Research program on common minke whale (*Balaenoptera acutorostrata*) in Icelandic waters. An overview of implementation and results.

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1. INTRODUCTION

In 2003, the Marine Research Institute, in collaboration with a number of other Icelandic research institutions, submitted to the IWC, a proposal for wide ranging research on cetaceans in Icelandic waters (Marine Research Institute 2003). The program had multiple objectives and involved limited sampling of three species of whales in Icelandic waters under scientific permit, while non-lethal methods were to be used when these were deemed feasible with respect to the objectives of the research. Specific dates for implementation were not set out in the proposal, although it was assumed that the sampling phase could be concluded in two years.

The original plan assumed a catch of a total of 200 common minke whales (*Balaenoptera acutorostrata*), 200 fin whales (*B. physalus*) and 100 sei whales (*B. borealis*) in two years of the program. In August 2003 the government of Iceland decided to start implementation of the part of the program concerning common minke whales however with a considerably slower sampling procedure than assumed in the original plan (see below).

The primary objective of the part of the research program concerning common minke whales was to increase our knowledge on the feeding ecology of minke whales in Icelandic waters by studies on diet composition, energetics, seasonal variation in distribution and abundance, consumption of different prey species and multispecies modelling.

The program also had the following secondary objectives:

- Examination of population structure:
  (a) Comparison of the genetic structure of common minke whales off Iceland, Norway (including the Jan Mayen area), the Faroes and Greenland.
  (b) Monitoring the movements of minke whales by satellite telemetry.
- Monitoring and evaluation of the morbidity of potential pathogens.
- Investigate potential temporal changes in biological parameters.
- Analyse contaminant burden and evaluation of the health status of individual minke whales and populations.
- Evaluate the applicability of non-lethal research methods in studies on feeding, energetics and pollutant burden.

It is important to emphasize that from the outset, the project was defined as a feasibility study. During discussions within the Scientific Committee (SC) of the IWC there were some discussions on the meaning of the term feasibility and some members found the term pilot study more appropriate (International Whaling Commission 2004). Irrespective of the language used, it has always been clear that study with a sample size of only 200 individuals was never expected to give definite answers to the research questions raised. As this kind of research program, with sampling taking place at sea onboard small boats had never been conducted before in Icelandic waters, the primary purpose of the project was to establish a basis for future research by trying out the methods suggested and providing preliminary results that could guide the design of future research on common minke whales in Icelandic waters.

In the following, we review the main findings of the program by individual papers under the following headings, reflecting the main objectives of the study: feeding ecology, energetics, biological parameters, stock structure, pollutants, parasites and pathology. Before those sections we describe the sampling procedures.

Sampling

While the total sample size of 200 minke whales was retained, the sampling period was extended to five years from the originally intended two years. The objectives, methodology, total sample size and spatial and seasonal distribution of the sample remained largely unchanged from the original proposal (for details see Marine Research Institute 2003) and the modifications involved primarily reduced rate of sampling.

Some minor changes were though made along the way, i.a. to accommodate criticism raised during discussion of the program within the Scientific Committee of the IWC. The development and progress of the program was reported annually to the Scientific Committee of the IWC (Víkingsson *et al*. 2004, 2005, 2006, 2007, 2008, 2009).

During the years 2003, 2004, 2005, 2006 and 2007 the numbers of 37, 25, 39, 60 and 39 respectively, common minke whales were caught under a special permit granted by the government of Iceland (Appendix 1). The sampling area was restricted to the Icelandic economic zone. No size limit was imposed but lactating females and accompanying calves were not taken. To avoid selective sampling attempts were made to catch the first whale sighted within a given subarea and period. These attempts were deemed to have failed if unsuccessful for at least one hour or if the whale was lost out of sight. The whales were caught from four minke whale catching boats hired by the Marine Research Institute. These are listed in Table 1 and shown in Fig. 1.

