# Report of the Joint NAMMCO/IWC Scientific Workshop on the Catch History, Stock Structure and Abundance of North Atlantic Fin Whales[1]

## 1. OPENING REMARKS

The Workshop was held in Reykjavík, Iceland from 23-26 March 2006. Johann Sígurjónsson, Director of the Marine Research Institute, welcomed participants (Annex A) to the meeting. He noted that, despite the recent growth in industry and tourism, fisheries remained a very important part of the Icelandic economy and culture. Fin whales are the most abundant large whale species around Iceland, and therefore play an important role in the marine ecosystem. Iceland may in the future choose to resume hunting of fin whales, subject to international obligations. Therefore the outcome of these deliberations was of great importance, and he wished the participants a productive meeting.

Genevieve Desportes, Chairman of the NAMMCO Scientific Committee, noted that the Scientific Committee of NAMMCO has carried out fin whale assessments on four previous occasions since 1999. The Committee operated on a general request to provide assessment advice for all North Atlantic stocks, but particularly for the East Greenland-Iceland (EGI), Norwegian and Faroese areas. Most recently, a Workshop of the Committee met in October 2005 to evaluate new information on stock identity, catch series, catch per unit effort (CPUE) and abundance, refine assessment models for the EGI area and prepare for assessments of Norwegian and Faroese stocks.

Greg Donovan, Head of Science from the IWC Secretariat welcomed the participants on behalf of the IWC. He noted that this was the first such joint meeting between the Scientific Committees of NAMMCO and the IWC. Although the management procedures and approaches of the two organisations were somewhat different, he was delighted that it had proved possible to cooperate on common scientific issues, especially since many of the participants attended both IWC and NAMMCO meetings.

## 2. APPOINTMENT OF CHAIR AND RAPPORTEUR

Lars Walløe was selected as Chair, and Daniel Pike, Greg Donovan, Phil Hammond and Cherry Allison were appointed as rapporteurs for the meeting.

## 3. ADOPTION OF AGENDA

The Agenda (Annex B) was adopted with minor changes. It was decided that the IWC and NAMMCO components of the Workshop would meet separately on the final day to address issues particular to their respective organisations.

[1] Presented to the meeting as SC/58/Rep3. This Report will also be published by NAMMCO (*http://www.nammco.no*).

## 4. REVIEW OF AVAILABLE DOCUMENTS AND REPORTS

Documents available for the meeting are detailed in Annex C. In addition some working papers from previous NAMMCO and IWC meetings, as well as published documents, were made available as needed.

## 5. STOCK STRUCTURE

The consideration of stock structure is of great importance to the understanding and interpretation of data on biological parameters, catch data and abundance, especially in a management context (irrespective of what that management context may be). For this reason it had been hoped to discuss stock structure at the start of the meeting. However, for practical and logistical reasons, especially related to the question of calibration and standardisation of work between different laboratories in order to arrive at an agreed genetic dataset, it was not possible to do so. However, it was agreed that the report would maintain the order of the original Agenda.

### 5.1 Genetic evidence

#### *5.1.1 Authors' summaries*

Daníelsdóttir presented paper SC/14/FW/5-SC/M06/FW5 outlining the genetic analyses from nuclear and mitochondrial DNA data collected so far. The analysis was conducted at two hierarchical levels; a micro- and macro-geographical scale.

The micro-geographical study used 900 samples collected off Iceland during the period from 1981 to 1989. The genotype was determined in each of these samples at nine nuclear microsatellite loci. Homogeneity tests revealed statistically significant levels of genetic heterogeneity among years as well as between seasons (spring, summer and autumn). However, the degree of genetic divergence among sample partitions was low (average $F_{ST} \simeq 0.005$).

The data was also used to estimate of the number of panmictic populations (referred to as 'clusters' in the employed software Structure by Pritchard *et al*. (2000)) contained in the Icelandic samples. The authors concluded that the most likely number of populations was two, when using the methodology outlined in Evanno *et al*. (2005).

The macro-geographical study was based upon the same nine loci but the sample sizes were smaller; 59 from Iceland, 54 from Norway, 39 from Spain, 16 from West Greenland and 13 from eastern Canada. The macro-geographical analysis revealed statistically significant levels of genetic heterogeneity among the above sampling localities before applying sequential Bonferroni corrections, after which statistically significant levels of heterogeneity was detected only between eastern Canada and the remainder North

Atlantic sampling localities. The average degree of genetic divergence between eastern Canada and the other North Atlantic localities was 0.0235 (estimated as Wright's $F_{ST}$), and 0.0022 among the remainder North Atlantic locales.

Mitochondrial control region DNA (mtDNA) sequences (285 base pairs) were also compared in the macro-geographical study for a total of 558 samples from the above described areas, in addition to new samples (19) from the Faroe Islands as well as those described in Bérubé *et al*. (1998). The homogeneity test conducted using the mtDNA sequences confirmed earlier conclusions that the North Pacific as well as the Mediterranean Sea are distinct from the North Atlantic locales. In addition, significant levels of heterogeneity (i.e. $P<0.05$) were also observed among years within single areas, such as the Faroe Islands, West Greenland and Atlantic Spain. As was the case for the nuclear DNA analysis (the nine microsatellite loci above), the overall level of genetic divergence among sampling locales in the North Atlantic was low ($H_{ST}$ in the range of 0 to 0.06). The Faroe Island samples (which were not part of the microsatellite analysis described above) were 'relatively' divergent from the other North Atlantic locales, although no assessment was conducted if this level of divergence was significantly higher (in a statistical sense) than that observed among the remainder North Atlantic locales. The authors used the method of Evanno *et al*. (2005) to estimate the number of breeding populations in the North Atlantic.

Palsbøll briefly presented the results of a preliminary analysis (using the six microsatellite loci employed by Bérubé *et al*. (1998)) considered as two data sets totalling 572 samples[2]. These were essentially the same as those employed in the macro-geographical analysis of mtDNA sequences. A total of 176 samples were analysed at the Institute of Marine Research in Reykjavík and the remaining 369 at University of California Berkeley. Calibration of the data generated at the two different laboratories was conducted using 28 samples that had been analysed in both laboratories. Of the 78 pairwise homogeneity tests conducted, 18 *P*-values higher than 0.05 were obtained, indicating statistically significant levels of heterogeneity among most sample partitions. Significant levels of genetic heterogeneity were also observed among samples collected in different years within one area (e.g. Gulf of St. Lawrence, Iceland, Faroe Islands and Atlantic Spain). However, most estimates of genetic divergence were low (between 0 and 0.04) among the North Atlantic and Mediterranean Sea sampling locales. Excluding the comparisons that include the Sea of Cortez, the highest degree of genetic divergence was observed between samples collected in three different years off the Faroe Islands ($F_{ST}$ estimated at 0.06 and 0.074). However, no assessment was conducted to ascertain if these levels of genetic divergence was significantly (in a statistic sense) larger than those observed among and within other North Atlantic sampling locales. No spatial trends (e.g. isolation by distance) were detected among the estimates of genetic divergence. However, the data may not provide sufficient statistical power to detect such correlations if the effect sizes are small.

Kitakado presented the results of a preliminary analysis using a new method aimed at estimating mixing proportions for stocks for North Atlantic fin whales under multiple stock scenarios[3]. The same data were used as in SC/14/FW/5-SC/M06/FW5 (1,023 individual's genotypes at 9 loci). The method is a likelihood version of his original method (SC/56/SD8) and it was first presented at the recent IWC Scientific Committee Testing of Spatial Structure Models (TOSSM) Workshop (SC/58/Rep6). The method is to estimate area-wise mixing proportions without assuming presence of baseline stocks. The integrated likelihood function with elimination of nuisance parameters was employed to estimate the mixing proportions, and then the maximum values under one-, two- and three-stock scenarios were compared to determine the likely number of stocks. Proportions of 70:30 and 72:27:1 were identified under the two- and three-stock hypotheses, respectively. A comparison of the results for the various scenarios by integrated likelihood indicated that one breeding stock was present in the whole feeding ground. Kitakado emphasised that the results of the model selection were only preliminary at this stage, because this new method must be subjected to more comprehensive testing (e.g. within the TOSSM framework). He also noted that to facilitate better understanding of spatial stock structure, he would undertake further investigation of areawise mixing proportions using his method. It was noted that difficulties were found in reaching convergence in this particular analysis of the fin whale data.

### *5.1.2 Discussion*

The Workshop welcomed the results of all these analyses, recognising the amount of work that they represented.

In the full discussion of the papers presented, a number of key factors emerged that require further work before a full understanding of the contribution of the genetic work to the elaboration of stock structure in the North Atlantic fin whales can be completed. These are described below. Given the importance of this in a management context to both the NAMMCO and IWC Scientific Committees, it was **agreed** that every effort should be made to complete this work before the next annual IWC Scientific Committee meeting in May 2006. It was also **agreed** that Donovan will send any resultant documents and working papers to the NAMMCO Secretariat for distribution to the NAMMCO Scientific Committee.

*(1) Finalisation of the complete genetic dataset*

As noted above, considerable effort has already been put into calibrating the work of the two major laboratories involved in analysing the samples. The Workshop **agreed** that it was essential that this work should be completed (including the investigation of error rates) as soon as possible so that a 'final' agreed genetic dataset can be used in statistical analyses of the data. It also noted that the most efficient way to achieve this was for the two key persons (Daníelsdóttir and Bérubé) to work together in either Reykjavík or Berkeley and it was hoped that funds could be found to allow this to take place.

[2] A working paper (Daníelsdóttir, A.K., Bérubé, M., and Palsbøll, P.J. Levels of nuclear differentiation among North Atlantic sample areas from combined data set from the Institute of Marine Research (Iceland) and University of California Berkeley (USA)) was circulated but it was agreed that rather than include this as an Annex to the report, the authors would be encouraged to finalise the paper and submit it to the IWC and NAMMCO Scientific Committees when it is complete.

