A proposal to initiate a pre-implementation assessment of sei whales in the Central North Atlantic.

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INTRODUCTION

In 2004 the Scientific Committee adopted a process for RMP implementations (IWC 2005). The first phase is a pre-implementation with the objective to evaluate whether there is sufficient data available on the cetacean stock or area in question to attempt an implementation. The decision on whether a pre-implementation can be attempted should be based on a proposal submitted by IWC member(s) that seek an RMP implementation. Such a proposal should include a summary of data and related information including i) operational data ii) extent of likely whaling operations, iii) abundance, and iv) stock structure and movement. The present paper constitutes such a proposal for sei whales (*Balaenoptera borealis*) in the Central North Atlantic.

The history of modern whaling for large whales in Icelandic waters dates back to 1883 with the first Norwegian land-based whaling station (Sigurjónsson 1988a; Sigurjónsson and Gunnlaugsson 2006). Catch data and sporadic other information exists from this first period of modern whaling, ending in 1915 when a total ban on large whaling, adopted by the Icelandic Parliament, took effect. With the exception of relatively small catches from a single land station during 1935-1939, this whaling moratorium was effective until the Hvalfjörður whaling station started operating in 1948. The main species targeted by the whaling fleet operating from the Hvalfjörður whaling station (Sigurjónsson 1988a) were fin whales (*Balaenoptera physalus*), sei whales and sperm whales (*Physeter macrocephalus*). The average catch of sei whales was 68 animals in the period 1948-1985. Research on the whales landed at the Hvalfjörður station was very limited until the late 1960's when British and Norwegian scientists conducted studies on fin, sei and sperm whales in co-operation with Icelandic authorities through the Marine Research Institute (MRI), Reykjavík. Variable proportions of the catch were sampled for biological studies, mainly centred around age and reproduction (see for example Rørvik *et al*. 1976; Lockyer and Martin 1983; Martin 1983). In 1979 the MRI initiated regular biological sampling from the catch in co-operation with British scientists.

During 1986-1989, a large scale research programme was conducted in Icelandic waters with the main objective to increase the knowledge of the state of the exploited whale stocks off Iceland fin and sei whales and to investigate the ecological role of large and small cetaceans in these waters (Anon. 1986). The programme aimed at providing data necessary for a thorough review of the effects of the IWC decision on temporary zero-catch limits in all commercial whaling operations, and to facilitate the Comprehensive Assessment of the exploited whale stocks of Iceland. The programme was divided into ten separate research areas, some of which were dependent on sampling of whales while others were not (e.g. sightings surveys). During this four year period, a total of 292 fin whales and 70 sei whales were caught for research purposes under a special permit granted by the Government of Iceland.

This extensive programme resulted in a greatly improved scientific basis for assessing the status of recently exploited whale stocks in the region as well as increased general knowledge on the distribution, abundance and biology of the involved species. Biological sampling from every landed fin and sei whale was then greatly increased. There are, however, still important gaps in our knowledge on the biology and ecology of sei whales in Icelandic waters. This is mainly due to the limited scope (temporal and spatial) of the research programme, and that sample sizes were too small for firm conclusions to be drawn for some of the research

projects. A drastic reduction in the number of sei whales sampled (from planned 160 to 70 animals) significantly limited the scientific value of the research takes of this species. The objectives of the research programme (Anon. 1986) could therefore not be fully accomplished by this much smaller sample.

No catches of sei whales have been taken in Icelandic waters since 1988. The pause in whaling in Icelandic waters has resulted in increased abundance and/or changes in distribution pattern of at least some of the previously exploited cetacean species.

REVIEW OF AVAILABLE DATA

Table 1 summarizes relevant data on Central North Atlantic sei whales.

Catch data

Catch statistics are maintained in the catch database held by the IWC.

North Atlantic

About 14,000 sei whales are recorded caught by modern whaling in the North Atlantic. In addition, an unknown proportion of the approximately 30,000 unspecified large whales caught in the North Atlantic in the late 19th and early 20th centuries were sei whales (Reilly et al. 2008).

Post-war catches of sei whales west of Iceland have a marked peak in late August and early September, whereafter the whaling season was usually terminated due to weather and visibility (Martin 1983, Sigurjónsson and Víkingsson 1997). The catches have been variable from year to year. Catches fluctuated between 0 and 240 per year during the recent commercial catch period, probably due to a combination of company decisions, whalers' preferences and apparently reflecting large between year fluctuations in occurrence of this species on the grounds (Sigurjónsson 1988). Sei whales are also reported to be highly variable in occurrence in other northerly parts of the Atlantic Ocean (Ingebrigtsen 1929; Jonsgaard 1974). The operational pattern of the Icelandic large whale fishery has been analysed, for better understanding of factors affecting the CPUE/stock size relationship (Sigurjónsson, 1988). Detailed time budget was kept since 1979 and has been validated (Sigurjónsson and Gunnlaugsson 1990). However an analysis of the logbooks of the whaling vessels in relation to the sei whale catch/effort relationship is not promising.

