Distribution and feeding ecology of fin (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*) in the Norwegian Sea during the summers of 2013 to 2018

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ABSTRACT

This study aims at describing the current (2013 to 2018) summer distribution and feeding ecology of fin whales (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*) in the Norwegian Sea. These waters function as a migration corridor and feeding ground for several cetacean species during the summer months. Oceanographic conditions, *e.g.* temperature, both at surface and in deeper waters, have been reported to be above long-term averages during the last decades. This has been found to impact prey feeding conditions and will potentially also alter traditional cetacean species composition and spatial distribution patters in the area. Cetacean sightings data were collected, in combination with concurrent collection of environmental variables, onboard vessels involved in the International Ecosystem Summer Survey in the Nordic Seas (IESSNS), covering large parts of the Norwegian Sea and associated waters. The data reveal that fin- and humpback whales are some of the most commonly observed species during all summer seasons. Similar numbers of fin-and humpback whale were observed each year, with the exception of 2014 which had an overall much lower number of cetacean sightings than other years. There was some spatial distribution variation in where the whale species where observed between each year, but most observations were made in the most northern part of the survey both species. A two dimensional Kernel-density estimation analyses revealed a pronounced hotspot for fin whales on the shelf-area between Svalbard and Norway, and around Bear Island for humpback whales. Fin whales were found associated with the occurrence of blue whiting (*Micromesistius poutassou*), capelin (*Mallotus villosus)* and mackerel (*Scomber scombrus*), humpback whales were associated with plankton and euphausiids in particular, capelin, herring (*Clupea harengus*) and mackerel. The results from this study provides and update the knowledge about these large cetacean species distributions and feeding patterns. This study shows a more northern distribution that differs from the previous descriptions that found a more spread and central spatial pattern and a higher association for macro-zooplankton and herring in the Norwegian Sea for both whale species.

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1. INTRODUCTION

It is still unknown how whales navigate during long distance migration but the most recognized theories are that they are influenced by the earth's magnetic field, the position of the sun, and/or learn from older individuals (Horton et al., 2011; Stern, 2002). Shifts in spatial distributional have been described for several species of cetaceans during the last decades. Some of these shifts are believed to be an indirect consequence of increasing temperatures, which in turn have influenced geographical food production and distribution (Kenney et al., 1996; MacLeod et al., 2005; Learmonth et al., 2006; Simmonds & Isaac, 2007; Laidre et al., 2008; Simmonds & Eliott, 2009; Víkingsson et al., 2009; 2014; 2015; Nøttestad, et al., 2014b; 2015; Víkingsson et al., 2015). There is little knowledge related to what degree whales may alter their migration route, or how plastic they can be in habitat choice and distribution (Stern, 2002), but the general perception is that whales display low variation in seasonal site fidelity (Mackintosh, 1966; Katona & Beard, 1990; Clapham et al., 1993). Understanding how oceanographic and biological variables in the Northeast Atlantic influence the habitat choice for cetaceans is central in management and for conservation efforts against habitat loss and anthropogenic activity.

The Norwegian Sea is considered a deep-sea ocean, with an average depth of around 1700m, consisting of two major basins that define the borders of the large Norwegian Sea ecosystem. It borders to the North Sea in the south, the Barents Sea in the north and to the Greenland Sea and Iceland Sea to the west (Blindheim, 2004; Skjoldal et. al, 2004). The Norwegian North Atlantic Current (NwAC) is an extension of the Gulf Stream and transports warm saline water north along the coast of Norway into the Barents Sea and Arctic Ocean. From the Arctic Ocean less saline water is brought south at the western border of the Norwegian Sea (Blindheim, 2004; Skjoldal, 2004; Loeng & Drinkwater, 2007; ICES, 2017). In the Norwegian Sea temperature and heat content have been above long-term average since the beginning of the 2000s (ICES, 2016, 2018; Frantzen et al., 2019) . Temperatures are expected to continue to rise in the future however at a slower rate than seen from the 1990s. The increase in temperature is attributed to the inflow of warmer Atlantic water from the NwAC (Blindheim, 2004; Skjoldal, 2004; Loeng & Drinkwater, 2007; ICES, 2017; Frantzen et al., 2019). There has also been an increase in anthropogenic activity (fishing activity, seismic surveys, oil and gas extraction) in the Norwegian Sea the last decade (Blindheim, 2004; Skjoldal, 2004; Skagseth & Mork, 2012; ICES, 2017).

Fin whales (*Balaenoptera physalus*) and humpback whales (*Megaptera novaeangliae*) perform annual feeding trips to high latitudes in summer and reside at lower latitudes during the winter months where calving typically occurs (Aguilar, 2002; Clapham, 2002; Nøttestad & Olsen, 2004; Horton et al,. 2011). Popular feeding grounds in the Northeast Atlantic are usually around continental shelf areas such as around Iceland, Jan Mayen, Bear island, coastal northern Norway and Svalbard (Aguilar, 2002; Clapham, 2002; Øien, 2013; Víkingsson *et al.*, 2009, 2015; Nøttestad *et al.*, 2014b, 2015).

Sightings and descriptions from surveys gathering data on the abundance and distribution of cetaceans in the Norwegian Sea and adjacent waters have been conducted regularly since 1987 (Nøttestad & Olsen, 2004; Pike et al., 2005; Vikingsson et al., 2009, ; Øien, 2013; Nøttestad et al., 2014,2015; NAMMCO 2018). Previous studies based on these data have demonstrated that both the abundance and distribution of large baleen whales have changed in recent decades in the Norwegian Sea (Víkingsson et al., 2009; Øien, 2013; Horton et al., 2011; Nøttestad et al., 2014b; 2015; NAMMCO; 2018;).

There have also been a few studies on the feeding ecology and distribution of cetaceans in the Norwegian Sea, which suggest that these shifts seem to be linked with the structural changes in their ecosystem (Macleod et al., 2005; Laidre et al., 2010; Nøttestad et al., 2014b, 2015). This change seem to have become more apparent during the last decade, compared to earlier studies. A study based on sightings in summers of 2006 and 2007 found no apparent changes between earlier studies and their findings that both fin-and humpback whales seemed to prefer krill and amphipods and had a similar distribution pattern (Nøttestad et al., 2014b). However, in a study only a few years later, Nøttestad et al., (2015) found that fin whales seemed to have switched toward a fish prey diet and had fewer observations of humpback whales indicating a change of distribution. Humpback whales showed very low overlap between their distribution and potential prey species which contrasts with the earlier study by Nøttestad et al., (2014b), that showed higher sighting numbers and a distribution toward the northernmost waters of the Norwegian Sea associated with NSS herring (*Cluepea harengus*). This could be connected to the change in distribution and reduction in biomass of krill and amphipods in the Norwegian Sea in recent decades (Dalpadado et al., 1998; Melle et al., 2004; Buchholz et al., 2010; Krafft et al., 2013). Another important variable to consider is that valuable prey fish species for fin and humpback whales such as; herring, mackerel (*Scomber scombrus*), caplin (*Mallotus villosus*), and blue whiting (*Micromesistius poutassou*) in the Norwegian Sea have all been found to have experienced shifts in both abundance and distribution during the last decades

(Watkins, 1981: Tershy et al,. 1993; Tershy et al,. 1993; Gjøsæter, 1998; Aguilar, 2002; Hewitt & Lipsky, 2002; Berge et al., 2015; Clapham, 2002; Hjermann et al., 2004; Nøttestad et al., 2004; Sissener & Bjørndal, 2005; Heino et al., 2008; Dolgov et al., 2010; Huse et al., 2012; Payne et al., 2012; Utne et al., 2012; Nøttestad et al., 2014b; 2015; ICES, 2017; Frantzen et al., 2019) .

Fin- and humpback whales foraging thresholds are limited mainly by metabolic demand, but also foraging style. Both fin- and humpback whales need to optimize foraging behaviour, i.e feeding on high densities of prey species to meet their metabolic demands (Piatt & Methven, 1992; Laidre et al., 2010). Fin whales capture prey with lunge feeding, where they engulf water and aggregate prey in their open mouth (Lambertsen, 1983). While feeding behaviour of humpback whales is more diverse and can be categorised into two types, lunging and bubbling. (Hain et al,. 1982; Heithaus & Dill, 2002). Lunge feeding is an energy costly feeding method and the energy cost increases with body size. For fin whales with limited diving depths and periods, it is necessary to put effort in feeding on dense aggregations of prey (Piatt & Methven, 1992; Acevedo-Gutiérrez et al.,2002; Goldbogen *et al.*, 2012; 2013). Fin whales usually perform short dives around 15 minutes, and rarely dive deeper than 200 m (Croll et al., 2001; Nøttestad & Olsen, 2004). Humpback whale body type allows for more manoeuvrability and additional feeding tactics, such as cooperative bubble nets, which allows for a broader diet and feeding on lower-density prey aggregations compared to fin whales (Hain et al,. 1982; Heithaus & Dill, 2002; Croll et al., 2005; Goldbogen et al., 2012; 2013).

In this study, data from systematic cetacean sightings collected over six consecutive years (2013-2018) will be analysed to describe their current species composition and distribution pattern and potential relationships with environmental physical and biological variables. The aim is to give insight in how changes documented in the physical and biological prey environment may have caused changes in distribution and feeding ecology of fin whales and humpback whales' in the Norwegian Sea. By looking at both the physical and biological factors it is possible to better understand important driving forces such as changes in temperature and prey distribution. Prey availability is often what connects high-trophic level predators and environmental variables, and it is suspected that the lack of food availability may have caused fewer fin and humpback whales to be found in the southern and central part of the Norwegian Sea.

Understanding how oceanographic and biological variables in the Northeast Atlantic influence the habitat choice for cetaceans is central in management and for conservation efforts against habitat loss and anthropogenic activity. There has also been an increase in anthropogenic activity (fishing activity, seismic surveys, oil and gas extraction) in the Norwegian Sea the last decade (Blindheim, 2004; Skjoldal, 2004; Skagseth & Mork, 2012; ICES, 2017).

Understanding what affects the distribution of cetaceans is central in management and conservational efforts. One example is that to predict the effects anthropogenic activity such as fishing activity or seismic surveys it is important to know how many whales will be affected. In order to understand how the two whale species may respond to changes in environmental conditions, we compared overlapping distributions of prey and oceanographic conditions based on the available sources of data and information from 2013 to 2018 analysed in this study with findings in previous studies. This study builds on earlier findings of plastic responses in distribution for fin- and humpbacks whales to the changing prey community and its trophic relationships to changing environmental habitats, and our findings corroborates with this and indicate a further northern shift in distribution for both fin- and humpback whales.

2. MATERIAL AND METHODS

The data used in this study, was collected during the International Ecosystem Summer Surveys in the Nordic Seas (IESSNS), during six consecutive summer seasons from 2013 to 2018 (Table 2.1). It is in the summer months that both fin and humpback whales display the densest distribution in the Norwegian Sea and surrounding waters for feeding, making it the optimal time to observe the summer feeding distribution of the whales. The geographical survey coverage was designed based on the expected main distribution of pelagic fish species, especially the North East Atlantic (NEA) mackerel. The project is a collaboration between Norway, Iceland, Denmark, Greenland, and Faroe Islands and is coordinated by the Institute of Marine Research (IMR) in Norway. However, the scientific information used herein was obtained from only the Norwegian vessels surveying primarily in the Norwegian Sea (Table 2.1) (ICES (WGWIDE), 2013, 2014, 2015, 2016, 2017, 2018).

Table 2.1. Survey effort during the IESSNS by each Norwegian vessel 2013-2018.

Year	Survey period (d/m)	Vessel	Length of cruise track (nmi)
2013	6/7 -29/7	Libas	4213
2013	6/7 -29/7	Eros	3454
2014	2/7-28/7	Brennholm	4283
2014	2/7-28/7	Vendla	3462
2015	3/7-28/7	Brennholm	4395
2015	1/7-28/7	Eros	4511
2016	1/7-30/7	Vendla	3813
2016	1/7-30/7	M.Ytterstad	3731
2017	5/7-4/8	Vendla	5735
2017	5/7-4/8	Kings Bay	4969
2018	4/7-5/8	Vendla	5275
2018	4/7-5/8	Kings Bay	5205

The surveys followed the predetermined transect lines, keeping a nominal vessel speed of 10 knots, and sampling stations were spaced approximately 60 nautical miles (nmi) apart (Figure 2.1). Cetacean sightings were made with the naked eye and binoculars along cruise tracks between stations and when possible documented with photographs and videos. The observations were from the bridge or roof top, by either designated whale observers or by experienced vessel-crew during all light hours. All cetaceans observed were registered with date, time, coordinates, number of individuals, and identified to species if possible. Some were only identified down to "dolphin" or "large whale". Behaviour, such as number of observed dives and the duration of dives were noted when possible. The sighting methodology employed were not designed to derive any abundance estimate. Therefore, sightings were not corrected for surface sighting probability as the aim of the observations of cetaceans were primarily conducted for use in studies related to distribution, ecology, and behaviour. Both passing and closing mode were used, where passing mode is observation while the vessel moves continuously along the transect and closing mode is when the vessel leaves the transect line to approach a sighted large group of cetaceans to identify the species, stock composition and group size (Schwarz et al., 2010). When this information is gathered, and possible documentation is made, search effort restarts (goes back to the transect and passing mode).

