

Distribution and density estimates of cetaceans along the mid-Atlantic Ridge during summer 2004

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ABSTRACT

During 4 June–2 July 2004, the Norwegian R/V *G.O. Sars* conducted a multi-disciplinary survey along the mid-Atlantic Ridge (MAR) from the Reykjanes Ridge to north of the Azores. This provided the first systematic survey information on MAR cetacean populations. Using naked eye or 7×50 hand-held binoculars, observers searched in a 140° arc centred along the ships' heading. Eleven cetacean species and 10 other taxonomic groups were identified along 2,321 km of transect effort. The sei whale (*Balaenoptera borealis*) and sperm whale (*Physeter macrocephalus*) were the most commonly sighted species (53 and 48 sightings, respectively). There were 12 sightings of the fin whale (*B. physalus*). There were 26, 13 and 12 sightings, respectively of the common dolphin (*Delphinus delphis*), pilot whale (*Globicephala* sp.) and striped dolphin (*Stenella coeruleoalba*). Density estimates of species ranged from 0.018 to 0.238 animals km⁻². The precision of the estimates (CV) was low, ranging from 40% to 61%. Species distribution varied north to south; the highest aggregations of baleen whales were sighted at the Charlie Gibbs Fracture Zone (CGFZ). Sperm whales were also observed at the CGFZ as well as north of this area. Pilot whales and Atlantic white-sided dolphins (*Lagenorhynchus acutus*) were sighted mainly in the cold (5–16°C) and less saline (34.6–35.8‰) water masses along the Reykjanes Ridge. Conversely, common dolphins and striped dolphins were most commonly sighted south of the CGFZ in areas with warmer (12–22°C) and more saline (34.8–36.7‰) surface water temperatures.

KEYWORDS: ATLANTIC OCEAN; NORTHERN HEMISPHERE; DISTRIBUTION; SURVEY-VESSEL; ABUNDANCE ESTIMATE; SPERM WHALE; SEI WHALE; COMMON DOLPHIN; FIN WHALE; PILOT WHALE; STRIPED DOLPHIN; ATLANTIC WHITE-SIDED DOLPHIN

INTRODUCTION

Under the Census of Marine Life initiative, the mid-Atlantic Ridge Ecology Program (MAR-ECO) was initiated in 2003 (Bergstad *et al.*, 2008; Wenneck *et al.*, 2008). One principal goal of the program is to obtain quantitative data on the abundance and distribution of marine species inhabiting the mid-oceanic North Atlantic (Bergstad and Godø, 2002; Decker and O'Dor, 2002; O'Dor, 2003).

Knowledge of cetacean species inhabiting the Mid-Atlantic Ridge (MAR) and adjacent waters has come from historical whaling data (Clark, 1887; Reeves *et al.*, 2004), anecdotal reports from fishermen (G. Vikingsson, pers. comm.), sighting surveys off Iceland (Sigurjónsson *et al.*, 1991; Sigurjónsson *et al.*, 1989), fishery observer data (Morato *et al.*, 2008) and more recently from marine mammal observer sightings made in June 2003 aboard the Russian R/V *Akademik Mstislav Keldysh* (NMFS, NEFSC, unpubl. data). Recent acoustic studies (Mellinger and Clark, 2003; Nieukirk *et al.*, 2004) have recorded baleen whale vocalisations near the MAR. These findings indicate that the MAR is an important cetacean habitat.

Various studies conducted worldwide have shown strong correlations between cetacean distribution and physiographic and oceanographic features and biological productivity (Ballance and Pitman, 1998; Baumgartner, 1997; Cañadas *et al.*, 2002; Davis *et al.*, 1998; Griffin, 1999; Hui, 1985; Kiszka *et al.*, 2007; Moore *et al.*, 2002; Reilly and Fiedler, 1994; Tynan, 1997; Tynan *et al.*, 2005; Waring *et al.*, 2001). The MAR is a region of high biodiversity and bio-productivity (Felley *et al.*, 2008; Fock *et al.*, 2004; Fossen *et al.*, 2008; Gaard *et al.*, 2008; Hareide and Garnes, 2001; Sigurjónsson *et al.*, 1991; Vinogradov, 2005) and

supports several important fisheries for deep-water species such as redfish (*Sebastes* spp.), Greenland halibut (*Reinhardtius hippoglossoides*) (Hareide and Garnes, 2001) and blue whiting (*Micromesistius poutassou*) (Gerber, 1993). Some of these species have been documented in odontocete stomachs sampled from adjacent regions (Desportes and Mouritsen, 1993; Roe, 1969; Sigurjónsson and Vikingsson, 1995). Zooplankton biomass and production particularly of the marine copepod (*Calanus finmarchicus*) were found to be highest in the area close to the Sub-Polar Front (SPF) and within the Charlie-Gibbs Fracture Zone [CGFZ] (Gaard *et al.*, 2008; Gislason *et al.*, 2008). The Boreoatlantic gonate squid (*Gonatus fabricii*) was the dominant cephalopod species found in the northern part of the MAR north of CGFZ (M. Vecchione, pers. comm., NMFS, National Systematics Laboratory, Washington, DC).

This paper provides information on cetacean distribution and density from the first systematic survey conducted along the entire northern mid-Atlantic Ridge.

METHODS

Study area

The MAR is a tectonic spreading zone between the Eurasian and American plates, running from Iceland in the North to the Azores in the South (Rossby, 1996); (Fig. 1). The area is characterised by rough bottom, hydrothermal activity, seamounts and other topographical features. The CGFZ is the deepest feature associated with the MAR, descending to around 4,500 m at its deepest point (<http://www.mar-eco.no/>). The MAR has an important influence on the circulation of the North Atlantic, partly separating waters of

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the eastern and western basins (Rossby, 1996; Sy, 1988). There is flow of surface, intermediate and deep water between the basins through the CGFZ at 53°N (Bower *et al.*, 2002; Rossby, 1996). The dominating water masses of the region are the North Atlantic Deep Water (which is formed by mixing of the overflowing water masses from the Norwegian and Greenland seas with the Labrador Sea Water), the low-saline intermediate depth Labrador Sea Water and the northeastwards flowing high-saline surface mode North Atlantic Current (i.e. one of the major branches of the Gulf Stream), which at the CGFZ marks the SPF as it turns eastwards as 2-4 major branches (Bower *et al.*, 2002; Rossby, 1996; Sy *et al.*, 1992).

Survey design and data collection

During 4 June – 2 July 2004, the Norwegian R/V *G.O. Sars* conducted a single transect (3,016km) multidisciplinary survey along the MAR from the Reykjanes Ridge to north of the Azores (Fig. 1). To investigate potential cetacean habitats, the ship track was designed to cross as many seamounts and rises as possible when steaming between 20 oceanographic sampling stations. The vessel transited the trackline 24hr day⁻¹, except at some multi-day sampling sites (e.g. CGFZ) (Wenneck *et al.*, 2008). Vessel speed ranged from 9.0 to 12.9kt during transects, but slowed when approaching sampling (e.g. CTD, trawl) stations.