Sightings data

The seasonal occurrence of this species in Icelandic waters is less regular than that for minke and fin whales, possibly due to the fact that Icelandic waters include the northern boundaries of sei whale distribution in the central North Atlantic. Although abundance of sei whales in this area is generally highest in late summer and fall (Sigurjónsson and Víkingsson 1997), there is considerable between-year variation, and in some years (sei whale years) they are encountered in high abundance earlier in the summer as seen from catch and sightings data. Because of this seasonal difference in peak abundance between sei whales and most other large cetaceans, it is problematic to incorporate sei whales as target species in multi-species sightings surveys.

Available sightings data from Icelandic and adjacent waters are from three main sources: the whaling vessels, MRI's fish- and hydrographical surveys and dedicated cetacean surveys.

Sightings data have been collected on-board the whaling vessels since 1979. In 1986-89 improvements were made in this data collection when sightings and effort were recorded more in accordance with line-transect methodology.

Occurrence of sei whales in 0-group fish surveys late summer/autumn surveys with cetacean sighting effort around Iceland and over to Greenland 1983, 1984, 1986 (Fig. 1) and 1990-1995 (Fig. 2) has also been highly variable from year to year, more so than for other species (Gunnlaugsson 2005). Sightings were very few in

a red-fish survey in June 2003 (Fig. 7). No sei whales were sighted during cetacean sighting effort in oceanographic surveys in spring 1991-1994 in coastal Icelandic waters.

Dedicated surveys

Positively identified sei whales have rarely been sighted in mid-summer aerial surveys in coastal Icelandic waters 1986, 1987, 1995 2001, 2007 and 2009 (Donovan *et al.* 1989; Gunnlaugsson *et al.* 2008; Pike *et al.* 2008, 2009) nor in aerial spring and autumn surveys in 2003 and 2004 (Pike et al. 2004; Gunnlaugsson 2005).

Co-ordinated international North Atlantic Sighting Surveys (NASS) were initiated in 1987 (Sigurjónsson *et al.* 1989) and have been conducted five times, in 1987, 1989, 1995, 2001 and 2007 (TNASS) (Gunnlaugsson *et al.* 1988; Sigurjónsson *et al.* 1989, 1991, 1996; Víkingsson *et al.* 2002, 2009 (Figs 3-6). In the NASS surveys, large areas in the northern N-Atlantic have been covered simultaneously by up to 15 vessels and 2 aircraft with participation of up to five countries. Iceland, Norway and the Faroes have participated in all NASS surveys while Greenland and Spain took part in the earliest surveys (Fig. 1). TNASS was even more extensive including Canada and Russia as partners and co-ordination with simultaneous surveys off the US (SNESSA) and West European (CODA) coasts. NASS-95, NASS-2001 and TNASS were co-ordinated by the Scientific Committee of NAMMCO. There has been some difference in area coverage between surveys (Fig.1). While all cetacean sightings are recorded, the Icelandic part of the NASS surveys has been primarily devoted to abundance estimation of the East Greenland/Iceland stock of fin whales and the Central North Atlantic stock of minke whales. However, in NASS-89 special emphasis was placed on obtaining information on distribution and abundance of sei whales (Sigurjónsson *et al.* 1991; NAMMCO 1998) by surveying farther south in the Central N-Atlantic and later in the season (from July 10. to August 14) covering a large part of the Iceland-Denmark Strait schedule stock area. A resulting abundance estimate was 10,300 animals (C.V. 0.268) (Cattanach *et al.* 1993). The highest densities of sei whales were found during the latter part of the survey (early August) at the southern limit of the search area which was at 50°N. Consequently, the estimate was significantly higher if only the latter half of the survey was used, but that estimate has a higher variance. This estimate was therefore considered to be downward biased as the survey clearly only covered part of the distribution area with an unknown number in the unsurveyed area to the south.

The Icelandic part of the 2001 survey reached farther north to 74ºN and east to 3ºE (Fig. 2) than previously. No sei whales were sighted in this northern extension of the area. The mid summer surveys (1987, 2001) encountered rather few sei whales in overlapping areas (Gunnlaugsson et al. 2005). The mid-summer exception is the 1995 survey which had around 4 times higher sighting rates in overlapping areas and gave an estimate of 9.249 (Borchers and Burt 1997) sei whales in an area that only comprises 30% of the area on which the 1989 survey was based. The 2007 T-NASS covered an area in the central Atlantic similar to the 2001 survey with a similar distribution of sightings. A total of 63 sei whale sightings were made in the TNASS, 44 of these coming from the area south and southwest of Iceland. In addition, 18 sei whales sighting were made off the west European coast (CODA) and six in the SNESSA survey off USA's east coast (NAMMCO 2009).

Very low numbers of sei whales have been observed by the Norwegian, Faroese and Spanish NASS survey vessels in the eastern Northeast Atlantic (Christensen et al. 1992, Øien 2009, Lens 1991)

Sei whales were the most commonly sighted cetaceans during the MAR-ECO cruise along the Mid Atlantic Ridge from the Azores to Reykjanes Ridge during 4 June-2 July 2004 (Waring *et al* 2008). Highest densities were found near the Charlie Gibb's fracture zone, not far from the sei whale concentrations found in NASS-89. In the northern part of the survey area the mean density of sei whales was estimated as 0.018 whales/km^2 (CV 0.47).

No recent abundance estimates are available for the western North Atlantic. The population size during 1966–69 was estimated at 2,078 (Mitchell and Chapman 1977) from sightings surveys, using strip transect methodology. About 1,200 sei whales were taken off Nova Scotia during 1962–72 (Reilly *et al.* 2008).