[3] A working paper (Kitakado, T. and Daníelsdóttir, A.K. Brief report on preliminary estimation of mixing proportions under multiple-stock scenarios for North Atlantic fin whales using individuals multi-locus genotypes data) was submitted but it was agreed that rather than include this as an Annex to the report, the authors would be encouraged to finalise the paper and submit it to the IWC and NAMMCO Scientific Committees when it is complete.

*(2) Better understanding of the assumptions and methods of new analytical techniques*

It was clear from the discussions at the Workshop that before final conclusions can be reached concerning the implications of the genetic data for stock structure and management, more time was required to understand aspects of certain newer analytical methods presented at this meeting. While ideally, this should take place in the TOSSM framework, it was recognised that this will not be possible this year. It therefore **agreed** that Skaug, Kitakado and Butterworth, in consultation with Palsbøll, Daníelsdóttir and Pastene, should examine more fully the methods and assumptions used, particularly with respect to the work of Evanno *et al*. (2005) and Kitakado (2004; Kitakado *et al.*, 2006). It is advisable that this group should also be consulted if analyses using methods previously unconsidered by the IWC or NAMMCO Scientific Committees are to be presented in the future.

*(3) Further investigation of the statistical power of genetic analyses and the estimation of confidence intervals*

In several instances, there was considerable discussion over the interpretation of *P*-values when values of, say *F*st, were very small. The Workshop **agreed** that this topic requires further investigation and discussion and referred the matter to the intersessional Workshop above. In particular it noted that it was important when presenting results of *F*st values that confidence intervals be calculated (e.g. using bootstrapping). This should also be undertaken for previously published data (e.g. the allozyme data) (Daníelsdóttir *et al.*, 1992) where significant differences have been reported.

*(4) Completion of preliminary analyses presented by Palsbøll and Kitakado*

See authors' summaries section of 5.1 above.

**5.2 Non-genetic evidence**

It is recognised that a full elaboration of stock structure may best be achieved by a combination of information of a suite of techniques, both genetic and non-genetic (e.g. Donovan, 1991). SC/14/FW/7–SC/M06/FW7 summarised the available data on stock structure of North Atlantic fin whales based on non-genetic methods. This included data from a wide range of methods including:

(1) mark-recapture data;
(2) satellite tagging;
(3) morphometrics;
(4) photo-identification;
(5) acoustics;
(6) biological parameters;
(7) pollutant concentrations;
(8) historical depletion patterns.

The Workshop also received summary maps of sightings information obtained from the North Atlantic Sighting Survey (NASS) surveys (Víkingsson *et al.*, In press). Although it is recognised that the discriminatory power of each of these methods individually is rather poor with respect to providing conclusions on stock structure, the authors note that collectively they indicate a separation between fin whales summering in the western, central and eastern North Atlantic. There also appears to be a more or less isolated stock in the Mediterranean Sea, perhaps extending out to southern Portugal. The implications of these data for stock structure hypotheses are considered under Item 5.3.

**5.3 Stock structure hypotheses**

The Workshop noted the synthesis of possible stock structure hypotheses developed by Daníelsdóttir *et al*. (in IWC, 2006) and agreed that consideration of these would form a useful basis for its discussion of stock structure hypotheses, recognising that this was not intended to be limiting. On the basis of the analyses of Bérubé *et al*. (1998) it was agreed to treat the Mediterranean Sea and adjacent waters as a separate stock and not consider it further here. However, it was recognised that this may need to be reconsidered after the completion of the genetic work identified above.

For the first stage of the discussions, it was agreed to focus on hypotheses presented with respect to the number of breeding stocks. Table 1 summarises the available genetic and non-genetic evidence in terms of its ability to discriminate among breeding stock hypotheses. The Workshop agreed not to specify whether it believed any hypothesis was the 'best' at this stage. It recognised that this level of discussion was more appropriate to the respective Scientific Committees as it was related to management objectives and procedures.

The Workshop then went on to consider the hypotheses with respect to feeding areas, using the schematic figures of Daníelsdóttir *et al*. (1992) as a guide. It is important to stress that the figures are schematic and the location of the 'breeding stocks' is not intended to suggest any specific geographical location. The Workshop agreed to consider each of the figures in turn and modify them where appropriate. The Workshop noted that in many cases the discriminatory evidence is weak. The results of these discussions are given in Fig. 1.

The Workshop agreed that pressures of time meant that it had not been possible to fully consider the need for possible further scenarios (e.g. incorporating possible north-south structure, alternative links and/or strength of links between breeding stocks and feeding areas, or finer structure within feeding areas). It also noted that the results of the suggested future genetic work (Item 5.1) may lead to changes in stock structure hypotheses. It was **agreed** that this could be revisited at the 2006 Annual Meeting (in an IWC context) and scientists wishing to make proposals were encouraged to be specific and to document their rationale. Any such proposals will also be circulated to the NAMMCO Secretariat.

## 6. BIOLOGICAL PARAMETERS

**6.1 Review of available estimates**

SC/14/FW/11–SC/M06/FW11 presented information on biological parameters estimated from whaling data of varying quality and precision for the following stock management areas (Donovan, 1991): EGI; British Isles, Spain and Portugal; West Norway and Faroe Islands; North Norway; and Eastern Canada (Newfoundland to Labrador plus Nova Scotia). Available parameters included age and length at sexual maturity, asymptotic length, length at age 5yr, age at recruitment, mortality rate, ovulation interval and proportion pregnant in the mature female catch. The most recent information is from the EGI area, although none is more recent than before 1990. No data are available from West Greenland. For at least two areas, EGI and British Isles, Spain and Portugal, trends over time in reproductive and age parameters are suggested. Of particular note is the apparent increasing age at sexual maturity in EGI area between 1967 and 1989 together with a decreasing size at age during the same period. During the late 1960s, the

Table 1

Available genetic and non-genetic evidence in terms of its ability to discriminate among breeding stock hypotheses. Options – compatible (C), incompatible (I), perhaps incompatible, requires further work (I?), provides no information (NI), *requires further consideration and possible reanalysis of data (see Item 5.1).

| Breeding stocks | 1 (complete mixing) | 1 (isolation by distance) | 2 | 3 | 4 | 5+ |
|---|---|---|---|---|---|---|
| DNA nuclear* | I? | C | C | C | I? | I? |
| DNA mitochondrial | NI | NI | NI | NI | NI | NI |
| Allozyme* | I? | C | C | C | C | NI |
| Morphology | I? | C | C | NI | NI | NI |
| Biological parameters | C | C | C | NI | NI | NI |
| Mark-recapture | NI | NI | NI | NI | NI | NI |
| Telemetry | NI | NI | NI | NI | NI | NI |
| CPUE (depletion pattern) | NI | NI | NI | NI | NI | NI |
| Sightings | NI | | NI | NI | NI | NI |

eastern Canadian areas had a higher age at sexual maturity than the EGI and British Isles, Spain and Portugal stocks. Sizes at both sexual maturity and at physical maturity were similar in these latter two stocks, while whales from the east Canadian areas were smaller. However there may be some methodological differences in these measures which confound comparisons.

This compilation was welcomed. However the comparison of these parameters across stock areas is problematic because many of the studies were conducted in different time periods, and the magnitude of temporal changes in some parameters is as great as the differences seen between stock areas. In addition the studies were conducted by different workers and using somewhat differing methodologies. In some cases the uncertainty in the estimates is poorly documented or unavailable. For these reasons apparent variation in biological parameters across stock areas is considered a weak indicator of stock structure, unless well controlled studies coincident in time have been conducted.

### 6.2 Evidence for trends in estimates

Víkingsson presented a preliminary analysis of temporal trends in ovulation interval and age at maturity in whales sampled from the grounds west of Iceland between 1969 and 1989 (SC/14/FW/12–SC/M06/FW12). Previous studies (Konrádsson *et al.*, 1991; Lockyer, 1981; 1986; 1987; Sigurjónsson, 1992; Víkingsson, 1990; 1995) have shown that such changes are correlated with the body condition of whales and food availability in this area. Estimates of age at maturity can be extended back to 1910 though studies of the transition phase of the ear plug. Trajectories in these parameters were compared to predicted abundance in the area from the model described under Item 9.1.1. The peaks and troughs in both time series appear roughly synchronous, although formal analyses of this relationship have not yet been carried out.

The Workshop **agreed** that a full analysis would require consideration of a number of factors including environmental conditions, food availability and other factors causing fluctuations in carrying capacity, in addition to changes in the abundance of fin whales.

### 6.3 Values for use in modelling (see Item 9.1.1)

The Workshop agreed that there was nothing in the review presented in SC/14/FW/11–SC/M06/FW11 to necessitate change to the parameter values used in by both the IWC (1992) and NAMMCO (2000; 2001; 2004; 2006) Scientific Committees.

## 7. CATCH DATA

### 7.1 Available catch data, level of detail and level of disaggregation of data

Bloch presented SC/14/FW14–SC/M06/FW14 containing information on Norwegian pelagic catch operations by 18 companies between 1917 and 1937. The total number of whales taken was 4,147, which is known to be a minimum. Of these, 3,516 whales were known by species, where 72% were fin whales, 9% blue and 8% humpback whales.

From Jonsgård (1966) and daily reports from whalers and land stations it can be seen that the whalers were operating close to western Iceland from Reykjanes to Straumnes in the years 1931-1934 and 1937 in the months July-October.

A total of 775 whales was taken in Icelandic waters of which 672 or 87% were fin whales. The exact numbers exist for 1931, 1933 and 1937, while the 1932 catch was estimated assuming half the whales were taken in west Greenland and the other half outside west Iceland. The operating area was Faxafloi, west of Iceland in all years, except the Pioner expedition operating June-July 1933 which took 48 whales north of Iceland from Axarfjörður to Straumnes, the most northwestern point of Iceland.