Data were collected between stations by 1-3 observers located on the ship's flying bridge at an eye height of 15.5m above sea level, during daylight hours (0400-2300), weather conditions permitting (i.e. Beaufort ≤5 and no rain or fog). Three observers worked overlapping shifts. Generally two observers were sighting simultaneously, but one extra observer assisted when passing high-density areas. In areas of low densities (or in association with meals), a single observer generally was on watch. The survey was conducted in passing mode (i.e. the vessel did not close with sightings).

Each observer searched for cetaceans and seabirds in a 140° arc centred along the trackline. When two observers were on duty, one observer searched by naked eye aided by 7×50 hand-held binoculars to identify possible sightings; the second observer searched using 7×50 hand-held binoculars. Observers recorded sightings and effort data onto data sheets. Sighting data included: time; species; group size; number of calves; radial distance; bearing; swim direction; behaviour and association with seabirds. Calibration of distance measurements was made by regularly using calipers with distance markings from 100m to 2,000m. Effort and environmental data included: transect number; date; time; course; speed; observer position and environmental variables (e.g. weather, cloud cover, wind direction Beaufort sea state, visibility, swell size, sea surface temperature, glare (severity and angle)). Vessel sensor data

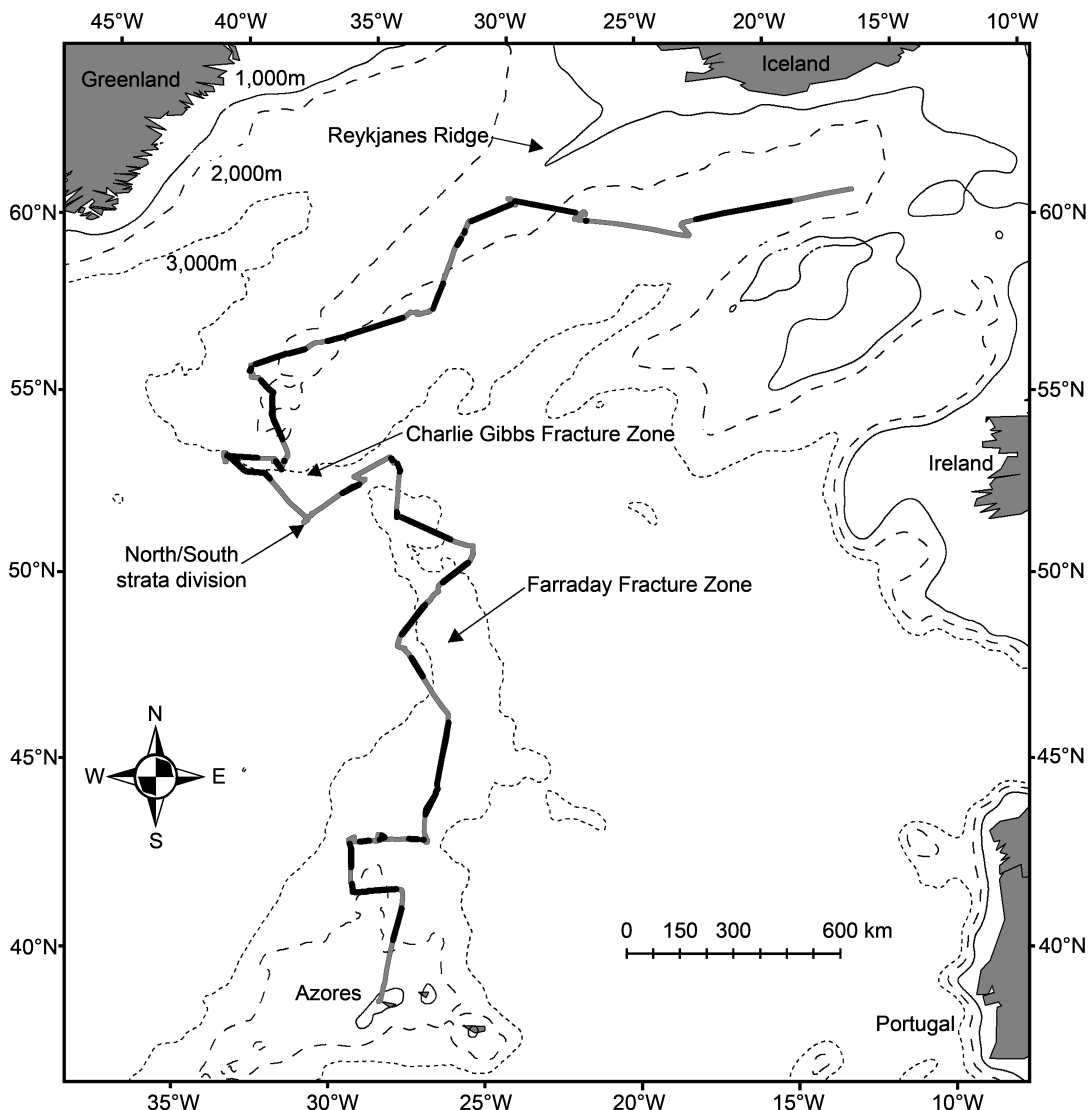


Fig. 1. Cruise track (grey), survey transects (black) and place names mentioned frequently in the report.

(e.g. latitude, longitude, speed, wind direction and speed, etc.) were downloaded from the ship's computer system on a daily basis.

Analytical methods

All on-effort data were included in the analysis, where transect effort was both parallel and perpendicular to the north/south orientation of the MAR. Because of the strong thermal gradient north and south of the CGFZ (Bower *et al.*, 2002; Rossby, 1996), the survey area was post-stratified into two strata: North and South.

Density was estimated for each species or taxonomic group and each strata with line-transect methods using the program *DISTANCE* 4.1 (Buckland *et al.*, 2001; Thomas *et al.*, 2003). The parameter $g(0)$ was not estimated, and so was assumed to be 1 (Buckland *et al.*, 2001), i.e. all animals on the trackline were assumed to be seen. The variances of the densities were estimated as 4.1, using the empirical option.

Transect length was based on the distance (km) of on-effort searching between consecutive stations. The perpendicular distance of each sighting was estimated using radial distance and bearing measurements to the sighting. Since the vessel transited a 'single line', stratum area was set to zero. Sample sizes for sei whales, *Balaenoptera borealis*, ($n=53$) and sperm whales, *Physeter macrocephalus*, ($n=48$) were sufficient to estimate the effective half-strip width (*ESW*) (Table 1; Figs 2 and 3). Since the number of common dolphin or striped dolphin sightings were insufficient to estimate *ESW*, they were pooled with other 'unidentified small dolphins' (Table 2; Fig. 4). This pooling was appropriate since the two identified species have similar sighting characteristics and they were the only small dephinidae recorded in the southern strata.

