Paper 1

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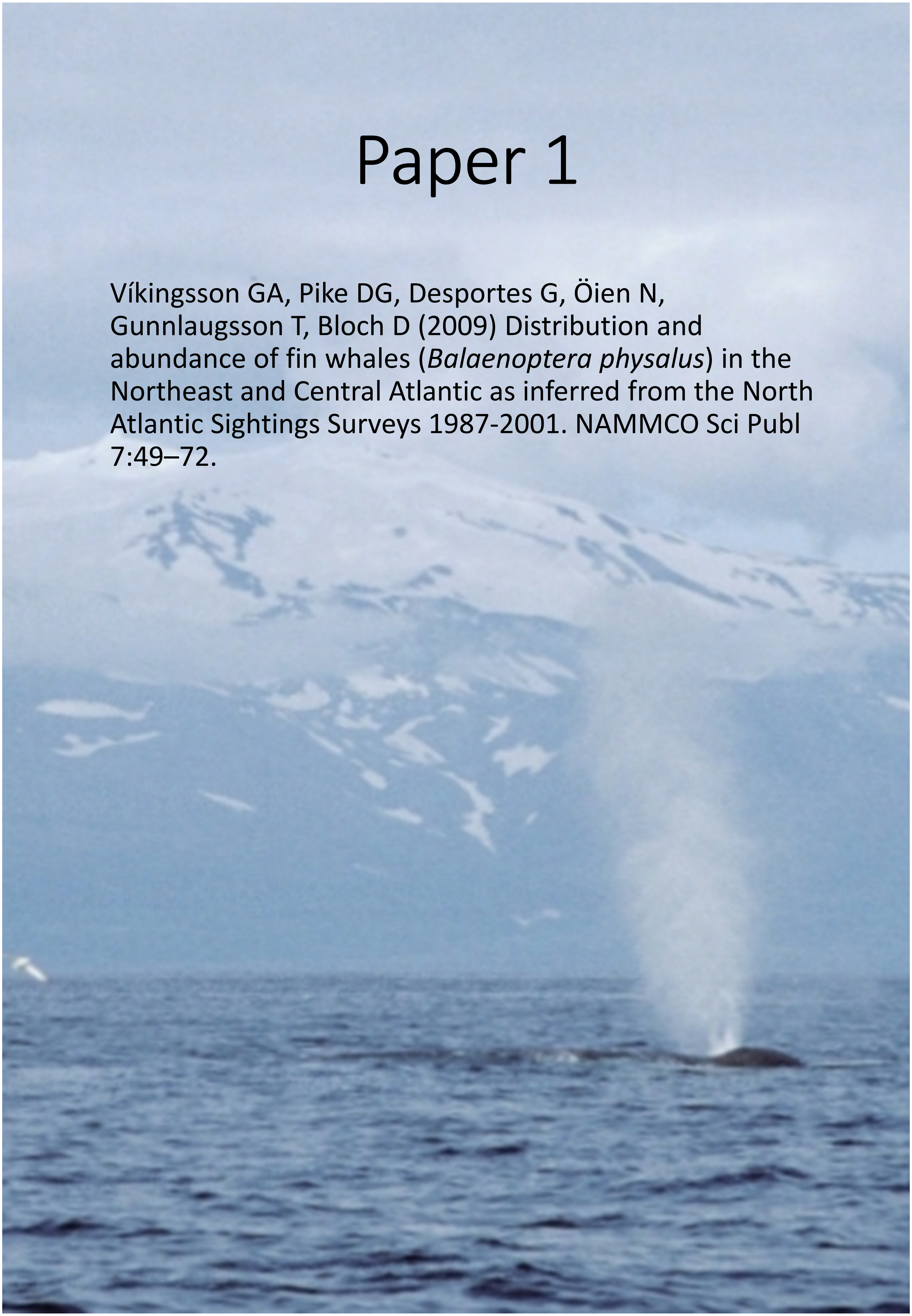

Distribution and abundance of fin whales (*Balaenoptera physalus*) in the Northeast and Central Atlantic as inferred from the North Atlantic Sightings Surveys 1987-2001.

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ABSTRACT

North Atlantic Sightings Surveys (NASS) is a series of large scale international cetacean line transect surveys, conducted in 1987, 1989, 1995 and 2001, that covered a large part of the central and eastern North Atlantic. Target species were fin (*Balaenoptera physalus*), common minke (*B. acutorostrata*), pilot (*Globicephala melas*) and sei (*B. borealis*) whales. Here we present new estimates of abundance for fin whales from the 2 most recent surveys and analysis of trends throughout the survey period. Fin whales were found in highest densities in the Irminger Sea between Iceland and Greenland. Abundance of fin whales in the survey area of the Icelandic and Faroese vessels (Central North Atlantic) was estimated as 19,672 (95% C.I. 12,083-28,986) animals in 1995 and 24,887 (95% C.I. 18,186-30,214) in 2001. The estimates are negatively biased because of whales diving during the passage of vessels, and whales being missed by observers, but these and other potential biases are likely small for this species. The abundance of fin whales increased significantly over the survey period. For all areas combined the estimated annual growth rate was 4%. An estimated annual increase of 10% in the area between Iceland and Greenland was responsible for most of this overall increase in numbers of fin whales in the area. Although high, the estimated rates of increase are not out of bounds of biological plausibility and can thus be viewed as recovery of a depleted population. However, the apparent pattern of population growth and the whaling history in the area indicate that fin whales made a significant recovery during the first half of the 20th century and that the recent observed high growth rates cannot be explained solely by recovery after overexploitation.

Víkingsson, G.A., Pike, D.G., Desportes, G., Øien, N., Gunnlaugsson, Th. and Bloch, D. 2009. Distribution and abundance of fin whales (*Balaenoptera physalus*) in the Northeast and Central Atlantic as inferred from the North Atlantic Sightings Surveys 1987-2001. *NAMMCO Sci. Publ*. 7:49-72.

INTRODUCTION

The fin whale (*Balaenoptera physalus*) is the most abundant large baleen whale species in the North Atlantic. Due to their fast swimming abilities they were, however, not available to the whaling industry until the invention of the explosive harpoon and steam driven vessels in the late 19th century, marking the beginning of modern whaling. From then on they were, together with blue whales (*B. musculus*), th e most important species for the whaling industry in the North Atlantic and subsequently in other ocean areas. Judging from whaling records the stocks of large whales, including fin whales, were severely depleted in many localities of the North Atlantic, including Norway, the Faroes and Iceland, during the first few decades of modern whaling in the late 19th and early 20th centuries (Risting 1922, Tønnessen and Johnsen 1982, Jónsson 1964, 1965). According to a decision taken by the Icelandic Parliament a total ban on all whaling for large whales in Icelandic waters took effect in 1916, by which time the industry was commercially barely viable because of over harvesting (Risting 1922, Jónsson 1965). According to indices of relative abundance, the fin whale stock(s) off Iceland had made a significant recovery when whaling was resumed in 1948, after 3 decades of near total protection (Gunnlaugsson *et al.* 1989, Butterworth and Punt 1992, Cunningham and Butterworth 2003).

The first attempts to estimate abundance and trends of fin whales in the Central North Atlantic were based on mark-recapture data as well as analysis of catch per unit effort (CPUE) from the Icelandic fishery (Rørvik *et al.* 1976, Rørvik 1981, Sigurjónsson and Gunnlaugsson 1984, 1985a). The CPUE data did not show any significant trend in relative abundance on the Icelandic whaling grounds during the post war (after 1948) whaling period (Sigurjónsson and Rørvik 1983, Sigurjónsson and Gunnlaugsson 1985a, Gunnlaugsson *et al.* 1989).

Based on mark-recapture experiments on fin whales, mainly on the whaling grounds west of Iceland, Sigurjónsson and Gunnlaugsson (1985b) came to an estimate of around 7,000 whales in 1970. This and other mark-recapture estimates of absolute abundance based on discovery markings were surrounded by large uncertainty. In particular, these marking studies (Gunnlaugsson and Sigurjónsson 1989) and subsequent photo-id studies (Agler *et al.* 1993, Seipt *et al.* 1990, Clapham and Seipt 1991), showed some degree of site fidelity of individuals, indicating that the fundamental assumption of random mixing within the whole "EGI stock area" was likely violated.

Few systematic cetacean sightings surveys were conducted in the Central North Atlantic prior to the mid 1980's and these had only partial coverage and/or had other primary objectives than to estimate total population size (Sigurjónsson 1983, 1985, Martin *et al.* 1984).