Estimates to the west have been reported of a few thousand animals at the coast of America (Mizroch *et al.* 1984). In 2007, the SNESSA survey and Canada and Greenland T-NASS covered areas to the west, but there are large gaps in between these and the Iceland NASS areas.

Marking data

Discovery-type marking of sei whales was conducted off Iceland in 1979-1984. Analysis of marking and recoveries from sei whales off Iceland with regard to movements and stock size and identity is reported to this meeting (SC/62/O1). The marking data indicate short term site fidelity of the marked animals on the grounds being gradually thinned by movement to other areas and replaced with animals that were out of reach at the time of marking.

Stock identification

Genetics

Genetic studies of the stock structure and dispersal of North Atlantic baleen whales have traditionally been limited to research on harvested individuals from their feeding grounds. The main disadvantage of these studies was the relatively low sample sizes, in particular lack of samples from large areas. Recently the skin biopsy sampling technique has facilitated the collection of more samples from large areas and opened new research opportunities such as genetic mark-recapture programs. While a large scale international research project on humpback whales, based on biopsy sampling, was successful (Smith *et al.*1999; Palsbøll *et al.* 1995 and 1997; Palsbøll 1999), studies on other North Atlantic baleen whales have been hampered by the difficulty in obtaining large enough sample sizes (Daníelsdóttir *et al.* 1992; Daníelsdóttir 1997, 1999).

There is limited knowledge on the migratory patterns, stock structure and dispersal of North Atlantic baleen whales, apart from humpback whales. The North Atlantic minke, fin and sei whales are believed to undertake seasonal migrations, moving northwards in spring to their high latitude feeding grounds and south again in the autumn to their breeding grounds. Very little is known about winter distribution of these species in the North Atlantic, and available genetic data is entirely based on samples from feeding areas (Árnason and Jónsdóttir 1988; Daníelsdóttir *et al.* 1991a, 1991b, 1992, 1994; Daníelsdóttir 1999; Bérubé *et al.* 1998) In the few instances where samples have been obtained a number of years in a sequence, an interesting temporal variation and/or stock heterogeneity has been observed in some fin whale stocks (Daníelsdóttir *et al.* 1991a; Bérubé *et al.* 1998) and Northeast Atlantic minke whales (Daníelsdóttir *et al.* 1995; Martinez and Pastene 1999) but not in Icelandic sei and West Greenland minke whales (Daníelsdóttir *et al.* 1991a; Andersen *et al.* 2003).

On the basis of relatively little evidence, the IWC defined three sei whale management areas (Donovan 1991): (1) Iceland-Denmark Strait; (2) Eastern (west of Norway, the Scottish Islands, Spain and Portugal) and (3) Nova Scotia.

The available genetic data (Daníelsdóttir *et al.*1991a, 1994) showed that the Icelandic sei whale represented homogenous population with no significant temporal variation in samples from 1995-1998. The great variation revealed by the DNA fingerprinting method indicates that sei whales have not undergone bottleneck effect (Spillaert *et al.* 1989).

Satellite telemetry

Satellite telemetry has, in recent decades, proven to be a useful technique to monitor movements of free ranging animals. The use of the technique for studying large cetaceans is, however, much more problematic than for terrestrial mammals. The additional problems include the need for remote deployment of the tags and short communication time between tags and satellite because of diving.

Although the location of wintering grounds of sei whales in the North Atlantic is unknown, the species is regularly sighted close to the Azores during spring. The first successful satellite tagging of sei whales in the N-Atlantic was conducted as a part of the MAR-ECO project in 2005, when a sei whale was tracked between the Azores and the Labrador Sea during 12th April and 7th June (Olsen *et al.* 2009). During May-June 2008 and 2009, a total of 7 sei whales were successfully tracked from the Azores and to the Labrador Sea, west and southwest off Greenland (Prieto et al. 2010). One sei whale tagged in the same area in September 2009 moved south-eastward from the Azores towards Africa (Fig. 8). These studies clearly show a spring migration route from the south-eastern part of the North Atlantic, passing the Azores and continuing north to the Labrador Sea and West Greenland. Since very few signals were received into the time of peak abundance in Icelandic waters (late summer/autumn), conclusions cannot be drawn regarding a link between sei whales

in that area and the Labrador Sea. However, the only whale that transmitted regularly into late summer (last signal 19. August) had indeed passed the southern tip of Greenland heading eastwards (Fig.8).

Biological parameters

Studies on the biological parameters of sei whales were conducted in connection with the whaling activities west and southwest of Iceland in the seasons 1967, 1969, 1972-1975 and 1977-1981 (Lockyer and Martin 1983). Lockyer (1979) found a decline in age at sexual maturity in Southern Hemisphere sei whales, and concluded that this was most likely linked to exploitation.

The readability of Icelandic fin and sei whale earplugs is around 70% (IWC 1984; Konráðsson and Sigurjónsson 1989). The age at sexual maturity in Icelandic sei whales is estimated 8-10 growth layers for both sexes. There are no indications of temporal changes in age at maturity (Lockyer and Martin 1983), but data are, however, very meagre in that respect.