Table 1. Basic data for the sampling boats

Boat	Id	Year in use	Length	Brt.tons	Built year	Material
Halldór Sigurðsson ÍS-14	A	2003, 2004, 2005, 2006, 2007	17.6m	40.9	1974	steel
Njörður KÓ-7	B	2003, 2004, 2005, 2006, 2007	18.0m	29.7	1975	oak
Sigurbjörg ST-55	C	2003	31.5m	94.7	2001	steel
Trausi ÍS-111	C	2004, 2006, 2007	25.0m	92.9	1961	steel
Dröfn RE-35	C in **2005**, D therafter	2005, 2006, 2007	25.9m	154.6	1981	steel

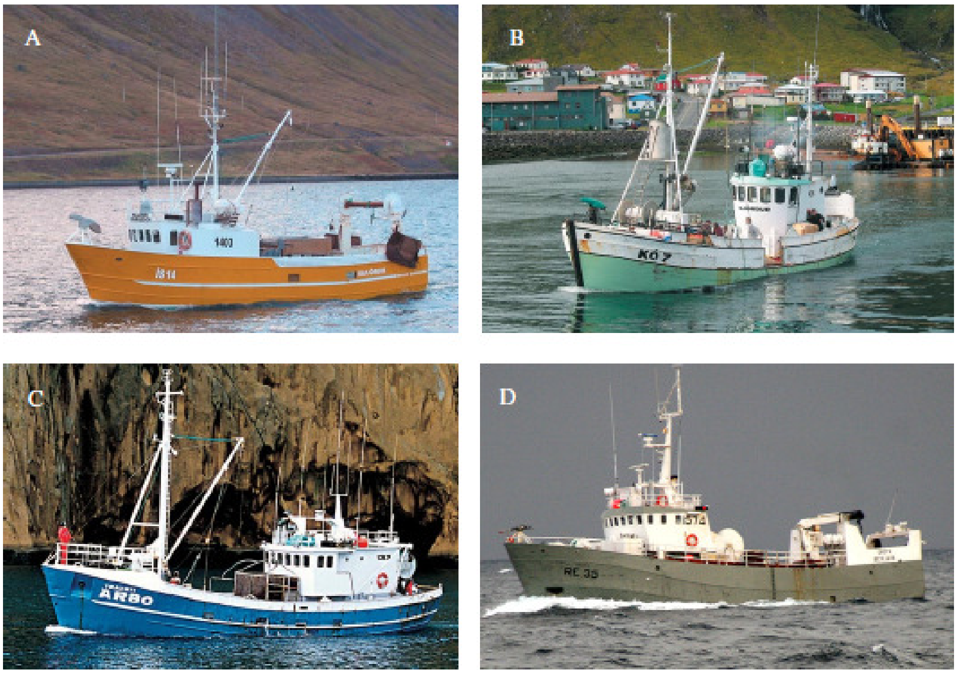


Figure 1. The minke whaling catching boats used for sampling (sampling procedures can be seen in Appendix 2).

The spatial and temporal distribution of the sampling is illustrated in Fig. 2 and Table 2. A total of 190 minke whales were sampled during 2003-2007. In addition 10 animals were struck and lost, and could not be sampled (Appendix 1). The number of animals taken is in accordance with the original plan with total removals of 200 common minke whales.

The temporal and spatial distribution of the samples is also broadly in accordance with the original plan, though with minor modifications made along the way to account for changes in distribution of minke whales and spatial variation in diet diversity. The original sampling design assumed the sampling intensity to be roughly proportional to the relative abundance of minke whales in Icelandic continental shelf waters in time and space as indicated by sightings surveys 1986-2001 (Borchers *et al.* 2009). As shown by more recent sightings surveys (Pike *et al.* 2011a, Pike *et al.* 2011b; SC/F13/SP6) considerable changes in distribution and abundance of minke whales occurred during the implementation of the research program. Preliminary results from the first two years gave clear indications of much higher variability in the diet composition in the northerly areas than off the south and southwest coasts where the diet consisted overwhelmingly of sandeel. As the northern areas had been assigned relatively low sample sizes (based on the pre-2003 distribution from surveys) it was decided to increase the sample size there at the cost of sample size along the south cost where most stomachs contained only sandeel. These changes in sampling distribution should not affect the overall results, as the analyses take account of geographical variation. With these relatively minor changes from the original plan, and with reference to Fig. 2 and the aerial sightings surveys, we conclude that the objective of sampling in proportion to the relative abundance of minke whales in the Icelandic continental shelf area was achieved.

From each whale around 80 samples were taken and around 70 measurements made onboard the catching boats (Appendix 3). Some of these samples were outside the scope of the research program as outlined in the original proposal (Marine Research Institute 2003), but they were taken to maximize the use of these animals for future research.

