FINAL REPORT

OF THE

JOINT MEETING OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

AND THE

CANADA/GREENLAND JOINT COMMISSION ON CONSERVATION AND MANAGEMENT OF NARWHAL AND BELUGA SCIENTIFIC WORKING GROUP

9-13 May, 2001

Qeqertarsuaq, Greenland

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EXECUTIVE SUMMARY

The Scientific Working Group of the Joint Commission on the Conservation and Management of Narwhal and Beluga (JCNB) met May 9-13, 2001 in Qeqertarsuaq, Greenland. The meeting was held jointly with the Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic of the North Atlantic Marine Mammal Commission (NAMMCO). The group reviewed 16 working papers, containing information about stock structure, catches, harvesting patterns and practices, behaviour, and population sizes of beluga and narwhal in the Baffin Bay area (Figure 1). The meeting was further informed by material that was in working papers reviewed at a NAMMCO workshop held in spring of 2000. Six hunters from Greenland participated in the first two days of the meeting, and two hunters from Canada participated in most of the meeting. They provided both written and oral contributions, and their contributions of traditional knowledge were considered in discussions of each relevant agenda topic.

BELUGA

With regard to beluga stock structure the group considered information on both genetic analyses and levels of contaminants in the blubber. The information supported past conclusions that there are several stocks of beluga in the Baffin Bay area, and clarified some of the relationships among beluga from different areas. According to genetic analyses, Grise Fiord and Greenland sample populations were very similar and both of these groups differ from Southeast Baffin and Lancaster Sound populations. Grise Fiord and Greenland samples differ in organochlorine contaminant signature. Hunters agreed that different beluga populations occurred throughout the area, and thought that in some places there would be beluga from different populations at different times of the year.

The debate about the accuracy of the methods used to determine the age of beluga was considered. An analysis concluded that regardless of the interpretation of the growth layers in beluga teeth, there would be relatively little change in the estimated maximum rate at which the beluga population could grow. Hunters said that they thought there were older beluga in some areas than were represented in the catch data of the scientists. It was concluded that there was no reason to change current practices, and that the information on the ages of beluga in the catch would continue to be used in analyses of population status.

New information on catches of beluga in Canada and Greenland were presented. Landed catches in Canada between 1996 and 2000 averaged 38 beluga annually for communities hunting in the Baffin Bay and High Arctic areas. This is similar to catch levels over the past 25 years. Beluga are harvested in other part of Canada but these animals are not believed to be part of the Baffin Bay-High Arctic population. Reported catches in West Greenland in the 1990s averaged 577 beluga landed annually, somewhat higher than earlier years. Unreported catches are thought to occur in at least some years in some localities in West Greenland, and these may be substantial. The reported landings do not include

beluga killed-and-lost. New information on this source of death was reviewed at the meeting. The new information confirmed that killed-and-lost rates vary greatly with local conditions, and it will be hard to apply common correction factors to account for such mortality in assessments. However, the practice in recent assessments of taking each beluga reported in landings as representing 1.2 to 1.5 beluga killed by hunters was considered to still be the appropriate way to convert reported landings into total mortality due to hunting. Table 1 presents the catch statistics for beluga from selected Nunavut communities. Table 2 presents the catch statistics for beluga from West Greenland communities.

In past years the accuracy of the West Greenland aerial surveys in 1981 and 1982 had been questioned. New analyses of those surveys confirmed that the estimates were not the results of an error in the analysis. Revised estimates were similar to those previously reported. The early surveys may still not be completely comparable to the subsequent ones, because of the presence of larger pods in the 1980s and changes in survey equipment. The larger pods are thought to be easier to see than small pods, but harder to count accurately. Some hunters said that they thought beluga had changed their wintering distribution and possibly their fall migration path and timing. These concerns were discussed, and it was agreed that the expanded area surveyed in 1998 and 1999 would have covered the area used by beluga in winter as well as earlier surveys had, even if beluga had made some changes to their wintering distribution.

It was also noted that analyses of the survey of beluga in the Canadian High Arctic conducted in 1996 were being redone to provide better estimates of beluga abundance. The new analyses may change the estimate of 28,500 (95% CI = 13,900-58,200) beluga, reported in 1997, although the amount and direction of change in the estimate is not known at this time.

In response to a specific request from NAMMCO, the group considered the effect of taking account of ice entrapments on estimates of beluga populations and impacts of hunts on the populations. The concern here is that ice entrapments are accounted for in the assessments as a source of natural mortality. When hunters take beluga that are trapped in ice, if these beluga are included in catch statistics, it is accounting for mortality of the same beluga twice. Several analyses were conducted with catch data including beluga that had been trapped in ice, and the same data with the entrapped beluga removed from the catch data. The effects on estimates of population size and on the response of beluga populations to management measures were very small. It was concluded that, where possible, ice entrapped whales should be excluded from the historic catch records when catches are used to estimate population size. However, it was also concluded that their inclusion or exclusion would have a very small effect on the calculations. There was some discussion of how landings from ice-entrapped beluga in future years should be treated in analyses. It was concluded that this would depend on the frequency of such entrapments, the numbers of beluga killed, and how those numbers of belugas compared to estimates of sustainable yield from the stocks.

The group reviewed several different mathematical models for estimating how the population of beluga changed in West Greenland during the recent past, and predicting possible future stock sizes under various assumed management regimes. The models differed in many assumptions about the reliability of survey data from various years and the biology of beluga; particularly the way that reproductive rate and life expectancy may changed when the abundance of beluga is near the highest that the environment can support. The models also differed in mathematical details regarding how past knowledge and uncertainties about data and biology are used. However, the models did use generally the same catch data (some models ran in 2001 used catch data with improvements not available in 2000), and very similar values for rates of biological processes like birth rate and age at which females first give birth (Table 3).

Table 3. Biological parameters of West Greenland beluga. From: Heide-Jørgensen and Teilmann (1994).

Parameter	
Length at birth (cm)	150-160
Length of gestation (days)	330
Period of implantation	May
Period of births	April – May
Length at sexual maturity (cm)	
Females	345
Males	390
Length at physical maturity (cm)	
Females	386
Males	483
Age at sexual maturity (yrs)	
Females	4 – 7
Males	6 – 7
Pregnancy rate	0.31
Sample size	36

Some of these values were discussed extensively with hunters, who expressed doubts about some of the values used, particularly the interval between calves for mature females. These issues will be pursed in more depth during further discussions with hunters and possibly additional research. Also, some model runs were made assuming that beluga have much greater potential reproductive rates. However, such models either could not fit the data or could fit the data, but only by changing the value of some other aspect of beluga biology, and consequently produced population estimates within the range of the other runs.

Regardless of which model was used in the calculations, results of the population modelling are quite similar. Beluga in the West Greenland area in winter are depleted to less than 25% of their abundance in 1950s, and more likely are 20% or less of their abundance 40-50 years ago. Landed catches in the 1990s are not sustainable, and are the reason for the continuing decline. The models all estimate a sustainable harvest of around

100, and certainly not more than 150 beluga killed annually at current population size. This number includes both beluga landed and killed-and-lost. These results are quite similar to results presented last year to NAMMCO but the additional models that were considered allowed more alternative ideas about the survey data and beluga biology to be examined.

There are many sources of uncertainty associated with these estimates, and different sources affect different models in slightly different ways. In general, however, uncertainties about the biology of beluga, such as their maximum potential rate of reproduction and maximum life expectancy, contribute relatively little to estimates of the current state of the stock and its recent rate of decline. On the other hand, uncertainties about the true landed catches, killed-and-lost rates, and the survey estimates, contribute much more to the uncertainty about the recent dynamics of the beluga population supporting the West Greenland hunt.

Specific management objectives for this beluga stock have not been set by the Commission to guide in the choice of catch options. However, given its currently depleted state, on biological grounds it is desirable to halt the decline as quickly as possible, and to commence some rebuilding of the stock. For consistency with advice provided last year to NAMMCO, a series of scenarios were explored with one model, whose performance was similar to all the models explored and was not affected greatly by changes to key biological assumptions. The meeting considered eight different harvesting plans, ranging from immediate cessation of all hunting to continuation of harvesting at about the average catch of the 1990s (Table 4). Most of the options, though, focused on moving to the current estimate of sustained removal (total of the number landed and killed-and-loss) of 100 beluga and maintaining catches there for the rest of the decade. These options simply differ in the speed with which the hunt is reduced to 100 beluga killed annually. Some of these options were also presented to NAMMCO last year, and others were investigated at the request of the Greenland Government during this meeting.

Table 4. Probability that the abundance of West Greenland beluga will be lower in 2011 than in 2001 under various catch options. Eight options for future catches are provided for the period from 2001 through 2011. The probabilities are given in the range from 0 to 1 where 0 is no probability of a decline and 1 is certainty that the population will be lower in 2011. The population trajectories are presented for a 10-year projection. The model in use is Logistic, including the abundance in 1993 and removal of the ice entrapment effect in the catch for the estimation. No ice entrapments are assumed to occur in the projections.

Option	2001	2002	2003	2004	2005	2006	2007-2011	Probability
1	700	700	700	700	700	700	700	0.95
2	500	300	300	300	300	300	300	0.59
3	500	300	150	100	100	100	100	0.33
4	100	100	100	100	100	100	100	0.20
5	700	700	500	300	150	100	100	0.57
6	0	0	0	0	0	0	0	0.00
7	400	300	150	100	100	100	100	0.31
8	400	200	100	100	100	100	100	0.28

Options that include keeping catch at 700 beluga annually beyond 2002 all result in further declines in the population. Continuing catches of 700 beluga/year nearly guarantees a continued decline for the coming decade, with a risk of 25% or greater that all beluga would be hunted out of West Greenland. However immediate reductions in catch to even 500 beluga, and subsequent reductions to 100 beluga annually over one to three more years all produce a halt to the decline and a low risk that the population in 2011 will be lower than the population in 2001. The more rapidly the total catch is reduced to 100 beluga, the greater the chance that the population will have increased by 2011, and be on a path to further increase. Figure 2 illustrates the predicted population size for 2001 to 2011 under the various management options presented in Table 4.

It is clear from the figure that there is high uncertainty in the predictions of the beluga stock size under various management strategies. Such uncertainty is unavoidable when predicting the future of biological populations. However, the uncertainty should not detract from the clear overall message that catches in the 1990s are not sustainable, and on biological grounds, conservation of the stock requires that catches be reduced. The greater and faster the reduction, the more likely it is that the population will stop declining and begin to rebuild. Moreover, if accurate and precise surveys are done at regular intervals over that period, the uncertainty in the present predictions will be reduced greatly. Subsequently, if management makes appropriate adjustments based on the future survey results, there can be even greater confidence that the stock is being kept on the path that is chosen by the managers.

The meeting also identified several areas for future research:

- The highest priority is to conduct reliable surveys in West Greenland at regular intervals, with careful planning including local knowledge. The 2004 survey currently being planned would be an essential step.
- A series of focused discussions with hunters should be implemented, to review in greater detail their concerns about assumptions in the assessment models, and the values used for aspects of beluga biology, and to plan appropriate programs in response to their concerns.
- The re-analyses of the 1996 survey in the Canadian High Arctic should be completed, to evaluate whether or not the estimate of stock size is altered substantially from the estimate previously tabled.
- Co-operative programs with hunters, to improve the accuracy of reported landings and provide better data on killed-and-lost should be continued, and expanded to other communities where possible.
- Continue research on stock discrimination using contaminant and genetic study and satellite tagging.

NARWHAL

Narwhal stock structure was investigated using genetic analyses and contaminant levels in samples from diverse areas. The genetic analyses found only two or three genetic types that dominated all samples. The genetic analyses performed to date were not helpful in resolving detailed differences and relationships among narwhal from different areas. The contaminants information did show that narwhal from different parts of the Baffin Bay might carry different contaminant concentrations, indicating that the populations are not completely mixed. More work is required to resolve population structure. Hunters also reported that they are aware of different types of narwhal being present in some areas at different seasons.

There was no new information presented on age composition or biological rates of narwhal. We continue to be unable to tell the true age of narwhal beyond the age of sexual maturity. It also continues to be necessary to use data from beluga as estimates for narwhal biological traits. Until we know more about the narwhal, it may be necessary to assume that they live, growth and reproduce much like beluga.

New catch data from Canada were presented. The average annual Canadian catch of narwhal from the Baffin Bay narwhal population (1996-2000) is about 364 narwhal (Table 5). Catches from more southerly and westerly areas are thought to be from other stocks, resident in Canada and are not reported here. New data on narwhal killed-and-lost from a few communities were also presented. As with beluga, these rates are highly variable, depending on local conditions and hunting methods.

Progress on improving the historic narwhal catch data from West Greenland back to 1962 was also reported. This work is not complete, but it has revealed many unreliable periods in the catch record. The group agreed that efforts should focus on making the catch data from the last 10-20 years as complete and accurate as possible, because those data would be the ones that were important to assessments of current status. Although the data for 1980 to the present are not finalised, there is clear evidence that narwhal catches have increased in recent years in West Greenland, with reported landings averaging 577 annually between 1993 and 1999 (Table 4). These landings do not include non-reported catches, which are thought to have been large in at least some years; based on maktak sales in areas with no reported landings. They also do not include any correction for narwhal killed-and-lost. Taken together, these catch data indicate catches have probably exceeded 1000 narwhal annually for at least much of the 1990s.

The meeting reviewed what knowledge was available regarding the origin of narwhal that supported catches in different areas and seasons. Summer and early fall catches from many Canadian areas are supported by local summering aggregations, but even in that period, some Canadian catches are of migrating narwhal whose summer aggregations are uncertain. Large catches are taken in West Greenland from October through February and the origin of these narwhals is not known. Satellite tagging of stocks summering in Canada shows extensive migrations in the western Baffin area, before over-wintering in central Davis Strait. However no tagged narwhal from Canada migrated far enough east to be vulnerable to the fall hunts in West Greenland. Hunters also report that narwhal from Canadian waters do not contribute to catches in West Greenland. They also note that groups of narwhal with different appearances can be present in some areas at different seasons, and some of these groups travel widely within the Canadian coastal waters.

These results suggest that some Canadian summering aggregations may be exposed to hunting in different areas during their annual migration route, but they do not seem likely to be contributing to catches in West Greenland. Correspondingly, the fall hunts in West Greenland are exploiting stock units summering elsewhere, possibly further north along the Greenland coast, where they are also hunted. In both cases, hunting mortality does not seem to be distributed evenly among all narwhal aggregations in the Baffin Bay area, with the possibility of some units being harvested several times and in different locations during a given year. The available information has resulted in a preliminary map of what stock units may contribute to what hunts (Figure 3). Figure 4 illustrates a conceptual model of the relationships between stocks or aggregations and hunts in different areas for Canadian and West Greenland stocks of narwhal. This hypothesis has many question marks. These must be resolved if reliable scientific advice is to be provided on narwhal.

There are no recent reliable survey estimates for narwhal in either the Canadian High Arctic or West Greenland. The previous estimate of the narwhal summer aggregation in Prince Regent Inlet and Peel Sound obtained from the 1996 Canadian High Arctic survey for beluga is also being recalculated, using an improved method of analysis. New information was presented on the diving pattern of narwhal. Using new instrumentation, it was possible to measure the proportion of time narwhal spent at depths where they could be seen by aerial surveys, and the proportion of time when they would be so deep that they would be unlikely to be seen. Such information is essential for converting survey counts of narwhal into population estimates. The results demonstrate that the proportion of time that narwhal would be too deep to be seen during aerial surveys varies with local conditions such as water depth, but the observed values were similar the value of 1.8 used in previous analyses.

It was not possible to assess the status of narwhal in the Baffin Bay area at this meeting or the impact of the hunt on the present population. Further work is still required to produce the best possible recent catch history for the stock. Reliable surveys are also needed, in order to provide a population estimate for use in the analyses of effects of catches on the population. In the past, it was assumed that all narwhal in the Baffin Bay area comprised a single functional stock that was quite large, and removals from this stock were considered low relative to the size of the stock. Both of those views supported the conclusion that narwhal harvest may be sustainable. However, at the 1997 Scientific Working Group meeting, it was specified that an increase in narwhal harvest would require further refinement of the population estimate and evaluation of stock discreteness. At the same time, it was advised that there was little evidence that the stock could support an increase in harvest.

New information seriously challenges our previous confidence that the hunting has been sustainable. First, mortality due to hunting has increased, and when reasonable allowances are made for unreported catches and narwhal killed-and-lost, annual removals almost certainly exceed 1,000 narwhal. Moreover, the evidence for the existence of several stocks of narwhal in the area, rather than a single one, although not complete, is strong, and there is a high chance that some stock units are contributing to several hunts annually. Therefore there is a risk that at least some stock units may be over-harvested. There is also the concern that some of the largest catches, from West Greenland in the fall, are from stocks whose summering sites are unknown.

All these results argue strongly for a focused effort to assess these stocks as quickly as possible. It should be possible to complete improvements to catch data for both Canada and West Greenland within a year. Surveys are already planned for summer 2001, to count narwhal in Inglefield Bredning and Melville Bay, two potentially large summering aggregations whose sizes are unknown. With this information it should be possible to conduct an analytical assessment of narwhal in West Greenland by 2002.

Surveys of the Canadian summer aggregations should also proceed as quickly as possible. It may not be feasible to survey the entire area where narwhal may occur within a single year. However, a high priority should be given to the development of a comprehensive plan for such a survey. A team, including technical experts and knowledgeable local hunters, should be formed to develop the survey plan. Priority should be given to new surveys in areas known to support large abundance of narwhal, and areas where catches are concentrated. Satellite tagging and contaminants work should also proceed on as wide a basis as feasible to help clarify stock structure and seasonal migration patterns.