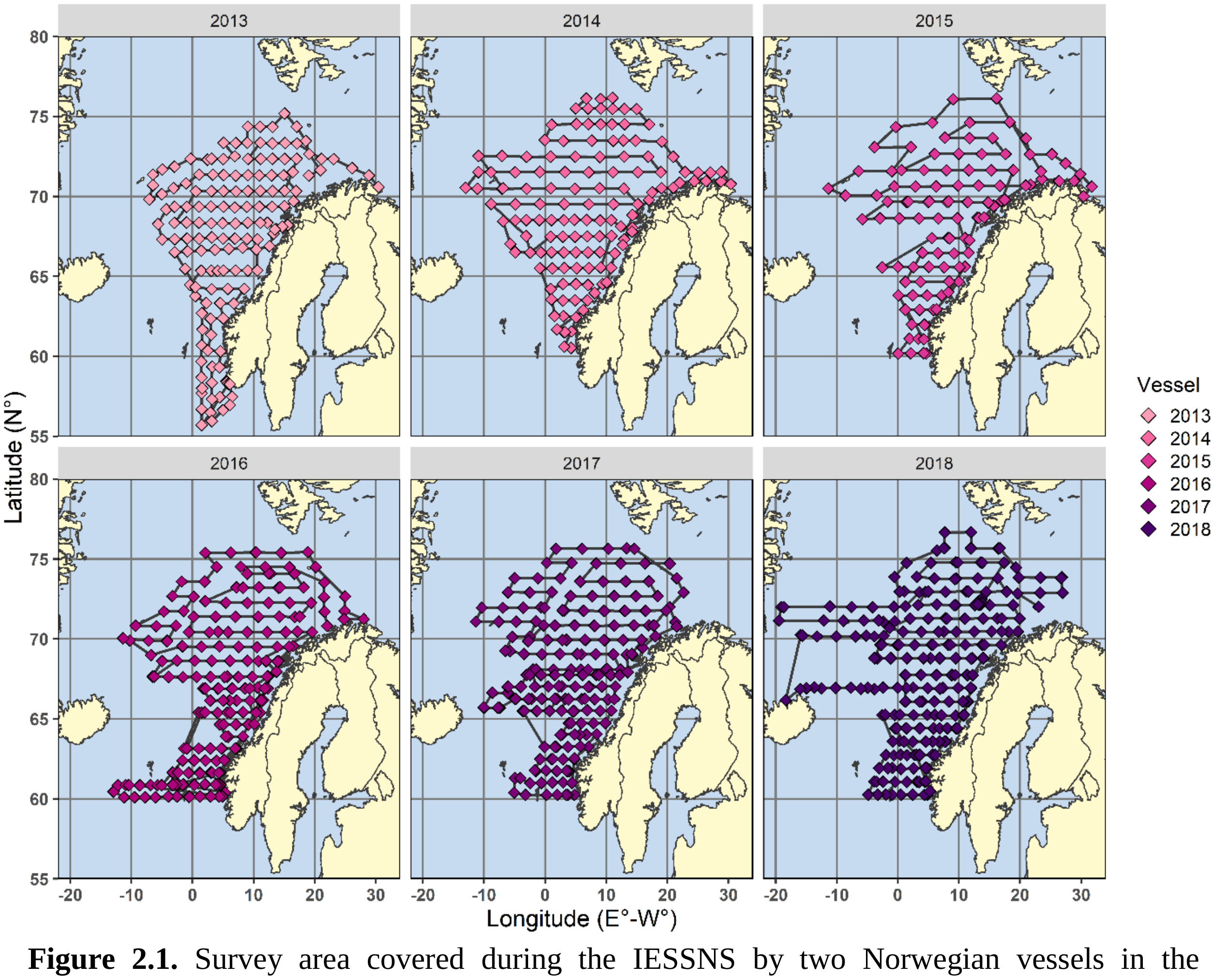

Figure 2.1. Survey area covered during the IESSNS by two Norwegian vessels in the Norwegian Sea during the summers in 2013-18. Lines illustrate cruise tracks and squares represent stations for biological (trawl and zooplankton) and oceanographical (CTD casts) data sampling.

Data from the acoustic echosounders and multibeam sonar were occasionally used in order to detect potential prey species close to the whales, or to get an overview of concurrent prey patches in relation to whale observations (Appendix A.5). Sonar and echosounder logged continuously throughout the cruises. Acoustic recordings were collected with multifrequency echosounder (Simrad fisheries sonar SX90 all years except M/V “Kings Bay” where in 2018 SH90 was used) calibrated for 18, 38, 70, 120 and 200 kHz. These recordings were used to closer observe feeding events with large groups during closing mode in order to get determine prey and feeding behaviour. The different instruments and settings were in accordance with the recommendations for pelagic fish from the manual for International Pelagic Surveys (IPS) in ICES (Appendix A.3).

Station work included collection of meso- and macro-zooplankton, using a 180 µm meshed WP2 net. The net was hauled vertically to surface from 200m, or five meters above the bottom at shallower stations, at 0.5 m/s. The net was rinsed with seawater from the outside on deck before the codend was emptied. Half of the samples were size fractioned, dried (24 hours at 70°C) frozen and weighed on shore for biomass calculations, following the procedures described in the Working Group on International Pelagic Surveys (WGIPS) (2014). The other half of the zooplankton samples were fixated on 4% formaldehyde and borax buffered seawater for taxonomic species determination on shore. Nekton were sampled using a Multpelt 832 trawl. Trawl gear methods for rigging and operations followed the manual for International Pelagic Surveys (IPS) (ICES, 2013a; Working Group of International Pelagic Surveys, 2014). Trawl hauls were taken on every station, and trawl catches were sorted to the nearest taxonomic level. Weights, lengths and maturity stages were determined immediately after catch landed on deck.

A SAIV (SAIV A/S, Environmental Sensors & Systems, Norway) or SEABIRD (SEA-BIRD Scientific, USA) Conductivity Temperature Depth (CTD) sensors were used to collected environmental information from each station. The CTD was hauled vertically from 500 m depth to surface at each station. Bottom depth was extracted from the National Oceanic and Atmospheric Administration using the function getNOAA.bathy (NOAA, https://www.noaa.gov/) from the marmap package (Pante and Simon-Bouhet, 2013)

All statistical analyses were performed, and data plotted, using the software R version 3.4.2 (R Development Core Team 2017; http://www.r-project.org) in R studio (RStudio Team, 2016).

Graphical visualizations of the spatial data for different parameters were all plotted using packages ggplot2, ggmap, maps, mapdata, marmap and ggspatial (Kahle and Wickham, 2013; Pante and Simon-Bouhet, 2013; Becker et al., 2018: Wickham, 2016; Dunnington, 2018). To test whether there were significant differences between the years, number of observations for fin– and humpback whales was compared using a linear mixed effect model (lme) with number of whale individuals in each observation as the response variable, and year as the categorical predictor (Table 2.2). Each station was set as a random effect factor (uninformative factor levels), with station names not replicated over the years. The relationship between the whale species and prey species were analysed with Pearson product-moment correlation, and a generalized linear model (glm). Observations that could not relate to a station less than 30 nmi (55.6 km) from their closest station were not used in either analyses. They were used in graphical visualizations and in analysis of latitude, but not used with prey species as they could not be connected with any catch data. Altogether 26 observations were removed and can found in the Appendix A.2. An alpha of 0.05 was used to indicate statistical significance ($p<0.05$).

Table. 2.2 Number of observations of fin- and humpback whales made each year during the IESSNS

Year	Observations of Fin Whales	Observations of Humpback whales
2013	23	12
2014	10	2
2015	24	19
2016	23	15
2017	28	6
2018	21	19
Sum	129	73

Centre of Gravity (CoG) for each year was calculated and graphically visualised for both whale species. The CoG was calculated by using the average of all longitude and the average of all latitude points and weighted against the number of individuals observed at each point. A function taken from McGowan 2018, was adjusted to the dataset with all fin and humpback whale observations and used to calculate the CoG in R (McGowan, 2018) (Appendix A.4).

Kernal density maps were made by pooling all the samples and preforming a two-dimensional kernel density estimation (kde2d) using stat_density_2d function from the "ggmap" package in

R (Kahle & Wickham, 2013). Each sample of catch was converted into a pseudo-frequency where the prey species catch was rounded up to the nearest whole number. From this, maps showing hotspots of all fin-and humpback whales, prey species and temperature were made. These maps are used to visualize density and spatial distribution based on the available catch data; the scales are not equal across maps. Based on the visualisation of hotspots the observation data was divided into two groups, inside the hotspot and outside the hotspots. The groups were compared for both abiotic and biotic factors, such as temperature and prey species abundance. Each variable was tested for significant differences using a Wilcoxon rank sum t-test with continuity correction.

The relationship between the fish species, krill/amphipod catches and fin- and humpback whale observations was analysed using Pearson's product-moment correlation test assuming a linear relationship between amount of prey with predator. The relationship between temperature and bottom depth, and fin-and humpback whales were analysed using Spearman rank-order correlation test. All years were analysed together. Spearman rank-order correlation looks at a monotonic relationship and is based on ranked values and was used to test the associations between temperature and bottom depth with the whale species.

A generalized linear model regression analysis, using a quasipoisson distributional fit, was used to test the relationship between fin- and humpback whales and their prey species. The station catch data for mackerel, herring, capelin, blue whiting and krill was used as predictor variables, and the number of whales observed within a 30nmi distance of the station was included as the response variable. A generalized linear model (glm) was chosen to look at the relationship between the prey species and the whale species, using a quasipoisson distributional fit in order to account for the extra variance of overdispersion.

3. RESULTS

A total of 608 cetacean observations, including 2565 individuals, were sighted in the Norwegian Sea during summer in the IESSNS between 2013 and 2018. In total 13 different species were observed during the six summer seasons, some of them every year (fin whale, humpback whale, killer whales (*Orcinus orca*), minke whales (*Balaenoptera acutorostrata*), white-beaked dolphins (*Lagenorhynchus albirostris*) and sperm whales (*Physeter macrocephalus*)). Some were only observed in certain years (blue whale (*Balaenoptera musculus*) in 2018; bottlenose dolphin (*Hyperoodon ampullatus*) in 2014; harbour porpoise (*Phocoena phocoena*) in 2013; pilot whale (*Globicephala melas*) in 2014 and 2016; sei whale (*Balaenoptera borealis*) in 2014; white-sided dolphin (*Lagenorhynchus acutus*) in 2016-2018) (Figure 3.1). In addition, 163 individuals were not identified to species, these had a distribution all over the Norwegian Sea (Figure 3.1, Appendix A.1). The two species focused on in this study, the fin and humpback whales were some of the most common, of the total 608 observations 22.1% (129) were fin whales and 12.0% (73) humpback whales (Table 3.1, Appendix A.1). Most observations of all species were made between 70°N and 75°N, and within 0°E to 20°E, including a high number of sightings on fin- and humpback whales. However, there was no clear pattern or visual correlation in distribution between the different cetaceans but there seemed to be some spatial overlap for several whale species (Figure 3.1, Appendix A.1).

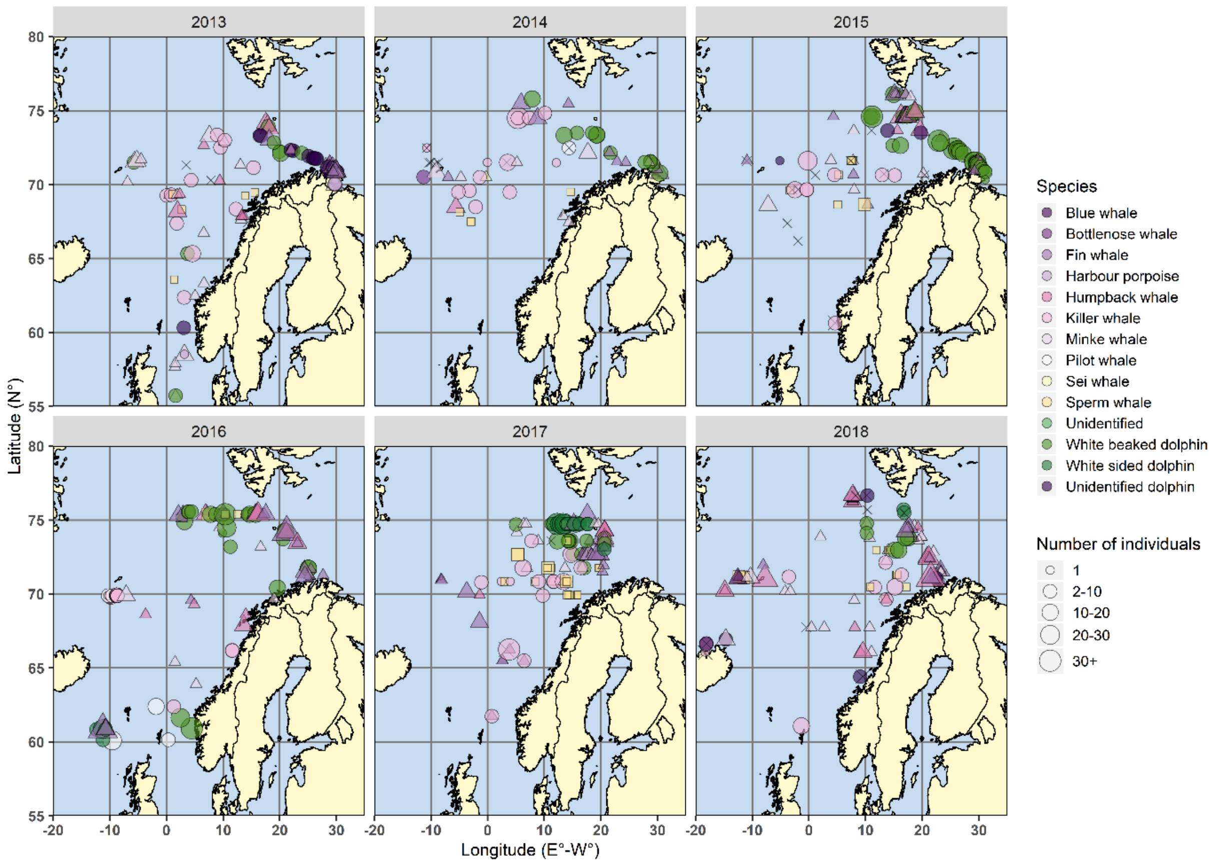

Figure 3.1 Distribution of sighted cetaceans during the IESSNS in the Norwegian Sea during t he summers in 2013 to 2018. Shape indicates family, *Balaenopteridae* Δ, *Delphinidae:* ○, *Physeteroidea* □ and Unknown: X. Colour indicates species.

