NAMMCO Scientific Committee Working Group on Management Procedures

Report of meeting in Copenhagen, 13 - 14 October 1997

1. Opening remarks and terms of reference

The Chairman, N. Øien, welcomed the participants (Appendix 1), and M. P. Heide-Jørgensen explained the practical arrangements for the meeting which was held in the offices of the Greenland Institute of Natural Resources in Copenhagen.

The meeting was arranged to answer a request from the Council to the Scientific Committee, dated 4 March 1997, to provide scientific advice on the following matter prior to the next meeting of the Council: "In the light of the new survey abundance results the Scientific Committee is requested to undertake an assessment of the status of the Central North Atlantic Minke Whale stock, including to evaluate the long term effects of past and present removal levels on the stock."

Preparations for the meeting had been arranged by correspondence and included review of stock structure, biological parameters and abundance estimates of minke whales in the North Atlantic, as well as population modelling.

2. Adoption of agenda

The agenda as adopted is given in Appendix 2.

3. Appointment of rapporteur

M.P. Heide-Jørgensen was appointed to assist the Chairman as rapporteur.

4. Review of available documents and reports

The Working Group had received several working papers as listed in Appendix 3 to assist in discussions.

5. The Central North Atlantic minke whale stock

5.1 Stock structure

North Atlantic minke whales have been divided into four management stocks by the International Whaling Commission (Donovan 1991): (1) the Canadian East coast stock; (2) the West Greenland stock; (3) the Central stock and (4) the Northeastern stock. During the IWC Scientific Committee's development of the Revised Management Procedure these stock areas were considered medium areas and further divided into small areas (IWC 1994). The Central medium area was divided into an East Greenland coastal area (*CG*), a coastal Icelandic area (*CIC*), an area around Jan Mayen (*CM*) and finally the waters south of Iceland (*CIP*). Most of the studies presented on North Atlantic minke whale stock structure refer to these divisions and these are therefore shown in Figure 5.1.1.

