**SC/59/SM5**

# Distribution and abundance of killer whales in the North East Atlantic

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ABSTRACT

We present a review of 3,787 sightings from across the NE Atlantic from 1970-2007. In light of a large migration shift in the late 1960's by the Norwegian spring spawning herring *Clupea harengus* stock, a key prey species, we compare these sightings with whaling catch data from 1938 to 1967. The two datasets show a similar distribution pattern suggesting that there are populations of killer whales in the NE Atlantic that do not follow the NSS herring migration. We estimate abundance using data from several large-scale line transect North Atlantic Sighting Surveys (NASS) in 1987, 1989, 1995 and 2001, which covered mainly the eastern NE Atlantic between the Faroe Islands and East Greenland. There was high inter-annual variability in these estimates, ranging from 4,413 to 26,774; we discuss possible reasons for this variability in abundance estimates.

KEYWORDS: KILLER WHALE; ATLANTIC OCEAN; ABUNDANCE ESTIMATES; DISTRIBUTION; SURVEY – COMBINED; TRENDS.

## INTRODUCTION

This review is a synthesis of previously published and unpublished data and the first for 20 years examining sightings distribution across the entire NE Atlantic. Killer whales are distributed throughout the North East (NE) Atlantic (Jonsgård and Lyshoel, 1970; Hammond and Lockyer, 1988; Øien, 1988). Distribution in density varies seasonally in some locations correlated with changes in the distribution and abundance of prey species, in particular lipid-rich fish species (Christensen, 1988; Bloch and Lockyer, 1988; Sigurjónsson *et al*. 1988; Similä *et al*. 1996; Luque *et al*. 2006). Large aggregations of killer whales are found annually associated with the Icelandic summer-spawning (ISS) herring *Clupea harengus* stock in their wintering ground off Southeast Iceland during October-November (Sigurjónsson *et al*., 1988). Killer whales also regularly interact with the North Sea mackerel *Scomber scombrus* fishery between the Shetland Islands and Southern Norway during the winter months (Couperus, 1993; Luque *et al.* 2006) and Northwest of Scotland during spring (Bloch and Lockyer, 1988; Luque *et al.* 2006). One of the best studied aggregations of killer whales appear to follow the Norwegian spring-spawning (NSS) herring migration from the wintering grounds in the Lofoten area of Northern Norway to the spring-spawning ground in the Møre region and then to the offshore feeding grounds in the Norwegian Sea (Christensen, 1988; Øien, 1988; Similä *et al*. 1996; 2002). The migration of the NSS herring stock changed dramatically during the late 1960s concurrent with a dramatic decline in abundance and changes in oceanographic features (Røttingen, 1990; Torensen and Østvedt, 2000). Records of small whale catches between 1938-1967 by Norwegian whalers show that killer whales were distributed continuously between Iceland and Norway during this period (Jonsgård and Lyshoel, 1968; Øien, 1988). Jonsgård and Lyshoel (1970) suggested this was linked to the NSS herring migration. NE Atlantic killer whales are also known to take seal and seabirds (Bloch and Lockyer, 1988).

The number of catches of killer whales total 2,472 across the NE Atlantic, mainly by Norwegian whalers and date back as far as 1920 (Bloch and Allison, 2005). Catches of killer whales by Norwegian whalers were recorded from 1938 until 1981 when this species was no longer targeted, and totalled 2,435 for this period (Øien, 1988). Small numbers were taken by a live-capture fishery from Icelandic waters (51 animals; Sigurjónsson and Leatherwood, 1988) and by opportunistic drive fisheries in the Faroes (64 animals recorded 1960-1983,

protected since 1986; Bloch and Lockyer, 1988). The US navy targeted killer whales in Icelandic coastal waters during October 1956, following interactions with fishing activity, but the number of animals taken is unknown (Sigurjónsson *et al*. 1988). Previous abundance estimates for NE Atlantic waters have been published; Christensen, (1988) estimated between 483-1507 based on sightings in Norwegian Coastal waters on five given questionnaire-based survey dates between 1982-1987. Øien, (1990) estimated 3,100 animals from line transect surveys of the Norwegian Sea. Analysis of the NASS-87 data estimated 6,618 animals (Gunnlaugsson and Sigurjónsson, 1990) in waters between Greenland and the Faroes. Forney and Wade, (in press) categorise killer whales as abundant in Norwegian waters, common in Icelandic and Faroe waters, and uncommon to rare around the UK based on a literature review of surveys.

