Report of the First Intersessional RMP Workshop on North Atlantic Fin Whales

The meeting was held at the Greenland Representation, Copenhagen from 31 March to 4 April 2008. The Workshop thanked Mads-Peter Heide-Jørgensen and Susanne Nøddesbo for the excellent arrangements. A list of participants is given in Annex A.

1. INTRODUCTORY ITEMS

1.1 Convenor's opening remarks

Donovan noted that the primary objective of the Workshop is to develop the *Implementation Simulation Trials* structure and to specify the appropriate conditioning so that it can be carried out before the 2008 Annual Meeting. The relevant section of the Committee's 'Requirements and Guidelines for *Implementations*' (IWC, 2005) is given in Annex B2.

1.2 Election of Chair and appointment of rapporteurs

Donovan was elected Chair. Butterworth, Allison and Palsbøll acted as rapporteurs with assistance from the Chair.

1.3 Adoption of Agenda

The adopted agenda is given as Annex B1.

1.4 Review of documents

The list of documents available is given as Annex C.

2. HYPOTHESES FOR INCLUSION IN TRIALS

2.1 Stock structure and mixing

2.1.1 Review of information available

In the mid-1970s, the IWC divided fin whales in the North Atlantic into the following seven management stocks (Fig. 1), based largely on catch and marking data (Donovan, 1991):

(1) the British Isles, Spain and Portugal;
(2) North Norway and the Arctic Eastern North Atlantic;
(3) West Norway and the Faroe Islands;
(4) East Greenland and West Iceland;
(5) West Greenland;
(6) Newfoundland and Labrador; and
(7) Nova Scotia.

However, this delineation was developed before a considerable body of information with a bearing on this question became available during the last two decades. Much of this new information has been reviewed by the Scientific Committee and a number of hypotheses developed as part of the *pre-Implementation assessment* (IWC, 2007b). It is recognised that a full elaboration of stock structure may best be achieved by a combination of information from a suite of techniques, both genetic and non-genetic (e.g. Donovan, 1991). In developing a final list of hypotheses, the Workshop took account of previous discussions and welcomed some further analyses presented to the Workshop. A brief summary of the more important available information is given below and an updated table from the joint NAMMCO/IWC workshop (IWC, 2007a) is given as Table 1. Specific aspects of the data are covered under Items 2.1.1.1 to 2.1.1.5.

In developing hypotheses for the *Implementation* process, the Workshop noted that future whaling operations were planned only for the area to the immediate west and southwest of Iceland (see Item 3.2). Accordingly greater attention was paid to capturing possible structures to the immediate west and east of this area, and less to the areas adjacent to the European and North American continents, as alternative representations of fin whale dynamics in these last two areas would probably have very little impact on the response of whales to harvesting in the vicinity of West Iceland.

2.1.1.1 GENETICS

Palsbøll presented a brief overview of the recent genetic analyses and the results given in SC/M08/RMP1. In SC/M08/RMP1, an analysis of 15 microsatellite markers and sequencing of the mtDNA control region of 475 fin whales from five different feeding locations was presented. Overall those genetic analyses using DNA-based data show very low levels of genetic divergence amongst different sample partitions of fin whales in the North Atlantic. The degree of divergence is typically at 1% or less. In general, different data sets from among the involved laboratories agree well. The estimates do not show any changes of consequence with number of loci analysed (6, 9 or 15). The one notable exception is 13 eastern Canadian samples from 1972/73 analysed at the Marine Research Institute in Iceland where the degree of divergence to other North Atlantic regions is at ~2% at microsatellite loci and 5.5% at the mitochondrial control region DNA sequences. The Workshop also noted that due to small sample sizes in some areas (e.g. 11 in Canada and 15 in Greenland), the precision of the estimates of genetic divergence and the power to detect significant differences is likely to be low for some comparisons. The 1972/73 result is in stark contrast to the much lower degree of genetic divergence observed in estimation based upon a study using a much larger sample (109) from eastern Canada (Gulf of St. Lawrence), a larger sample from West Greenland (46), and a smaller sample from Iceland (33), which yielded a divergence at 0.1% for the microsatellite loci and 3.3% for the mitochondrial control regions sequences (Bérubé *et al*., 1998).

The low levels of genetic divergence among geographic fin whale samples may be interpreted in two different ways; (i) that the degree of gene flow between sampling partitions is high, or (ii) that the rate of gene flow in fact is low, and that the low degree of genetic divergence is due to a recent divergence of current North Atlantic fin whale populations. This latter hypothesis implies that current North Atlantic fin whale populations are not in mutation-drift-migration equilibrium. This notion was supported by the observed mismatch distributions estimated from the mitochondrial control region sequences which (in most areas) were indicative of a recent (in evolutionary terms) exponential population expansion since the last glacial maximum (Bérubé *et al*., 1998).

The spatial distribution of dyads of close relatives (identified by the degree of genetic similarity at microsatellite loci) as described by Skaug (see below) considered for all available fin whale samples from the North Atlantic would most likely resolve which of the two hypotheses listed above (i) or (ii) is the correct one. The Workshop **recommended** that such an analysis be undertaken. Such an analysis would reveal if the spatial distribution of dyads of close relatives is consistent with high (dyads are far apart) or low (dyads are close together) movement.

There have been two allozyme studies of fin whales in the North Atlantic. The first study (Daníelsdóttir *et al*., 1991) was based on 11 polymorphic allozyme loci on liver and muscle samples from Spain (1985) and Iceland (1985-1988). The second study (Daníelsdóttir *et al*., 1992) was based on five allozyme loci on skin samples from Newfoundland Canada (1971), Norway (1991) and Iceland (1988). In the first study, the level of significance of the genetic differences between the Spanish and Icelandic samples suggested that they represent separate stocks. In the second study, significant differences were found between samples from Newfoundland Canada, Norway and Iceland indicating at least three separate breeding stocks.

Thus, in contrast to the DNA-based genetic analyses, estimates of genetic divergence based upon 5-11 allozyme loci shows a much higher degree of genetic divergence between the sample partitions analysed (Norwegian, Icelandic, Canadian and Spanish samples); the degree of genetic divergence was estimated at 30-50% which is very high. So far divergent selection has been invoked as an explanation for the discrepancy between the DNA- and allozyme-based results. However, no data analyses aimed specifically at detecting signatures of selection have been undertaken (e.g. by analysis of those DNA sequences encoding for the allozymes at which high levels of genetic divergence was detected). The Workshop **recommended** that such an analysis be undertaken.

It was noted that a large number of pairwise homogeneity tests were conducted in SC/M08/RMP1 upon which sequential Bonferroni corrections were applied. This led to a discussion of the appropriateness of applying sequential Bonferroni corrections to table-wide *p*-values. The Workshop **agreed** that the number of pairwise comparisons conducted (and to which Bonferroni corrections are applied) should be limited to those relevant to the stock hypothesis under consideration. Specifically, in SC/M08/RMP1, Bonferroni sequential correction should be applied only to comparisons between adjacent feeding areas (e.g. West Greenland and Canada but not necessarily Canada and Spain). Such a reduction in the number of pairwise comparisons may result in an increase of tests where homogeneity in allele frequencies is rejected.

It was also noted that even though the degree of genetic divergence was low for most of the estimates based upon microsatellite genotypes and mitochondrial control region DNA sequences, several pairwise comparisons did yield significant *p*-values (i.e. homogeneity in allele frequencies was rejected) which should be taken into consideration when evaluating stock hypotheses.

Skaug (Annex D) presented an updated analysis of relatedness based on pairwise comparisons of DNA-profiles (15 loci) in the sample of 469 North Atlantic fin whales. The previous analysis (Skaug and Daníelsdóttir, 2006) based on a sample size of 226 found five dyads of related individuals, while the new study found 23 dyads using a FDR (False Discovery Rate) of 10%. The FDR controls the proportion of detected dyads consisting of unrelated individuals that by chance have similar DNA-profiles. The 23 identified dyads mostly involved individuals from Icelandic whaling grounds, as can be expected from the large sample size from this area. One notable exception was a 'match' between Greenland and Norway.

The Workshop briefly discussed if the results of Skaug's analysis could be used to infer migration rates, but concluded that (a) the relatively few observations, and (b) the detailed demographic simulations required, made such an exercise infeasible at this time.

In Annex E, the data used in SC/M08/RMP1 was corrected for problematic samples identified by Skaug's analyses (i.e., the presence of duplicate samples from the same individual) and F_{ST} values for mitochondrial control region DNA sequences and microsatellite genotypes were re-estimated and the number of sample partitions reduced to five (Canada, Spain, Western Greenland, Iceland and Norway). Estimates of genetic divergences for both kinds of genetic markers essentially remained unchanged. The Workshop discussed the higher-than-average level of divergence between the 'old' Canadian samples (now 11 samples from 1972/73) and the remaining areas. However, the estimates may not be statistically different, and accordingly the Workshop **recommended** that the revised version of SC/M08/RMP1 include 95% confidence intervals for divergence estimates. It further **recommended** that the presentation of confidence intervals should be the norm when any such estimates are presented to the Scientific Committee.

As a result of its discussions of the genetic data, the Workshop made a number of more general recommendations with respect to the use of genetic data and the presentation of the results of such analyses (see also IWC, 2008)

(1) data should always be checked for possible errors, such as duplicate samples from the same individual – for instance, such a check may be undertaken by determining the minimum number of matching loci (taking the possibility of close relatives into account) at which identity is supported and then screening the entire dataset for samples that match at the minimum or more loci;
(2) authors should specify in clear detail what procedures have been implemented to check and correct for genotype/sequencing errors in their analyses.

In conclusion, the different genetic data sets and analyses conducted support one or more of the population structure hypotheses for North Atlantic fin whales (see Item 2.1.2), such as a single breeding population with some low degree of maternally-determined structure of feeding grounds (i.e.

microsatellite genotypes and mitochondrial control region DNA sequences), or three or more highly divergent breeding populations (i.e. allozyme data).

2.1.1.2 MARK RECAPTURE

SC/M08/RMP2 examined between-season fin whale markings and recoveries within the whaling grounds of Iceland on a fine scale. Recoveries appeared to be less likely the farther west and north-west from the station that the marks were placed and there is a lack of mark recoveries in the catches taken on the grounds to the south of Iceland from the markings on the grounds west of Iceland and farther west. Whales taken in the south are generally larger and older than whales to the west. The length of whales increases with distance from the station (and see Martin, 1982). The authors suggest that local site fidelity may have led to a gradient of depletion of larger whales with distance from the station. This would be more pronounced for females, which grow to a larger size and could explain some of the difference in recoveries by sex. The age structure of the catch will reflect this and will not be representative for the whole area. Animals dispersed from other areas may not follow the 'local' distribution pattern by age, and dispersion must be low for the age distribution to be affected in this manner by the operation. This agrees well with the single recovery nine years after marking off Canada (314 marks, 38 recovered there) and lack of recoveries from markings in other areas (101 marks, 1 recovery in the same area). There is however some gradual dispersal since the rate of recovery of marks placed on the grounds is high 1 to 4 years after marking (some animals were marked while not recruited to catchable size), but then falls to less than expected considering the age structure of the catch (average delay 2.7 years). The whales marked on the Greenland side of the Irminger Sea (off East Greenland) are recovered at a lower rate (8 out of 73 compared to 25% on the Icelandic grounds) and on average five years after marking (here, the single same season recovery has been included).

The Workshop **agreed** these data provided some interesting insights into the local movements of fin whales at a fine scale in a limited area, but also **agreed** that the scale was too fine and the data were too few to inform hypotheses of stock structure at the ocean basin level.

The Workshop also recalled the detailed discussions of the marking data considered at the Comprehensive Assessment meeting in 1991 (IWC, 1992) and the joint NAMMCO/IWC meeting in 2006 (IWC, 2007a). A summary of the marking data is provided in Annex F. The Workshop **agreed** that the marking data were not informative with respect to numbers of breeding stocks or to distinguishing among the hypotheses considered under Item 2.1.2.

2.1.1.3 CATCH DISTRIBUTIONS

Annex G provides plots by month of the catch data (for which positions are known) for fin whales in the North Atlantic. Whilst recognising the limitations of such data when considering stock structure issues (e.g. see Donovan, 1991), the Workshop **agreed** that the data provided some insights into stock structure.

Discussions particularly focussed on the central region. Given the monthly patterns of catches and the continuous distributions between East Iceland and the Faroes, the Workshop **agreed** that there was little justification in the historic boundary that has been used to divide East Iceland and the Faroes in the past (which had primarily been included because of the different whaling operations off Iceland and the Faroes). The Workshop also **agreed** that the lack of catches immediately south of the centre of Iceland (quite within the range of shore-based whaling vessels) provided a reasonable basis for placement of a boundary there to separate fin whales to the west and to the east of Iceland.

2.1.1.4 DISTRIBUTIONS OF SIGHTINGS

The Workshop also examined the information from the NASS sightings surveys (Pike and Gunnlaugsson, 2006) from 1987, 1989, 1995 and 2001. Whilst again recognising the limitations of such data when considering stock structure issues (e.g. see Donovan, 1991), the Workshop **agreed** that whilst the information was largely uninformative with respect to stock structure, the observed distributions were not incompatible with the hypotheses outlined under Item 2.1.2.

2.1.1.5 RESOURCE DYNAMICS

Past attempts to model the dynamics of fin whales in the East Greenland-Iceland region (e.g. Branch and Butterworth, 2006) have encountered difficulties in reconciling evidence of heavy depletion of fin whales off West Iceland in the early 1900s (based on the CPUE analysis discussed under Item 4.2) with recent large estimates of fin whale numbers in the region from recent sighting surveys (e.g. see Item 4.1). One way to reconcile the available information is by postulating that the fin whales off West Iceland form a separate sub-unit of the 'Central' breeding population, whose recovery after the early 1900s was assisted by mixing gains from further sub-units of the Central population, specifically those associated with feeding areas off East Greenland and East Iceland.

2.1.2 Final choice of plausible hypotheses for inclusion in the trials

The Workshop noted that although the information above relating to stock structure and mixing is better than is typically available, much of the available information is largely uninformative with respect to stock structure and especially the number of breeding stocks (Table 1). For this reason a somewhat broad set of hypotheses has had to be considered. It is also worth re-emphasising that the primary aim of these hypotheses is not to describe the full stock structure of fin whales in the North Atlantic, but rather to develop a broad set of hypotheses consistent with the data that will allow the conservation implications of catches off West Iceland (see Item 3.2) to be adequately explored in the context of *Implementation Simulation Trials*.

Taking into account the information above and discussions at previous IWC meetings and the joint NAMMCO/IWC workshop, a set of one baseline (hypothesis I) and six alternative stock structure hypotheses (hypotheses II to VII) were developed. The baseline hypothesis (and indeed all six alternative hypotheses) distinguished seven feeding areas: Canada; West Greenland; East Greenland; West Iceland; East Iceland and the Faroes; North Norway and West Norway; and Spain (see Fig. 1). Of the four breeding populations (West, Central, East and Spain), the Central population was split into three sub-populations C1, C2 and C3 linked by diffusive mixing to be better able to account for the probable recovery of the C2 sub-population (feeding essentially off West Iceland) through mixing from the C1 (feeding off East Greenland) and C3 (feeding off East Iceland and the Faroes) sub-populations.

Table 1

Available genetic and non-genetic evidence in terms of its ability to discriminate among hypotheses for the number of breeding stocks. Options – compatible (C), incompatible (I), perhaps incompatible and requires further work (I?), provides no information (NI).