Diet composition

Sei whales are generally believed to feed primarily on copepods, although euphausiids and small schooling fish have also been reported as food items (Leatherwood and Reeves 1983; Horwood 1987; Klinowska 1991; Lockyer 1995). On the whaling grounds west and southwest of Iceland, 98% of the 250 examined stomachs contained euphausiids, primarily *Meganyctiphanes norvegica* (Sigurjónsson and Víkingsson 1997), while sandeel, capelin and copepods were also among the identified food items.

Energetics

As a part of the research programme 1986-1989, extensive data was collected on energetic indices of fin and sei whales. Similar methods as used by Lockyer and co-workers (Lockyer 1986, Lockyer and Waters 1986) were applied on a larger sample, to estimate the amount of seasonal accumulation of energy reserves. In general, these studies supported the conclusions of Lockyer of large variation in body condition of different reproductive classes and considerable seasonal deposition of energy reserves in fin whales (Víkingsson 1990, 1995). Vikingsson *et al.* (1988) studied the relationship between weight, length and girth. The sei whale sample collected during the research project was much smaller, only 70 animals spread over three years, 1986-1988 (Víkingsson 1990). Although this sample is clearly insufficient for quantitative estimation of energy deposition similar to the studies on fin whales, some indications of similar processes were detected in the limited sei whale data. Thus, significant seasonal fattening was found for immature males in blubber thickness and girth as well as in the lipid content of the posterior dorsal blubber (Víkingsson 1990).

Parasites and pathology

Disease induced mortality may vary with age and population density. The fishing mortality is usually higher in older age classes leading to higher proportion of young and immunologically naïve individuals and higher overall disease induced mortality in depleted populations (Allen 1980). The general assumption of the currently used population models for mammals that natural mortality is constant may therefore lead to biased estimates of recruitment rates.

A preliminary investigation on disease biomarkers in fin and sei whales was carried out by American scientists in relation to the commercial whaling in Iceland in 1981–1983 and continued during the research programme 1986-1989 (Lambertsen 1986, 1990; Lambertsen *et al.* 1986).

The objectives of these studies were to systematically examine all pathogens observed in the whales with the final aim to identify all potentially lethal pathogens and estimate the disease induced mortality in the populations.

The studies included detailed necropsies of the animals in order to detect pathogens that potentially affected the survival of the host. Fin and sei whales contrasted in the variety and internal parasitic infections, the incidence of presumptive viral diseases and the frequency of external lesions. These studies revealed severe infections of the giant kidney worm (*Crassicauda boopis*) in fin whales that were considered to cause congestive renal failure and occlusion of the renal veins that probably could kill the host (Lambertesen 1986; Lambertsen *et al.* 1986). The sei whales did not seem to suffer from crassicaudiasis in the same extent as fin whales. On the other hand, 92% of the examined sei whales (N=24) had invasive infections of *Bolbosoma*

spp. (Acanthocephala) in the colon. The severity of these infections varied between individuals and systemic effects were difficult to determine. The sei whales were frequently scarred with bite wounds and external lesions that could not be identified. Furthermore, 18% of the sei whales showed an inflammation in the lungs that appeared consistent with viral or micoplasma pathogen but histopathological studies failed to detect the viral agent (Lambertsen 1990).

Age determination

The most commonly used method for age determination of baleen whales has been by reading growth layers in ear plugs (Lockyer 1972).

In fin and sei whales age determination from growth layers in ear plugs is less problematic than for North Atlantic minke whales. The readability of Icelandic fin and sei whale earplugs is around 70% (IWC 1984; Konráðsson and Sigurjónsson 1989).

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Table 1. A summary of available information on sei whales in the Central Nort Atlantic according to the agreed guidelines (IWC 2005).

Item	Details	Raw format	Where held	Key papers	Comments
Operational data					
Catch history	Nation, operation, date, length, sex	Electronic	IWC		Catch data subject to the same uncertainties as fin whales for the first period of whaling.
Effort data	Icelandic operation	Electronic	MRI		Not likely useful for CPUE analysis.
Abundance					
Shipboard	Line transect	Electronic	MRI	Cattanach et al. 1993, Borchers and Burt 1997	
aerial					
Stock structure and dispersal rates					
Genetic	Allozymes, DNA,	Electronic	MRI	Spilliaert et al, 1989, Danielsdóttir, 1994,	

				Danielsdóttir et al 1991	
Morphometric	Full morphometry on 70 sei whales taken during 1986-1989	Electronic	MRI		
Discovery tags	68 tags placed off Iceland and W-Greenland	Electronic	MRI, IWC	SC/62/O1	
Telemetry	Satellite tagging	Electronic	R. Prieto and E. Olsen.	Prieto et al 2010, Olsen et al 2009	
Biological parameters	Age (earplugs), reporoductive rates	Electronic	MRI	Lockyer abd Martin, 1983, Konráðsson and Sigurjónsson 1989	
Ecological				Sigurjónsson and Víkingsson 1997	