In 1986 the International Whaling Commission's (IWC) temporary ban (moratorium) on commercial whaling took effect. This drastic decision was supported by the fact that very limited data existed on abundance and status of most whale populations. The moratorium was to be reconsidered by 1990 at the latest after a so called "Comprehensive Assessment" (CA) of whale stocks. Member nations were urged to increase their research efforts to facilitate the CA. As a response Iceland initiated a large and wide ranging whale research programme in 1986. The programme included large scale sightings surveys in Icelandic and adjacent waters. After consultations with other nations with similar research interests in the region the survey was expanded to include simultaneous coverage of a large part of the central and eastern North Atlantic. The first North Atlantic Sightings Survey (NASS) was conducted in 1987 with participation from Greenland, Iceland, Norway, the Faroe Islands and Spain. The 2nd NASS was conducted in 1989 with a more southerly coverage in the central North Atlantic than the previous survey. Abundance estimates from these first 2 NASS have been published separately for the main target species (Sanpera and Jover 1989, Larsen *et al.* 1989, Hiby *et al.* 1989, Gunnlaugsson and Sigurjónsson 1990, Buckland *et al.* 1992a, 1992b, 1993, Øien 1989, 1991, Schweder *et al.* 1997). In this paper we review fin whale distribution and abundance in the Northeast Atlantic from the shipboard components of NASS and present 2, previously unpublished, estimates of abundance for the Central North Atlantic. These are from surveys conducted in 1995 and 2001 by Iceland and the Faroe Islands. Together, these 4 large scale surveys have produced a valuable time series of the distribution and abundance of fin whales and other cetaceans in the Northeast Atlantic that for the first time enables direct analysis of trends in abundance and distribution over a 15 year period.

Methodology, narrative and primary abundance estimates from the Norwegian surveys are reported separately (Øien 2009). However, for completeness, Norwegian data are included here in relation to distribution and trends in abundance.

METHODS

Survey design

In all NASS the design and planning of the surveys has been done cooperatively by the participating nations and laboratories well in advance of the surveys. For the first 2 NASS the methods and survey design were determined at pre-cruise meetings which were coordinated through the Scientific Committee of the IWC (*e.g.* Anon. 1987). From 1995, planning and coordination took place through the Scientific Committee of NAMMCO (NAMMCO 1995, 2002).

Target species

The primary objective of the NASS is to obtain simultaneous coverage of as large a portion as possible of the summer area of the cetacean species of most interest to the nations involved. This requires the participating institutes to define their primary target species which are then used as a basis for the design of the surveys with respect to timing, area coverage and observation procedures. The primary target species as defined by the different participating nations are given in Table 1. Fin whales were the primary target species in all the Icelandic shipboard surveys except in 1989 when sei whales (*Balaenoptera borealis*) were the main target species (Sigurjónsson *et. al.* 1989, 1991, 1996, Víkingsson *et al.* 2002). Fin whales were also the primary target species in both Spanish surveys (Lens *et al.* 1989, Lens 1991), the Greenlandic aerial survey in 1987 (Larsen *et al.* 1989) and the Faroese survey in 2001 (Desportes *et al.* 2002). Minke whales (*B. acutorostrata*) were the primary target species in all the Norwegian surveys as well as in the aerial surveys in coastal Icelandic waters (Øien 2009, Pike *et al.* 2009). Irrespective of the declared primary target species, sightings of all cetaceans were systematically recorded in all the surveys. In some instances modifications of the survey procedures were made to improve the abundance estimation of primary target species of other countries surveying in adjacent areas. For example, in 1995 the Icelandic vessels adopted, as the Faroese vessel, a special procedure for estimating group size of long-finned pilot whales (*Globicephala melas*) (Desportes *et al.* 1996) although fin whales were the main target species.

Table 1. Target species and survey mode for all NASS cruises 1987 2001.

Year	Country	Primary target species	Secondary target species	Survey mode
1987	Greenland (aerial)	Minke and fin whale		
	Iceland	Fin (shipboard) and minke (aerial) whale	Other large cetaceans	Modified passing mode
	Faroes	Long finned pilot whale	Large whales	Passing mode (delayed closing)
	Norway	Minke whale		Alternating passing/closing mode
	Spain	Fin whale		Passing mode (exceptional closing)
1989	Iceland	Sei whale	Fin whales	Passing mode (delayed closing)
	Faroes	Long finned pilot whale	Large whales	Passing mode (delayed closing)
	Norway	Minke whale		Passing mode (delayed closing)
	Spain	Fin whale		Passing mode (delayed closing)
1995	Iceland	Fin (shipboard) and minke (aerial) whale		Passing mode (delayed closing)
	Faroes	Long finned pilot whale	Minke and bottlenose whales, common and white-sided dolphins	Buckland & Turnock mode, with delayed closure for pilot whales and target species and special group size estimation experiment for pilot whales
	Norway	Minke whale		Passing mode
2001	Iceland	Fin (shipboard) and minke (aerial) whale	Humpback whales	Buckland & Turnock mode
	Faroes	Fin and minke whale		Buckland & Turnock mode
	Norway (1996-2001)	Minke whale		Passing mode

Area coverage and timing

Figure 1 shows the total area covered by vessels in the 4 NASS conducted to date and information on timing and search effort is given in Tables 2 and 3. Timing of the surveys was generally centred in July (Table 2) while the 1989 NASS was conducted about 2 weeks later in the season and covered areas further to the southwest for better coverage of the distribution of sei whales (Sigurjónsson *et al.* 1991). Areas north of Iceland were not surveyed in 1989 (Fig. 1). The largest total shipboard effort was obtained during NASS-89 when a track of 26,512 nm was searched from 15 vessels covering an area of 1.7 million nm^2 (Table 3). In addition, substantial areas were surveyed off West Greenland, Iceland and Norway from aircraft (Larsen *et al.* 1989, Donovan and Gunnlaugsson 1989, Hiby *et al.* 1989, Øritsland *et al.* 1989, Pike *et al.*, 2009).

In 1995 the coverage was similar to that in 1987, except that the areas off Spain and West Greenland were not covered. Both the timing of the survey and the area coverage were planned with consideration of the primary target species: fin, long finned pilot and common minke whales. Two Icelandic vessels surveyed the seas between East Greenland and Iceland, including the traditional large baleen whaling grounds off West Iceland, coastal and offshore waters around Iceland and the waters northeast of Iceland as far north as 74°N (Figs 1 and 2). The Faroese vessel surveyed the area between south eastern Iceland and western Ireland bounded by 5°W and 18°W longitude and 65°N and 52°N latitude (see Figs 1 and 2). The Norwegian vessels covered the eastern part of the survey area from the North Sea in the south to the Barents Sea in the north (Øien 2009). The cruise track design in the Icelandic survey was the same as

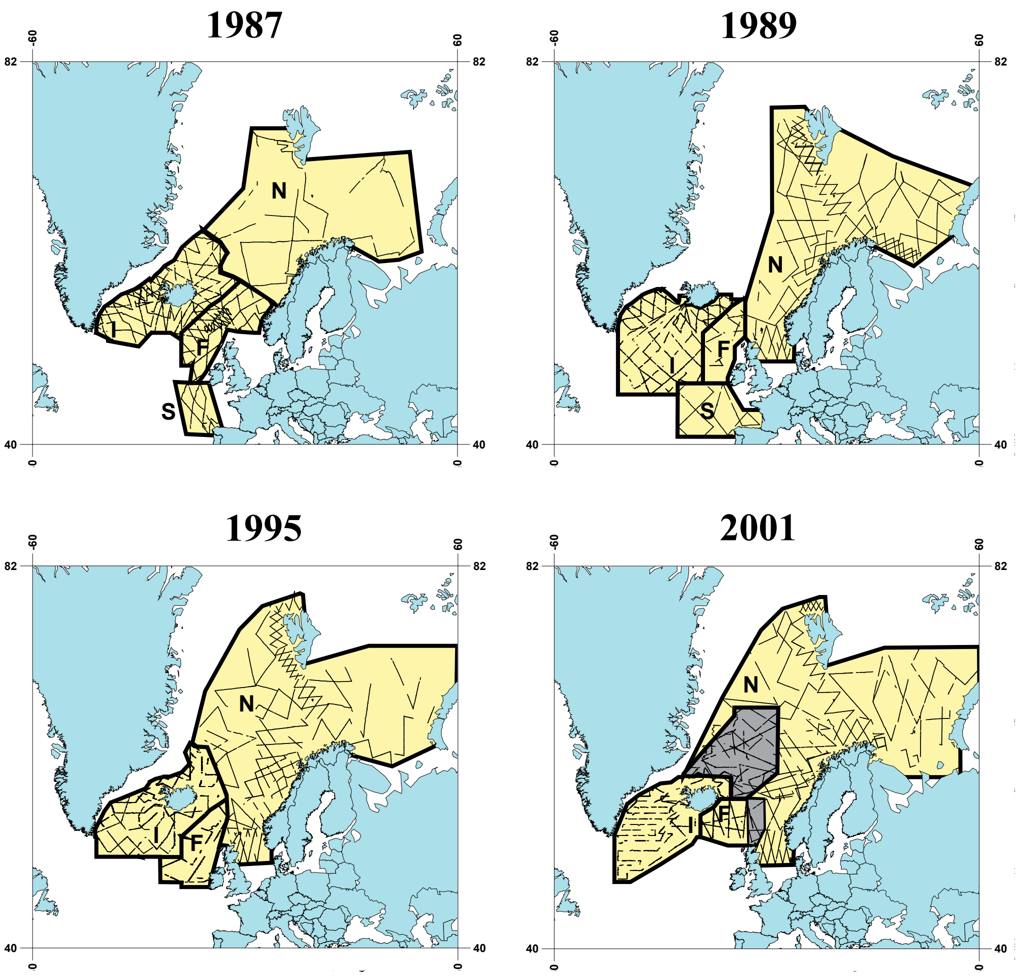

Fig. 1. *Realized survey effort in Beaufort sea state (BSS) 5 or less. Gray areas are areas of overlap. F, Faroe Islands; I, Iceland; N, Norway; S, Spain. For the Norwegian survey area, 2001 refers to the mosaic survey period 1996-2001.*

