., *Oikopleura* spp., *Themisto libellula* and *Aglantha* spp. Smaller copepod species such as *Pseudocalanus* spp., *Oithona similis* were also present and a few *Oncaea* spp. and *Microcalanus* spp. (data not shown).

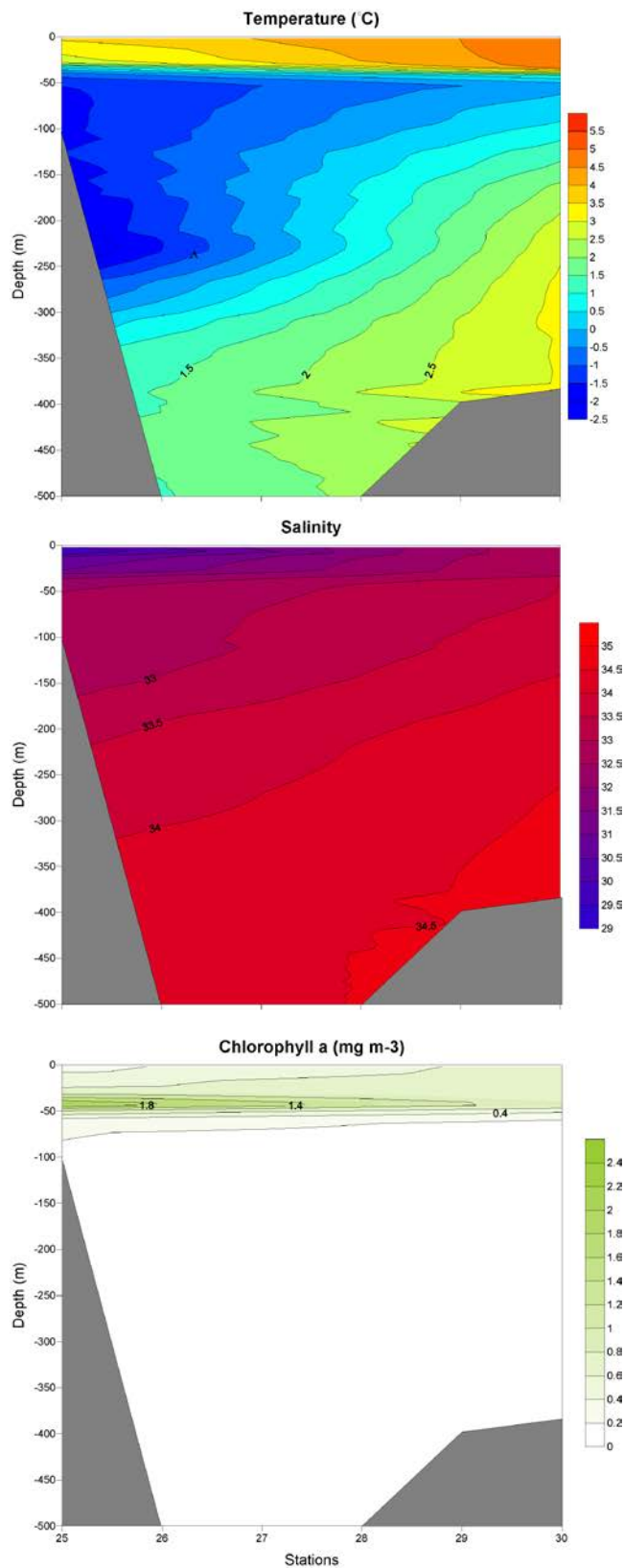


Figure 2. Transect performed during the ship based survey in September 2009 documenting temperature ($^{\circ}\text{C}$), salinity and chlorophyll a (chl. a) concentration (mg m^{-3}); see Figure 1 for transect station numbers. Relative warm surface waters (up to 5-6 $^{\circ}\text{C}$) and salinity around 30 is typical during summer and autumn as a result of solar heating and glacial melting. The cold intermediate waters (50-250 m column), with a cold core (-2°C) close to the Canadian Shelf is presumably caused by the Baffin Island Current, originating from polar water through the Nares Strait. The relatively warm and high saline bottom water close to the Greenland Shelf is presumably due to the warm Irminger Current which is sub-ducted under the Polar Current, forming the West Greenland Current. The relatively cold, low saline intermediate water mass between 50-100 m close to the Greenland Shelf is presumably a mixing zone of glacier water and the West Greenland Current. The main chl. a concentration seems to be associated with a pycnocline in 40-50 m depth.