Similar numbers of fin- and humpback whales were observed, with the exception of 2014 (Figure 4.5). The linear mixed effects model (lme) did not find any significant difference between the years for neither fin whales (p-value = 0.977) nor humpback whales (p-value= 0.153) (Table 2.2). Overall a larger proportion of fin whales were observed than humpback whales consistently over the study period (Figure 4.5, Table 2.2). Most observations were of single individuals, 61.2% of fin whale observations and 50.7% of humpback whale observations were of lone whales (Figure 3.2). Of the fin whale observations 38.4% and 19.2% of humpback whales were of groups of two, often representing a mother and calf (Appendix A.6) In 2016 and 2018 five observations were made of large gatherings including up to 50 and 100 individuals in 2016. These years had a higher average group size than the other years, especially for fin whales in 2016. These observations were not found to be connected to any environmental and biological stations, but supplementary data, such as sonar and echogram recordings and comments made by the observers, showed that they were assumed to be feeding on capelin and blue whiting (Appendix A.5).

Most observations of fin whales (70.5%) and humpback whales (63.0%) were made between 70-75 °N (Figure 3.2A, 3.3A). Only a few fin whales (3.9%) and no humpback whales were observed below 65 °N. However, there were more humpback whales (21.9%) between 65-70 °N than fin whales (6.2%). In contrast there were more fin whales (19.4%) than humpback whales (15.1%) above 75 °N (Figure 3.2A, 3.3A). This was also where most surveys had their northernly most limit (Figure 2.1).

A large part of the fin whale sightings was made along the shelf area between Svalbard and Norway, and those observed in the centre of the Norwegian Sea were also often found along shelf areas or around islands (Figure 3.2A). The spatial distributions of observations in the Norwegian Sea have varied and the centre of gravity (CoG) marked in the figure show that the differences between years was enough to move the CoG between the 10 and 20 °W longitude, but mostly stayed within the same latitude °N (Figure 3.2B).

Most observations of humpback whales were gathered around Bear Island, and the shelf area between Svalbard and Norway (Figure 3.3A). Individuals observed in the Norwegian Sea were also often found along shelf areas or around islands (Figure 3.3A). The distribution each year varied enough to move the centre of gravity between years both in terms of longitude and latitude (Figure 3.3B).

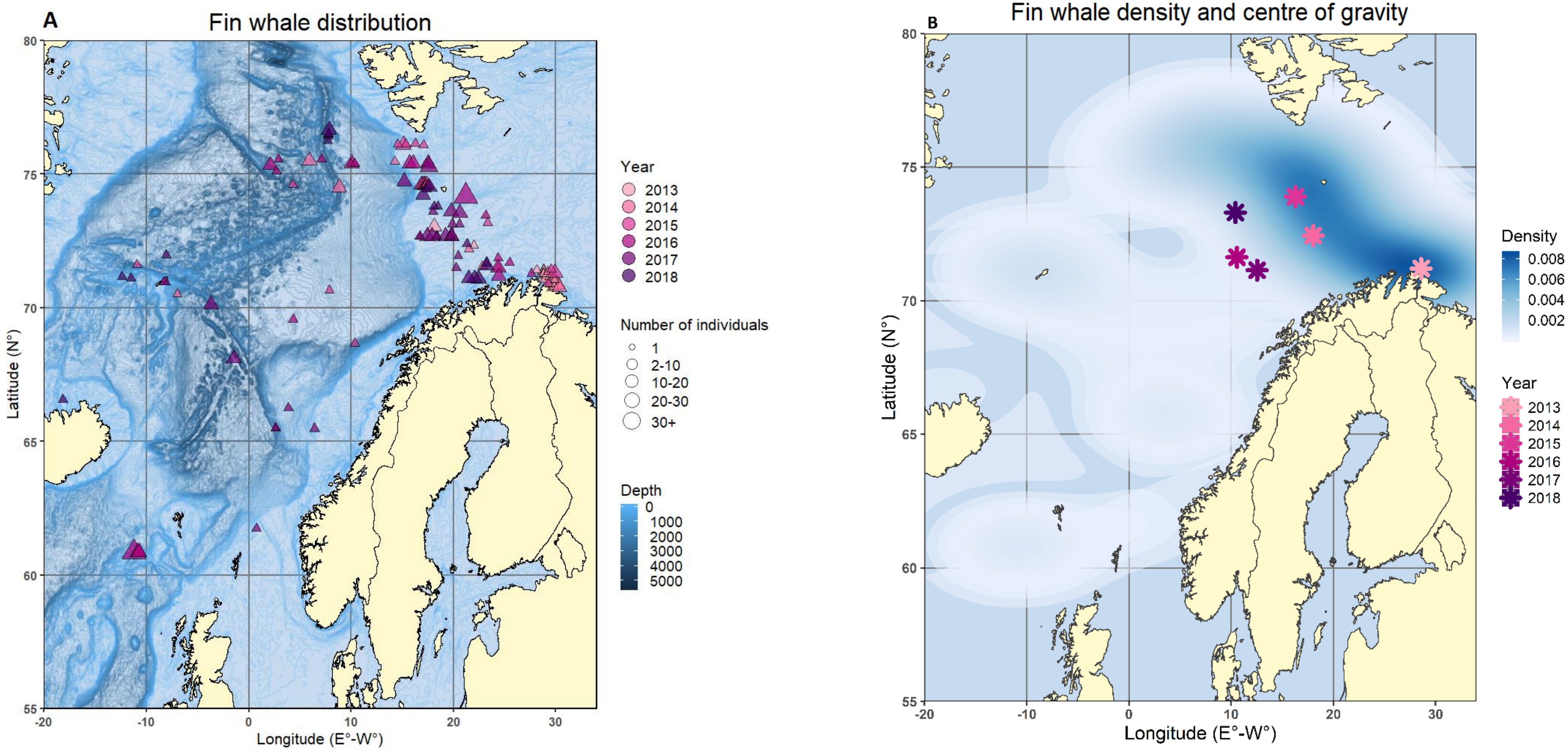

Figure 3.2. (A)Distribution of fin whales observed during the IESSNS in the Norwegian sea during the summers in 2013 to 2018. Triangles represent each observation, and size of the triangle indicate the number of individuals. Depth is based on bathymetry data from NOAA where colour indicates depth. (B) Hotspots of fin whales defined by two-dimensional kernel density estimation. Density is defined by the colour gradient, areas with the highest density of fin whales are dark blue, and areas outside the hotspot are white with much fewer individuals. Star markings represent the Centre of Gravity (CoG) for each year.

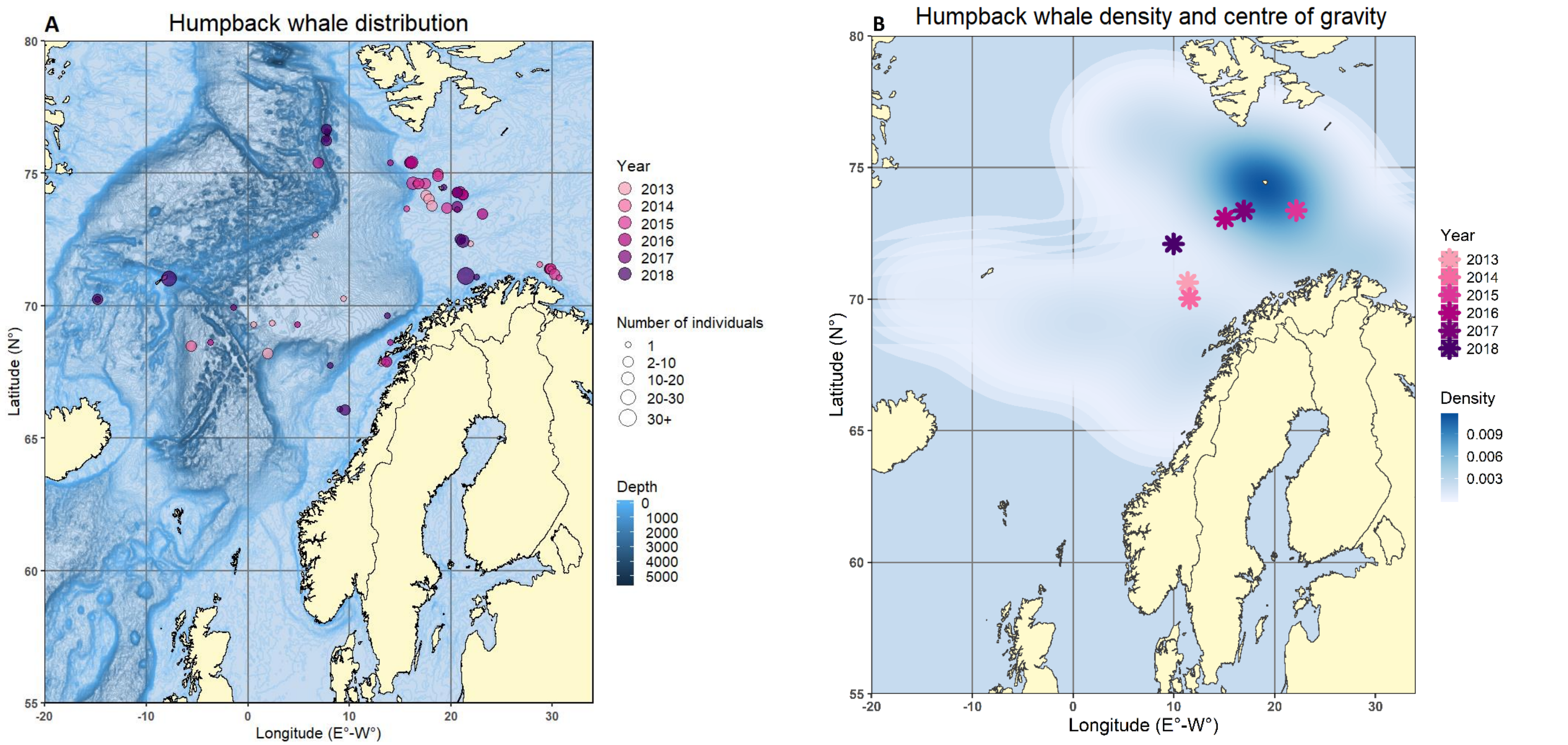

Figure 3.3 (A)Distribution of humpback whales observed during the IESSNS in the Norwegian sea during the summers in 2013 to 2018. Dots represent each observation, and size of the dot indicate the number of individuals. Depth is based on bathymetry data from NOAA where colour indicates depth. (B) Hotspots of humpback whales defined by two-dimensional kernel density estimation. Density is defined by the colour gradient, areas with the highest density of humpback whales are dark blue, and areas outside the hotspot are white with much fewer individuals. Star markings represent the Centre of Gravity (CoG) for each year.

Temperatures measured for the depths at 10 m and 20 m ranged from 0°C to 15°C, at 50 m the temperature ranged between -1°C to 11°C, while temperatures at 400 m ranged between 0°C to 8°C. Higher temperatures were found especially along the coast of Norway, but also in some shelf areas between northern Norway and Svalbard. Lower temperatures were found in western and central parts of the Norwegian Sea (Figure 3.5). Temperature at 400 m was only measured in areas that were deeper than 400 m and had a slightly different distribution of temperatures than 10 m and 20 m (Figure 3.5B).

Humpback whales were significantly negatively correlated with temperatures at 10 m and 20 m depths whereas both fin and humpbacks were positively correlated with temperature at 400 m depth (Table 3.1.) Based on this there were more observations of both whale species in areas with higher measured temperatures at 400 m (Table 3.1). But fewer observations of humpback whales in areas with higher measured temperatures at 10 m and 20 m.

By comparing the temperature between inside and outside of whale hotspots it was also found that there was a significant difference between hotspot related to all temperatures for the fin whale, but only for the temperatures at 10 m and 20m for the humpback whale (Table 3.1).

There was a significant negative correlation between both whale species and bottom depth, the hotspot comparisons also showed a significant difference inside and outside hotspots for bottom dept (Table 3.1). Showing that there is a decrease of depth in areas with high density of whale observations, that is they were more often observed in shallower areas (Figures 3.3,3.4). Mackerel, capelin, blue whiting and macrozooplankton catches were on the other hand positively correlated with bottom depth, they were associated with deeper areas (Table 3.1).

Table 3.1. Spearman's rank correlation test results for temperature and bottomdepth. Wilcoxon rank sum test output from comparing observation data from inside hotspots. ¨ Variables are shown as species and temperature with depth measured (Temp10 = Temperature at 10 m depth), or as species and bottomdepth (Bottdepth). rho is the correlation coefficient which indicate association of ranks (between -1 to 1). S is the sum of all squared rank differences.