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

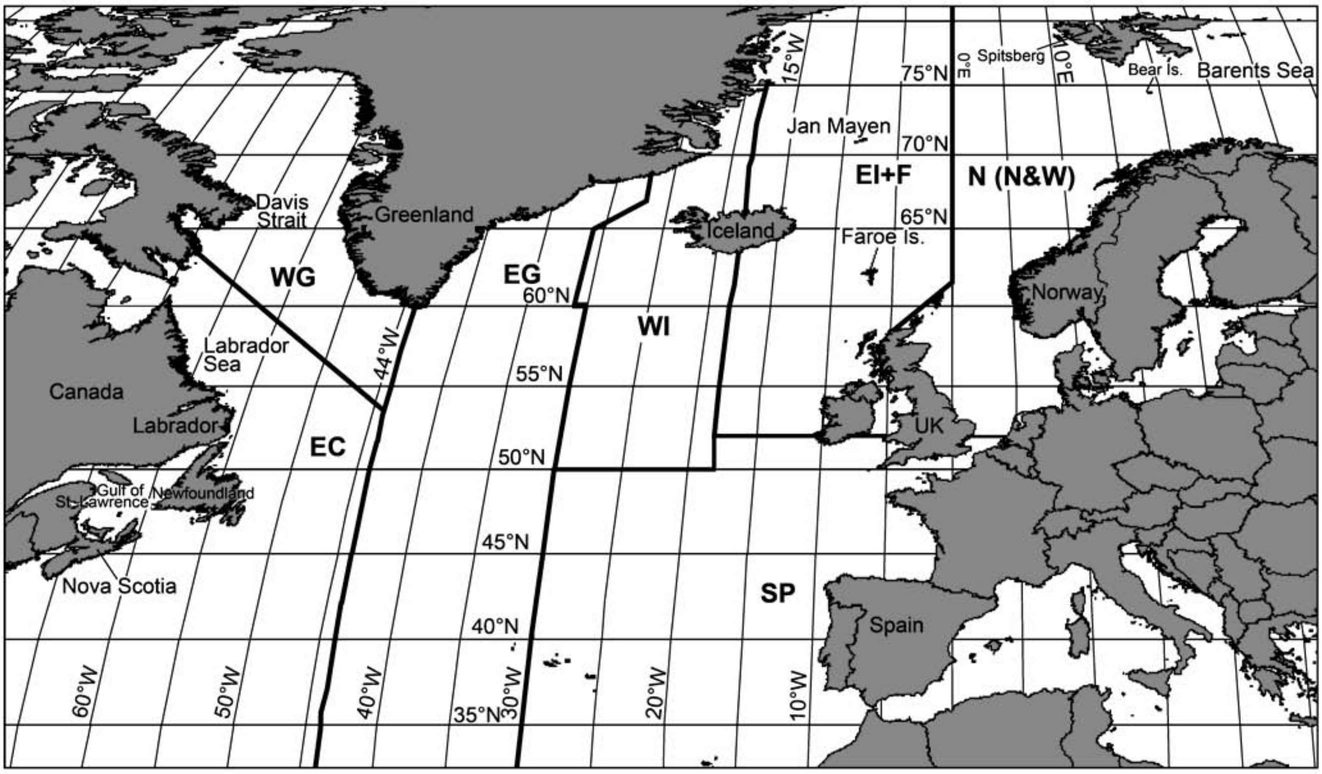

Fig. 1. Map showing the feeding sub-areas (solid lines) used in explaining the hypotheses shown in Fig. 2. EC = eastern Canada plus the eastern USA; WG = West Greenland; East Greenland; WI = West Iceland; EI+F = East Iceland plus Faroe Islands; N = North and West Norway; Sp = Spain.

The alternative hypotheses (see Fig. 2) consider two forms of variation about the baseline hypothesis. First some mixing of breeding stocks on the feeding grounds is introduced, in part to make allowance for uncertainties about boundaries between populations. For example, under hypothesis II, some of the West breeding population feeds in the East Greenland and West Iceland feeding areas, and similarly some of the East breeding population feeds in the West Iceland and East Iceland plus Faroes feeding areas. In contrast, under hypothesis III, the C1 and C3 sub-populations also feed in the Canada and West Greenland and in the North and West Norway feeding areas respectively. In a separate variation on this theme (hypothesis IV), there is no interchange between the C sub-populations, but instead these mix in the two adjoining sub-areas as well as the one to which each primarily moves for feeding. For the last variation of this form, the Spain breeding stock, instead of being entirely separate from the others, feeds also in the North and West Norway and in the East Iceland and Faroes sub-areas (hypothesis V). The final two alternative hypotheses involve simplifying the baseline hypotheses by reducing the number of breeding populations first to three (hypothesis VI which eliminates the East breeding population by combining this with C3), or two (hypothesis VII which eliminates both the East and West breeding populations with the latter combined with C1), where diffusive mixing between three Central sub-populations remain, and these sub-populations feed also in areas off the continental coastlines but not off Spain. For modelling purposes, the C1, C2 and C3 sub-populations will be treated as independent stocks.

Provisional values for the fraction of the stock feeding in different sub-areas were specified and will be tested (tuned) using hypothesis II. The initial values are: for a stock that feeds in three sub-areas, 88% of the stock will go to its ‘home’ feeding area, 10% to the nearest and 2% to the furthermost sub-area (except for the Spain stock in hypothesis V for which values of 94%, 5% and 1%

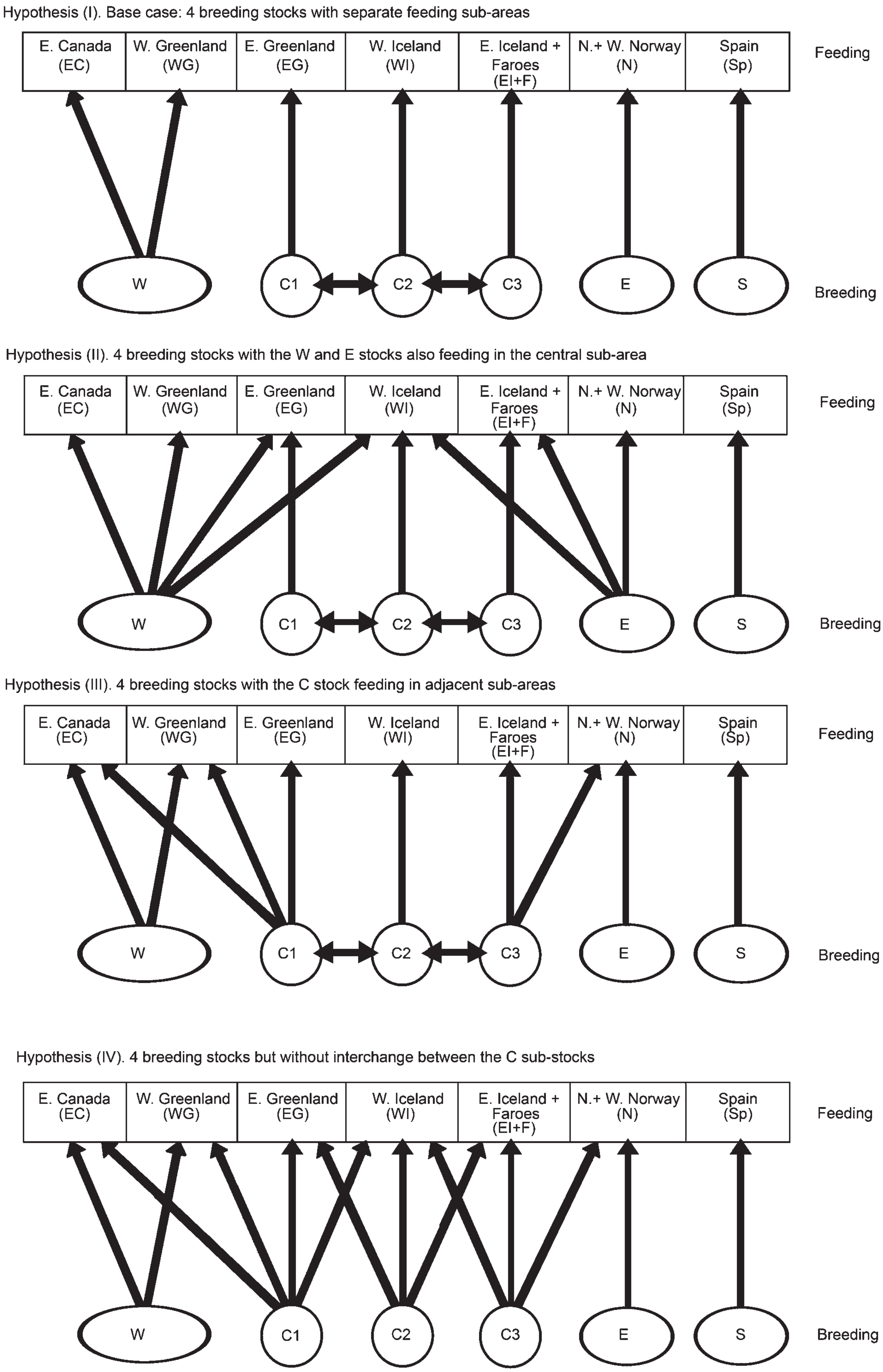

Fig. 2. Stock structure hypotheses for North Atlantic fin whales.

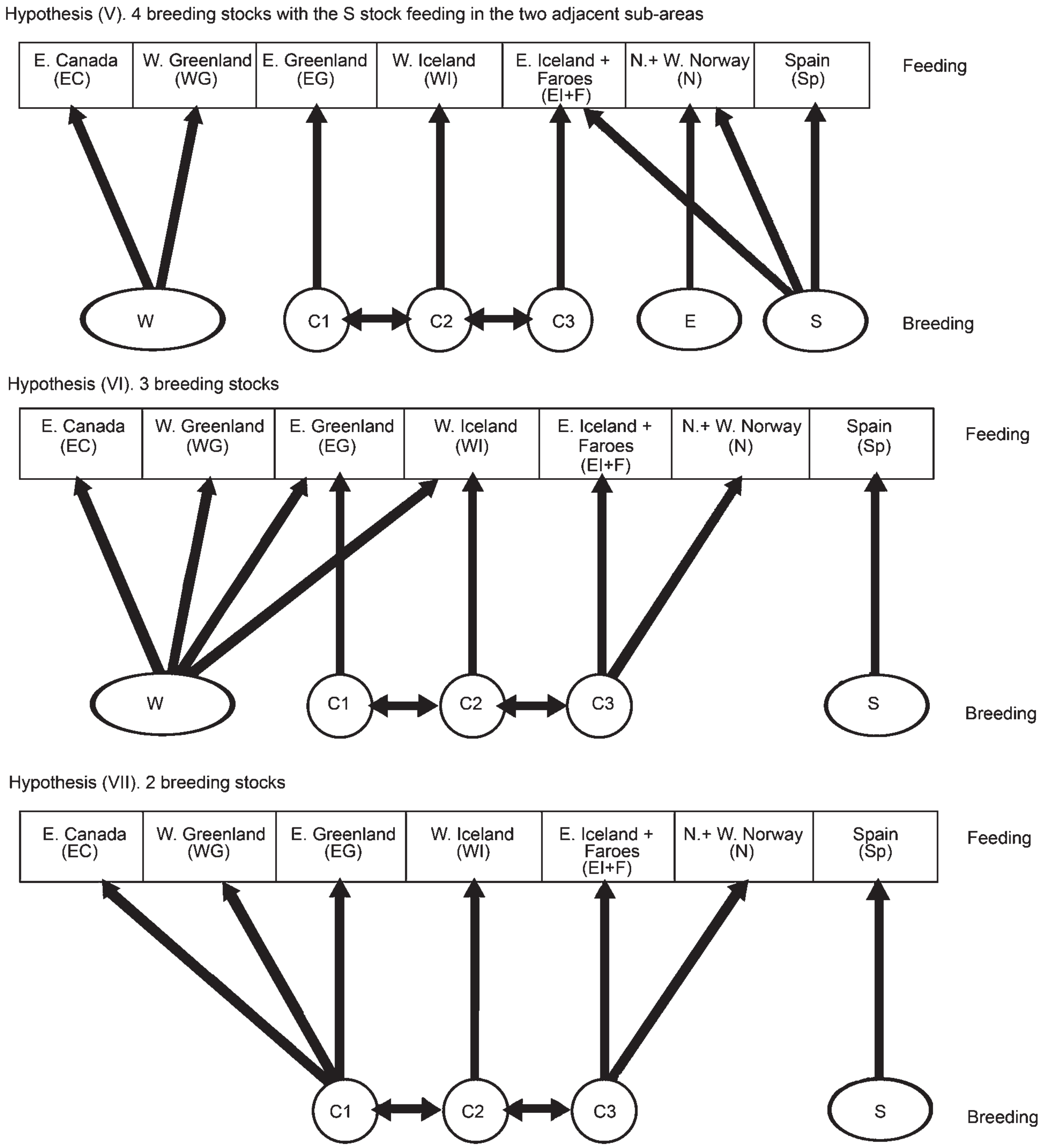

Fig. 2 (cont.) Stock structure hypotheses for North Atlantic fin whales.

respectively will be used); for a stock that feeds in two sub-areas, 90% of the stock will go to its 'home' feeding area and 10% to the other sub-area.

2.2 *g*(0)

The Workshop considered that *g*(0) for shipboard surveys for fin whales should be taken to be 1 for the purposes of trials (although some recent surveys allow for *g*(0) correction). Given the large size and strong blow of fin whales, which taken together with their surfacing rate means that in most instances there are one or more opportunities to sight them on the trackline, it seems unlikely that assuming *g*(0) = 1 introduces substantial negative bias to shipboard sighting survey estimates of abundance; furthermore *g*(0) corrections would result in higher associated CVs. The same is not true for aerial surveys and the estimates should estimate availability and perception bias (components of *g*(0)) to the extent possible (see Item 4.1).

2.3 Maximum sustainable yield rate (MSYR)

The Workshop noted that the Scientific Committee is in the process of reviewing the appropriate range for MSYR values to use in *Implementation Simulation Trials*. It held the view that it was inappropriate to consider changing the values customarily used in the past until that review had been completed. Accordingly the core MSYR values to be used for these trials will be $MSYR_{mat}$ = 1% and 4%. Depending *inter alia* on the results of the initial conditioning, the Workshop agreed that the option of using e.g. 2.5% should be retained.

2.4 Catch series

Allison reported on progress with the catch series. It was agreed that a 'best', 'low' and 'high' series should be developed, as had been the case for the western North Pacific Bryde's whale *Implementation*. Discussions thus focussed on how to (1) account for missing information and (2) develop the alternative catch series to account for uncertainties.

2.4.1 Lost whales

It is known that during the early period (prior to 1915), relatively large numbers of animals were struck-but-lost, and Tønnessen and Johnsen (1982) stated that 'the number that were killed was almost certainly at least 30% greater than the number actually recovered'.

Based on this information, the Workshop **agreed** that for the early period, the 'best' catch series, 30% should be added to the landed totals; values of 20% and 50% should be used for the 'low' and 'high' series respectively.

2.4.2 Unspecified species

Particularly in the early period, a number of whales were not identified to species. The Workshop **agreed** with Allison that the 'best' series should be based on using the species proportions for the nearest group of years by region; for the 'low' series none of the unspecified whales should be considered to be fin whales, whilst for the 'high' series all of the unspecified whales should be assumed to be fin whales.

2.4.3 Unspecified sex

The Workshop also considered how best to allocate sex where this was not known; about half of the total catch was of unknown sex and less than 25% of the catch prior to 1920 had sex information. For the known catches, the sex ratio was 1:1 with little variation by area; hence the Workshop **agreed** that a 1:1 ratio should be assumed where sex was not known.

2.4.4 No positional data

The Workshop noted that for some operations, positional information was lacking. In many cases the position of the land station was known but not the catch position. In a relatively small proportion of cases, there was no information for pelagic operations. The Workshop **agreed** that Allison should use the available information to place catches into the appropriate sub-areas and use her best judgement with respect to the development of 'low' and 'high' series.

2.4.5 Other issues

Allison reported that there were occasional instances of contradictory information about catches in the database. The Workshop **agreed** that the 'best' series should be based on the more plausible information, with the less plausible information being used for the minimum or maximum series, as appropriate.

The resultant catch series per sub-area is given in Annex G, Appendix 1. A summary of the available information is given in Table 2.

3. SPECIFICATION OF *IMPLEMENTATION SIMULATION TRIALS*

3.1 Selection of sub-areas

The baseline hypothesis envisages seven feeding areas, for which boundaries need to be explicitly defined so that the corresponding abundance estimates from past surveys can be calculated (see Item 2.1.2). The general approach taken was to give primary consideration to biological information and reasonable associated inferences; if, following that, possible alternative specifications could not be distinguished, boundaries compatible with past NASS survey strata would be selected to ease the computation of corresponding past survey abundance estimates.

The following boundaries were agreed (as shown in Fig. 1).

(1) *Between East Iceland and Faroes, and North and West Norway*: a line at 0°, which at its southernmost extremity runs roughly southwest through the Shetlands and Orkneys to the UK mainland. This choice was based on consideration of the catch position plots in Annex G; the southernmost feature was introduced for compatibility with past NASS survey strata.
(2) *Between West Iceland and East Iceland*: a line at 18°W, both north and south of Iceland. These choices were based primarily on catch distributions. To the north of Iceland, 18°W was preferred to 22°W because catches to the north of Iceland were considered more likely to be from the same group of animals harvested to the west of Iceland and because these animals were landed there.
(3) *Between East Greenland and West Iceland*: a line running for the most part north-south at 30°W (see Fig. 2). This was chosen to distinguish land station catches made from Iceland from catches made off East Greenland.
(4) *Between West and East Greenland*: a line running south from the southernmost point of Greenland. This reflects the conventional boundary between these two regions.
(5) *Between Spain and East Iceland and Faroes:* a line based on catch distributions and compatibility with past NASS survey strata was set at 52°N.
(6) *Between Spain and West Iceland:* for compatibility with past NASS survey strata the line was set at 50°N.

Table 2

Estimated total catch by sub-area and the percentage known by sex. The catches of unknown area were taken by pelagic operations.