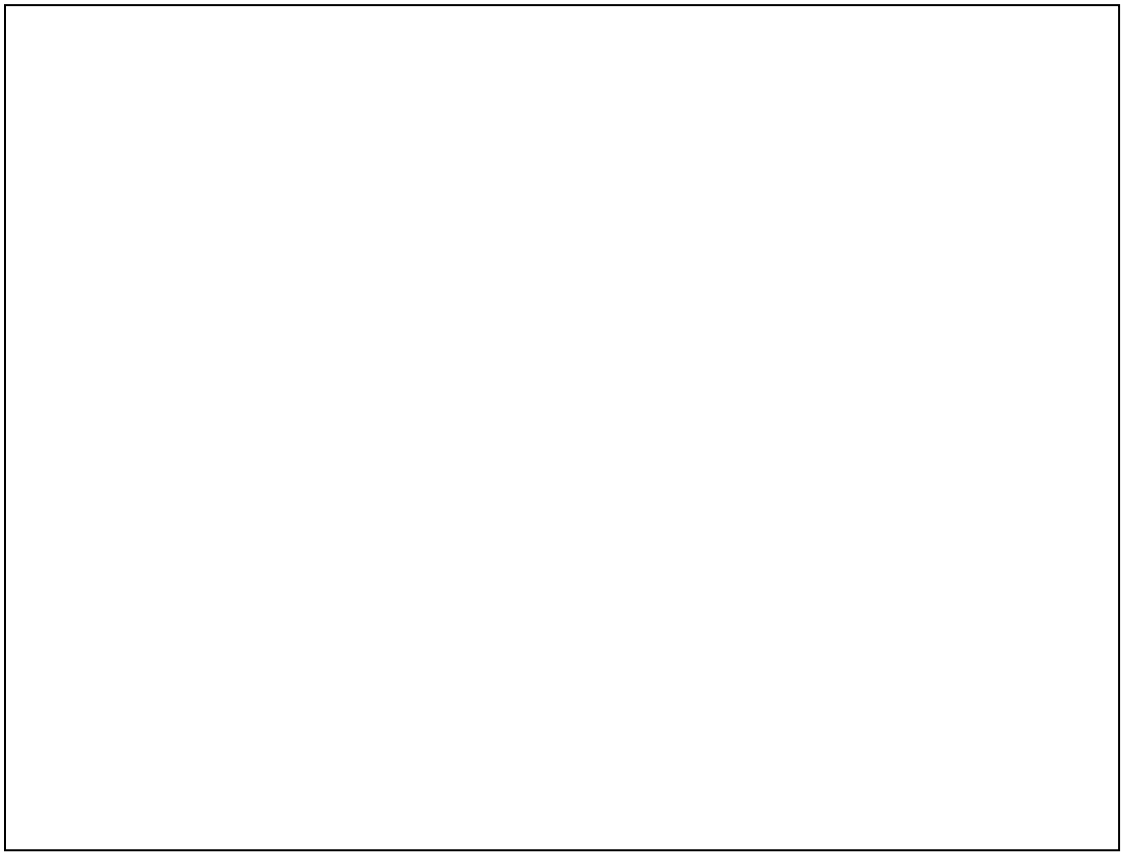

Figure 5.1.1. Map showing the IWC small areas. ES, EB, EC and EN constitute together a medium area which taken together is the Northeastern stock area, while CM, CIC, CG and CIP constitute the Central medium area.

A. Daníelsdóttir presented her review of the population genetic structure of North Atlantic minke whales (SC/6/MP1). The review describes the results from various nuclear (n) and mitochondrial (mt) DNA methods used to study the genetic relationship of minke whales (*Balaenoptera acutorostrata*) from different geographical locations in the North Atlantic: The West Greenland area, the Central area (Iceland) and the Northeastern Atlantic area. The sampled areas are shown in Figure 5.1.2. The results from the studies are discussed and compared with genetic studies of minke whales from other locations. Daníelsdóttir concluded that when nonselective nDNA and/or mtDNA genes show significant differences between sample locations, then it is possible to conclude that there is restricted gene flow between them and they can be managed as separate populations. Concordant and nonconcordant results have been obtained using both nDNA and mtDNA on the same populations and samples in a number of species. It is more common that the mtDNA shows differentiation between populations and that the nDNA does not (e.g. dispersal of males, recent bottlenecks), but less differentiation in mtDNA than nDNA is also found (smaller genome size, founder effects, female biased breeding and/or migration ratio). There is a tendency for the mtDNA to show greater population differences, because of its lower effective population size and effective migration rate (maternal inheritance) which make the effect of genetic drift greater and therefore may lead to greater population differentiation. The gene diversity, however, at equilibrium between mutation and drift, is much lower for mtDNA than

nDNA (assuming mutation rates are similar). The different evolutionary dynamics of nDNA and mtDNA can, if combined in a study, provide information on otherwise hidden behaviour and/or population structure. It should be emphasised that it can be misleading to conclude that there are similarities between samples, when the study considered is based on variation at a single gene or locus.