Gunnlaugsson presented SC/14/FW13-SC/M06/FW13 containing a new analysis of historical catch records from land stations in Iceland during the early whaling period 1883-1915, before whaling was banned in Iceland. Original catch records (some partial and some incomplete) were available for just over half the catches. Some graphical presentation of these data has been given in an earlier paper (Gunnlaugsson *et al.*, 1989) but now all known catches are presented. The data are divided between the Westfjord and east coast regions, but stations operated on the east coast only during the years 1901-13. In the previously published literature, the only complete data available were for grand totals by year for all stations combined. Published partial data by station and in some cases species composition were used to complement the data where the catch record data are missing. Some totals by station are still missing for the years 1893-1900 where the published totals have to be used, and for the Westfjord operation in the years 1901-03 when the totals by station for the east coast were subtracted from the published totals to get totals for the west. The total fin whale

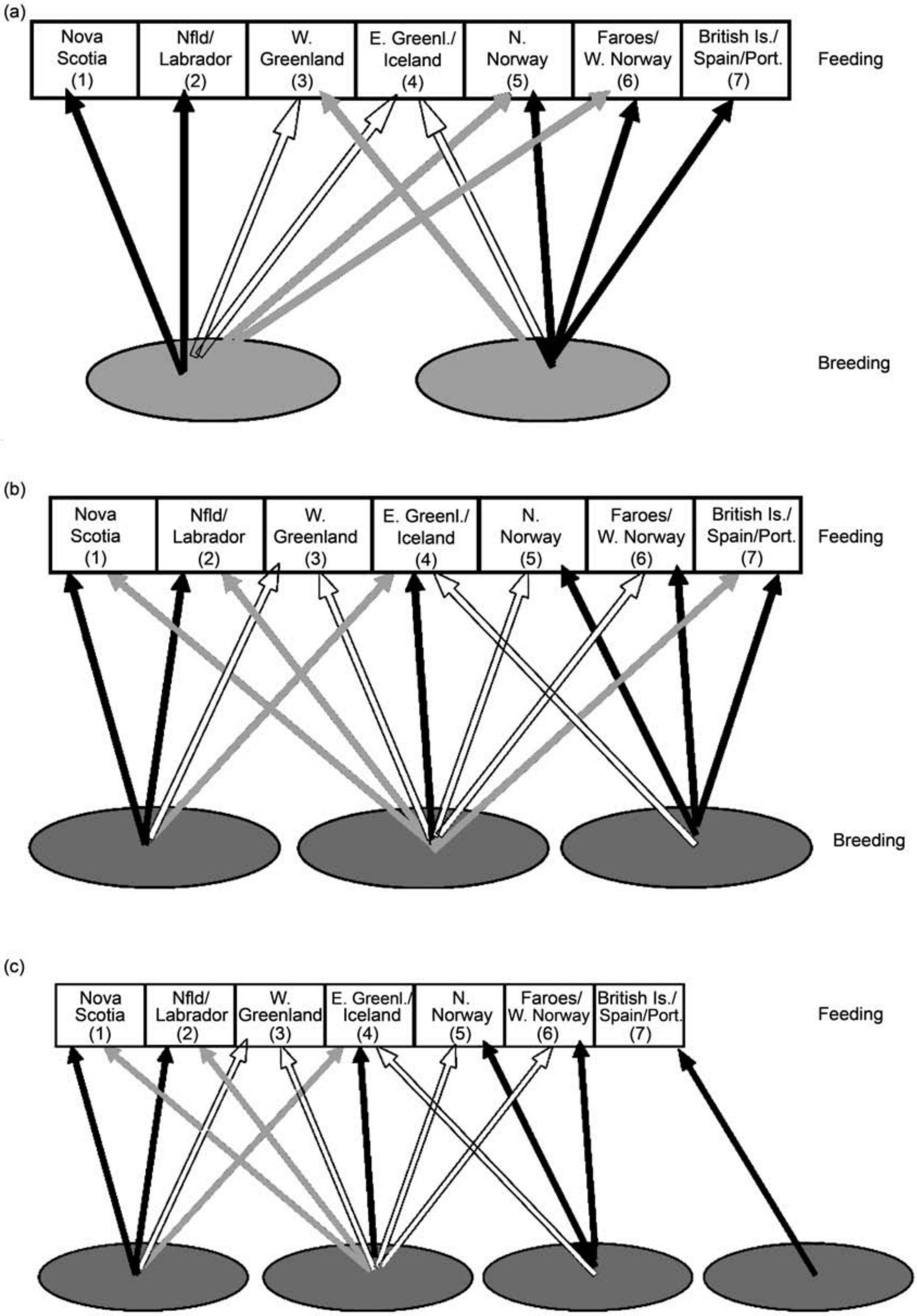


Fig. 1. Feeding – breeding stock scenarios for North Atlantic fin whales, showing scenarios for seven feeding stocks and (a) 2, (b) 3 and (c) 4 breeding stocks. Arrow colours indicate the strength of the evidence supporting the link: black – strong; grey – weak; white – very weak.

catch was then prorated from the observed proportion of fin whales by year and region. The available sex-determined catch showed a ratio of 52% females and gives no indication of variation over time or space. The season was short in Iceland and concentrated in mid summer. Catch position records show that there was very little overlap in the range of the east and west operations, but the operational range expanded with time. Different CPUE series are derived. CpB as used in previous fin whale assessments is total catch of all species per boat-season by year and now split by region, FprB90 is fin catch per boat-season rectified for effort expended catching other species. CpBM is catch per boat month available only where the catch dates are known and the operation time is taken to be from the first to the last whale caught and alternately FpBM. The CpB series using catches of all species (implicitly assuming effort proportional to species composition) and FpB series with a constant correction per other species are considered to be opposite extremes in an attempt to capture the signal of decline in these data.

The positions of the catches in SC/14/FW13–SC/M06/FW13 showed that many fin whales prior to 1915 appeared to be taken close to Icelandic coasts, especially on the East coast where whales are not often seen nowadays. It was suggested that a component of the stock was harvested which may no longer exist, but the effect might be explained by a change in fin whale distribution.

Bloch then presented SC/14/FW15–SC/M06/FW15, which gave details of the catches of North Atlantic fin whales taken off Norway, the Faroes, Scotland, Ireland and Greenland, and SC/14/FW16-SC/M06/FW16, which showed CPUE data from the fin whale catch in the same area, 1901-71. The CpBM was calculated from landstations in Ireland, Hebrides, Shetland, the Faroes, Norway coastal catch, and Norwegian pelagic catch for the period 1901-71. The working season was estimated as the period from the first to the last day whales were taken that year. Often a whaler had worked for a few days and then again 0.5-2 months later in the same waters. In these cases, the number of weeks in work is noted for every whaler. The modern whaling was more or less based on fin whales as they were the most numerous species. The time used to shoot other species was removed from the total CpBM to obtain the fin-CpBM. The smaller and less fat sei whale was less desirable to whalers compared to larger and fatter species like blue and humpback whales. Sperm whales were taken in increasing numbers as the fin whale numbers decreased. One day was subtracted for catches of sei whales, while two days each were subtracted for blue, humpback and sperm whales. Other species (right, bottlenose, pilot, minke and killer whales) were very few in number and were excluded from the calculations. Other factors that may have influenced CPUE, for example engine trouble, bad weather, the boat leaving to whale in another district or the best gunners and captains leaving for the more profitable whaling in the Antarctic, were not considered in the calculations.

Previously (IWC, 1992; NAMMCO, 2000; 2004; 2006), 25% of the Faroese catch in the period 1916-39 was assumed to have been taken in the EGI area. The rationale for this assumption was questioned in view of the Faroese regulation requiring catches to be landed within 36hr of killing, meaning that catches were taken within 40 n.miles of the station. Allison explained that the decision had been taken following inspection of the Faroese catch positions from 1948-84, of which up to 25% appeared to have been taken to the West of the specified boundary between the EGI and West Norway-Faroe Islands areas (a line from 60°N, 17°W to 67°N 3°E).

Bloch noted that she had obtained position data for ~11,000 catches, of which about half are from the Faroes. Many of these position records are in the form of a bearing and distance from a specified point and need to be converted to latitude and longitude for mapping. Once this has been done, it may be possible to see migration routes through the year in the data. Plots of these catch data will be developed in the future. Gunnlaugsson agreed to supply Bloch with the program he had used to convert bearing and distance data to latitude and longitude.

Donovan presented Aguilar's paper SC/14/FW17–SC/M06/FW17, which gave a comprehensive summary of fin whale catches around the Iberian peninsula. Catches were listed by year and by area (Straits of Gibraltar, Portugal and NW Spain), and included information on lost whales. The high loss rate by an operation in Portugal in 1945 was reported to be 43%. The group thanked Aguilar, in his absence, for his work.

It was noted that the crash in availability of fin whales near Gibraltar and Southern Portugal was not reflected in Spanish catches further north, which might be evidence that the southern whales are from a different stock, possibly from the Mediterranean Sea.

Lawson presented SC/14/FW21–SC/M06/FW21 which provided information on the distribution of fin whale catches in Newfoundland and Labrador, Canada. Whaling was banned in 1972, but most stations had already closed by then, following the collapse of the stock in the mid 1960s. Plots showed the change in catch distribution over four time periods. It was suggested that the fishery continued over time by moving to different catch areas, until the stock collapsed. Lawson reported that he had found detailed catch and CPUE data from the 1969 season and is looking for further data. Lawson was thanked for his work. In answer to a question about the distribution of fin whales between Canada and West Greenland, Lawson reported that fin whales were seen right across the Davis Strait, but that the survey effort was low.