Here we collate and review sightings of killer whales between Iceland and Norway since 1970 using published and previously unpublished data. We compare seasonal spatial variation in sightings from these data and compare with the distribution of killer whale catches between 1938-1967. We calculate abundance estimates using distance-sampling techniques from effort-based sightings from periodic line-transect surveys and assess the potential for these data to detect trends in abundance.

## METHODS

All available previously published and unpublished sighting records of killer whales in the eastern North Atlantic between 40°N and 80°N latitude and 50°W and 30°E made between 1970-2006 were collated from the following databases and sources: European Seabirds at Sea; Fisheries Research Services, Aberdeen; Hebridean Whale and Dolphin Trust; Institute for Marine Research, Reykjavík; Irish Whale and Dolphin Group; Marine Research Institute, Bergen; Museum of Natural History, Faroe Islands; North Atlantic Sighting Surveys (NASS); Shetland Biological Records Centre; and from the literature (Hammond and Lockyer 1988). We are confident of correct species identification due to the distinctiveness of this species and the fact that the sightings were by experienced observers in most cases. Questionable and duplicate sightings were excluded. Sightings were lumped for all years into 3 four month time periods (Jan-Apr, May-Aug, Sep-Dec) and plotted using ARCVIEW to explore possible seasonal trends in distribution (only May-Aug, Sep-Dec are presented separately here). Sightings from NASS surveys, which had roughly equal coverage across our study area, were plotted together in an additional chart as an unbiased indication of distribution during the summer months.

Sightings from the NASS database had associated effort data from several large-scale line transect surveys by Icelandic and Faroese vessels during the summer months of 1987 (17 Jun – 12 Aug), 1989 (10 Jul – 15 Aug), 1995 (22 Jun – 6 Aug) and 2001 (20 Jun – 30 July). A number of vessels were used during these surveys, the numbers in brackets indicate the year, platform height(s) and number of observers: *Arni Fridriksson* (1987, 1989, 1995, 2001; 14/9.1m; 3), *Hviti Klettur* (1987; 6.2m; 3), *Keflvíkingur* (1987; 13.8/8.8m; 3), *Skírnir* (1987, 1989; 13.8/9.3m; 4), *Hvalur 8* (1989; 19&14.5/10m; 5), *Hvalur 9* (1989; 20.7&14.5/10.5m; 5), *Olivar Halgi* (1989; 13/8.2m; 4), *Miðvingur* (1995; 9.35/11.5/5.5m; 5), *Strákur* (1995; 15.5/10.5m; 4), *BS* (2001; 16.3/10.3M; 5), *AF RE100* (2001; 13.9/9m; 6), *AF RE200* (2001; 18.6/15.3m; 5), *West Freez* (2001; 11/13.8m; 5). See (Gunnlaugsson and Sigurjónnson, 1989; Sigurjónsson and Gunnlaugsson, 1989; Sigurjónsson *et al*. 1991) for further details on survey design, vessel comparison and observer differences. Track lines of effort are shown in Fig 2a-d and block size and effort and area of coverage for each year are listed in Table 1. Species, vertical distance, angle relative to the ships heading and group size were recorded for each sighting. Density and abundance were estimated for each year separately using conventional distance sampling methodology. Analyses were carried out using the software DISTANCE 5.0 (Thomas et al. 2006). The probability of detecting whales on the track-line (g[0]) was assumed to be 1, as although there are several potential and unknown biases such as responsive movement, killer whales are large, short-diving, conspicuous cetaceans and unlikely to be missed (Waite *et al*. 2002).

## DISTRIBUTION

A total of 3,787 sightings of killer whales were plotted using Arcview. As the majority of sightings were opportunistic in nature and without search effort data, it is not possible to make strong inferences about seasonality. However the overall distribution of sightings (Fig. 1a) was similar to the distribution of catch data from Norwegian whaling records (Fig. 1b) despite the biases associated with each dataset. Additionally the sighting distribution from the NASS data, which had approximately even coverage of the study area during the summer months suggest killer whales are evenly distributed across the NE Atlantic at this time of year (Fig. 1c).