Spearmans's rank correlation test				**Hotspot Wilcoxon t-test**
Species	**S**	**p-value**	**rho**	**P-value**
Humpback -Temp10m	75564000	**0.041**	-0.075	**0.078**
Humpback-Temp20m	76555000	**0.015**	-0.089	**0.003**
Humpback-Temp50m	73709000	0.151	-0.053	0.183
Humpback-Temp100m	65366000	0.740	-0.012	0.810
Humpback-Temp200m	46434000	0.497	0.027	0.985
Humpback-Temp400m	13850000	**0.024**	0.106	0.590
Humpback-Bottdepth	233990000	**<0.001**	-0.105	**<0.001**
Fin -Temp10m	71105000	0.758	-0.011	**0.008**
Fin-Temp20m	67447000	0.265	0.041	**0.018**
Fin-Temp50m	65909000	0.108	0.059	**0.013**
Fin-Temp100m	65602000	0.667	-0.016	**0.046**
Fin-Temp200m	47122000	0.757	0.012	**0.033**
Fin-Temp400m	13331000	**0.003**	0.140	**0.001**
Fin-Bottdepth	251830000	**<0.001**	-0.190	**<0.001**
Mackerel-Bottdepth	149350000	**<0.001**	0.2887	
Herring-Bottdepth	207420000	0.627	0.0148	
Capelin-Bottdepth	250400000	**<0.001**	0.1828	
Blue whiting-Bottdepth	182340000	**<0.001**	0.1315	
Krill-Bottdepth	71301000	0.473	0.0263	
ZooplanktonSumDryWt - Bottdepth	59021000	**<0.001**	0.1436	

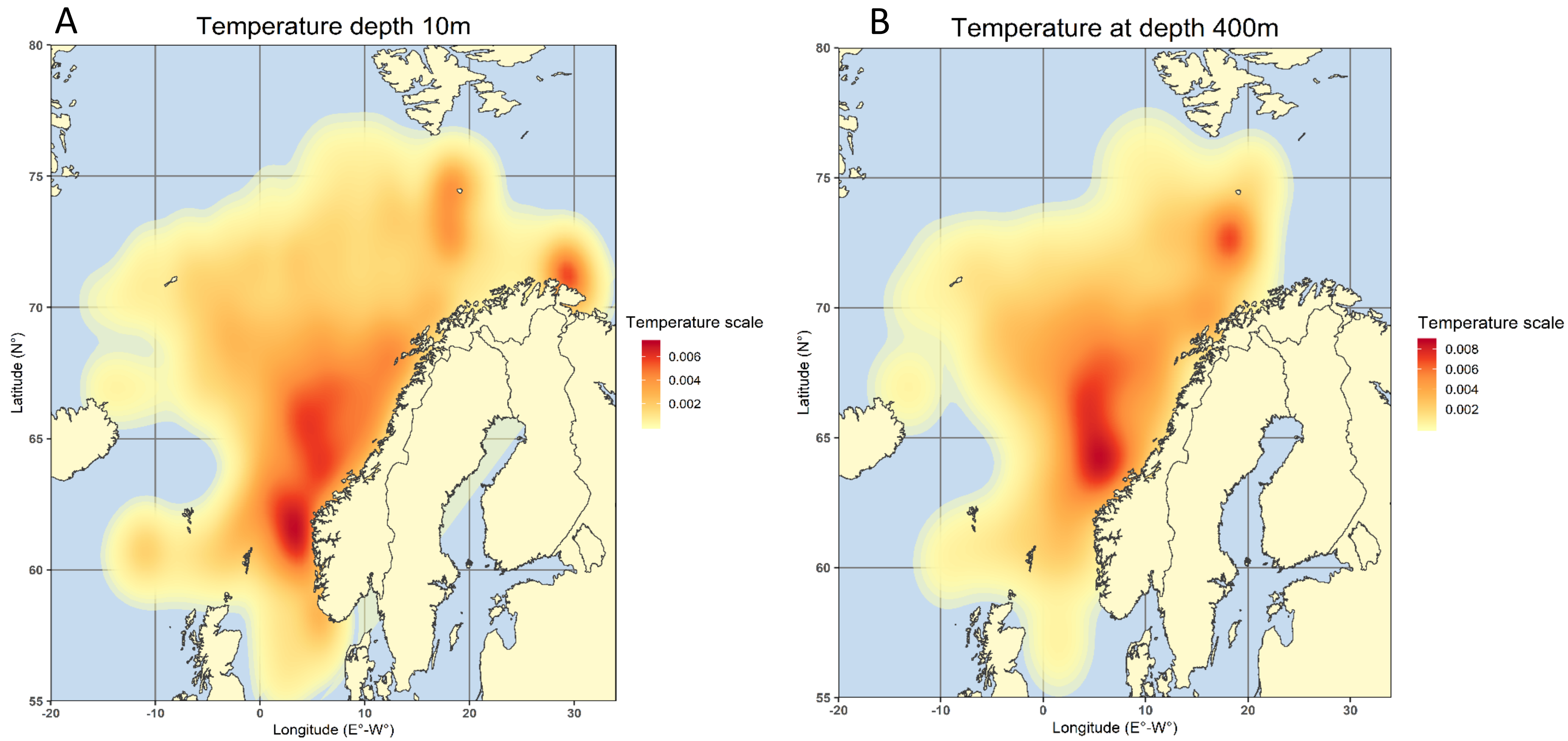

Figure 3.5. A) Temperature distribution at depth 10m, temperature at
10 m and 20 m ranged between 0°C-15°C, at 50m the temperature ranged between -1°C -11°C but had a similar distribution to 10m and 20m and is therefore represented with 10 m and 20 m by this figure. B) Temperature distribution at 400m, temperature ranged between 0°C-8°C.

Colour gradient indicates temperature scale, areas with higher temperatures have darker colours and were defined by two-dimensional kernel density estimation. CTD cast data collected during the IESSNS in the Norwegian Sea during the summers in 2013 to 2018

A significant correlation between humpback whales and mackerel, capelin, krill/amphipods, and zooplankton, but none between fin whales and any prey species were found using the Pearson product-moment correlation test.

Humpback whales, and krill have hotspots (high density areas) around or near Bear Island (Figures 3.4, 3.6). The Pearson's-product moment correlation test found a positive significant correlation between humpback whales and krill ($p<0.001$), and almost capelin ($p<0.054$) (Table 3.2). Fin whale hotspot areas stretched along the shelf area between Svalbard and Norway, and overlapped with the hotspot of krill, and high catches of capelin, and herring (Figure 3.4B, Figure 3.7).

The generalized linear model (glm) also found a significant positive interaction between humpbacks and krill, and zooplankton, but not with capelin (Table 3.2). There was a significant negative correlation between humpback whales and mackerel, which shows that abundance of humpback whales decreases with an increase in mackerel. However, the glm found a significant negative interaction between mackerel and fin whales (Table 3.2).

The t-test compared differences inside and outside the hotspots of fin- and humpback whales and found a significant difference for mackerel, herring, and blue whiting for both whale species (Figure 3.2, Table 3.2). The kernel density map indicates a hotspot for krill around Bear Island, zooplankton were found to have high density more spread out, but concentrated with the Norwegian coast

Mackerel catches through all years were higher than all others and are spread throughout the entire survey area (Figure 3.7). Capelin catches were much lower and was concentrated around Svalbard and Bear Island (Figures 3.8, 3.6A). Herring catches were often highest around Jan Mayen, or in the border of the Barents Sea and the northern part of the North Sea. Blue whiting had, as mackerel and herring, a centred distribution, but had much smaller trawl catches, (Figure 3.7).

Table 3.2 Statistical correlation between fin and humpback whale, and prey species. Regression model components and output from generalized linear model with quasipoission distribution. Data from 2013 to 2018 included in all analysis. The corr.coeff (correlation coefficient) is the strength of association (between -1 to 1).

Wilcoxon rank sum test output from comparing observation data from inside hotspots as defined in figure 3.2, 3.3.

	Correlation		**Generalized linear model**			**Hotspot Wilcoxon t-test**
Species	**P-value**	**Cor.coeff**	**Pr(>F)**	**Effects**	**F**	**p-value**
Fin-mackerel	0.219	-0.037	**0.045**	-0.002	4.029	**0.001**
Fin -herring	0.915	0.003	0.923	>0.001	0.0094	0.953
Fin-capelin	0.704	0.012	0.764	0.001	0.0904	**0.017**
Fin-blue whiting	0.849	-0.006	0.265	-0.048	1.2461	**<0.001**
Fin-krill	0.519	-0.024	0.421	-0.002	0.6482	0.161
Fin-plankton	0.800	-0.009	0.798	>0.001	0.0653	0.613
Hump-mackerel	**0.028**	-0.067	0.769	-0.001	0.0861	**0.001**
Hump -herring	0.714	-0.011	0.600	>0.001	0.2755	**<0.001**
Hump-capelin	0.054	0.059	0.210	0.002	1.5723	**<0.001**
Hump-blue whiting	0.742	-0.010	0.546	-0.001	0.3653	0.606
Hump-krill	**<0.001**	0.254	**<0.001**	0.002	13.665	0.174
Hump-plankton	**0.018**	-0.086	**0.012**	>0.001	6.4018	0.279

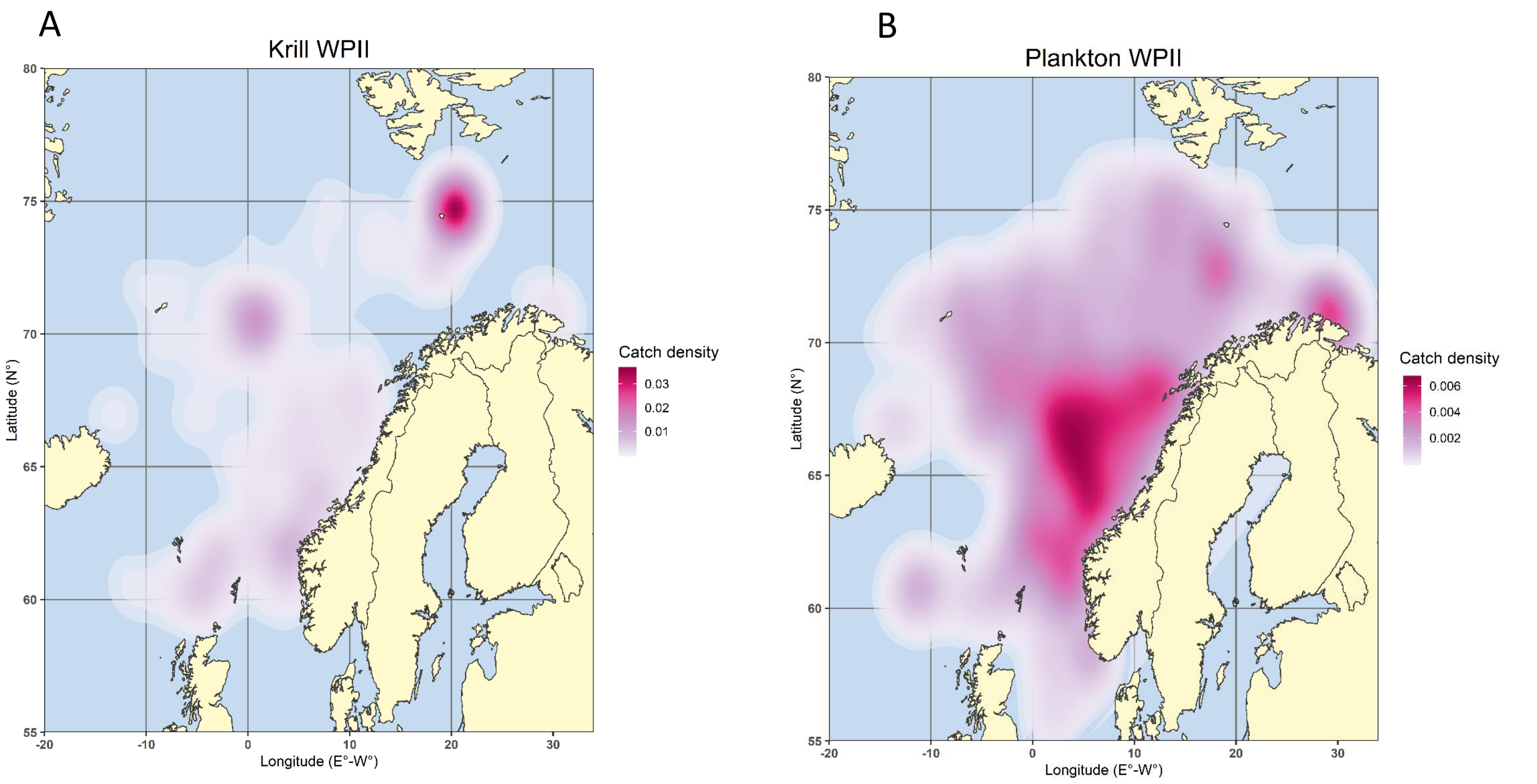

Figure 3.6. A) Krill and B) general zooplankton hotspots defined by two-dimensional kernel density estimation. Density is defined by the colour gradient, areas with the highest density of catch are darker, and areas outside the hotspot are white with much fewer and smaller catch. Both are from WPII plankton net, and zooplankton density is in sum dry weight in gram per m^3. Zooplankton collected during the IESSNS in the Norwegian Sea during the summers in 2013 to 2018.

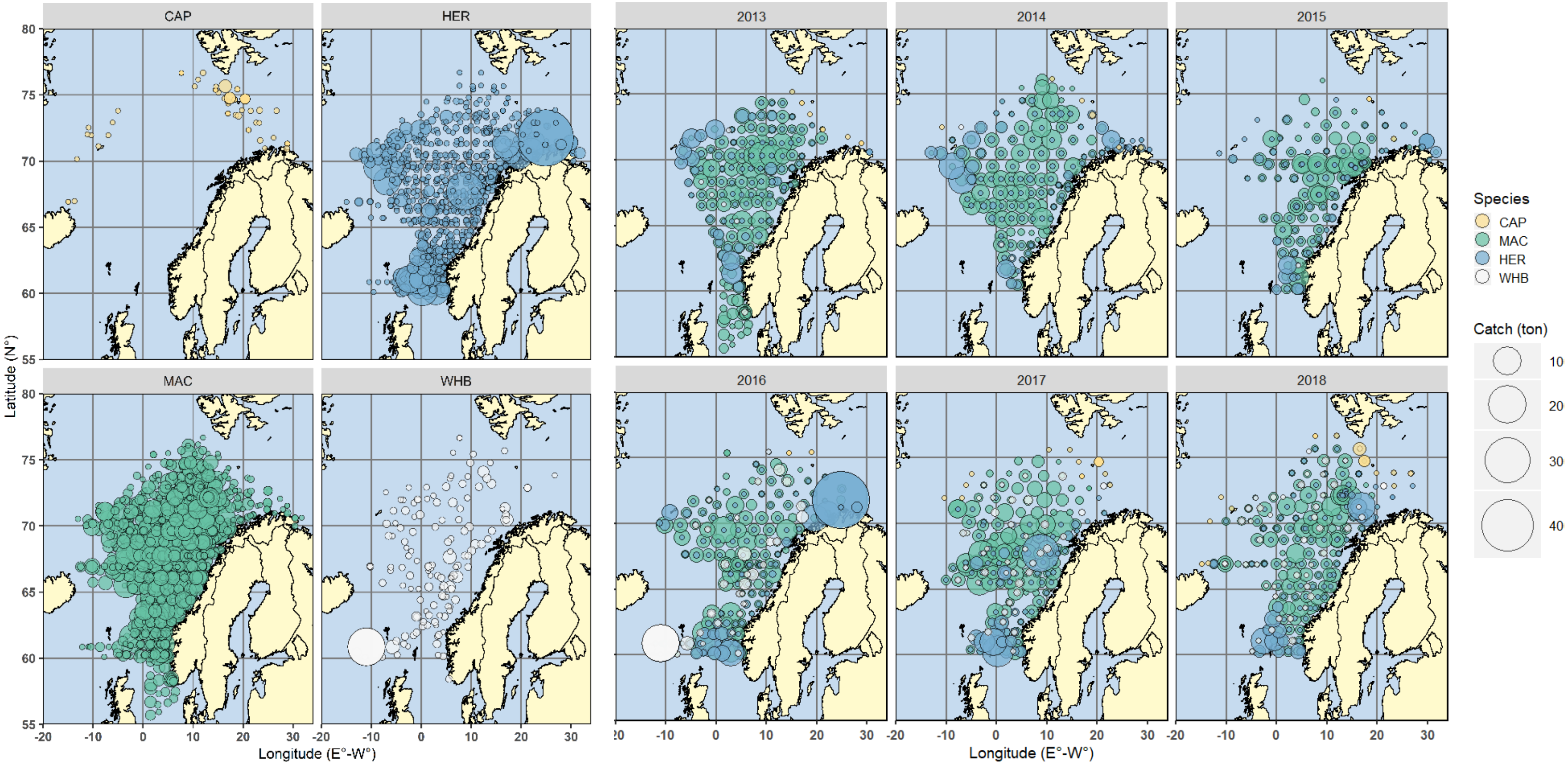

Figure 3.8. Distribution of; mackerel (MAC) in green, capelin (CAP) in yellow, herring (HER) in blue, blue whiting (WHB) in white. A) The distribution of all summers 2013-2018 for each fish prey species. B) The total catch distribution for all prey species for each year from 2013 to 2018. Circles represent station catch with size showing catch in ton, stations with zero catch are not shown. Data was collected during the IESSN in the Norwegian Sea during the summer season.