Reasons for the closure of North Atlantic whaling stations were discussed, including bankruptcy due of the scarcity of whales and/or general economic difficulties (e.g. in 1930). In the Icelandic east coast fishery the whales had become smaller and more difficult to find and the station closed on economic grounds before the Icelandic ban on whaling in 1915. It was recalled that that the reasons for the Icelandic ban included pressure from herring fishermen opposed to whaling, pollution from whaling stations as well as the need for rebuilding of the stocks for future use by Icelanders themselves (Einarsson, 1987; Tonnessen, 1967). However the profitability of the whaling had been reduced considerably and it can be argued that whaling would have ended anyway for commercial reasons (Tonnessen, 1967). In Northern Norway, the whaling ban from 1905-15 was imposed following bad years in the cod and herring fisheries, and was not reopened until World War I when the meat was needed for food. Similarly, whaling was banned in the Shetland Islands during the herring season (1905-08). It was also noted that in operations off the West coast of Norway the proportion of fin whales in the catch remained fairly constant until after World War II, after which sperm whaling took over. The fin whale catch was used for meat whereas the sperm whale was not eaten but used for other purposes.

Following these discussions it was agreed to refer discussions of CPUE data to a small group (see Item 7.2). It was also agreed that it would be useful to summarise the information available on fin whale catches in the North Atlantic. A small group was set up to prepare the data, but did not have time to complete the task during the course of the meeting. It was agreed that a table would be produced to list the catches by year and area showing the assumptions made and the extent of data available in each case including whether the number of whales had been estimated as a proportion of the known total catch, the extent of information available on catch positions and the numbers of struck and lost whales.

### 7.2 CPUE data

The purpose of attempting to develop CPUE series is to use the values as an index of abundance, either (a) of a 'stock' or (b) in a geographical area. If it can be used, the actual relationship with abundance must be determined. Use of such data has been common in both fisheries and whaling management in the past and there is an extensive literature on the assumptions and potential difficulties of using such data in this regard (e.g. see IWC, 1989).

*What is it to be used for?*
There are a number of questions and assumptions to consider before deciding whether a CPUE series can be used in a management context. In the context of this meeting, the first question to be asked is what is the series to be used for? The potential answers (not always mutually exclusive) include:

(1) as a direct index suitable for estimating trends in abundance of (a) a 'stock' or (b) a geographical area;
(2) as a direct index suitable for 'fitting' in an assessment model such as HITTER-FITTER (see Item 9.1.1 and SC/14/FW/23–SC/M06/FW23), or 'conditioning' in an IWC RMP *Implementation* process; and
(3) a crude qualitative measure of trend for use in evaluating the results of modelling exercises.

The suitability of a particular series (or not) depends on the potential use to which it is put.

*Factors that can affect the suitability of an index*
To be used as an index of abundance, it is important that the measurement of effort reflects searching effort for the target species – in this case the fin whale. There are a number of factors that can influence these two features that must be considered when determining whether an appropriate CPUE series can be developed. In the context of determining trends (or lack of trend) in an index of abundance, two aspects of such factors should be examined: trends and 'noise'; the former is more important than the latter.

TARGET SPECIES
In the simplest case, where a fishery takes only one species – then this is clearly the target species. Difficulties can arise in multispecies fisheries as is commonly the case for fin whaling. In some datasets it may be that it is possible to isolate a time period within a season when only fin whales are taken because they are either the only species present or the only species allowed to be caught. Provided certain information is available (e.g. knowledge of days when boats were at sea) this may be used to select a period when it is clear that fin whales were the sole target species.

However, in most cases, the situation is more complex with two or more species being taken at the same time. In such cases, there may be one or more 'preferred' species and the reasons for any preferences must be examined to see how this may affect the use of the series as an index of abundance of fin whales. For example, in the case of the early Icelandic whaling series the order of preference of species at the start was blue whale (products), humpback whale (ease of capture, hence profits) and then fin whales (apparently wider, more even distribution). If an appropriate fin whale CPUE catch series is to be developed, then it must be for time periods when it can be assumed that the target species was the fin whale – inter-related factors that should be considered in this, include examination of:

(1) the proportion of fin whales in the catch (uncertainty in species composition should be taken into account as well as economic aspects relating to the preferred choice of the whalers. Note that there may be situations where a species may still not be the target species even if it starts to account for a large portion of the catch);
(2) when the searching area can be considered to be determined by the expected distribution of the fin whale and not by the distribution of other preferred species (this relates to the above point and may have economic component);
(3) the temporal component of the composition of the catch within a season (e.g. it may be possible to restrict consideration to a subset of the longer season where the fin whale is the target species);
(4) differences in strategy amongst operations (e.g. whether all of the vessels have the same target species or whether different operations adopt different priorities, i.e. the index may be appropriate for some vessels but not others).

If/once a decision is made on the basis of one or more of the above factors, sensitivity to the choice must be investigated.

SEARCHING AND RELATED FEATURES
Even if it can be assumed that for a certain period or periods, the target species is the fin whale, there are a number of factors that must be considered before it can be decided whether a suitable index reflecting search time can be developed (both in terms of affecting the noise around a value and affecting conclusions regarding trends).

Methods need to be developed to try to reduce the 'handling time' (i.e. time not spent searching for the target species. In a full 'time budget model' this includes all activity from the moment the first animal is seen to the time searching begins again). This interacts with the considerations under target species above. In effect one should try to remove handling time for all species, including the target species. An example of this approach is given in SC/14/FW/13–SC/M06/FW13 and called FiBM −01, −02. This assumed a constant time per 'other' (i.e. non-fin) whale caught of one and two days respectively.

The Workshop requested that to the extent possible, such methods take into account *inter alia*:

(1) 'handling' time of target and other species;
(2) possible differences between operations (e.g. different species priorities during the same season or group of seasons);
(3) factors affecting searching strategy and decisions made at sea (e.g. cooperation among boats);
(4) changes in vessel efficiency over time (e.g. engines, experience etc.);
(5) changes in searching efficiency as a result of environmental factors (e.g. weather);
(6) the number of whales that can be brought back to land at one time by a vessel and the possible use of towing vessels.

A further complication can arise if there is no/little information on the length of the season, as is the case for the early Icelandic series. SC/14/FW/13–SC/M06/FW13 provided one way of considering this in its FprB90 index (season assumed 90 days in length with one day subtracted per other whale captured). The Workshop requested that this method be reconsidered to take into account *inter alia*:

(1) an assessment as to whether there may have been operational/environmental factors that may have increased the noise and more importantly affected trends in the index (e.g. caused different season lengths due to breakdowns, weather etc.);
(2) possible alternative values to those assumed and the sensitivity to these.

The Workshop **recommended** that papers proposing CPUE series provide adequate documentation of the rationale behind any assumptions made and values chosen and consideration of alternative values and assumptions to capture uncertainty/possible bias. In particular, given discussions under Item 9, it **recommended** that priority be given to investigating whether appropriate CPUE series can be developed for the 'early' (pre-1915) Icelandic whaling operations and Faroese whaling after the 1st World War.

### 7.3 Possible under- or over-reporting, including struck and lost animals, ship strikes and bycatches

There was little information available on struck and lost rates. At the IWC fin whale meeting in 1991 (IWC, 1992), a loss rate of 50% was assumed for catches up to and including 1915. Tønnesen (1967, p.44) discussed struck and lost rates in the early operations: 'There are those that believe that the numbers for the first 20-25 years from 1867 should be doubled and for the next 15-20 years increased by 50%'. A reduction in the struck and lost rate after the learning period of 20-25 years appears reasonable, but the loss factor may have increased somewhat again at the turn of the century due to more catches being taken in off shore waters as well as long towing distances along the coast in later years. The group also noted the high loss rate of 43% by an operation in Portugal in 1945 owing to the poor quality of harpoon lines (SC/14/FW17–SC/M06/FW17); (Tonnessen and Johnsen, 1982, p.507).

No evidence was known to suggest that any significant number of fin whales are caught incidentally in the North Atlantic.

The Workshop thanked Bloch, Gunnlaugsson and Allison for all their hard work on catch and CPUE data.

### 7.4 Development of catch series in relation to stock structure hypotheses, including alternative catch series to capture uncertainty if necessary

It was agreed that there was sufficient uncertainty in the catches, in particular in years when the fin whale catch was estimated from the total catch and in years when the struck and lost rate was thought to be appreciable, to warrant development of alternative catch series. It was agreed that the information in the catch series will be used as a basis to develop a 'high' and a 'low' series containing the maximum and minimum catches.

## 8. ABUNDANCE ESTIMATES (RECENT)

### 8.1 Review of available estimates by area and year

*8.1.1 Central and eastern North Atlantic*

Pike introduced SC/14/FW/18-SC/M06/FW18, which presented spatially stratified abundance estimates for fin whales from the Icelandic and Faroese components of North Atlantic Sightings Surveys (NASS) conducted in 1987, 1989, 1995 and 2001. Of particular interest were areas considered useful in modelling, namely East Greenland, West Iceland, the remainder of the EGI area and surrounding areas (Fig. 2); these areas were defined as recommended by the NAMMCO Workshop in 2003 (NAMMCO, 2004). The data were re-analysed using a standardised methodology to make the estimates internally consistent. As the stratification scheme has been different for each survey, post stratification was used to derive common areas for comparison between surveys. Total abundance estimates for each survey were mostly similar to previous published and unpublished estimates (Table 2). The exception was the 1989 survey, for which the new estimate was about 15% higher than the estimate presented by Buckland *et al.* (1992). This is likely due to minor differences in analytical methods and the spatial post-stratification. Estimates for the portion of the EGI area covered by the surveys ranged from a low of 4,657 (CV=0.161) in 1987 to 23,676 (CV=0.133) in 2001.