Sub-area	EC		WG		EG		WI		EI+F		N		Sp		Unk		Total
Period:	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	Total	%	
1864-79	0	-	0	-	0	-	0	-	60	0	326	0	0	-	0	-	386
1880-99	219	0	0	-	0	-	2,833	0	207	0	10,433	3	0	-	0	-	13,692
1900-19	6,180	0	0	-	0	-	3,483	4	14,935	46	4,333	2	0	-	22	0	28,952
1920-39	2,889	50	750	68	68	100	1,120	98	5,799	45	4,884	83	6,531	8	918	90	22,959
1940-59	3,913	98	323	100	0	-	2,906	100	1,747	98	4,090	100	1,275	23	0	-	14,254
1960-79	3,960	100	70	0	19	100	4,825	100	60	98	882	100	3,354	79	0	-	13,170
1980-99	0	-	256	8	0	-	1,449	100	13	100	0	-	784	100	0	-	2,502
2000-7	0	-	73	0	0	-	7	100	0	-	0	-	0	-	0	-	80
Total	17,161		1,472		87		16,623		22,820		24,948		11,944		940		95,995

(7) *Between West Greenland and Canada:* a diagonal line as shown in Fig. 1 was established taking into account catches and recent abundance survey boundaries.

The Workshop **agreed** that (1) the continuous catch distributions between East Iceland and the Faroes shown in Annex G, along with (2) the absence of evidence of breaks in the sightings distributions, was sufficient to discard consideration of a sensitivity test splitting this sub-area into two containing different mixtures of breeding populations, on the grounds of biological implausibility.

3.2 Specification of expected future operations

The Workshop was advised that Iceland had requested advice for future catches of fin whales within the West Iceland sub-area; this will be a land station operation. It was considered appropriate to assume that the selectivity patterns would be unchanged from the recent commercial operations. No notifications of intent to undertake commercial whaling elsewhere in the North Atlantic had been received from other countries.

3.3 Future survey plans

Comprehensive surveys of the central North Atlantic have taken place at six-yearly intervals over the past two decades, with the last such survey in 2007. The Workshop was informed that Iceland intended to continue this practice, with the next survey to take place in 2013; Iceland, either itself or in combination with other countries, would ensure that all of the East Greenland, West Iceland and the East Iceland/Faroes sub-areas were covered in such surveys.

The Workshop did not see it necessary to specify a programme of future surveys for sub-areas to the west and east of the three sub-areas above. This is because future catches are desired from the West Iceland sub-area only. Any impact of these catches on the status of the populations feeding in Canada, West Greenland, Norway and Spain is likely to be very small, and so does not of itself render surveys in those sub-areas necessary to monitor the possible effects of such catches. Similarly, if the population feeding in West Iceland is only part of a much larger breeding population that feeds much more widely throughout most of the North Atlantic, catches set on the basis of abundance estimates for the West Iceland sub-area only would be too small to have any appreciable impact at that geographical scale. Sensitivity to different area coverage within sub-areas (e.g. truncating effort in the south) will be investigated. This is discussed under Item 3.4.

3.4 Trials structure

Given the interaction between Items 2-4, a discussion of the final trial structure was considered after completion of discussions under Item 4. The stock structure hypotheses underlying the trials are detailed in Item 2. A number of the remaining items were discussed under Item 4. The factors listed below will be included in the trial structure.

(a) $MSYR_{mat}$. Values of 1% and 4% will be tested; the possibility of using an intermediate value (e.g. 2.5%) will be retained.

(b) *Uncertainty in the estimates of historical catches*. In addition to the best estimates of historical catches (including an estimated lost whale rate of 30%), sensitivity to using a low and a high catch series (with lost whale rates of 20% and 50% respectively) will be considered (see Item 2.4).

(c) *Process error due to boundary mis-specification*. Sensitivity to the position of the northern part of the boundary between the WI and EI/F sub-areas will be investigated by including all catches taken north of Iceland from 14-18°W into the WI area.

(d) *Alternative survey strategy*. Two alternative survey strategies will be investigated in the robustness trials:
  (1) future surveys will cover only the WI sub-area but with greater survey sampling precision (variance = base case value/3) – the additional variance contribution to the estimate observed will remain unchanged;
  (2) future surveys in WI and EI/F will not cover the strata to the south of 60°N – the proportion covered will be estimated from past surveys (using data in Annex H).

(e) *Survey process error* will be estimated from comparisons of the sampling CVs with the variance in the model residuals for the base case runs (1% and 4%).

(f) *Pro-rate abundance data for use in conditioning*. As some historic abundance estimates do not cover the full sub-area, a robustness trial will be included in which the data used in conditioning are pro-rated upwards. (These revised estimates will not be available to the *CLA*). (Øien/Gunnlaugsson to do pro-ratios)

(g) *Inclusion of CPUE data in the likelihood calculation*. In the base case, CPUE data will be used qualitatively to compare with model output rather than being included directly in the likelihood calculation. In addition trials NF31 and NF32 will investigate the effect of including all CPUE series (West Iceland 1962-87, East Iceland 1904-13 (see Annex I) and West Iceland 1902-14 (Gunnlaugsson series 2)) in the likelihood calculation.

(h) *Marking data*. All North Atlantic marking data will be included, excepting data from Canada for 1960 and 1965 (for which the numbers are uncertain). Same season recoveries will be removed from the population, accounting for tag-reporting, but not included in the likelihood function. The mark reporting rate will be assumed to be 1 in all cases (though subject to reconsideration if found necessary in the process of conditioning the trials), and a loss rate of 0 is assumed in the base case. In addition a loss rate of 0.2 in year 1, and 0.1 per year thereafter will be tested.

(i) *Selectivity*. In the base case, a fixed age of recruitment is used (see Annex K). A robustness trial will be included in which there is an annual decrease of 4% in selectivity/year after age 8 (see Item 4.5).

(j) *The split of stocks between different feeding areas*. Provisional values for the fraction of the stock feeding in different sub-areas are specified in Item 2.1.2. Trials to investigate sensitivity to the proportions used will be developed once the base case values have been tested and accepted.

The following factors were also discussed but the Workshop **agreed** that they did not need to be considered in the robustness trials:

(k) *Sex ratio in the catches*. The average sex ratio in the historic catch data (see Item 2.4) was hardly different from 0.5, so the Workshop **agreed** that a fixed sex ratio of 50% should be used for historic catches of unknown sex and for future catches.

(l) *Uncertainty in the natural mortality rate M*. Test trials will be run using the base case with a fixed value of M=0.08yr^{-1}. This value will be adjusted if necessary to ensure that the model output shows the expected behaviour.
(m) *Stochasticity in feeding*. This factor addresses the problem of a mismatch between survey area and model sub-area, and the issue of surveyed whales moving out of the area before catching occurs. The Workshop agreed that this factor would be adequately addressed under items (c) and (d) above.
(n) *Age data*. This data will not be used directly in the trials but rather the model catch age structure will be used for comparison with the observed age data.
(o) *g(0)=1*. All of the trials assume that $g(0)$=1.

The full list of trials is given in Table 3.

The Workshop **agreed** that this trials structure (Annex K) adequately captures the full range of uncertainty for the western North Atlantic fin whales, and **recommends** that a control program that implements these trials be developed and that the trials be conditioned and results reported to the 2008 Annual Meeting.

4. CONDITIONING

The process of specifying *Implementation Simulation Trials* involves identifying 'plausible hypotheses' for the species/Region in question and developing appropriate models to represent these hypotheses. This process therefore differs from identifying the 'best' assessment of a species in a Region. 'Conditioning' the trials on the existing data refers to the process of fitting the alternative models (or 'operating models') to the existing data. The conditioned trials should be able to mimic the available data satisfactorily.

4.1 Abundance estimates and covariances

The *Implementation Simulation Trials* operating model is conditioned on abundance estimates for each sub-area. Therefore, the Workshop reviewed surveys and available

Table 3

The *Implementation Simulation Trials* for North Atlantic fin whales.

Trial No.	No. of stocks	Stock structure hypothesis	$MSYR_{mat}$	Catch series	Boundaries	Future surveys	Mark loss rate	Other	Notes
NF01	4	I	1%	Best	Baseline	EG,WI,EI+F	0	-	Base case: 4 stocks, separate feeding areas
NF02	4	I	4%	Best	Baseline	EG,WI,EI+F	0	-	Base case: 4 stocks, separate feeding areas
NF03	4	II	1%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks; 'W' & 'E' feed in central sub-areas
NF04	4	II	4%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks; 'W' & 'E' feed in central sub-areas
NF05	4	III	1%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks; 'C' feeds in adjacent sub-areas
NF06	4	III	4%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks; 'C' feeds in adjacent sub-areas
NF07	4	IV	1%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks without sub-stock interchange
NF08	4	IV	4%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks without sub-stock interchange
NF09	4	V	1%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks as in I but 'S' in adjacent sub-areas
NF10	4	V	4%	Best	Baseline	EG,WI,EI+F	0	-	4 stocks as in I but 'S' in adjacent sub-areas
NF11	3	VI	1%	Best	Baseline	EG,WI,EI+F	0	-	3 stocks (no 'E' stock)
NF12	3	VI	4%	Best	Baseline	EG,WI,EI+F	0	-	3 stocks (no 'E' stock)
NF13	2	VII	1%	Best	Baseline	EG,WI,EI+F	0	-	2 stocks (no 'W' or 'E' stock)
NF14	2	VII	4%	Best	Baseline	EG,WI,EI+F	0	-	2 stocks (no 'W' or 'E' stock)
NF15	4	I	1%	**High**	Baseline	EG,WI,EI+F	0	-	High historic catch series
NF16	4	I	4%	**High**	Baseline	EG,WI,EI+F	0	-	High historic catch series
NF17	4	III	1%	**High**	Baseline	EG,WI,EI+F	0	-	High historic catch series
NF18	4	III	4%	**High**	Baseline	EG,WI,EI+F	0	-	High historic catch series
NF19	4	I	1%	**Low**	Baseline	EG,WI,EI+F	0	-	Low historic catch series
NF20	4	I	4%	**Low**	Baseline	EG,WI,EI+F	0	-	Low historic catch series
NF21	4	III	1%	**Low**	Baseline	EG,WI,EI+F	0	-	Low historic catch series
NF22	4	III	4%	**Low**	Baseline	EG,WI,EI+F	0	-	Low historic catch series
NF23	4	III	1%	Best	**NI catch from WI**	EG,WI,EI+F	0	-	N Iceland catch inc. in WI sub-area
NF24	4	III	4%	Best	**NI catch from WI**	EG,WI,EI+F	0	-	N Iceland catch inc. in WI sub-area
NF25	4	III	1%	Best	Baseline	**WI**	0	-	Survey WI only with greater precision
NF26	4	III	4%	Best	Baseline	**WI**	0	-	Survey WI only with greater precision
NF27	4	III	1%	Best	Baseline	**N 60ºN**	0	-	WI & EI+F surveys exc. S 60ºN strata
NF28	4	III	4%	Best	Baseline	**N 60ºN**	0	-	WI & EI+F surveys exc. S 60ºN strata
NF29	4	III	1%	Best	Baseline	EG,WI,EI+F	0	**Pro-rate abund.**	Pro-rate abundance data for conditioning
NF30	4	III	4%	Best	Baseline	EG,WI,EI+F	0	**Pro-rate abund.**	Pro-rate abundance data for conditioning
NF31	4	III	1%	Best	Baseline	EG,WI,EI+F	0	**Fit to CPUE**	Inc. CPUE data in the likelihood calculation
NF32	4	III	4%	Best	Baseline	EG,WI,EI+F	0	**Fit to CPUE**	Inc. CPUE data in the likelihood calculation
NF33	4	I	1%	Best	Baseline	EG,WI,EI+F	**0.2 → 0.1**	-	Mark loss =20% in yr 1; 10%/yr thereafter
NF34	4	I	4%	Best	Baseline	EG,WI,EI+F	**0.2 → 0.1**	-	Mark loss =20% in yr 1; 10%/yr thereafter
NF35	4	III	1%	Best	Baseline	EG,WI,EI+F	**0.2 → 0.1**	-	Mark loss =20% in yr 1; 10%/yr thereafter
NF36	4	III	4%	Best	Baseline	EG,WI,EI+F	**0.2 → 0.1**	-	Mark loss =20% in yr 1; 10%/yr thereafter
NF37	4	IV	1%	Best	Baseline	EG,WI,EI+F	**0.2 → 0.1**	-	Mark loss =20% in yr 1; 10%/yr thereafter
NF38	4	IV	4%	Best	Baseline	EG,WI,EI+F	**0.2 → 0.1**	-	Mark loss =20% in yr 1; 10%/yr thereafter
NF39	4	I	1%	Best	Baseline	EG,WI,EI+F	0	**Selectivity decr**	Selectivity decreases by 4%/yr after age 8
NF40	4	I	4%	Best	Baseline	EG,WI,EI+F	0	**Selectivity decr**	Selectivity decreases by 4%/yr after age 8

abundance estimates within each sub-area to calculate abundances to be used in the conditioning process. The results of this review are summarised in Table 2 and in Annex H, where abundance by year for each sub-area is summarised. A complete description of the source of the abundance estimates and how they were combined within sub-areas is also given in Annex H. In common with the practice used in developing previous *Implementation Simulation Trials,* totals for each sub-area were created only in years where it was agreed (on a necessarily somewhat arbitrary basis) that the survey coverage was somewhat complete and similar across years. Details about surveys used where coverage in some years was less than ideal are noted in Annex H.

In 2007, a TNASS aerial survey was conducted in Canadian waters and preliminary estimates from this survey were combined with an estimate from a survey in US waters in 2006 to calculate abundance for the Canada/US sub-area; estimates are available for earlier years in US waters but not for Canada. Abundance estimates are available for three years (1987/88, 2005, and 2007) in West Greenland. For the central three sub-areas (East Greenland, West Iceland, East Iceland and Faroes), estimates of abundance were available from NASS surveys conducted in 1987, 1989, 1995, and 2001 (Pike and Gunnlaugsson, 2006). Calculations of total abundance within these sub-areas here (combining estimates for individual survey blocks) differ in some cases from similar calculations made during the joint NAMMCO/IWC Workshop (IWC, 2007a); this is in part due to decisions such as to average abundance in one survey block from the 1987 and 1989 surveys, rather than to use the 1989 estimate only (see details in Annex H). In the years 1987 and 1995, the abundance in the East Iceland and Faroes sub-area also includes estimates from Norwegian surveys for survey blocks west of 0°. For the Norway sub-area, estimates are available for 1995 and 1996-2001 (assigned to year 1999) from Norwegian surveys, using the total abundance from all survey blocks east of 0°. For the Spain sub-area (that includes Portuguese and French waters), a single abundance estimate is available from the 1989 NASS Spanish survey (Buckland *et al*., 1992). The Workshop **agreed** that Donovan would forward any new abundance estimates from the forthcoming TNASS Workshop to Allison and that these, with appropriate annotations, would be added to Annex H.

The Workshop **agreed** that further work could be done to improve some of these estimates or add additional estimates. These include:

(1) Revise calculations of the 1988 survey data for the Norway sub-area to make an abundance estimate available for that time period; a request for this had been made to Øien (see IWC, 2007a).
(2) Prorate abundance in NASS block WN-SPB in 1995 and 2001 for East Iceland and Faroes sub-area because of incomplete coverage of the southern portion of the block (this could be done by simple area proration or by encounter rate ratios between subdivisions of the block).
(3) Prorate abundance in NASS block A-West in 1995 because of incomplete coverage in the southern portion of the block.
(4) Revise abundance in 1987 NASS block WN-SPB to remove portion of block that occurred to the east of Faroe Islands in Norway sub-area (east of 0°).

4.2 Catch-per-unit-effort (CPUE) data

A number of CPUE indices have been developed for fin whale fisheries in the North Atlantic, ranging from crude measures using simple indices such as catch per boat day to more complex indices that use time budget data to develop measures such as catch per unit of time spent searching. As noted at the IWC workshop on the use of CPUE data (IWC, 1988), quantitative use of CPUE data (as an index of abundance) in assessments ideally requires *inter alia* considerable knowledge of the operations and accurate time budget data; such information is rarely available. For example, at the Comprehensive Assessment meeting on the North Atlantic fin whales in 1991 (IWC, 1992), despite considerable work to refine the modern (1962-87) Icelandic CPUE series based on searching time (e.g. Sigurjónsson *et al*., 1991b), there had been no general agreement as to whether the data were suitable for use in assessments.

There are three potential levels of incorporation of CPUE data into the *Implementation* process:

(a) quantitative use in estimating MSYR in the conditioning process;
(b) quantitative use as an index of trend with fixed MSYR values in the conditioning process;
(c) qualitative use as a coarse check on the output of the operating model in the conditioning process.

The Workshop discussed the available information in the context of these three levels, initially focussing on level (c).

4.2.1 Early CPUE data: Iceland (east and west); Faroes, Norway, Ireland, Scotland

There had been considerable discussion of these early CPUE data at the joint NAMMCO/IWC Workshop (IWC, 2007a). Inevitably perhaps, for such an early dataset, there are considerable gaps in the data, even for relatively simple CPUE analyses, let alone in the context of the Scientific Committee’s general views on the use of CPUE data (IWC, 1988).

4.2.1.1 ICELAND

The particular difficulties identified include:

(1) issues surrounding the multispecies nature of the fishery;
(2) no data for some vessels;
(3) lack of operational details.