Although the migration pattern of the NSS herring stock, a key prey species for killer whales in NE Atlantic waters (Similä and Ugarte, 1993; Similä *et al*. 1996; Similä, 1997), changed dramatically during the late 1960's (Røttingen, 1990), the distribution in opportunistic sightings in the period following this change (1970-2006) is not markedly different to the distribution in recorded killer whale catches prior to the change (1938-1967). There

are a number of biases in both datasets (see Jonsgård and Lyshoel, 1968; Øien, 1988), and neither is fully accompanied by effort data, but the results would suggest that the movement of not all killer whales in the NE Atlantic are correlated with the movement of the NSS herring stock. Distinct aggregations are identifiable in the period September- December (Fig. 1d), as stated above these incidental sightings may be subject to bias in effort, however it is known that the aggregation in the north of Norway is feeding upon the NSS herring stock (Similä and Ugarte, 1993; Similä *et al*. 1996; Similä, 1997), those off Iceland are feeding upon the ISS herring (Sigurjónsson *et al*., 1988) and those between the Faroe islands and southern Norway appear to feeding upon the North Sea mackerel (Luque *et al.* 2006). The effort based NASS surveys (Fig. 2) show a high sighting concentration in the summer feeding area of the NSS herring, consistent with satellite tag data which indicated at least some killer whales follow the NSS herring migration year-round (Similä *et al.* 2002), but also in other areas outside the migration of the NSS herring stock such as South of Iceland. Resource specialisation has led to genetic divergence and isolation and phenotypic divergence in killer whales in other areas. Several genotypes have been identified in NE Atlantic waters (Hoelzel *et al.* 2002) and there is preliminary evidence of phenotypic variation (Pitman *et al.* 2007). A NE Atlantic-wide study of genotypic and phenotypic variation in killer whales is currently underway using photo-id and genetic data. This will clarify if these aggregations are distinct stocks or part of a large spatially dispersed single population.

## ABUNDANCE

Abundance estimates of killer whales from the NASS surveys ranged from 4,413 in 1995 to 26,774 in 1989 and density was similar to other areas of high-density sightings such as the Bering Sea, Gulf of Alaska and Aleutian Islands (Waite *et al.* 2002; Zerbini *et al.* 2007) but lower than for Antarctic areas (Hammond, 1984). There was high inter-annual variability, with no clear trend, this could be due to several factors; the surveys covered different areas in different years (see Fig. 2). Variation in resource distribution could also be a factor; the NSS herring stock summer feeding ground has shifted westwards in recent years (Holst *et al.* 2000). The NSS herring stock spends the summer in the high latitude area between Iceland and Norway, which had a high sighting density in the NASS 2001 survey. The opportunistic sightings data for the period (May-Sep) when the NASS surveys took place combined with Forney and Wade, (in press) suggest that the highest areas of killer whale density in the NE Atlantic may be outside the area covered by the NASS surveys, therefore these estimates may not be indicative of abundance for the entire study area.

## ACKNOWLEDGEMENTS

We would like to thank Kate Brookes and Thorvaldur Gunnlaugsson for their help in preparing this report, Tiu Similä, Patrick Miller, Sanna Kuningas, Ari Shapiro, and Jen Snowball for their support. Financial assistance for AF was from the University of Aberdeen, Iceland Air, Shetland Sea Mammal Group and Shetland Biological Records Centre.

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| Year | Area ($km^2$) | Effort (km) | No. sightings | Sightings rate | Mean group size | Density (CV) | Abundance (CV) | 95% CI |
|---|---|---|---|---|---|---|---|---|
| 1987 | 2,285,353 | 26,545 | 21 | 0.0008 | 8.4 | 0.012 (0.45) | 8,260 (0.45) | 3,516-19,408 |
| 1989 | 3,011,133 | 17,226 | 23 | 0.0013 | 10.3 | 0.031 (0.63) | 26,774 (0.63) | 8,341-85,943 |
| 1995 | 2,428,812 | 12,648 | 5 | 0.0004 | 7.2 | 0.006 (1.21) | 4,413 (1.21) | 575-33,990 |
| 2001 | 2,728,383 | 15,891 | 42 | 0.0026 | 7.6 | 0.019 (0.42) | 15,014 (0.42) | 6,637-33,964 |

**Table 1. Estimate of abundance and related parameters for NASS surveys.**

**Figure Headings**

**Fig. 1a.** Approximate locations of killer whale catches (n = 1413) by Norwegian whalers 1938-1968 based on Fig.1. from Jonsgård and Lyshoel (1970). Group size: ◦ 1, ⋅ 5, • 10, ● 50, ⬤ 100.