Data modelling and analysis followed protocol recommended by Buckland *et al.* (2001). Each data set was modelled with and without covariates using the hazard-rate and half-normal key functions, and the cosine and simple polynomial series expansions. The right-hand truncation values were based on visual inspection of initial model runs. Expected group size by stratum was estimated based on regression of log group size against $g(y)$. The best group size estimate was the regression based group size if the regression was significant (P -value <0.15), otherwise the average group size was used. Encounter rate and density of each taxonomic category were estimated for each 'stratum', and the model option to estimate the variance of the encounter rate analytically was selected. The best model for each category was selected based Akaike's Information

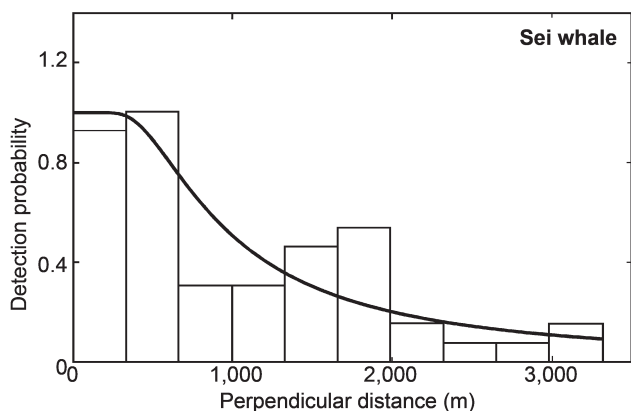


Fig. 2. Hazard-rate key model fit to sei whale perpendicular distance.

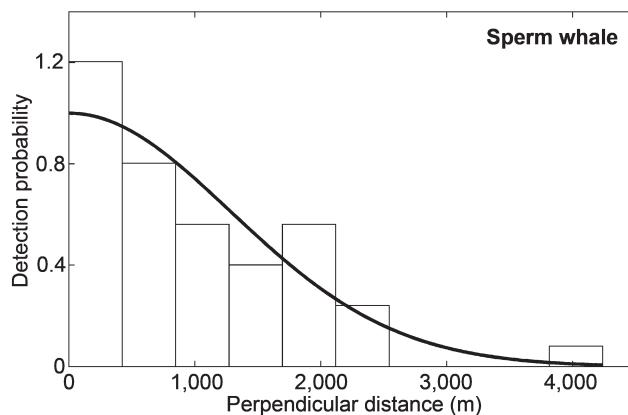


Fig. 3. Half-normal key model fit to sperm whale perpendicular distance.

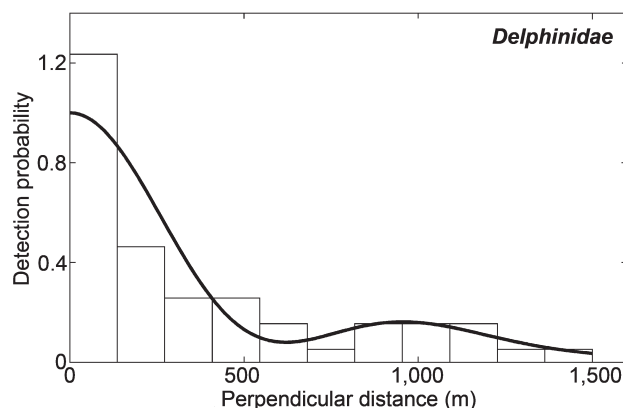


Fig. 4. Half-normal key model fit to delphinidae (common dolphin, striped dolphin, common/striped dolphin, and unknown dolphin in the southern strata) perpendicular distance.

Table 1

Estimate of $f(0)$ for each species or species group sighted ≥ 40 times along the MAR during 4 June – 2 July 2004; n = number of sightings after truncation; *ESW* = effective half-strip width, = $1/f(0)$.

Species/species group	n	Truncation (m)	<i>ESW</i> (m)	$f(0)$	%CV
Sei whale	52	3,000	1,282.7	0.0008	26.84
Sperm whale	48	4,200	1,646.4	0.0006	8.64
Small delphinidae *	58	1,500	406.8	0.0024	10.60

*Species include: common dolphin, striped dolphin, common/striped dolphin, and unidentified dolphin (southern strata).

Criteria (AIC). For each model the following covariates were investigated: sea surface temperature (SST); group size; and Beaufort sea state.

RESULTS

Effort and weather

Effort was distributed along the entire length (3,016 km) of the cruise track from the Reykjanes Ridge to north of the Azores (Fig. 1). Of the total cruise track, 1,741km (57.8%) was in the northern stratum and 1,275km (42.2%) in the southern stratum. The total on-effort trackline was 2,321km, of which 1,274km (54.9%) was north and 1,047km (45.1%) south of the CGFZ.

The overall weather conditions were highly varied, being influenced by cyclonic systems, with a mean wind speed of 9.9ms^{-1} (Beaufort 5) and up to 8m wave height. Flat sea

Table 2

Number of on-effort sightings (*n*), mean group size (*S*) and range thereof (*G*), sighting rate (*n/L*=animals/km) with %CV, and density (*D*=animals/km²) with %CV, of cetaceans sighted along the MAR, north and south of the Charlie Gibbs Fracture Zone during 4 June - 2 July 2004.

Species/species group	North							South						
	<i>n</i>	<i>S</i>	<i>G</i>	<i>n/L</i>	%CV	<i>D</i>	%CV	<i>n</i>	<i>S</i>	<i>G</i>	<i>n/L</i>	%CV	<i>D</i>	%CV
Sei whale	53	1.42	1-4	0.076	38.54	0.018	47.32	-	-	-	-	-	-	-
Sperm whale	40	1.89	1-15	0.038	32.69	0.042	40.06	8	1.6	1-3	0.04	56.5	0.036	60.53
Blue whale	-	-	-	-	-	-	-	4	1	1	0.007	63.21	-	-
Fin whale	5	1	1	0.006	77.27	-	-	7	1.71	1-2	0.012	93.2	-	-
Fin/sei whale	5	1.2	1-2	0.006	77.27	-	-	-	-	-	-	-	-	-
Fin/sperm whale	1	1	1	0.001	74.55	-	-	-	-	-	-	-	-	-
Sei/Bryde's whale	-	-	-	-	-	-	-	1	1	1	0.002	68.92	-	-
Humpback whale	1	2	2	0.001	84.6	-	-	-	-	-	-	-	-	-
Unidentified large baleen whales	7	1	1	0.007	40.9	-	-	-	-	-	-	-	-	-
Unidentified large whales	6	1	1	0.009	35.47	-	-	4	1	1	0.007	42.1	-	-
Minke whale	1	1	1	0.001	84.61	-	-	-	-	-	-	-	-	-
Unidentified beaked whales	6	1.33	1-3	0.009	34.07	-	-	2	3	1-5	0.004	68.92	-	-
Killer whale	1	5	5	0.001	85.62	-	-	-	-	-	-	-	-	-
Long-finned/short-finned pilot whales	9	11.44	1-40	0.013	33.77	-	-	4	25.76	3-60	0.007	55.69	-	-
Atlantic white-sided dolphin	7	14.71	3-60	0.01	34.47	-	-	-	-	-	-	-	-	-
White-beaked dolphin	3	3	1-5	0.004	111.89	-	-	-	-	-	-	-	-	-
Unidentified small whales	-	-	-	-	-	-	-	1	1	1	0.002	68.92	-	-
Common* dolphin	-	-	-	-	-	-	-	26	9.15	1-30	0.046	37.24	0.238	45.23
Striped dolphin*	-	-	-	-	-	-	-	12	9.69	3-25	0.021	35.43	0.122	45.54
Common/striped dolphin*	-	-	-	-	-	-	-	14	9.08	1-20	0.025	34.42	-	-
Unidentified* dolphin	1	100	100	0.001	84.61	-	-	8	3.43	2-5	0.014	68.92	-	-