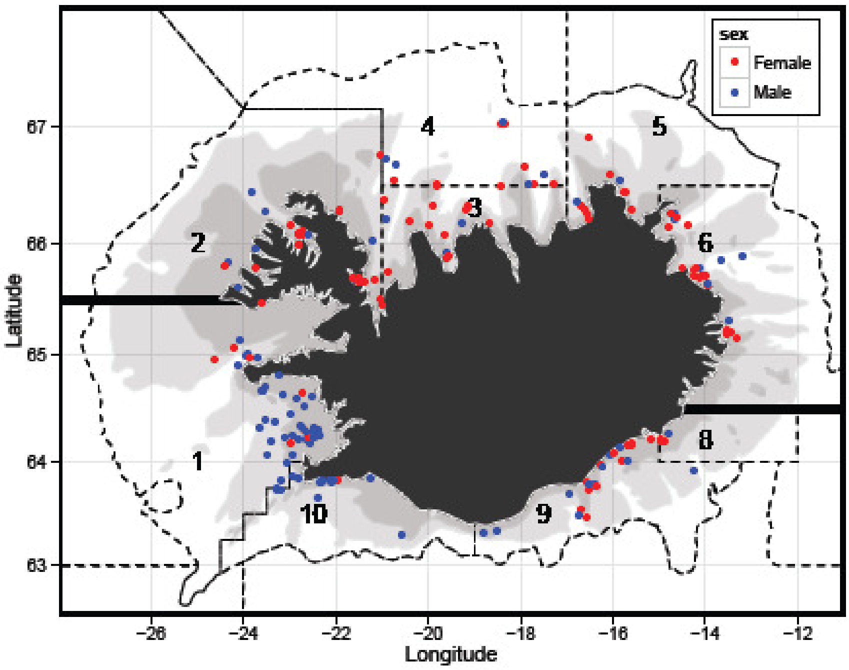


Figure 2. Sampling distribution of common minke whales in the Icelandic continental shelf area 2003-2007. The nine areas are indicated by numbers 1-6 and 8-10.

As seen in Fig. 3, the commercial whaling was mostly confined to the northern and northwestern coastal areas of Iceland. Thus, all previous studies based on sampling from the commercial whaling fall short of representing the distribution of common minke whales in Icelandic coastal waters. The data from the 2003-2007 research program thus represent the first biological investigations on minke whales off southern Iceland including the two areas which have highest abundance of minke whales in Icelandic waters according to sightings surveys (Borchers *et al.* 2009).

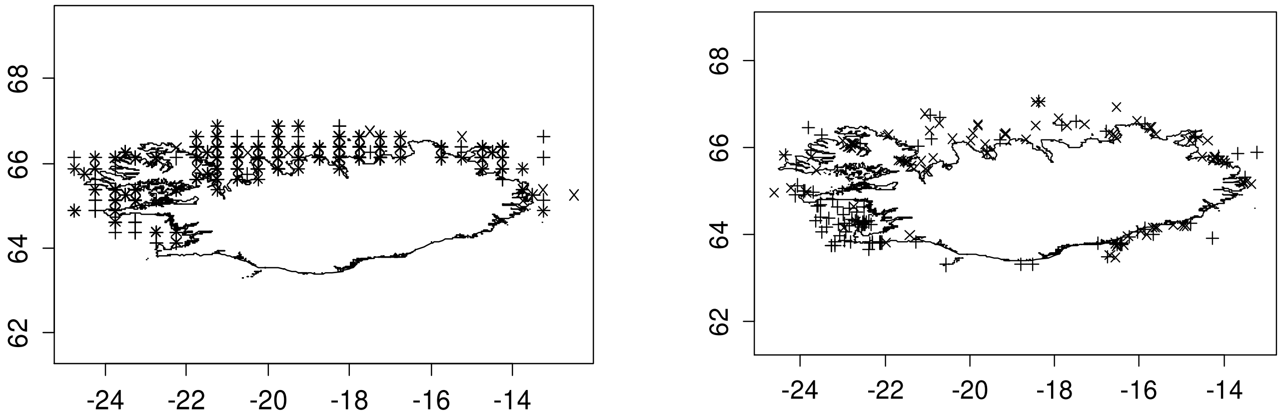


Figure 3. Catch distribution from the commercial minke whaling 1974-1985 (left) and the scientific program 2003-2007 (right)..