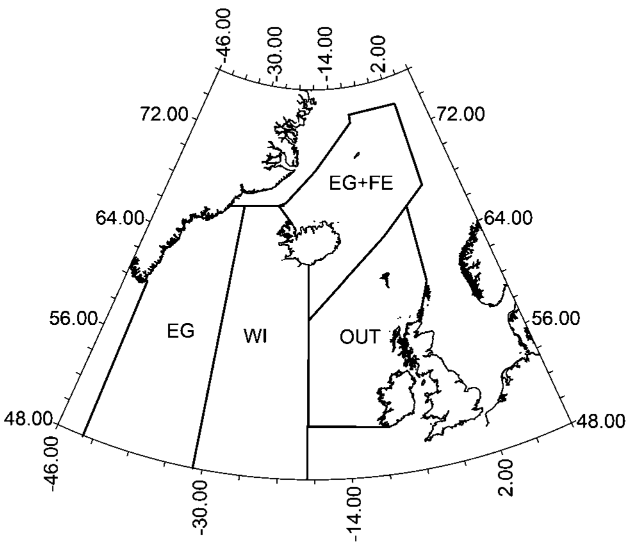


Fig. 2. Approximate boundaries of subpopulation areas used in the assessment model for the EGI stock (see Item 9.1.1). EG – East Greenland (area 1); WI – West Iceland (area 2); EI+FE – East Iceland and Far East (areas 3+4); OUT – outside of EGA area (not used).

Table 2

Regional abundance estimates from Icelandic and Faroese North Atlantic sightings surveys. Areas are as defined in Fig. 2.

| Survey | Region | *N* | CV | Survey | Region | *N* | CV |
|---|---|---|---|---|---|---|---|
| 1988 | EG | 5,024 | 0.228 | 1995 | EGI-TOT | 19,357 | 0.22 |
| 1988 | WI | 3,452 | 0.259 | 1995 | EGI-TOT[2] | 20,265 | 0.211 |
| 1988 | EI+FE | 6,856 | 0.427 | 1995 | TOTAL | 20,951 | 0.213 |
| 1988 | OUT | 675 | 0.284 | 1995 | TOTAL[2] | 21,859 | 0.205 |
| 1988 | EGI-TOT[1] | 15,332 | 0.216 | 2001 | EG | 11,706 | 0.195 |
| 1988 | TOT | 16,007 | 0.205 | 2001 | WI | 6,565 | 0.195 |
| 1995 | EG | 8,412 | 0.294 | 2001 | EI+FE | 5,405 | 0.292 |
| 1995 | WI | 6,800 | 0.231 | 2001 | OUT | 2,085 | 0.282 |
| 1995 | EI+FE | 4,145 | 0.442 | 2001 | EGI-TOT | 23,676 | 0.133 |
| 1995 | EI+FE[2] | 5,053 | 0.368 | 2001 | TOTAL | 25,761 | 0.125 |
| 1995 | OUT | 1,594 | 0.285 | | | | |

[1]Includes Norwegian estimate for Jan Mayen area from 1987 (IWC, 1990, p.141). [2]Includes Norwegian blocks NVN and JMC from 1995 (Øien, 2003).

The analysis used AIC to select the model for the detection function. There was little difference in AIC among models but the estimates of effective strip half width (*esw*) varied little among different models indicating a lack of model uncertainty. Nevertheless, to avoid variation in abundance estimates due to selection of different functional forms of the detection function because of slight variations in AIC, in future it might be appropriate to weight estimates of *esw* from competing models by AIC to obtain the most robust results.

Øien introduced SC/14/FW/25-SC/M06/FW25, a summary of previously presented estimates of fin whale abundance from the Norwegian surveys since 1988. Fin whale abundance was estimated by combining non-duplicate sightings from both platforms on the Norwegian surveys conducted in 1995 and later, assuming that $g(0)=1$. The survey in 1995 covered the whole northeast Atlantic synoptically and resulted in an estimate of abundance of 5,395 (CV=0.20) (Øien, 2003). Over the period 1996-2001, a corresponding area was covered by partial surveys and a total estimate of 10,500 (CV=0.24) calculated (Øien, 2004). This latter estimate included survey block NVS (to the north and east of Iceland) which contributed about 4,000 individuals to the estimate; this block was not covered in 1995. For the partial surveys in 1996-2001, additional variance reflecting any changes in distribution from year to year had not been included in the estimate of variance. The Workshop recommended that this be done using methods developed for minke whales.

### *8.1.2 Estimates of g(0) from Icelandic, Faroese and Norwegian surveys*

Pike introduced SC/14/FW/19-SC/M06/FW19, an estimate of *g*(0) for fin whales from the NASS-2001 surveys in Icelandic and Faroese waters. Previous abundance estimates for fin whales from the Icelandic and Faroese NASS (Buckland *et al.*, 1992; Gunnlaugsson *et al.*, 2002; Víkingsson *et al.*, In press) have not been corrected for visible whales that are missed by observers (perception bias) or whales that are missed because they are diving while the vessel passes (availability bias). The paper provided an estimate of the probability of detection on the trackline (*g*(0)) for the primary platform and corrected estimates of abundance for the 2001 survey, the only one for which double platform methods were fully implemented, based on mark-recapture methodology available in *DISTANCE 5*. Models assuming full and point independence (Laake and Borchers, 2004) were considered, and the latter type were selected based on minimisation of AIC. Of the covariates considered, *g*(0) was dependent on perpendicular distance from the trackline, certainty of species identification (fin or probable fin) and Beaufort sea state. The mean value for *g*(0), averaged over all covariates, was 0.812 for the primary platform. The total abundance in the survey area corrected for *g*(0) was 28,724 (CV=0.16), compared to 25,761 (CV=0.13) from the conventional analysis including non-duplicate sightings from both platforms. This indicates that *g*(0) for the combined platforms, which is not directly estimable because the platforms were not symmetrically independent, was about 0.9.

Øien presented SC/14/FW/20-SC/M06/FW20, an estimate of *g*(0) for fin whales from Norwegian surveys in 1995 and 1996-2001, which were conducted with a two-way independent double platform configuration. Abundance estimates presented earlier from these data have been based on combining non-duplicate data from these two platforms and assuming *g*(0)=1 for this configuration (see Item 8.1.1). Estimates of *g*(0) were calculated using the mark-recapture distance sampling module in *DISTANCE 5*. Assuming point independence, estimated *g*(0) for the combined platform ranged from 0.91-0.92 for 1995 and 0.93-0.94 for 1996-2001. For the single primary platform, corresponding values were 0.71 for 1995 and 0.74-0.75 for 1996-2001. The total abundances of fin whales calculated taking *g*(0) into account were very similar to those based on combining the platforms with non-duplicates.

The Workshop discussed whether the available abundance estimates should be corrected for *g*(0). It noted that the primary purpose of the *g*(0) analyses had been to investigate the effect of using available double platform data for correcting abundance estimates and to use the results to inform the design of future surveys. Although there was no loss of precision in the corrected estimates for the Norwegian surveys, the CVs of the corrected estimates for the Icelandic/Faroese surveys were larger. The Workshop agreed that these analyses were useful in informing whether or not it would be necessary to implement double platform methods in future surveys but that it was preferable to use the uncorrected estimates at this time.

The Workshop **agreed** that for general purposes the best estimate of current abundance in the Central North Atlantic (including the Faroes) is 25,800 (CV=0.125) for the year 2001. The best estimate for the eastern North Atlantic is 4,100 (CV=0.210) from the 1996-2001 survey series. These estimates are based on the assumption that *g*(0)=1. It was noted that discussion of the use of abundance estimates for specific purposes (e.g. use in the IWC's RMP *Implementation* process) would occur in the respective scientific committees.

### *8.1.3 West Greenland*

Witting presented SC/14/FW/22-SC/M06/FW22 reporting on a ship-based line transect survey conducted in September 2005 for large whales off East and West Greenland. The survey platform primarily targeted capelin, *Mallotus villosus*, using acoustic methods and systematically covered the east and west coasts of Greenland from the coast to the shelf break. The surveyed area comprised 81,000 km$^2$ in East Greenland and 225,000 km$^2$ in West Greenland. A total of 194 sightings of 13 cetacean species were made and standard line transect methods were used to derive abundance estimates of the four most commonly encountered large cetaceans. The authors developed abundance estimates for East and West Greenland. Despite good conditions and considerable effort, few cetaceans were observed in the northernmost strata in West Greenland. This suggests that the southbound fall migration of large whales from Northwest Greenland may have started by the time the survey was initiated.

The Workshop discussed the possible implications of the survey design and the distribution of realised survey effort. In West Greenland, the square-pattern survey design provides approximately equal area coverage but the transect parallel to the coast should not be included in a standard line transect analysis (at least not in estimation of encounter rate). In the northern part of East Greenland, the zig-zag design is reasonable but the sole transect in the southeast area, along which most of the fin whales were seen, is parallel to the coast and thus not representative of the area surveyed. Realised survey effort was very patchy, being mostly close to the coast in some areas but offshore in other areas. These factors could all potentially cause bias when extrapolating estimated density to the whole study area. The Workshop noted that the estimated variances seemed low given the number and distribution of sightings. It was unclear what had been used as replicate transects in the calculation of variance.

The Workshop welcomed this presentation. It was recognized that the survey was designed for other purposes but encouraged the authors to attempt a reanalysis to try to account for some of the problems identified. Given the above problems, the Workshop agreed that it could not accept the estimates presented in SC/14/FW/22-SC/M06/FW22. The Workshop noted that an aerial survey had been conducted at the same time but analyses of the data had not yet been completed. It looked forward to a revised presentation incorporating a reanalysis of the shipboard survey data and presentation of the aerial survey analysis. Confidence in the extrapolation aspects of the shipboard survey analysis arising from poor realised coverage of some regions might be enhanced by comparing with distribution patterns evident from previous surveys and the recent aerial survey.