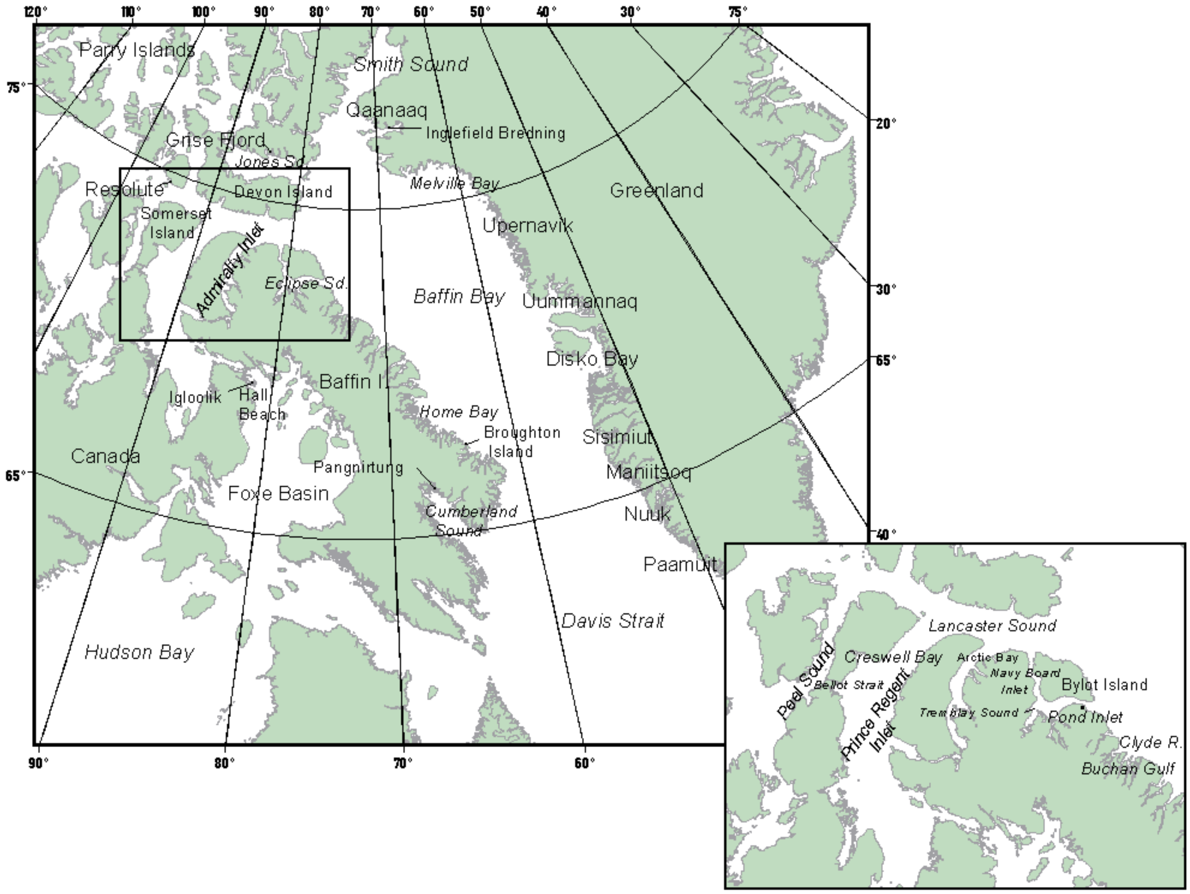

Figure 1. Map of the Canadian eastern Arctic and of Western Greenland localities mentioned in the report. (from: Heide-Jørgensen et al. 2001, Working Document SC/9/BN/9).

Figure 2. Predicted trajectories for the beluga population off West Greenland obtained after applying eight different harvest schedules. Solid lines represent the 50th percentile of the Bayesian posterior distribution; broken lines represent the 5th and 95th percentiles. Also shown are the initial and final values, if the lowest population level is not one of them, then it is shown separately. P values represent the maximum probability of decline from year 2001 to year 2011.

Figure 3. Map of the major summering aggregations (=stocks) of narwhals, the Uummannaq November aggregation and the Disko Bay winter aggregation. Narwhals from the Melville Bay, the Eclipse Sound and the Prince Regent Inlet-Peel Sound stocks have been tracked by satellite and their late summer and autumn movements to two different wintering grounds are shown. Other less important summering areas include those shown in italics on the map; Smith Sound-Kane Basin and adjacent fjords (Smith Sound Stock), Jones Sound (Jones Sound Stock), the waters around the Parry Islands (Parry Islands Stock) and Buchan Gulf, Home Bay and Cumberland Sound (East Baffin Small Stock). (From: Heide-Jørgensen *et al*. 2001; Working Document SC/9/BN/9).

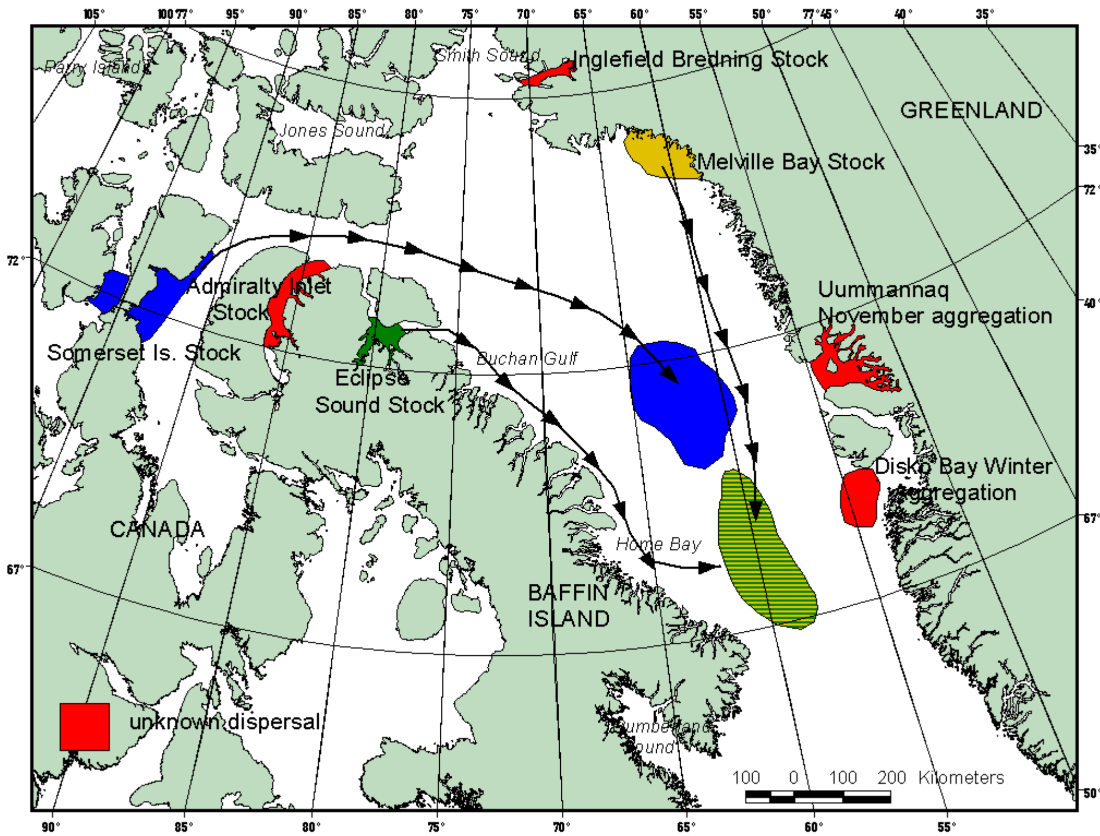

Figure 4. Conceptual model of the relationships between stocks or aggregations and hunts in different areas for Canadian and West Greenland stocks of narwhals. The dotted darts illustrate unknown levels of contributions to the hunt: 1) indicate probably a very small contribution, 2) indicate a minor contribution during winter months, 3) indicate that hunting may take place along the ice edge in spring, 4) indicate that one settlement, Savissivik, from the municipality of Qaanaaq hunt this stock, and 5) indicate that hunting takes place during autumn migration. (From: Heide-Jørgensen *et al*. Working Document SC/9/BN/9).

Table 1. Beluga Catch Statistics for Selected Nunavut Communities. The catch statistics represent reported landed catches. The data were not corrected for killed-and-loss and unreported landings. *There is uncertainty whether these communities harvest from the High Arctic 'Stock', therefore their harvest were not included in the totals. nr – indicates no record of harvest was reported to DFO.

	1996	1997	1998	1999	2000	total	average (1996-2000)	average (1977-2000)
***Hall Beach**	2	8	0	Nr	5	**15**	**4**	**9**
***Igloolik**	12	10	0	Nr	4	**26**	**7**	**28**
Qikiqtarjuaq	0	0	0	0	0	**0**	**0**	**1**
Clyde River	0	0	0	0	0	**0**	**0**	**1**
Pond Inlet	1	0	1	0	0	**2**	**0**	**1**
Arctic Bay	1	1	2	0	0	**4**	**1**	**4**
Resolute Bay	11	20	21	7	0	**59**	**12**	**8**
Grise Fiord	1	2	40	23	22	**88**	**18**	**14**
Pelly Bay	0	0	nr	nr	0	**0**	**0**	**0**
Gjoa Haven	0	0	nr	3	Nr	**0**	**0**	**0**
Taloyoak	15	nr	nr	nr	Nr	**15**		
TOTALS	29	23	64	33	22	**192**	**38**	**50**

Table 2. Catches of belugas from official reports by municipality with corrections for under-reportings (in parenthesis) for 1954 to 1998. The year 1999 only covers the period from January through September. The column 'under-reporting' shows the sum of the corrections for under-reporting or 'ALL' if it is a general correction factor for all areas. 'Disko Bay' includes the municipalities Kangaatsiaq, Aasiaat, Qasigiannguit, Ilulissat and Qeqertarsuaq.

YEAR	QAA-NAAQ	UPER-NAVIK	UUMMA NNAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT-QAQORTOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1954		16	61	1774	23					1874	1774
1955		10	3	275	11	1				300	
1956		9	8	373	29	5				424	
1957		6	11	391	95					503	
1958		3	4	182	35	1				225	
1959		12	12	243	42					309	50
1960		13	6	179	17		1			216	
1961	32	15	6	219	47	1	11	14		345	
1962	85	9	7	186	23	8	11			329	
1963	75	18	12	93	8	12	11			229	
1964	125	4	6	166	8	4	18			331	
1965	150	20	53	214	24	18	9			488	
1966		25	88	398	24	13	12	1		561	
1967		34	66	369	76	47	4			596	50
1968		97	65	1013	46	38				1259	234
1969		111	36	661	100	40	30			978	
1970	17	334	6	1133	10	24				1524	1050
1971	2	238	3	328	123	4	41			739	
1972		293	25	362	135	11	14	1		841	
1973		262	33	581	121		70			1067	
1974	21	195	15	512	135	8	25	2		913	
1975	(47) 50	150	19	268	130	4	33		(47)	654	

Table 2. Continued.

YEAR	AVANER-SUAQ/ QAA-NAAQ	UPER-NAVIK	UUMMAN-NAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT-QAQOR-TOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1976	(37) 50	77	12	953	72		48		(37)	1212	653
1977	(36) 50	240	49	379	43	13	65		(36)	839	
1978	20	104	44	452	77	5	17			719	
1979	25	250	22	379	35	12	18			741	
1980	30	191	100	412	109	45	1			888	
1981	76	343	95	340	62	23	78			1017	
1982	127	329	17	313	95	13				894	100
1983	(10) 53	(165) 233	19	(100) 194	(50) 99	2	1		(325)	601	
1984	21	(60) 333	15	(150) 352	(25) 25	16	1		(235)	763	220
1985	190	(135) 188	6	(75) 177	(25) 25	17	8		(425)	611	
1986		(335) 500	4	114		2			(335+ALL 75)	695	
1987		550	13	29		8	6		(ALL 90)	696	
1988		125		125					(ALL: 25)	275	125
1989		(311) 427	2	(18) 30		40			(339)	499	
1990	(2) 2	(346) 346	8	(591) 684		23			(939)	1063	500
1991	(50) 50	(400) 400		(100) 100					(550)	550	
1992		(661) 661		(26) 26					(687)	687	
1993	119	(169) 339	26	194	80	25	14	1	(169)	798	
1994	24	(90)188	19	239	105	38	3	2	(90)	618	
1995	84	(111) 194	18	301	116	56	10	1	(111)	780	
1996	7	86	21	245	131	26	25	1		542	
1997	16	162	28	243	101	7	18	1		576	
1998	51	162	38	312	125	19	30	7		744	
1999	21	42	14	116	30	4	6	6		239	

Table 4. Catches of narwhals from official reports by municipality with corrections for under-reportings (in parenthesis) for 1954 to 1998. The year 1999 only covers the period from January through September. The column 'under-reporting' shows the sum of the corrections for under-reporting or 'ALL' if it is a general correction factor for all areas.

YEAR	AVANER-SUAQ/ QAA-NAAQ	UPER-NAVIK	UUMMAN-NAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT - QAQORTOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1954										47	
1955		179	2	14	11	1				300	
1956		15	282	21						318	
1957		55	11	8						74	
1958		24	3	45		1				73	
1959										57	
1960										332	
1961										203	
1962										213	
1963										317	
1964										319	
1965										99	
1966										110	
1967										140	
1968										472	
1969										204	
1970										322	
1971										186	
1972		23								107	
1973		28								199	
1974		25								147	
1975	1	54	11	44		6		1	ALL: 149	266	
1976	9	22	27	57					ALL: 141	264	
1977	16	62	113	53	8	1			ALL: 134	387	
1978	110	56	183	262		1				612	

Table 4. Continued.

YEAR	AVANER-SUAQ/ QAA-NAAQ	UPER-NAVIK	UUMMAN-NAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT - QAQOR-TOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1979	120	22	132	100			3			377	
1980	130	61	146	120		4	1			462	
1981	118	83	140	249			18	1		609	
1982	164	59	162	76						461	
1983	(25) 135	(30) 72	164	(68)						439	
1984	274	80	245	(15) 66	1					666	
1985	(115) 115	(20) 34	(3) 39	67		1				256	
1986		81	97	23		36				237	
1987		145	334	25			1		(50)	505	
1988									(500)	500	
1989		17	288	2			5			312	
1990		27	1019	11						1057	
1991				40							
1992											
1993	144	66	301	75	10	6	4	8		614	
1994	183	59	297	268	6	14	7	11		845	150
1995	107	94	159	108	4	5	8			485	
1996	45	69	405	154	10	4	2	2		691	
1997	66	90	381	156	13	5	9	26		746	
1998	94	105	344	163	21	18	6	24		775	
1999	115	87	7	132	4	4	17	6		372	

Table 5. Narwhal Catch Statistics for Selected Eastern Canadian Arctic Communities. C – indicates communities with no quota for 1999 & 2000.

Community	Quota	1996	1997	1998	1999	2000	average (1996-2000)	Average (1977-2000)
Pangnirtung	40	19	2	2	41	50	23	19
Iqaluit	10	0	0	1	0	0	0	0
Qikiqtarjuaq	C (50)	23	50	50	81	137	68	46
Clyde River	50	10	15	27	4	48	21	26
Pond Inlet	C (100)	100	75	108	130	166	116	94
Arctic Bay	100	99	66	130	101	101	99	84
Resolute Bay	32	2	7	9	1	12	6	8
Grise Fiord	20	1	1	10	16		7	7
Taloyoak	10	0	0	0	0	3	0	1
Gjoa Haven	10	0	0	0	0	0	0	1
Hall Beach	10	1	2	10	0	0	3	3
Igloolik	25	5	3	29	4	2	9	14
Pelly Bay	10	7	15	8	0	30	12	3
TOTALS	487	267	236	384	378	549	364	306

FINAL REPORT

JOINT MEETING OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

AND THE

CANADA/GREENLAND JOINT COMMISSION ON CONSERVATION AND MANAGEMENT OF NARWHAL AND BELUGA SCIENTIFIC WORKING GROUP

Qeqertarsuaq, Greenland

9-13 May 2001

1. OPENING REMARKS

Chairmen Jake Rice and Øystein Wiig welcomed the participants (Appendix 1) to the first joint meeting of the Canada/Greenland Joint Commission on Conservation and Management of Narwhal and Beluga (JCNB) Scientific Working Group and the North Atlantic Marine Mammal Commission (NAMMCO) Scientific Committee Working Group on the Population Status of Narwhal and Beluga in the North Atlantic (hereafter referred to as the Joint Working Group or JWG).

In 1999, the NAMMCO Council asked the Scientific Committee to provide advice on the level of sustainable utilisation of West Greenland beluga in different areas and under different management objectives, and to identify the information that is required to carry out a similar assessment for West Greenland narwhal. The Scientific Committee established a Working Group that took up these questions at their meeting in Oslo in June 2000. The Scientific Committee accepted the conclusions of the Working Group (NAMMCO 2000), that:

- The beluga stock that winters off West Greenland is substantially depleted and that present harvests are several times the sustainable yield, and, if continued, will likely lead to stock extinction within 20 years.
- Harvest must be reduced to about 100 animals per year to have any significant chance of stopping the decline in the stock within the next 10 years. The benefits of a delayed or graduated reduction in harvest must therefore be weighed against the increased risk of continued stock decline, and several possible scenarios for harvest reduction were presented.
- Developing recommendations on the sustainable harvest of narwhal in Greenland will require significant additional research and cannot be done at present.

The Joint Working Group agreed to use the findings of the NAMMCO Scientific Committee (NAMMCO 2000) as a starting point for their deliberations. However, the JWG expected to draw its conclusions based on the merits of the deliberations at this meeting, and would not be bound *a priori* by conclusions of the NAMMCO meeting last year. The Joint Working Group received the following requests for advice from JCNB and NAMMCO:

Advice Request from JCNB:

- Recommend sustainable harvest level for beluga and narwhal under different management objectives.
- Are hunters from Nunavut and West Greenland hunting narwhal from the same stock(s)?
- Are the parameters used in Narwhal population model(s) adequate?
- What are the effects of potential errors in the ageing of narwhal (and beluga) on modelling of population growth rate and recommended harvest level?

- What are the effects of struck/lost on the recommended harvest level?
- What is the status of shared narwhal and beluga stocks and are the present harvest levels sustainable?

The advice request from JCNB is addressed in Appendix 4.