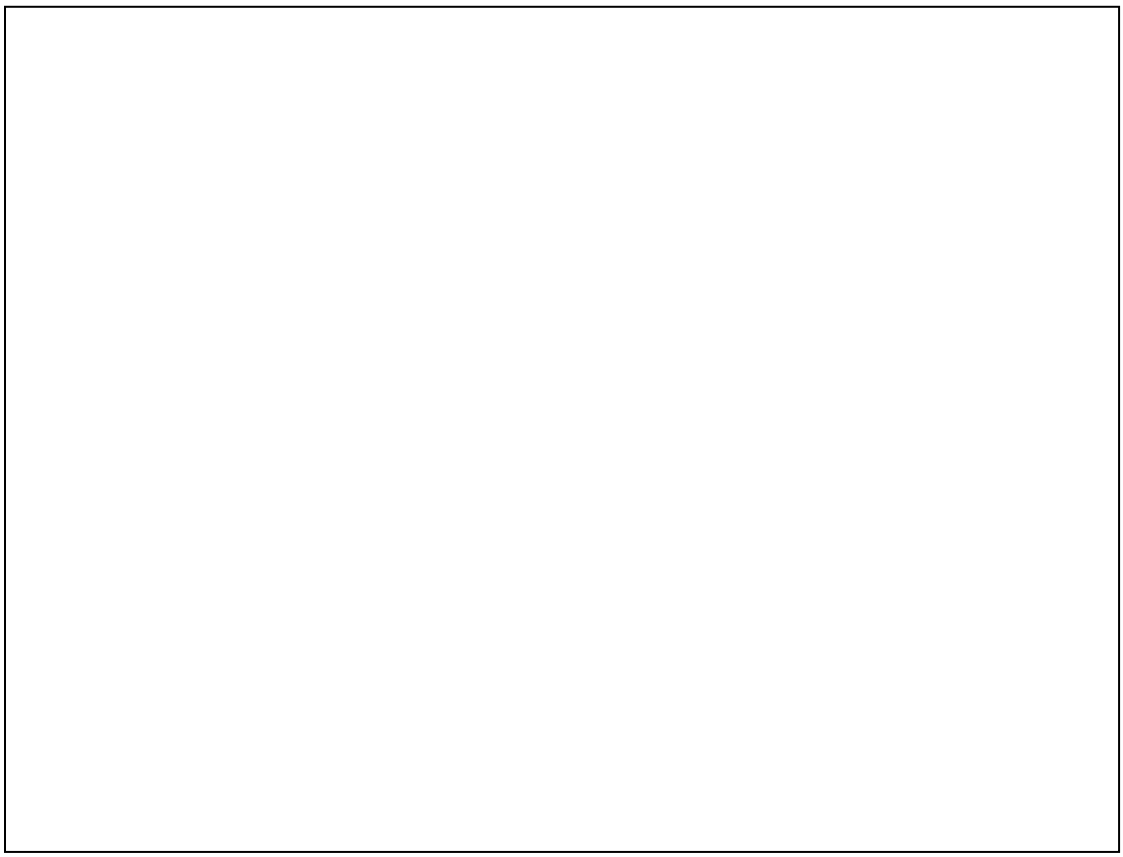

Figure 5.1.2. Map showing the approximate locations of samples used in the genetics studies reviewed.

Daníelsdóttir concluded that, based on the genetic evidence available today: 1) Northeastern and Central Atlantic minke whales represent separate populations, and 2) Northeastern Atlantic and West Greenland minke whales represent separate populations.

In the discussions, the importance of comparing the same tissues between investigations when dealing with allozymes was pointed out. Temporal variations due to different sampling periods between areas must also be taken into account, as well as possible heterogeneity related to sex. As suggested in SC/6/MP4, the analyses done so far have detected indications of certain structures among North Atlantic minke whales, but a satisfactory model which provides a coherent explanation compatible with most of the data has yet to be identified.

From the manager's point of view the basic question would be: How large are migration rates, and how do they affect management goals? Conclusions are also hampered by the

fact that no internal comparisons have been made within the Central stock area, or between Jan Mayen and Icelandic coastal waters.

The review of the population genetics revealed an equivocal picture of the structure of the minke whale population in the North Atlantic. Two lines of evidence (allozymes and nuclear DNA) supported a splitting between West Greenland, Central and Northeastern Atlantic, whereas no distinctions could be made for minke whales within the Northeastern Atlantic. Other genetic studies based on mtDNA did not detect heterogeneity between these areas, but this should not be interpreted as proof of an homogenous population structure. Also, different weight should be given to different studies and it was specifically argued that studies based on a relatively limited part of the genome of mtDNA were unsuitable for detecting population delineation. Generally the genetic studies were conducted on a large scale, i.e. trans-Atlantic comparisons, where isolation by distance seems to be a reasonable hypothesis. On a finer scale it seems unlikely that genetic studies can establish management units.

To summarise, the available evidence in support of ***population heterogeneity*** in North Atlantic minke whales is:
- studies of allozymes and nuclear DNA support large-scale segregation in regions;
- mark-recapture analyses of minke whales around Iceland and in the Barents Sea (Northeastern Atlantic) show little chance of exchange of minke whales between these two areas (IWC 1991);
- Morphometric studies suggest that there is substantial heterogeneity between minke whales sampled from West Greenland, Central and Northeastern stocks, but the data were not conclusive on whether these stocks can be treated as completely isolated populations as overlap was considerable (Christensen et al. 1990);
- temporal differences in lengths and sex in some areas suggest segregation in the migrations of minke whales (IWC 1977).