**Fig. 1b.** Distribution of sightings (n = 3,787) 1970-2006.

**Fig. 1c.** Distribution in sightings (n = 151) from all NASS surveys (1987, 1989, 1995, 2001) including from Norwegian vessels Jun-Aug.

**Fig. 1d.** Distribution in sightings (n = 1,031) Sep-Dec.

**Fig. 2a.** NASS-87, **b.** NASS-89, **c.** NASS-95, **d.** NASS-01 survey tracks by Iceland and Faroese vessels and killer whale sightings.

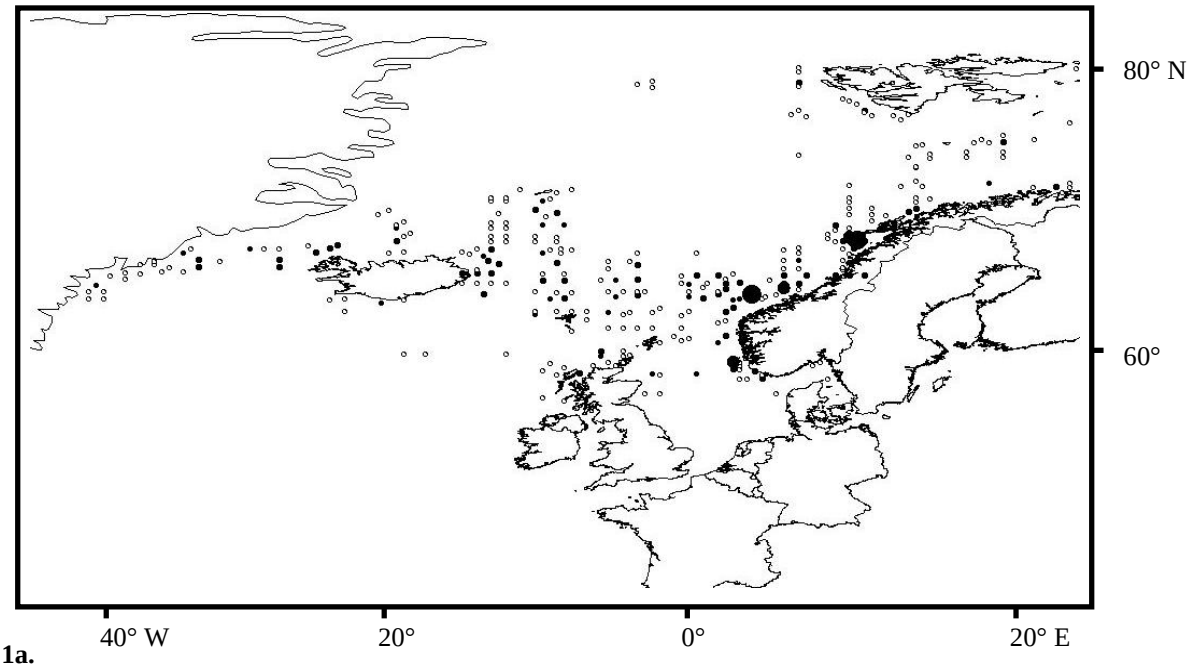
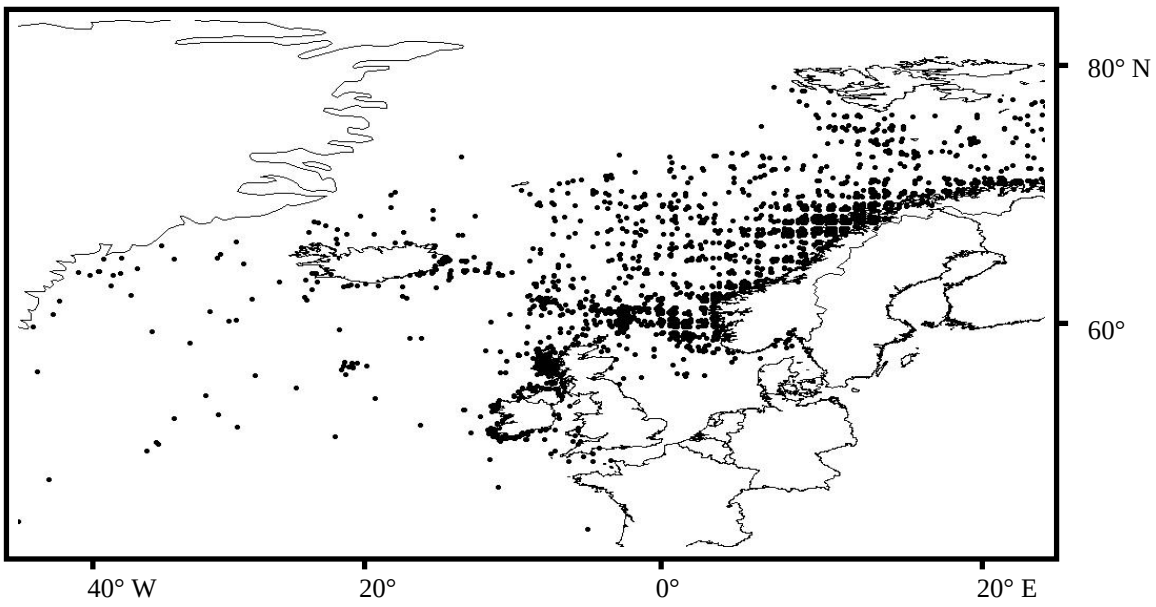