*Species used in Delphinidae distance analysis, excluding unidentified dolphin (North).

conditions only occurred during short periods of time; 32.5% of the effort (km) was in Beaufort 2 or less, while 67.5% was in Beaufort 3 or more.

The proportion of search effort (km) conducted by an observer team comprised of one, two or three individuals, respectively, was 21.7%, 44.0% and 35.3%.

Most search effort (km) (65.7%) occurred at depths between 2,000m and 4,000m, with relatively little search effort at depths less than 1,000m (5.5%) and greater than 4,000m (0.6%).

Sightings and abundance

Two hundred and thirty-seven on-effort sightings were grouped into 21 categories based on species identification (Table 2). Fourteen species were recognised; the most commonly sighted species were sei whales (53); sperm whales (48), common dolphins, *Delphinus delphis*; (26) and striped dolphins, *Stenella coeruleoalba*; (12). Sperm whales were the large whales most commonly detected in both strata (Table 2). Among the smaller cetaceans, pilot whales (*Globicephala* sp.) and Atlantic white-sided dolphins (*Lagenorhynchus acutus*) were the most common species in the northern stratum, while common dolphins and striped dolphins were the most common in the southern stratum. Mean group sizes were ≤ 2 for all large and medium sized whales (Table 2). For delphinids, excluding a single sighting of 100 unidentified dolphins, mean group sizes ranged from 3 to 26.

Sighting rates of species ranged from 0.001 to 0.076 animals km⁻¹, and the precision of the estimates (CV) was low-ranging from 33% to 112% (Table 2).

The hazard-rate key function was the best model for the sei whale data, whereas, the half-normal key function with a series expansion was best for the delphinidae and sperm whale data sets (Figs 3-5). The AICs were nearly identical when the covariate SST were examined in the sei whale and sperm whale models, thus the more parsimonious model without covariates was used. None of the covariates improved the model selected for the delphinidae. Estimates

of $f(0)$ ranged from 0.0006 for sperm whales to 0.0022 for delphinidae (Table 1). Density estimates of species ranged from 0.018 to 0.238 animals km⁻², and the precision of the estimates (CV) was low-ranging from 40% to 61% (Table 2).

Cetacean distribution and behavioural observations

Distribution summaries exclude off-effort sightings, thus there are some differences with delphinidae data presented in Doksæter *et al.* (2008). Six species of baleen whales: blue whale (*Balaenoptera musculus*), fin whale (*B. physalus*), humpback whale (*Megaptera novaeangliae*), sei whale, Bryde's whale (*B. edeni*) and common minke whale (*B. acutorostrata*) were sighted during the survey (Table 2).

A total of 53 sightings were made of 85 sei whales. All sei whales were observed north of the CGFZ region (Fig. 5), near the frontal area just north and southwest of the CGFZ, where 80 sei whales were sighted. This area was a local zone of maximum surface temperature and salinity. In general, sei whales were at the slopes of seamounts and rises and were in waters varying from 1,160m to 4,500m deep (Fig. 5). The whales were often observed feeding and in areas where zooplankton (calanoids) were sampled. A wide range of size classes was observed and most groups contained 2-5 animals, although schools of up to 10 animals were observed.

Two sightings of single blue whales were made just south of the Faraday Fracture Zone [FFZ] (49°30'N-31°00'W) and one sighting of one blue whale was made approximately 100km further south (Fig. 6). Another sighting of a possible blue whale was also made in the Faraday region. The Faraday region was characterised by krill patches and fin whales were seen feeding on these patches (see below). All observations of blue whales were made in areas with depths between 2,200m and 2,800m.

Twelve sightings of 20 fin whales were made. The fin whale sightings consisted of one animal at the Reykjanes Ridge, seven animals north of the CGFZ, and 12 animals in the southern part of the MAR (Table 2; Fig. 6). In the