The comments and recommendations made at the joint NAMMCO/IWC workshop had been incorporated to the extent possible for the East and West Iceland series in a revised paper (Sigurjónsson and Gunnlaugsson, 2006) considered at the 2006 Annual Meeting. The Workshop examined these in some detail, focussing first on the series for East Iceland for which a much greater proportion of the individual records were accessible and were also available to the Workshop in encoded form. Although Sigurjónsson and Gunnlaugsson (2006) had corrected for month effects to some extent, the Workshop decided to apply a GLM-standardisation approach to the encoded data to quantitatively examine the possible effects of month, vessel, and targeting of blue and humpback whales on the fin whales per boat month series. These analyses were carried out for the period from 1904 to 1913 during which fin whales constituted the dominant proportion of the catch and effort had been quite widely distributed, as reported in Annex I. The standardised indices, whether or not corrections for targeting on other species were included, did not differ substantially from the catch per boat month series advocated by Sigurjónsson and Gunnlaugsson (2006). Comparison with the coarser catch per boat season, which does however take the complete catch data into account (see table 4 of Sigurjónsson and Gunnlaugsson (2006)), showed that the catch per boat season index reflected about double the level of variability, and hence provided less precise estimates of trend.

The lesser quantity and fewer years for which individual records are available precluded a similar standardisation analysis of the early CPUE series for West Iceland. Thus only the catch per boat season series from table 4 of Sigurjónsson and Gunnlaugsson (2006) are available for this sub-area. Given these differences between the West and East, the Workshop agreed that, at a qualitative level, comparatively less reliance could be placed on trend inferences for West Iceland.

The Workshop **agreed** that for baseline trials, these data would not be used for conditioning, but rather for a qualitative check of the output from the conditioning model. They are however used for conditioning in certain robustness trials (see Item 3.4).

4.2.1.2 OTHER REGIONS OF THE NORTH ATLANTIC

The Workshop noted the difficulties associated with the early CPUE (catch per boat month) data from other regions in the North Atlantic (Bloch and Allison, 2006) as discussed at the joint NAMMCO/IWC Workshop (IWC, 2007a). The authors had actually provided data up to the early 1980s but the series was not complete. The data here are even more problematic than for the early Iceland series; no revised paper addressing the comments of the joint workshop was available and the data were not available in an encoded form. The Workshop **agreed** that, given these difficulties, it would not consider these CPUE data during the *Implementation* process. It noted that should further analysis occur that overcame the identified difficulties, such information might be used in a future *Implementation Review*.

4.2.2 Icelandic later period CPUE

As noted above, considerably more information is available for the post-1962 Icelandic fishery. An assessment model (Branch and Butterworth, 2006) considered at the joint NAMMCO/IWC workshop had used CPUE series (Sigurjónsson *et al*., 1991b) for the modern period from 1962 to 1987. This information was treated as providing separate abundance indices for fin whales in the West Iceland sub-area for each of the four vessels concerned. However, when incorporated in the likelihood when fitting the population model, co-variances between these four series were taken into account, where these covariances were estimated from consideration of the residuals about quadratically detrended log-transformed indices for each vessel (Butterworth and Punt, 1992).

The Workshop **agreed** that in the light of the lack of general agreement at the Comprehensive Assessment meeting on the North Atlantic fin whales in 1991 (IWC, 1992) regarding the suitability of these data for assessment purposes, they would not be used for conditioning the baseline trials, but rather for a qualitative check of the output from the conditioning models for these trials. They are however used for conditioning in certain robustness trials (see Item 3.4).

4.3 Mark-recapture data

As noted under Item 2.1.1.2, considerable attention has been paid to the marking data at both the Comprehensive Assessment meeting and the joint NAMMCO/IWC workshop (IWC, 1992; 2007a). The full North Atlantic mark recapture data are reviewed in Sigurjónsson *et al*. (1991a) and the Iceland only data have been discussed in SC/M08/RMP2. The available data are summarised in Annex F.

The Workshop **agreed** that for the purposes of the trials all of the marking data (with the exception of the early Canadian years) would be used except where incompatible with any hypothesis. The Workshop also **agreed** that the available (although limited) evidence (Gunnlaugsson and Sigurjónsson, 1989) suggested that, for the purposes of the trials it was appropriate to assume: (1) a reporting rate of 1 (subject to reconsideration if found necessary during the process of conditioning the trials); and (2) a tag loss rate of 0. A robustness trial using a tag loss rate of 0.2 in the first year and 0.1 for subsequent years will be undertaken.

4.4 Age data

Vikingsson and Gunnlaugsson (2006) reports that 1,290 male and 1,443 female fin whales have been aged from catches made since 1967. The ageing was initially sporadic, but the sampling for the period from 1976 covered almost all of the catch.

The Workshop decided not to attempt to use these data in conditioning models to attempt to deduce annual variations in year-class strength, as such information was seen as unlikely to impact trial outputs to any major extent. Instead these data were to be used to estimate selectivities for the commercial catch, and for qualitative comparison with operating model outputs as a diagnostic.

Annex J details calculations undertaken towards this end, and based on data from 1976 to the end of commercial whaling so as to avoid possible confounding by a change in operating pattern for whaling under scientific permit. These indicate a total mortality Z for age 8 and above of 0.12yr^{-1} for females, and 0.11 for males, and ages at 50% recruitment of 3.6yr for males and 4.1 for females.

4.5 Biological parameters

The Workshop noted that Lockyer and Sigurjónsson (1991) report transition-phase-based estimates of mean age-at-maturity from samples of females taken off West Iceland which vary from 6 to 10 years over the period from 1967 to 1989, when the population in this area was probably not highly depleted. It also noted that for an average pregnancy rate of 0.5 (a calf every two years), and age at first parturition above six years, adult natural mortality M needs to be below 0.08yR^{-1} to give maximum steady growth rates compatible with the higher of the two values of MSYR_{mat} (1 and 4%) customarily used for *Implementation Simulation Trials*. If selectivity is monotonic increasing to a constant level as age increases, as conventionally assumed for baseline *Implementation Simulation Trials*, the values for total mortality Z reported in Item 4.4, coupled to fishing mortality rates over the period analysed in Annex J, which seem unlikely to have exceeded about 3%, suggest that M can hardly be less than 0.08 .

Density dependence in the population models used for conditioning is introduced implicitly, rather than through explicit changes in biological parameter values, but it is nevertheless important that biological parameter values selected for trials remain consistent with choices for MSYR_{mat}. Taking the information in the previous paragraph into account the Workshop decided to set the age at first parturition as T=6 yrs for all trials. It also decided to initially set M=0.08 for all trials, with this value to perhaps be adjusted (possibly in a trial-specific manner) in the light of comparisons with model predictions for the catch curve slopes reported in Annex J.

However, to allow for the possibility of dome-shaped selectivity, and noting that the Comprehensive Assessment meeting (IWC, 1992) used a value of *M*=0.04, the Workshop **agreed** that robustness tests would be run for a value of 0.04 and a selectivity that decreases by 4% per year for ages above 8 (see Table 3).

5. SPECIFICATION OF MANAGEMENT OPTIONS

5.1 Potential *Small Areas* definitions

The management variants will be based on three *Small Area* definitions:

(a) West Iceland
(b) West Iceland + East Greenland
(c) West Iceland + East Greenland + East Iceland-Faroes

All of the future catches will be assumed to be taken from the West Iceland sub-area, given advice to the Workshop regarding the whaling operation planned.

5.2 Potential management options

The management variants to be considered in trials will be:

(1) Catch limits set by *Small Areas* (although as noted above the entire catch will be taken from West Iceland sub-area).
(2) Catch cascading over the following two groups of sub-areas: (1) West Iceland+East Greenland, and (2) West Iceland+East Greenland+East Iceland-Faroes. The catch limits for the East Greenland and East Iceland-Faroes *Small Areas* will be ignored and only the catch limit for West Iceland will be removed from the modelled breeding populations.
(3) Catch limits set for the West Iceland *Small Area* based on the survey estimates for the area of the West Iceland sub-area north of 60°N.

6. PERFORMANCE STATISTICS AND PRESENTATION OF RESULTS

The Workshop **agreed** that the approach followed during the Bryde's whale *Implementation* was generally appropriate for the present *Implementation*. However, there were a number of features of the present *Implementation* that required further consideration, particularly with respect to the conditioning plots. It was **agreed** that these would be dealt with by the intersessional group established under Item 8.2, in the light of experience gained during the conditioning process itself.

7. CONSIDERATION OF WAYS TO DISTINGUISH AMONG COMPETING STOCK HYPOTHESES

As noted under Item 2, the genetic data are somewhat difficult to interpret. The low levels of genetic divergence among geographic fin whale samples may be interpreted in two different ways: (i) that the degree of gene flow between sampling partitions is high, or (ii) that the rate of gene flow in fact is low, and that the low degree of genetic divergence is due to a recent divergence of current North Atlantic fin whale populations. The Workshop therefore **recommended** that the spatial distribution of dyads of close relatives (identified by the degree of genetic similarity at microsatellite loci) be applied to all available fin whale samples from the North Atlantic. This should be able to resolve whether hypothesis (i) or (ii) above is correct.

In addition, divergent selection has been invoked as an explanation for the discrepancy between the DNA- and allozyme-based results (and the implications for the number of breeding stocks). In order to address this, the Workshop **recommended** that data analyses aimed specifically at detecting signatures of selection are undertaken (e.g. by analysis of those DNA sequences encoding for the allozymes at which high levels of genetic divergence was detected).

8. WORK REQUIRED PRIOR TO THE 2008 ANNUAL MEETING

8.1 Schedule

Prior to the 2008 Annual Meeting (the 'First Annual Meeting'):

(1) the catch series as agreed in Item 2.4 should be finalised (Allison);
(2) the *Implementation Simulation Trials* in Annex K should be coded and conditioned (Allison and Rademeyer);
(3) revised abundance estimates in the Norway sub-area and their CVs should be calculated as detailed in Annex H (Øien); and
(4) pro-rated abundance estimates for use in conditioning robustness trials NF29 and 30 (see Item 3.4) should be calculated (Øien and Gunnlaugsson).

The main tasks for the 'First Annual Meeting' are to review the results of the conditioning runs and finalise the *Implementation Simulation Trials*. Plausibility ranks will also be assigned to each simulation trial during the 'First Annual Meeting'.

8.2 Terms of Reference for the intersessional group to facilitate the conduct of this work

The Workshop **agreed** that it was important to establish an intersessional group to review progress with the conditioning process and to provide advice as necessary. It **agreed** that the most appropriate group would be the Workshop participants themselves. The group will work by email and, if necessary, by conference call.

9. ADOPTION OF REPORT

At the close of the meeting, the Chair thanked the staff of the Greenland Representation for their courtesy and assistance, especially Susanne Nøddesbo. He also thanked the rapporteurs and the participants for their co-operation and assistance.

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Sigurjónsson, J., Mitchell, E. and Gunnlaugsson, T. 1991a. Fin whale markings in the North Atlantic with special reference to the stock identity question. Paper SC/F91/F20 presented to the Comprehensive Assessment Special Meeting on North Atlantic Fin Whales, February 1991 (unpublished). 17pp. [Paper available from the Office of this Journal].

Sigurjónsson, J., Víkingsson, G., Gunnlaugsson, T. and Árnason, A. 1991b. Summary report on Icelandic investigations on North Atlantic fin whales prepared for the Scientific Committee's Special Meeting. Paper SC/F91/F21 presented to the IWC Scientific Committee Special Meeting on North Atlantic Fin Whales, February 1991 (unpublished). 11pp. [Paper available from the Office of this Journal].

Skaug, H. and Daníelsdóttir, A.K. 2006. Relatedness of North Atlantic fin whales. Paper SC/58/PFI9 presented to the IWC Scientific Committee, May 2006, St. Kitts and Nevis, West Indies (unpublished). 8pp. [Paper available from the Office of this Journal].

Tønnessen, J.N. and Johnsen, A.O. 1982. *The History of Modern Whaling*. C. Hurst & Co., London. i-xx+798pp.

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Annex A

List of Participants

ICELAND
Th. Gunnlaugsson
G. Víkingsson

NORWAY
H. Skaug

USA
P. Wade

INVITED PARTICIPANTS
D.S. Butterworth
A. Daníelsdóttir
P. Palsbøll
A.E. Punt
R.A. Rademeyer

IWC
C. Allison
G.P. Donovan

Annex B1

Agenda

1. Introductory items
   - 1.1 Convenor's opening remarks
   - 1.2 Election of Chair and appointment of rapporteurs
   - 1.3 Adoption of Agenda
   - 1.4 Review of documents

2. Hypotheses for inclusion in trials
   - 2.1 Stock structure and mixing
     - 2.1.1 Review of hypotheses considered at the *pre-Implementation assessment*
     - 2.1.2 Review of new information
     - 2.1.3 Final choice of plausible hypotheses for inclusion in the trials
   - 2.2 *g*(0)
   - 2.3 Maximum sustainable yield rate (MSYR)
   - 2.4 Catch series

3. Specification of *Implementation Simulation Trials*
   - 3.1 Selection of sub-areas
   - 3.2 Specification of expected future operations
   - 3.3 Future survey plans
   - 3.4 Trials structure

4. Conditioning
   - 4.1 Abundance estimates and covariances
   - 4.2 CPUE
   - 4.3 Mark-recapture data
   - 4.4 Age data
   - 4.5 Biological parameters

5. Specification of management options
   - 5.1 Potential *Small Areas* definitions
   - 5.2 Potential management options

6. Performance statistics and presentation of results

7. Consideration of ways to distinguish among competing stock hypotheses

8. Work required prior to the 2008 Annual Meeting
   - 8.1 Schedule
   - 8.2 Terms of Reference for the intersessional group to facilitate the conduct of this work

9. Adoption of Report

Annex B2

Extract from 'Requirements and Guidelines for *Implementations*'

The following is an extract from 'Requirements and Guidelines for *Implementations*' (IWC, 2005).

2. First intersessional Workshop

The primary objective of the first intersessional Workshop is to develop an appropriate *Implementation Simulation Trials* structure and to specify the associated conditioning so that it can be carried out before the following Annual Meeting. The aim of such trials[1] is to encompass the range of plausible scenarios involving *inter alia* stock structure, MSY rates (MSYR), removals and surveys. These trials are used to investigate the implications of various choices of RMP variants such as *Catch-cascading* from a risk- and catch-related perspective, with a view to recommending an appropriate variant for implementation of the RMP for a specific species/area.

Workshop discussions will include the items listed below.

(1) A final review of the plausible hypotheses arising from the *pre-Implementation assessment* (and, if appropriate, elimination of any hypotheses that are inconsistent with the data) – this will take into account the probable management implications of such hypotheses to try to avoid unnecessary work in the precise specifications of hypotheses for which these are very similar.

(2) An examination of more detailed information in expected operations, including whether coastal, pelagic, on migration, on feeding, on breeding or combinations of these. When providing such information, users and scientists may provide options or suggest modifications to the pattern of operations.

(3) The determination of the small geographical areas ('sub-areas') that will be used in specifying the stock structure hypotheses and operational pattern.

(4) The development of (options for) potential *Small Areas*[2] and management variants.

(5) The specification of the data and methods for conditioning the trials that will be carried out before the next annual meeting (an e-mail correspondence group will be established to make revisions should any problems arise).

(6) Further consideration of experimental ways to distinguish amongst competing stock hypotheses.

[1] A trial is the combination of a set of 'hypotheses' (e.g. about stock structure, MSYR).

[2] *Small Areas* cannot be smaller than sub-areas.

It is **important** to note that after this stage:

(1) there shall be no changes to the agreed trials structure that implements the agreed plausible hypotheses;
(2) no new data will be considered, although new analyses of existing data may be presented to the First Annual Meeting (see below).

REFERENCE

International Whaling Commission. 2005. Report of the Scientific Committee. Annex D. Report of the Sub-Committee on the Revised Management Procedure. Appendix 2. Requirements and Guidelines for *Implementation*. *J. Cetacean Res. Manage. (Suppl.)* 7:84-92.

Annex C
List of Documents

SC/M08/RMP

1. PAMPOULIE, C., DANÍELSDÓTTIR, A.K., BÉRUBÉ, M., PALSBØLL, P.J., ÁRNASON, A., GUNNLAUGSSON, Th., ÓLAFSDÓTTIR, D., ØIEN, N., WITTING, L. and VÍKINGSSON, G.A. Lack of genetic divergence among samples of the North Atlantic fin whale collected at feeding grounds: congruence among microsatellite loci and mtDNA in the new Icelandic dataset. [This is also SC/60/PFI11 and published as Annex E to this report]
2. GUNNLAUGSSON, Th. and VÍKINGSSON, G.A. Update on fin whale (*Balaenoptera physalus*) markings in Icelandic waters. [This is also SC/60/PFI13]

Annex D
Relatedness of North Atlantic Fin Whales: An Update

Hans Skaug, Christophe Pampoulie, Anna Daníelsdóttir and Gísli Víkingsson

DNA-profiles (15 microsatellite loci) from 469 North Atlantic fin whales were used to detect close relatives (Table 1). This is an extention of a previous study involving 226 animals (Skaug and Daníelsdóttir, 2006).

REFERENCE

Skaug, H. and Daníelsdóttir, A.K. 2006. Relatedness of North Atlantic fin whales. Paper SC/58/PFI9 presented to the IWC Scientific Committee, May 2006, St. Kitts and Nevis, West Indies (unpublished). 8pp. [Paper available from the Office of this Journal].