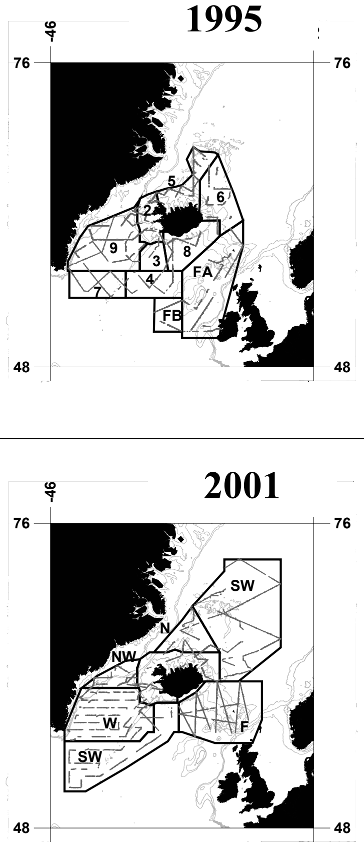

***Fig. 2.** Original block structure and realized search effort in NASS 1995 and NASS 2001.*

used for the NASS-87 survey, i.e. the saw tooth pattern described by Cooke (1987) and Cooke and Hiby (1987). The Faroese cruise track design was also of a saw tooth pattern with a rather simple structure because a large area had to be surveyed with limited effort. The track was divided into primary and secondary track lines where coverage of the latter depended on the progress of the survey (Desportes *et al.* 1996).

After the completion of NASS-95, Norway decided to change their strategy by conducting surveys every year with partial coverage, so that their intended total coverage could be reached over 6 years. Thus, the 2001 survey had lower simultaneous coverage than previous NASS. The surveys by 2 of the 3 Icelandic vessels were conducted jointly with an acoustic redfish survey west and southwest of Iceland. The survey area reached farther to the southwest than in the NASS-95 and the track lines followed those used in previous redfish surveys in the area. These were different from the zigzag track lines used in earlier surveys. The third Icelandic vessel R/V Árni Friðriksson RE 100 (AF1) surveyed the areas north and northeast off Iceland (Jan-Mayen block, see Fig. 2). The planned Faroese survey area was from the Scottish coast in the south, around the Faroe Islands and to the southeast coast of Iceland in the north. The Faroese and remaining portions of the Icelandic survey areas were designed using the programme "Distance" (Thomas *et al.* 2002).

Observation procedures

Data collection and analytical methods in NASS-87 and NASS-89 were according to standard line transect methods (see Joyce *et al.* 1990 and Buckland *et al.* 1992b, 1993 for details) while some modifications were made in the 2 latter surveys (see below). Observation procedures for the NASS-95 and NASS-2001 were determined at planning meetings coordinated by the Scientific Committee of NAMMCO (NAMMCO 1995, 2002). Table 2 gives technical information on the vessels and observation platforms used by Iceland and the Faroes in all 4 NASS.

NASS-87, -89 and -95

Iceland

Data collection methods used on the Icelandic vessels during NASS-87 and NASS-89 involved a primary observation platform on the roof of the navigation bridge and a higher single man barrel above with unlimited communication between them (Sigurjónsson *et al.* 1989, 1991). For the latter part of NASS-89 2 whaling vessels with 2 single-man barrels on the front mast were used, in addition to the primary platform, but this configuration has not been used since. The NASS-95 survey was conducted using similar vessels and equipment, and using a delayed-closure mode. On each of the vessels observations were made from 2 platforms, a primary platform on top of the wheelhouse and a higher level barrel (see Table 3). Full communication between the different platforms and the navigation bridge was allowed. The vessels were equipped with GPS navigation aids that were linked with computers on the primary platform, which were also used for all data entry, unlike in the 2 previous surveys where all

Table 2. Timing and duration of the Icelandic and Faroese NASS cruises 1987-2001, technical details of the participating vessels and number of observers (R/V Árni Friðriksson RE 100 was modified in 1990).

Year	Nationality	Vessel name	Length (m)	Tonnage (Btn)	Power (HP)	Cruising speed (knots)	Duration of cruise	No of platforms (eye height)	No of observers on lower/higher platforms
1987	Iceland	R/V Árni Friðriksson RE 100	42.15	449	996	10	24/6-28/7	2 (9m & 13.8m)	2-3/1
	Iceland	M/V Skírnir AK 16	37.8	233	660	9.5-10.5	24/6-28/7	2 (9.3m & 13.8m)	2-3/1
	Iceland	M/V Keflvíkingur KE 100	33.9	210	750	9-10	24/6-27/7	2 (8.7 & 13.8m)	2-3/1
	Faroes	M/V Hvítaklettur	34.7	276	550	10		1 (6.2m)	3 4
1989	Iceland	R/V Árni Friðriksson RE 100	42.15	449	996	10	10/7-14/8	2 (9m & 13.8m	3/1
	Iceland	M/V Barðinn	37.8	233	660	9.5-10.5	11/7-13/8	2 (9.3m & 13.8m)	3/1
	Iceland	M/V Hvalur 8	48.2	481	1,800	10-11	27/7-12/8	3 (10m, 14.5m & 19m	3/1/1
	Iceland	M/V Hvalur 9	51.2	631	1,900	10-11	27/7-12/8	3 (10.5m, 14.5m & 20.7m)	3/1/1
	Faroes	Ólavur Halgi	55.0	792	1,470	10	21/7-15/8	2 (8.2m & 13m)	3/2
1995	Iceland	R/V Árni Friðriksson RE 100 (AF1)	42.15	475	996	9-10	4/7-1/8	2 (9m & 13.8m	3/1
	Iceland	M/V Strákur GK (STR)	38.1	329		9-10	22/6-4/8	2 (10.5m & 15.5m)	3/1
	Faroes	M/V Miðvingur (MID)	36	266	500	9.5	7/6-6/8	2 (9.35 & 5.5m)	2-3/2
2001	Iceland	R/V Árni Friðriksson RE 100 (AF1)	42.15	475	996	8.5-11.5	25/6-29/7	2 (9m & 13.8m	2/3
	Iceland	R/V Árni Friðriksson RE 200 (AF2)	69.9	2,233	5,710	8.5-11.5 (1-3 during trawling)	21/6-12/7	2 (15.3m & 18.6m)	2/3
	Iceland	R/V Bjarni Sæmundsson RE 30 (BS)	56	822	1,800	8.5-11.5 (1-3 during trawling)	19/6-12/7	2 (10.3m & 16.3m)	2/3
	Faroes	West Freezer (WF)	42	486	750	11	29/6-25/7	2 (13.8m & 11m)	3/2

entries were made on paper. All observers were equipped with aids for estimating distance (see Sigurjónsson *et al.* 1991, 1996). Usually 3 or 4 persons were on watch on the primary platform and 1 in the barrel. Searching was done with the naked eye while binoculars were used primarily for species identification. Data collected comprised all standard parameters used for estimation of abundance of large whales (Buckland *et al* 2001). As fin whales were the main target species searching was generally continued in sea states up to Beaufort Sea State (BSS) 7.

Faroes

In NASS-87 the single Faroese vessel operated with only 1 observation platform while during NASS-89 2 platforms were used: a primary observation platform on the roof of the navigation bridge and a higher two man barrel in the front mast with unlimited communication between the platforms (see Table 3).