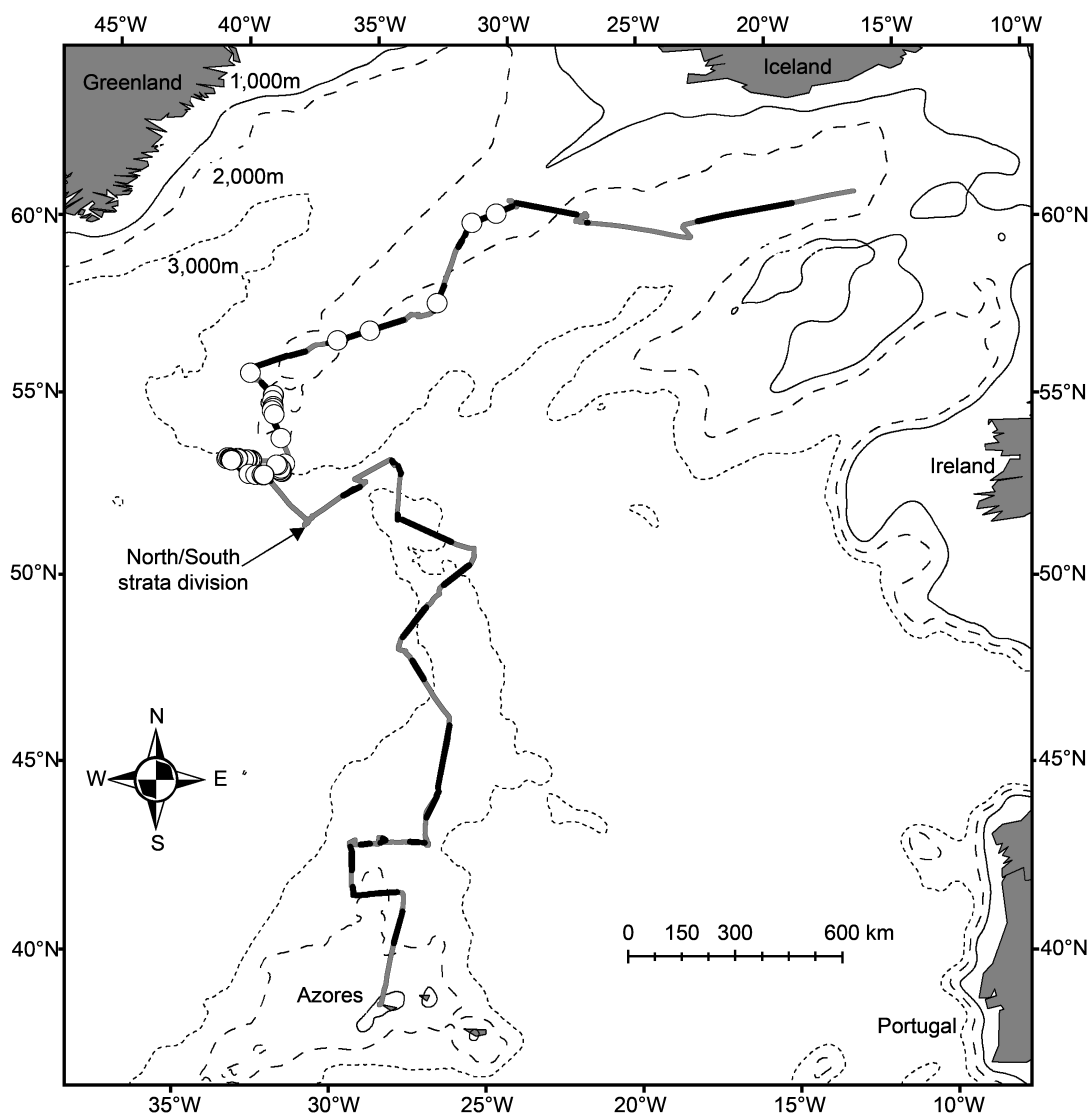


Fig. 5. Distribution of on-effort sightings of sei whale during R/V *G.O. Sars* survey.

Reykjanes region, several unidentified large rorquals may have been fin whales. The animals in the CGFZ and in the southern part of the MAR were frequently observed feeding, and a wide range of size classes were seen. In the FFZ, three fin whales were sighted feeding on krill patches. The animals were seen in waters with depths varying between 1,760m to 4,470m.

A possible Bryde's whale was recorded in the southern part of the study area (Fig. 6), where the surface temperature was warmer than 20.5°C. The species was identified by its size, surface behaviour and dorsal fin, though the dorsal ribs on the head were not seen (Jefferson *et al.*, 1993).

One sighting of two humpback whales was recorded just north of the CGFZ (Fig. 6). One animal was recorded feeding, and an attempt was made to attach a satellite transmitter to it.

One minke whale was observed in the CGFZ in waters of 2,900m depth (Fig. 6).

A total of 48 sightings were made of 83 sperm whales. School sizes varied from 1-15 animals (Fig. 7). Animals were seen along the entire length of the MAR, with a notable concentration north of the CGFZ and smaller concentrations in the southern region. The area at the CGFZ coincided with a frontal region with local maximum surface temperature

and salinity gradients. Unlike the sei whales, sperm whales were usually seen at the tops of the seamounts and rises and did not generally occur over the slopes. Sperm whales were recorded over depths varying from 800m to 3,500m, where the highest mean sighting rate was over areas shallower than 2,000m.

Eight sightings of 14 beaked whales (*Mesoplodon* spp.) were made in the southern part of the Reykjanes Ridge to the southern part of the MAR (Fig. 8). Observation conditions were generally sub-optimal for effective sightings of beaked whales, and species identification was virtually impossible.

A total of 206 long/short-finned pilot whales (*G. melas/macrorhynchus*) in 13 schools were recorded, mainly in the cold (5-16°C) and less saline (34.6-35.8‰) water masses (Doksaeter *et al.*, 2008) along the Reykjanes Ridge (Fig. 8). Most animals are identified as *G. melas*, but *G. macrorhynchus* cannot be ruled out for animals seen south of the CGFZ region. School size varied between 1 and 60 animals and sightings were recorded over depths from 1,500m to 3,900m.

One school of five killer whales (*Orcinus orca*) was observed in the southern part of the Reykjanes Ridge (Fig. 8).