Evidence for ***population homogeneity*** in North Atlantic minke whales is:
- mtDNA studies found no significant differences between widely separated areas such as West Greenland, Icelandic coastal waters and the Barents Sea;
- when the allozyme genotypes were tested for Hardy-Weinberg equilibrium for each of the small areas, no support for heterogeneity within small areas could be detected;
- during the summer minke whales are distributed in a continuum on the continental shelves in the North Atlantic. Only the deep slopes between Iceland and the Faroe Islands, between the Greenland Sea and the Norwegian Sea and south of Greenland, show disjunction in minke whale distributions. No hiatus in distribution is evident between coastal Iceland, East Greenland and Jan Mayen. Thus it seems unlikely that discrete subunits of minke whales persist in this area, considering the long-range migratory abilities of minke whales.

Minke whales in the eastern and western North Atlantic are, at least during summer, separated by the land masses of Greenland and by the deep water of the mid-Atlantic. It thus seems reasonable to assume that on a large scale some segments of the North Atlantic have been isolated because of distance and topography. This is supported by some genetic studies. The tagging studies, albeit biased to hunted whales, indicate philopatry to the Central and Northeast Atlantic with little expected exchange, whereas distributional inference gives no indication of population structure on a finer scale than the Central, Northwest and the Northeast Atlantic.

In conclusion, some heterogeneity of the minke whale population may be expected, but at present the evidence is too limited, inconsistent or scattered to support a conceptual model for the dispersal and mixing of minke whales in the North Atlantic. On a finer scale, e.g. within the Central stock area, nothing supports a further delineation of the stock, however, the available studies suffer from incomplete or biased sampling of the whales in the area or from deployment of inadequate techniques.

Although nothing supports a delineation of minke whales between coastal Icelandic waters, East Greenland and the area between Iceland and Jan Mayen, a safe approach, in the light of inadequate research, would be to maintain the small areas as putative stock units.

5.2 Biological parameters

Víkingsson reviewed the available information on biological parameters (SC/5/MG3). As part of the International Whaling Commission's work on the Comprehensive Assessment of minke whale stocks in the North Atlantic, a table of available data on biological parameters was prepared (Larsen 1991). Since then, no new information on the relevant biological parameters of minke whales in the North Atlantic appears to have been published. Víkingsson prepared Tables 5.2.1 and 5.2.2 based on the information given in Larsen (1991) and the parameter values used in the IWC's assessment in 1990 (IWC 1991). The Working Group decided to base their assessments on these data.

Table 5.2.1. Biological parameters in Central North Atlantic minke whales.

Parameter	Value	Note	Small area	Reference
Age at recruitment	5.5 11.5	50% recruited 95% recruited	CIC CIC	IWC 1991 IWC 1991
Age at sexual maturity (females)	6 6-7 5-6	Regression 50% mature Regression	CIC CIC CIC	Sigurjonsson 1988 Sigurjonsson 1988 Sigurjonsson et al. 1990
Sex ratios in catch	43% females 43.4% females		CG CIC	Larsen & Øien 1988 Sigurjonsson et al. 1990
Pregnancy rates	0.94		CIC	Sigurjonsson 1988
Natural mortality rates	0.10 (approx)			Horwood 1990.

Table 5.2.2. Parameter values used in recent assessments of Central North Atlantic minke whales.

Parameter	% of population	Value	Year	Reference
Age at recruitment	100	4	1988	IWC 1989
	50	5.5	1990	IWC 1991
	50	7.5	1990	IWC 1991
	50	3	1990	IWC 1991
	95	11.5	1990	IWC 1991
	95	13.5	1990	IWC 1991
	95	6	1990	IWC 1991
Age at first parturition	50	8	1990	IWC 1991
	95	13	1990	IWC 1991
Natural mortality rate		0.10	1988	IWC 1989
		0.09	1990	IWC 1991

5.3 Catch data

Catch data used in the assessments were compiled by Víkingsson and presented in Table 5.3.1. The CIC subarea comprises the coastal shelf of Iceland and the Central Medium Area is the union of small areas CIP, CG, CIC and CM; all these are defined in IWC (1994), and shown in Figure 5.1.1. The Central Medium Area catches include catches taken by Inuits at East Greenland, as supplied by Barner Neve.

Table 5.3.1. Catch data for minke whales in the Central Medium Area and CIC subarea.