Due to problems in estimating group size of pilot whales and possible responsive movements of the species, a different approach was taken

Table 3. Total searching effort in the shipboard component of NASS 1987-2001.				
Survey	**Nation**	**Total track length (nm)**	**Total area coverage (nm²)**	**Source**
NASS-87	Faroes	5,608	212,855	Sigurjónsson *et al.* 1989
	Iceland	11,786	452,362	Sigurjónsson *et al.* 1989
	Norway	3,493	397,823	Øritsland *et al.* 1989; Øien 1989
	Spain	2,323	193,947	Sanpera & Jover 1989
Total		**23,210**	**1,256,987**	
NASS-89	Faroes	2,448	236,185	Joyce *et al.* 1990; Buckland *et al.* 1993.
	Iceland	9,314	673,111	Sigurjónsson *et al.* 1991
	Norway	13,858	653,984	Øien 1991
	Spain	3,345	415,290	Lens 1991; Buckland *et al* 1992a
Total		**26,512**	**1,742,385**	
NASS-95	Faroes	1,662	341,183	NAMMCO 1998 p.176
	Iceland	6,125	443,813	NAMMCO 1998 p.176
	Norway	13,522	824,336	NAMMCO 1998 p.176
Total		**21,309**	**1,609,332**	
NASS-2001	Faroes	2,457	117,500	NAMMCO 2003 p.232
	Iceland	7,470	551,051	NAMMCO 2003 p.232
Total		**9,927**	**668,551**	

in the 1995 survey. The method developed by Buckland and Turnock (Buckland and Turnock 1992) and modified for the 1994 Small Cetacean Abundance in the North Sea (SCANS) survey (Hammond *et al.* 2002) was used, with a special procedure for estimating pilot whale group size (Desportes *et al.* 1996). The procedure involved 1 platform tracking detections obtained at a sufficient distance ahead of the vessel that responsive movement would not yet have occurred. The purpose of the tracking procedure was to detect the proportion of sightings missed by the primary platform and to account for potential responsive movements. The survey was conducted in passing mode with 2 independent observation platforms, a primary and a tracking platform. Two trackers and a duplicate identifier (DI, also entering data online onto a computer) were simultaneously on duty on the tracking platform. The trackers searched beyond 1,000 m ahead of the vessel, using mounted 7x50 binoculars coupled with an angle board. They tracked pilot, minke and bottlenose (*Hyperoodon ampullatus*) whales and common (*Delphinus delphis*) and white-sided (*Lagenorhynchus acutus*) dolphins via multiple sightings until they were observed by the primary platform or had passed abeam. Other species were not tracked and data were collected in a standard way. The primary platform was audio visually isolated from the tracker platform, but sighting information was communicated to the DI by telephone. The 2 primary observers searched without visual aids, but used binoculars for species identification. They concentrated their search within 1,000 m of the vessel. Searching effort was generally abandoned when BSS exceeded 4. The remaining observation procedures were similar to those on the Icelandic vessels.

Norway

The 11 Norwegian vessels operated in a passing mode with 2 independent observer teams, although minor parts of the survey were run from 1 platform. As minke whales were the main target species, searching effort was generally abandoned when BSS exceeded 4 and/or visibility fell below 1 nm. Further information on the survey methodology is given by Øien (1995 and 2009).

NASS-2001

Iceland

The basic methodology followed to the Buckland and Turnock (BT) survey method (Buckland and Turnock 1992). Thus, in contrast to earlier Icelandic surveys the primary observers searched independently of others. There were 2 primary observers, 2 trackers and 1 duplicate identifier working simultaneously. The general observation procedures and setup was thus similar to that used in the Faroese survey in 1995, except that the trackers were positioned at the higher platform in the Icelandic survey while the reverse was true for the Faroese. On all 3 vessels, observers on the primary platform operated independently of the tracker platform, but made all sightings known to the duplicate identifier on the tracker platform where they were entered on forms designed for this purpose. On the vessel AF1 this procedure could not always be followed in high density areas and during periods of communication failure. In these cases, records were kept separately on the primary platform. General practice on this platform was to spot animals with the naked eye, but binoculars were used for identifying animals at long ranges. Trackers in the upper platform scanned the horizon with binoculars and naked eye for distant sightings and tracked them until they were observed by the primary platform or until they passed abeam. Special emphasis was put on tracking minke whales and dolphins. Two pairs of 7x50 reticule binoculars coupled with angle boards were mounted on the tracking platform.

Effort was made to identify to species at least all sightings within 1.5 nm. As the few blue whale sightings in earlier surveys had been masked by the relatively large number of "like" fin and "unidentified large baleen whale" sightings, identifying blue whales was assigned priority. The decision to close on such unidentified large whales was however dependent on the distance from the trackline and whale density in the area. Searching was generally abandoned if visibility dropped below 1 nm or BSS exceeded 6.

In the joint redfish cetacean surveys conducted by R/S Bjarni Sæmundsson (BS) and R/V Árni Friðriksson RE 200 (AF2), the procedure differed somewhat from traditional whale sighting surveys. The vessels followed the predetermined track lines designed for the redfish survey (Fig. 2). However the vessels would close on sightings when necessary. The intention was also to zigzag up to the coast of Greenland where the east west going transects were connected by south north going segments, however poor weather conditions (fog) never allowed this to happen. These vessels continued other operation during the night and in weather conditions too poor for whale observation. Once or twice a day, whale search had to be paused for 3 to 7 hours during trawling. During the trawls the vessels cruised at 1-3 knots with no search effort. Efforts were made to co-ordinate the timing of trawling and other activities of the redfish survey so as to minimise the loss of whale sighting effort.

Faroes

The observation procedures on the Faroese vessel were similar to those applied on the Icelandic vessels. The survey was conducted in the BT mode using 2 independent observation platforms at different heights (see Table 3). The primary platform was situated higher than the tracking platform, contrary to the placement on the Icelandic vessels. Otherwise the setup and equipment were similar to those on the Icelandic vessels. Searching was generally discontinued if visibility was less than 1 nm, if it was raining or if the wind exceeded 4 on the Beaufort scale.

Norway

The observation procedures applied onboard the Norwegian vessels during 1996 2001 mosaic survey are described by Øien (2009).

Narrative

Narratives for the surveys conducted in 1987 and 1989 have been published and will not be repeated here (Sigurjónsson et al 1989, 1991, Larsen *et al.* 1989, Lens *et al.* 1989, Lens 1991, Øritsland *et al.* 1989). Narratives for the Norwegian survey in 1995 and the mosaic surveys 1996-2001, used in the trend analysis are given by Øien (2009).

1995

Iceland

R/V Árni Friðriksson operated during the period July 4th to August 1st and M/V Strákur between June 22nd and August 4th. Both vessels had brief stops in ports for changing crew and bunkering. The Icelandic survey area was covered twice during the survey period in order to spread the effort in time and thus prevent bias due to possible systematic movements of fin whales within the area. Although rough conditions hampered somewhat survey activities in the Irminger Sea and Denmark Strait, the realized tracklines were much in accordance with the planned ones. However, in the north and northeast, adjustments had to be made due to unfavourable weather (mainly fog) and in particular due to unexpected distribution of sea ice.

Faroes

The Faroese vessel Miðvingur operated during the period 7 July to 6 August. During this period the vessel returned to harbour twice for logistical or meteorological reasons, a short stop at Tvöroyri on 10 July and sailing off scheduled effort to Galway during 22-26 July. Weather conditions hampered progress in the first half of the survey but improved substantially from the end of July.

2001

Iceland

The surveys were conducted on 3 vessels: R/S Bjarni Sæmundsson (BS) operated from 19 June to 12 July; R/V Árni Friðriksson RE 200 (AF2) operated from 21 June to 12 July and R/V Árni Friðriksson RE 100 (AF1) operated in 2 periods, from 25 June to 13 July and from 16 July to 29 July. The 2 joint redfish cetacean vessels (BS and AF2) covered areas west and southwest of Iceland. Considerable changes had to be made to the planned tracklines for the southernmost vessel (AF2) due to late changes in the plans of redfish survey vessels of other nationality. This involved a westward shift of the southern area. To compensate for this, a homebound transit line was added east of the already surveyed area. Due to persistent fog conditions areas close to the ice edge off East Greenland could not be surveyed as planned by BS.

The main area surveyed by AF1 was covered twice during the survey period in order to spread the effort in time and thus prevent bias due to possible systematic movements of fin whales within the area. Considerable changes had to be made to the planned tracklines north of Iceland due to prevailing fog and drift ice further east than expected (Fig. 2).

Faroes

The vessel West Freezer was in operation during the period 29 June to 25 July 2001, with a weather break from 10-12 July. Considerable modifications had to be made to the planned survey track lines as UK authorities refused the Faroese and Norwegian vessels permission to enter UK waters. This was unexpected as we are not aware of any other examples of Governments hindering sightings surveys of marine mammals in the North Atlantic.

Analytical methods

Density and abundance of fin whales from the NASS-95 and NASS-2001 data was estimated using the Distance software package (Thomas *et al.* 2002) and stratified line transect methods (Buckland *et al.* 2001).