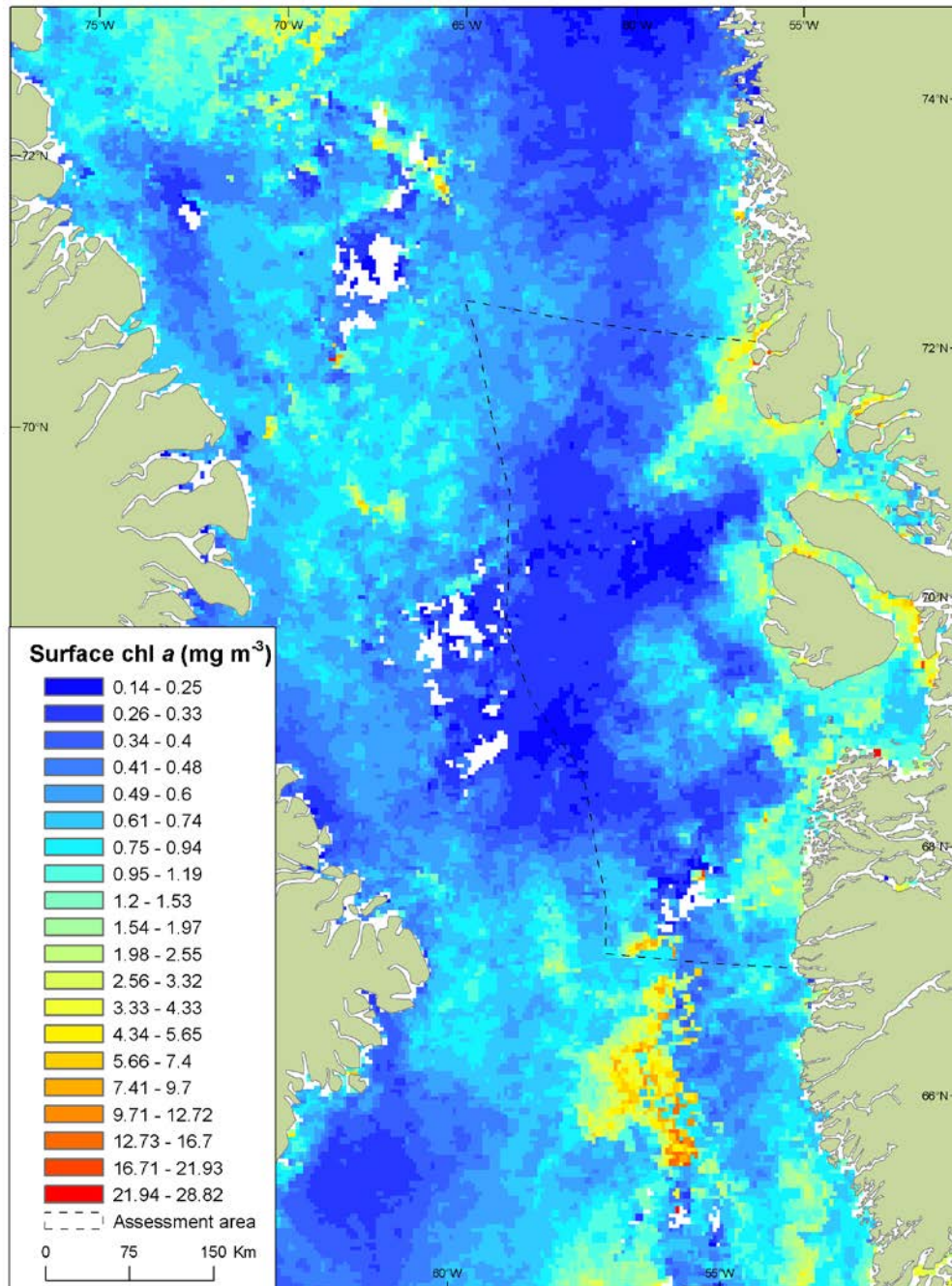


Figure 3. Sea surface chlorophyll *a* (chl. *a*) concentrations (mg m^{-3}) in September 2009. Data are presented as a monthly average from MODIS level 3 aqua. The colours indicate different chl. *a* concentrations: blue areas - very low; red - high chl. *a* concentration; white - no data. The chl. *a* concentration showed relatively high levels, mainly in the northern Davis Strait, at Store Hellefiskebanke and close to the Greenlandic coast. A high chl. *a* concentration was also observed more locally in Disko Bay, Vaigat, Nuussuaq and in the northern limits of the assessment area. (Source: Oceancolor homepage, NASA).

The relatively high biomass on the Canadian Shelf (CS) as well as the spatial distribution of the zooplankton are likely a result of the surface and subsurface chl. *a* concentrations in that area. A high zooplankton biomass was also found at Store Hellefiskebanke (0-50 m), in the

southern part of the assessment area, where the main surface chl. *a* bloom was located (Figure 4). *Calanus* represented the main species on the CS (0-50 m depth stratum; Figure 5 and 6), as well as in the deeper waters in the Deep Basin (DB) and on the Greenlandic Shelf (GS). Some spatial trends were observed for the three *Calanus* species and *M. longa* (Figure 7).

Polar cod, *Themisto* and seabirds (little auk and thick-billed murre)

The occurrence and distribution of juvenile polar cod (*Boreogadus saida*) (Figure 8) was estimated in the survey area to approximately 97×10^9 individuals or equivalent to 56×10^3 tonnes. Other fish species such as juvenile Atlantic cod (*Gadus morhua*) and sandeel (*Ammodytes marinus*) were only found at a southern station and only in very low numbers.

The relative abundance and distribution of larger zooplankton (e.g. *Themisto*) and polar cod is also apparent from the analyses of the acoustic values measured during the survey up to a water depth of 500 m (Figure 9 and 10).

Bird observations were carried out during the ship based survey according to the Distance Sampling method (Webb & Durinck 1992, Buckland et al. 2001). Observations were performed when the ship was sailing with constant speed between sampling stations, but not when trawling or operating other sampling instruments. This method allows calculating densities of the species present (Figure 11). In order to gain a better overview of the seabird distributions, an aircraft based survey was performed simultaneously, applying the same observations methods (Figure 12).

Stomach analysis of little auk and thick-billed murre collected at one location on the Greenlandic Shelf showed that the amphipod *Themisto libellula* was predominately present in stomachs of both seabird species (Figure 13).

Summary

The results from the cruise in September 2009 clearly indicate that the phytoplankton was in a post bloom phase with max chl. *a* concentration in the subsurface (30-50 m). The distribution of zooplankton in the water column followed a similar trend as the chl. *a*. The seasonal downward migration of *Calanus* was most likely already initiated. The species distribution patterns also document well known distribution patterns.

The low zooplankton biomass in the upper water layers could also be a result of top down grazing by the present juvenile polar cod and thick-billed murre on the Greenlandic Shelf (Figure 14). The much higher abundance of little auk just off the Canadian shelf compared to the Greenlandic shelf could be a result of feeding on the relatively high concentrated zooplankton in the 0-50 m column.

It also seems that *Calanus* is widespread in Baffin Bay but mainly abundant in the shallower coastal areas. Juvenile polar cod seems also widespread in the Baffin Bay, particularly east and west of the important fishery banks. In these areas high upwelling occur bringing nutrients to the surface and creating local bloom events. These areas are of high importance for successful linkage of lower to higher trophic levels of the marine food web.

The most interesting result is the spatial overlap of a high density area for thick-billed murres and high density areas for both larger zooplankton and polar cod, indicating that the occurrence of polar cod/larger zooplankton govern the offshore density of staging thick-billed murres.