Advice Request from NAMMCO:

- Investigate the impacts of ice entrapments on: (1) population (develop model to simulate effects on population) and (2) catch statistics.
- Examine the occurrence of ice entrapment events and the relationship to sea surface temperature.
- Examine past aerial survey data for: (1) detection probabilities of small vs. large pods and (2) estimation biases due to differing pod sizes among years. Re-examine the quality of the 1981 and 1982 aerial surveys. Are these surveys useful for trend analysis?
- Review results on the potential stock structure of beluga in west Greenland; specifically evaluate tooth morphology data and tagging data that will be available late in 2000.
- Models currently assume a 50:50 sex ratio in the harvest. Include data on sex ratio of the harvest in the models; evaluate results of the model and predicted impacts on the population of beluga and on recommended quotas.
- Conduct a formal and independent review of the model (formulation and estimation techniques) presently used in the assessment.
- Establish a method for formally collecting "anecdotal" data on beluga distribution and abundance in Baffin Bay and Davis Strait. These observations could be from surveys conducted for other projects or from local ecological knowledge.
- In addition, the Council asked the Scientific Committee to evaluate the extent of movements of narwhal between Canada and Greenland.

The advice request from NAMMCO is addressed in Appendix 5.

2. ADOPTION OF JOINT AGENDA

The agenda was adopted as written (Appendix 2).

3. APPOINTMENT OF RAPPORTEURS

Daniel Pike, Patrice Simon and Michelle Wheatley acted as primary Rapporteurs for the meeting.

4. REVIEW OF AVAILABLE DOCUMENTS

Documents that were available for the meeting are listed in Appendix 3. In addition to the scientific documents, the Joint Working Group received input from resource users during a meeting with Greenlandic and Canadian hunters that preceded the detailed technical discussion at the meeting, and from Canadian hunters who participated throughout much of the JWG meeting (see 7.1 and Appendix 6).

5. BELUGA

5.1 Stock Structure

SWG-2001-4: de March, B.G.E., Maiers, L.D. and Friesen, M.K. An overview of genetic relationships of Canadian and adjacent populations of belugas (*Delphinapterus leucas*) with emphasis on Baffin Bay and Canadian eastern Arctic populations.

Our current knowledge of the molecular genetics of high Arctic beluga populations (West Greenland, Lancaster Sound/Barrow Strait, Grise Fiord) and populations that are related (southeast Baffin, Beaufort Sea), is presented. In general, genetic analyses confirmed the designation of putative stocks and suggested the existence of more stocks than previously described.

Comparisons based on mitochondrial DNA haplotypes showed that West Greenland (1992) belugas were significantly differentiated from Lancaster Sound/Barrow Strait, Kimmirut, Iqaluit, and/or Pangnirtung but not from Grise Fiord (AMOVA, table-wide α = 0.05). Grise Fiord haplotypes were not significantly differentiated from Lancaster Sound/ Barrow Strait and not from southeast Baffin locations in some years. Lancaster Sound and southeast Baffin collections were not significantly differentiated from each other. These patterns existed for most years within locations, however a few yearly collections within major locations had different patterns. The collections that differed were small groups with few haplotypes, most likely relatives.

Patterns in microsatellite differentiation were slightly different than those for haplotypes. West Greenland and Grise Fiord microsatellites were not significantly differentiated from each other. However, Greenland differed from Lancaster Sound and southeast Baffin Island, while Grise Fiord did not. In southeast Baffin Island, Pangnirtung samples differed from Kimmirut using both haplotypes and microsatellites. Iqaluit samples had intermediate genetic characteristics between Pangnirtung and Kimmirut.

Patterns of significant differentiation among collections within locations was believed to be due to a combination of temporal patterns, sampling of relatives, chance, seasonal hunting, small sample sizes, and actual differences among populations.

SWG-2001-5 Innes, S., Muir, D.C.G., Stewart, R.E.A., Heide-Jørgensen, M.P. and Dietz, R. Stock identity of beluga (*Delphinapterus leucas*) in eastern Canada and West Greenland based on organochlorine contaminants in their blubber. (Presented by R. Stewart)

Beluga caught by hunters from various hamlets in the Arctic differed in the concentrations of organochlorine contaminants in their blubber. By applying Canonical Discriminant Analysis (CDA) it was possible to separate all seven sampling locations from each other. Over 90 per cent of the samples could be classified back to their landing location based on the data transformations developed by CDA. The analysis provides evidence that most beluga caught by hunters from Grise Fiord are not the same as beluga caught while migrating along West Greenland. It also suggested that there might be more than one stock in West Greenland. There is a need to redefine the stock descriptions of some beluga in Canada and Greenland. This analysis suggested that “stock” or management unit for beluga is best described by their migration route.

SWG-2001-6 de March, B.G.E., Stern, G. and Innes, S. The use of organochlorine contaminant profiles for stock discrimination – weaknesses and strengths of multivariate methods. A case study with beluga (*Delphinapterus leucas*) hunted in three communities on Southeast Baffin Island.

Concentrations of 64 of 88 organochlorine (OC) compounds examined differed among beluga samples from the three southeast Baffin communities of Pangnirtung (PA), Iqaluit (IQ), and Kimmirut (KI). In comparing PA and KI, levels were significantly different in 64 of 88 OCs examined; PA and IQ in 67/88 OCs, and IQ and KI in 19/88. ($Pr \leq 0.05$). On the basis of these results alone, it can be concluded that three stocks are represented.

However, it was difficult to assess the amount of overlap or mixing among stocks. The degree of differences among the three locations depended on which OCs were used in the analysis. In the model with all 88 OCs, 98 of 124 belugas were correctly identified to their source location (50 of 63 from PA, 27 of 37 from KI, and 21 of 24 from IQ). The best separation of belugas from locations (110/124 correctly placed) was obtained by allowing the model to sequentially pick the OCs that separated the locations best. Other models less prone to statistical artefacts correctly identified approximately 83 of 124 belugas correctly, (mean of 45 of 63 from PA, 22 of 37 from KI, and 16 of 24 from IQ). Caution is advised in accepting the results of such studies before scrutinising the statistical methodology. These results are similar to genetic results that also do not give sharp stock boundaries.

Although we confirm that there are at least three separate stocks of beluga that are hunted in the Southeast Baffin Island area instead of the putative single stock previously used for management purposes, we do not believe we can assign belugas back to their stock with great certainty. This is similar to genetic results that also do not give sharp stock “boundaries”.

Discussion

These analyses confirm that West Greenland animals are different from most Canadian stocks, except Grise Fiord in some years, and Creswell Bay in 1993. Beluga samples collected in Creswell Bay in 1996 were different from West Greenland animals, although one of these beluga actually did migrate to West Greenland as determined from satellite tagging. There is nothing in these analyses that rejects the hypothesis that there is a conglomeration of different animals in the summers in the Canadian High Arctic and that they may be hunted as they pass near Grise Fiord and other locations. The proportion of animals sampled in Canada is tiny relative to the total population size, and many areas have not been sampled at all. The time of year in which an animal is sampled should be considered in interpreting the genetic and contaminants data. There is a need to build hypotheses and models based on migration patterns and then to interpret the genetic and contaminant results based on these hypotheses.

The stock structure within West Greenland is equivocal. While evidence from organochlorine signatures (SWG-2001-05) suggests that there is more than one stock wintering in West Greenland, genetic evidence (SWG-2001-06) does not. However it was noted that another genetic analysis (Pålsboll *et al.* in press) had found suggestions of stock structure in West Greenland. The JWG concluded that there was insufficient information to divide West Greenland stocks at present, although there is some indication that such a division may be warranted. It was noted however that division into two or more stocks would result in a lower sustainable yield than that from the single stock situation, and that the conclusion of the JWG was not conservative in this regard.

5.2 Age estimation

SC/9/BN/4 Report of the workshop to determine the deposition rates of growth layers in teeth of Beluga, *Delphinapterus leucas*.

It has been accepted that two Growth Layer Groups (GLGs) form annually in the dentine of beluga teeth since the initial suggestion of Sergeant (1959) that the deposition rate of beluga could be similar to that of sperm whales. Although at that time it was believed that sperm whales deposited two GLGs per year in dentine, this has long since been revised to one per year (IWC, 1969; 1980; Best, 1970; Gambell, 1977). Further investigation of deposition rate in dentine of three captive belugas attempted to resolve any uncertainty (Brodie, 1982; Goren *et al.*, 1987; Heide-Jørgensen *et al.*, 1994). However, none of the results and arguments for two GLGs per year that came from these investigations is unequivocal. The dilemma is thus that it is still uncertain whether one or two GLGs form annually, yet this criterion is essential to the correct interpretation of age from GLGs.

Recently, Hohn and Lockyer (1999), using information on two captive belugas of known history, one with tetracycline antibiotic marking in the teeth, presented new evidence that there is an equally likely deposition rate of one GLG per year, so reopening the question of deposition rate. The most effective agreed way to resolve the matter has been to convene a workshop of experts who are / have worked extensively on the aging of beluga (IWC, 2000; NAMMCO, 2000), to examine teeth from captive beluga that have spent the majority of their lives in captivity and in some cases have received tetracycline antibiotics that would have time-marked the teeth. Teeth from ten such animals were available to the workshop.

Differences among readers generally increased with the number of GLGs in the tooth. For half of the animals, three or four of the readings were close while the other one or two readings were not. For the other half of the samples, the readings ranged widely with no obvious tendency towards agreement. In some cases, this was related to the quality of the tooth section while in other cases the readers were definitely counting different structures as GLGs.

The workshop was not able to reach a consensus on GLGs count for most of the animals so a range of counts was agreed upon during the second day when the individual counts were being compared. These consensus minima and maxima were neither always the extremes of range nor within the range of the original counts by individuals. The ageing working group came to no definite conclusion.

SWG-2001-7 Richard, P. Population dynamics consequence of single growth layer group per year in belugas.

Questions have recently been raised on the validity of the use of two dentinal growth-layer-groups to age belugas. The JCNB Commissioners asked the SWG to consider if using such an assumption might lead to management decisions that are not sustainable. Results of comparisons of age structures that might result from one or two growth layers suggest that the two-growth layer assumption would lead to conservative management decisions.

Discussion

While there was some concern that the deposition of growth layers in captive animals might be different from that in wild beluga, it was noted that this is not the case with other captive toothed whales. It is important to resolve the question of whether beluga deposit 1 or 2 GLGs per year, and the JWG therefore supported the research recommendations in SC/9/BN/4. However, it was noted that the recommendation to administer tetracycline to live-caught and released free-ranging beluga was probably not realistic, as there would be potential human health issues if the beluga were consumed.

The model used in SWG-2001-7 resulted in a change in the instantaneous rate of increase from 3.4% for the 2GLG model to 3.7% for the 1GLG model, a much smaller increase than the group had intuitively anticipated. With the 1GLG model, age of maturity would change from 3 years of age to 6 years of age and adult survivorship would take effect at 2 years of age. Using the 2GLG model, belugas have been aged to 38 years. Under the 1GLG model, beluga would reach the age of 76 years, implying yearly survival of 99%.

The life history parameters that would be implied by the 1GLG model used in SWG-2001-7 raise concern that the assumption of 1 GLG per year may be unrealistic. The JWG agreed that, while there was no definitive proof for either the deposition of 1 or 2 GLGs per year, maintaining the present assumption of 2 GLGs per year would be the more conservative approach and was the recommended approach until definitive evidence for changing the assumption is presented.

5.3 Catches

5.3.1 Segregation of sexes and age groups in catches

No new information was presented on sex selection in the catch. Information on the effects of the age structure on the catch on projections of sustainable harvest is presented in Section 5.5.2 (Working Document SC/9/BN/7).

5.3.2 Struck and loss study in Nunavut

SWG-2001-8 Ditz, K. Catch statistics for narwhal and beluga in the Eastern Canadian Arctic (1996-2000).

Catch statistics for beluga in the Canadian high Arctic region for the period 1996-2000 are presented. The landed beluga catches are reported by community and are not corrected for under-reporting or killed-but-lost animals. In general, it is believed that the reported harvests for beluga are accurate although there may be under-reporting in some communities. The Canadian communities that are considered to harvest beluga from the high Arctic stock(s) are Qikiqtarjuaq, Clyde River, Pond Inlet, Arctic Bay, Grise Fiord, Resolute Bay, Gjoa Haven, Pelly Bay and Taloyoak. The averaged reported landed catch was 38 beluga per year for the period 1996-2000. The harvest did not change significantly compared with the 1977-1995 average harvest.

There is additional harvesting of beluga in other parts of Nunavut, in Nunavik (northern Quebec) and in the Northwest Territories but hunters in these areas are not believed to be harvesting beluga that from the high Arctic stock(s).

In 1999, a new management system was introduced in Iqaluit and Kimmirut, 2 southeast Baffin communities. Under this new management system, the government-imposed quotas were removed and replaced with a community-based system in which the communities were asked to develop rules and guidelines to ensure the proper management and conservation of the beluga. Hunters were asked to report all the animals that were landed as well as the animals that were killed-but-lost. Beluga that were wounded superficially and which the hunters predicted would survive were reported as "wounded and escaped".

The reported ratio of killed-but-lost to landed beluga was 9% and 11% for the two communities in 1999 and 18% and 7% in 2000. If it is assumed that all whales reported as "Wounded & Escaped" in fact are lethally wounded, these ratios rise to 51% and 16% in 1999 and 18% and 15% in 2000. The reported loss rate results are still preliminary and the reporting system is being reviewed to improve hunters' participation. Effort to collect information on loss rates using different hunting techniques and under various conditions will be made. The results of this study will be used to identify areas where hunting methods can be modified to reduce the loss rate. As more information is collected, the result will be used to correct catch estimate under various conditions.

Discussion

The JWG welcomed these new data on loss rates and encouraged the continued collection of this information. Loss rates are highly variable with hunt type, environmental conditions and hunter skill, and may vary greatly from year to year at the same location. Therefore the application of loss rates to correct past harvest data will have to be done with caution. The JWG noted that the newly reported loss rates were within the range of those found in other studies (Burns and Seaman 1986, Weaver and Walker 1988, Roberge and Dunn 1990) and those used in modelling studies of West Greenland beluga (NAMMCO 2000).

5.4 Abundance

5.4.1 Re-examination of past aerial surveys

SC/9/BN/6 Laidre, K.L. and M.P. Heide-Jørgensen. Re-examination of the index estimates of beluga abundance off West Greenland 1981 and 1982.

In 2000, NAMMCO recommended the 1981 and 1982 aerial survey of belugas in West Greenland be re-examined for trend analysis. The original abundance estimates, reported in Heide-Jørgensen *et al.* (1993), did not fit a population model that utilised abundance estimates from surveys in the 1990s and resulted in estimates of population parameters that were inconsistent with beluga life history information. This re-analysis was conducted to verify if the 1981-82 abundance estimates were not results of an error in the original data analysis. In 1981, the revised abundance estimate for all five strata (including all transects) combined (3,045 CV=27) was smaller than that reported for all five strata in Heide-Jørgensen *et al.* (1993) (3,615 CV=33). In 1982, the revised abundance estimate for all five strata (including all transects) (2,209, CV=19) was not different from the estimate reported in Heide-Jørgensen et al. (1993) (2,120, CV=19). In 1981, the pod rate for all strata were 0.087 pods per kilometre (CV=0.30) and in 1982, 0.076 pods per kilometre (CV=0.22). The combined pod rate in the 1998-99 surveys combined was 0.011 pods per kilometre (CV=0.21). In the 1990s, the mean pod size (ranging from 2.4 to 3.3) was about half that of 1981 and 1982. The revised estimates reported here provide an improved abundance estimate for 1981 and 1982.

Discussion

The re-analysis demonstrated that the estimates reported by Heide-Jørgensen *et al.* (1993) were not a result of calculation error, and the revised estimates are close to the originals. However, the JWG noted that there were differences in methodology between the 1981/82 surveys and those conducted in later years, including:

- The plane used in 1981/82 flew faster and lower than the plane used in later surveys.
- The plane used in 1981/82 did not have bubble windows, which resulted in a blind area near the trackline;
- Different observers were used in the earlier surveys.

The first two differences may have decreased the efficiency of the earlier surveys; the last one may have affected in an unknown way.

Although no effect of pod size on sightability was detected in the later surveys, it was noted that pod sizes in 1981/82 were larger on average and included pods outside the size range of those observed in more recent surveys. It was considered likely that these larger pods would have had a higher sightability and that the earlier surveys would therefore have a positive bias compared with those conducted in the 1990's. It was also noted that the estimation of pod size becomes less reliable with larger pods, which may have resulted in a higher degree of error or bias in the earlier surveys.

It was therefore concluded that the surveys conducted in 1981/82 may not be directly comparable to the index surveys conducted in the 1990's. However, the JWG could not rule out that the earlier surveys did in fact reflect actual abundance, so they were used in subsequent population modelling. The JWG considered it unlikely that any further analyses could be carried out to further clarify the issue.

5.5 Ice entrapment events

5.5.1 Relationship to sea surface temperature

No information on this topic was presented

5.5.2 Ice entrapment mortality and its significance for population assessment

SC/9/BN/7 Alvarez, C. and Heide-Jørgensen, M.P. Alternative perspectives in the assessment of the beluga hunt in West Greenland

This paper addressed the influence of the revised estimates of relative abundance for 1981 and 1982 and the effect of ice entrapments on alternative options for future catch policies in West Greenland. The revised estimates from the 1981 and 1982 surveys from SC/9/BN/6 were included in initial runs of the model. Other variations in the input data included an additional estimate of absolute abundance for the years of 1993-94 and a revision in the catch statistics from 1954 to 1999. In addition, a comparison was made of the results obtained if the assessment is conducted using a logistic model or an age structured model.

The recalculated indices for 1981 or 1982 were not very different from those reported previously. Their inclusion in the model resulted in unrealistically low estimates for the rate of population increase (*Rmax*), as had been found previously (NAMMCO 2001), and they were dropped from subsequent model runs. Results indicated that the uncertainty in model structure have a stronger effect that any other aspect that was investigated. The reason for this result may be due to the uncertainties associated to basic parameters of life history that accumulate within the model and how they interact with the uncertainty associated to the estimates of abundance. Ice entrapment did not have a great impact either in the estimation of population dynamics parameters or the estimation of management parameters after forecasting projections.