*8.1.4 Canada*

Lawson presented SC/14/FW/25-SC/M06/FW25, which described aerial surveys for marine megafauna conducted off Newfoundland in mid Sept-Oct of 2002 and 2003. Transects were flown at 204km $hr^{-1}$ and 152m ASL. The 11,123km of effort were flown in a Cessna 337 Skymaster with two rear observers. The area under the aircraft out to ~16.6m from the track line was not visible. The 106 transects were arranged in a parallel design, placed to cover most of the bathymetric gradient, from shore to at least 172 km, with many extending beyond 260km. *DISTANCE 5* was used to analyse the data. No fin whales were sighted on the west coast in 2002, although they have been sighted there subsequently. Twenty-nine fin whales were seen in 12 sighting events; most on the NE coast, with a single whale seen off the east coast and two off the south coast. Fin whales were sighted at perpendicular distances of 26-1,238m; other sightings were made at greater distances while off-effort. Five additional 'large whale' sightings made at times and places near the fin whale sightings were assumed to be fin whales and incorporated into the data. Analyses yielded a density estimate of 0.006182 fin whales per $km^2$ (95% CI: 0.00257-0.01487). This equates to a point estimate of 1,103 fin whales (95% CI: 459-2,654) in the study area, uncorrected for *g*(0). It is not appropriate to extrapolate this estimate to the entire Newfoundland stock area.

The Workshop welcomed this presentation, which was the first attempt to estimate the abundance of fin whales in this area. Comments were made about the low number of sightings and the lack of visibility directly under the aircraft. The Workshop **agreed** that it was not reasonable to extrapolate densities estimated from the survey to unsurveyed areas but looked forward to the presentation of results from future surveys.

### 8.2 Estimates of trends in abundance

Information on trends in abundance in the eastern North Atlantic from Norwegian surveys was available in SC/14/FW/25-SC/M06/FW25. Prior to 1995, large parts of the northeast Atlantic were covered in single-platform surveys in 1988 and 1989. To investigate trends in relative abundance, an area was defined which had been covered in all surveys ('kernel' area). Estimates of abundance from the primary platform data from double platform surveys from 1995 onwards and from the single platform data prior to 1995 were calculated. A non-significant increase of about 2% per year was found.

The Workshop noted that the 'kernel' area was chosen to incorporate survey data common to all survey years rather than to incorporate a core area of distribution. It discussed how to interpret the estimate of trend from these data, given the observed variation in distribution from year to year. It agreed that, although the estimated trend provided information on the change in abundance in the 'kernel' area, it was unknown whether this area provided information on trend in possible stocks.

Information on trends in abundance in the central North Atlantic from Icelandic and Faroese surveys was available from work in preparation by Víkingsson *et al*., the results from which are reproduced in Annex D. Estimated abundance in the area west and southwest of Iceland increased at an annual rate of 10% (95% CI: 6%-14%) between 1987 and 2001. This is the area where nearly all fin whaling has been conducted since 1915. Estimated abundance in the whole EGI area has increased at 3% (95% CI: –1%-7%) per year, i.e. this rate of increase is not significant at the 5% level. It is possible that there have been increases in survey efficiency, i.e. *g*(0) may have been lower in the earlier years, but the Workshop **agreed** it was unlikely that this factor could fully explain the observed increases in abundance. The difference between the estimated rates of increase in the western area and the EGI area covered by these surveys indicates that some shift in the relative abundance of whales has occurred between 1987 and 2001.

## 9. ABUNDANCE ESTIMATES (PRE-EXPLOITATION)

### 9.1 Methods

*9.1.1 Use of population models*

SC/14/FW/23–SC/M06/FW23 reported a new assessment model of the EGI fin whale population, modelled as four subpopulations with movement between the following areas: East Greenland (area 1), West Iceland (area 2), East Iceland (area 3) and the Far East (area 4) (See Fig. 2). The model is sex- and age-structured, and is fitted to CPUE, sightings survey abundance split by area, and mark-recapture data using both maximum likelihood and Bayesian approaches. Movement parameters are not differentiated by sex since the inclusion of sex-specific movement parameters did not improve the AIC. For the base case assessment scenario, best fits to the data were obtained when the West Iceland and East Iceland are effectively fully mixed, with an annual interchange with East Greenland of a few percent and virtually no interchange with the Far East region. For the base case and most sensitivity tests, the overall recruited population is increasing and above 80% (base case 84%) of pre-exploitation abundance (*K*), and subpopulations in all areas are above 70% (base case>79%) of the individual K values; $MSYR_{(1+)}$ is estimated at 1.7%. Projections for annual catches of 0, 100, and 200 whales indicated that only the last would result in abundance decreases compared to current levels. Under catch levels of 200 whales there was less than a 12% probability that any of the 1+, recruited or mature female components of the total EGI population would fall below 60% of pre-exploitation levels within the next 30 years.

A minor discrepancy in the catch series used in the model was noted, in that 25% of catches landed in the Faroe Islands between 1916 and 1929 were assumed to come from West Iceland when they should have been applied to East Iceland. The validity of this assumption needs further consideration. However these catches were small and would have no effect on the general outcomes of the model.

Some of the predictions of the model did not coincide with our present understanding of fin whales in this area. Firstly, the model predicts a low rate of mixing between East Greenland and West Iceland, whereas Discovery marking and a radio tagging experiments suggest higher rates of exchange over recent years. However it was pointed out that most markings applied in the East Greenland area were quite close to the borderline with West Iceland. Secondly, the model provided a poor fit to the trends in abundance estimates in Area 1 (East Greenland), an area for which sightings surveys have shown a large and significant increase in abundance since 1987. The model predicted little increase in this area. However it was noted that the apparent increase in abundance might be exaggerated because of differences in bias between surveys and distributional shifts (see Item 8.2). Finally, the model suggested a high rate of mixing between West and East Iceland. This is contrary to the history of whaling in the area, which indicates that the

West Iceland whales were depleted first, around the turn of the last century, after which whalers moved to East Iceland where the stocks were apparently much less depleted. This suggests that there was not a high rate of exchange between these areas. There were too few Discovery marks placed off East Iceland to be informative about this exchange rate.

Butterworth suggested that the inconsistencies suggested above might be partially due to distributional shifts, which were not accounted for in the model. Such shifts have been observed in the NASS series, for example in the area west of Iceland and around Norway. It was also suspected that these conflicting results may have been due to an overemphasis on the two early CPUE series in the model, because of low associated variances. These series are assumed to be linearly proportional to abundance, but there is considerable uncertainty about this (see Item 7.2) and it was considered that additional sensitivity runs, incorporating improved CPUE indices, indices entered with higher levels of variance and alternative assumptions about their relationship to abundance, would be of value. Furthermore, it was suggested that sensitivity runs incorporating two or more factors simultaneously would be useful, particularly runs combining combinations of alternative CPUE assumptions and choices of natural mortality.

The Workshop could not draw firm conclusions from this modelling exercise, but noted that the more complex models involving two or more spatial components, such as this model and that of Cunningham and Butterworth (2003), did fit the historical and modern CPUE and abundance data better than single homogeneous stock models. The model can be improved as the stock structure of fin whales in the area is clarified, particularly with regard to stock boundaries and mixing rates.

## 10. FUTURE WORK AND RESEARCH RECOMMENDATIONS

The Workshop reiterated research recommendations made in previous NAMMCO meetings (NAMMCO, 2000; 2001; 2004; 2006), and identified those most important to refine existing assessment and extend assessments to other areas.

**Catch series:**

(1) Produce an agreed catch series, explicitly listing assumptions and estimates for each year and area (see Item 7.1).
(2) Provide position data for as many catches as possible, including conversion of data expressed as a bearing and distance from a fixed point into a latitude and longitude.
(3) Produce alternative catch series incorporating different levels of struck and lost rates and varying other assumptions as necessary.

**Stock structure:**

(1) Finalise the complete genetic dataset as documented under Item 5.1.
(2) Better understand assumptions and methods for new genetic analytical techniques and further investigate power of genetic analyses and estimation of confidence intervals as documented under Item 5.1.
(3) Completion of preliminary analyses presented under Item 5.1.
(4) Additional genetic sampling in all areas, but particularly in areas from which samples are few or lacking, such as East Greenland, northern and eastern Iceland, the Faroes, Norway, Canada and the USA. Inclusion of biopsy programs in future sightings surveys should be considered.
(5) Use microsatellite analysis to determine if closely related individuals are present on different feeding grounds.
(6) Run duplicate analyses and interlaboratory comparisons to estimate error rates in genetic typing.
(7) Satellite tagging to determine habitat use and migratory patterns once methodological/technical issues are addressed. If possible, a biopsy should be obtained from all tagged animals for genetic analysis and sex determination.

**Abundance:**

(1) Incorporate additional variance into estimates from Norwegian mosaic surveys.
(2) Future surveys, such as the proposed Trans-NASS (T-NASS) in 2007, should cover as wide an area as feasible, including eastern Canada and West Greenland.
(3) New abundance estimates from the ship and aerial surveys carried out off Greenland in 2005 should be produced.

**Assessment models:**

(1) The following pertain to assessment models for the EGI, Faroes and Norwegian areas as relevant.
(2) Extend modelling to include neighbouring areas, including Norway, the Faroes and West Greenland.
(3) Incorporate agreed catch series using existing boundaries and conduct sensitivity analyses with alternate series.
(4) Incorporate improved CPUE series, with appropriate variances, when they are completed, and conduct sensitivity analyses with alternate series.
(5) Conduct sensitivity analyses using alternative CPUE series and levels of mortality simultaneously.
(6) Analyse correlation of predicted abundance with observed trends in biological parameters.
(7) Ascertain why the present model estimates a high mixing rate between West and East Iceland.

**Other:**

(1) If new catches are taken, samples should be taken if possible both within and outside the traditional whaling grounds. The material should be investigated to get an updated view of age structure and sex distribution on and outside the whaling grounds and biological parameters such as age at sexual maturity and fecundity.
(2) Compile information on incidental sightings, marking with Discovery tags, satellite tagging tracks, biopsy samples and age determinations of some samples for areas where this has not already been done.