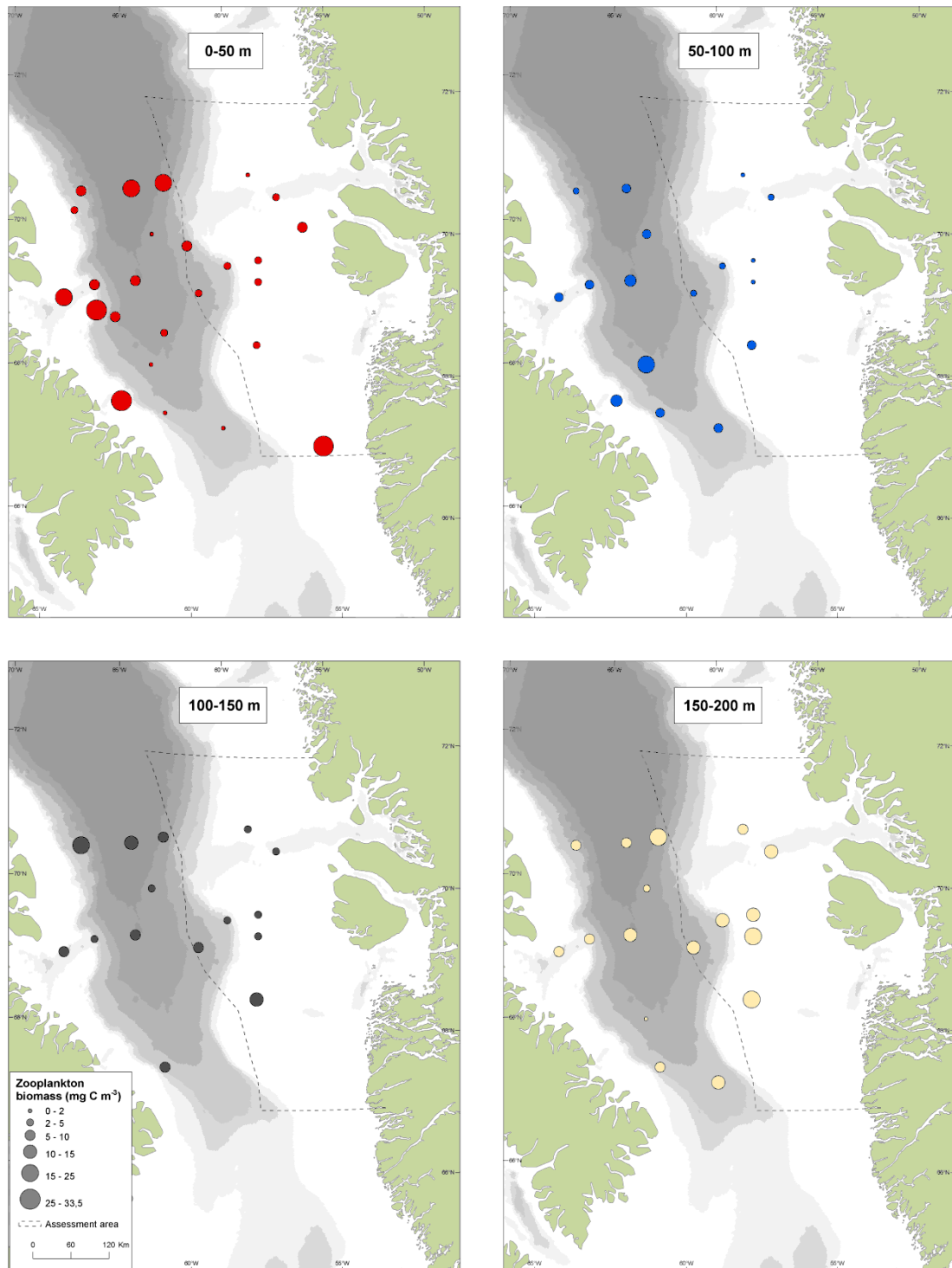


Figure 4. Zooplankton biomass (mg C m^{-3}) during the Disko West survey in September 2009 in 0-50 m, 50-100 m, 100-150 m and 150-200 m water depth. In general, the highest zooplankton biomass was found on the shelf-breaks, mainly on the Canadian shelf-break (0-100 m). On the Greenland shelf-break, the zooplankton biomass was low in the upper water column but increased with depth (150-200 m). The average zooplankton biomass in the upper 200 m was 0.6 mg C m^{-3} and varied widely, from 0.2 to 33 mg C m^{-3} among stations and depth strata.

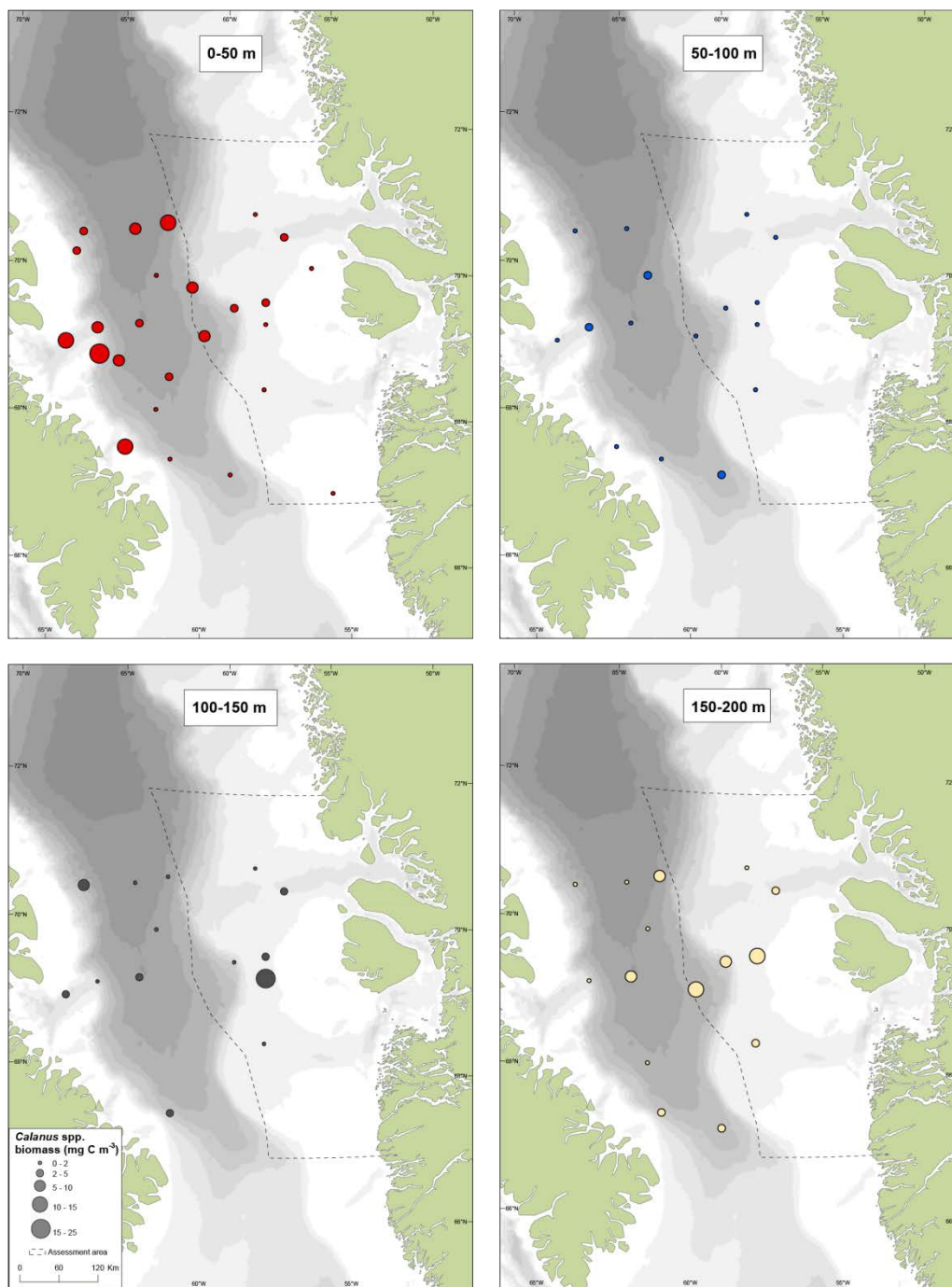


Figure 5. *Calanus* spp. biomass (mg C m^{-3}) during the Disko West survey in September 2009 in 0-50 m, 50-100 m, 100-150 m and 150-200 m water column. In the surface layer (0-50 m), a relatively high *Calanus* spp. biomass was observed on the Canadian shelf-break compared to the Greenland shelf-break. *Calanus* spp. biomass increased at the Greenland shelf-break towards deeper water layers (100-200 m). In the 200-500 m (data not shown), high biomass of solely *C. hyperboreus* were found, occupying this column, indicating that the seasonal decent for dormancy has already been initiated in *C. hyperboreus*. The *Calanus* biomass accounted for 37 % of the total zooplankton biomass (0-200 m) measured during the study (*C. hyperboreus* 19 %, *C. glacialis* 14 % and *C. finmarchicus* 4 %). Another important species was the non-*Calanus* copepod *Metridia longa*, contributing with 9 % to the overall zooplankton biomass.