The main conclusion of this paper was that results of assessment analyses and the resulting advice depend on the assumptions that are accepted as valid. Because there is not sufficient and satisfactory information on all life history parameters and because an assessment model does not need to include all details of the real population biology, we considered that the current use of a generalised logistic model is appropriate for the definition of alternative catch options. However it is recommended that the performance of specific policies are also evaluated using an age structured model to learn about the consequences of different selectivity patterns in the hunt and the sensitivity of our management tools to variations on the knowledge of life history.

Discussion

While the correction of catch data for past ice entrapment events and the inclusion of ice entrapment events in model projections had a relatively small effect on model predictions, the JWG noted that only historically recorded ice entrapment events had been used to derive their frequency and magnitude, and that these events may be more frequent than recorded in the historical record. Nevertheless it is likely that all events that resulted in harvest were recorded. Therefore it was considered that these events did not have great significance for population assessment.

The age structured model resulted in higher estimates for the maximum rate of increase (*Rmax*) and the maximum sustainable yield rate (MSYR) than the logistic model. However, the finding that the stock is depleted to around 20% of the level in the early 1950s is consistent with other models. The age-structured model predicts a much higher risk of depletion in 10 and 30 years under the harvest scenario considered than the logistic model. However the JWG considered that there were uncertainties in the implementation of this model, and that it required more development. Issues in ageing may affect age structure models and need to be resolved.

5.6 Update of assessment

5.6.1 Sustainable harvest levels

SWG-2001-9 Innes, S. Population size and yield of Baffin Bay white whale stocks (*Delphinapterus leucas*). [Presented by Rob Stewart]

Previous analysis of the population size of beluga that migrate from West Greenland to waters adjacent to Somerset Island concluded it had declined by about 62% between 1981 and 1994. This paper used a different statistical approach, Sampling, Importance Resampling (SIR) Bayesian analysis to estimate stock sizes and yields. It uses distributions for various parameters, sampled repeatedly, to produce a distribution of likely estimates. This analysis estimated that the stock size of beluga wintering off West Greenland in 1997 was 5230 (3090-8910, 95% Credibility Interval - CI), about 11% (4-23% CI) of estimated carrying capacity. The estimated decline between 1981 and 1994 was 56%, similar to the 62% previously estimated. Projected to 1999, the model predicted sustainable median landings of about 96 (21 to 271, 95% CI) with a total kill of 160 (27-489, 95%). The stock size estimate for the beluga wintering in the North Water was 23130 (5580-39200, 95% Credibility Interval) but there is no information about the population biology of these whales. The estimated yield for the North Water stock was 584 (36-2105, 95% CI) beluga killed.

Discussion

The JWG considered that the Innes model was useful because it used a methodology and information sources markedly different from those used in other models. Unlike other models, the Innes model used the estimates from the 1996 summer survey in the Canadian High Arctic, and generated an estimate for the stock wintering in the North Water. Most parameter estimates produced, including maximum rate of population increase (R_{max}) and sustainable yield for West Greenland, are consistent with other models considered.

The model also provided estimates of two parameters that have been difficult to determine directly. These are the adjustment factor for the survey index estimates and the number of whales that are killed but not recorded in the catch statistics. The parameter for killed-but-lost and underreporting is higher than killed-but-lost ratios reported and used in other analyses. However, as the parameter incorporates both killed-but-lost and whales that are landed but not reported, this was expected. The posterior distribution of the adjustment factor that converts the index for the surveys off West Greenland to an estimate of absolute abundance had a median of 0.151, somewhat less than the mean of 0.175 which was the correction factor developed empirically for the 1998-99 surveys. However, this adjustment factor also adjusts for whales that were outside of the index survey area, and so does not correspond directly to the empirical survey correction.

The JWG encouraged further development and refinement of this model. A revised survey estimate for the 1996 summer survey is being developed and should be incorporated. The revised survey estimate for the 1998-1999 West Greenland Survey should be used instead of just the 1999 survey.

SC/9/BN/8 Witting, L. On model uncertainty in the assessment of Beluga in West Greenland: Inertia versus traditional density regulated dynamics.

Density regulated models of the beluga off West Greenland have encountered difficulties in explaining the strong downward trend in the time-series of relative abundance estimates. To explain the data, in particular the earlier 1981/82 index estimates, a maximum sustainable yield rate (MSYR) at the lower bound of reality had to be assumed. This study applied an alternative model of inertial dynamics, which is a density-regulated model with superimposed density dependent changes in the intrinsic component of the life history. This model allows for a continuum of dynamics; ranging from the monotonic return to population equilibrium predicted by traditional density-regulated models to cyclic dynamics with damped, stable, and unstable cycles. For the full range of likely MSYRs, the model of inertial dynamics fit the downward trend in the abundance data but this might lead to unrealistic estimates for other parameters in the model.

The management related conclusions are comparable with those of the other models. The inertial model estimates that the current population size is approximately 20% of the expected abundance had the stock not been hunted. The model also estimates that the population can only be expected to recover if total annual removal is reduced to approximately 100 animals.

Discussion

The JWG noted that this model was consistent with other models considered in its estimate of depletion and present sustainable yield. This model therefore does not affect the conclusion that the stock is depleted and that present catches exceed sustainable yield. The fluctuation of life history parameters such as fecundity in the model would however have implications for sustainable yields over the longer term. While the incorporation of inertial dynamics to explain the decline in the index surveys was regarded as a useful approach, it was noted that it would be difficult to gather the data necessary to confirm the mechanisms incorporated in the model. The fit of the model to the index survey series, including the 1981/82 surveys, was not considered sufficient evidence to adopt such a model since the lack of fit of the 1981/82 surveys in other models can be explained by other hypotheses.

5.6.1.1 General discussion of sustainable harvest

Greenlandic hunters had pointed out to the JWG that they believed that belugas had changed in distribution, and were now wintering farther offshore and in areas farther south than in previous years. If this were true, it could explain the apparent decline in the abundance index from 1981/82 to the 1990’s. The JWG agreed that while it is conceivable that the apparent depletion of the stock could have been caused by a shift in winter distribution out of the survey area, there is no direct evidence to support this hypothesis.

The distribution of beluga in the core index survey area has not changed over the 18 years surveys have been conducted. The surveys were extended to the south to Paamuit and Kap Farvel in 1998 and 1999, but no additional animals were found in this area. There are no quantitative observations from other sources or surveys to indicate that beluga are occurring in significant numbers outside the survey area. In addition, even if there has been a shift in distribution, it may have been to an area where they are no longer supporting the Greenlandic harvest. The JWG therefore concluded that the substantial depletion observed in the index survey area should not be attributed to a distribution shift unless direct evidence for such a shift is provided.

Hunters noted that although the models predicted extinction at present harvest levels, they would not hunt the stock to extinction. It was not discussed whether this would be due to a voluntary change in hunting behaviour or forced on harvest rates by catch per effort rates too low to support a viable hunt. There was no examination of the capacity of the hunt to detect and kill beluga at very low abundance.

5.6.1.2 General conclusions

All analyses examined agree that the stock is depleted to 20% to 25% of carrying capacity, and that the present sustainable yield is about 100 beluga per year. The JWG supported the conclusions of the NAMMCO Scientific Committee (NAMMCO 2000) that the West Greenland stock is substantially depleted and that present harvests are several times the sustainable yield. The model predicts that if harvests are kept at current level, there is a high risk that it will lead to stock extinction within 20 years. A significant reduction in catch will be required to halt the decline of this stock and allow recovery. The parameters used in the model are presented in Tables 1 and 2.

Table 1. Boundaries for prior distributions of parameters estimated from data

	Lower	Upper
Juvenile Survivorship	0.5	0.9
Adult Survivorship	0.9	0.999
Original Population Size	4915	984609
Index Rescaling Parameter	0.01	2

Table 2. Parameters values assumed known in age structured model.

Age at Sexual Maturity	4
Calving Interval	3
Age Early Risk Over	2
Siler Parameter	1
Siler Parameter	0.35
Age Late Risk Starts	40
Shaping Parameter	3

5.6.1.3 Catch Options

The JWG chose to build on the model used by the NAMMCO Scientific Committee (NAMMCO 2000) to assess the risk associated with various catch options. The JWG concurred that the primary management objective to be addressed should be to arrest the decline of the West Greenland beluga, and that all catch options should be judged against this objective. Further objectives, such as allowing the stock to recover to a specified level within a specified time, can be developed after this primary objective is achieved. It was also decided to present options incorporating a delayed or gradual reduction in catch, since these were considered the most likely options to be adopted.

The model used was the same as that used by the NAMMCO Scientific Committee (NAMMCO 2000) with the following developments:

- The correction for under-reporting and killed-but-loss was estimated for each catch area and year since 1952 and was, on average, 1.2 times the reported landed catch.
- The documented harvest for 1998 was used in the model. The value used for 1999 was still incomplete, but was used.
- Catches were corrected for mortality in ice entrapment, but future ice entrapments were not projected in the model.
- Two additional catch options were considered.

Table 3 shows the probability that the stock size in 2011 will be lower than the stock size in 2001 under the various catch options considered, and Figure 1 shows the probability distributions of stock trajectory to 2011 under these options. If the management objective is to arrest the decline of beluga numbers, this objective will be met most quickly by ceasing beluga harvesting immediately (Option 6). On the other hand, harvesting at present or higher rates (Option 1) will cause continued stock decline. Management options between these two extremes were also explored including options specifically requested by the Government of Greenland (Option 7 and 8; Table 3).

Table 3: Probability that the abundance of West Greenland beluga will be lower in 2011 than in 2001 under various catch options. Eight options for future catches are provided for the period from 2001 through 2011. The probabilities are given in the range from 0 to 1

where 0 is no probability of a decline and 1 is certainty that the population will be lower in 2011. The population trajectories are presented for a 10-year projection. The model in use is Logistic, including the abundance in 1993 and removal of the ice entrapment effect in the catch for the estimation. No ice entrapments are assumed to occur in the projections.

Option	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007-2011**	**Probability**
1	700	700	700	700	700	700	700	0.95
2	500	300	300	300	300	300	300	0.59
3	500	300	150	100	100	100	100	0.33
4	100	100	100	100	100	100	100	0.20
5	700	700	500	300	150	100	100	0.57
6	0	0	0	0	0	0	0	0.00
7	400	300	150	100	100	100	100	0.31
8	400	200	100	100	100	100	100	0.28

It is apparent that the total number of beluga killed by hunters must be reduced to about 100 animals per year to have any significant chance of stopping the decline in the stock within the next 10 years. Delay in implementing harvest reductions increases the risk of continued stock decline, as illustrated by the stepwise harvest reduction options (Options 2, 3, 5, 7 and 8). In addition, the stepwise reduction options result in a further decline before the stock begins to recover.

The JWG again emphasised that continued abundance surveys at roughly 5-year intervals will be essential to monitor the progress of the recovery of the stock. An additional abundance estimate will allow greater precision in projecting the stock size, and thus allow managers to adjust catch levels if required to maintain the selected recovery trajectory.

Figure 1. Predicted trajectories for the beluga population off West Greenland obtained after applying eight different harvest schedules. Solid lines represent the 50th percentile of the Bayesian posterior distribution; broken lines represent the 5th and 95th percentiles. Also shown are the initial and final values, if the lowest population level is not one of them, then it is shown separately. P values represent the maximum probability of decline from year 2001 to year 2011.

5.6.2 Review of research requirements

SC/9/BN/5 Heide-Jørgensen, M.P. A proposal for a renewed effort to determine the stock identity of belugas summering in the Canadian high Arctic.

Despite considerable effort, both satellite tracking and genetic studies have failed to clarify the stock structure of belugas summering in the Canadian high Arctic sufficiently to determine which fraction migrates to West Greenland for wintering and where it concentrates in summer has not been answered. This is of particular concern since the harvest of belugas in West Greenland is the most significant management question for both the JCNB and NAMMCO. This paper presents a proposal for a new effort to elucidate the origin of the large number of whales presently being harvested in West Greenland. It is proposed that a two-year field period should be launched to tag a large number of belugas and to track them through the winter. Areas that have not previously been sampled will be given priority and samples for genetic analyses will be provided as well. The results of the tracking will be used to develop a model for the dispersal of the belugas that can be tested by the genetic studies.

Discussion

The JWG noted that it would be more logical to tag animals in their wintering areas to determine where they go in the summer. However, this has been attempted in Greenland and found to be logistically unfeasible. The JWG therefore supported the work proposed in the working paper SC/9/BN/5.

<u>Ranked Research Recommendations</u>

1. A new abundance and trend estimate (index survey) will be needed in 3 to 5 years. The next survey should include areas to the north of Disko Island and to west of the current index survey area. The survey methods should be identical to previous surveys to facilitate comparison. The use of video for the estimation of correction factors should be continued.
2. The plan for a satellite tagging program with the primary objective of determining the summering area and migratory patterns of West Greenland beluga developed in working paper SC/9/BN/5 should be developed and supported. In addition, beluga diving data should be collected from the West Greenland wintering area in March, for use in estimating correction factors for abundance estimates.
3. Stock delineation efforts using genetic and contaminant analyses should be continued. In particular the contaminant analyses should be re-evaluated to determine if changes in laboratory techniques or sampling methods have influenced the results. The JWG encourages further collection of samples for genetic and contaminant analyses. The availability of skin samples in March from areas north and south of the hiatus in beluga distribution (near 67^{o} 30’) in the West Greenland index survey area should be determined. If a sufficient number of samples are available, genetic analyses for stock structure should be conducted. Any new informative techniques should be explored.

4. Studies should be conducted to determine whether 1 or 2 growth layer groups (GLGs) are deposited annually in beluga teeth. In this regard the research recommendations in working paper SC/9/BN/4 are supported.

6. NARWHAL

6.1 Stock structure

SWG-2001-10 de March, B.G.E., Maiers, L.D and Tenkula, D. A preliminary analysis of the molecular genetics of narwhal *(Monodon monoceros*) samples collected from Canadian and adjacent waters from 1982-2000.

The molecular genetics of 301 narwhal samples collected from hunts in 9 communities in Canada and 2 locations in Greenland were examined. Other than a weak differentiation of samples from Repulse Bay from Baffin Bay samples, there is little evidence of genetic differentiation among the populations examined. This result may be due to small sample sizes. However, even if sample sizes were increased, there still would be considerable genetic overlap between locations examined. In addition, we believe that genetic differences can be convincingly demonstrated only if they can be shown to persist through time. The results of this study, though, do not necessarily negate the existence of different stocks.

Discussion

It is already apparent that genetics will not be as strong a tool for stock delineation as it has been for beluga. However the JWG encouraged the completion of genetics analyses on the remaining samples as soon as feasible. Dr. Brigitte de March also presented preliminary results that indicated that contaminant analyses may be a more powerful tool for stock delineation of narwhal, and encouraged further work in this area.

SC/9/BN/9 Heide-Jørgensen, M.P., Dietz, R., Laidre, K.L. and Richard, P. Do narwhals from Canada contribute to the harvest in West Greenland?

A model of the dispersal of narwhals in Baffin Bay and adjacent waters is proposed based on a review of recent genetic studies, satellite tracking and compilations of local knowledge. The default definition of a stock or management unit should be based on the assumption that disjunct summering aggregations of narwhals are separate stocks with little or no exchange between whales from other summering grounds. Nine coastal summering concentrations of narwhals, proposed to constitute stocks, are identified. A late fall and an early winter concentrations of narwhals in West Greenland have been tentatively classified as ‘aggregations’ of unknown stock identity. Hunting of narwhals by Inuit communities in Canada and Greenland will impact the stocks and aggregations on various levels depending on the temporal dispersal of the whales. To assess the sustainability of the harvest in these areas, it is important to identify which stocks and aggregations contribute to which harvest. Nine major hunting grounds in Canada and Greenland are identified and several stocks appear to be harvested at two or more hunting grounds. Apparently whales from Canadian stocks have a low risk of being taken in West Greenland.

Discussion

The JWG welcomed this synthesis as an important step forward in the stock delineation of Baffin Bay narwhal and determining which stocks are hunted where. Significant questions remain, however. It is still not known which summer aggregation supplies the heavily harvested November aggregation at Uummannaq and winter aggregation in Disko Bay: potential candidates include the East Baffin and Admiralty Inlet summer aggregations. Other summer aggregations, such as Eclipse Sound, Admiralty Inlet and Somerset Island, may be hunted by communities outside of the aggregation areas during their spring and fall migrations. Several aggregation areas, particularly Inglefield Bredning, Admiralty Inlet and the East Baffin, should be a high priority for further satellite tracking work. Additional genetic and contaminants studies may also be useful to further advance the dispersal model for Baffin Bay narwhal.

6.2 Age estimation and life history parameters

No new information on this topic was available to the JWG. In particular, a method for ageing narwhal past the age of maturity is required, and the JWG encouraged research to develop such a method.

6.3 Catches

SC/9/BN/10 Heide-Jørgensen, M.P. Reconstructing catch statistics for narwhals in West Greenland 1862-1999.

Information and statistics including trade statistics on catches of narwhals in West Greenland since 1862 were presented in working paper SC/9/BN/10. Detailed statistics split by narwhal hunting grounds are missing for most of the years. For a future assessment of the sustainability of narwhal catches it is required that: i) statistics are broken down by municipalities and in some cases by settlements to allow pooling by hunting grounds, ii) statistics are corrected for underreporting, and iii) that correction factors are applied for different hunting situations.

Discussion

The JWG welcomed this information and encouraged Heide-Jørgensen to further develop the compilation. However, it was recognised that catch records are highly inaccurate for some time periods and it may prove impossible to retrieve a complete catch history. The Piniarneq catch reporting system began in 1993, and since then catch records have been more complete. The JWG noted with concern that records of the trade in maktak indicate that catch records for Qaanaaq, Upernavik and Uummannaq are incomplete by a substantial margin, and recommended that reporting be improved in these areas.