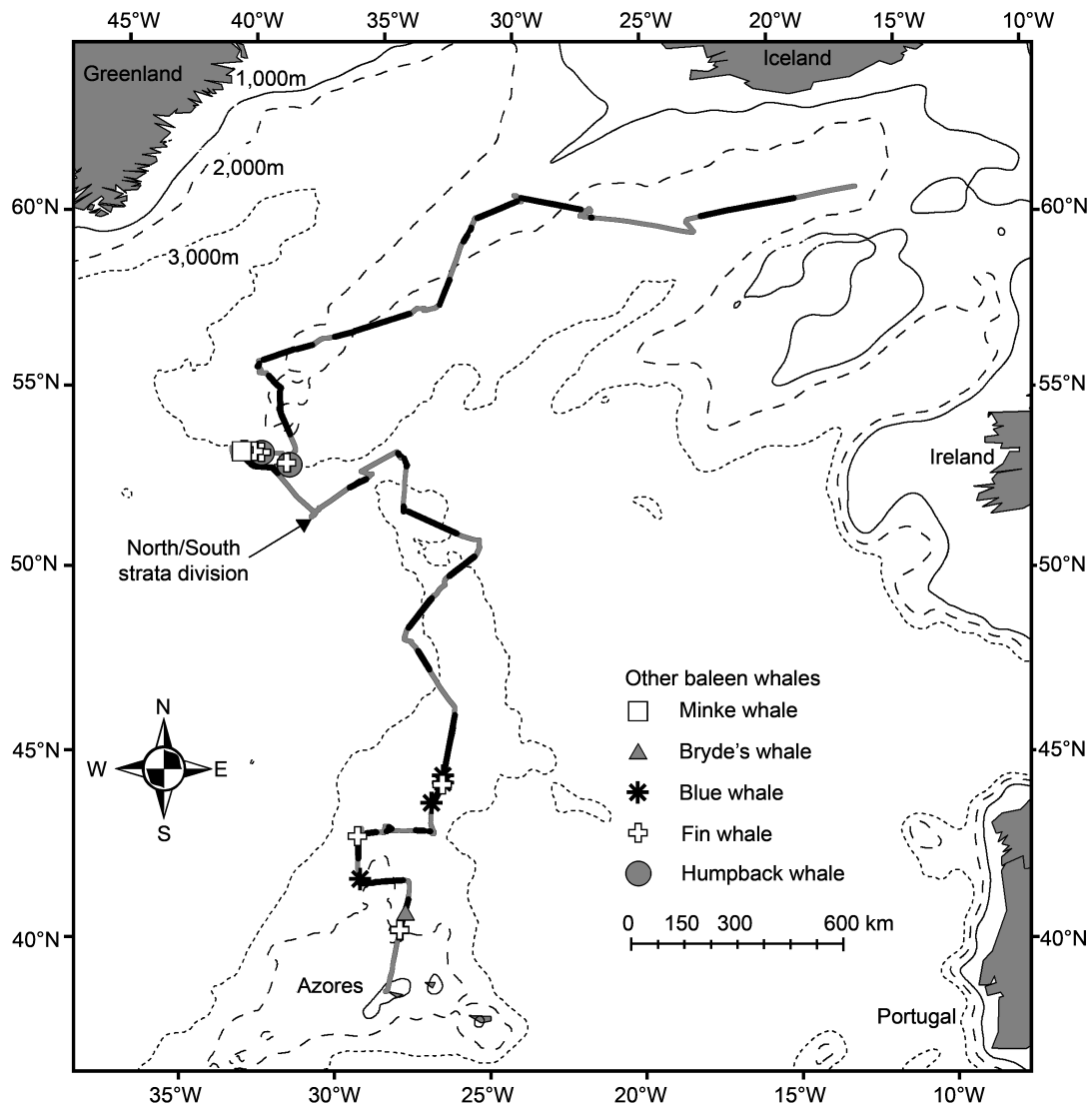


Fig. 6. Distribution of on-effort sightings of other baleen whales during R/V *G.O. Sars* survey.

Atlantic white-sided dolphins were sighted along and north of the CGFZ (Fig. 8) and observed only in the cold (5–16°C) and less-saline (34.6–35.8‰) water masses (Doksaeter *et al.*, 2008). A total of 103 animals were observed in seven schools. The dolphins were sighted in areas with water depths between 1,200m and 2,400m, and one of the schools was also accompanied by pilot whales.

Three schools of 11 white-beaked dolphins (*L. albirostris*) were observed over the central part of the Reykjanes Ridge (Fig. 8).

Common dolphins were only observed south of the SPF in the CGFZ (Fig. 9) in areas with warmer (>14°C) and more-saline (34.8–36.7‰) water masses (Doksaeter *et al.*, 2008). A total of 272 animals were observed in 26 schools. The animals were sighted in areas with water depths between 1,600m and 2,800m, and one of the schools was mixed with striped dolphins. In some cases, Cory's shearwater (*Calonectris diomedea*) were associated with the dolphins.

Striped dolphins shared a latitudinal trend in distribution with common dolphins (Fig. 9), although relatively more striped dolphins were sighted when surface water was warmer than 18°C (Doksaeter *et al.*, 2008). A total of 86 animals were observed in 12 schools. The dolphins were sighted in areas with water depths between 2,100m and

2,500m, and one of the schools was mixed with common dolphins. In some cases, Cory's shearwater were associated with the dolphins.

DISCUSSION

Cetacean distribution and abundance along the MAR have not been previously reported, although North Atlantic Sighting Surveys (NASS) in 1989 covered some of the present study area between the CGFZ and Iceland (Sigurjónsson *et al.*, 1991). The 1989 NASS survey, historical whaling information, acoustic recordings, cetacean studies in adjacent areas, and opportunistic sightings all suggested that seasonally the MAR was an important cetacean habitat (Nieukirk *et al.*, 2004; Reeves *et al.*, 2004; Sigurjónsson *et al.*, 1991). For example, the aggregation of sei whales at and just north of the CGFZ in 2004 overlaps spatially with the observations of the July–August 1989 NASS survey, when large numbers of sei whales were recorded in the region (Sigurjónsson *et al.*, 1991; Skov *et al.*, 2008).

Species diversity and habitat associations along the north-south gradient of the RV *G.O. Sars* survey track are similar to those seen in other oceanographic regions influenced by complex bathymetry and strong frontal features