4. DISCUSSION

This study provides an update of the distribution and feeding ecology of cetaceans in the Norwegian Sea based on data collected during ecosystem surveys conducted during the summer months of 2013-2018. The highest number of sightings of cetaceans found for all years were above 70°N and were along pronounced shelf-areas during IESSNS 2013-2018. Especially large baleen whales such as fin- and humpback whales dominated in numbers at these high latitudes. This is to some extend different than reporting's of cetaceans sighted in previous ecological studies where this northern cetacean prevalence was found to be less pronounced (Nøttestad et al., 2014b; 2015). The patterns found during this study are probably linked to the available prey situation as this is a highly productive area for several pelagic fish and large zooplankton species. Several earlier studies of fin- and humpback whales have defined these areas to be important feeding grounds during the summer season (Christensen et al., 1992; Nøttestad & Olsen, 2004; Øien, 2013; Nøttestad et al., 2014b; 2015). In these studies, fin- and humpback whales were also frequently observed in the area around Jan Mayen. The shelf area around Jan Mayen has been considered a highly productive area with cold artic water, providing high densities of herring, capelin, krill, amphipods, and other zooplankton species (Blindheim, 2004; Melle et al., 2004; Skjoldal, 2004). This study however shows a more northern pattern of distribution of fin- and humpback whales during summer in the Norwegian Sea compared to earlier studies (Vikingsson et al., 2009; Øien, 2013; Nøttestad et al., 2014b)and seem to correspond to the recent findings that cetaceans such as the fin-and humpback whale are capable of rapid shifts in distribution and abundance patterns (Nøttestad et al., 2015; NAMMCO, 2018).

There has been an overall increase in temperature in the Norwegian Sea during recent decades (ICES, 2013; Frantzen et al., 2019). Increased temperatures may have both direct and indirect effect on marine ecosystems, and though changes in complex ecosystems are difficult to predict, several studies have shown that responses to increased water temperatures can lead to major changes in species composition (Hjermann et al., 2004; Perry et al., 2005; Loeng & Drinkwater, 2007; Berge et al., 2015; ICES, 2018). These changes include in shift in distribution towards more northern latitudes in zooplankton (Dalpadado et al., 1998; Skjoldal et al., 2004; Melle et al., 2004; Buchholtz et al.,2010; Krafft et al., 2013). The distribution and abundance of several fish species in the Norwegian Sea have also changed during the last decades (Watkins, 1981; Gjøsæter, 1998; Aguilar, 2002; Clapham, 2002; Hjermann et al., 2004; Sissener & Bjørndal, 2005; Heino et al., 2008; Dolgov et al., 2010; Huse et al., 2012; Payne et al., 2012; Utne et al., 2012; Berge et al., 2015; ICES, 2017; Frantzen et al., 2019). Shifts in the ecosystem structural communities often lead to a trophic cascade of effects, such as increased competition and changes in prey availability. This likely explain why we observe the prevalence of fin-and humpback whales further north during the main feeding season in the Norwegian Sea because they follow preferred prey species further north compared to previous years. The North Atlantic Sightings Surveys (NSS) have since 1987 found a high abundance of both whale species around Jan Mayen and near Svalbard in the Norwegian Sea, however in 2015 this survey found that most fin whales (80%) were seen off northern Norway (Vikingsson et al., 2009; Øien, 2013; NAMMCO; 2018). Humpback whales were in the same survey also found mostly further north and nearly all observations (~80%) were described as being off the coast of Northern Norway (NAMMCO; 2018). The findings from the 2015 NASS survey is in accordance with the observations found during 2013-2018 in this study, which further supports the claim that the area around Jan Mayen area may no longer be a preferable feeding ground for fin- and humpback whales.

While finding how distribution is related to environmental variables is useful in order to try to find a way to predict and understand the preferred habitats of these species, it must be remembered that they are often proxies for a more complex relationship between them and their environment. While both fin- and humpback whales were correlated with shallower waters in this study, this does not necessarily mean that they are dependent on shallow water in a direct physiological way, but rather that shallow water could be a reflection of the distribution of prey species or related to applied hunting strategies (Nøttestad et al., 2002). This also applies to the possible effects of changing temperatures. Both fin- and humpback whales are endotherm migratory whales, which experience a varied range of temperatures from below zero to around 30°C and should thus not physiologically be affected by the temperature fluctuations in the Norwegian Sea (Aguilar, 2002; Clapham, 2002). However, the prey species of these whales are ectotherms and are often found to be affected in varied degrees by temperature fluctuations in their habitat (Aguilar, 2002; Clapham, 2002; Hjermann et al., 2004; Perry et al., 2005; Loeng & Drinkwater, 2007; Berge et al., 2015; Nøttestad et al., 2015; ICES, 2018). This makes it difficult sometimes to distinguish between indirect and direct relationships between distribution and environmental factors.

The preference of macro-zooplankton as prey for both fin- and humpback whales in this and similar studies, are related to the energetic trade-off between the cost of prey capture and prey consumption gain. While fish species such as mackerel, herring, capelin, and blue whiting have a higher fat content than krill or amphipods, they are also more mobile and perform active antipredator manoeuvres that increase energy cost during capture (Acevedo-Gutiérrez et al., 2002; Nøttestad et al., 2004; Nøttestad, et al., 2014b; 2015). Fin whales are dependent on dense aggregations of prey due to their energy costly feeding method of lunge feeding, this also applies to the humpback whale though it is more diverse in feeding tactics (Piatt and Methven, 1992; Acevedo-Gutiérrez et al.,2002; Croll et al., 2005; Goldbogen et al., 2012, 2013). In this study large aggregations of whales were found in years with large station catches. These years had a higher average group size than the other years, especially for fin whales in 2016.

Mackerel has had high abundance throughout the entire Norwegian Sea in recent decade (Nøttestad et al., 2016). However, mackerel was significantly negatively correlated with both fin- and humpback whales. Mackerel have been found to have the highest fat content of the other prey species in this study but are also faster swimmers and may have more energy costly antipredator manoeuvres (Holst, 2004; Iversen, 2004; Nøttestad et al., 2004, 2014a). In our study they were also found to be associated with deeper waters, which could suggest the whales are limited by diving ability as well. Hence despite the strong increase in mackerel abundance in the Norwegian Sea during summer in recent years, this study cannot find any evidence that neither fin whales nor humpback whales preferred mackerel over other prey species during the summer months.

Blue whiting has also shown an increase in abundance and distribution in the Norwegian Sea, but was not correlated with either whale species (Heino et al., 2008; Dolgov et al., 2010; Payne et al., 2012; Utne et al., 2012). However, in contrast to mackerel, which showed a negative correlation indicating that they are not a preferred prey species, the catches of blue whiting were small, which would also affect the analyses and make it more difficult to pick up on any association between them and the whale species. Blue whiting is a deep-water species and often found at deeper depths than the other prey species, it is most often found at 100-600 m but can move up to shallower waters during its daily vertical migration (Monstad, 2004; Heino et al., 2008). The catches found in this study were mainly in deeper waters, and blue whiting was positively correlated with bottom depth. However, a large aggregation of up to 50 fin whales was observed feeding on blue whiting in 2016 outside the Faroe Islands (Appendix A.6). This was also where a very large catch of blue whiting was made at the same time, which indicates that there was a very high density of blue whiting to support this large gathering of whales. This is a shallower area than most catches of blue whiting were made. Altogether this indicates that while blue whiting often is dispersed to deep or in too low densities, fin whales will feed on blue whiting when energetically beneficial. This strengthens the belief that fin whales are opportunistic in prey choice but is dependent on a foraging threshold due to energy expensive feeding tactics.

Herring has been considered one of the most important prey species for both whale species, and a recent study on humpback whales in the Norwegian Sea connected humpback whales with herring in the northern Norwegian Sea (Aguilar, 2002; Nøttestad & Olsen, 2004; Nøttestad et al., 2015). Fin whales have also been observed feeding on large schools of herring in the Norwegian Sea (Nøttestad et al., 2002). However, the recruitment of herring has been low since 2004, which is assumed to be due to the decrease and northern shift of zooplankton biomass (Melle et al., 2004; Sissener & Bjørndal, 2005; Toresen, 2019). Herring catches in this study varied between the six years, where 2014 had the highest catches and 2017-2018 had the lowest catches. Neither fin- nor humpback whales were correlated with catches of herring. Norwegian spring-spawning herring has since 2009 been in decline (ICES, 2017). A study looking at the hunting tactics of fin whales on herring, found that all interactions with herring took place at night when the schools were shallower than 200m, which most likely is related to the energy limitations of their feeding tactics (Nøttestad et al., 2002). Herring catches in this study were not found to be correlated with bottom depth, since the catch was spread throughout the Norwegian Sea it would cover a too great and diverse an area for the correlation test to pick up on. There could therefore be a connection between the shallow shelf area off the coast of northern Norway and the easier availability of herring for at least fin whales.

Capelin appears to be an important and preferred prey species for humpback whales despite its decrease in abundance. Capelin stocks stayed relative stable from mid 2000s until 2013, when a decline started and by 2016 the stock had collapsed (Hjermann et al., 2004; Huse et al., 2012; ICES, 2017a,b). Humpback whales were positively significant correlated with both capelin and krill and were more often found in large aggregations and annually in areas with high capelin and krill catches. The large group of up to 100 fin whales were observed to be feeding on capelin, and a few other observations were also commented to be feeding on capelin (Appendix A.5). The catches of capelin and the fin whale hotspot did overlap, indicating that they are found in the same area. All this indicates that capelin is an important prey species for both fin- and humpback whales, something that is supported by earlier studies (Piatt et al., 1989; Piatt & Methven, 1992; Aguilar, 2002; Clapham, 2002;).

Several cetaceans were observed in the Norwegian Sea, and many observations were in close proximity to fin- and humpback whales (Figure 3.1). Minke whales were some of the most common cetaceans observed throughout all six years, and a very similar distribution to fin- and humpback whales, though the observations were more evenly spread out in the Norwegian Sea (Perrin & Brownell, 2002) (Appendix A.1). Associations between cetacean species is often explained by similar habitat preference but has been linked to having possible antipredator or foraging advantages (Söderström, 2012). Studies have found northward shifts in warmer water cetaceans in the North Atlantic, and there could be potential for increased association from other cetaceans or other trophic relationships (MacLeod et al., 2005; Nøttestad et al., 2014b, 2015). A recent study in the Norwegian Sea has found an increase in toothed (Odontoceti) whales, in particular killer whales (*Orcinus orca*), and pilot whales (*Globicephala melas*) (Nøttestad et al., 2015). Killer whales were during the six years of this study one of the most abundant species observed, and a had wide distribution throughout the Norwegian Sea (Appendix A.1). In this study there were not that many observed pilot whales, but they were observed much further north than their previously described northernly limit (Olsen & Reilly, 2002) (Appendix A.1). Sei whales and white sided dolphin have also previously been describes as having a much more southerly distribution than they were observed in this study (Hoewood, 2002; Kinze, 2002; Nøttestad & Olsen, 2004). This could however also be due to difficulties in identification, as sei whales and fin whales are very similar, the same going for white beaked and white sided dolphins (Aguilar, 2002; Hoewood, 2002; Kinze, 2002; Nøttestad & Olsen, 2004; Schwarz et al., 2010). There were a lot of sightings of unidentified dolphins, indicating a weakness in the sighting method for smaller whales. The category "unidentified" is less defined, but also quite large. Nevertheless, the findings in this study indicate that there may be a shift in the species composition in the Norwegian Sea, and further research into the relationship between fin-and humpback whales and other cetaceans in the area might uncover more about the associations between these species.

Despite the demonstration of the significant role macro zooplankton have as prey for the large baleen whales, a shortcoming in this study is the lack of representative catches of macro zooplankton. Macro-zooplankton, such as krill and amphipods were sampled using vertical hauls with WPII nets from 0-200 m depth. However, these nets with such small mesh and opening size are not considered efficient sampling gear for macro-zooplankton (Melle et al., 2004). The WP2 net is designed for capturing meso zooplankton, it has a small mouth opening and it is hauled at low velocity. Macro zooplankton, such as euphausiids are rarely caught by

WP2 as they easily escape or avoid the net. Also, the trawl used in this study, is designed for catching pelagic fish. Krill is rarely herded by the side panels when entering the mouth like many pelagic fish species. Thus, using a trawl with coarse meshes in the panels near the mouth and decreasing mesh panels towards the codend provides possibilities for a large proportion of the euphausiids to escape the trawl gear. Macro zooplankton as prey species were not sampled in a representative manner during the surveys, thus indicating that these prey species may have been highly underestimated compared to what was present in the water column at the different stations.