All sightings recorded as definitely or most likely fin whales (BP and BP?) were included in the analysis, while more uncertain categories ("like fin/like blue", "like fin/like humpback (*Megaptera novaeangliae*)," "large baleen whales", "large whales" *etc.*) were excluded. In the case of surveys conducted with double platforms, sightings from both platforms were used, excluding duplicate sightings. All sightings and effort conducted at BSS greater than 5 were excluded prior to analysis in 2001, while sightings and effort conducted at BSS greater than 7 was excluded in 1995 as a larger proportion of sightings in 1995 were made under high Beaufort conditions. This resulted in loss of 0 and 8 observations and 0.8 and 3.7% of the effort in 1995 and 2001 respectively. When group size was given as a range, the midpoint of the range (rounded up to a whole number) was used.

Effective strip half width (*esw*) was estimated from the distribution of grouped perpendicular distances to fin whale sightings after truncation to a distance beyond which observations became infrequent and sporadic. A variety of models for the detection function $g(x)$ were initially considered, and the final model was chosen by minimisation of Akaike's information criterion (AIC) (Buckland *et al.* 2001), goodness of fit statistics and visual inspection of model fits. Covariates were considered for inclusion in the model to improve precision and reduce bias. Covariates were assumed to affect the scale rather than the shape of the detection function, and were incorporated into the detection function through the scale parameter in the key function (Thomas *et al.* 2002). Covariates were retained only if the resultant AIC value was lower than that for the model without the covariate. The following covariates were considered: BSS, as recorded and in

2 (0 to 2 and 3 to 7 (1995) or 3 to 5 (2001)) and 3 (0 to 1, 2 to 3 and 4 to 7 (1995) or 4 to 5 (2001)) level classifications; vessel identity; group size, weather code and sightability. Unlike in some previous treatments of these data (Buckland *et al.* 1992b, Borchers and Burt. 1997), smearing and binning of perpendicular distance intervals were not used as these techniques were found to have little effect on the analytical outcome.

Effective strip width was estimated at the stratum level and could therefore vary between strata depending on covariate levels. This necessitated estimation of total variance and confidence intervals by bootstrap methods as variance estimates at the stratum level are not independent (Buckland *et al.* 2001, Thomas *et al.* 2002).

No attempt was made to correct for availability bias, thus it was assumed that all fin whales on the trackline would be detected (*i.e.* $g(0)=1$).

To determine if there was size bias in detectability due to group size, ln(s) (group size) was regressed against the estimated detection probability. If this regression was significant at the $P<0.15$ level, the detection of groups was considered to be size biased and the estimate of mean group size was adjusted using this regression. When the regression was not significant, the observed mean group size was used.

Analysis of trends

While all the surveys covered large areas in the central and eastern North Atlantic, there was considerable variation in area coverage between years. Thus, for analysis of trends in abundance over the period, some post stratification was necessary.

Common to all surveys was large coverage of the Central North Atlantic area surveyed by the Icelandic and Faroese vessels (Fig. 1). The stratification of the first NASS was based on expected densities of the target species but was modified somewhat as experience was gained. Post stratification could thus not be done by simple combination of the original blocks. As coverage varied between strata, simple post stratification across the original stratum boundaries would result in uneven coverage within post-strata, potentially resulting in bias. Therefore, post

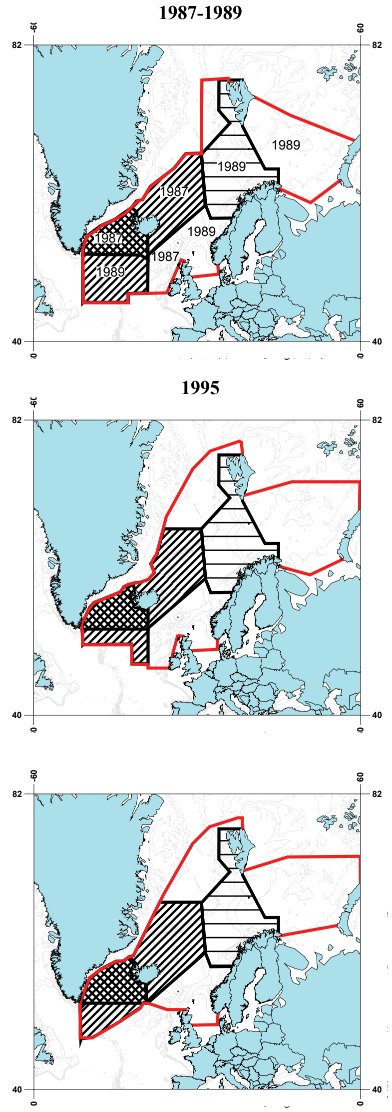

Fig. 3. *Regions used in examining trends in fin whale abundance. Survey year is indicated for the 1987-1989 compilation. The Norwegian sector of the 2001 survey was surveyed in the period 1996-2001. Cross hatched – WEST; Diagonally hatched – EGI; Horizontally hatched – NORWAY; TOTAL outlined in red.*

stratification was done by dividing the original strata into smaller areas for which abundance estimates were calculated, and these small areas then combined into larger regions that are roughly equivalent in size across surveys (Fig. 3). The following regions were defined: WEST, corresponding to the area of Icelandic fin whale harvesting in the past century; EGI, corresponding to the East Greenland Iceland stock area for fin

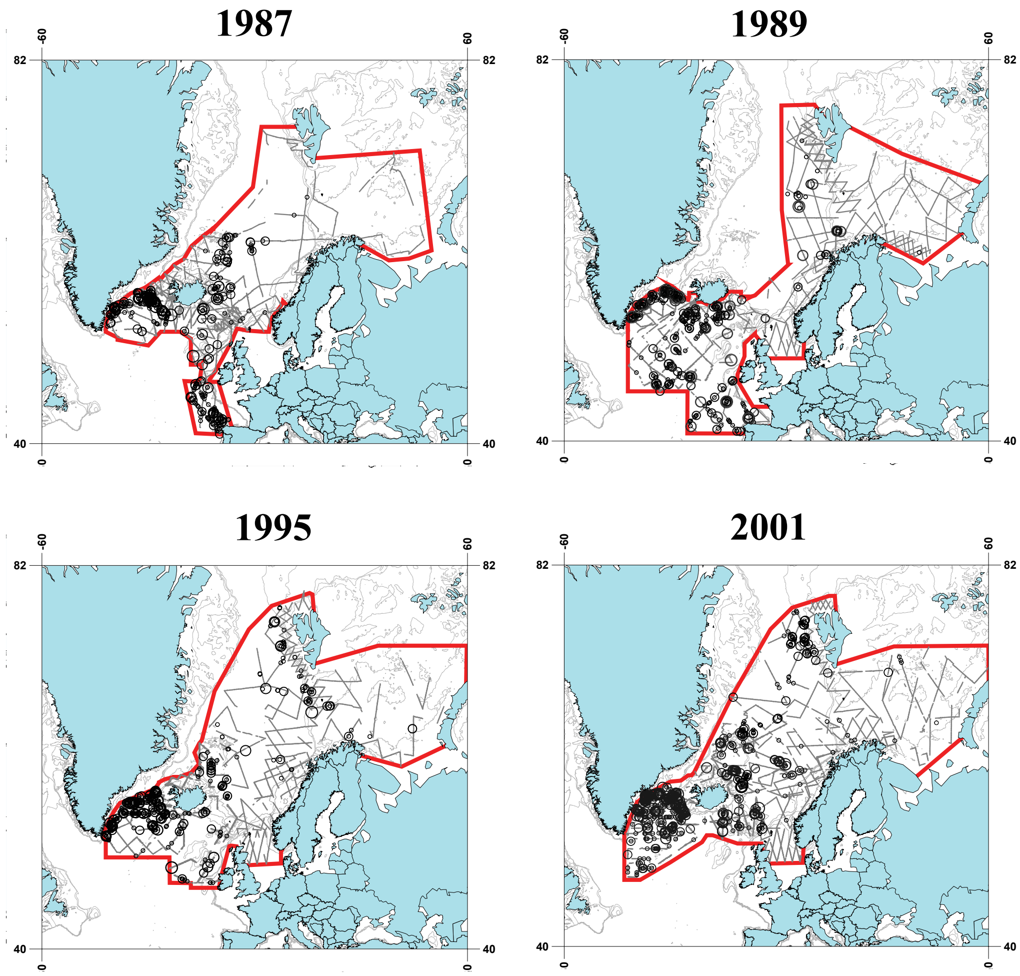

Fig. 4. Realized survey effort and sightings of fin whales in NASS ship surveys, 1987 to 2001. Symbol size is proportional to group size from 1 to 4+. The Norwegian sector of the 2001 survey was surveyed from 1996-2001.

whales (Donovan 1991), which includes WEST; NORWAY, corresponding to the kernel area surveyed off Norway in all surveys (Øien 2009); and TOTAL, which is the total for the Icelandic, Faroese and Norwegian survey areas. For the part of the EGI region northeast of Iceland that was surveyed in 2001 by Iceland and by Norway in 1997, the former estimate was used for 2001.