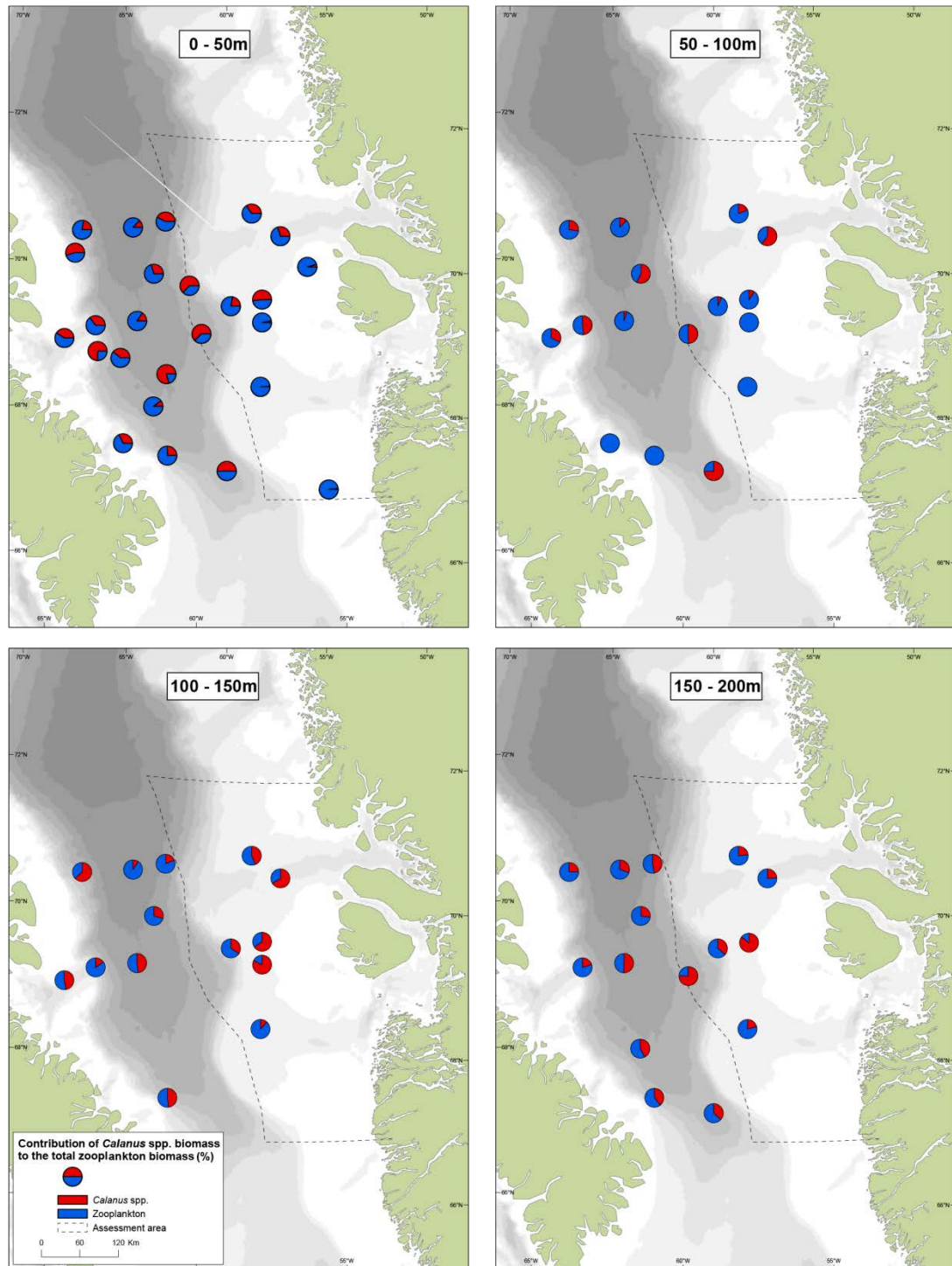


Figure 6. Pie chart of relative zooplankton biomass distribution (%) in the water column during the Disko West survey in September 2009; *Calanus* spp. (red colour) compared to the remaining zooplankton assemblage (blue) in the 0-50 m, 50-100 m, 100-150 m and 150-200 m column.

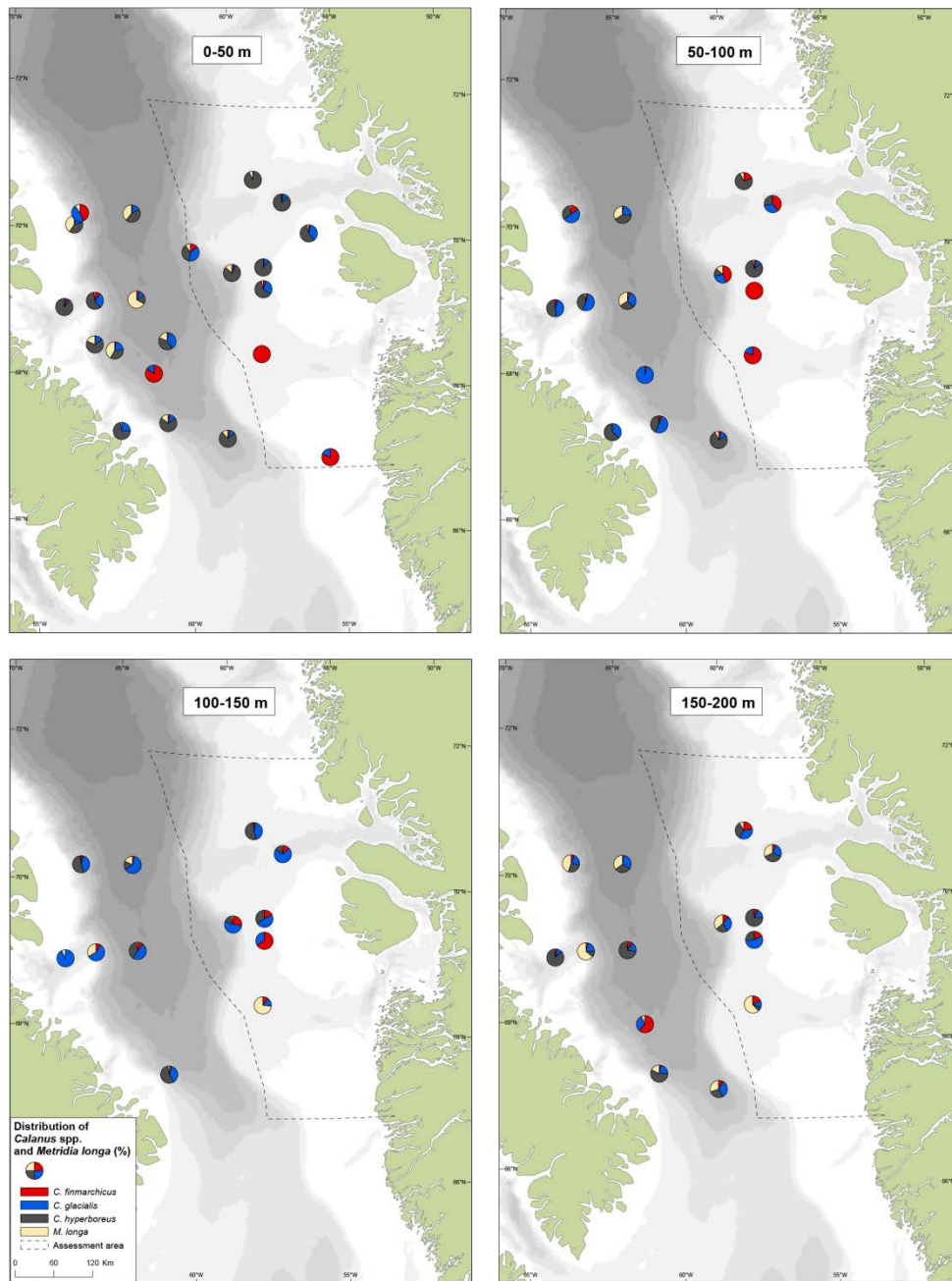


Figure 7. Pie charts of *Calanus* spp. and *Metridia longa* relative biomass contributions (%) during the Disko West survey in September 2009 in the 0-50 m, 50-100 m, 100-150 m and 150-200 m depth strata. *C. finmarchicus* is dominating the *Calanus* biomass along the Greenland coast from 68° to about 69° N in the upper 100 m. The southern distribution of the North Atlantic species *C. finmarchicus* could be a result of its transportation into the Disko West area from the south with the West Greenland Current. At the northernmost stations of the assessment area and along the Canadian coast, *C. glacialis* and *C. hyperboreus* biomasses dominated in the upper 200 m. *C. glacialis* which is of Arctic origin seems mainly abundant on the Canadian Shelf (CS) in the 50-150 m column, probably a result of the south-going cold Baffin Island Current. *C. hyperboreus*, which is predominantly Arctic, is almost exclusively dominant in the 200-500 m, mainly on the Greenland shelf (GS) (data not shown). This may indicate that the seasonal decent of *Calanus*, mainly *C. hyperboreus*, towards winter hibernation has been initiated. *M. longa* which is predominantly Arctic and living in deep water is mainly found in the 150-200 m stratum.