Table 1

List of dyads most likely to be related, ordered according to descending LOD score (Skaug and Daníelsdóttir, 2006). The list of dyads has a false discovery rate of 10%, i.e. the list contains in expectation 2.3 dyads that are not truly related. Dyads detected in Skaug and Daníelsdóttir (2006) are marked by a '*'. K_2 is the number of loci at which the individuals match for both alleles (used as a measure for detecting the presence of duplicate individuals in dataset).

Pair	ID 1	ID 2	K_2
1	IC-85-B8-29	IC-85-B8-06	4
2*	IC-89-B0-57	IC-89-B0-14	4
3	IC-89-B0-47	IC-83-B8-13	2
4	NOR-00-07-23-06-32	GRE-04-09-12-07	12
5	IC-87-B8-38	IC-85-B9-44	4
6	IC-89-B0-04	IC-85-B8-01	2
7	IC-89-B0-36	IC-85-B6-36	10
8*	NOR-02-07-19-15-32	NOR-02-07-19-14-32	2
9*	NOR-03-08-05-14-32	NOR-00-07-23-10-32	0
10	IC-89-B0-19	IC-83-B8-78	5
11	IC-85-B8-30	IC-83-B9-42	3
12*	NOR-02-07-03-02-32	NOR-02-07-03-01-32	3
13	IC-87-B9-31	IC-85-B6-53	0
14	IC-85-B9-18	IC-83-B9-04	3
15	IC-85-B8-33	IC-83-B9-41	3
16	IC-85-B8-22	IC-83-B6-22	2
17	IC-85-B6-18	IC-83-B9-21	5
18	IC-87-B8-36	IC-83-B8-12	5
19*	NOR-00-07-23-10-32	IC-89-B0-20	6
20	IC-85-B6-13	IC-85-B6-12	7
21	IC-87-B9-38	IC-83-B8-12	3
22	IC-89-B0-29b	IC-85-B8-20	2
23	IC-85-B8-19	IC-83-B8-03	5

Annex E

Genetic Divergence Among Samples Collected at Feeding Grounds: Congruence among Microsatellite Loci and mtDNA in the new Icelandic Dataset

C. Pampoulie, A.K. Daníelsdóttir, M. Bérubé, P.J. Palsbøll, A. Árnason, Th. Gunnlaugsson, D. Ólafsdóttir, N. Øien, L. Witting and G.A. Víkingsson

INTRODUCTION

This Annex is presented in response to discussions on the Bonferroni correction of pair-wise comparisons made on the data presented in SC/M08/RMP1 (appendix 1 and table 6).

For an examination of population structure across linear spatial arrangements, it is not necessary to evaluate all pairwise comparisons. In particular, if the information is being used to examine whether adjacent feeding areas should be pooled or not, the pair-wise comparisons, and associated Bonferroni correction, should be restricted to just the pair-wise comparison of adjacent feeding areas. In the context of North Atlantic fin whales, this would mean the following comparisons:

Canada-Greenland; Greenland-Iceland; Iceland-Norway; Iceland-Spain; Norway-Spain

That would result in five pair-wise comparisons, with a Bonferroni correction based on that for both the microsatellite and mtDNA datasets and pooling the Icelandic sample years. Given the spatial arrangement, a Spain-Iceland comparison is included as the distances from Spain to Iceland and Spain to Norway are similar.

RESULTS

The microsatellite loci and then the mtDNA F_{ST} analysis

The recalculation of pairwise F_{ST} of the microsatellite and mtDNA data did not change the main results. The degree of genetic divergence between the Canadian and the other samples remains similar. The homogeneity test resulted in significant P value for the Canadian and Icelandic samples based on microsatellites. Bonferroni corrections are applied to the microsatellite results but not to the mtDNA results.

Table 1

Microsatellite loci differentiation based on five samples. Population pairwise F_{ST} s: above diagonal, F_{ST} P values; below diagonal, computed conventional F-Statistics from allele frequencies. P-values obtained after 10,000 permutations. Indicative adjusted nominal level (5%) for multiple comparisons is 0.005 (**).

	Canada	Spain	Greenland	Iceland	Norway
Canada	0	0.061	0.069	0.001**	0.006
Spain	0.017	0	0.351	0.306	0.118
Greenland	0.020	0.000	0	0.430	0.721
Iceland	0.018	0.001	0.0001	0	0.079
Norway	0.020	0.002	-0.006	0.003	0

Table 2

mtDNA test based on five samples. Population pairwise F_{ST}s: above diagonal, F_{ST} P values; below diagonal, computed conventional F-Statistics from haplotype frequencies.

	Norway	Canada	Greenland	Spain	Iceland
Norway	0	0.056	0.571	0.091	0.155
Canada	0.027	0	0.184	0.026	0.187
Greenland	-0.005	0.020	0	0.196	0.580
Spain	0.014	0.055	0.011	0	0.056
Iceland	0.004	0.010	-0.005	0.009	0

Table 3

Population average pairwise differences: above diagonal, corrected average pairwise difference (PiXY-(PiX+PiY)/2); below diagonal: P values.

	Norway	Canada	Greenland	Spain	Iceland
Norway	0	0.026	-0.005	0.012	0.004
Canada	0.060	0	0.019	0.045	0.008
Greenland	0.552	0.186	0	0.007	-0.005
Spain	0.089	0.041	0.222	0	0.010
Iceland	0.166	0.207	0.593	0.044	0

Annex F

A Summary of the Available Marking Data

Table 1

Summary of information on the number of marks placed (recorded as 'hits') since 1960 by feeding sub-area as shown in Fig. 1. Of the 674 marks placed, positional data are available for 403 (≈ 60%). Most of the missing positions are known to be from the Canadian sub-area. Note that in 1950, 8 fin whales were marked about 50 n.miles off present-day Cotes d'Ivoire (between 4°10'-4°15'N and 5°16'-6°00'W and 1 off the coast of southern present-day Senegal (12°41', 17°45'W) but no marks were recaptured. Also in 1969, 2 fin whales were marked in the Mediterranean.

Year	Canada	West Greenland	East Greenland	West Iceland	East Iceland/Faroes	Norway	Spain	Total
1960	1[1]	0	0	0	0	0	0	1
1961	0	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0
1965	2[2]	0	0	13	0	0	0	15
1966	78	0	0	0	0	0	0	78
1967	53	5	8	0	0	0	0	66
1968	2[3]	0	15	2	0	0	0	19
1969	45	0	0	0	0	0	0	45
1970	3	0	3	1	0	0	0	7
1971	19	0	2	0	0	0	0	21
1972	59	0	0	3	0	0	0	62
1973	12	3	3	0	0	0	0	18
1974	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0
1976	2	0	0	0	0	0	0	2
1977	0	0	0	0	0	0	0	0
1978	0	0	0	0	0	24	0	24
1979	27	3	0	33[3]	0	0	0	63
1980	0	8	0	11	0	0	0	19
1981	0	4	26	62	0	0	3	95
1982	0	0	0	52	14	0	2	68
1983	0	0	5	10	0	0	17	32
1984	0	0	31	0	7	0	0	38
1985	0	0	0	0	0	0	0	0
1986	0	1	0	0	0	0	0	1
Total	303	24	93	187	21	24	22	674

[1]Species given as 'probably fin'. [2]D. Sergeant reports 2 fin marked + 1 possible hit; Mitchell (1977)* lists 3 fin. [3]Includes a fin whale marked between Nov. 1968 - Jan. 1969. *Mitchell, E. 1977. Canadian progress report on whale research – June 1975 to May 1976. *Rep. Int. Whal. Commn.* 27:73-85.

Table 2

Mark-recoveries (including same-season recoveries) by feeding sub-area. Double marks excluded from the totals (there were 3 in West Iceland, 2 in Canada and 1 in East Greenland).

	Canada	West Greenland	East Greenland	West Iceland	East Iceland/ Faroes	Norway	Spain
Canada	39	0	0	1	0	0	0
West Greenland	0	0	0	0	0	0	0
East Greenland	0	0	0	7	0	0	0
West Iceland	0	0	0	50	0	0	0
East Iceland/Faroes	0	0	0	0	1	0	0
Norway	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0

Table 3

Recapture information for whales moving between feeding sub-areas. (C-Canada; Ic=Iceland; No=Norway).

Area	Mark no.	Date	Position marked	Area	Mark no.	Date	Position recaptured	Sex	Age
C	c1866	August 1979	49°45'N; 53°12'W	WI	c1866	07 July 1988	62°37'N; 24°15'W	F	21-
EG	39875	14 July 1984	65°17.5'N; 32°11'W	WI	39875	23 July 1986	64°0'N; 26°0'W		
EG	39876*	14 July 1984	65°17.5'N; 32°11'W	WI	39876	09 July 1988	63°52'N; 28°45'W	M	14-15
EG	38254	15 July 1981	64°33'N; 35°27'W	WI	38254	13 July 1989	63°37'N; 27°15'W	F	14
EG	16144	13 July 1968	63°27'N; 38°15'W	WI	16144	24 July 1969	64°38'N; 28°0'W	M	25
EG	16150	13 July 1968	63°27'N; 38°15'W	WI	16150	21 July 1968	65°25'N; 28°30'W	F	
EG	15565	13 July 1968	63°27'N; 38°15'W	WI	15565	17 September 1977	65°40'N; 28°45'W	F	
EG	15600**	28 July 1973	62°30'N; 41°5'W	WI	15600	28 June 1983	64°38'N; 28°15'W	F	14

Double marked: *39881; **15572.

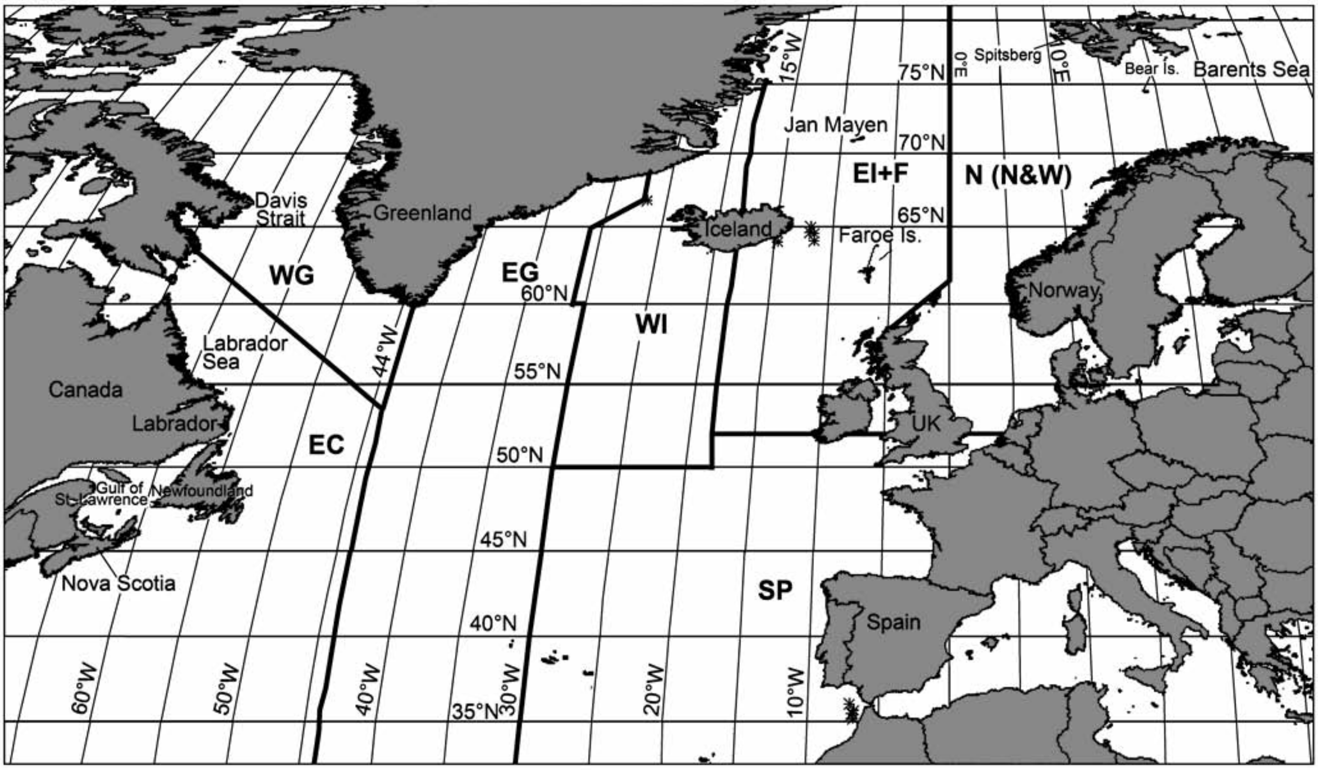
Annex G

A Summary of the Catch Data

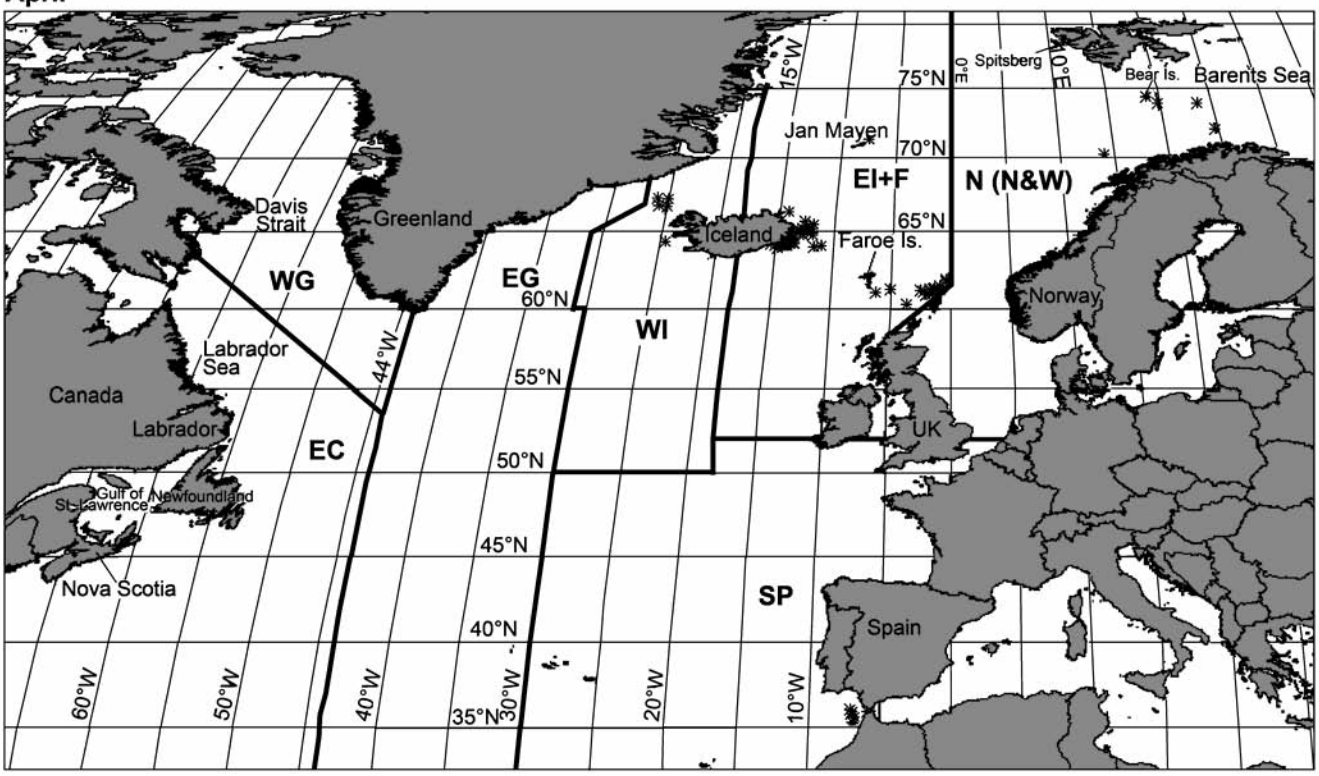
The maps below show fin whale catches by month, for those catches for which individual data are available (in the IWC catch database), summed over all years.

Table 1 summarises the fin whale catch data in the IWC database by half month and also indicates areas/periods for which no individual position data are available.