For improved comparability, data from all Icelandic and Faroese surveys were re analysed using standardized methods. Sightings of BP and BP? were included, sightings made at Beaufort sea state higher than 5 were discarded, the data were truncated to discard 10% of the greatest perpendicular sighting distances, and group size was estimated at the stratum level. Otherwise analytical methods were the same as noted above.

Because the 1987 and 1989 surveys did not achieve the spatial coverage of later surveys, we combined them for the purpose of estimating abundance in the EGI and TOTAL regions (Fig. 3). The resulting estimates were applied to the year 1988.

For the Norwegian surveys, the previous estimates (Christensen *et al.* 1992, Øien 2003, 2004) are used which were based on similar analyses. For maintaining compatibility with other areas surveyed in 2001 the Norwegian "mosaic estimate" for 1996 2001 was applied to the year 2001, while acknowledging that any trends dependent on the latter series must be interpreted with caution.

Table 4. Estimated density and abundance of fin whales from NASS-95 and NASS-2001, using a covariate model to estimate the detection function and incorporating stratum level estimates of effective search width (*esw* in *m*). *n*-number of sightings; *D* density of animals; *E(S)* group size; *N*-total abundance by blocks. Track length (*L*) in nautical miles and area in square nautical miles. For vessel identity see Table 2.

Block	Area	*n*	*L*	*n/L*	*cv%*	*E(S)*	*cv%*	*esw*	*cv%*	*D*	*N*	*cv%*	Lower CI	Upper CI	Vessel
2001															
Icel.SW	190,577	31	1,169	.0265	27	1.19	6.04	2,329	10	0.0126	2,399	32	899	3,800	AF2
Icel.W	154,692	271	2,424	.1118	14	1.38	3.12	2,067	8	0.0693	10,720	16	7,027	13,608	BS AF2 AF1
Icel.NW	28,154	144	616	.2336	38	1.86	4.91	2,140	8	0.1816	5,121	39	2,041	9,881	AF1
Icel.N	31,781	38	556	.0683	52	1.55	7.94	2,140	8	0.0459	1,459	46	370	2,897	AF1
JanMayen	145,847	47	1,791	.0262	37	1.57	8.14	2,140	8	0.0179	2,607	41	926	4,874	AF1
Faroe Isl.	117,500	62	2,457	.0252	26	1.44	6.13	1,650	8	0.0203	2,580	33	939	4,199	WF
Combined	**668,551**	**593**	**9,013**			**1.55**	**0.02**			**0.0367**	**24,887**	**13**	**18,186**	**30,214**	
1995															
2	21,171	8	468	0.0128	63	1.74	17	2,378	25	0.0102	216	77	0	586	AF1/STR
3	26,779	7	161	0.0434	16	1.08	26	1,092	25	0.0331	888	35	511	1,578	AF1/STR
4	67,708	2	641	0.0031	76	1	0	1,092	61	0.0021	144	92	0	436	AF1/STR
5	47,506	31	447	0.0581	48	1.67	25	2,378	12	0.0440	2,088	49	251	4,176	AF1/STR
6	33,512	5	841	0.0048	43	1.02	17	1,263	44	0.0029	99	51	0	207	AF1/STR
7	67,708	6	834	0.0072	59	1	0	1,708	35	0.0038	260	47	45	518	AF1/STR
8	55,472	13	817	0.0159	23	1.37	9	1,139	24	0.0150	834	34	346	1,415	AF1/STR
9	123,957	212	1,973	0.0994	17	1.52	5	1,220	6	0.0977	12,108	26	7,046	18,981	AF1/STR
Faroese (A+B)	341,183	12	1,747	0.0068	18	1.70	25	1,263	25	0.0073	2,498	32	1,106	4,213	MID
Combined	**784,996**	**296**	**7,930**			**1.54**	**0.04**			**0.0244**	**19,136**	**21**	**12,235**	**27,497**	

Regional estimates were derived by summing the estimates for the appropriate post blocks. The variance estimates for each post block are not independent as they contain common components of variance for the estimation of effective strip width and group size (*E(s)*). The variances of regional estimates were calculated by summing the variances for those components that were calculated independently for each post block (encounter rate) and incorporating the additional variance for *esw* and group size using the Delta method (Buckland *et al.* 2001). When calculating confidence intervals for abundance we assumed that the estimated density is log-normally distributed.

Regional and total rates of increase were calculated using log-linear regression, and confidence intervals for the rates of increase were estimated using a parametric bootstrapping procedure, assuming a log-normal distribution for the abundance estimates.

RESULTS

Distribution

Fig. 4 shows the distribution of sightings of fin whales made in all surveys. The distribution pattern was broadly similar in all surveys with highest densities between Iceland and Greenland (in the Irminger Sea and Denmark Strait area). Large numbers of fin whales were also sighted off northeast Iceland and Jan Mayen Island and off north-western Spain. In the Irminger Sea Denmark Strait area fin whales were mainly distributed along the slope of the continental shelf areas of Iceland and East Greenland in the first 2 surveys. In 1995 and particularly in 2001 they had a more continuous distribution in this area with many sightings in deep waters between these 2 continental shelves. There also appear to be higher densities around Spitsbergen in the 2 latter surveys, and around the Faroes in 2001 as compared to previous surveys.

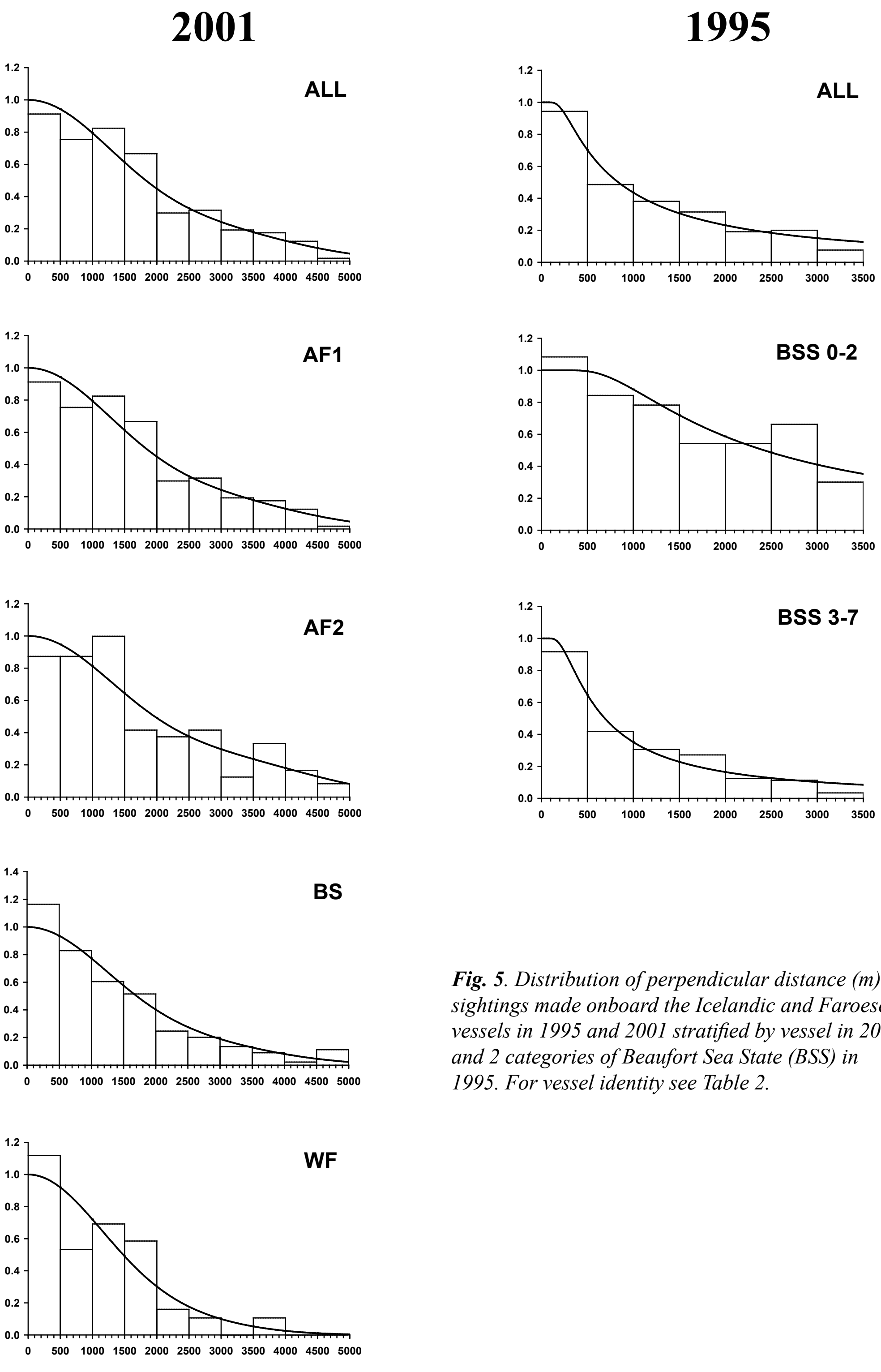

Fig. 5. *Distribution of perpendicular distance (m) to sightings made onboard the Icelandic and Faroese vessels in 1995 and 2001 stratified by vessel in 2001 and 2 categories of Beaufort Sea State (BSS) in 1995. For vessel identity see Table 2.*

Abundance

Effective strip half width

Fig. 5 shows the distribution of perpendicular distances to sightings made onboard the Icelandic and Faroese vessels. For 1995 the perpendicular distance function (pdf) was best modelled using a hazard rate function with BSS in 2 categories (0-2 and 3-7) as a categorical covariate. There was a substantial decrease in *esw* in the higher BSS category. For 2001 the pdf was best fit using a half-normal model with vessel identity, but not BSS, as a categorical covariate. The Faroese vessel WF and the vessel BS had noticeably narrower effective strip widths than AF1 and AF2.