**Fig. 1a.**

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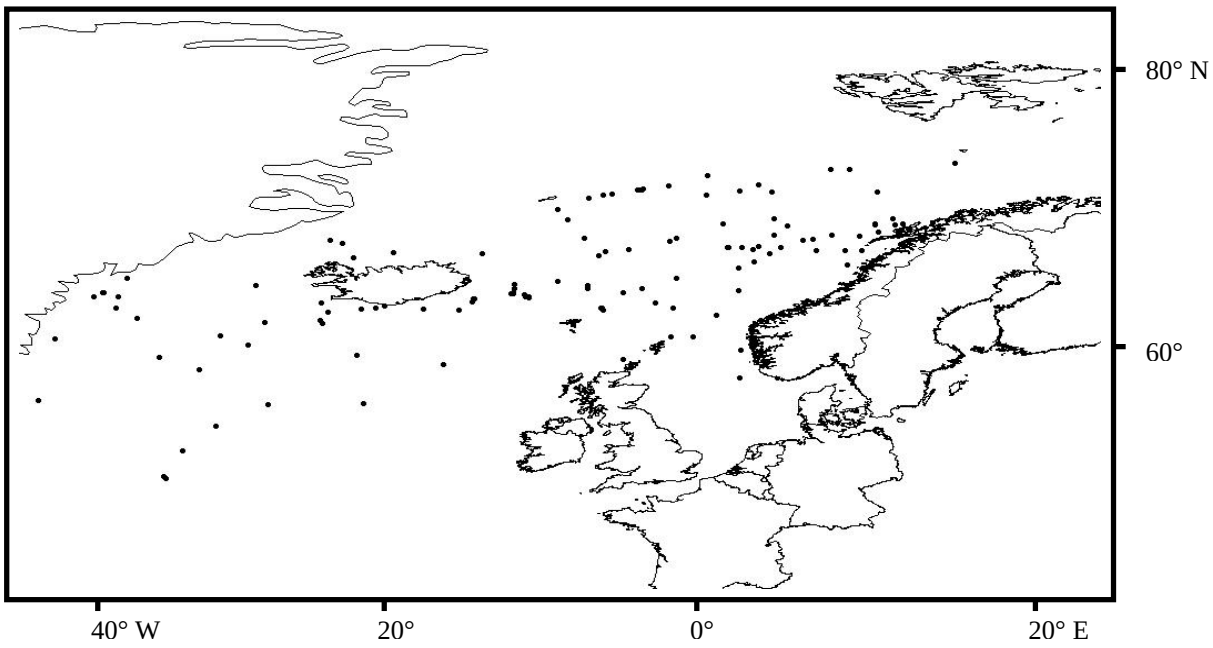