Year	Central Medium Area		CIC subarea		Year	Central Medium Area		CIC subarea	
	Male	Female	Male	Female		Male	Female	Male	Female
1930	5	5	5	5	1964	208	114	114	48
1931	3	3	3	3	1965	194	206	80	62
1932	3	3	3	3	1966	181	173	87	77
1933	3	3	3	3	1967	315	159	135	87
1934	3	3	3	3	1968	386	350	219	206
1935	3	3	3	3	1969	171	120	93	66
1936	1	0	1	0	1970	203	159	112	81
1937	1	0	1	0	1971	172	131	121	98
1938	0	0	0	0	1972	204	166	115	87
1939	0	0	0	0	1973	250	127	78	64
1940	0	0	0	0	1974	143	109	61	63
1941	7	7	7	7	1975	180	221	89	80
1942	7	8	7	7	1976	175	110	114	87
1943	7	7	7	7	1977	107	88	106	88
1944	7	7	7	7	1978	146	162	85	114
1945	7	7	7	7	1979	166	118	111	87
1946	18	15	18	15	1980	198	120	121	81
1947	27	18	27	18	1981	129	117	119	82
1948	56	43	56	43	1982	212	109	127	85
1949	59	52	56	48	1983	164	125	117	87
1950	18	15	18	15	1984	136	149	100	78
1951	20	18	20	18	1985	113	123	94	51
1952	21	19	21	19	1986	6	46	0	0
1953	20	18	20	18	1987	12	42	0	0
1954	20	18	20	18	1988	4	1	0	0
1955	25	33	24	27	1989	1	0	0	0
1956	26	21	23	21	1990	5	0	0	0
1957	25	21	24	21	1991	5	2	0	0
1958	23	21	23	21	1992	8	0	0	0
1959	33	28	24	21	1993	7	8	0	0
1960	37	32	30	23	1994	8	38	0	0
1961	120	61	71	34	1995	6	38	0	0
1962	164	125	78	50	1996	12	40	0	0
1963	114	105	69	54					

5.4 Abundance estimates

The NAMMCO Scientific Committee Working Group on Abundance Estimates had at its meeting in February 1997 reviewed and analysed data collected during NASS-95, including presentation of synoptic distributional maps as well as abundance of minke whales in the Northeast Atlantic (NAMMCO/7/6). Estimates for the Central Medium Area and the CIC subarea are given in Table 5.4.1. The part of the estimate for the Central Medium Area based on Icelandic shipboard surveys is not corrected for whales missed on the track line (g(0) assumed to equal 1). The Icelandic shipboard surveys were conducted with only one platform on each of two ships, thus no data could be collected to estimate the negative bias introduced by the assumption of g(0) = 1.

As can be seen from Table 5.4.1, the 1987 and the 1995 point estimates for the Icelandic coastal area CIC differ by a factor of about 2.8. A large part of the difference is due to the fact that the 1987 aerial survey covered a substantially smaller area than the aerial survey in 1995. Also, the continuity in distribution of minke whales from Icelandic coastal areas towards the ice edge at Greenland and Jan Mayen may allow substantial movements in and out of the aerial survey area. No conclusion can be reached on whether the difference is due to a change in abundance, local movements or methodological differences.

Table 5.4.1. Abundance estimates for minke whales in the Central Medium Area and the CIC subarea

Estimate, ref. year	c.v. of estimate	lower 95% c.l.	upper 95% c.l.
Central Medium Area			
1995: 72,130	0.244	44,711	116,362
CIC - Iceland coastal waters			
1987: 20,096	0.20	13,579	29,741
1995: 55,922	0.31	30,458	102,674

5.5 Assessments

The Working Group had before it SC/6/MP2 which contained a series of population trajectories produced by using the Hitting-with-fixed-MSYR model and with projections for 1997-2001 for different assumptions on annual catch options. The catch options investigated were:

(a) 0 catches;
(b) 35, which is the average for the most recent 5-year period in the Central stock area;
(c) 185, which is the annual average catch over the period 1961-85 within Icelandic coastal waters (CIC);
(d) 292, which is the average over the period 1980-84 in the Central stock area;
(e) 451, which is the average over the Central stock area's most intensive catching period 1965-1969.