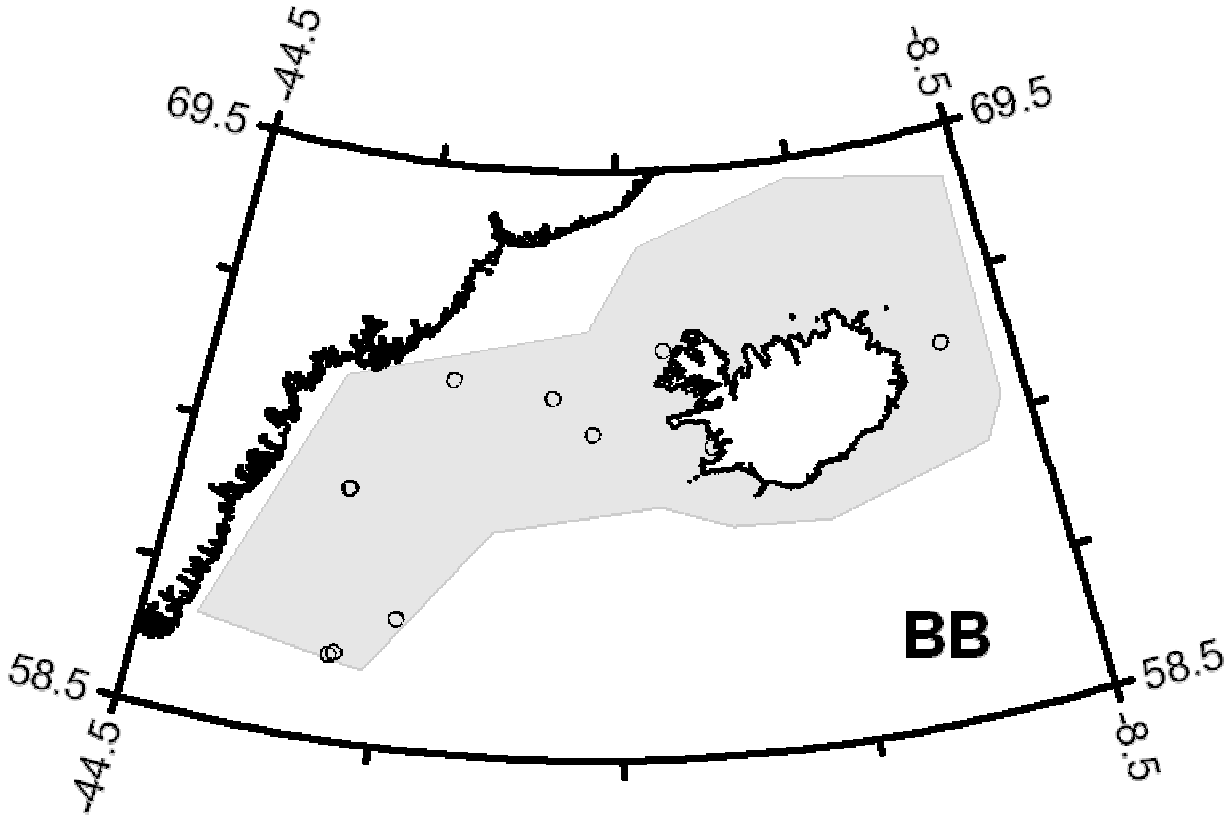


Figure 1. Sei whale sightings in 0-group late summer/autumn fish surveys in 1983, 1984 and 1986.

Figure 2 (below). Sei whale sightings in 0-group fish surveys in 1990-1995 (late summer/autumn).