Landed catches of narwhal were presented for several communities in the Canadian Eastern Arctic in working document SWG-2001-8 (see Section 5.3). These reports do not include corrections for underreporting or killed-but-lost whales. Underreporting of narwhal catches is likely not a large problem for Canadian communities, since most communities hunt under a tag/licensing system. However it is possible there was some underreporting of female narwhal in the catch.

The average yearly reported landed catches for the period 1996-2000 is 364 for Baffin Region communities. Narwhal harvest in Nunavut has increased in recent years. There is additional harvesting of narwhal in other parts of Nunavut (Hudson Bay communities) but they are not believed to be harvesting narwhal from the Baffin Bay population.

6.4 Struck and loss Study in Canada

The program for collecting information on the proportion of narwhal that are killed-but-lost, or wounded but lost from Canadian narwhal hunting communities described in SWG-2001-8 (see section 5.3.1) has begun to provide valuable information on these important parameters. The reported ratio of killed-but-loss to landed narwhal is between 6% and 31% for 4 communities in 1999 and 2000. These ratios rise to between 19% and 86% if it is assumed that all narwhal reported as "wounded & escaped" are in fact lethally wounded. The ratios of killed-but-lost to landed narwhal reported in this study are similar to the ranges that have been reported in previous studies. However the program is at an early stage and is ultimately directed in reducing losses. The data require additional analyses to show the loss rates in various types of hunts using different methods. The JWG strongly encouraged the continued collection and analysis of this information. Care should be taken in using the results to correct total removal from historic harvest, as historical changes in hunting practices and the management regime for narwhal could be expected to affect loss rates.

6.5 Abundance

No new abundance estimates for narwhal were presented.

6.5.1 Review of survey plans

SC/9/BN/11: Laidre, K.L., Heide-Jørgensen, M.P. and Dietz, R. Diving behaviour of narwhals (*Monodon monoceros*) in the Canadian Arctic determined by Time Depth Recorders (TDRs).

In August 1999 and 2000, four suction cup attached TDRs were deployed and retrieved from free ranging narwhals in Tremblay Sound, Baffin Island and Creswell Bay, Somerset Island, Canada. The TDRs were attached to a flotation device consisting of three oval net buoys held together with 6mm nylon pins, made to withstand pressure at over 400 m. The tags remained on the whales for between 12 and 33 hours. The two whales tagged in Tremblay Sound exhibited clear differences in diving behaviour, which could not be attributed to sex or body size, as both whales were males of similar size and length. In Tremblay Sound, narwhal 1 made longer, deeper dives (mean depth = 50.8 m, mean duration = 4.93 min) and spent less time at the surface than narwhal 2 (mean depth = 20.3, mean duration = 2.55 min). In Creswell Bay, the two narwhals (3 and 4) had similar diving behaviour. Both whales generally made short, shallow dives (mean depths = 20.75 m and 34.4 m, mean duration = 3.35 min and 4.26 min), especially when compared to the whales tagged in Tremblay Sound, which had dove at depths and for duration almost twice those in Creswell Bay. The percentage of time spent within specific depth bins was calculated for both narwhals tagged in Tremblay Sound. Only these two tags provided the resolution necessary for this analysis. In Tremblay Sound, narwhals 1 and 2 spent 30.3% and 52.9% of their time in depths < 5 m. These data are fairly consistent with other studies. Correction factors to 5 m depths, generally applied to aerial survey data to account for whales that are below depths at which they can be counted from the air, were calculated as 3.3 and 1.9.

Discussion

The JWG found this information useful and recommended that TDR deployments should continue in conjunction with other tagging projects. It can be expected that diving activities will be site-specific and related to bathymetry and the activities of the animals. It was considered likely that there was a period of time after the initial deployment when the disturbance of the animal from the tagging process would render the diving data unreliable for the calculation of correction factors, and this initial period should be detected and removed from the analysis. It was also considered useful to have simultaneous monitoring from both TDRs and satellite-linked TDRs on the same animal, in order to calibrate and ground-truth the diving data received from satellite-linked TDRs.

SWG-2001-11: Richard, P.R., Proposal for winter or summer surveys of Baffin Bay narwhals

Narwhals from the "Baffin Bay population" winter throughout Baffin Bay and Davis Strait and summer in several aggregation areas in Northwest Greenland, along Baffin Island and in the Arctic archipelago. Population estimates are hampered by low precision due to the aggregated distribution of narwhals and are biased by lack of coverage of their complete range in both summer and winter surveys. It was proposed that future surveys use adaptive sampling designs in areas of aggregation to increase survey precision and that the range of surveys be extended to cover more of the seasonal range of narwhals to assess fully their numbers.

Discussion

In considering the technical aspects of the proposal, the JWG noted that the adaptive framework was a promising avenue towards obtaining more precise and reliable survey estimates. The cost of the survey could be quite high depending on the level of coverage chosen, however it should be feasible to conduct the survey over 2 to 3 years. The JWG noted that digital cameras were to be used in surveys for narwhal in Greenland (see below), and recommended that this technology be considered for the Canadian surveys if it proves successful in Greenland.

Heide-Jørgensen updated the JWG on surveys to be carried out in August 2001 in Greenland. The summer aggregations around Qaanaaq and Melville Bay will be surveyed using a plane equipped with 2 digital cameras. In addition to abundance estimates using strip transect methods, it will be possible to sex and measure subsamples of narwhal. Some individuals will be photographed at closer range, and animals with visible marks will be used to provide separate mark-recapture estimates of abundance and information on movement in the areas.

Priorities for surveys

The JWG noted that narwhal have an extensive distribution in summer and winter, and that areas should therefore be prioritised in order to provide some guidance as to the urgency of surveys and the allocation of survey effort. In general, it was considered that surveys of the summer aggregation areas were of greater value than surveys of the wintering areas in Baffin Bay, as it is difficult to assign the latter aggregations to hunting areas (see Section 6.1). Survey effort should be concentrated on summer aggregations that are hunted in the aggregation area or during migrations. In addition a higher priority should be given to areas that have not been surveyed recently, or that have never been surveyed. This suggests that the following summer aggregation areas should be of highest priority for surveys: Inglefield Bredning, Melville Bay, Admiralty Inlet, Eclipse Sound and East Baffin aggregations. It was also considered of high priority to survey the Uummannaq fall aggregation as this group supports high takes in some years. The Smith Sound, Jones Sound, Somerset Island and Parry Island areas were considered of lesser priority primarily because they probably support less hunting. However the JWG noted that it would be preferable to cover all areas in the Canadian Arctic rather than surveying only high priority areas.

The JWG considered that the best way to proceed was to establish a subcommittee to plan, conduct, and analyse a survey in the Canadian High Arctic, as had been done for beluga in the past. The subcommittee should further develop the prioritisation scheme outlined here and provide a cost plan for a survey for the consideration of the JWG.

6.6 Assessment

The quality of narwhal assessment would be improved by a number of research activities

6.6.1 Review of research needs

Catch Statistics

- Improve the collection of current harvest statistics, including information on loss rates. Loss rate may be significant in some areas and times, and all population removals must be considered in stock assessment.
- Review historical harvest statistics, providing, to the extent possible, corrections for underreporting and killed-but-lost animals.

Stock identity

- Sampling should be continued in hunting areas and genetic and contaminant analyses should be pursued.
- Satellite tracking experiments should be conducted from all aggregation areas, to determine if significant mixing between aggregation areas occurs, and to identify migration routes and wintering areas.
- Other methods of stock delineation should be investigated.

Abundance

- Abundance surveys should be carried out in summer concentration areas in Canada and Greenland. The technical aspects of the surveys should be developed by a subcommittee of the JWG.
- The deployment of TDRs and satellite-linked TDRs should be continued to provide data to correct surveys for diving animals.

Life history

- Methods for ageing narwhal should be developed and tested.

6.6.2 Sustainable harvest levels

Recommendations on the sustainable harvest of narwhal for Canada and West Greenland could not be produced at this meeting. Narwhal harvests have increased in some areas of Canada and Greenland over the past 10 years. Further increases might be expected in Greenland if hunters switch from beluga to narwhal in the case where restrictions are implemented on beluga harvest, and in Canada if quotas are removed. New information on narwhal stock structure from tagging and genetic studies suggests that there are several stocks, some of which might be susceptible to overexploitation. The JWG suggested that this was cause for some concern, as there was insufficient information available to assess whether such harvest increases were sustainable. The JWG therefore considered that the assessment of narwhal stocks should assume a much higher priority in the coming years.

6.6.3 Schedule for assessment

If the planned summer surveys for Inglefield Bredning and Melville Bay are successfully completed in summer 2001, there should be sufficient information to complete an assessment for these stocks by 2002. The JWG considered that the assessment of stocks summering in Canada is also a priority and should be completed as soon as feasible.

7. OTHER SOURCES OF INFORMATION

7.1 Local knowledge

7.1.1 Meeting between Greenlandic/Canadian Hunters and the JWG

The JWG met twice with the hunters from Greenland and Canada. During the first meeting, the hunters from each country made a presentation. A review of traditional knowledge studies that have been conducted in Canada was also presented (Working Paper SWG-2001.12) along with information on the procedure for changes to hunting regulations currently underway in Greenland. This was followed by discussions on the presentations.

The hunters were asked to consider the same questions posed to the JWG by NAMMCO and JCNB and to provide feedback on those questions. The hunters from both countries met together to discuss these questions. The JWG met again with the hunters to discuss their responses to the questions posed by NAMMCO and JCNB, and to have some general discussions on beluga and narwhal. While the Greenlandic hunters left on Friday morning, the Canadian hunters remained and participated in other parts of the meeting of the JWG. The list of hunters that participated at this meeting is presented in Appendix 1.

7.1.1.1 Greenlandic Hunters

The Greenlandic hunters had been asked by the Greenland delegation to review the "Hvidbog om Hvidhvaler" and provide comments on that for this meeting. The Hvidbog om Hvidhvaler (Rydahl and Heide-Jørgensen 2001) is a publication produced by the Greenland Institute of Natural Resources that summarised the information available on beluga. The presentation from the Greenlandic hunters focused on points of disagreement between their knowledge and what was presented in Hvidbog om Hvidhvaler. Their presentation included:

- **Breeding frequency and gestation period.** The hunters reported that they believe that beluga are pregnant for one year, and calve every year. As support for this, they report observing many female beluga that were both pregnant and accompanied calves. Female beluga have also been seen with the tail flukes of a newborn already outside their body and accompanied by a calf. Herds of beluga are also seen to contain calves of various ages, i.e. individuals that are various colours of grey.

- **Time of breeding.** Hunters believe that beluga may mate at all times of the year, even in winter. In the Avanersuaq/Thule Region, mating may occur in March, as well as in winter and summer. In Central West Greenland, female beluga tend to have foetuses in May and June. In Northern Greenland – the Upernavik region – beluga have larger calves.
- **Sexual maturity.** Hunters believe the beluga mature at 3 to 4 years of age. By this time the beluga are a fairly large size and the hunters believe they are therefore sexually mature and able to breed, as do other mammals at this stage.
- **Migration patterns.** Hunters believe that migration patterns are very variable. Beluga have started to migrate to the southern regions of Greenland and have been spotted near Nuuk and further south. Hunters believe that the beluga have moved from Vaigat Strait in May and June to the area off Disko Bay and they believe this is due to the increased traffic in Vaigat Strait. The hunters believe that noise can be disruptive to the migration of beluga, and that the whales can be scared from their feeding grounds, and may not return to those areas. However, in some areas the beluga appear to get used to the noise
- **Stock size.** The hunters believe that if the stocks were depleted, they would be catching fewer beluga, and this is not happening.

On behalf of Leif Fontaine, Chairman of the Organisation of Fishermen and Hunters in Greenland, a prepared letter was presented by Jeremias Jensen with respect to the inquiry into a stricter management of beluga and narwhal that is currently being undertaken by the Greenland Department of Industry. The letter is presented in Appendix 6. The organisation fully agreed that there is a need for regulation of harvesting practices in Greenland, and did not object to separate management practices for beluga and narwhal. However, they stressed that this must be done in consultation with the users. They would like to see surveys conducted at close range, not just by airplane, and investigations of other factors including migration patterns. They would like to see these investigations over a longer period of time prior to major changes in the management system. They hope to work with biologists to find answers.

7.1.1.2 Canadian Hunters

The two hunters from Canada came from Pangnirtung, on southeast Baffin Island and Grise Fiord, at the southern tip of Ellesmere Island. Jooeelee Papatsie from Pangnirtung, shared his thoughts and understanding on the behaviour of beluga and narwhal in the Canadian arctic. Jooeelee reported that there is a separate stock of beluga in Clearwater Fiord, where they calve all through the summer. Hunters do not harvest from there.

Clearwater Fiord is located near the end of Cumberland Sound. A different stock, which does not go to the Clearwater Fiord area also comes to the Pangnirtung area. In April, these beluga arrive at the floe edge in Cumberland Sound. These are smaller beluga than those that enter Clearwater Fiord and tend to stay in Cumberland Sound. Their maktak is softer and tastes different.

Jooeelee also noted that elders have reported seeing whales in regions where scientists claim there are none, so he believes there are animals in these regions, such as in the vicinity of Wakeham Island in Cumberland Sound. He would like to invite the scientists to come and conduct surveys together with Inuit on beluga whales.

The satellite tagging done recently is in conformity with the knowledge of the Inuit on the migration patterns. As with the Greenlandic hunters, Jooeelee notes that the animals breed in different patterns than scientists say, and pregnant beluga may also have young with them. They can get pregnant again while they still have a calf. Pollution is also a problem for the whales and this is why it is harder to catch whales in recent times. While hunters used to be able to catch the animals year round, the quotas now mean that people rush to get animals before the quota is gone. Hunters and biologists need to work together to solve this. Hunters and biologists must share knowledge with each other so that both can benefit.

Jooeelee noted that 3 different types of narwhal are seen at Pangnirtung: smaller ones, the larger ones that are whiter and a blacker one. These blacker ones are further offshore. Hunters butcher the animals and know the different types when they find them. While the animals eat squid before they enter Cumberland Sound they switch to eating Greenland halibut in Cumberland Sound.

Larry Audlaluk from Grise Fiord in Nunavut also provided some comments on his knowledge of beluga and narwhal. He noted that in the high Arctic, the beluga and narwhal are very familiar to people. Beluga are present year round near Grise Fiord. The beluga that are present in the winter are small in size, while those that come in summer are larger in size.

Narwhal are also known to Grise Fiord people and they believe they do not share same stock with Pond Inlet. The pattern of movement of narwhals past Grise Fiord depends on how the ice melts. When the ice goes out in the spring, if the Ellesmere Island side opens first, then the narwhals will go to Grise Fiord, but if the ice opens first near Devon Island they tend to stay on that side of Jones Sound, and do not go to Grise Fiord. In some years they arrive early in Grise Fiord while at other times, they do not show up. Larry noted that the community would like to see research conducted on the narwhals that come by their community. Larry reported that the narwhals come from different areas and do not always come from the same stocks and he believes that the narwhals in Grise Fiord and Qaanaaq are not from the same stock. Sometimes narwhal arrive that behave differently than normal – much more shy. There are enough whales and Inuit harvest them only to meet their needs. While Inuit used to harvest more animals, there are now fewer dogs and therefore fewer narwhal are harvested.

As Jooeelee noted, Larry hoped that scientists would also learn from the people. It is easy to understand that those who are striving to acquire knowledge don't always want to listen to traditional knowledge and this hurts the Inuit. Larry believes that people notice what Inuit do today because of the actions of the commercial whalers in the past, not because of the action of the Inuit themselves.

7.1.1.3 Summary of Canadian Traditional Knowledge Studies

SWG-2001-12 D.B. Stewart. Inuit Knowledge of beluga and narwhal in the Canadian Eastern Arctic [presented by K. Ditz].

This report summarised three traditional knowledge studies of beluga and narwhal in the Eastern Canadian Arctic. Because of differences in study designs, it was not possible to clearly differentiate between knowledge and opinion about beluga and narwhal behaviour. The behaviour and distribution patterns of beluga and narwhal were described for the 6 Inuit seasons, which are based on environmental conditions:

- Ukiu (equivalent to winter, early January – mid-March) – period of extensive sea ice which continues to thicken and coalesce, snow on the land and ice, short periods of daylight getting longer, and very cold.
- Upingaaksak (equivalent to early spring, mid-March – late May) – period of maximum ice cover and ice thickness, snow on the land and ice, long daylight period getting longer.
- Upingaa (equivalent to late spring, late May – mid-July) – period of progressive snow melt, widening of ice leads and disappearance of ice, 24 hours daylight.
- Auja (equivalent to summer, mid-July – early September) – period of open water with some drifting pack ice, daylight period long but decreasing.
- Ukiaksak (equivalent to early fall, early September – late October) – period of open water with ice beginning to form late in the season along the shoreline, snow on the land and ice on the lakes, daylight period short and decreasing.
- Ukiak (equivalent to late fall, late October – early January) – period when new ice hardens and thickens to form extensive areas of landfast or drifting pack ice, snow on the land and ice, near 24 hour darkness.

In many cases the lack of observation of beluga and narwhal in an area is due more to hunters not being present in those areas, rather than to a true absence of the animals from that area. The two major reasons for this would be proximity to a community and season (i.e. periods of little or no daylight).

For beluga, ukiu is a period of ice entrapments, especially in Fury and Hecla Strait and Queen Anne's Strait. In upingaaksak, there are more observations, especially feeding at the floe edge near southeast Baffin Island communities and movement is reported northward past Qikiqtarjuaq. Beluga are also widespread but sparsely distributed around north Baffin Island, and are moving north near Ellesmere Island. In upingaa, beluga move through Hudson Strait, going northwest past Kimmirut, while those in Frobisher Bay and Cumberland Sound are around the floe edge, moving up the west coast of each as ice recedes inland. Elsewhere on Baffin, they continue to migrate northwards and enter fiords and inlets as the ice melts. Some beluga congregate at the floe edge in Lancaster Sound waiting for ice break up to allow continuation into Barrow Straight and Peel Sound whereas others continue from Lancaster Sound south into Prince Regent Inlet. In northern Foxe Basin they are observed moving northwards. In auja there are few sightings near Iqaluit and Kimmirut, while near Pangnirtung there is large-scale calving in Clearwater Fiord. Calving is also reported in the Clyde River area and Milne Inlet. There are few beluga near Pond Inlet in auja. Beluga are seen near Grise Fiord and are moving north near Igloolik and Hall Beach in Foxe Basin. In ukiaksak beluga are migrating south past Kimmirut and moving out of the bays near Pangnirtung and Iqaluit. Most are females with young, or juveniles. On north Baffin, they are moving out of Admiralty Inlet and east out of Jones Sound near Grise Fiord. In ukia, there are no sightings reported from south Baffin, while on north Baffin they continue to move out of Admiralty Inlet. In northern Foxe Basin there is southward movement past Hall Beach.