## 11. OTHER BUSINESS

It was **agreed** that future work on fin whales, including meeting documents, working papers and reports, would be exchanged between the IWC and NAMMCO Scientific Committees.

## 12. ADOPTION OF REPORT

A draft version of the Report was adopted by consensus on 26 March 2006. The first joint meeting between the NAMMCO and IWC Scientific Committees was considered successful, efficient and productive. The Chair thanked the

rapporteurs and the staff of the Marine Research Institute for their hard work during the meeting. The Chair was thanked for his efficient management of the meeting.

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# Annex A

# List of Participants

C.A. Allison (I)
IWC
The Red House
135 Station Road
Impington, Cambridge
CB24 9NP UK
*cherry.allison@iwcoffice.org*

D. Bloch (N)
Natural History Museum,
Futalag 40,
FR-100 Tórshavn,
Faroe Islands
*doreteb@ngs.fo*

D.S. Butterworth (EN)
Dept of Mathematics and Applied Mathematics
University of Cape Town
Rondebosch 7701
South Africa
*DLL@maths.uct.ac.za*

A. K. Danielsdottir (EN)
Marine Research Institute,
PO Box 1390,
IS-121 Reykjavik,
Iceland
*andan@iti.is*

G. Desportes (N)
Gdnatur
Stejlestræde 9, Bregnør
DK-5300 Kerteminde
Denmark
*genevieve@gdnatur.dk*

G.P. Donovan (I)
IWC
The Red House
135 Station Road
Impington, Cambridge
CB24 9NP UK
*greg.donovan@iwcoffice.org*

Þ. Gunnlaugsson (I, N)
Marine Research Institute,
PO Box 1390,
IS-121 Reykjavik,
Iceland
*thg@hafro.is*

P.S. Hammond (EN)
Sea Mammal Research Unit
University of St Andrews
St Andrews, Fife KY16 8LB
Scotland
*psh2@st-andrews.ac.uk*

T. Kitakado (EN)
Department of Marine Biosciences
Tokyo University of Marine Science and Technology 5-7
Konan 4, Minato-ku
Tokyo 108-8477
Japan
*kitakado@s.kaiyodai.ac.jp*

J. Lawson (EN)
Newfoundland & Labrador Region
Fisheries and Oceans Canada
P.O. Box 5667, 80 East White Hills Road
St. John's, NL
A1C 5X1, Canada
*LawsonJ@DFO-MPO.GC.CA*

C. Lockyer (N)
NAMMCO
Polar Environmental Centre
N-9296 Tromsø
Norway
*christina.lockyer@nammco.no*

B. Mikkelson (N)
Natural History Museum,
Futalag 40,
FR-100 Tórshavn,
Faroe Islands
*bjarnim@ngs.fo*

N. Øien (EN)
Institute of Marine Research
P.O.Box 1870 Nordnes
N-5024 Bergen
Norway
*nils@imr.no*

D. Ólafsdóttir (I, N)
Marine Research Institute,
PO Box 1390,
IS-121 Reykjavik,
Iceland
*droplaug@hafro.is*

P.J. Palsbøll (EN)
University of California, Berkeley
Ecosystem Sciences Division – ESPM
151 Hilgard Hall #3110
Berkeley, California, USA
*palsboll@nature.berkeley.edu*

L. Pastene (I)
Institute of Cetacean Research,
4-5 Toyomi-cho, Chuo-ku,
Tokyo 104-0055, Japan
*pastene@cetacean.jp*

D. Pike (N)
NAMMCO
Polar Environmental Centre
N-9296 Tromsø
Norway
*dan.pike@nammco.no*

H. Skaug (EN)
Department of Mathematics
University of Bergen
Johannes Brunsgate 12
5008 Bergen, Norway
*Hans.Skaug@mi.uib.no*

G. Vikingsson (I, N)
Marine Research Institute,
PO Box 1390,
IS-121 Reykjavik,
Iceland
*gisli@hafro.is*

L. Walløe (I, N)
Department of Physiology
University of Oslo
P.O. Box 1103, Blindern
N-0317 Oslo, Norway
*lars.walloe@basalmed.uio.no*

L.Witting (I, N)
Greenland Institute of Natural Resources
P.O.Box 570
DK-3900 Nuuk, Greenland
*larsw@natur.gl*

**Affiliations:** N–NAMMCO Scientific Committee; I–IWC Scientific Committee; EN–expert invited by NAMMCO.

# Annex B

# Agenda

1. Opening remarks
2. Appointment of Chair and rapporteur
3. Adoption of Agenda
4. Review of available documents and reports
5. Stock structure
   - 5.1 Genetic evidence
     - 5.1.1 Author's summaries
     - 5.1.2 Discussion
   - 5.2 Non-genetic evidence
   - 5.3 Stock structure hypotheses
   - 5.4 Mixing rates
6. Biological parameters
   - 6.1 Review of available estimates
   - 6.2 Evidence for trends in estimates
   - 6.3 Values for use in modelling (see Item 9.1.1)
7. Catch data
   - 7.1 Available catch data, level of detail and level of disaggregation of data
   - 7.2 CPUE data
     - 7.2.1 Searching and related features
   - 7.3 Possible under- or over-reporting, including struck-and-lost animals, ship strikes and bycatches
   - 7.4 Development of catch series in relation to stock structure hypotheses, including alternative series to capture uncertainty if necessary
8. Abundance estimates (recent)
   - 8.1 Review of available estimates by area and year
     - 8.1.1 Central and eastern North Atlantic
     - 8.1.2 Estimates of *g*(0) from Icelandic, Faroese and Norwegian surveys
     - 8.1.3 West Greenland
     - 8.1.4 Canada
   - 8.2 Estimates of trends in abundance
   - 8.3 Development of abundance estimates in relation to stock structure hypotheses
9. Abundance estimates (pre-exploitation)
   - 9.1 Methods
10. Future work and research recommendations
    - 10.1 Catch series
    - 10.2 Stock structure
    - 10.3 Abundance
    - 10.4 Assessment models
    - 10.5 Other
11. Other business
12. Adoption of report

# Annex C

# List of Documents

SC/14/FW/1 List of participants.

SC/14/FW/2 Draft annotated agenda.

SC/14/FW/3 Draft list of documents.

SC/14/FW/4-SC/M06/FW4 Pastene, L.A. and Kitakado, T. Thoughts on stock structure analysis/hypotheses of North Atlantic fin whales based on the experiences of North Pacific common minke and Bryde's whales RMP implementations.

SC/14/FW/5-SC/M06/FW5 Daníelsdóttir, A.K., Bérubé, M., Palsbøll, P.J., Stefánsson, M.O., Thorgilsson, B., Jorunsdóttir, Th.D., Ragnarsdóttir, A., Árnason, A., Gunnlaugsson, Th., Ólafsdóttir, D., Øien, N., Witting, L., Pampoulie, C. and Víkingsson, G.A. Genetic stock delineation of fin whales.

SC/14/FW/7-SC/M06/FW7 Víkingsson, G.A. and Gunnlaugsson, Th. Stock structure of fin whales (*Balaenoptera physalus*) in the North Atlantic – indications from non-genetic data.

SC/14/FW/8-SC/M06/FW8 Mikkelsen, B., Bloch, D. and Heide-Jørgensen, M.P. Movements of two fin whales (*Balaenoptera physalus*) tracked by satellite telemetry in Faroe Islands in 2001.

SC/14/FW/11-SC/M06/FW11 Lockyer, C. A review of the biological parameters of fin whales: focus on the North Atlantic.

SC/14/FW/12-SC/M06/FW12 Víkingsson, G.A. Trends in biological parameters for the EGI stock.

SC/14/FW/13-SC/M06/FW13 Sigurjónsson, J. and Gunnlaugsson, Th. Revised catch series and CPUE for fin whales taken from the early modern whaling land stations in Iceland.

SC/14/FW/14-SC/M06/FW14 Bloch, D. Norwegian coastal and pelagic whaling, 1917-1986.

SC/14/FW/15-SC/M06/FW15 Bloch, D. and Allison, C. The North Atlantic catch of fin whales, 1894-1984, taken by Norway, the Faroes, Shetland, the Hebrides, Ireland and Greenland.

SC/14/FW/16-SC/M06/FW16. Bloch, D. and Allison, C. Whale catches in the North Atlantic 1894-1984, taken by Norway, the Faroes, Shetland, the Hebrides, Ireland and Greenland.

SC/14/FW/17-SC/M06/FW17. Aguilar, A. Catches of fin whales around the Iberian Peninsula: Statistics and sources.

SC/14/FW/18-SC/M06/FW18. Pike, D.G. and Gunnlaugsson, Th. Regional estimates of density and abundance of fin whales (*Balaenoptera physalus*) from Icelandic and Faroese North Atlantic Sightings Surveys.

SC/14/FW/19-SC/M06/FW19. Pike, D.G., Gunnlaugsson, Th. and Víkingsson, G.A. An estimate of $g(0)$ for the NASS-2001 survey for fin whales (*Balaenoptera physalus*) in Icelandic and Faroese waters.

SC/14/FW/20-SC/M06/FW20. Øien, N. and Bøthun, G. Estimates of $g(0)$ for fin whales in Norwegian double platform surveys, 1995 and 1996-2001.

SC/14/FW/21-SC/M06/FW21. Lawson, J. Preliminary information on distribution and abundance of fin whales in Newfoundland and Labrador, Canada.

SC/14/FW/22-SC/M06/FW22. Heide-Jørgensen, M.P., Simon, M.J. and Laidre, K.L. Estimates of large whale abundance in Greenland waters from a ship-based survey in 2005.

SC/14/FW/23-SC/M06/FW23. Branch, T.A. and Butterworth, D.S. Assessment of the East Greenland/Iceland fin whale population using a four-substock model.