**Fig. 1c.**

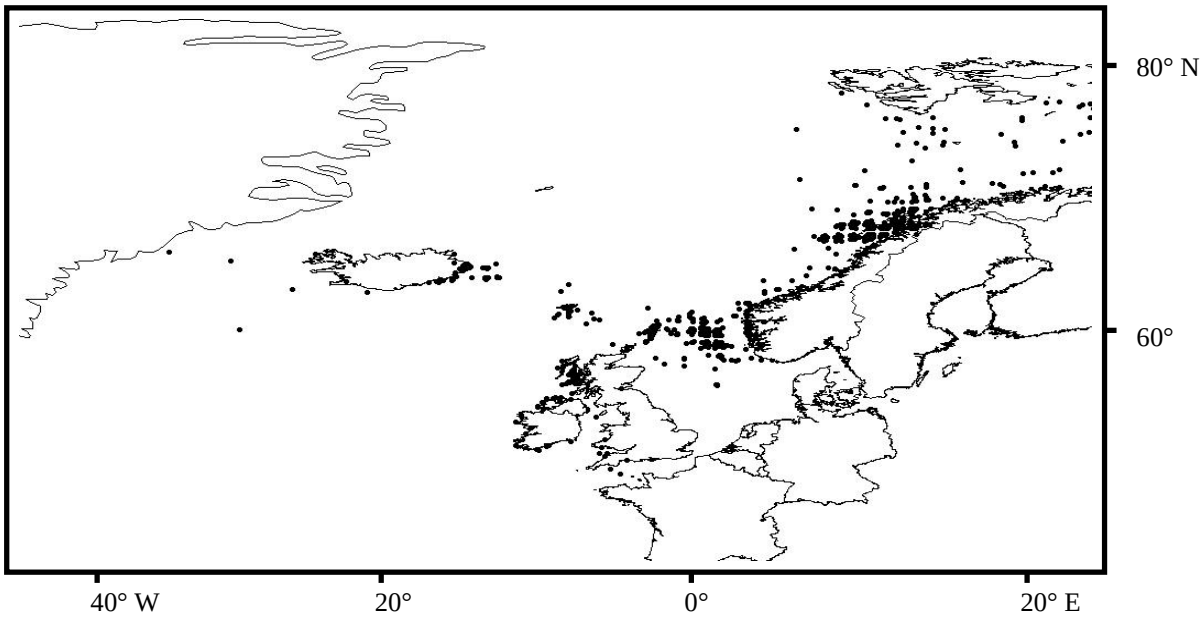



**Fig. 1d.**

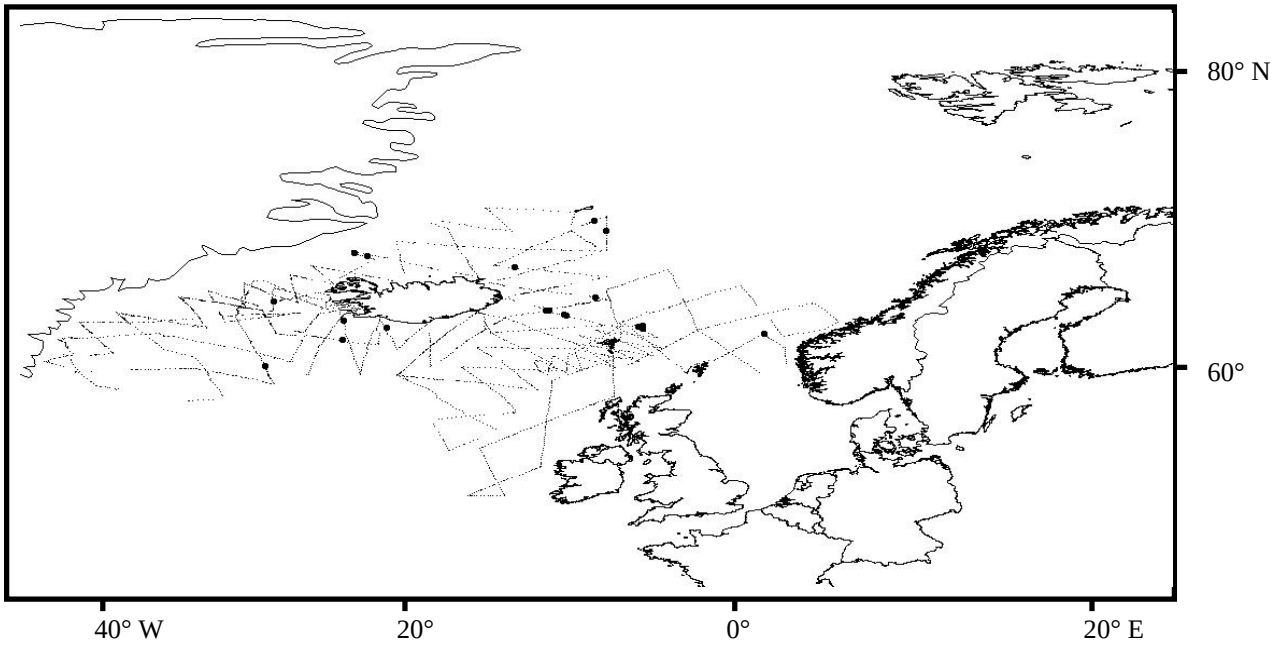