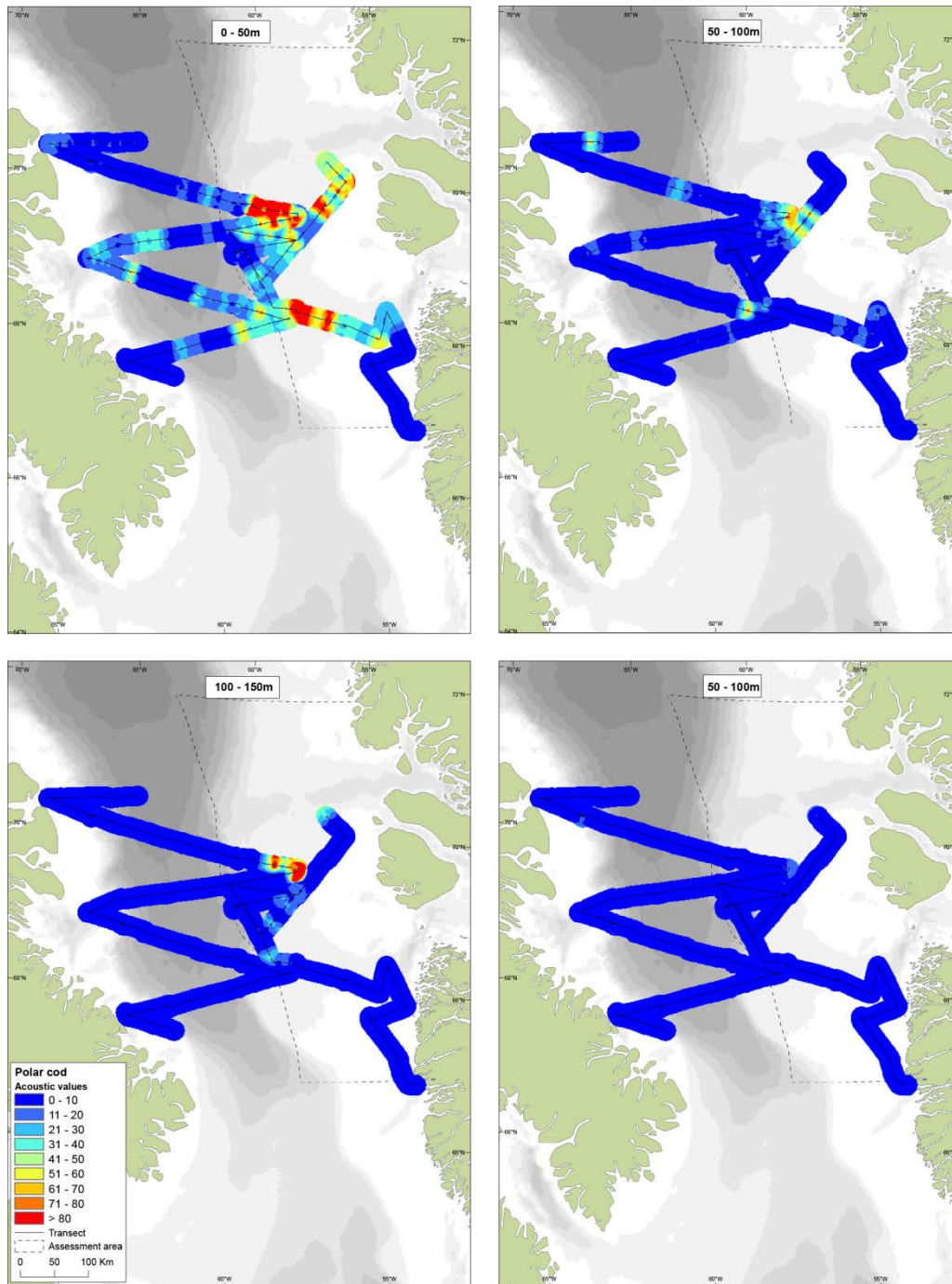


Figure 8. Abundance ($N\ m^{-2}$) of larvae and juvenile polar cod during the Disko West survey in September 2009 (red and blue dots) and during other surveys. Dark grey dots - September 2005 (Bergstöm & Vilhjalmarsson 2007), yellow, pale green, black, dark-red and light-grey dots - May-July 1996-2000 (Munk et al. 2000, 2003, Munk pers. comm. and REKPRO-data from C. Simonsen and S.A. Pedersen pers. comm.). Juvenile polar cod seems to be widely abundant in the southern Baffin Bay and Disko Bay and appeared to be more abundant in the surface waters (0-15 m) than in the deeper layers (100-290 m) during the survey in September 2009. The distribution in the northern Davis Strait is more patchy and e.g. east and west of the important fishery banks. High abundances of juvenile polar cod were found at station PT30 (25 m and 100 m) and PT39 (25 m and 120 m), respectively (see Figure 1 for station locations). Here, potential prey items were present, indicated by a high biomass of *Calanus* in the 50-150 m column, and the amphipod *Themisto libellula* which were found in the 25-120 m depth stratum (data not shown). Note: sampling gear e.g. net types vary among studies.