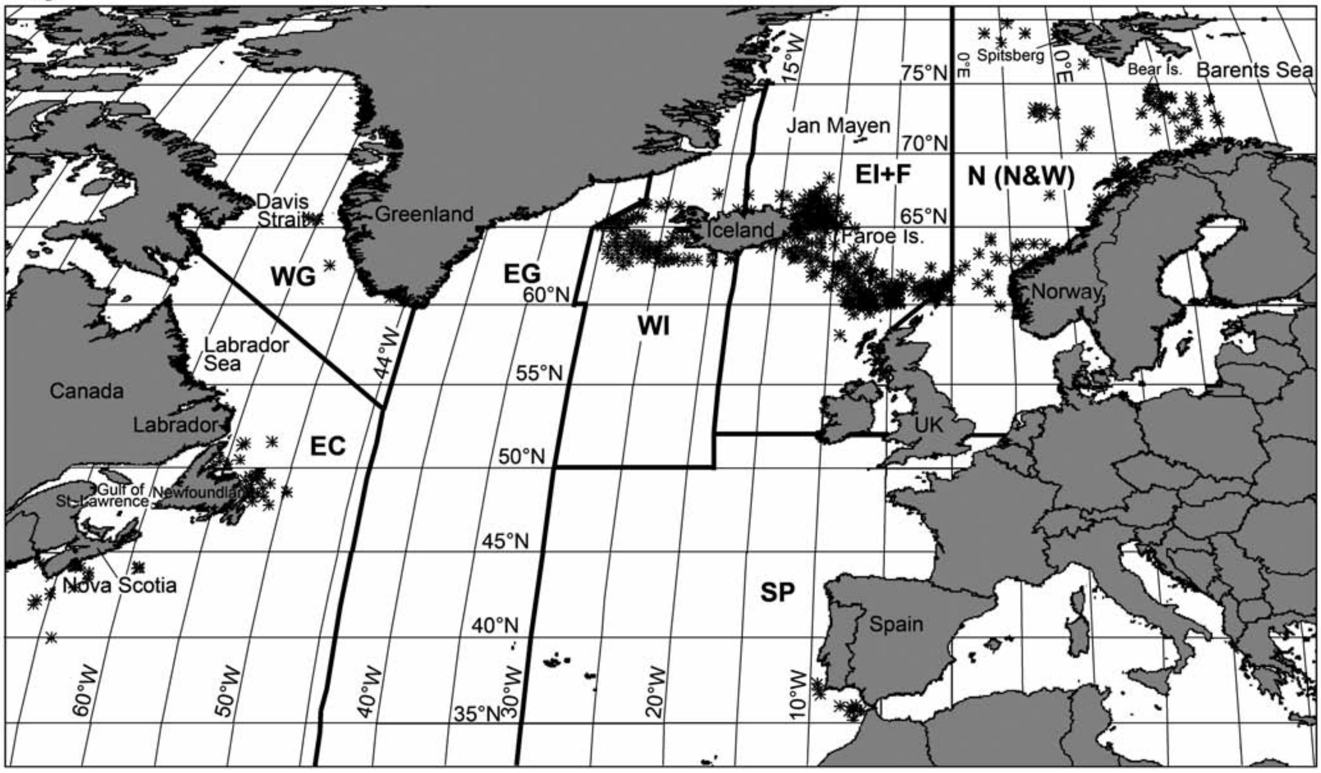
March



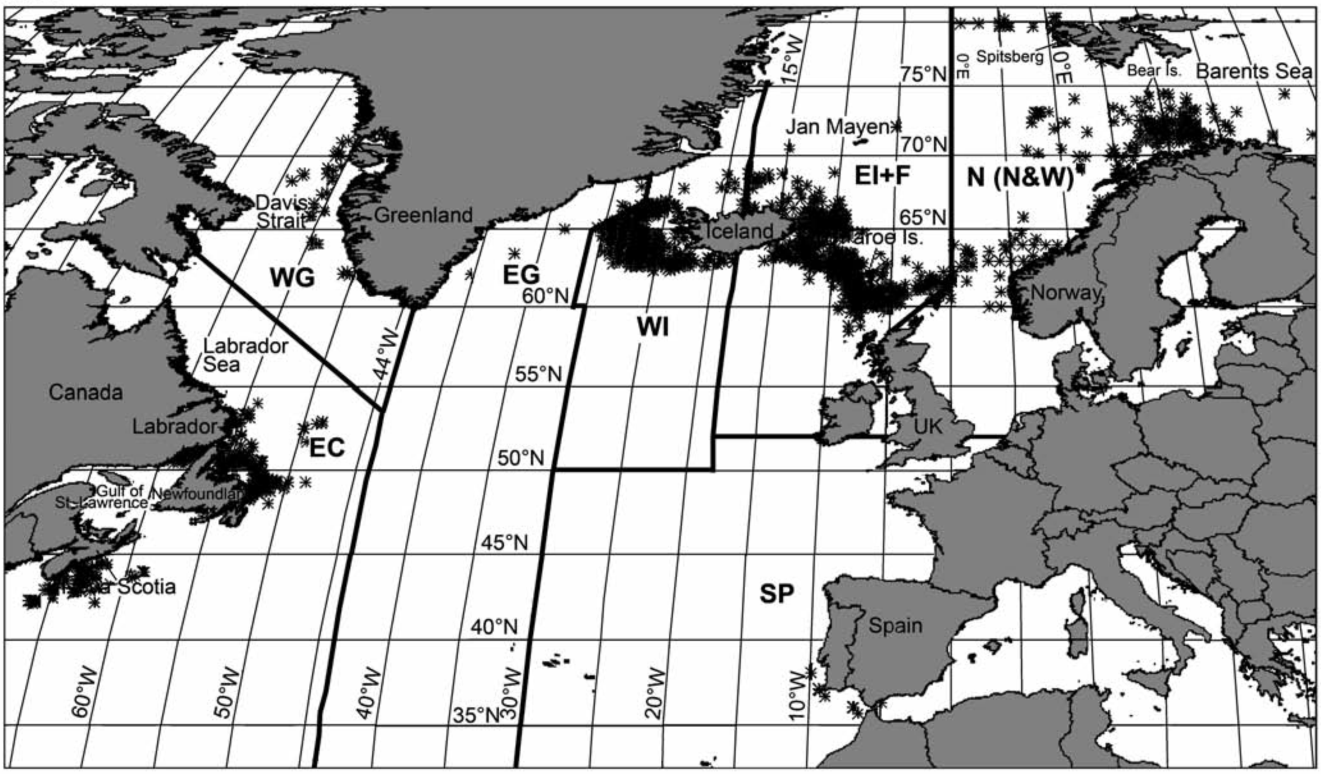
April



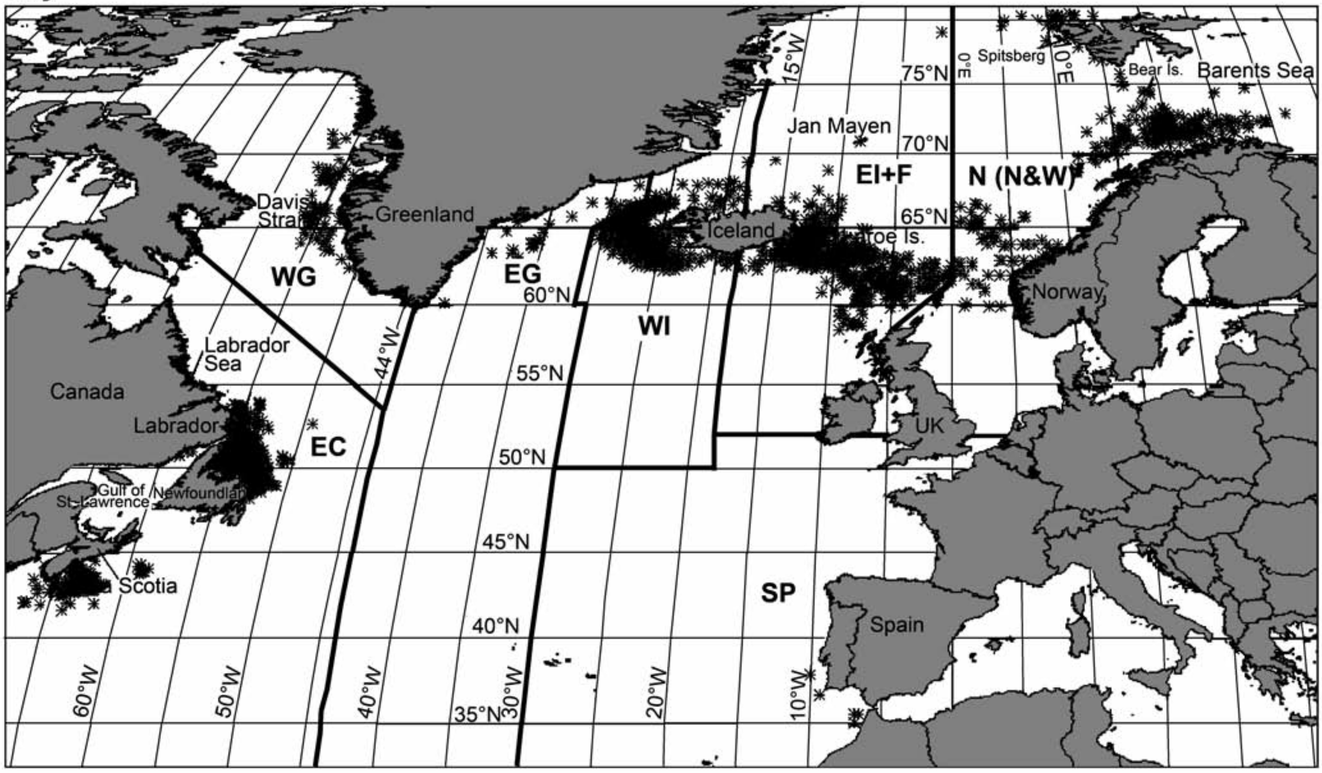
May


Spitsberg
Bear Is.
Barents Sea
75°N
0°E
15°W
Jan Mayen
70°N
EI+F
N (N&W)
Davis Strait
Greenland
65°N
Iceland
Faroe Is.
WG
EG
60°N
Norway
WI
Labrador Sea
44°W
55°N
Canada
Labrador
EC
UK
50°N
Gulf of St-Lawrence
Newfoundland
45°N
Nova Scotia
SP
Spain
40°N
60°W
50°W
40°W
30°W
35°N
20°W
10°W

June

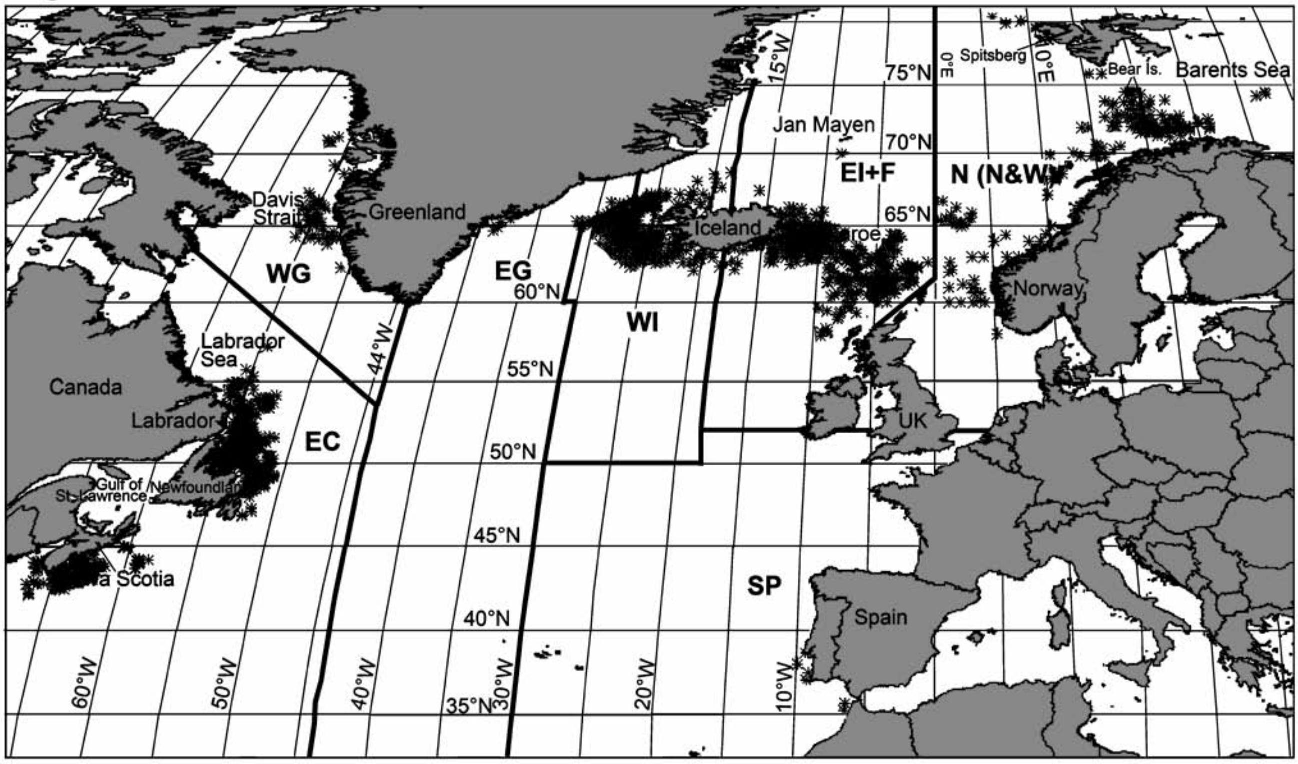

Spitsberg
Bear Is.
Barents Sea
75°N
0°E
15°W
Jan Mayen
70°N
EI+F
N (N&W)
Davis Strait
Greenland
65°N
Iceland
WG
EG
60°N
Norway
WI
Labrador Sea
44°W
55°N
Canada
Labrador
EC
UK
50°N
Gulf of St-Lawrence
Newfoundland
45°N
Scotia
SP
Spain
40°N
60°W
50°W
40°W
30°W
35°N
20°W
10°W

July



Davis Strait
Greenland
Iceland
Spitsberg
Bear Is.
Barents Sea
Jan Mayen
EI+F
N (N&W)
WG
EG
WI
EC
SP
Labrador Sea
Canada
Labrador
Gulf of St Lawrence
Newfoundland
Norway
UK
Spain
75°N
70°N
65°N
60°N
55°N
50°N
45°N
40°N
35°N
60°W
50°W
44°W
40°W
30°W
20°W
15°W
10°W
0°E
10°E