The MSYR assumption of 0 was run only to show the effect of accumulated catches on the population trajectories. A recent paper by Schweder and Hjort (1997) had investigated the population dynamics of minke whales in the Barents Sea by a likelihood synthesis of a relative abundance series and two abundance estimates combined through a population dynamics model. They found a point estimate of MSYR of 1.7% with a 95% likelihood contour of 0.2% - 3%. This estimate relates to the 1+ population, while the MSYRs used in SC/6/MP/2 refers to the mature stock, which implies that MSYRs are proportionally higher. The Working Group subsequently focused on runs based on MSYRs of 2% and 3%.

The total Central stock is at present close to its carrying capacity as judged from the population modelling conducted. The total stock estimate from the 1995 surveys includes a shipboard component from the Icelandic vessel survey not corrected for g(0) (that is, animals missed on the trackline), and thus considered to be conservative. For the MSYR values considered by the group as the most probable (2% and 3% of mature stock), present removal levels are of no concern. The highest past removal level projected, that is an annual catch of 451 whales, would cause concern if the total abundance is at the lower range of its estimated 95% confidence interval (i.e. 44,751 minke whales). The Working Group therefore concluded that the total Central stock is now close to its carrying capacity, and that present as well as past catch levels with the exception of the highest catch level projected, will not adversely affect this stock.

The group then decided to consider the coastal waters of Iceland, CIC, as a unit with all the projected catches taken within that area. The lower 95% confidence limit for the CIC 1995 point estimate of 55,922 minke whales, that is 30,458 whales, was considered as a conservative approach in evaluating the status of the stock. This lower 95% estimate is consistent with the 1987 estimate when the limited coverage in 1987 is accounted for (Borchers et al. 1997). All projections showed that the stock in 2001 would not be adversely affected by past or present removal levels at parameter values considered to be appropriate by the group. However, the group considered the catch level of 451 in the CIC area, corresponding to the highest catch levels taken from the total Central stock, as too high and unsustainable in the long run. Also the catch projection based on an annual catch of 292 whales may be unsustainable. The Working Group concluded that the feeding stock of minke whales in Icelandic coastal waters (CIC) is presently close to its carrying capacity, and that present as well as past catch levels with the exception of the two highest catch levels (annual catches of 292 and 451 whales) projected, will not adversely affect this stock. Summary statistics for Hitting-with-fixed-MSYR calculations including five-year projections are given for a selection of options in Table 5.5.1. Some example trajectories for a range of MSYRs of 0-6% hitting the 1995 point estimate of 55,922 minke whales and its 95% confidence limits within the Icelandic coastal area CIC, and projected annual catches of 185 whales (the annual average over the period 1961-1985 within CIC) over the period 1997-2001, are shown in Figure 5.5.1.