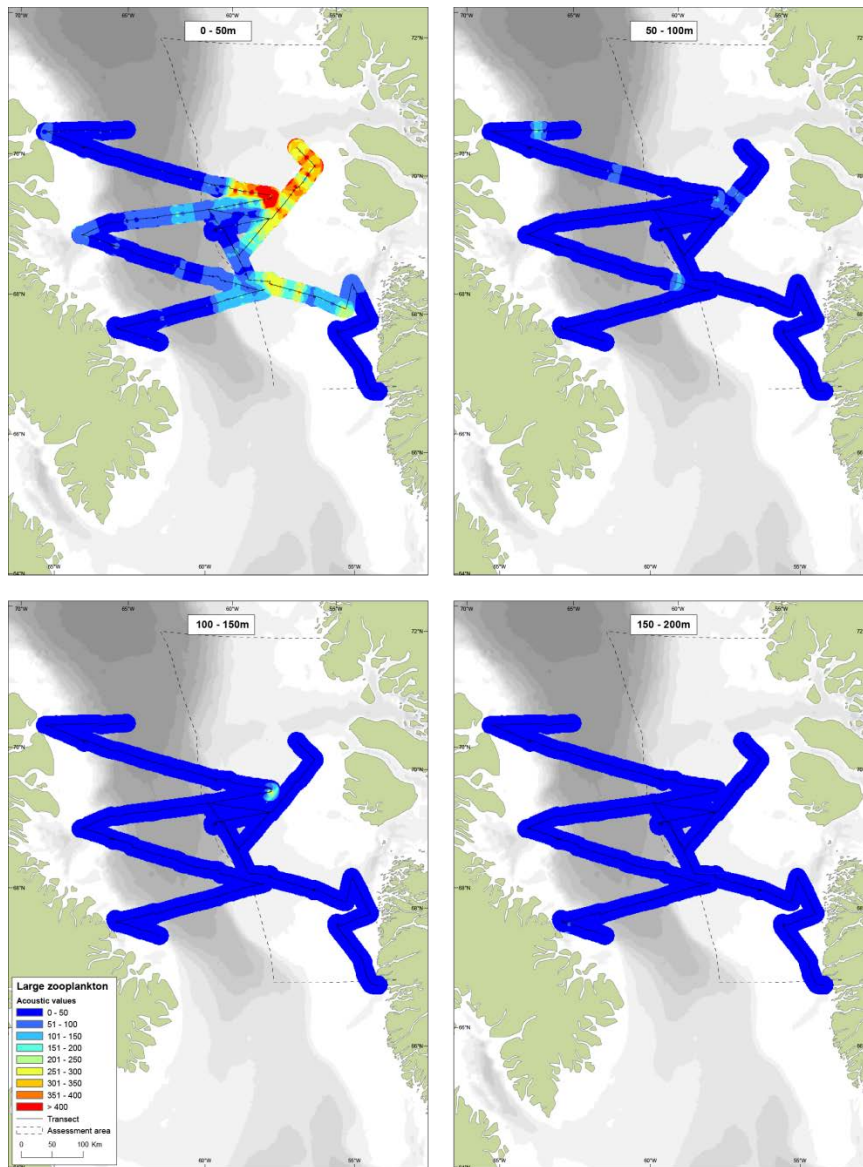


Figure 9. Spatial distribution of larger zooplankton (i.e. mainly *Themisto libellula*, size > 5 mm) based on relative acoustic values (SA-values) in the 0-50, 50-100, 100-150 and 150-200 m water columns. Acoustical separation between the different zooplankton groups (e.g. amphipods, euphausiids or copepods) was not possible using the traditional scrutinizing procedure. However, from the catch composition of trawl and bongo net samples, it was concluded that these represent mainly the larger zooplankton species (in particular the amphipod *Themisto libellula*). The analyses of the acoustic values document that large zooplankton is predominantly found in the upper water column and on the Greenland shelf. Acoustic scatters were recorded continuously during the survey. An exception was at two parts of the survey from station 1 to 3 (~22:30 on Sept. the 8th until ~18:00 on the 9th) and 27 to 31 (from ~19:00 on Sept. the 15th until ~23:00 on the 16th) where no data were collected. Continuous recording of acoustic data (measurements of volume backscattering strength (S_v , dB re 1 m²) of echo signals were obtained using a Simrad EK 500 echo sounder with hull-mounted transducer. The acoustic data from one frequency (38 KHz) were scrutinized by using BI 500 post-processing software with a S_v threshold in decibels (dB) set at -72 dB. The species identification during the scrutinizing procedure was based on information from the catch composition of the trawl and bongo net samples, the S_v threshold, and the frequency distribution of the target strength (TS, dB re 1 m²) values. Characteristics of the depth distribution of organism from the net samples were also used.

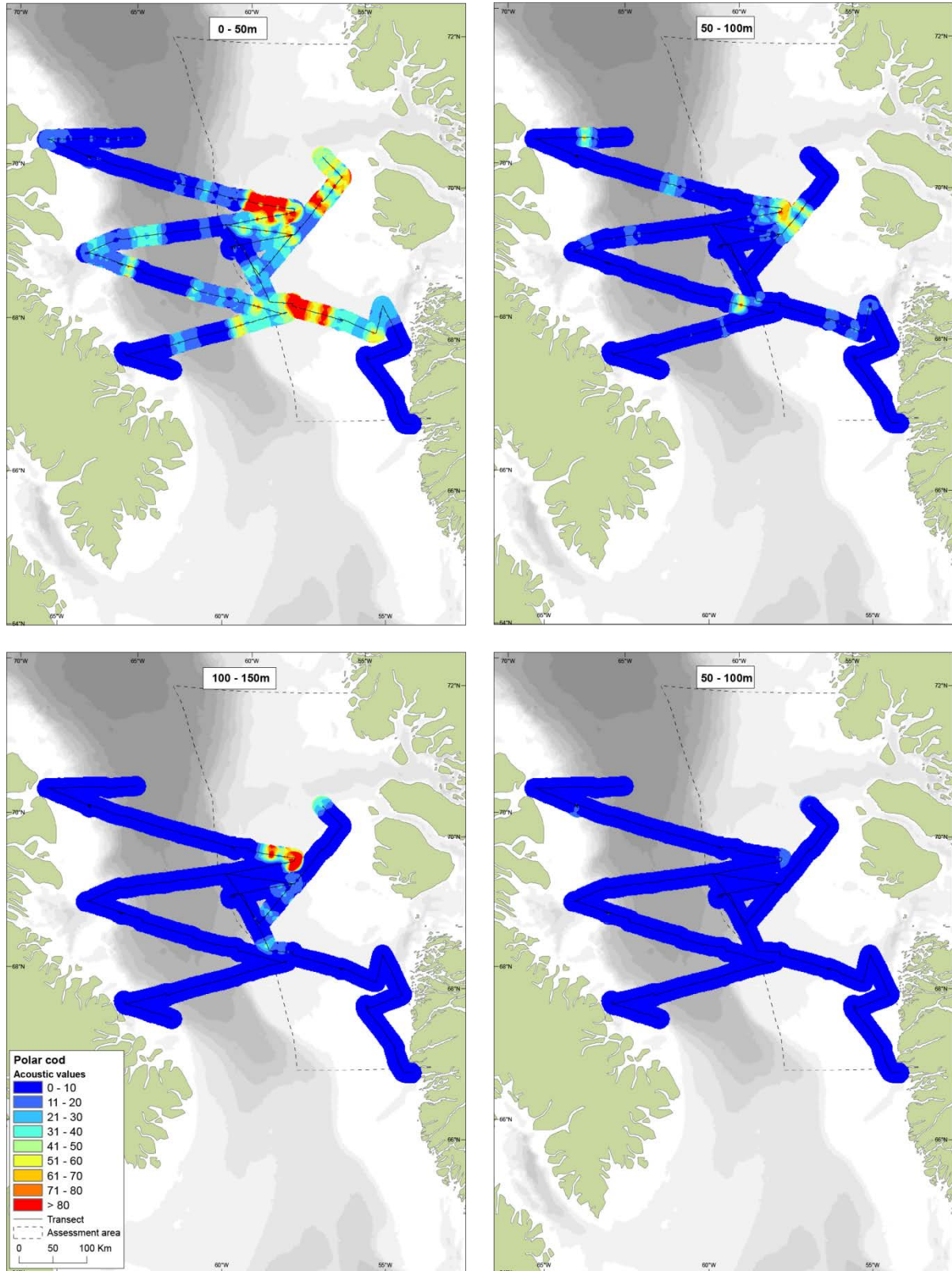


Figure 10. Spatial distribution of juvenile polar cod based on relative acoustic values (SA-values) in the 0-50, 50-100, 100-150 and 150-200 m columns. The distribution of juvenile polar cod is very similar to those of the large zooplankton (see Figure 9) and the distribution of the total acoustic registrations is therefore similar. The acoustic signal decreases with depth; however a strong signal was measured in the 100-150 m for both large zooplankton and polar cod on the Greenland shelf (St. 19).