August



Davis Strait
Greenland
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Spitsberg
Bear Is.
Barents Sea
Jan Mayen
EI+F
N (N&W)
WG
EG
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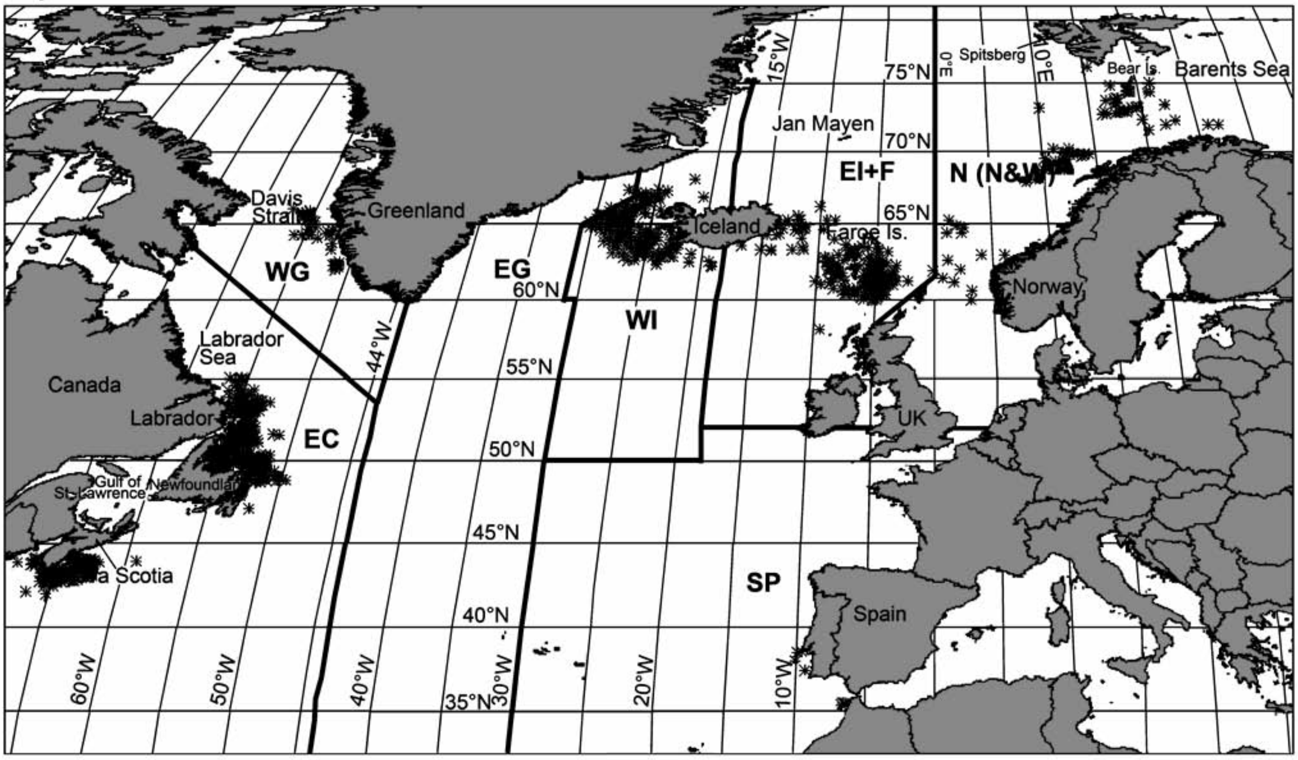
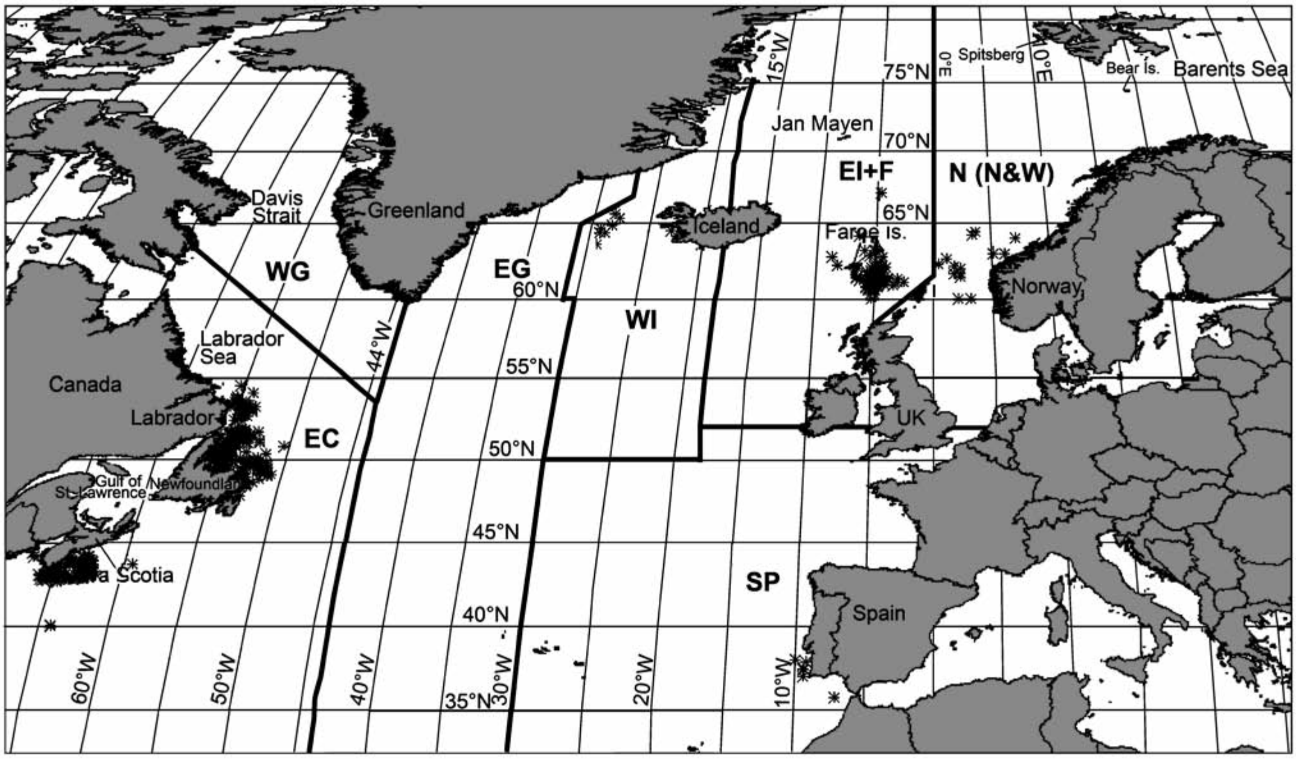
EC
SP
Labrador Sea
Canada
Labrador
Gulf of St Lawrence
Newfoundland
Norway
UK
Spain
75°N
70°N
65°N
60°N
55°N
50°N
45°N
40°N
35°N
60°W
50°W
44°W
40°W
30°W
20°W
15°W
10°W
0°E
10°E

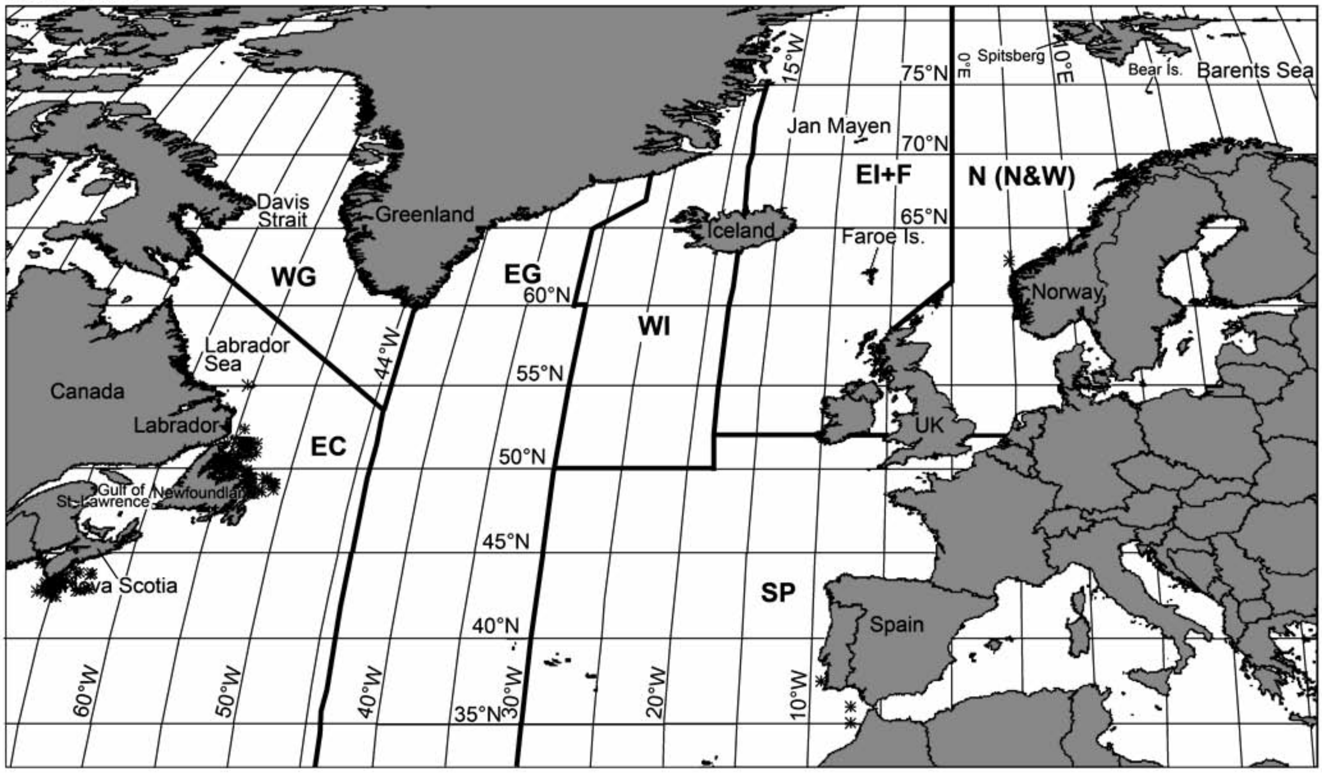
September



October



November



Dec - Feb

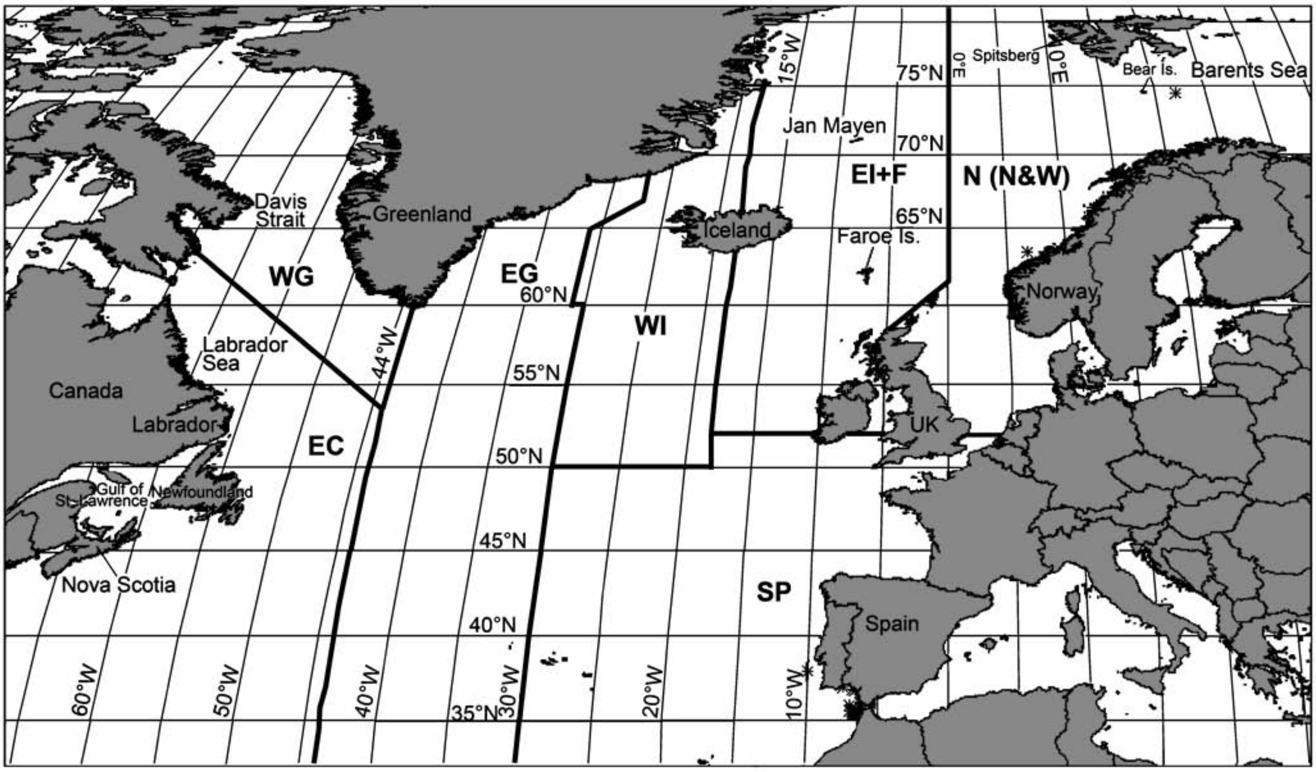


Table 1

Summary of individual fin whale catch data in the IWC database. The Table shows the catch by area and by half month (A = 1-15th; B=16-31st). The periods of highest catch are highlighted. The percentage of catches for which the individual position is known is also shown. ? date = date unknown.

Dates	Area	Jan A	Jan B	Feb A	Feb B	Mar A	Mar B	Apr A	Apr B	May A	May B	Jun A	Jun B	Jul A	Jul B	Aug A	Aug B	Sep A	Sep B	Oct A	Oct B	Nov A	Nov B	Dec A	Dec B	? date	Total	Lat range	Long range	%with posn
1927-72	Newfoundland	0	0	0	0	0	0	3	11	26	102	263	401	675	[illegible]	[illegible]	[illegible]	[illegible]	795	694	497	245	60	0	0	0	7,677	47N-57N	56W-49W	56
1964-72	Nova Scotia	0	0	0	0	0	0	0	0	12	14	56	77	126	[illegible]	[illegible]	[illegible]	169	124	106	128	92	51	0	0	0	1,564	40-46N	67-58W	100
1927-89	Greenland W	0	0	0	0	0	0	0	0	1	2	3	29	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	30	4	2	0	0	0	26	471	60N-71N	56W-45W	29
1924-70	Grnlnd/Iceland	0	0	0	0	0	0	0	0	0	1	55	53	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	55	9	0	0	0	0	0	0	834	60N-72N	59W-29W	62
1902-13	Iceland E	0	0	0	0	0	6	23	73	98	115	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	46	1	0	0	0	0	0	0	39	2,188	62N-68N	19W-3W	36
1902-13	Iceland W	0	0	0	0	1	0	0	8	12	10	22	34	52	[illegible]	[illegible]	71	23	14	0	0	0	0	0	0	0	442	65N-67N	27W-10W	0
1936-2006	Iceland W	0	0	0	0	0	0	0	0	20	198	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	609	370	200	2	7	0	0	0	0	20	9,537	62N-67N	32W-20W	98
1929-37	NA Pelagic	19	20	21	6	0	0	0	12	28	73	129	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	170	115	53	7	0	0	0	0	0	2,037			49
1901-16	Faroe Is	0	0	0	0	0	0	18	24	155	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	273	239	98	12	5	0	0	0	0	0	4	2,726	60N-63N	12W-0E	8
1920-84	Faroe Is	0	0	0	0	0	0	0	2	56	246	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	342	265	177	68	2	0	0	0	1	3,934	59N-65N	16W-2W	42
1909-22	Ireland N	0	0	0	0	0	0	0	0	10	22	12	43	[illegible]	[illegible]	[illegible]	34	51	6	0	0	0	0	0	0	0	401	54-55N	11-10W	0
1904-51	Hebrides, UK	0	0	0	0	0	0	0	13	63	86	82	70	[illegible]	[illegible]	[illegible]	[illegible]	49	24	6	0	0	0	0	0	3	925	56-60N	10W-6W	5
1904-51	Shetland, UK	0	0	0	0	0	0	87	85	117	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	77	6	0	0	0	0	0	0	243	2,439	60-62N	4W-0E	5
1883-1904	Norway N	0	0	0	0	0	15	47	55	37	22	53	63	[illegible]	[illegible]	[illegible]	31	0	0	0	0	0	0	0	0	0	618	71-72N	22-31E	0
1918-20	Norway N	0	0	0	0	7	0	5	10	0	0	35	71	74	[illegible]	[illegible]	72	0	0	0	0	0	0	0	0	0	543	71-72N	25E	0
1948-71	Norway N	0	0	0	0	0	0	0	4	24	63	131	[illegible]	[illegible]	[illegible]	[illegible]	123	78	39	2	0	0	0	0	0	0	1,466	68N-75N	7E-34E	52
1918-69	Norway W	3	91	115	101	149	134	44	120	243	433	[illegible]	[illegible]	[illegible]	[illegible]	608	535	371	257	209	184	68	19	9	0	5	7,462	58N-69N	0E-15E	8
1957-85	Spain N	0	0	0	0	0	0	5	19	31	69	144	243	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	374	202	134	99	71	20	2	1	3,955	42-44N	10-8W	0
1925-58	Gibr/S.Port	13	9	16	13	21	20	29	31	[illegible]	[illegible]	36	29	27	31	29	27	52	48	41	27	14	11	5	9	9	636	35N-39N	10W-6W	22

Annex H

Compilation and Calculation of North Atlantic Fin Whale Abundance by Sub-area

Paul Wade

ABUNDANCE ESTIMATES FOR EACH SUB-AREA

For each sub-area, surveys within the sub-area were reviewed, and estimates from appropriate surveys were added together to create a total for the sub-area. Totals for each sub-area were only created in years where survey coverage was somewhat complete and similar across years. When coverage in some years was less than ideal this is noted in the sections below. When adding estimates together, CVs for the sums were calculated assuming the estimates were independent. In some cases where only confidence limits were provided, CVs were calculated from the confidence limit, assuming a log-normal distribution. For the NASS surveys, details of the survey coverage were taken from inspection of the survey maps provided in figs 1 and 2 of Pike and Gunnlaugsson (2006). Calculations of total abundance within sub-areas provided here differ in some cases from calculations made during the joint NAMMCO/IWC Workshop (IWC, 2007); details are provided in each section. One example is the averaging of 1987 and 1989 block B-West instead of using only the estimate from 1989.

Eastern Canada and eastern USA sub-area

Several abundance estimates are available for US waters from 1999 to 2006. The current US Stock Assessment Report for fin whales (D. Palka, pers. comm.) identifies the best estimate as the most recent estimate (2,269, CV 0.37) from the 2006 survey, covering waters from the southern edge of Georges Bank to the upper Bay of Fundy and to the entrance of the Gulf of St. Lawrence. In 2007, the TNASS aerial survey was conducted in Canadian waters. Preliminary estimates (un-corrected for *g*(0)) for Newfoundland were provided to the Workshop (J. Lawson, pers. comm.). Those estimates will need to be updated with a correction factor, as well as have added to them an estimate from Quebec that is not yet available. A TNASS survey was also conducted in US waters in 2007; an estimate from that survey will be available at a later date. Additional estimates not used here (because they do not cover the complete area in adjacent years) include two line-transect aerial surveys in Canadian waters, giving un-corrected estimates of 79 to 926 fin whales on the eastern Newfoundland/Labrador shelf, August 1980 (Hay, 1982) and a few hundred in the northern and central Gulf of St. Lawrence, August 1995/96 (Kingsley and Reeves, 1998).

West Greenland sub-area

All of the estimates for this sub-area are from aerial surveys. The most recent abundance estimate for fin whales off West Greenland is 4,656 animals (CV 0.46) for 2007 (Heide-Jørgensen *et al*., 2008). Earlier estimates are 1,100 (95% CI=520-2,100) from 1987/88 combined surveys (IWC, 1992), and 3,218 animals (95% CI=1,431-7,240) from a survey in 2005 (Heide-Jørgensen *et al*., 2007). That CI yields a CV of 0.43. The 2005 and 2007 surveys were conducted with similar methods; the 1987/88 was different in that it was a cue-counting survey.