Some communities, particularly in the Southeast Baffin area, report a decrease in the numbers of beluga. Pangnirtung reports fewer beluga than historically, but believe the population has stabilised and is now increasing. Iqaluit respondents report seeing smaller groups. Changes in migration pattern and changes in ice conditions are reported and an avoidance of areas where engine noises are present has been noted. Only one large-scale calving area is reported - Clearwater Fiord in auja. Food items include cod year-round, turbot at the floe edge and in the bays, anadromous char in fall, along with other fish in some locations and also shrimp. Ice entrapment is widespread but infrequent, reoccurring in some areas. For three years after one ice entrapment reported near Grise Fiord no whales were seen in the area. Predators are believed to include Greenland shark and polar bears although observations of successful predation are limited. All the southeast Baffin communities report differences (some seasonal) in the appearance of the beluga near their communities and believe this is indicative of different stocks. However, the northern communities did not report seasonal differences in beluga.

For narwhal, in ukiu, large breathing holes are reported at the floe edge near Qikiqtarjuaq and narwhal may overwinter there. In upingaaksak, narwhal are at the floe edge and moving north. In upingoa, narwhal continue to move north and are seen at the ice edge near Grise Fiord. Some whales congregate at the floe edge in Lancaster Sound waiting for ice break up to allow continuation into Barrow Straight and Peel Sound whereas others continue from Lancaster Sound south into Prince Regent Inlet. In auja narwhal are found in the fiords on east Baffin Island and in Admiralty Inlet and are seen moving both east and west through Fury and Hecla Strait. In ukiaksak there is migration out of the fiords and southwards and there are fewer animals than in auja. In ukia, narwhal are occasionally seen in the Igloolik area and Pond Inlet, and are moving out of the bays and southwards.

Hunters generally report that the narwhal population increased in the 1960s and 1970s, but the distribution of the narwhals has changed, which they attribute to the noise from shipping and other activities and earlier break up of the ice. Calving is believed to occur in fiords, inlets and sounds where the animals feed. Narwhal feed on a variety of fishes and invertebrates, with few discrete feeding areas. Ice entrapment is infrequent and predators include killer whales, polar bears and sharks. Clyde River and Resolute Bay hunters identified two varieties of narwhal based on appearance, while Grise Fiord identified two different stocks based on behaviour. Other communities did not identify the occurrence of different stocks.

7.1.1.4 General Discussion

These presentations were followed by a general discussion among the hunters and members of the JWG. Greenlandic hunters reaffirmed that they too are interested in a sustainable harvest of beluga, and they want to work with scientists. They want to see decisions made based on real information, and not on assumptions. The hunters also wanted to have confidence in how the studies are conducted and that they will provide accurate results.

They do not believe that beluga give birth to young only every 3 years and they believe that beluga may give birth at just about any time of the year, as evidenced by the capture of 5 pregnant beluga last February along with one beluga with a calf. The hunters believed that they would never hunt whales to extinction. Rather they are concerned that other factors such as pollution might cause the whales' extinction. Changes have been noted in the fat of beluga and perhaps this has something to do with pollution.

Hunters noted that it is very important for the scientific community to explain what it is they are doing in the community closest to where they are doing the work. It was felt that some of the questions would not be asked if the communication was better. Hunters are also always curious on whether the methods are improving, for instance tagging and tranquillising, for all species and all methods. There was concern over the effect tagging may have on the normal movements of the whales and on their survival. Scientists noted that they have re-captured and re-sighted tagged animals up to 11 months after tagging and they have continued to look healthy.

Second Meeting with Hunters

The meeting adjourned and the next day the hunters from both countries met together to discuss issues of common concern and their responses to the questions posed by NAMMCO and the JCNB for the JWG to address. The hunters met again with the JWG members to discuss their responses to the questions. The full text of the responses is presented in Appendix 6.

In summary, the responses to the questions posed by the JCNB were that:

- Current hunting practices should be maintained and quotas removed.

- Both Canadian and Greenlandic hunters believe they harvest local stocks, but that there can be some exchange between stocks.
- Narwhal parameters are not accurate because they don't use hunters' knowledge.
- Using teeth to age the beluga is not adequate; they would like to see more effective methods. They believe that beluga reproduce annually.
- Stocks are not shared because Canadian and Greenlandic hunters harvest at the same time of year.

In summary, the responses to the questions posed by NAMMCO were that:

- Ice entrapments are part of the natural cycle of the population.
- Warmer air and sea conditions will lead to less ice entrapment events.
- Hunters must be consulted before surveys are undertaken.
- Some of the questions had to be answered by the biologists.

The issue of the frequency with which beluga and narwhal give birth was raised again. The hunters reiterated their belief that based on their observations of both species; calves could be born every year and could be born at different times of the year. JWG members explained how scientists had come to the conclusion that females had a calf every 3 years, noting that their work had shown that, on average, about one in three females was nursing or about to give birth. It was explained that this does not mean that a female cannot reproduce more often, but that this is an average number. This is based on information gathered in many areas across the arctic from the whales landed by hunters. It was suggested that the differences between the hunters and the JWG members resulted from differences in the interpretation of the same observations, and that the scientists did not disbelieve the hunters' observations. It was agreed that the hunters and scientists needed to work together to address this and other issues.

Hunters also reiterated concerns about decisions being made that affect their livelihood based on assumptions. The hunters indicated that they would like to work with scientists to ensure that surveys and studies are conducted in representative areas. It was stated by the hunters that if scientists had worked with them from the start, perhaps money and time could have been saved and some of these issues that face us today could have been avoided.

The meeting concluded with an agreement that the consideration of traditional knowledge from hunters is important to assist the scientists in doing their work and to help the managers in their work. JWG members have worked with the hunters of various communities in the past and will continue to do so in the future. However, it was believed that this meeting had been an important step in developing the relationship between hunters and scientists and that the lines of communication between the two groups should be kept open and active.

When the JWG discussed the input of the hunters later in the meeting, it was agreed that an agenda for discussing the issues raised by hunters during this meeting, and other issues that may arise, should be developed in consultation with the hunters. It was suggested that the issue of birth rates might be well suited as the lead issue on the agenda, given the prominence this issue had in the discussions with the hunters. It is believed that with continued dialogue and communication a better understanding of each group's point of view can be achieved.

7.2 Incidental sightings from other sources

The JWG noted that other activities being conducted in Davis Strait and Baffin Bay, such as surveys for other animals, oil exploration and fishing, might provide the opportunity for the collection of opportunistic sightings of beluga and narwhal in areas and in seasons that have not been surveyed recently. This might be useful in detecting unknown concentrations and/or distribution shifts of narwhal and beluga in the area. The JWG suggested that contacts should be established with people working in these areas, and that they be asked to record the extent of their travels in the area and the locations where beluga or narwhal were seen. If a larger scale project that has good potential for collecting reliable sightings of beluga or narwhal (such as a polar bear survey) is to be conducted in the area, a more formal method of data collection should be established.

8. OTHER BUSINESS

There was no other business.

9. ADOPTION OF REPORT

A draft version of the report containing all major sections was adopted on May 13, 2001.

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APPENDIX 1

JOINT MEETING OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

AND THE

CANADA/GREENLAND JOINT COMMISSION ON CONSERVATION AND MANAGEMENT OF NARWHAL AND BELUGA SCIENTIFIC WORKING GROUP

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APPENDIX 2

AGENDA

JOINT MEETING OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

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CANADA/GREENLAND JOINT COMMISSION ON CONSERVATION AND MANAGEMENT OF NARWHAL AND BELUGA SCIENTIFIC WORKING GROUP

Qeqertarsuaq, Greenland, 9-13 May 2001

1. Opening remarks

2. Adoption of joint agenda

3. Appointment of Rapporteurs

4. Review of available documents

5. Beluga
   - 5.1 Stock structure
   - 5.2 Age estimation
   - 5.3 Catches
     - 5.3.1 Segregation of sexes and age groups in catches
     - 5.3.2 Stuck and loss study in Nunavut
   - 5.4 Abundance
     - 5.4.1 Re-examination of past aerial surveys
   - 5.5 Ice entrapment events
     - 5.5.1 Relationship to sea surface temperature
     - 5.5.2 Ice entrapment mortality and its significance for population assessment
   - 5.6 Update of assessment
     - 5.6.1 Sustainable harvest levels
     - 5.6.2 Review of research requirements

6. Narwhals
   - 6.1 Stock structure
   - 6.2 Age estimation and life history parameters
   - 6.3 Catches
   - 6.4 Struck and loss Study in Canada
   - 6.5 Abundance
     - 6.5.1 Review of survey plans
   - 6.6 Assessment
     - 6.6.1 Review of research requirements
     - 6.6.2 Sustainable harvest levels
     - 6.4.2 Schedule for assessment

7. Other sources of information
    7.1 Local knowledge
    7.2 Incidental sightings from other sources
8. Other business
9. Adoption of report

APPENDIX 3

JOINT MEETING OF THE

NAMMCO SCIENTIFIC COMMITTEE WORKING GROUP ON THE POPULATION STATUS OF NARWHAL AND BELUGA IN THE NORTH ATLANTIC

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List of Documents

Document No.	Agenda	
SC/9/BN/1 SWG-2001-1		List of participants.
SC/9/BN/2 SWG-2001-2	2.	Agenda.
SC/9/BN/3 SWG-2001-3	4.	Draft list of documents.
SWG-2001-4	5.1	de March, B.G.E., Maiers, L.D and Friesen, M.K. An overview of genetic relationships of Canadian and adjacent populations of belugas *(Delphinapterus leucas)* with emphasis on Baffin Bay and Canadian eastern Arctic populations.
SWG-2001-5	5.1	Innes, S., Muir, D.C.G., Stewart, R.E.A., Heide-Jørgensen, M.P. and Dietz, R. Stock identity of beluga (*Delphinapterus Leucas*) in Eastern Canada and West Greenland based on organochlorine contaminants in their blubber. [Presented by R. Stewart]
SWG-2001-6	5.1	de March, B.G.E., S. Innes and G. Stern**.** The use of organochlorine contaminant profiles for stock discrimination – weaknesses and strengths of multivariate methods. A case study with beluga (*Delphinapterus leucas*) hunted in three communities on Southeast Baffin Island.
SC/9/BN/4	5.2	Report of the Workshop to Determine Deposition Rates of Growth Layers in Teeth of White Whales, *Delphinapterus leucas.*
SWG-2001-7	5.2, 6.2	Richard, P. Population dynamics consequence of single growth layer group per year in belugas.
SC/9/BN/5	5.1, 5.6.2	Heide-Jørgensen, M.P. A proposal for a renewed effort to determine the stock identity of belugas summering in the Canadian high Arctic.
SWG-2001-8	5.3.2, 6.3, 6.4	Ditz, K. Catch Statistics for Narwhal and Beluga in selected communities in the Eastern Canadian Arctic (1996-2000).
SWG-2001-9	5.4	Innes, S. Population size and yield of Baffin Bay white whale stocks (*Delphinapterus leucas*). [Presented by R. Stewart]

SC/9/BN/6	5.4.1	Laidre, K.L. and M.P. Heide-Jørgensen. Re-examination of the index estimates of beluga abundance off West Greenland 1981 and 1982.
SC/9/BN/7	5.5, 5.6	Alvarez-Flores, C. and Heide-Jørgensen, M.P. Alternative perspectives in the assessment of the beluga hunt in West Greenland.
SC/9/BN/8	5	Witting, L. Model uncertainty in the assessment of West Greenland Beluga: Inertia versus traditional density regulated dynamics.
SC/9/BN/9	6.1	Heide-Jørgensen, M.P., Dietz, R., Laidre, K.L. and Richard, P. Do narwhals from Canada contribute to the harvest in West Greenland?
SWG-2001-10	6.1	de March, B.G.E., Maiers, L.D and Tenkula, D. A preliminary analysis of the molecular genetics of narwhal *(Monodon monoceros*) samples collected from Canadian and adjacent waters from 1982-2000.
SC/9/BN/10	6.3	Heide-Jørgensen, M.P. Reconstructing catch statistics for narwhals in West Greenland 1862-1999.
SC/9/BN/11	6.5	Laidre, K.L., Heide-Jørgensen, M.P. and Dietz, R. Diving behaviour of narwhals *(Monodon monoceros*) in the Canadian Arctic determined by Time Depth Recorders (TDRs).
SWG-2001-11	6.5.1, 6.6	Richard, P. Proposal for a winter or summer surveys of Baffin Bay narwhals.
SWG-2001-12	7.1	Stewart, D.B. Inuit knowledge of beluga and narwhals in the Canadian Eastern Arctic. [presented by K. Ditz]

Other References Available at the Meeting:

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Previous reports of the JCNB Scientific Working Group.

Working Papers from the 2000 meeting of the NAMMCO Working Group.

APPENDIX 4

ANSWERS TO QUESTIONS FROM JCNB

1. Recommend sustainable harvest level for beluga and narwhal under different management objectives

The sustainable harvest level for beluga in the West Greenland area, interpreted as the catch that will be risk neutral with regard to keeping the current population stable in the short term, is estimated to be approximately 100 beluga per year, including beluga landed and killed-and-lost. Allowing for uncertainties in both catch and survey data, and in the biology of beluga, the sustainable catches (landed and killed-and-lost animals) could be as low as 79 or as high as 150 beluga. If the total kill is reduced to 100 beluga in 2002 and kept there until 2011, there is a high likelihood that the current decline would be stopped within a very few years, and by 2011 the stock will have begun to increase.

Moving immediately to the estimated sustainable harvest would require substantial reductions in catches in West Greenland in the short term. To inform managers about the consequences of achieving the necessary catch reductions over a longer time frame, several other catch scenarios between 2001 and 2011 were examined. These are described in Section 5.6. Failure to reduce catches to no more than 500 beluga by 2002 is likely to allow the stock to decline further. Failure to reduce total kills to around 100 beluga by 2005 and maintain them at that level until 2011 is unlikely to allow the stock to commence rebuilding by then. The current hunt in the Canadian high arctic is believed to be sustainable.

There is insufficient information to provide scientific estimates of a sustainable harvest rate for narwhal. However, attention is called to previous advice that there was no evidence that narwhal in the Baffin Bay area could support expanded catches (SWG 1997), and to the fact that total catches have increased in the 1990s, and catches in some local areas have increased substantially. New information on stock structure of narwhal increases the risk that some local stock units may be over-harvested, given recent harvests. A return to catches characteristic of the late 1980s, particularly in areas where catches increased substantially through the 1990s, would reduce the risk that some stock units of narwhal are being harvested at unsustainable rates.

2. Are hunters from Nunavut and West Greenland hunting narwhal from the same stocks?

Stock structure of narwhal has not been resolved with certainty. A conceptual model of the dispersal of narwhals in Baffin Bay and adjacent waters based on a review of recent genetic studies, satellite tracking and compilations of local knowledge was considered by the JWG. Tagging studies have shown that there is little exchange between summering areas. Genetic studies have not demonstrated any difference between narwhal caught in Canada and Greenland, but it appears that they may have some power to do so. Satellite tracking studies have shown that narwhal that summer in Melville Bay in Greenland and

Eclipse Sound in Canada share a common wintering area in Baffin Bay where they are not subject to harvesting. Narwhal tagged around Somerset Island in Canada winter in a separate area in Baffin Bay that is also inaccessible to Greenlandic and Canadian hunters.

The possibility that summering aggregations in areas such as Smith Sound and Jones Sound contribute to the hunt in West Greenland cannot be eliminated. However, sufficient numbers of narwhal to support the catches in West Greenland have not been found in those areas, nor is there evidence that narwhal from those areas migrate to West Greenland waters in fall and winter. Although the migratory patterns of several stocks remain to be elucidated, to date it has not been demonstrated that narwhal that summer in Canada are accessible to Greenlandic hunters, or that narwhal that summer in Greenland are accessible to Canadian hunters.

3. Are the parameters used in Narwhal population models adequate?

Many of the parameters used in population models of narwhal are borrowed from estimates for beluga, or based on small and geographically scattered sampling. Improved data on almost any aspect of narwhal biology could improve parameters used in narwhal population models. However, by far the most important data for improving the ability to assess the status of narwhal are accurate and precise survey data on regular intervals, reliable data on catches, and information on the population affinities of narwhal contributing the catches in various areas and seasons.

4. What are the effects of potential errors in the aging of narwhal (and beluga) on modelling population growth and recommended harvest level.

Results of specific analyses demonstrate that errors in aging would have relatively little impact on model estimates of population growth and recommended harvest levels. Model trajectories for beluga are sufficiently constrained by the catch and survey data that even major changes to aging criteria for beluga would require compensatory changes in parameters related to fecundity. The detailed interaction of fecundity and survivorship schedules in the models would be specific to the model formulation used, but in all cases examined the net effects on population growth and recommended harvest levels would be differences of less than 10%. They would not change our perception of the current stock status of beluga as depleted, nor the conclusion that major reductions in harvest are necessary for sustainability.

At present it is not possible to age mature narwhal, so age structured models would be of limited use in estimating population growth rates or recommended harvest levels.