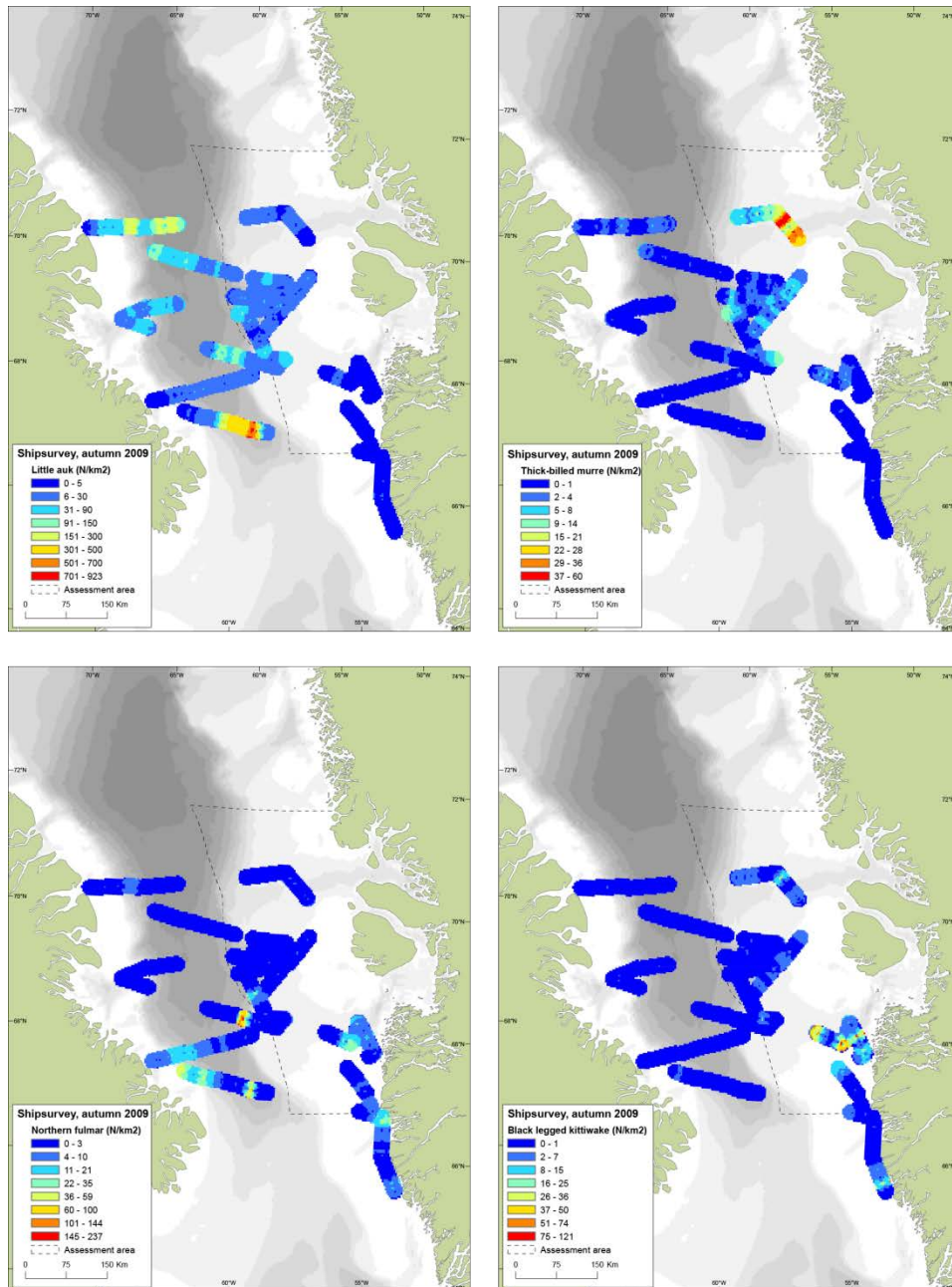


Figure 11. Densities (n/km²) of the most numerous seabird species recorded during the ship based survey in September 2009. Little auk was the most numerous species ($n = 29,000$ individuals, on transect) and they were mainly found and concentrated in parts of the Canadian shelf. These post breeding birds were either on passage on their way to winter quarters further south in the Labrador Sea or birds assembled in moulting areas (Mosbech et al. 2011). The highest densities ($n = 2000$ individuals on transect) of another species, thick-billed murres were observed on the northeastern transect on the Greenland shelf, while lower densities were found further south also on the Greenland shelf. Very few were observed on the Canadian shelf. Note that the same high density area was also recorded during the aerial survey and that it overlaps with the high-density zooplankton and polar cod area. Northern fulmar ($n = 4600$ individuals on transect) were also sighted, but more widespread and dispersed, and high density areas were usually found in areas with fishery. Black-legged kittiwakes ($n = 2600$ individuals on transect) were almost exclusively observed on the Greenland shelf with the highest densities on the northern part of the Store Hellefiskebanke.

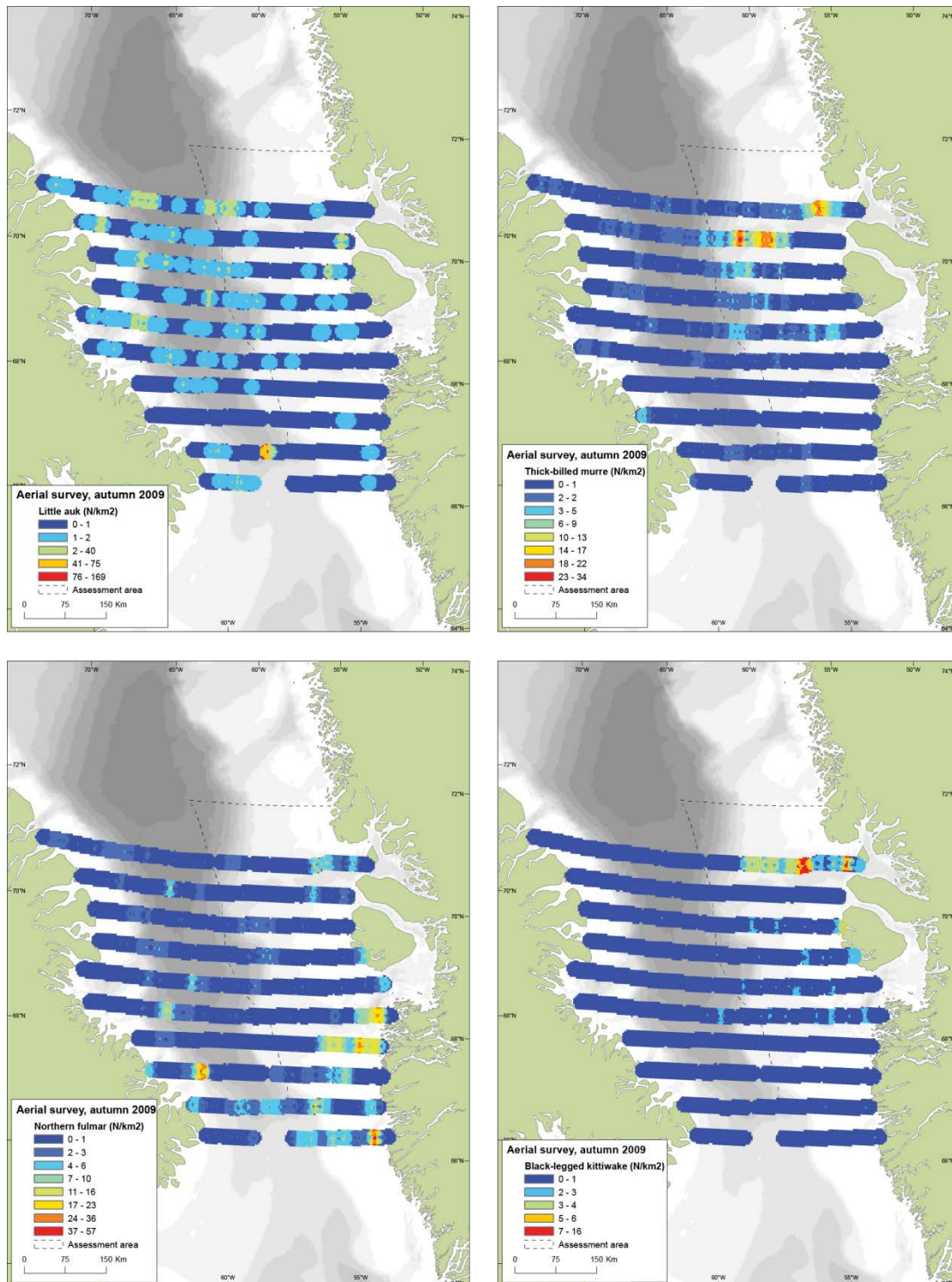


Figure 12. Densities (n/km²) of the most numerous seabird species recorded during the aircraft based survey in September 2009. Little auks ($n = 550$ individuals on transect) were more dispersed than observed during the ship based survey, but generally found outside the shelf waters. Thick-billed murres ($n = 1800$ individuals on transect) were concentrated in the same area as recorded during the ship based survey (Figure 11). Northern fulmar ($n = 3700$ individuals on transect) were concentrated on Store Hellefiskebanke (see also text to Figure 11). Black-legged kittiwakes ($n = 370$ individuals on transect) were primarily observed on the northernmost transect on the Greenland shelf.