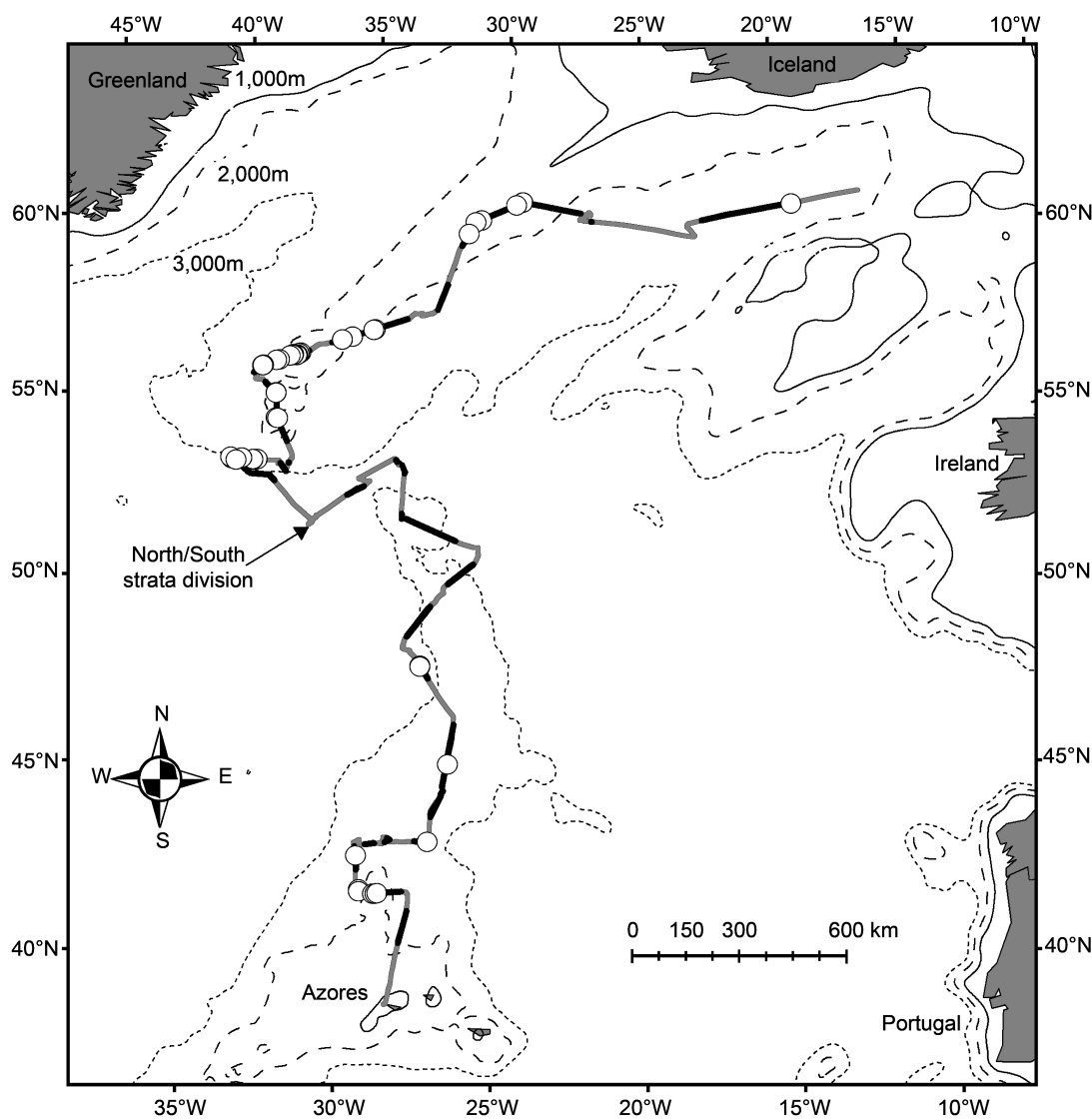


Fig. 7. Distribution of on-effort sightings of sperm whale during R/V *G.O. Sars* survey.

(Baumgartner, 1997; Davis *et al.*, 1998; Kenney and Winn, 1987; Kiszka *et al.*, 2007; Mullin and Fulling, 2004; Reilly and Fiedler, 1994; Smith and Whitehead, 1993; Tynan, 1997; Waring *et al.*, 2001).

Sei whales were most common over the slopes of seamounts and rises in waters with depths between 1,500m and 3,000m, while sperm whales were common in waters shallower than 2,000m. Dolphins, however, were widespread over all categories of water depth, but showed marked inter-specific differences in relation to surface temperatures with almost allopatric distributions of white-beaked/Atlantic white-sided dolphins and common/striped dolphin around the 14°C isotherm. The distinct use of 'shallows' and 'slopes' by sperm and sei whales, respectively, was evident when passing over seamounts in the CGFZ (Skov *et al.*, 2008), with sperm whales being found mainly over the top of the ridge and sei whales mainly over the slopes. Analyses of potential prey associations have not been completed. However, calanoids were abundant at stations in the CGFZ coinciding with concentrations of sei whales (Gislason *et al.*, 2008; Skov *et al.*, 2008). This implies that the CGFZ may be a 'hotspot' for sei whales along the MAR. Likewise, sightings of sperm whales and catches of the squid (*Gonatus* spp.) co-occurred in the

northern part of the MAR. *Gonatus* spp. is an important prey item for sperm whales in northern Atlantic waters (Bjørke, 2001; Christensen *et al.*, 1992; Clarke *et al.*, 1993).

The density estimates are negatively biased due to operational constraints, environmental conditions, few number of observers, and the assumption that cetaceans on the trackline are detected with certainty (i.e. $g(0)=1$). Sea state, group size and animal characteristics are known to affect perception bias (e.g. Mullin and Fulling, 2004). In addition, searching was conducted by naked eye or using low-powered hand-held binoculars, as opposed to high-powered binoculars used in some other multi-disciplinary surveys (Moore *et al.*, 2002; Tynan *et al.*, 2005); these may have assisted with species identification and school size estimates but would only have improved abundance estimates if used to assist in experiments to determine $g(0)$. Multi-disciplinary surveys mean that the vessel could not be diverted to identify species or to improve group size counts. These operational constraints likely impaired the ability of observers to identify some species (Mullin and Fulling, 2004). Conversely, the trackline covered high relief areas, which may have biased samples (Buckland *et al.*, 2001) to high-density areas. High relief features are known to influence oceanographic processes that concentrate prey

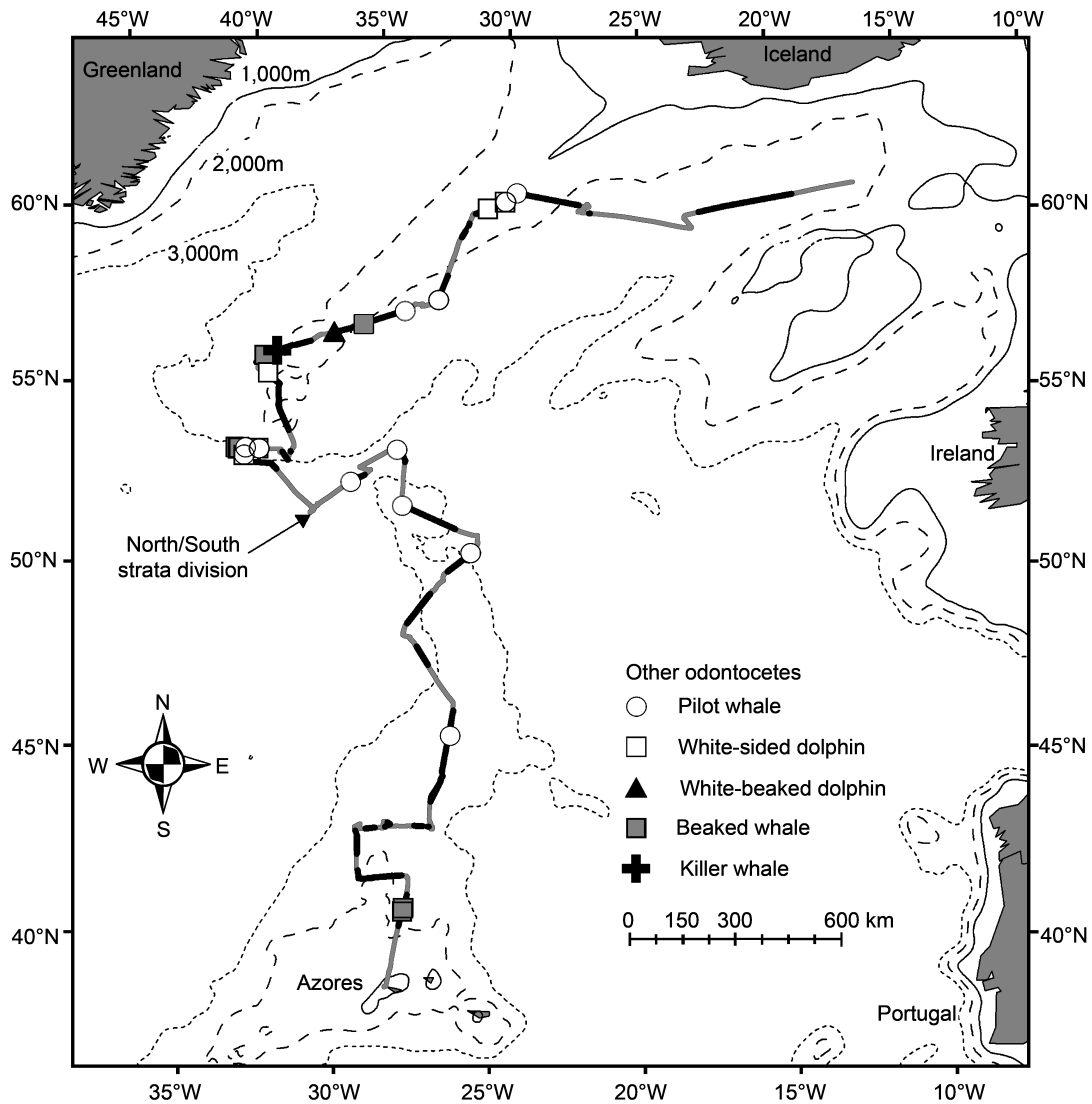


Fig. 8. Distribution of on-effort sightings of killer whale, beaked whale, pilot whale, Atlantic white-sided dolphin and white-beaked dolphin during R/V *G.O. Sars* survey.