5. What are the effects of killed-and-lost on recommended harvest levels?

Estimates of killed-and-lost whales are included in catch-related to increase the accuracy of recommended harvest levels. Ignoring whales killed but not landed would lead hunting mortality to be underestimated, and expected population size to be underestimated when fitting a population model to reported catches and survey data. Sustainable harvest options provided in scientific advice represent all mortality due to hunting, including killed-and-lost, so reliable reporting of these data is important for successful implementation of management plans. Information on whales injured-and-escaped, killed-and-lost, and landed show that these rates are highly dependent on local conditions of a hunt. This suggests that rates of killed-and-lost can be reduced through selection of hunting conditions and practices.

6. What is the status of shared narwhal and beluga stocks and are present harvest levels sustainable.

Beluga in West Greenland are depleted to less than 25% of the population size in the early 1950s, and harvests in the 1990s are not sustainable. Beluga in the Canadian High Arctic may be somewhat reduced from the maximum population supportable in the area, but are not depleted. Catches are low and believed to be sustainable.

The status of narwhal is uncertain, but there is no evidence that any populations are greatly depleted at present, or at risk of serious depletion in the near future. However, catches have increased overall through the 1990s, and there is now some uncertainty that the overall catch of narwhal is sustainable. In some areas catches have increased greatly in recent years, and there is growing evidence that some aggregations may contribute to several different hunts during a year. In those areas there is greater concern that catches may have become unsustainable. It is important that work be completed to allow analytical assessments of populations where hunts have increased in recent years, and to document better the origin of narwhal contributing to catches outside the summering aggregations.

APPENDIX 5

ANSWERS TO QUESTIONS POSED BY THE NAMMCO COUNCIL

1. Investigate the impacts of ice entrapments on: (1) population (develop model to simulate effects on population) and (2) catch statistics.

The influence of ice entrapments was examined by looking at the recorded frequency and intensity of ice entrapment events in the historical record, and integrating this into a population model for West Greenland beluga. It was assumed that all entrapped beluga were destined to die, so beluga killed by hunters in ice entrapments were subtracted from the catch and considered as natural mortality. Ice entrapments occurred infrequently and did not have much effect on the catch statistics over the long term. In making predictions about the future status of the beluga stock under various management regimes, it was concluded that ice entrapments will not have a great influence on the rate of stock recovery, unless they occur at higher frequency or intensity than they have in the past.

2. Examine the occurrence of ice entrapment events and the relationship to sea surface temperature.

This question was not addressed.

3. Examine past aerial survey data for: (1) detection probabilities of small vs. large pods and (2) estimation biases due to differing pod sizes among years. Re-examine the quality of the 1981 and 1982 aerial surveys. Are these surveys useful for trend analysis?

Average pod sizes seen in 1981 and 1982 were nearly twice as high as those observed in the aerial surveys conducted in the 1990's. Because of the methods used for data recording in 1981-82 surveys, it was not possible to assess the influence of pod size on detection probability. In the later surveys, pod size did not have a significant effect on detection probability. However, many pods larger than the largest pods seen in the 1990's were observed in the earlier surveys, so this analysis cannot rule out a pod size effect on detection probability in the 1981/82 surveys.

A re-analysis of the data from the 1981/82 surveys produced estimates that were not markedly different from those originally reported, so the original estimates were not the result of calculation error. However, the JWG noted that there were differences in methodology between the 1981/82 surveys and those conducted in later years, including:

- The plane used in 1981/82 flew faster and lower than the plane used in later surveys.
- The plane used in 1981/82 did not have bubble windows, which resulted in a blind area near the trackline;
- Different observers were used in the earlier surveys.

The first two could reduce the efficiency whereas the effect of the third is unknown. It was therefore concluded that the surveys conducted in 1981/82 may not be directly comparable to the index surveys conducted in the 1990's. However the JWG could not rule out that the earlier surveys did in fact reflect actual abundance, and considered it unlikely that any further analyses could be carried out to further clarify the issue.

4. **Review results on the potential stock structure of beluga in west Greenland, specifically evaluate tooth morphology data and tagging data that will be available late in 2000.**

The information on tooth morphology is not yet available, and there was no new tagging data available.

5. **Models currently assume a 50:50 sex ratio in the harvest. Include data on sex ratio of the harvest in the models; evaluate results of the model and predicted impacts on the population of beluga and on recommended quotas.**

This matter was not investigated.

6. **Conduct a formal and independent review of the model (formulation and estimation techniques) presently used in the assessment.**

The assessment model presently used is being considered for publication in a future volume of NAMMCO Scientific Publications. The peer review process for that publication constitutes a formal and independent review that will be completed within 6 months. Further review can best be planned when the results of the journal review are completed.

7. **Establish a method for formally collecting "anecdotal" data on beluga and narwhal distribution and abundance in Baffin Bay and Davis Strait. These observations could be from surveys conducted for other projects or from local ecological knowledge.**

The deliberations of the JWG were enhanced by a meeting with Greenlandic and Canadian hunters held immediately before the main technical meeting (See section 7.1 and Appendix 6). At this meeting the hunters presented their knowledge about the distribution, changes in abundance and life history of narwhal and beluga in their areas. The findings of the hunters, particularly about West Greenland beluga, differ from those of the scientists in many respects. It will be necessary to hold further discussions with hunters on specific topic areas in order to bridge these differences. Many points of agreement were also found.

In addition, a compilation of 3 traditional knowledge studies on beluga and narwhal in the Canadian Arctic was presented to the JWG. Two of these studies, and a similar study from Greenland (Thomsen 1993) had been reviewed by the JCNB SWG in the past. Such studies have proven useful and have been used by researchers in planning research projects and interpreting results.

The JWG noted that other activities being conducted in Davis Strait and Baffin Bay, such as surveys for other animals, oil exploration and fishing, might provide the opportunity for the collection of opportunistic sightings of beluga and narwhal in areas and in seasons that have not been surveyed recently. This might be useful in detecting unknown concentrations and/or distribution shifts of narwhal and beluga in the area. The JWG suggested that contacts should be established with people working in these areas, and that they be asked to record the extent of their travels in the area and the locations where beluga or narwhal were seen. If a larger scale project that has good potential for collecting reliable sightings of beluga or narwhal (such as a polar bear survey) is to be conducted in the area, a more formal method of data collection should be established.

8. Evaluate the extent of movements of narwhal between Canada and Greenland.

A conceptual model of the dispersal of narwhals in Baffin Bay and adjacent waters based on a review of recent genetic studies, satellite tracking and compilations of local knowledge was considered by the JWG. Tagging studies have shown that there is little exchange between summering areas. Genetic studies have not demonstrated any difference between narwhal caught in Canada and Greenland, but it appears that they may have little power to do so. Satellite tracking studies have shown that narwhal that summer in Melville Bay in Greenland and Eclipse Sound in Canada share a common wintering area in Baffin Bay where they are not subject to harvesting. Narwhal tagged around Somerset Island in Canada winter in a separate area in Baffin Bay that is also inaccessible to Greenlandic and Canadian hunters.

The possibility that summering aggregations in areas such as Smith Sound and Jones Sound contribute to the hunt in West Greenland cannot be eliminated. However, sufficient numbers of narwhal to support the catches in West Greenland have not been found in those areas, nor is there evidence that narwhal from those areas migrate to West Greenland waters in fall and winter. Although the migratory patterns of several stocks remain to be elucidated, to date it has not been demonstrated that narwhal that summer in Canada are accessible to Greenlandic hunters, or that narwhal that summer in Greenland are accessible to Canadian hunters.

Thomsen, M.L. Local knowledge of the distribution, biology and hunting of beluga and narwhal. A survey among Inuit hunters in West and North Greenland. SWG/WP93-08.

APPENDIX 6

- **Letter from the Organization of Fishermen and Hunters in Greenland to the Government of Greenland, Department of Industry. RE: The inquiry into a stricter management of narwhal and beluga.**

- **Hunters responses to questions from JCNB and NAMMCO.**

- **Knowledge shares from the Greenlandic hunters (In response to points made in "Hvidbog for hvidhvaler", p. 26ff)**

APPENDIX 7

BELUGA STATUS REPORT

Introduction

This report summarises current knowledge about the stock identity, sizes, vital parameters, harvest rates, and other impacts relevant to belugas in Davis Strait, Baffin Bay, and the waters of the Canadian archipelago. These whales are referred to as the Baffin Bay stock.

Stock Definition

In the eastern Arctic of Canada, belugas are found from the south and east coasts of Ellesmere Island to James Bay, although they are rare around Clyde River (~70°N) and Qikiqtarjuaq (67°N). In western Greenland, they range from approximately 79°N south to Kap Farvel but mainly in autumn or winter. They occur in low numbers south of approximately 66°N. The belugas found south of the Arctic Circle in Canada are thought to belong to different stocks, separated from the belugas of the Baffin Bay area by this break in distribution. The failure of belugas to reappear in South Greenland after commercial hunting stopped suggests that belugas found there were not part of the Baffin Bay stock.

Genetic analyses of Brown Gladden (1997, 1999) reported considerable genetic variation among putative beluga stocks in North America. Analyses of high Arctic populations based on mitochondrial DNA demonstrated beluga in four locations in West Greenland in 1990 were significantly different from Lancaster Sound/Barrow Strait, Kimmirut, Iqaluit, and/or Pangnirtung but not from Grise Fiord (de March *et al.* 2002, also SWG-2001-5). Grise Fiord beluga were not significantly differentiated from Lancaster Sound/Barrow Strait nor from southeast Baffin locations in some years. Lancaster Sound and southeast Baffin collections were not significantly differentiated from each other. These patterns existed for most years within locations, although data from some years did not match the general patterns. Other genetic markers also indicated that the high Arctic stocks discussed above differed from other North American stocks, including some in Hudson Bay, the Beaufort Sea, several stocks in Alaska, and the St. Lawrence River (de March *et al.* 2002, also SWG-2001-5). Palsbøll *et al.* (2002) showed further genetic differentiation among West Greenland stocks on the basis of mtDNA.

The general distribution patterns, the timing of the occurrence of belugas in different areas, and results of radio satellite tagging studies suggest that Greenland and Canada share one stock. Twenty-six satellite-linked radio tags were applied to belugas in the Canadian High Arctic in summer, in estuaries along Somerset Island and southeast Devon Island (Richard *et al.* in press). Almost all transmitted until September, and 15 of the tags continued to transmit during the period when belugas are normally observed migrating along the West Greenland coast (late September-early October). Tagged belugas moved to eastern Devon Island and Jones Sound, as has been observed in previous studies (Martin and Smith 1994, Smith and Martin 1993). Only one was observed to cross Baffin Bay to West Greenland waters, and was still heading south when the transmission was lost in southern Baffin Bay. All other belugas were still in the North Water (Northeast Baffin Bay and Smith Sound) when last detected. It is important to note that some summer aggregations have not been tagged, particularly those of Southern Devon Island. It is not known if these belugas migrate on courses similar to those that were tagged. Aside from the satellite tracking, the observations of beluga migration have not been systematic and migration evidence of a shared stock remains circumstantial.

Morphometric data have been used to suggest that there is no exchange of belugas between Greenland and Canada (Sergeant and Brodie 1969). However, these Canadian and Greenlandic data were collected 40 years apart and the Greenlandic sample came from South Greenland where belugas are no longer found. Recent analyses indicate that belugas sampled in 1984-87 at Grise Fjord and Pangnirtung, and in 1985 and 1989-92 in West Greenland attain similar final body size (Heide-Jørgensen and Teilmann 1994, Stewart 1994a). Some Greenlandic hunters observed differences in the appearance of belugas which they attributed to "Canadian" whales, but the majority of those who had expressed an opinion, had not noted different types of belugas (Thomsen 1993).

Multivariate analyses of organochlorine concentrations in blubber of belugas found a significant differences among samples from Grise Fiord and West Greenland (Innes *et al.* 2002, also SWG-2001-5), and Kimmirut, Iqaluit, and Pangnirtung (de March e*t al.* SWG-2001-6). It is believed that organochlorine signature may be a powerful method for discriminating stocks, however data used must be standardised between laboratories and appropriate statistical models using contaminants with known effects must be used (de March *et al.* SWG-2001-6).

Stock Size

The summer distribution and abundance of Baffin Bay belugas in the Canadian High Arctic was surveyed most recently between July 31 and August 3, 1996, with a line transect survey. Information on this estimate was provided to the JCNB in the 1997 Report of the SWG. At that time the estimate of the population adjusted for missed data, whales at the surface but missed by observers, and for belugas beneath the surface, was 28,500 belugas (95% CI = 13,900 - 58,200) in the summer in the Canadian High Arctic. Aspects of the analysis of the survey observations are being revised and a new estimate is expected. The revisions are expected to change the estimate of the mean and variance, and at this time neither the magnitude nor direction of the change is known.

Surveys of the West Greenland coast from Disko Bay south to Paamiut and Kap Farvel were conducted in March of 1998 and 1999, continuing the index series begun in 1992 and reviewed previously by JCBN. These surveys, reviewed in previous NAMMCO meetings, provided a total abundance estimate of 7,941 beluga (95% CI 4,262-14,789) wintering in West Greenland in 1998-1999, when corrected for beluga that were either submerged or at the surface but missed by observers. The winter surveys noted some belugas on the western boundary of the survey tract, and beluga are known to occur in small numbers north of Disko Island, so this value underestimates the wintering population in West Greenland in 1998/99 to an unknown extent. Changes to details for survey operations and the near absence of large pods (>20 beluga) in surveys of more recent years, mean that these survey results may not be exactly comparable, even as an index, to survey results from 1981 and 1982. Nonetheless, it was considered highly likely that the overall large decline in survey estimates between the two sets of surveys reflected some degree of real decline in over-wintering population size. The complete absence of beluga in the southernmost portion of the surveyed area, between Maniitsoq and Paamiut, suggests that the decline is not completely a result of a redistribution of over-wintering beluga to more southerly areas, a factor proposed by some hunters.

Previous analyses of the index surveys in West Greenland in 1981-82 and 1991, 1993, and 1994 indicated a decline (average 10.3% per year evaluated in 1994) in the number of belugas wintering off West Greenland (SWG 1997). At the 2000 NAMMCO workshop and the 2001 joint meeting of the NAMMCO SWG and JCNB SWG five different population dynamics models were reviewed. These models differed in assumptions made about many details of beluga life history and population dynamics, and how the catch data since 1953 and the West Greenland index surveys since 1981 were used. Limitations on data necessary to confirm model assumptions made it impossible to select one model formulation as better than all the others. The important consideration, though, is that despite the many differences in model formulations and data used, the major results were quite consistent across all the analyses.

The population in 2001 is highly likely to be reduced to less that 25% of the population in the early 1950s, and probably is no more than 20%. The current population could not sustain total kills due to hunting (landings plus kill-and-lost) in West Greenland of more than 100 to 150 beluga per year without further declines. The absolute size of the population in the late 1990 varies slightly among model formulations, but all estimates are between 5,000 and 8,000 beluga, with 95% probability intervals from around about 40% of a specific estimate to about 170% of the estimate. The uncertainties due to model formulations can be reduced by improvements to knowledge of beluga life history parameters, such as age of first calving and natural mortality rates of older beluga, which would be time-consuming and expensive to acquire. The uncertainty in population projections for any preferred formulation could be reduced by more and by complete data on total catches and numbers killed but lost.

Vital Parameters

Published estimates of vital rates for the West Greenland stock are:

Age of first ovulation	4-7 years (Heide-Jørgensen and Teilmann 1994)
Age of first pregnancy	5-8 years (Heide-Jørgensen and Teilmann 1994)
Pregnancy rate	0.31 (Heide-Jørgensen and Teilmann 1994)
Mean calving interval	3 years (Heide-Jørgensen and Teilmann 1994)

For other beluga stocks, estimated rates are:

Mean age at first ovulation	5 years (Brodie 1971, Sergeant 1973)
Mean calving interval	3 years (Brodie 1971, Stewart 1994b)
Maximum rate of population increase (r_{max})	2-3% per year (Béland *et al.* 1988)
	3-4% per year (Kingsley 1989)

Past investigations have supported the conclusion that the maximum annual rate of population growth (called "net recruitment rate" in previous reports) of the population is likely to be between 2-4% per year (SWG reports 1992, 1993), and that 4% rate of growth is possible only with very high survival rates or a population size which is a small fraction of carrying capacity (SWG Report 1997). Catches in West Greenland in the 1990s included disproportionate numbers of young animals and more females than males (Heide-Jørgensen and Lockyer 1995). Both of those factors would increase the likelihood that the annual rate of population growth would lie in the lower part of the possible range, compared to the rate of growth that would be possible if catches had been proportionate to age or directed to adult males (Kingsley *et al.* 1995). Analytical results reviewed at this meeting continue to support the past conclusions, and indicate that if higher fecundity rates, as proposed by traditional knowledge, are used in the population models, compensatory changes to survivorship schedules are necessary to fit the survey and catch data, so the net rate of increase the population remains within the range of 2-4%.

Current Catch Levels

The best estimates of average total landed catches in the eastern Canadian High Arctic are 31 beluga annually between 1996 and 2000 (Table 3, Ditz SWG-2001-8). The allocation of theses catches between the North Water stock and the West Greenland stock is not known with certainty. However genetic and contaminate indicators suggest they came predominately from the North Water stock (deMarch *et al*. 2002, Innes *et al*. 2002, SWG 2001). Landings in West Greenland averaged 706 whales per year between 1990 and 1998 (Table 2, Heide-Jorgensen and Rosing-Asvid in press). These landings do not include beluga killed but lost during hunts. Killed-and-lost rates vary greatly, depending on details of local conditions such as location (e.g. near-shore vs ice-edge), season, and hunting methods, so it is not possible to calculate a reliable and universally applicable correction factor. However, both hunters' reports and analytical results are consistent with total kills being between 120% and 150% of total landings. During the 1990s both Canada and Greenland have implemented procedures for improved reporting of belugas landed and killed-but-lost, but the reliability of these reporting systems has not yet been established. There are no restrictions on harvest levels for this stock in either country, but both countries regulate harvesting methods. Since October 1995, drive hunting has been banned in West Greenland.