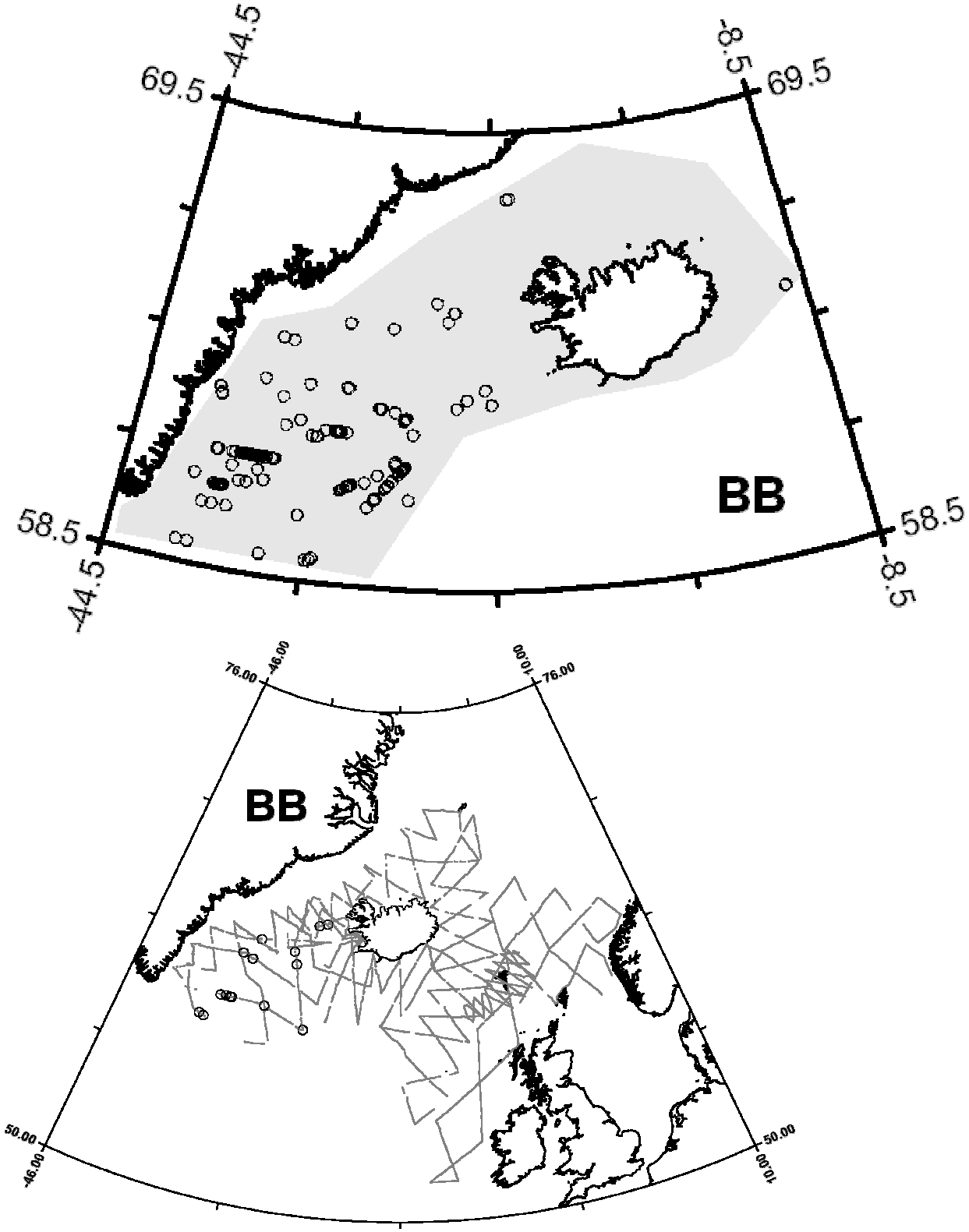


Fig. 3. Sei whale sightings in mid-summer NASS-87

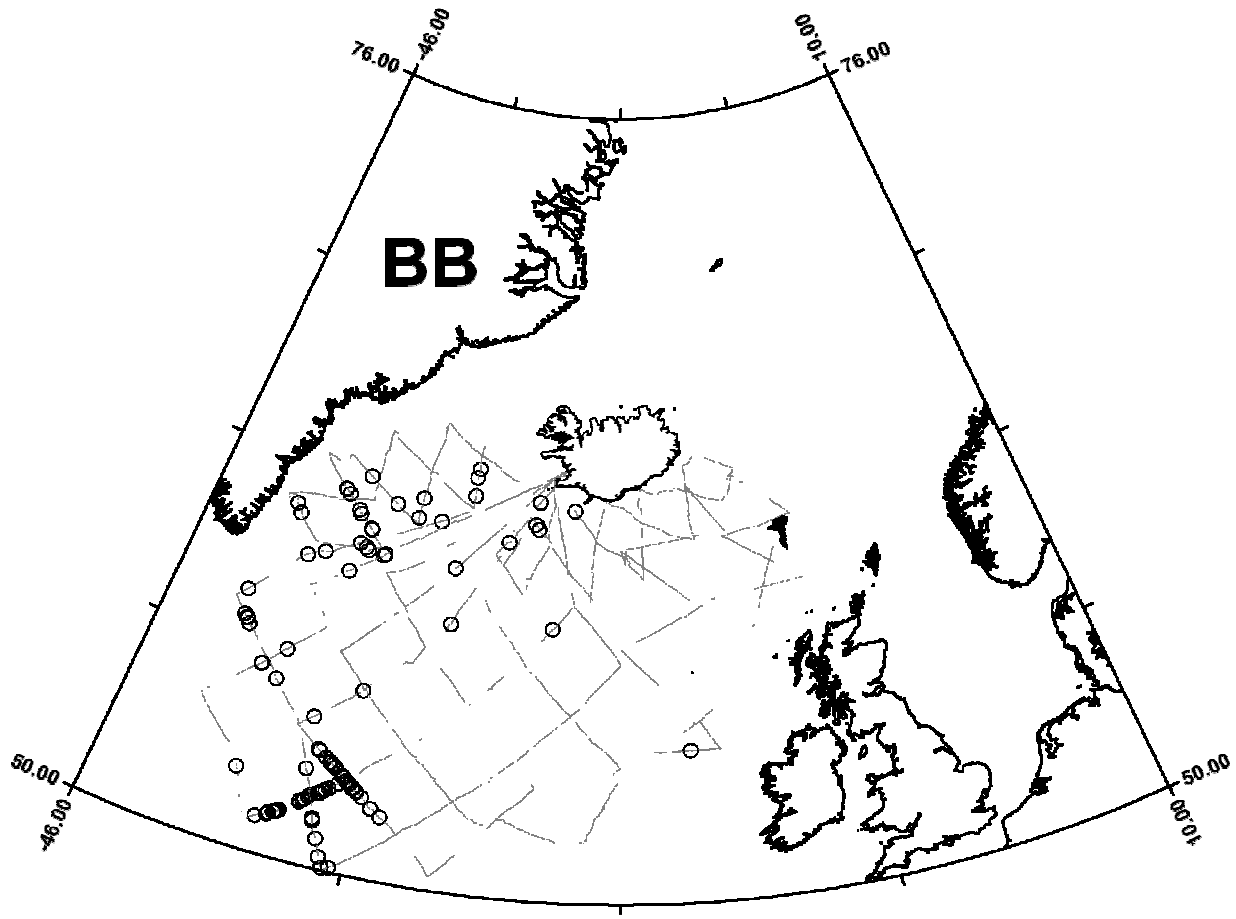