Sighting efforts are also assumed to be equal, although it is dependent on both experience and ability of the individual observers, and visibility. This thesis did not have any systematic quantitative data on weather conditions or observation visibility distances during the transects, with the expectation of the survey in 2012 and parts of the transect for Kings Bay during the survey in 2018. There are therefore uncertainties connected to number of sightings from each cetacean species. With that is said, the weather conditions in most years during summers of 2013 to 2018 were very good, with only a few days preventing sightings of cetaceans due to dense fog and/or high waves combined with strong winds. Another uncertainty is the fact that the geographical coverage is not the same from year to year, which could influence the number of sightings on humpback whales and fin whales in northern waters to some extent. For future studies a systematic documentation on weather conditions and visibility to include in potential analyses could help avoid false zeroes (zeroes that affect the analyses by claiming no whales were present, when it was only due to sighting errors). Nevertheless, this should not influence the major findings presented in this study related to the distribution and feeding ecology of fin- and humpback whales.

At most pre-determined stations during the IESSNS surveys, there were no fin-or humpback whales observed. In some areas between stations there were large groups or aggregations making the data skewed or overdispersed. This may create problem with spatial autocorrelation which could cause Type I errors in statistical analyses, meaning that an unimportant variable would appear to have a significant correlation or interaction (Hedley & Buckland, 2004). However, the relationships found between biological and environmental variables are likely to reflect the preferred habitat conditions and prey species despite these limitations. The limitations only question the relative importance of the variables for the whale species. Nevertheless, it would be recommended in future studies to transform data in order to reduce skewness, such as a log transformation.

The efforts at all stations are assumed to be standardized between vessels and years. The IESSNS aim to find obtain an abundance index for mackerel, blue whiting, and Norwegian spring spawning herring. The cruises trawl catches are focused on the upper water masses, which does not always reflect the deeps fin-and humpback whales feed at. In future studies on the feeding ecology and prey preferences of fin-and humpback whales it could be advantageous to focus more on these prey species and their vertical and horizontal distribution relating to the whale species.

The hotspot that were defined for the whale species indicate a preferred feeding ground. For both whale species this was found to be in the shelf area between Svalbard and the coast northern Norway. Fin whales had a wide hotspot that compared to humpback whales stretched out along the shelf edge between Svalbard and Norway, and which could indicate that they are more mobile when searching for feeding grounds, this could be connected with the higher foraging threshold fin whales are limited to due to feeding tactics. The hotspot overlapped with krill, and areas with high catch of herring and capelin but the fin whale were not correlated to any of them (Figure 3.3B,3.6A, 3.8). This indicates a weakness in the choice of analyses that might not be able to catch the associations between the whales and their prey species. All correlation coefficients were close to zero, meaning there was a high variation around the line of best fit (Table 3.2). However, another variable affecting the results of the analyses is that several observations could not be connected with any station and were not included in any analyses. This means 37 fin whale individuals and 50 humpback whale individuals that were in the kernel density estimation were not included in the analyses. There was also a large part of unidentified whales.

Humpback whales had a very concentrated density around Bear Island, together with hotspots of both krill and capelin. Bear Island has been recognised as an important feeding ground for humpback whales in several earlier studies, especially because of its upwelling and productive area. Capelin catches were concentrated along the shelf area between Svalbard and Norway, and around Jan Mayen. Both are areas with several observations of humpback whales which corroborates to the positive correlation. Even though the p-value for humpback whale-capelin was at slightly above the 0.05 significance limit, it has been chosen to be included. However, as humpback whales were occasionally observed in large numbers feeding in Jan Mayen and other areas enough to move the CoG in both latitude (70ºN-73 ºN) and longitude (9ºW-22ºW), and was often outside the hotspot, it seems that there is a meaningful variation in distribution between years. This means it is still essential to continue to monitor these areas for further changes and potential returns, and that humpbacks are capable of rapid shifts in distribution and abundance patterns in order to search for preferable prey. Further research into the feeding ecology of humpback whales in this area, and possible an expanded survey further into the Barents Sea could help increase knowledge on the feeding ecology and prey preferences of humpback whales.

In conclusion Bear Island has been recognised as an important feeding ground for humpback whales in several earlier studies, due to its upwelling which makes it to a highly productive area. The findings in this study indicates that this area still is important. Much suggest that the Jan Mayen area is no longer as attractive for the large baleen whales as foraging ground as previous studies demonstrate. Fin- and humpback whale distribution seem to be affected by changes in the Norwegian Sea ecosystem, the distribution and abundance and seem to be highly affected by their traditional preferred prey undergoing a geographic northward shift, rather than switching to other expanding temperate species as prey, such as mackerel. In this study however, this is where most surveys had their northerly border. Further research into this area could uncover more on the prey preferences of fin whales.

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APPENDIX A.1

All cetacean sightings and the individual species number and distribution in the Norwegian Sea during IESSNS 2013-2018.

Table 1.A Cetacean sightings

	Species	Number of observations	Number of individuals
Baleen whales	Blue whale (*Balaenoptera musculus*)	1	3
	Fin whale (*Balaenoptera physalus*)	120	371
	Humpback whale (*Megaptera novaeangliae*)	73	215
	Minke whale (*Balaenoptera acutorostrata*),	82	98
	Sei whale (*Balaenoptera borealis)*	1	1
Odontoceti	Bottlenose dolphin *(Hyperoodon ampullatus)*	1	3
	Harbour porpoise (*Phocoena phocoena*)	3	8
	Killer whales (*Orcinus orca*),	71	441
	Pilot whale (*Globicephala melas*)	6	54
	Sperm whale (*Physeter macrocephalus*)	58	66
	White-beaked dolphins (*Lagenorhynchus albirostris*)	109	1008
	White-sided dolphin (*Lagenorhynchus acutus)*	25	256
	Unidentified dolphin	24	132
	Unidentified	39	51

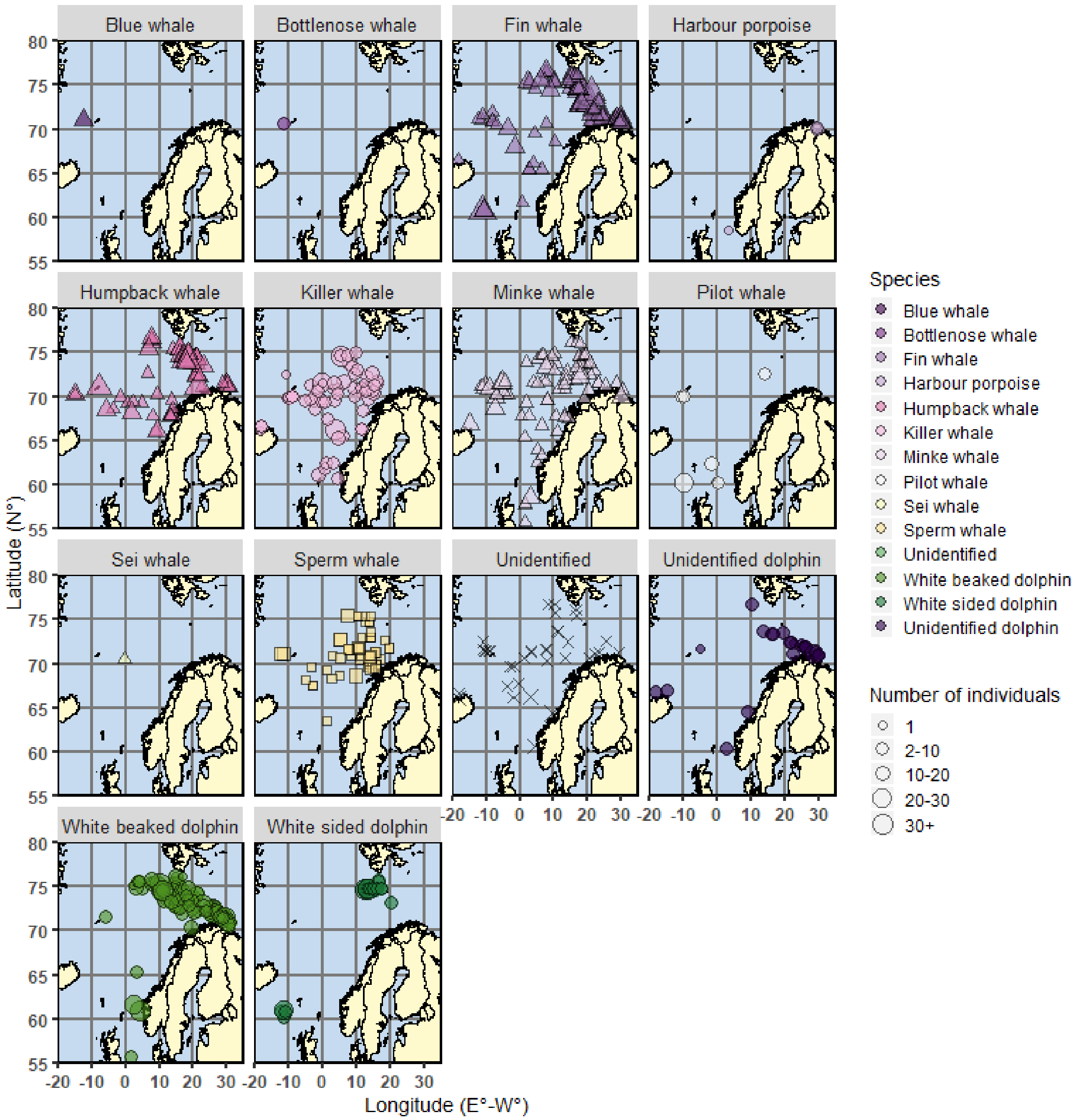

Figure 1.A The distribution of all cetacean sightings during the IESSNS 2013-2018.

APPENDIX A.2

All observations that were removed from analyses due to being too far away from any station. These could not be connected with the biological and environmental variables.

Table B.1. Observations more than 55.56km from the nearest station.

Date	OBS_LON	OBS_LAT	HUMP	FIN	ID	DIST (km)

20.12.2180	70.661	7.866	0	1	2015_LCNG_2	59.7332
22.07.2015	74.6	16.25	10	0	2015_LWIG_2	60.701241 4
30.07.2018	73.8022	18.4519	0	1	2018_LCYN_3 6	65.885857 5
01.08.2017	73.133	19.9	0	1	2017_LCYN_1 2	70.497342 9
01.08.2018	74.4858	19.2683	1	0	2018_LCNN_1 9	72.453637 5
23.07.2015	73.167	23.333	0	1	2015_LWIG_19	82.096511 3
01.08.2017	73.6	19.767	0	3	2017_LCYN_1 3	87.238435 4
04.08.2017	73.133	20.6	0	1	2017_LCYN_2 2	87.949124 2
02.08.2017	75.283	17.583	0	12	2017_LCNN_5	92.200723 3
04.08.2018	71.0847	22.5	1	0	2018_LCNN_2 7	105.23413 1
04.08.2018	71.0847	22.4689	0	4	2018_LCNN_2 8	105.43269 3
28.07.2016	73.45	23.133	0	1	2016_LCYN_3 2	106.36183 3
04.08.2017	73.75	20.633	2	0	2017_LCYN_1 9	106.90746 1
04.08.2018	71.1017	22.0339	0	4	2018_LCNN_2 9	107.53177 6
28.07.2016	73.467	23.083	3	0	2016_LCYN_3 1	108.82097 6
04.08.2017	73.633	20.633	1	0	2017_LCYN_2 0	114.38175 9
04.08.2017	73.55	20.633	0	2	2017_LCYN_2 1	114.76633 6
04.08.2018	71.1017	21.5	30	0	2018_LCNN_3 0	115.02188 2
04.08.2018	71.1017	21.5	0	4	2018_LCNN_3 1	115.02188 2
31.01.1940	71.611	-10.924	0	1	2015_LCNG_3	125.47384 5
02.05.1914	75.052	18.626	1	0	2015_LCNG_1 0	137.73661 6
12.01.1934	74.976	18.688	1	0	2015_LCNG_1 2	146.03813 8
21.07.2018	66.5678	-18.1836	0	1	2018_LCNN_1	146.35530 7

APPENDIX A.3

Settings and details for vessel equipment.

Table C.1. Acoustic instruments and settings for the primary frequency. Taken from ICES 2013,2014,2015,2016,2017,2018.

	2013		2014		2015		2016		2017		2018	
Properties	**Libas**	**Eros**	**Brennholm**	**Vendla**	**Brennholm**	**Eros**	**Ytterstad**	**Vendla**	**Kings Bay**	**Vendla**	**Kings Bay**	**Vendla**
Echo sounder	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK60	Simrad EK80	Simrad EK60
Frequency (kHz)	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200	18, 38, 70, 120, 200
Primary transducer	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B	ES38B
Transducer installation	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel	Drop keel
Transducer depth (m)	9	9	9	9	9	9	9	9	9	9	9	9
Upper integration limit (m)	15	15	15	15	15	15	15	15	15	15	15	15
Absorption coeff. (dB/km)	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.9	9.8	9.9	9.6	9.1
Pulse length (ms)	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024	1.024
Band width (kHz)	2.43	2.425	2.43	2.425	2.43	2.425	2.43	2.425	2.43	2.425	2.43	2.43
Transmitter power (W)	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000	2000
Angle sensitivity (dB)	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9	21.9
2-way beam angle (dB)	-21.1	-20.6	-21.1	-20.6	-21.1	-20.6	-21.1	-20.6	-20.6	-20.6	-20.7	-20.6
TS Transducer gain (dB)	24.87	23.27	24.87	23.27	24.87	23.27	24.87	23.27	23.1	23.27	24.33	25.56
sA correction (dB)	-0.6	-0.65	-0.6	-0.65	-0.6	-0.65	-0.6	-0.65	-0.64	-0.65	0.01	-0.69
alongship:	6.89	7.01	6.89	7.01	6.89	7.01	6.89	7.01	6.98	7.01	7.01	7.03
athw. ship:	6.87	7.11	6.87	7.11	6.87	7.11	6.87	7.11	7.03	7.11	7	7.09
Maximum range (m)	500	750	500	500	500	750	500	500	500	500	500	500
Post processing software	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS	LSSS

Table C.2. Trawl settings and operation details. Taken from ICES 2013,2014,2015,2016,2017,2018. Influence indicates observed differences between vessels likely to influence performance. 0 means no influence and x means some influence.