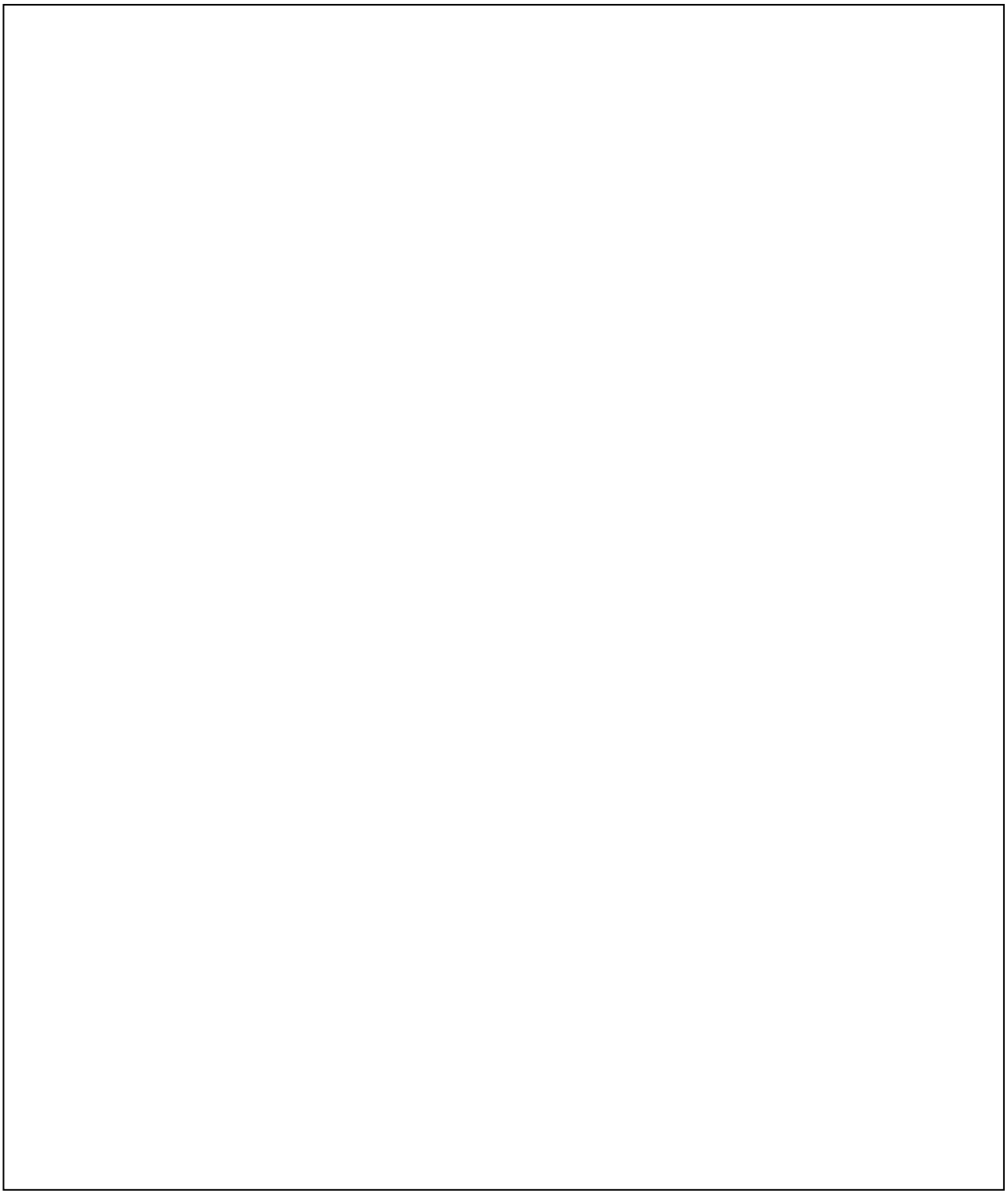

Figure 5.5.1. Population trajectories hitting the 1995 point estimate, as well as lower and upper 95% confidence limits, for the Icelandic coastal area CIC, and projecting the population for annual catches of 185 whales over the period 1997-2001. Trajectories are given for a range of MSY rates of 0-6%.

Table 5.5.1. Summary statistics for a selection of Hitting-with-fixed-MSYR calculations. MSY is the maximum sustainable yield in terms of harvesting of the recruited component of the population; K^e is the pre-exploitation size of the recruited component of the population; N^e_{97} is the size of the recruited component of the population at the start of 1997; N^e_{02}/ K^e is the ratio of the size of the recruited component of the population at the start of 2002 to the corresponding pre-exploitation level - results are shown for this statistic for each of the five levels of future catches.

MSYR, %	MSY	K^e	N^e_{97}	N^e_{97}/ K^e	N^e_{02}/ K^e Annual catch 1997-2001				
					0	35	185	292	451
1995 abundance estimate Central Medium Area									
Point estimate 72,130									
2	589	49103	46973	0.96	0.97	0.96	0.95	0.94	0.93
3	867	48151	46975	0.98	0.99	0.98	0.97	0.96	0.95
Lower 95% confidence limit 44,711									
2	375	31265	28987	0.93	0.94	0.94	0.92	0.91	0.89
3	545	30284	28979	0.96	0.97	0.97	0.95	0.94	0.92
Upper 95% confidence limit 116,362									
2	936	78029	75991	0.97	0.98	0.98	0.97	0.97	0.96
3	1388	77098	76000	0.99	0.99	0.99	0.98	0.98	0.97
1995 abundance estimate CIC, Icelandic coastal waters									
Point estimate 55,922									
2	452	37671	36537	0.97	0.98	0.97	0.96	0.95	0.93
3	668	37129	36542	0.98	0.99	0.99	0.97	0.96	0.94
Lower 95% confidence limit 30,458									
2	253	21053	19832	0.94	0.96	0.95	0.92	0.90	0.87
3	369	20492	19831	0.97	0.98	0.97	0.95	0.93	0.90
Upper 95% confidence limit 102,674									
2	820	68295	67209	0.98	0.99	0.99	0.98	0.97	0.96
3	1220	67765	67217	0.99	1.00	0.99	0.98	0.98	0.97

5.6 Recommendations for future research

Based on the discussions above, the Working Group considered that future research should primarily focus on resolving the questions on stock structure and population monitoring.