East Greenland sub-area

The NASS shipboard estimates (Pike and Gunnlaugsson, 2006) for block B-west in 1987 and 1989 were averaged (weighted by their respective inverse squared CVs), then added to the estimate for block A-West in 1989 (there was no estimate for A-West in 1987) to create a total for this sub-area. This abundance was assigned to the mid-point year 1988. 1995 and 2001 estimates are the sum of NASS blocks A-West and B-West in those years. Note that in 1995 there was very low coverage of block A-West (not corrected for here).

West Iceland sub-area

The NASS shipboard estimates (Pike and Gunnlaugsson, 2006) for blocks B-East in 1987 and 1989 were averaged (weighted by their respective CVs), then added to the estimate for A-East in 1989 (there was no estimate in 1987 for A-East). This abundance was assigned to the mid-point year 1988. 1995 and 2001 estimates are just the sum of A-East and B-East in those years. Note that in 1995 there was very low coverage of block A-East (not corrected for here).

East Iceland and Faroes sub-area

There are NASS shipboard estimates for surveys in years 1987, 1989, 1995 and 2001 (Pike and Gunnlaugsson, 2006). However, the area surveyed in this sub-area changed substantially between all surveys. The 1987 survey provided good coverage of the sub-area as far south as Ireland whilst Norwegian surveys provided coverage of the Jan Mayen area (not surveyed by NASS in that year). Therefore, estimates from Norwegian surveys in 1987 (Christensen *et al*., 1992), citing (IWC, 1989) and 1988 (Øien, 1990) for blocks west of 0°, were averaged, then added to the NASS estimates for blocks EGI and WN-SPB. Note that the 1987 NASS survey in block WN-SPB also went all the way to the Norwegian coast east of the Faroe Islands (and therefore into the Norway sub-area), but few fin whales were seen in that area (only one sighting from inspection of fig. 2 of Pike and Gunnlaugsson, 2006) Ideally, the estimate from this block should be recalculated removing the area east of 0° latitude.

The 1989 survey did not go north of Iceland and does not provide a comparable estimate to other years; therefore the 1989 estimates are not used. Coverage in 1995 was similar to the coverage in 1987, but better in the sense that the 1995 survey of block GB-SPD did not go into the Norway sub-area (east of 0°). To calculate total abundance in 1995, the estimates from NASS blocks EGI and WN-SPB were added to 1995 Norwegian survey estimates from the Jan Mayen area (blocks NVN and JMC from Øien, (2003)). The 2001 NASS survey covered the Jan Mayen area, so there was no need to add estimates from Norwegian surveys. However, note that in 2001 the coverage of the WN-SPB block did not go as far south as in previous years and thus surveyed a much smaller area (not corrected for here).

Norway sub-area

Norway completed full surveys in 1995, in the years 1996-2001 and in the years 2002-2007. Estimates for 2002-2007 are not yet available. The border between the Norway sub-area and the East Iceland and Faroes sub-area is at 0° in the northern part of the sub-area. Four blocks from the Norwegian surveys (SVI, NVN, JMC and NVS) are to the west of that longitude and therefore the estimate for this sub-area is based on the total abundance from the Norwegian surveys less the abundance from those blocks. Skaug provided those estimates at the workshop as 3,964 for 1995 and 3,749 for 1996-2001 (assigned to year 1999) based on Øien (2003). A revised calculation of the CV of those estimates was not available at the workshop; the CVs from the total estimates (0.21 and 0.24 respectively) are used here until revised calculations can be made (hopefully by Øien). The revised CVs are not likely to be substantially different. Surveys were also conducted in 1988; the joint IWC/NAMMCO Workshop Report (IWC, 2007) indicates that estimates are not currently available without further analysis (presumably involving post-stratification), and that Øien had been requested to undertake such analyses.

Spain/Portugal/France sub-area

The Spanish NASS survey in 1989 covered an area from 42°-52°S in July and August, extending out to 25°W (Buckland *et al*., 1992). The survey covered the Bay of Biscay and also a large section of the Atlantic Ocean northwest of Spain, extending north to the southern tip of Ireland. The survey extended past the western boundary (18°W) of the 'Spain-Portugal-British Isles' stock (Donovan, 1991). The best estimate for the entire survey area is 17,355 (CV 0.265). As the earlier NASS survey in 1987 (Sanpera and Jover, 1989) covered about one half of the area covered in the 1989 survey (it did not extend as far east into the Bay of Biscay north of Spain or as far west) and thus is not used here. There is also an estimate from 1982 of 1,696 (Mizroch and Sanpera, 1984), but that survey also apparently covered a smaller area, so that estimate is not used here either. Further there is an estimate of 7,500 in 1993 (Goujon *et al*., 1995) from a survey designed primarily for small cetaceans; it is thought that this survey also covered a small area but this was not checked at the Workshop.

An estimate of abundance for the entire Mediterranean Sea population of fin whales is unknown, but the western basin portion, where most of the population is found, is estimated to be 3,500 animals (Notarbartolo di Sciara *et al*., 2003). This is considered a separate population that is not included in the trials conducted here, so this abundance is not used.

Further work could be conducted to improve some of these estimates or add additional estimates. Various tasks that could be completed include:

(1) Revise calculations of the 1988 survey data for the Norway sub-area to make an abundance estimate available for that time period; a request for this was made to Øien (IWC, 2007).
(2) Prorate abundance in NASS block WN-SPB in 1995 and 2001 for East Iceland and Faroes sub-area because of incomplete coverage of the southern portion of the block (this could be done by simple area proration or by encounter rate ratios between subdivisions of the block).
(3) Prorate abundance in NASS block A-West in 1995 because of incomplete coverage in the southern portion of the block.
(4) Revise abundance in 1987 NASS block WN-SPB to remove the portion of block that occurred to the east of Faroe Islands in the Norway sub-area (east of 0 degrees longitude).

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Annex I

Analysis of Historical Catch-rate Data for East Iceland

Andre E. Punt

The catch-rate series in tables 4 and 8 of Sigurjónsson and Gunnlaugsson (2006) do not account for the impact of the factors month and boat as well as the impact of some effort targeting blue and humpback rather than fin whales, although the series in table 8 addresses the impact of month in an approximate manner by restricting the analyses to the period May-August. The following GLM with Poisson error structure was therefore fitted to the catch of fin whales to standardise the CPUE index for these factors:

$$F_{y,m,b} = \exp(\mu + \alpha_y + \beta_m + \gamma_b + \delta_1 B_{y,m,b} + \delta_2 H_{y,m,b}) \quad (1)$$

where

- $F_{y,m,b}$ is the number of fin whales caught by boat b during month m of year y,
- μ is the intercept,
- α_y is the factor for year y (y=1904,..,1913; excluding 1912 for which there is insufficient data),
- β_m is the factor for month m (May, June, July, August),
- γ_b is the factor for boat b (restricted to the 19 boats which fished in at least 10 months during the period 1904-13),
- δ_1, δ_2 are the parameters associated with the blue and humpback whale effects,
- $B_{y,m,b}$ is the number of blue whales caught by boat b during month m of year y, and
- $H_{y,m,b}$ is the number of humpback whales caught by boat b during month m of year y.

Equation 1 contains no offset for effort because the effort unit is one month (i.e. effort is assumed to be the same for all months in which at least one whale was caught – exclusion of the first and last months of the season by restricting to the May-August period makes this a more reasonable assumption). The blue and humpback effects in equation 1 are intended to reflect respective CPUEs (given that the effort unit is one month). It can be shown (Glazer and Butterworth, 2002) that provided the proportion of total effort directed at other than the primary target species (here fin whales) is relatively small, the use of *ln*(CPUE) (approximated here by CPUE) as a co-variate for each of the other species at which effort is directed provides an appropriate basis for adjustment. Note that in line with this assumption, the analysis is restricted to years following 1903 because fin whales did not comprise the majority of the catches taken in earlier years.

The base model involves all of the covariates and factors. The fit of this model indicates that the factors year, month and boat are all highly significant (p<< 0.001) and that the covariate blue whale (CPUE) is significant at p=0.01. The covariate humpback whale (CPUE) is not significant at p=0.05. Figure 1 compares the model predicted annual indices based on the base model and a model that ignores the species covariates, and shows that these latter corrections for targeting on blue and humpback whales have relatively little impact. This figure also shows the indices in table 4 of Sigurjónsson and Gunnlaugsson (2006) (which restricts the data to the May-August period) [left panel] and the indices from table 8 of Sigurjónsson and Gunnlaugsson (2006) (raw catch/effort indices). The slope of the latter index (-0.125, SE 0.048) is notably higher, but also appreciably less precisely estimated, than that of the base model (-0.099 SE 0.025).

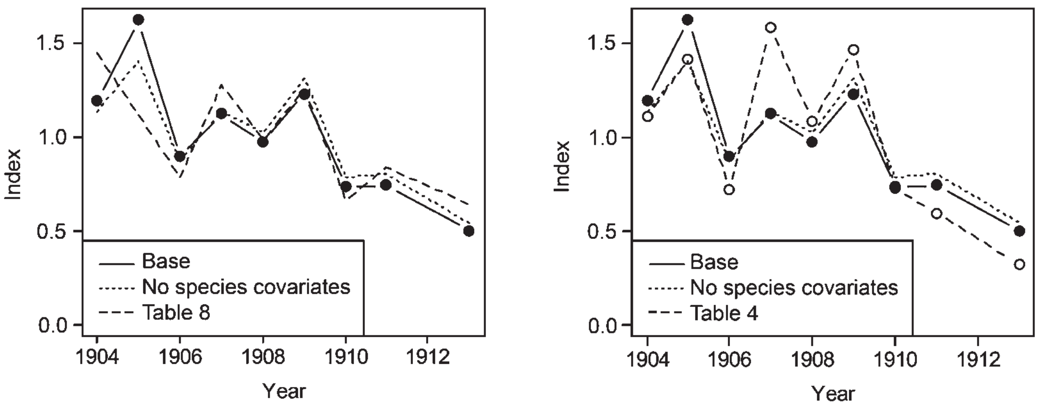

Fig. 1. Catch-rate indices based on the GLM with Poisson error structure (solid and dotted lines) and the indices from Sigurjónsson and Gunnlaugsson (2006); (table 8, column FpBM2, left panel; table 4, last column, right panel).

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Annex J

Estimation of Total Mortality and Selectivity for North Atlantic Fin Whales

Andre E. Punt

ESTIMATION OF TOTAL MORTALITY

Catch curve analysis was used to estimate total mortality (Z) based on catch age-data for fin whales caught off West Iceland during 1976-85 – a range of years selected to encompass the period when only commercial catches occurred and when most of the catch was aged. Figure 1 plots the catch age compositions in normal- (left panels) and log-space (right panels). Total mortality was estimated by regressing log-catch on age, after restricting the data to ages 8-40 (to ignore ages that are not fully selected and those for which sample sizes are low) and after excluding ages for which the sample size is not at least five. This approach to estimating total mortality assumes constant recruitment and constant age-invariant mortality for the ages included in the analysis; the estimate is biased as a measure of the sum of natural and fishing mortalities if there is a trend in selectivity with age.

The estimates of total mortality are: females, 0.122 (SE 0.010); males 0.109 (SE 0.011)

Estimation of selectivity

Figure 2 plots the ratio of the catch (by age) to the expected abundance inferred from the fit to the catch curve for each sex (extrapolated back to younger ages based on the estimate of total mortality for ages 7+) and a fitted logistic curve of the form: $y_a = \alpha/(1 + \exp((\mu - a)/\delta))$. The estimates for the parameters which determine the shape of the logistic curve (and hence the parameters of the selectivity ogive; the asymptote of the relationship is treated as a nuisance parameter) are: females, $\mu = 4.09$, $\delta = 1.00$; males, $\mu = 3.59$, $\delta = 0.570$.

The estimates of the parameters of the logistic curve depend on the assumption that the total mortality rate estimated above applies to all ages (effectively that fishing mortality is very low so that natural mortality is the dominant component of total mortality).

[*Figures 1 and 2 overleaf*]

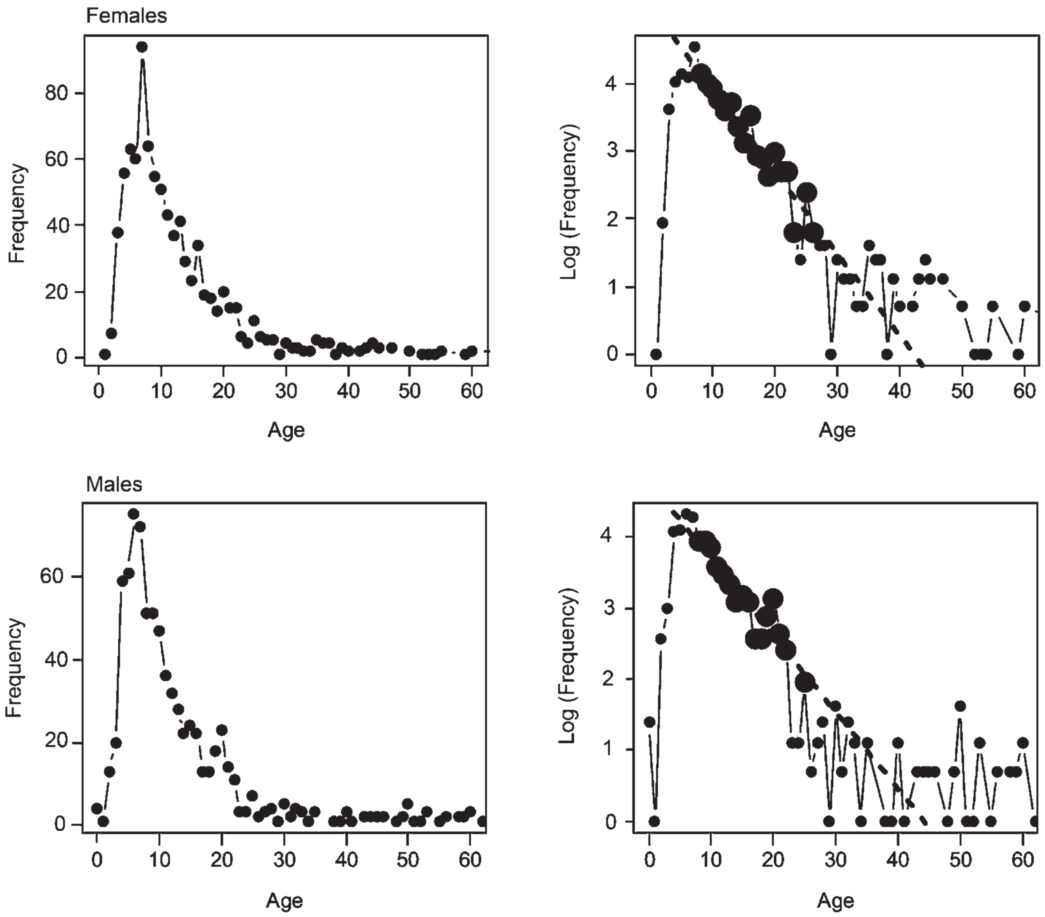

Fig. 1. Catch age compositions for fin whales off West Iceland (normal- and log-space; left and right panels respectively). The large solid dots in the right panels denote the data points used when estimating total mortality, and the dotted line indicates the fitted exponential/linear relationship.

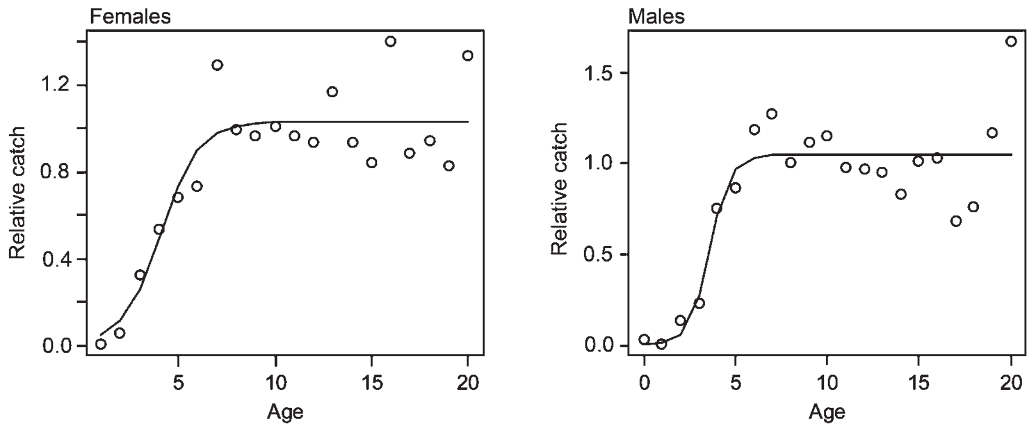

Fig. 2. Ratio of the catch (by age) to the expected abundance by age based on the results from a catch curve analysis and a logistic function fitted to these data.

Annex K

The Specifications for the *Implementation Simulation Trials* for North Atlantic Fin Whales

[See Scientific Committee Plenary report, Annex D]