	2013		2014		2015		2016		2017		2018		
Properties	**Libas**	**Eros**	**Brennholm**	**Vendla**	**Brennholm**	**Eros**	**Ytterstad**	**Vendla**	**Kings Bay**	**Vendla**	**Kings Bay**	**Vendla**	**Influence**
Trawl producer	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	Egersund Trawl AS	0
Warp in front of doors	Dyneema – 36 mm	Dyneema -32 mm	Dyneema -32 mm	Dyneema -32 mm	Dyneema -32 mm	Dyneema -32 mm	Dynex–34 mm	Dynex -34 mm	Dynex -34 mm	Dynex -34 mm	Dynex -34 mm	Dynex -34 mm	x
Warp length during towing	350 m	350 m	350 m	350 m	350 m	350 m	350	350 m	350 m	350 m	350 m	350 m	0
Difference in warp length port/starboard	0-4 m	0-4 m	0-4 m	0-4 m	0-4 m	0-4 m	2-10 m	2-10 m	2-10 m	2-10 m	2-10 m	2-10 m	0
Weight at the lower wing ends	400 kg	300 kg	400 kg	300 kg	400 kg	300 kg	2×400	2×400	2×400	2×400	2×400	2×400	0
Setback in metres	6 m	6 m	6 m	6 m	6 m	6 m	6 m	6 m	6 m	6 m	0	0	x
Type of trawl door	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex adjustable hatches	Seaflex 7.5m2 adjustable hatches	Seaflex adjustable hatches	Seaflex 7.5m2 adjustable hatches	Seaflex 7.5m2 adjustable hatches	0
Weight of trawl door	2000 kg	1700 kg	2000 kg	1700 kg	2000 kg	1700 kg	1700 kg	1700 kg	1700 kg	1700 kg	1700 kg	1700 kg	x
Area trawl door	9 m2 75% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	9 m2 75% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	9 m2 75% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	7.5 m2 75% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	7.5 m2 25% hatches (effective 6.5m2)	x
Towing speed (GPS) in knots	4.6 (4.3-5.2)	4.5 (4.3-4.7)	4.8 (4.5-5.2)	4.8 (4.5-5.2)	4.8 (4.5-5.2)	4.8 (4.5-5.2)	4.8 (4.5-5.2)	4.7 (4.4-5.2)	4.9 (4.2-5.4)	4.9 (4.2-5.7	4.8 (4.2-5.8)	4.5 (3.3-5.8)	x
Setting time	5-6 min	5-6 min											x
Trawl height	26-34	29-31	28-35	29-35	28-35	29-35	25-34	26-36	30-32	24-32	28-40	28-37	x
Door distance	115-125 m	120-125 m	110-117 m	110-117 m	110-117 m	110-117 m	112-128	110-125 m	120-130	114-131	115-132	115-128	x
Trawl width*									69	68	68.2	66.5	x
Turn radius	2-8 degrees turn	5-6 degrees turn	5-8 degrees turn	5-8 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	5-10 degrees turn	x
Hauling time warp	5-6 min	5-6 min											x
A flapper in front end of cod-end / A fish lock in front end of cod-end	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	x
Trawl door depth (port and starboard)	5-12, 5-12 m	10-15 m	5-15, 7-17 m	5-15, 8-18 m	10-18, 10-17 m	5-12, 7-14 m	5-15, 10-17 m	5-16, 7-18 m	5-15, 7-18 m	6-18, 7-19 m	5-15, 7-18 m	6-18, 7-19 m	x
Headline depth	0-1 m	0-1 m	0-1 m	0-1 m	0-1 m	0-1 m	0 m	0 m	0 m	0 m	0-1 m	0-1 m	x
Float arrangements on the headline	Kite +2 buoys on each wing	Kite with 1 elongated buoy + 2 buoys on each wingtip	Kite +2 buoys on each wing	Kite +2 buoys on each wingtip	Kite +2 buoys on each wing	Kite +2 buoys on each wing	Kite +2 buoys on each wingtip	Kite +2 buoys on each wingtip	Kite with fender buoy +2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	Kite with fender buoy +2 buoys on each wingtip	Kite with fender buoy + 2 buoys on each wingtip	x
Weighing of catch	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	All weighted	x

APPENDIX A.4

Centre of gravity was calculated using a adapted function from (McGowan, 2018)

```
geographic_average <- function(LON, LAT, weight = NULL, data = Kva.df) {
  if (is.null(weight)) {
    weight <- rep(1, length(LON))
  }
  tibble(
  lon = weighted.mean(LON, w = weight),
  lat = weighted.mean(LAT, w = weight)
  )
}
```

Figure A.4.1 Geographic average function R-script.

Table A.4.1. The weighted average distribution (Centre of Gravity) for each year in both whales

Year	Species	Longitude	Latitude
2013	Fin whale	28.579043	71.2087
2014	Fin whale	18.0218	72.4383
2015	Fin whale	16.287875	73.89696
2016	Fin whale	10.570261	71.62896
2017	Fin whale	12.536964	71.14029
2018	Fin whale	10.419952	73.3022

Year	Species	Longitude	Latitude
2013	Humpback whale	11.368	70.63608
2014	Humpback whale	11.558	70.025
2015	Humpback whale	22.126316	73.37395
2016	Humpback whale	15.080067	73.06667
2017	Humpback whale	16.955333	73.3555
2018	Humpback whale	9.955895	72.09691

APPENDIX A.5

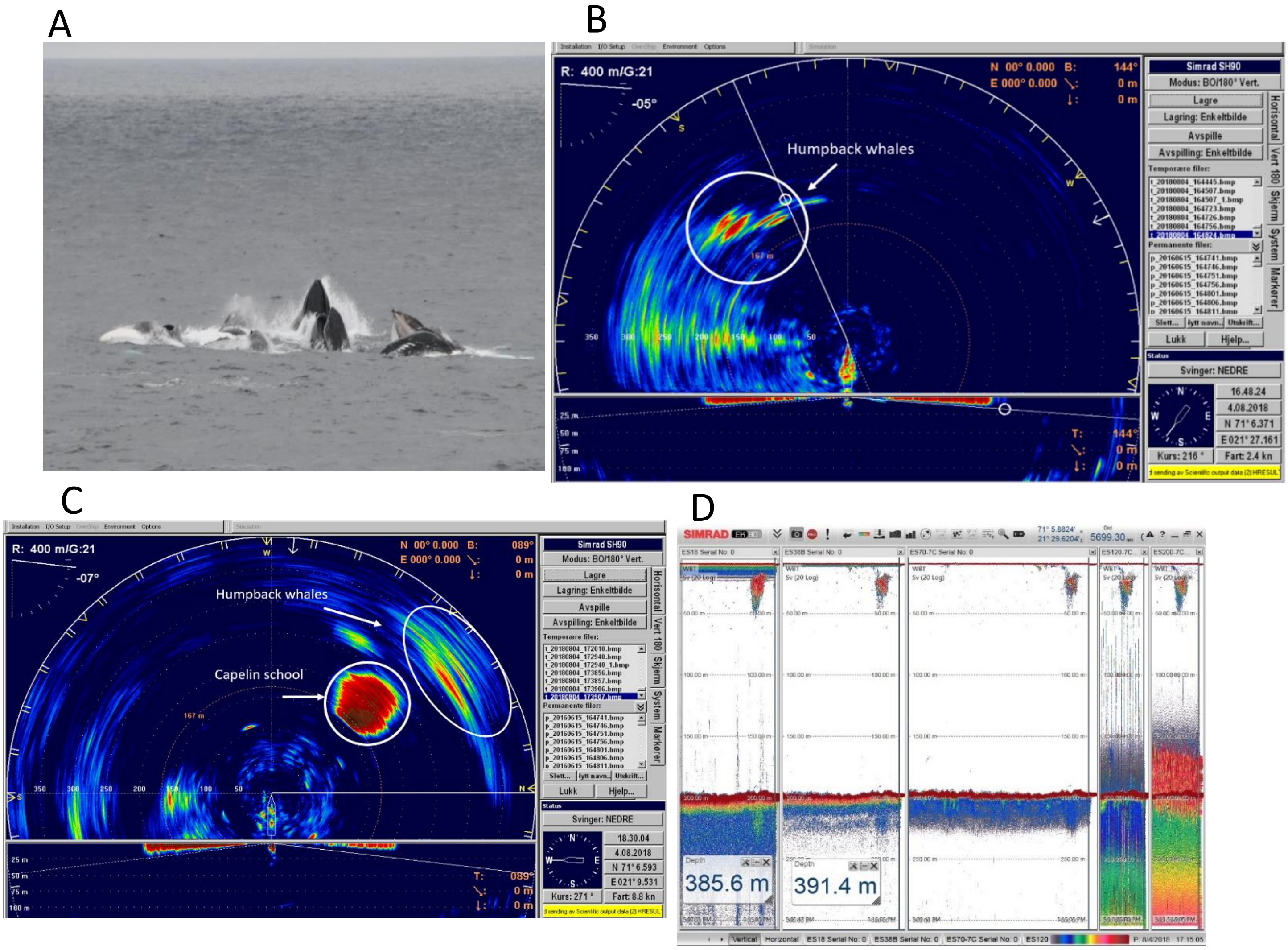

Figure 4.1. Humpback whales feeding event on 4 August 2018. A) Visual observation and (B, C, D) acoustic observation of coordinated swimming, diving and resurfacing for feeding in close knitted groups. A tight school of capelin were detected both acoustically on the sonar (B,C) and the echosounder (D).

APPENDIX A.6

Table A.6.1 Comments, position and timing of sighted fin- and humpback whales during the IESSNS in the Norwegian Sea during the summers in 2013 to 2018.

YEAR	Dato	LAT	LON	Species	Number	ORIGINAL COMMENT	ENGLISH COMMENT
2013	16.07.2013	67.833	13.167	Humpback whale	1		
2013	16.07.2013	67.850	13.650	Humpback whale	1		
2013	17.07.2013	67.883	13.283	Humpback whale	1		
2013	19.07.2013	68.200	1.950	Humpback whale	2		
2013	21.07.2013	70.267	9.400	Humpback whale	1		
2013	25.07.2013	73.033	18.133	Fin whale	2		
2013	25.07.2013	72.333	21.950	Humpback whale	1		
2013	25.07.2013	72.333	22.000	Fin whale	1		
2013	26.07.2013	71.400	28.133	Fin whale	1		
2013	26.07.2013	71.300	28.833	Fin whale	1		
2013	26.07.2013	71.267	28.767	Fin whale	1		
2013	26.07.2013	71.267	28.833	Fin whale	1		
2013	26.07.2013	71.283	28.833	Fin whale	3		
2013	26.07.2013	71.300	28.833	Fin whale	5		
2013	26.07.2013	71.050	28.850	Fin whale	1		
2013	26.07.2013	71.267	29.083	Fin whale	1		
2013	26.07.2013	71.167	29.317	Fin whale	2		
2013	26.07.2013	71.150	29.367	Fin whale	1		
2013	26.07.2013	71.067	29.617	Fin whale	1		
2013	26.07.2013	71.050	29.667	Fin whale	1		
2013	26.07.2013	71.017	29.783	Fin whale	1		

2013	26.07.2013	70.983	29.867	Fin whale	2		
2013	26.07.2013	70.900	30.067	Fin whale	3		
2013	26.07.2013	70.883	30.117	Fin whale	2		
2013	26.07.2013	70.800	30.367	Fin whale	1		
2013	27.07.2013	70.800	29.817	Fin whale	1		
2013	27.07.2013	70.800	29.817	Fin whale	2		
2013	27.07.2013	70.800	29.817	Fin whale	1		
2013	27.07.2013	70.883	29.400	Fin whale	1		
2013	16.01.2013	69.283	0.550	Humpback whale	1	Trekker vest	Heading west
2013	16.01.2013	69.350	2.350	Humpback whale	1	Trekker vestover	Heading west
2013	25.01.2013	72.667	6.600	Humpback whale	1	Trekker NV	Heading north-west
2013	27.01.2013	74.167	17.533	Humpback whale	5		
2013	27.01.2013	74.017	17.850	Humpback whale	4	Trekker NØ	Heading north-east
2013	27.01.2013	73.783	18.133	Humpback whale	2	Trekker øst	Heading-east
2014	09.07.2014	68.483	-5.617	Humpback whale	2	Trekker vestover	Heading west
2014	17.07.2014	70.783	30.350	Fin whale	4	Trekker nordøst	Heading north-east
2014	17.07.2014	71.033	29.900	Fin whale	1	Trekker nordøst	Heading north-east
2014	17.07.2014	71.350	29.267	Fin whale	1	Trekker sørøst	Heading south-east
2014	17.07.2014	71.567	28.733	Humpback whale	1		
2014	18.07.2014	71.500	24.367	Fin whale	1	Trekker vestover	Heading west
2014	18.07.2014	71.550	22.833	Fin whale	1	Trekker vestover	Heading west
2014	18.07.2014	72.200	21.517	Fin whale	1	Trekker nordøst	Heading west
2014	21.07.2014	74.500	8.800	Fin whale	2	Nord	Heading north
2014	23.07.2014	75.467	14.267	Fin whale	1	Øst	Heading east