**Fig. 2a.**

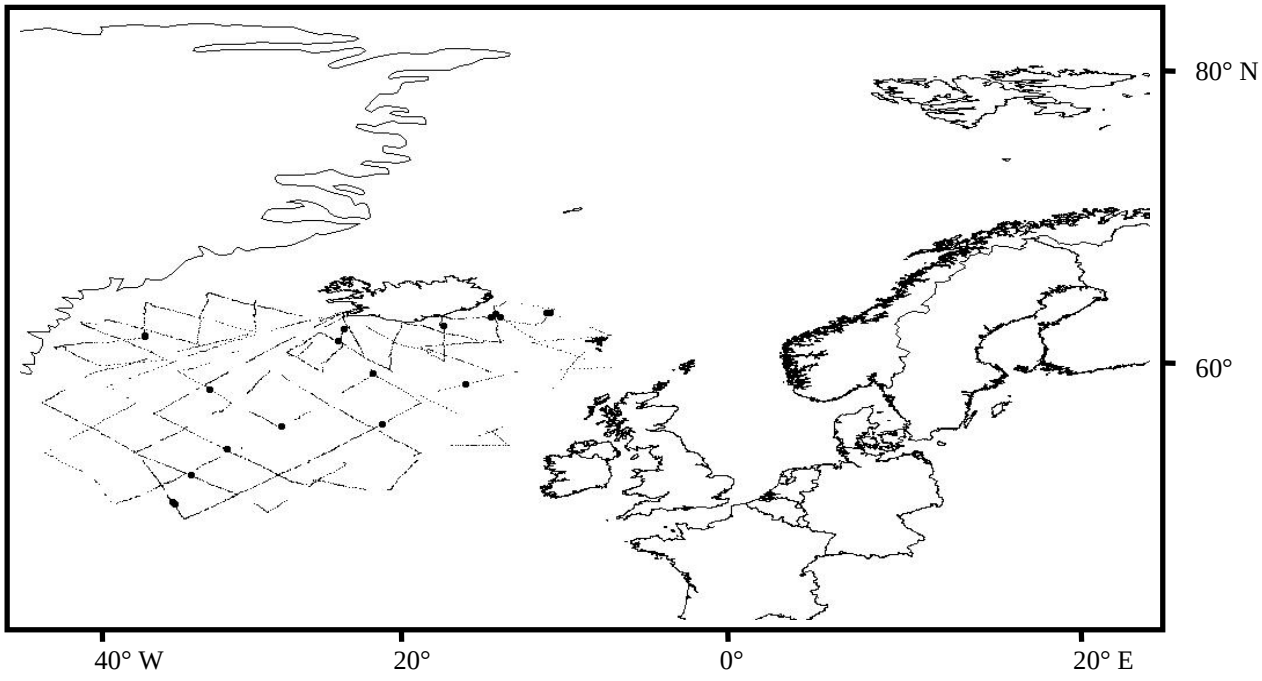
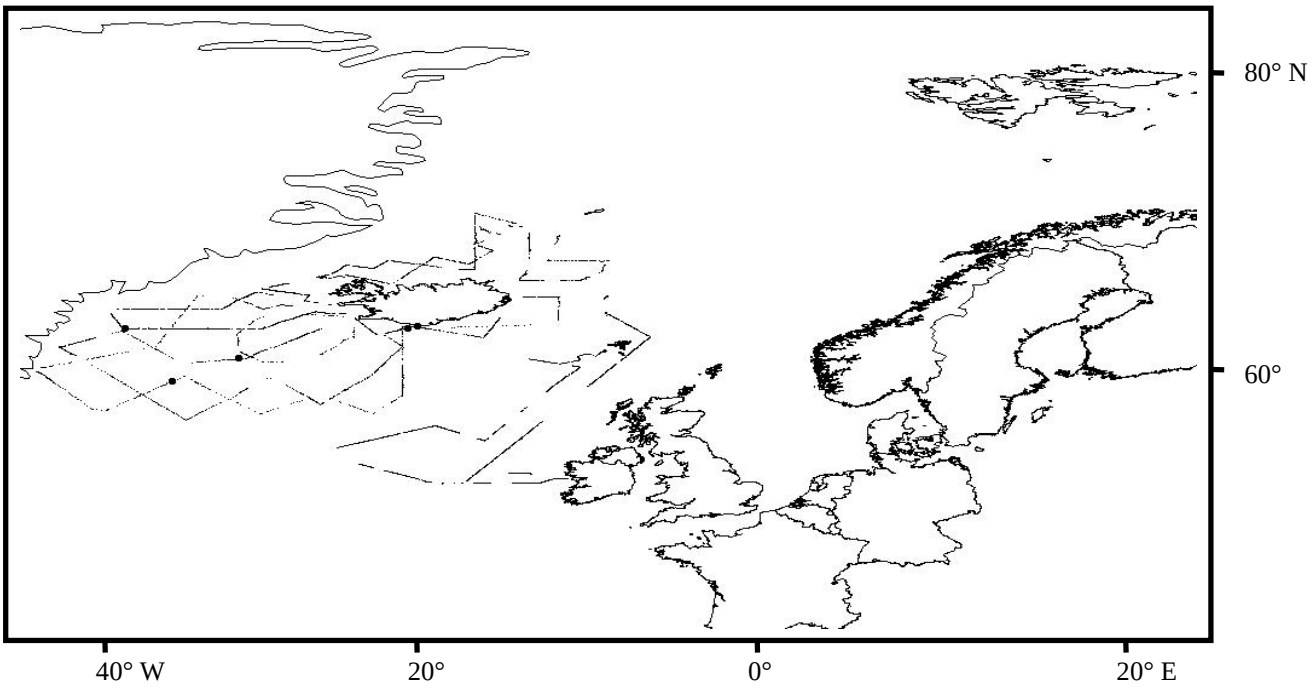