Fig 4. Sei whale sightings in July-August NASS-89

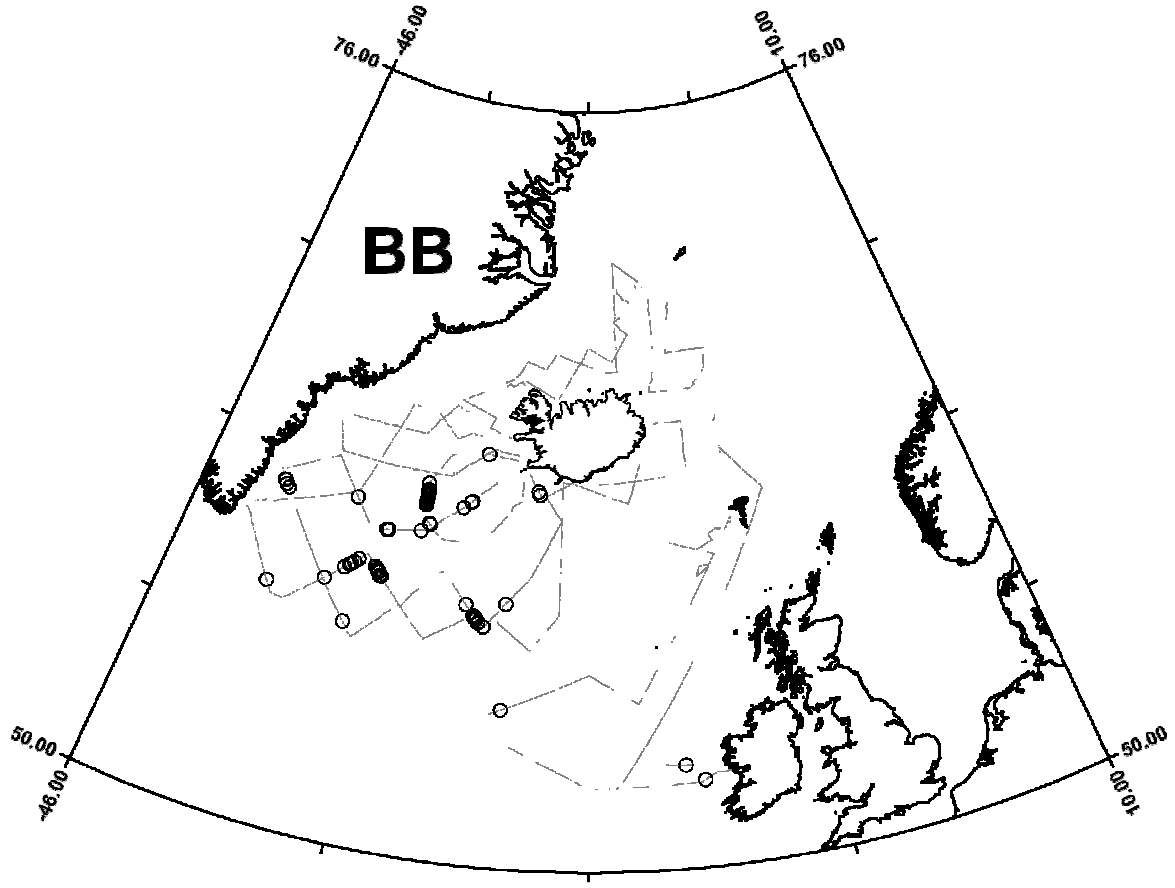
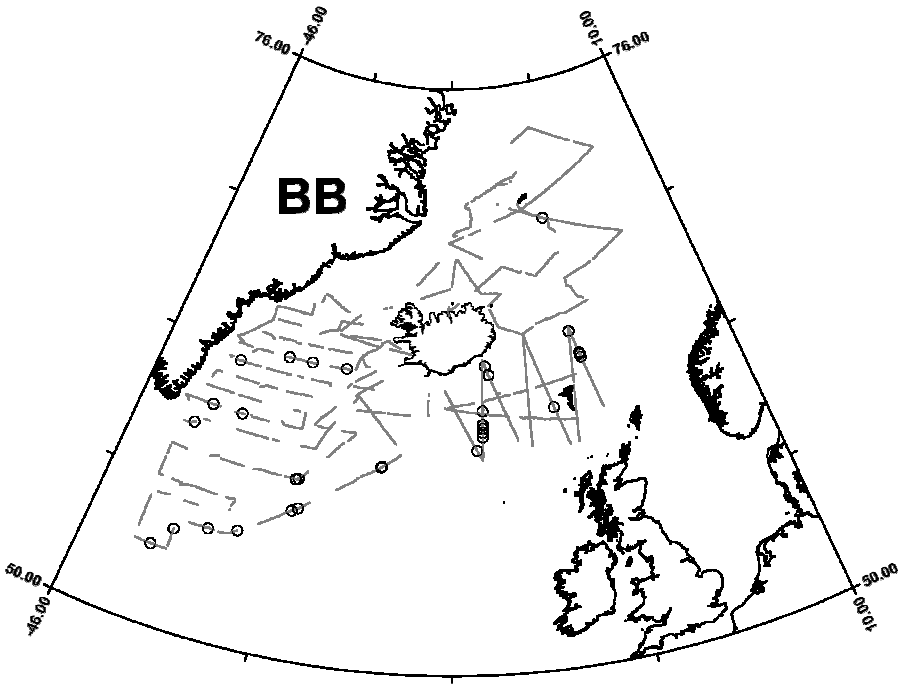