Group size

Fin whales were most commonly encountered as singles or pairs in all surveys. Overall more than half of the sightings were of single animals and over 85% were of singles and pairs. Larger groups were slightly more common in 2001 than in 1995, when groups larger than 2 comprised 16% of the total as opposed to 11% in 1995. Groups of 4 or more comprised only about 5% of the sightings in both years. In 2001 three groups estimated as 10 or more (max. 12) animals were encountered, whereas the largest group size seen in 1995 was 6. Mean group size did not differ significantly between years (Table 4, Buckland *et al.* 1992b).

There were significant differences in group size between blocks in 2001 but not in 1995: therefore separate block estimates were used to estimate abundance for 2001, whereas a survey mean group size was used for 1995. Group size was not significantly correlated with detection probability for any block or survey.

Abundance

Abundance estimates and associated parameters are shown in Table 4. The total abundance in the survey area was 19,672 (C.V. 0.23; 95% C.I. 12,083-28,986) in 1995 and 24,887 (C.V. 0.13; 95% C.I. 18,186-30,214) in 2001. In both years densities were highest off West Iceland, and second highest off northeast Iceland. Density in the Faroese area was significantly higher in 2001 than in 1995 but the spatial coverage was different.

Trends

Estimates of abundance and growth rates for the post stratified regions used for analysing trends are given in Table 5. Abundance of fin whales in the survey area increased from 17,482 (C.V. 0.19) in 1988 to 29,891 (C.V. 0.11) in 2001. This corresponds to an annual growth rate of 4% (95% C.I. 1-8%). However, the increase is largely a result of the increase in the area between Iceland and Greenland (the WEST sub-area). In this area fin whales increased from 3,607 (C.V. 0.18) in 1987 to 14,021 (C.V. 0.18) in 2001 (Table 5). This amounts to an annual increase of 10% (95% C.I. 6-14%). If the WEST area is excluded, there is no significant trend in any of the larger areas and it is thus apparent that the increase in the WEST region accounts for nearly all the increase in the EGI and TOTAL areas.

DISCUSSION

Potential biases

The estimates presented here are potentially biased both because of visible whales being missed by the observers (perception bias) and whales that are diving while the ship or plane passes (availability bias). For fin whales we would not expect these biases to be serious. Fin whales are large and under most circumstances have a clearly visible blow, and are not easily missed if they are nearby. Their mean diving times are relatively short, and long dives are relatively rare (Croll *et al.* 2001), so it is unlikely that they would remain underwater during the passage of a slow moving ship. However, these biases, if present, would lead to abundance being underestimated by an unknown degree. Preliminary analysis of the 2001 double platform data collected onboard the Icelandic and Faroese vessels indicates that about 20% of fin whales seen by the tracker platform within 500 m of the trackline were missed by observers on the primary platform (Pike *et al.* (MS) 2006). The estimated average value for $g(0)$ was 0.812 and g(0) corrected estimates were approximately 10% higher than those for the combined platforms.

It is likely that a large proportion of the large baleen whales that could not be identified to species were fin whales. These were, however rather few and most were far from the tracklines, so the potential downward bias from not including them in the abundance estimate is likely small. Including them would introduce a positive bias.

The surveys did not cover the entire summer range of fin whales, in particularly the EGI stock area. The southward extension of the 1989 NASS revealed that fin whales do occur to the south of the area normally surveyed. Therefore the estimates for the EGI stock area must be considered to be negatively biased.

Some of the regions varied in size from survey to survey, which would affect estimates of abundance. The WEST region varied little in size, and the NORWAY region did not vary in size. Even though the EGI and TOTAL areas were larger in 1987, 1989 and 1995 than in 2001, the abundance estimates for these regions were greatest in 2001. Therefore the positive trends in abundance observed cannot be attributed to variations in the size of the areas surveyed.

Distribution

On a broad scale distribution was similar in all surveys with highest concentrations in the Irminger Sea-Denmark Strait area between Iceland and Greenland. Relatively high densities were also observed east and northeast of Iceland towards Jan Mayen in all surveys that covered this area. Some changes were observed in distribution during the period, most notably a clear tendency towards a broadening of the distribution area in the Irminger Sea-Denmark Strait. In the 1987 and 1989 surveys, fin whales were concentrated near the East Greenland ice edge and along the continental slope areas west and southwest of Iceland. By 1995 and especially 2001, they were distributed throughout the Irminger Sea and Denmark Strait. The southward extension of the survey area in 1989 revealed that fin whales also occurred to the south of this area. In addition, there was a marked increase in the occurrence of fin whales in the northern Norwegian sector in later surveys, especially to the south and west of Svalbard.

The mean group sizes from NASS-95 and NASS-2001 are similar to those reported from earlier surveys. Fin whales are most commonly seen alone or in "pairs" although larger aggregations of up to 12 were occasionally seen.

Abundance estimates

Although the results from NASS-95 and NASS-2001 have been used in assessment work (NAMMCO 1998, 2000, 2001, 2004, Borchers and Burt 1997), abundance estimates for fin whales from these surveys have not been published until now. The new estimate for 1995 is very similar to a previous estimate discussed by the Scientific Committee of NAMMCO (Borchers and Burt 1997) where separate estimates of *esw* were calculated for 2 categories of BSS instead of incorporating BSS as a covariate as done here.

The estimate from 2001 of 24,887 (cv 0.13) is the most recent, and must be considered the best available estimate for the Central North Atlantic area. Taken together the potential biases mentioned above are more likely to be negative than positive, but presumably small in magnitude. The estimates for the EGI area, derived from the post-stratification and re-analysis for estimation of trends (Table 5), are very similar to the estimates based on the original stratification (Table 4). As the latter included a small area outside the traditional East Greenland-Iceland stock area (EGI) the best estimate for the EGI area is 23,676 (cv 0.13) (Table 5).

Sigurjónsson (1995) speculated that the fin whales in the total North Atlantic numbered about 50,000 around 1990. The present abundance estimate for the "TOTAL" area used in the trend analysis is around 30,000 fin whales. Adding to this the estimated abundance off Spain around 1990, 17,335 (cv 0.27) (Buckland *et al.* 1992a) and recognizing that an unknown number of fin whales were outside the survey area within the EGI stock area it can be concluded that fin whales in the eastern part of the North Atlantic (east of Greenland) number around 50,000 individuals. Much less is known about the whale abundance in the western North Atlantic, but from the available partial survey estimates and older mark recapture estimates (Mitchell *et al.* 1974, IWC 1992, Hain *et al.* 1992, Waring *et al.* 2004) it can be concluded that there are at least 60-70 thousand fin whales in the North Atlantic.

Table 5. Estimates of abundance by region for NASS shipboard surveys after post stratification. A – surface area (nm^2); *N* – abundance; *D* – density (no./nm2); cv – coefficient of variation for *N* and *D*; L, U – lower and upper 95% confidence intervals for *N*. Regions are shown in Fig. 3.