Other Impacts

Any commercial fishery which competes with belugas for food may reduce carrying capacity and could cause a population decline or impede recovery. However, if the beluga population is depleted to the extent estimated by all the population analyses, fisheries would have to reduce beluga food supplies very greatly before they would constitute a major impediment to recovery of beluga. There is no indication that such an interaction exists but the impact of Greenlandic fisheries and developing Canadian shrimp and turbot fisheries have not been examined. Mineral exploration and mining can expose the whales to contaminants (Muir *et al.* 1990; Wagemann *et al.* 1990) and, along with fishing, to disruptive industrial noise (Cosens and Dueck 1988; Finley *et al.* 1984; Remnant and Thomas 1992; Thomsen 1993). Contaminants from sources outside the High Arctic also are known to enter Arctic marine food chains, and are found in belugas (Innes *et al.* 2002 als SWG-2001-5, de March *et al.* 1998). The effects of contaminants and noise pollutants on the biology of belugas are unknown. Belugas respond to ship noise (Cosens 1995) but it is difficult to determine whether there are long-term population effects. Noise may be more disruptive to belugas in hunting areas than in non-hunting areas.

Status

The 1996 summer survey of the Canadian High Arctic estimated the beluga numbers to be 28,500 (13,900 - 53,500), although this estimate may be revised with further analyses. Catches in the Canadian High Arctic are low compared to the estimated stock size. The number of belugas wintering off West Greenland has declined since 1981 (SWG Report 1992, 1993, 1994, 1997), and most recent analyses indicate that the decline has continued to the present. The surveys in West Greenland, diverse analytical models of catch and survey data, the reduction in numbers of belugas seen in estuaries, and the contraction of the winter distribution over the past 80 years, all support this conclusion. The analyses estimate that the population may be as little as 20% of the abundance in the early 1950s. Population projections indicate that catches of the magnitudes taken in the 1990s will deplete the stock further, and cannot be sustained. Even if total kills are reduced to as low as 100 beluga annually there is a 20% probability that the stock in 2011 will not be larger than the population in 2001. Rebuilding of this stock to even half its historic abundance will require restricted hunting mortality for many years.

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Table 1. Beluga Catch Statistics for Selected Nunavut Communities. The catch statistics represent reported landed catches. The data were not corrected for killed-and-lost and unreported landings. *There is uncertainty whether these communities harvest from the High Arctic 'Stock', therefore their harvest were not included in the totals. nr – indicates no record of harvest was reported to DFO.

	1996	1997	1998	1999	2000	total	average (1996-2000)	average (1977-2000)
***Hall Beach**	2	8	0	Nr	5	**15**	**4**	**9**
***Igloolik**	12	10	0	Nr	4	**26**	**7**	**28**
Qikiqtarjuaq	0	0	0	0	0	**0**	**0**	**1**
Clyde River	0	0	0	0	0	**0**	**0**	**1**
Pond Inlet	1	0	1	0	0	**2**	**0**	**1**
Arctic Bay	1	1	2	0	0	**4**	**1**	**4**
Resolute Bay	11	20	21	7	0	**59**	**12**	**8**
Grise Fiord	1	2	40	23	22	**88**	**18**	**14**
Pelly Bay	0	0	nr	nr	0	**0**	**0**	**0**
Gjoa Haven	0	0	nr	3	Nr	**0**	**0**	**0**
Taloyoak	15	nr	nr	nr	Nr	**15**		
TOTALS	29	23	64	33	22	**192**	**38**	**50**

Table 2. Catches of belugas from official reports by municipality with corrections for under-reportings (in parenthesis) for 1954 to 1998. The year 1999 only covers the period from January through September. The column 'under-reporting' shows the sum of the corrections for under-reporting or 'ALL' if it is a general correction factor for all areas. 'Disko Bay' includes the municipalities Kangaatsiaq, Aasiaat, Qasigiannguit, Ilulissat and Qeqertarsuaq.

YEAR	QAA-NAAQ	UPER-NAVIK	UUMMA NNAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT-QAQORTOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1954		16	61	1774	23					1874	1774
1955		10	3	275	11	1				300	
1956		9	8	373	29	5				424	
1957		6	11	391	95					503	
1958		3	4	182	35	1				225	
1959		12	12	243	42					309	50
1960		13	6	179	17		1			216	
1961	32	15	6	219	47	1	11	14		345	
1962	85	9	7	186	23	8	11			329	
1963	75	18	12	93	8	12	11			229	
1964	125	4	6	166	8	4	18			331	
1965	150	20	53	214	24	18	9			488	
1966		25	88	398	24	13	12	1		561	
1967		34	66	369	76	47	4			596	50
1968		97	65	1013	46	38				1259	234
1969		111	36	661	100	40	30			978	
1970	17	334	6	1133	10	24				1524	1050
1971	2	238	3	328	123	4	41			739	
1972		293	25	362	135	11	14	1		841	
1973		262	33	581	121		70			1067	
1974	21	195	15	512	135	8	25	2		913	
1975	(47) 50	150	19	268	130	4	33		(47)	654	

Table 2. Continued.

YEAR	AVANER-SUAQ/ QAA-NAAQ	UPER-NAVIK	UUMMAN-NAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT-QAQOR-TOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1976	(37) 50	77	12	953	72		48		(37)	1212	653
1977	(36) 50	240	49	379	43	13	65		(36)	839	
1978	20	104	44	452	77	5	17			719	
1979	25	250	22	379	35	12	18			741	
1980	30	191	100	412	109	45	1			888	
1981	76	343	95	340	62	23	78			1017	
1982	127	329	17	313	95	13				894	100
1983	(10) 53	(165) 233	19	(100) 194	(50) 99	2	1		(325)	601	
1984	21	(60) 333	15	(150) 352	(25) 25	16	1		(235)	763	220
1985	190	(135) 188	6	(75) 177	(25) 25	17	8		(425)	611	
1986		(335) 500	4	114		2			(335+ALL 75)	695	
1987		550	13	29		8	6		(ALL 90)	696	
1988		125		125					(ALL: 25)	275	125
1989		(311) 427	2	(18) 30		40			(339)	499	
1990	(2) 2	(346) 346	8	(591) 684		23			(939)	1063	500
1991	(50) 50	(400) 400		(100) 100					(550)	550	
1992		(661) 661		(26) 26					(687)	687	
1993	119	(169) 339	26	194	80	25	14	1	(169)	798	
1994	24	(90)188	19	239	105	38	3	2	(90)	618	
1995	84	(111) 194	18	301	116	56	10	1	(111)	780	
1996	7	86	21	245	131	26	25	1		542	
1997	16	162	28	243	101	7	18	1		576	
1998	51	162	38	312	125	19	30	7		744	
1999	21	42	14	116	30	4	6	6		239	

APPENDIX 8

NARWHAL STATUS REPORT

Introduction

This report summarises current knowledge about the stock identity, sizes, vital parameters, catch levels, and other impacts relevant to narwhals in the waters of Davis Strait, Baffin Bay, and the Canadian Arctic Archipelago.

Stock Definition

The summer range of narwhals probably covers most of the waters of the Canadian Arctic Archipelago and northwestern Greenland. Baffin Bay narwhals winter in northern and central Baffin Bay and in Qeqertarsuaq, and they occur in large numbers in Uummannaq in November. Main summering areas in Canada are Peel Sound, Prince Regent Inlet, Admiralty Inlet and the Eclipse Sound area. Main summering areas in West Greenland are Melville Bay and Inglefield Bredning.

Results of a genetic study of mitochondrial DNA indicate differences between stocks in East and West Greenland. Low genetic diversity in narwhal from eastern Canada and western Greenland makes it difficult to resolve any stock structure in that area (deMarch *et al*. 2002). There is genetic evidence for more than one stock in West Greenland in late fall (Palsbøll *et al* 1995).

Satellite tracking of narwhals from three aggregations in West Greenland and Eastern Canadian High Arctic showed that these whales did not move to other areas of narwhal concentration in August. Narwhal from Melville Bay and Eclipse Sound moved to a common wintering ground in the middle of northern Davis Strait. Narwhal from Somerset Island moved to a wintering ground that was in southern Baffin Bay, distinct from the wintering ground of the other narwhal. The narwhal made only local movements on their wintering grounds and tracking results through June 2001 suggest a migration towards the summering areas where they were tagged (Heide-Jørgensen *et al*. 2001). None of the 27 narwhal tagged in Canadian waters went into areas where they would be subjected to hunting from Greenland. Narwhal from Eclipse Sound visited several East Baffin fjords during their fall migration, within the range of hunters from East Baffin communities.

About 40% of resource users have noted differences in narwhal appearance (Remnant and Thomas 1992, Thomsen 1993). Further clarification of the possible sub-stocks within the Baffin Bay region is needed.

Stock Size

Survey estimates of narwhals in the Commission area are old. The offshore population of narwhals wintering in northwestern Baffin Bay and Davis Strait was surveyed in 1979, resulting in an estimate of somewhat more than 34,000 (95% CI: 21,600-54,600) (Koski and Davis 1994; Reeves *et al.* 1994). This estimate was not adjusted for narwhals that were submerged at the time of the survey or those outside of the study area.

The summering concentration in Canada was estimated at 18,000 (95% CI: 15,000-21,000) from the 1984 aerial photographic surveys (Richard *et al.* 1994). Four thousand whales were seen concurrently in Inglefield Bredning (Born 1986). In a survey for belugas in the Canadian High Arctic in the summer of 1996, the estimated number of narwhals was 14,240 (95% CI 6,658 - 30,931). This estimate includes adjustment for several sources of observational error, but does not include any adjustment for narwhals below the surface. Also, the survey did not cover the entire area known to be inhabited by narwhals in summer, and thus underestimates the total population by an unknown amount. This analyses is being revised, and at this time it is not known if the new estimate will be higher or lower than the previous one.

Satellite tracking of narwhals in the Canadian High Arctic, Melville Bay and Baffin Bay suggested that the appropriate correction factors for narwhal submerged and not visible to observers during surveys are unlikely to be less than 2 (Heide-Jørgensen and Dietz 1995, SWG 1997). This is also confirmed by land-based observations of migrating narwhals (Born *et al.* 1994). New data on diving behaviour of narwhal in Tremblay Sound and Creswell Bay in summer, collected using time-depth recorders (TDRs), also provide correction factors (Laidre *et al.* 2001). Correction factors determined from TDR data ranged from 1.9 to 3.3, varying with season and habitat structure.

Without recent and complete survey information, and with high uncertainty about the reliability of catch data, it is still not possible to provide quantitative estimates of stock size for narwhal. Earlier reports concluded that there was no evidence of stock decline (Strong 1988, Remnant and Thomas 1992; Thomsen 1993) and SWG 1997 concluded "narwhal harvest may be sustainable". The new information on stock structure and the increased catches in the 1990s both reduce the confidence of the SWG in the previous conclusion. The true size and recent trajectory of narwhal remain unknown, but the new information increases the urgency of improving knowledge of stock sizes.

Vital Parameters

Neve (1995) has allowed determination of some vital rates for narwhals in West Greenland.

Age at first ovulation	4-9 years
Mean calving interval	3 years by extrapolation from gestation period and analogy to belugas
Maximum rate of population increase (r_{max})	3-4% by analogy to belugas

Current Catch Levels

Average reported landed catch in West Greenland between 1993 and 1999 is 577 narwhal per year, but these figures do not include any correction for non-reporting, which is thought to have been fairly high in some areas over at least some of those years, and does not include any correction for narwhal killed-and-lost (Table 1). Average reported landed catches in the Canadian Baffin Region for 1996-2000 were 364 narwhal per year (Table 1, Ditz 2001), and non-reporting rates are thought to be quite low. Reported information on narwhal killed-and-lost rates are extremely variable (Roberge and Dunn 1990, Ditz 2001), with reported numbers of narwhal killed-and-lost ranging from below 10% to above 30% of landed catches for a few selected communities in 1999 and 2000. Considering just reported catches and reasonable allowances for narwhal killed-and-lost, mortality due to hunting has been in excess of 1,000 narwhal annually through the 1990s, and there is a high likelihood that removals due to hunting have increased recently.

Other Impacts

Any commercial fishery which competes with narwhals for food can reduce carrying capacity and cause a population decline or impede recovery if the population has been reduced well below the usual carrying capacity. Fisheries interactions involving narwhals have not been examined. Mineral exploration and mining can expose the whales to contaminants (Muir *et al.* 1992; Wagemann *et al.* 1983) and, along with fishing, to disruptive industrial noise (Cosens and Dueck 1988; Remnant and Thomas 1992; Thomsen 1993). Contaminants from sources outside the High Arctic also are known to enter Arctic marine food changes, and are found in narwhal (deMarch *et al.* 2001, AMAP 1997). The effects of contaminants and noise pollutants on the biology of narwhal are unknown. Narwhals respond to ship noise (Cosens 1995) but it is difficult to determine whether there are long-term, population effects. Noise may be more disruptive to narwhals in hunting areas than in non-hunting areas.

Status

No status was assigned due to current inability to conduct an analytical assessment of the status of the population. However, two developments weaken the confidence expressed in SWG 1997 that the population could not currently be at risk of overexploitation. First, total catches have increased in recent years. Although there is no evidence to conclude they are currently unsustainable, past advice highlighted that there was also little evidence that the narwhal could support expanded catches. Second, the assumption made previously that all narwhal in the Baffin Bay area comprise a single functional stock is no longer considered tenable. Although the stock delineation is far from clear, and there is great uncertainty about the sources of narwhal taken in hunts of aggregations in West Greenland in Fall and Winter, there is now thought to be increased risk that some stock units may be over-harvested.

In summary, there is no cause to conclude that narwhal in the Baffin Bay area as a whole face immediate threats from unsustainable harvesting. However, the evaluation of stock status is partly based on old and incomplete data, and conditions of harvesting appear to have changed in recent years. There is also thought to be potential for increased hunting effort being directed at narwhal, as more restrictive management regimes are implemented for beluga. Hence, there is an urgent need for a focused and intensive effort to improve knowledge of narwhal, to strengthen the basis for advice on the conservation and management of this species in the North.

Work in West Greenland to complete improvements to the catch data, particularly from the recent few decades, should be completed within the year. Also aerial surveys in Inglefield Bredning and Melville Bay are planned for 2001. Data from both sources, complemented by any new information from satellite tagging and population identity studies on which summering aggregations contribute to the major West Greenland Fall hunts, should allow an analytical assessment of the West Greenland narwhal within a year.

Canada is also working to improve the database on historic catches. Co-operative programs with selected communities may provide more information on the relationship between reported landings and actual mortality due to hunting. Catch data must be augmented by survey data of summering aggregations, however, before full assessments of narwhal in the Canadian Arctic will be possible. A working Group to conduct detailed planning of a multi-year survey should be formed as quickly as feasible, and include both technical experts and knowledgeable community members. Expanded work on stock identification should also be given priority, to allow better allocation of catches in all seasons and areas to the various summer population units. Quantitative assessments of some summer aggregations may be possible in 2002.

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Table 1. Catches of narwhals from official reports by municipality with corrections for under-reportings (in parenthesis) for 1954 to 1998. The year 1999 only covers the period from January through September. The column 'under-reporting' shows the sum of the corrections for under-reporting or 'ALL' if it is a general correction factor for all areas.

YEAR	AVANER -SUAQ/ QAA-NAAQ	UPER-NAVIK	UUMMAN-NAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT - QAQORTOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1954										47	
1955		179	2	14	11	1				300	
1956		15	282	21						318	
1957		55	11	8						74	
1958		24	3	45		1				73	
1959										57	
1960										332	
1961										203	
1962										213	
1963										317	
1964										319	
1965										99	
1966										110	
1967										140	
1968										472	
1969										204	
1970										322	
1971										186	
1972		23								107	
1973		28								199	
1974		25								147	
1975	1	54	11	44		6		1	ALL: 149	266	
1976	9	22	27	57					ALL: 141	264	
1977	16	62	113	53	8	1			ALL: 134	387	
1978	110	56	183	262		1				612	

Table 1. Continued.

YEAR	AVANER-SUAQ/ QAA-NAAQ	UPER-NAVIK	UUMMAN-NAQ	DISKO BAY	SISIMIUT	MANIITSOQ	NUUK	PAAMIUT - QAQOR-TOQ	UNDER-REPOR-TING	TOTAL	MORTALITY IN ICE EN-TRAPMENT
1979	120	22	132	100			3			377	
1980	130	61	146	120		4	1			462	
1981	118	83	140	249			18	1		609	
1982	164	59	162	76						461	
1983	(25) 135	(30) 72	164	(68)						439	
1984	274	80	245	(15) 66	1					666	
1985	(115) 115	(20) 34	(3) 39	67		1				256	
1986		81	97	23		36				237	
1987		145	334	25			1		(50)	505	
1988									(500)	500	
1989		17	288	2			5			312	
1990		27	1019	11						1057	
1991				40							
1992											
1993	144	66	301	75	10	6	4	8		614	
1994	183	59	297	268	6	14	7	11		845	150
1995	107	94	159	108	4	5	8			485	
1996	45	69	405	154	10	4	2	2		691	
1997	66	90	381	156	13	5	9	26		746	
1998	94	105	344	163	21	18	6	24		775	
1999	115	87	7	132	4	4	17	6		372	

Table 2. Narwhal Catch Statistics for Selected Eastern Canadian Arctic Communities. C – indicates communities with no quota for 1999 & 2000.

Community	Quota	1996	1997	1998	1999	2000	average (1996-2000)	Average (1977-2000)
Pangnirtung	40	19	2	2	41	50	23	19
Iqaluit	10	0	0	1	0	0	0	0
Qikiqtarjuaq	C (50)	23	50	50	81	137	68	46
Clyde River	50	10	15	27	4	48	21	26
Pond Inlet	C (100)	100	75	108	130	166	116	94
Arctic Bay	100	99	66	130	101	101	99	84
Resolute Bay	32	2	7	9	1	12	6	8
Grise Fiord	20	1	1	10	16		7	7
Taloyoak	10	0	0	0	0	3	0	1
Gjoa Haven	10	0	0	0	0	0	0	1
Hall Beach	10	1	2	10	0	0	3	3
Igloolik	25	5	3	29	4	2	9	14
Pelly Bay	10	7	15	8	0	30	12	3
TOTALS	487	267	236	384	378	549	364	306