(Ballance and Pitman, 1998; Baumgartner, 1997; Hui, 1985; Kenney and Winn, 1987; Moore *et al.*, 2002; Tynan *et al.*, 2005). Further, the high CVs are attributable to aforementioned concerns and large variations in the sighting rates due to the well-known patchy distribution of cetaceans. The perpendicular distributions for sei whales and dolphins (Figs 3 and 4), also raise concerns regarding animal avoidance and rounded distance estimation.

Sighting rates derived from this survey are not comparable to values reported for dedicated shipboard cetacean surveys conducted in other regions, or other multi-disciplinary surveys where searching was conducted using high power binoculars. Further, the RV *G.O. Sars* values are substantially lower than rates obtained from a long-term platform of opportunity survey in the Bay of Biscay (Kiszka *et al.*, 2007), where observers also searched using naked-eye or 7×50 binoculars.

The *G.O. Sars* survey provided a snapshot of the cetacean community along the northern portion of the MAR in early summer. Despite the overall low encounter rates and density estimates, the survey identified a presumed foraging hotspot for sei whales around the Charlie Gibbs Fracture Zone. Future MAR-ECO multidisciplinary studies may provide additional data to designate the CGFZ as an important

seasonal feeding habitat (i.e. similar to the Great South Channel off the coast of Massachusetts for North Atlantic right whales (*Eubalaena glacialis*) and sei whales). The spatial distribution of sperm whales also suggests that the MAR is an important oceanic habitat for this species. A more comprehensive line-transect survey and fine-scale habitat sampling will be required to further delineate cetacean distribution and habitat use, and to obtain more precise density estimates. Furthermore, biopsy sampling will be important for understanding the stock structure of cetaceans utilising the MAR boundary between the eastern and western North Atlantic, and whether this is a large whale migration corridor between sub-tropical/tropical breeding grounds and boreal feeding habitats.

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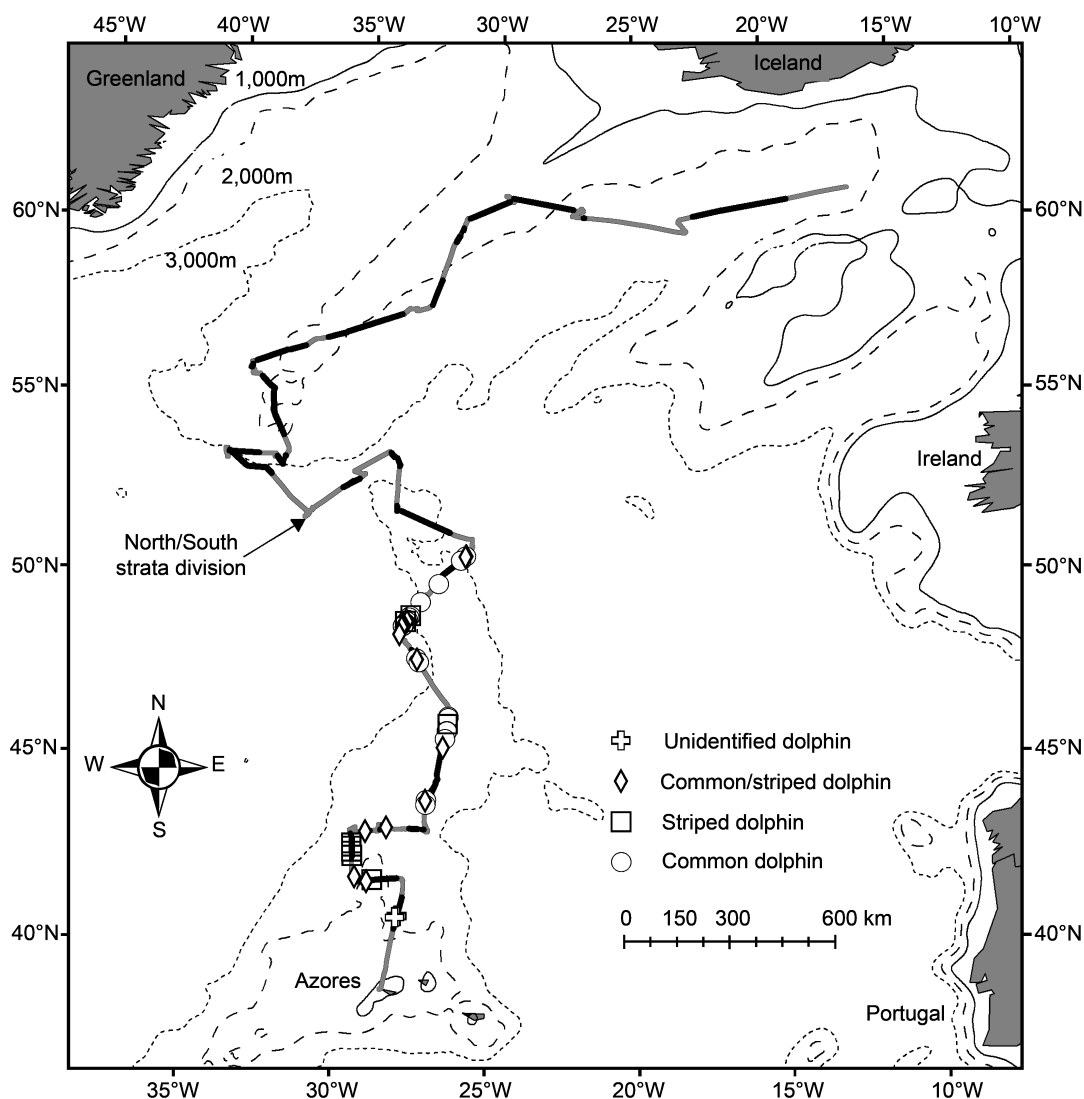


Fig. 9. Distribution of on-effort sightings of common dolphin, striped dolphin, common/striped dolphins, and southern strata unidentified dolphins during R/V *G.O. Sars* survey.

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