SC/14/FW/24-SC/M06/FW24. Bérubé, M., Bloch, D., Mikkelsen, B., Heide-Jørgensen, M.P. and Palsbøll, P.J. Stock-identity of Faroe Island fin whale biopsies.

SC/14/FW/25-SC/M06/FW25. Øien, N. Abundance estimates for fin whales from Norwegian surveys.

# Annex D

# Distribution and Trends in Abundance of Fin Whales in the Northeast and Central Atlantic as Inferred from the North Atlantic Sightings Surveys 1987-2001

Gísli A. Víkingsson, Daniel G. Pike, Geneviève Desportes, Nils Øien, Thorvaldur Gunnlaugsson and Dorete Bloch

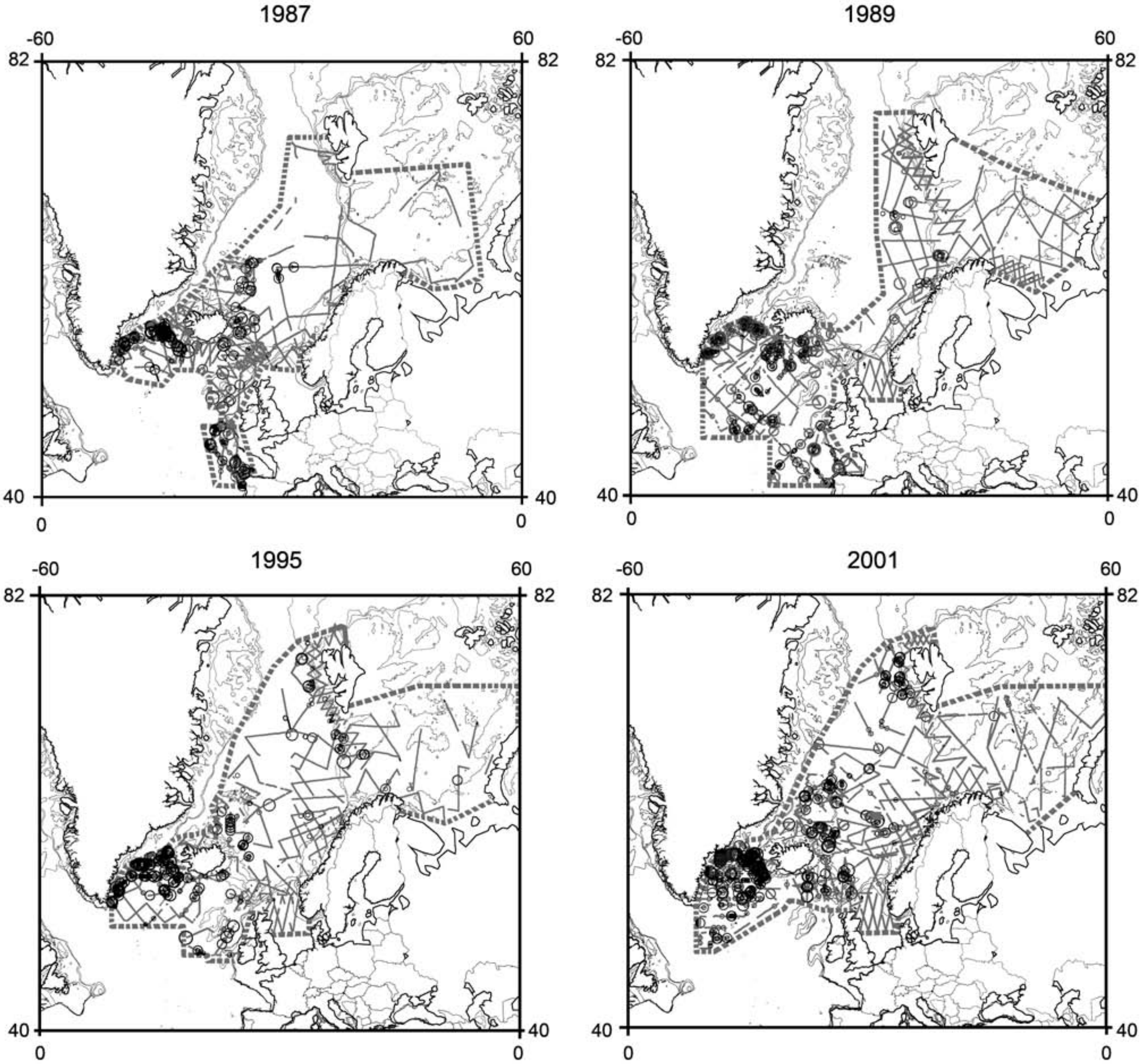


Fig. 1. Realized survey effort and sightings of fin whales in NASS ship surveys, 1987 to 2001. Symbol size is proportional to group size from 1 to 4+. The Norwegian sector of the 2001 survey was surveyed from 1996-2001.

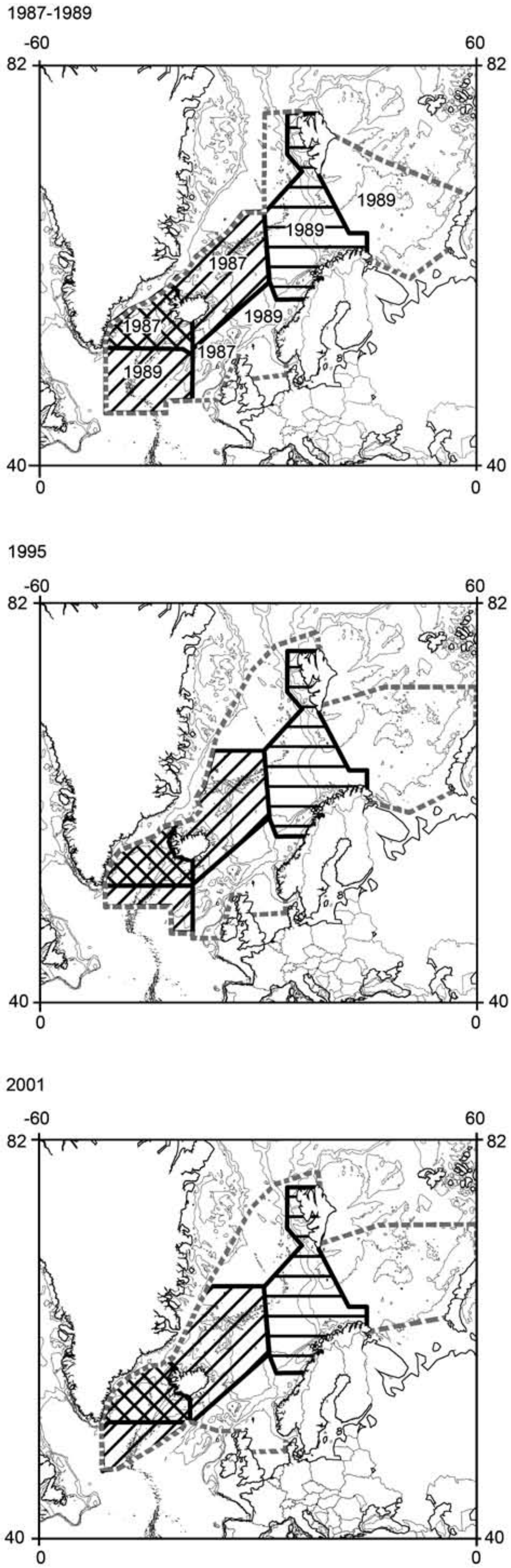


Fig. 2. Regions used in examining trends in fin whale abundance. Survey year is indicated for the 1987-1989 compilation. The Norwegian sector of the 2001 survey was surveyed in the period 1996-2001. Cross hatched – WEST; Diagonally hatched – EGI; Horizontally hatched – NORWAY; TOTAL outlined by grey dashes.

Table 1

Estimates of abundance by region for NASS shipboard surveys after post-stratification. *N*=abundance; CV=coefficient of variation; L, R=lower and upper 95% confidence intervals. Regions are shown in Fig. 2.

| Year | Region | *N* | CV | L | R | Comments |
|---|---|---|---|---|---|---|
| 1987 | West | 3,607 | 0.18 | 2,537 | 5,132 | |
| 1989 | West | 6,006 | 0.25 | 3,468 | 10,401 | |
| 1995 | West | 13,726 | 0.23 | 8,667 | 21,740 | |
| 2001 | West | 14,021 | 0.18 | 9,550 | 20,586 | |
| **Growth rate** | | **0.10** | | **0.06** | **0.14** | |
| 1988 | EGI | 15,237 | 0.22 | 9,990 | 23,239 | Includes components of 1987 and 1989 surveys |
| 1995 | EGI | 20,262 | 0.21 | 13,464 | 30,492 | Norwegian – Øien (2003) |
| 2001 | EGI | 23,676 | 0.13 | 18,024 | 31,101 | |
| **Growth rate** | | **0.03** | | **-0.01** | **0.07** | |
| 1988 | NOR | 1,242 | 0.38 | 512 | 3,009 | Øien and Bøthun (2005) |
| 1989 | NOR | 1,106 | 0.43 | 464 | 2,637 | Øien and Bøthun (2005) |
| 1995 | NOR | 1,806 | 0.51 | 576 | 5,668 | Øien and Bøthun (2005) |
| 1998 | NOR | 1,723 | 1.09 | 201 | 14,734 | Øien and Bøthun (2005) |
| **Growth rate** | | **0.05** | | **-0.13** | **0.26** | |
| 1988 | Total | 17,482 | 0.19 | 11,981 | 25,508 | Includes components of 1987 and 1989 surveys |
| 1995 | Total | 26,343 | 0.17 | 18,754 | 37,004 | Norwegian – Øien (2003) |
| 2001 | Total | 29,891 | 0.11 | 24,040 | 37,167 | Norwegian – Øien (2004) |
| **Growth rate** | | **0.04** | | **0.01** | **0.08** | |

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