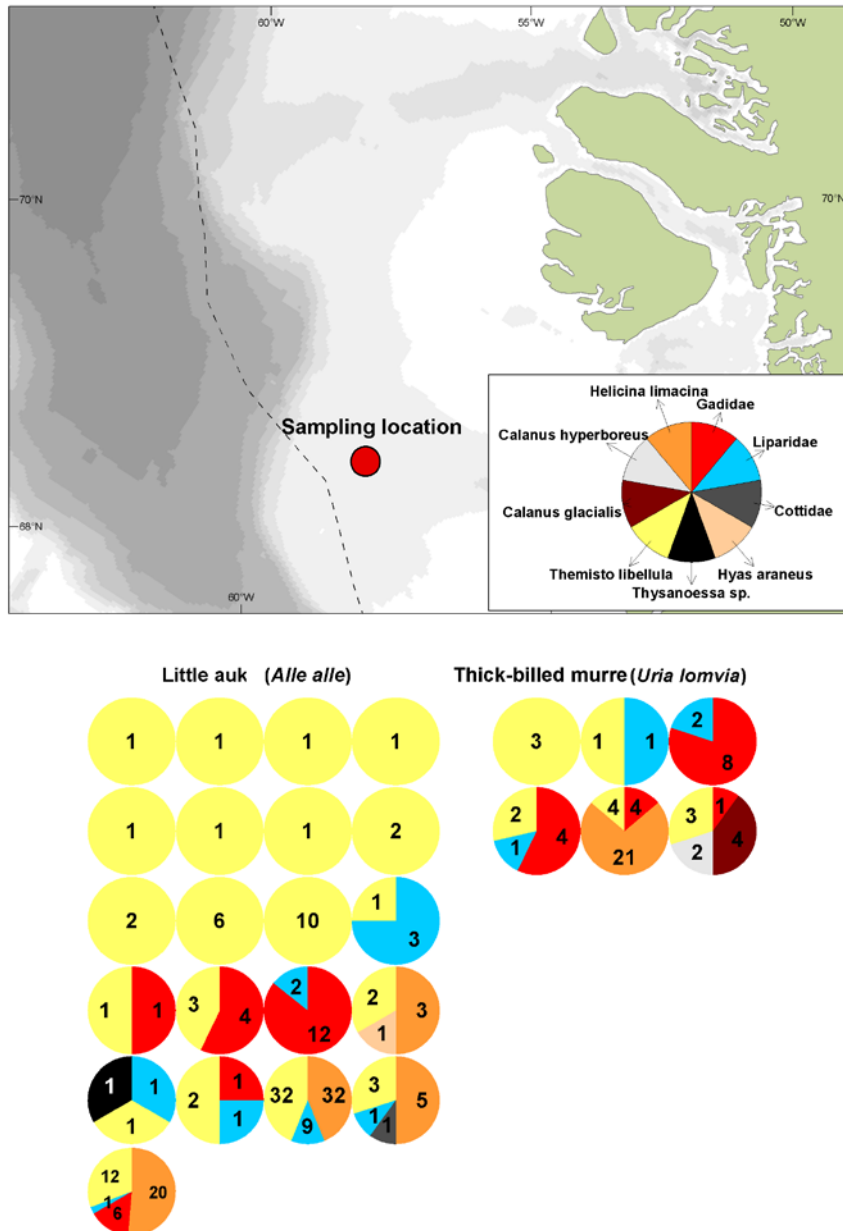


Figure 13. Pie charts of stomach contents of individual little auks ($n = 21$) and thick-billed murre ($n = 6$) collected during the Disko West survey in September 2009. Values inside pies indicate numbers of individuals of the different species ($n \text{ Ind}^{-1}$) present in the stomachs; the different colours indicate the relative abundance of species and/or families. *Themisto libellula* was found in almost all stomachs. Other species found in the stomachs of the two seabird species were juvenile fish of the cod family *Gadidae*. It can be assumed that this was polar cod (*B. saida*), since it is the only cod species found in this part of the assessment area. The cod remains in the stomachs corresponded well with the findings of relatively high abundance in net samples close to the sampling location (PT8 and PT39, see Figure 1 for station numbers). The wing snail (*Helicina limacina*) seems also to be an important food item for little auk in this area. *Calanus* occurred only in one thick-billed murre stomach. Analysis of *Calanus* from multinet and bongonet samples taken at the same location clearly showed that these species were mainly found in the 100-200 m column. Feeding on *Calanus* in that depth is considered to be rare for thick-billed murre and unlikely for little auk which is only feeding in the 0-50 m column.

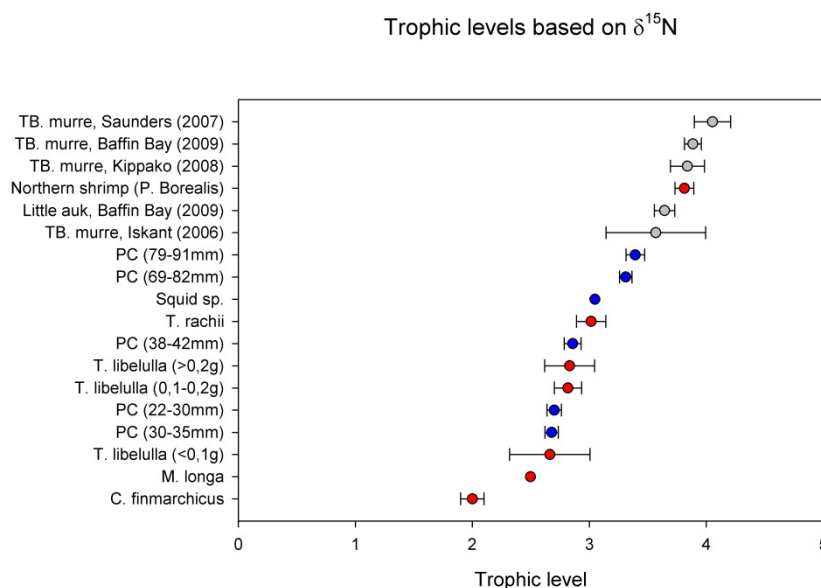


Figure 14. Trophic levels of selected zooplankton species and seabirds based on stable isotope analyses. Thick-billed murre (TB. Murre) and little auk are represented from different areas along West Greenland e.g. Saunders Island (Thule), Baffin Bay (September 2009 survey), Kippako (Upernavik) and marginal ice zone, while the zooplankton species are all from the September 2009 survey. As expected, seabirds represent the highest trophic level (~4) since they feed on the lower trophic levels such as juvenile polar cod (PC), *Themisto libellula* and copepods (*Calanus finmarchicus* and *Metridia longa*). *T. libellula* and polar cod (of different lengths, mm) feed on copepods and therefore represent trophic level ~3. Additional information for the seabird studies from the different areas can be found in Frederiksen et al. (2008) and Mosbech et al (2009).

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