2014	24.07.2014	75.500	5.917	Fin whale	2	Øst	Heading east
2014	25.07.2014	70.500	-7.000	Fin whale	1		
2015	20.07.2015	73.667	15.633	Humpback whale	1	beite 1	Feeding
2015	22.07.2015	74.600	16.250	Humpback whale	10	beiting 5-10	Feeding, 5-10
2015	22.07.2015	74.600	16.533	Humpback whale	1	vest	Heading west
2015	22.07.2015	74.600	16.683	Humpback whale	1	sør vest	Heading south-west
2015	22.07.2015	74.600	16.783	Humpback whale	2		
2015	22.07.2015	74.600	16.850	Fin whale	2	vest	Heading west
2015	22.07.2015	74.600	16.933	Fin whale	2	sør	Heading south
2015	22.07.2015	74.600	17.083	Fin whale	2	nord	Heading north
2015	22.07.2015	74.600	17.100	Fin whale	4	nord	Heading north
2015	22.07.2015	74.600	17.117	Humpback whale	1	nord	Heading north
2015	22.07.2015	74.583	17.167	Fin whale	3	nord	Heading north
2015	22.07.2015	74.583	17.183	Fin whale	1	nord	Heading north
2015	22.07.2015	74.600	17.250	Fin whale	1	nord/aust	Heading north-west
2015	22.07.2015	74.600	17.267	Fin whale	2	nord/aust	Heading north-west
2015	22.07.2015	74.600	17.300	Fin whale	1	nord/vest	Heading north-west
2015	22.07.2015	74.600	17.350	Fin whale	2	nord/aust	Heading north-west
2015	22.07.2015	74.600	17.450	Humpback whale	3	øst over	Heading east
2015	22.07.2015	74.600	17.450	Fin whale	1	øst	Heading east
2015	23.07.2015	73.167	23.333	Fin whale	1	nord	Heading north
2015	24.07.2015	71.450	29.550	Fin whale	1	nord/vest	Heading north-west
2015	24.07.2015	71.433	29.583	Humpback whale	1	øst	Heading east
2015	24.07.2015	71.400	29.700	Humpback whale	2	øst	Heading east

2015	24.07.2015	71.383	29.750	Humpback whale	2	beiting mor + kalv	Feeding mother and calf
2015	24.07.2015	71.383	29.833	Humpback whale	2	beiting	Feeding
2015	24.07.2015	71.383	29.850	Humpback whale	1	beiting	Feeding
2015	24.07.2015	71.317	29.933	Fin whale	2	blow	
2015	24.07.2015	71.200	30.233	Humpback whale	2	beiter	Feeding
2015	24.07.2015	71.050	30.650	Humpback whale	1	beiter	Feeding
2015	25.07.2015	70.917	29.233	Fin whale	1	nord	Heading north
2015	05.09.2284	68.659	10.354	Fin whale	1	minke or finn whale? (blow)	Minke or fin whale?
2015	20.12.2180	70.661	7.866	Fin whale	1	finnhval eller seihval	Finwhale or sei whale?
2015	31.01.1940	71.611	-10.924	Fin whale	1	finnhval	
2015	10.08.2073	74.611	4.311	Fin whale	1	trolig finnhval?	
2015	23.10.2230	76.111	14.541	Fin whale	1	finnkval	
2015	09.09.2243	76.106	15.086	Fin whale	2	finnkval 2stk	
2015	04.06.2260	76.109	15.348	Fin whale	1	finnkval	
2015	11.03.2321	76.141	16.272	Fin whale	1	finnkval	
2015	10.03.2370	76.101	17.073	Fin whale	1	Finnhval 1 stk	
2015	02.05.1914	75.052	18.626	Humpback whale	1	Knølkval	
2015	12.09.1933	74.971	18.684	Humpback whale	2	Knølkval 2stk	
2015	12.01.1934	74.976	18.688	Humpback whale	1	Knølkval. enda en	
2015	22.10.1940	74.906	18.738	Humpback whale	6	Knølkval. flere mer enn 6stk	
2015	26.09.2370	73.701	19.616	Humpback whale	3	Knølkval 2-3stk	

2016	05.07.2016	60.850	-11.233	Fin whale	50	Jaktet på kolmulestimer 0-gruppe	Hunting blue whiting 0 groups.
2016	05.07.2016	60.850	-10.883	Fin whale	7	Mye hvalblåst	
2016	05.07.2016	60.850	-10.767	Fin whale	5	Flere i horisonten	More in the horizon
2016	05.07.2016	60.850	-10.717	Fin whale	7	2+3+2 i sammen	3 groups of 2,3,2
2016	14.07.2016	67.883	13.650	Humpback whale	3	Vestfjorden vandret inn fjorden	
2016	15.07.2016	68.617	13.983	Humpback whale	1		
2016	18.07.2016	69.567	4.333	Fin whale	1	Stor høy blåst	
2016	19.07.2016	69.300	4.883	Humpback whale	1	Bred lav blåst	
2016	25.07.2016	75.100	2.700	Fin whale	1		
2016	25.07.2016	75.333	2.117	Fin whale	2	Beiter på store krillstimer	Feeding on krill
2016	26.07.2016	75.567	2.883	Fin whale	1	Trekker vestover	Heading west
2016	26.07.2016	75.567	7.100	Fin whale	1	Trekker vestover	Heading west
2016	26.07.2016	75.400	6.917	Humpback whale	2		
2016	26.07.2016	75.400	9.983	Fin whale	1	stor blåst på lang avstand	
2016	26.07.2016	75.400	10.033	Fin whale	3		
2016	26.07.2016	75.400	10.383	Fin whale	1	Død flytende i overflaten 10-12 m lang	Dead
2016	26.07.2016	75.400	14.050	Humpback whale	1	Liten knølhval som hopper helt ut i lufta	Small
2016	27.07.2016	75.400	15.717	Fin whale	3		
2016	27.07.2016	75.400	15.917	Humpback whale	7		

2016	27.07.2016	75.400	16.033	Fin whale	2		
2016	27.07.2016	75.400	16.083	Humpback whale	6	Dykker med sporen i lufta	Diving
2016	27.07.2016	75.400	16.150	Humpback whale	10		
2016	27.07.2016	75.400	17.300	Fin whale	1		
2016	27.07.2016	75.400	17.517	Fin whale	3		
2016	27.07.2016	74.300	20.917	Humpback whale	2		
2016	27.07.2016	74.233	20.967	Humpback whale	1		
2016	27.07.2016	74.217	21.017	Humpback whale	1		
2016	27.07.2016	74.183	21.100	Humpback whale	3		
2016	27.07.2016	74.183	21.167	Humpback whale	8		
2016	27.07.2016	74.183	21.217	Fin whale	100	Om lag 7 flokker med 3-20 individer Jakter loddestimer 60 m dyp	7 groups with 3-20 individuals hunting capelin at 60m depth.
2016	28.07.2016	73.467	23.083	Humpback whale	3	Trekker nordøstover	Heading north-east
2016	28.07.2016	73.450	23.133	Fin whale	1	Trekker på nordvest	Heading north-west
2016	28.07.2016	71.850	24.367	Fin whale	1	Trekker sør	Heading south
2016	28.07.2016	71.683	25.483	Fin whale	1		
2016	29.07.2016	71.283	27.633	Fin whale	1	To store blåst	
2016	29.07.2016	71.500	24.367	Fin whale	3		
2016	29.07.2016	71.183	24.417	Fin whale	2	Trekker nordøstover	Heading north-east
2016	13.07.2016	68.617	-3.683	Humpback whale	1	Sørvestlig retning	Heading south-west
2017	24.07.2017	69.933	-1.417	Humpback whale	1	1 blåst	
2017	31.07.2017	72.683	16.700	Fin whale	1	1 stor blåst	
2017	31.07.2017	72.683	16.700	Fin whale	1	Stor blåst lang avstand	

2017	31.07.2017	72.683	17.433	Fin whale	2	Flere blåst	
2017	31.07.2017	72.683	17.917	Fin whale	2	Trekker på SSØ	Heading south-east
2017	31.07.2017	72.683	18.400	Fin whale	1	Flere blåst	
2017	31.07.2017	72.683	18.300	Fin whale	1	Stor høy blåst	
2017	01.08.2017	72.683	19.250	Fin whale	2	Stor høy blåst	
2017	01.08.2017	72.683	19.667	Fin whale	1	Stor blåst	
2017	01.08.2017	72.683	19.800	Fin whale	2	Stor blåst	
2017	01.08.2017	72.683	19.817	Fin whale	2	Stor blåst	
2017	01.08.2017	73.133	19.900	Fin whale	1	Dykker ca 50 m om babord	Diving 50m
2017	01.08.2017	73.600	19.767	Fin whale	3	Stor blåst	
2017	01.08.2017	73.600	18.000	Fin whale	1	Stor blåst	
2017	03.08.2017	74.733	15.183	Fin whale	2	Forskjellige kurser	
2017	04.08.2017	74.283	20.633	Humpback whale	3	Beiter lodde nær overflaten	Feeding on capelin
2017	04.08.2017	74.267	20.617	Humpback whale	3	Beiter lodde nær overflaten	Feeding on capelin
2017	04.08.2017	74.267	20.633	Humpback whale	2	Beiter lodde nær overflaten	Feeding on capelin
2017	04.08.2017	73.750	20.633	Humpback whale	2		
2017	04.08.2017	73.633	20.633	Humpback whale	1	Dykker	Diving
2017	04.08.2017	73.550	20.633	Fin whale	2		
2017	04.08.2017	73.133	20.600	Fin whale	1		
2017	04.08.2017	71.950	20.467	Fin whale	1	Kurser sør-sørøst	Heading south-east
2017	05.08.2017	71.500	20.267	Fin whale	1		
2017	13.07.2017	65.500	2.617	Fin whale	1		
2017	18.07.2017	68.100	-1.467	Fin whale	2		

2017	25.07.2017	70.133	-3.700	Fin whale	2		
2017	28.07.2017	70.950	-8.133	Fin whale	1		
2017	02.08.2017	75.283	17.583	Fin whale	12		
2017	06.07.2017	61.750	0.733	Fin whale	1		
2017	13.07.2017	65.483	6.417	Fin whale	1		
2017	13.07.2017	65.500	2.600	Fin whale	1		
2017	14.07.2017	66.250	3.867	Fin whale	1		
2017	26.07.2017	70.950	-8.283	Fin whale	1		
2018	21.07.2018	66.568	-18.184	Fin whale	1		
2018	22.07.2018	70.234	-14.867	Humpback whale	3	Jaktadferd. 2-3 blås før dykking. Dykka varte i rundt 5-6 min. Store stimar i område, har skjermdump av sonar med både kval og stimar på.	Feeding, diving for 5-6min
2018	22.07.2018	70.234	-14.833	Humpback whale	1	Jaktadferd. 2-3 blås før dykking. Dykka varte i rundt 5-6 min.	Feeding, diving for 5-6min
2018	24.07.2018	71.034	-7.768	Humpback whale	20	Jaktadferd. Stor gruppe. Loddestim.	Feeding on capelin.
2018	24.07.2018	71.969	-8.068	Fin whale	1	Symde nordlig retning	Heading north-south
2018	25.07.2018	71.102	-11.517	Fin whale	1	Symjer sørover	Heading south
2018	25.07.2018	71.153	-12.384	Fin whale	1	Symde nordaust. Mykje	Heading north-east. Amphipods in the area.

						amphopode i område.	
2018	30.07.2018	76.251	7.718	Humpback whale	3	På veg aust	Heading east
2018	30.07.2018	76.268	7.718	Fin whale	1	På veg sør	Heading south
2018	30.07.2018	76.285	7.734	Humpback whale	1		
2018	30.07.2018	76.435	7.751	Fin whale	1	Jaktadferd, 6-7 min dykk, 4-6 blås	Feeding, 6-7 min dive
2018	30.07.2018	76.469	7.768	Fin whale	1	5blås, 6 min dykk, nordover	Heading north, dive 6 min
2018	30.07.2018	76.500	7.785	Fin whale	1		
2018	30.07.2018	76.517	7.785	Humpback whale	1		
2018	30.07.2018	76.517	7.785	Fin whale	1	4 blås, 5 min dykk, arr foran finne	5 min dive
2018	30.07.2018	76.568	7.802	Humpback whale	1	Jaktadferd	Feeding
2018	30.07.2018	76.667	7.833	Fin whale	2	4 blås, 6 min dykk, ein stor og ein liten	Assumed mother and calf
2018	30.07.2018	76.667	7.684	Humpback whale	3		
2018	01.08.2018	74.486	19.268	Humpback whale	1	Store stimar i område	Large schools in area
2018	03.08.2018	72.500	20.884	Humpback whale	2		
2018	03.08.2018	72.452	21.102	Humpback whale	1		
2018	03.08.2018	72.452	21.119	Humpback whale	1		
2018	03.08.2018	72.435	21.167	Humpback whale	10	Ein stor gruppe som mest sannsynligvis jakta på krill.	Large group, feeding on krill
2018	03.08.2018	72.401	21.319	Fin whale	1	Rett ved båten	
2018	04.08.2018	71.653	23.201	Fin whale	1	Låg i overflata, antagligvis	In the surface, probably

						pågrunn av sesimikk testing i nærleiken	due to seismic activity in the area
2018	04.08.2018	71.585	23.234	Fin whale	2		
2018	04.08.2018	71.085	22.500	Humpback whale	1		
2018	04.08.2018	71.085	22.469	Fin whale	4	Jaktadferd i gruppe	Feeding group
2018	04.08.2018	71.102	22.034	Fin whale	4	2 og 2 ilag, mor med avkom	2 mother and calf pairs
2018	04.08.2018	71.102	21.500	Humpback whale	30	5 store gruppar med 5-8 indvid, jakta på lodde ilag.	5 large groups with 5-8 individuals feeding on capelin.
2018	04.08.2018	71.102	21.500	Fin whale	4	Einsleg jaktar på lodde i nærleiken av knølane.	Feeding on capelin close to humpback gathering
2018	09.07.2018	66.085	9.051	Humpback whale	1	Nordover	Heading north
2018	10.07.2018	66.068	9.517	Humpback whale	4	Nordover	Heading north
2018	12.07.2018	67.751	8.100	Humpback whale	1	Nord-Vestover	Heading north-west
2018	18.07.2018	69.636	13.701	Humpback whale	1		
2018	30.07.2018	73.802	18.452	Fin whale	1	Dykkar	Diving
2018	30.07.2018	73.802	18.102	Fin whale	1		
2018	02.08.2018	74.517	17.636	Fin whale	3	Beita lodde	Feeding on capelin
2018	02.08.2018	74.435	17.384	Fin whale	1		
2018	02.08.2018	74.2175	17.000	Fin whale	3	Vestover i stor fart	Heading west