Fig 5 (above). Sei whale sightings in mid-summer NASS-95

Fig 6 (below). Sei whale sightings in mid-summer NASS-2001



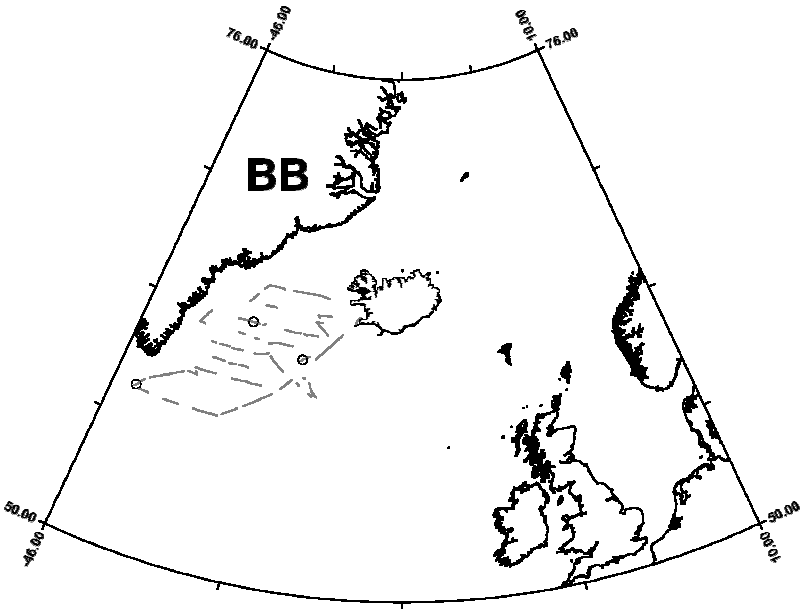
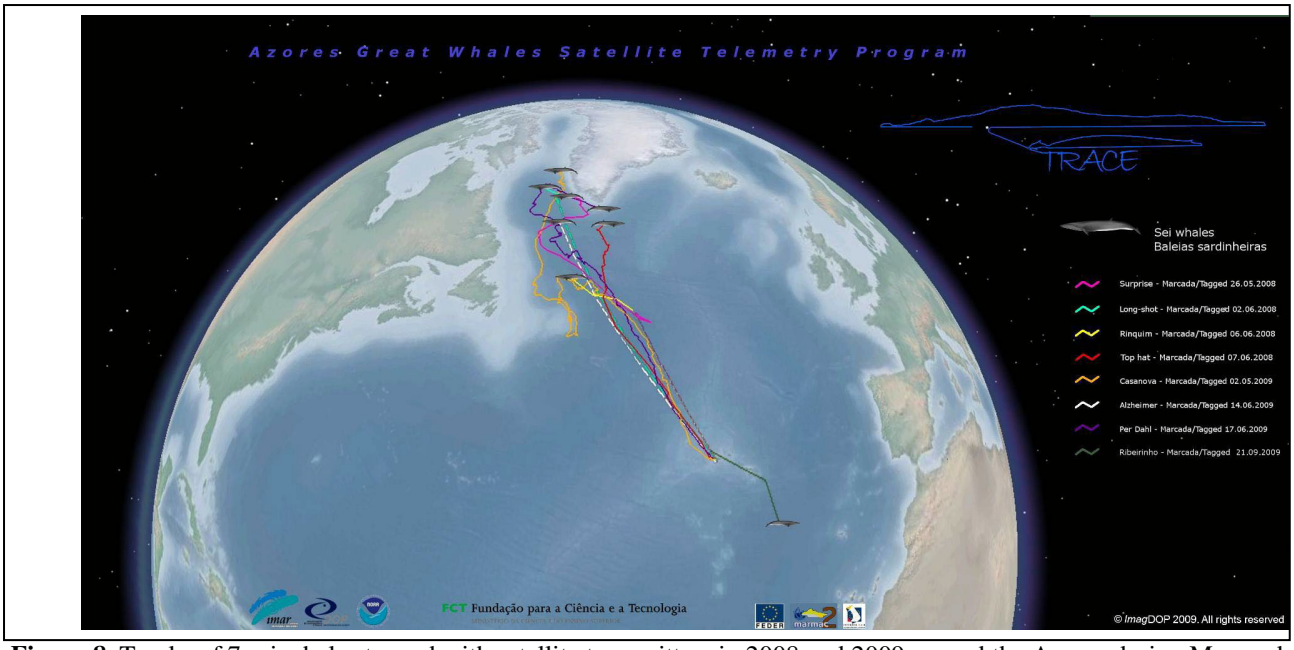


Fig 7. Sei whale sightings in June 2003 red-fish survey



.**Figure 8**. Tracks of 7 sei whales tagged with satellite transmitters in 2008 and 2009 around the Azores during May and June 2008 and 2009. Figure from Prieto (2010).