Stock structure

While recognising that there is some evidence of population heterogeneity in North Atlantic minke whales, it is evident that no conceptual model of dispersal and mixing of the whales can be proposed on the basis of present knowledge. Specifically such a model should

(i) identify segregation on breeding/wintering grounds, if any;
(ii) estimate the level of exchange between segregations;
(iii) estimate the mixing of putative stocks on feeding grounds and in areas with harvesting; and
(iv) identify philopatry of subunits of minke whales.

The research needed to elucidate these components of the population structure model should include a variety of techniques ranging from genetic studies, telemetric tracking of individual whales and isotope techniques to studies of levels and compositions of persistent pollutants. Some of these studies are in progress, while others will depend on the further development of techniques that are at present still in their infancy. Most research conducted so far has relied upon sampling of the whales from the harvest or at the harvesting grounds. Understanding of the population structure of North Atlantic minke whales will, however, require sampling on the wintering grounds and in areas without harvesting, in addition to sampling from the harvest.

Population monitoring

Sighting surveys are fundamental for the calculation of sustainable harvest levels and they need to be repeated at frequent intervals in areas where harvesting takes place. The abundance of minke whales in coastal areas of Iceland (area CIC) seems to have increased between 1989 and 1995 but the results are not conclusive due to the variability associated with the surveys. It would, however, be important to follow the changes in abundance in that area more closely to reveal whether the changes are due to a general increase in abundance or to temporal variability in the distribution of the whales and to possible problems in abundance estimation methodology. Likewise a comparison should be made between shipboard and aerial surveys.

6. Other business

There was no other business.

7. Adoption of report

The report was adopted by correspondence on 15 December 1997.

Appendix 1 - List of participants

Anna Kristín Daníelsdóttir (Iceland)
Þorvaldur Gunnlaugsson (Iceland)
Mads Peter Heide-Jørgensen (Greenland)
Pia Barner Neve (Greenland)
Nils Øien (Norway)
Gísli A. Víkingsson (Iceland)

Appendix 2 - AGENDA

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    5.2 Biological parameters
    5.3 Catch data
    5.4 Abundance estimates
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Appendix 3 - List of documents

List of Working Group Documents

SC/6/MP1. Daníelsdóttir, A.K. 1997. Review on the population genetic structure of North Atlantic minke whales (*Balaenoptera acutorostrata*).

SC/6/MP2. Punt, A. 1997. Implications of various levels of future catches on the dynamics of population of minke whales in the Central North Atlantic.

SC/6/MP/3. Víkingsson, G.A. 1997. Biological parametres of Central North Atlantic minke whales.

SC/6/MP/4. Palsbøll, P.J. 1997. Review for NAMMCO of manuscript by Anna Daníelsdóttir, entitled; "Review on the population genetic structure of North Atlantic minke whales (*Balaenoptera acutorostrata*)".

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Larsen, F. and Øien, N. 1988. On the discretness of stocks of minke whales at East and West Greenland. *Rep.int.Whal.Commn 38*:251-255.

NAMMCO/7/6. 1997. Scientific Committee. Report of the Fifth Meeting. Annex 3: Report of the Scientific Committee Working Group on Abundance Estimates.

Schweder, T. and Hjort, N. L. 1997. Indirect and direct likelihoods and their synthesis - with an appendix on minke whale dynamics. *Paper SC/49/AS9 submitted to the IWC Scientific Committee meeting, Bournemouth, 1997.*

Sigurjónsson, J. 1988. Studies on age and reproduction in minke whales (*Balaenoptera acutorostrata*) in Icelandic waters. Paper SC/40/Mi22 presented to the IWC Scientific Committee, May 1988 (unpublished), 33pp.

Sigurjónsson, J., Halldórsson, S.D. and Konráðsson, A. 1990. New information on age and reproduction in minke whales (*Balaenoptera acutorostrata*) caught in Icelandic waters. Paper SC/42/NHMi27 presented to the IWC Scientific Committee, June 1990 (unpublished), 17pp.