**Fig 2b.**

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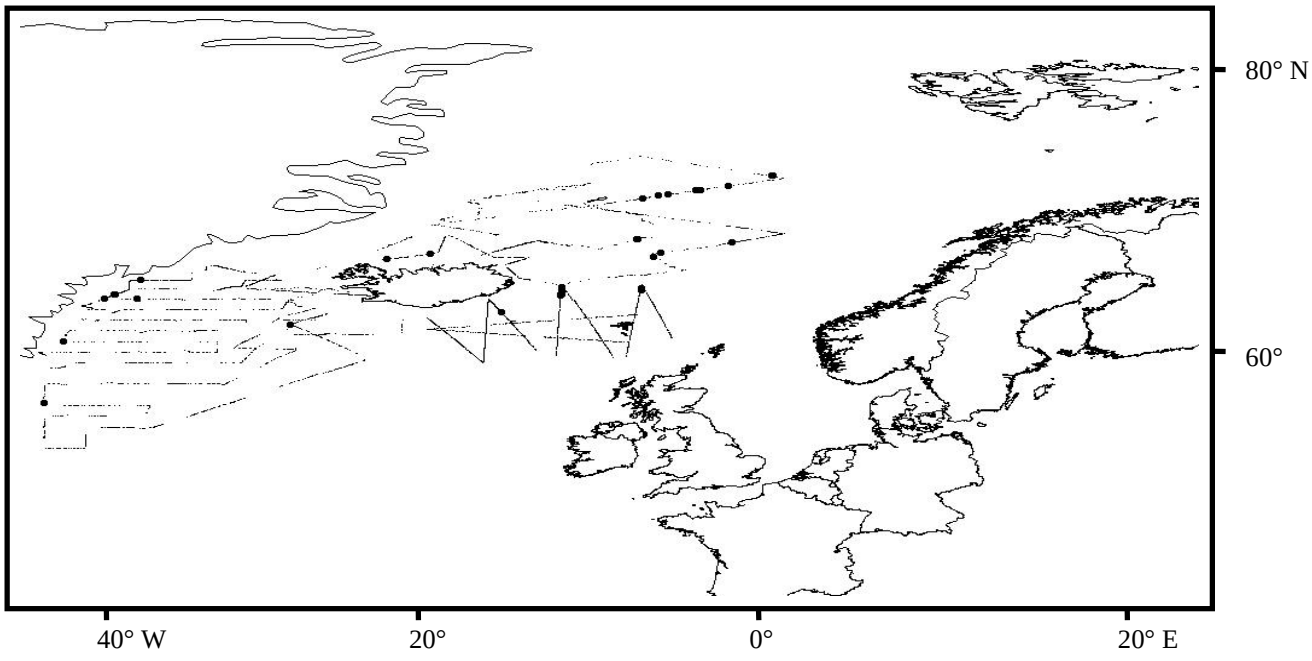


**Fig. 2d.**