YEAR	REGION	*A*	*N*	*D*	cv	*L*	*U*	COMMENTS
1987	WEST	192,302	3,607	0.0188	0.18	2,537	5,132	
1989	WEST	175,185	6,006	0.0343	0.25	3,468	10,401	
1995	WEST	178,763	13,726	0.0768	0.23	8,667	21,740	
2001	WEST	191,434	14,021	0.0732	0.18	9,550	20,586	
GROWTH RATE			0.1			0.06	0.14	
1988	EGI	908,077	15,237	0.0168	0.22	9,990	23,239	Includes components of 1987 and 1989 surveys.
1995	EGI	623,605	20,262	0.0325	0.21	13,464	30,492	Norwegian – Øien (2003)
2001	EGI	659,192	23,676	0.0359	0.13	18,024	31,101	
GROWTH RATE			0.03			-0.01	0.07	
1988	NOR	231,195	1,242	0.0054	0.38	512	3,009	Øien and Bøthun (2005)
1989	NOR	231,195	1,106	0.0048	0.43	464	2,637	Øien and Bøthun (2005)
1995	NOR	231,195	1,806	0.0078	0.51	576	5,668	Øien and Bøthun (2005)
1998	NOR	231,195	1,723	0.0075	1.09	201	14,734	Øien and Bøthun (2005)
GROWTH RATE			0.05			-0.13	0.26	
1988	TOTAL	1,982,281	17,482	0.0088	0.19	11,981	25,508	Includes components of 1987 and 1989 surveys.
1995	TOTAL	1,768,393	26,343	0.0149	0.17	18,754	37,004	Norwegian – Øien (2003)
2001	TOTAL	1,703,020	29,891	0.0176	0.11	24,040	37,167	Norwegian – Øien (2004)
GROWTH RATE			0.04			0.01	0.08	

Trends in abundance

There has been a substantial and significant increase in the numbers of fin whales in the WEST region (see Table 5) corresponding to an annual rate of increase of about 10%. The increases in the EGI and TOTAL regions are largely due to the increases in WEST. In contrast the NORWAY region shows no evidence of any trend over the period.

For survey bias to have been a factor in the trends seen in the NASS series, the magnitude and/or direction of these biases would have to have changed over the course of the surveys. While we have no evidence for this, one might expect that the earlier surveys were less efficient than later ones, as the observers and cruise leaders gained experience and became more proficient at their tasks. Also, platform heights and the number of observers on duty have tended to increase over the course of the surveys. Moreover, given the trends seen in fin whales and even more so in humpback whale abundance around Iceland (Pike *et al.* 2009), survey efficiency must have increased by over an order of magnitude if this factor alone were operating.

Slightly better coverage of Greenlandic coastal areas in 2001 with high fin whale densities might, at least in theory, have contributed to the observed trend. However, as the westward limit of the surveys was determined by ice extent, this would require that considerable numbers of fin whales were within the ice in the earlier surveys. This would be contrary to general knowledge about fin whale distribution and habitat preference. In addition, the fact that densities (no/nm^2) in the WEST area increase at approximately the same rate as abundance (Table 5), make different coverage in the WEST area an unlikely explanation for the observed trend.

The area west of Iceland is among the most important feeding grounds for fin whales in the North Atlantic. The species was severely depleted during the era of modern whaling from Norwegian land stations in Iceland during 1883-1915. The observed recent increase in abundance could thus be seen as recovery of a depleted population. However, model simulations of population growth during the 20th Century based on catch history and recent abundance estimates indicate that this is not likely to be the only factor responsible.

In 1915 the Icelandic parliament made a decision banning all whaling in Icelandic waters. When whaling was resumed from a single land station during 1935-1939, fin whales, in contrast to blue whales and humpback whales, had apparently made a significant recovery west of Iceland. The ratio of fin whales to blue whales in the catch increased from 1.4 during the period 1889-1915 to 12.5 in the period 1935-1939 and the corresponding ratios for fin to humpback whales were 3 and 188 respectively (Sigurjónsson 1988). This differential recovery of these species was further confirmed when whaling was resumed again in 1948 (Rørvik *et al.* 1976, Sigurjónsson 1988).

The assessment of fin whale stocks in the North Atlantic is complicated by uncertainty about stock structure. The Scientific Committee of NAMMCO has recently (NAMMCO 2000, 2001, 2004) conducted assessments of mainly the putative East-Greenland Iceland stock. In these assessments the most current information on historical catches, abundance and biological parameters is used in a model to attempt to replicate past population trends, and to forecast future abundance under various catch regimes. Under most simulations the stock was forecast to have been approaching its carrying capacity (K) by about 2000. However the modelling efforts fail to reconcile all sources of data, and in particular cannot explain why a catch of about 11,000 fin whales over around 30 years (1883-1915) should have reduced the population to a low level, if it was as large then as it is today. One explanation may be that there is population sub-structure within the EGI stock area, and that local areas within range of the shore stations were depleted. This is supported by the observation that the stock seemed to have rebounded by the 1930s when whaling around Iceland resumed. Models incorporating inshore and offshore "sub-stocks" that mix slowly have been more successful in fitting the apparent historical trends in the abundance of whales around Iceland (NAMMCO 2004).

An alternative explanation, that has not been formally assessed, is that the population now is higher than it was at the onset of modern whaling; *i.e.* that K has increased or stock distribution has changed. K is nearly impossible to measure directly. We must assume that a population is at K if it has not been harvested or has fully recovered from past harvesting. Changes in K could to some extent explain the trends observed especially around Iceland, where there is some evidence that the sizes of present populations of both fin and humpback whales exceed those of the pre-whaling populations. The North Atlantic is certainly not a "pristine" ecosystem, and it is not unreasonable to expect that K for many species has changed due to human intervention or climate changes over the past 100-200 years.

Significant hydrographical changes in the Northeastern Atlantic starting in the mid 1980's (Beare *et al.* 2000, Bersch 2002, Beaugrand and Reid 2003) may have contributed to the increase in abundance of fin whales in the Irminger Sea and Denmark Strait through increase in K. During the study period significant increases in salinity and temperature have been observed in the northern part of the North Atlantic (Berch, 2002, Hátún *et al.* 2005) and in particular in the deep waters of the Irminger Sea, where densities of fin whales have increased the most (Anon 2002, Pedchenko 2005). Direct measurements of the abundance of the Euphausiid *Meganychtiphanes norvegica*, the overwhelmingly dominant prey of fin whales in this area (Rørvik *et al.* 1976, Víkingsson 1997) are however virtually lacking. Sigurjónsson (1992) did not find a correlation between fin whale abundance and euphausiid abundance as indicated from continuous plankton recorders

(CPR). However, CPR data are generally not believed to be a good indicator of euphausiid biomass (Ástthor Gíslason, MRI pers. commn.).

Other changes in the ecosystem are directly attributable to human influence. Populations of large predatory fish have been heavily targeted by fisheries, and have been reduced in many parts of the world to 10% or less of their original size (Myers and Worm 2003). The diet of both humpback and fin whales is dominated by small pelagic fish and macrozooplankton (Mitchell 1975, Jurasz and Jurasz 1979, Sigurjónsson and Víkingsson 1997), which are also the prey of predatory fish. It is therefore easy to advance an argument that the decline of predatory fish has lead to a higher K for recovering whale stocks. Unfortunately there is little information on the long term trends of pelagic fish and macrozooplankton in the North Atlantic, so this appealing "ecological story" is difficult to confirm or falsify. It is also the case that populations of other cetaceans, such as right (*Eubalaena glacialis*), bowhead (*Balaena mysticetus*) and blue whales have been even more heavily impacted by past whaling activities than have fin and humpback whales, and populations do not seem to have recovered to nearly the same extent as have those of fin and humpback whales. As these species are, to some extent at least, ecological competitors, the selective removal of some may have lead to ecological opportunities for the others.

The stock of fin whales around Norway is much smaller than one might expect given historical harvests, which exceeded 10,000 between 1864 and 1904 with catches of over 1,000 in some years (Risting 1922). Clearly the abundance must have exceeded its present level of less than 2,000 animals to have supported such a take. However it must be borne in mind that fin whaling continued along the Norwegian coast up until 1972, and it is possible that the stock might have been reduced to a low level. Future assessments of fin whales by the Scientific Committee of NAMMCO will concentrate on this area.

The estimated rate of increase in the area between Iceland and Greenland, although high, is not inconsistent with the maximum rate resulting from inherent population dynamics for large baleen whales (Clapham *et al.* 2001, Lockyer and Sigurjónsson 1991). The possibility of immigration from other areas cannot however be ruled out, as recent estimates of abundance are not available for large areas of particularly the western Atlantic.

This study has demonstrated a significant positive trend in abundance of fin whales in the central North Atlantic while abundance in the eastern part of the study area has been stable, apparently at a considerably lower level than prior to whaling. The high rate of increase in the Irminger Sea may be partly explained by changes in distribution although the possibility of a purely intrinsic population growth cannot be excluded.

According to the Revised Management Procedure agreed by the IWC, new abundance estimates should be produced about every 5 years for whale stocks under exploitation to prevent catch quotas from phasing out (IWC 1999). Given the generally accepted ideas about growth rates of large cetaceans and the precision level of abundance estimates derived from sightings surveys, an interval of 5-6 years between surveys is expected to be the minimum for detecting trends in abundance. The 4 NASS surveys conducted during 1987-2001 have, somewhat unexpectedly shown large increases in the abundance of fin whale in the survey area, particularly in the area between Iceland and Greenland. Even larger increases have been shown for humpback whales in the same period (Pike *et al.* 2009). The experience gained from NASS confirms that 5-6 years is an appropriate interval between such surveys.

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