2. FEEDING ECOLOGY

Prior to this study, knowledge on feeding habits of minke whales in Icelandic and adjacent waters was very limited. Only 68 minke whale stomachs had been examined, thereof 56 from the commercial fishery during 1977-1978, one caught in 1984 and 11 stranded or bycaught animals (1988-1997). Of these 68 animals 50 were sampled off North Iceland and 57 were collected in June and July. The available data was thus not only limited in sample size, but also in sample distribution and left large parts of the distribution area (Fig. 3) and residence period of minke whales in Icelandic waters virtually unexamined. Based on frequency of prey occurrence this merged data indicated that approximately 65% of the diet consisted of fish while the remaining 35% were Euphausiid crustaceans (Sigurjónsson *et al.* 2000). Considering the large spatial and temporal variations in the diet of this species observed in other areas, and the important role played by this abundant species in the Icelandic marine ecosystem (Sigurjónsson and Víkingsson 1997; Stefánsson *et al.* 1997) there was clearly a need for further studies into the feeding ecology of minke whales in Icelandic waters.

In the original proposal the objective of this part of the research was “Estimation of the relative importance of different prey species and age classes based on analysis of stomach contents” (Marine Research Institute 2003). These results are presented in SC/F13/SP2.

In addition, the research program planned to evaluate the applicability of stable isotope analyses as an alternative for non-lethal sampling for feeding ecology studies of the common minke whale. Analyses of the carbon isotope ratio, $^{13}C/^{12}C$ and the nitrogen isotope ratio, $^{15}N/^{14}N$, of various tissues may, indeed, give information on the trophic level of the predator and a broad scale geographic origin of the diet respectively, but can usually not allow species identification of the prey. The nitrogen isotope ratio of an individual is normally about 3‰ to 4‰ greater than the diet it preys on. This trophic enrichment may give information of the trophic level of the animal. The carbon isotope ratio does normally not alter between trophic levels but seems to vary geographically and may thus give indications of the origin of the diet.

The results, presented in SC/F13/SP3, therefore addressed three main questions:

- How well do skin samples from the mid dorsal region (D4) resemble other tissues of the minke whale?
- How do information on the minke whale diet obtained by stable isotope analyses compare to traditional stomach content analyses?
- Can stable isotope ratio analyses lead to conclusive interpretations on the minke whale diet without supplementing information from stomach content analyses?

Fatty acids (FA) were also studied in order to assess if diet composition could be deducted from FA profiles of 23 minke whales (*Balaenoptera acutorostrata*). Fatty acids were analysed in tissues of outer blubber, inner blubber and blood and in some of the minke whales potential prey the years 2003, 2004 and 2006 in the waters around Iceland. The results are presented in SP/F13/SP4.

Closely related to the feeding ecology studies are several sub-projects on energetics discussed under section 2 as well as aerial surveys. These surveys (SC/F13/SP6) were intended to increase knowledge on seasonal variation in distribution and abundance for better estimation of residence time of minke whales in Icelandic waters.

The ultimate goal of the MRI's studies on feeding ecology and energetics is to provide data that can be used in multi-species or ecosystem models for evaluating the role of common minke whales in the ecosystem around Iceland. While realizing that a sample size of only 200 animals would not be sufficient to give precise answer to the research question, the present research program was intended to be a first step in such a process by testing different methods and providing data that could serve as an input in the design of multi-species models. The program has provided such data concerning diet composition using several methods (SC/F13/SP2, SC/F13/SP3, SC/F13/SP4), energy deposition (SC/F13/SP8, SC/F13/SP10, SC/F13/SP11), consumption rates (SC/F13/SP9) and seasonal variation in abundance (SC/F13/SP6). The construction of a multi-species model was delayed because of difficulties in recruiting a competent statistician despite intensive efforts, including advertisements in Iceland as well as internationally. This work is now underway as a PhD project and reported in SC/F13/SP7.

◊ **Paper of reference:** SC/F13/SP2

Recent changes in the diet composition of common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters. – Consequence of climate change?

Results

Most (97.4%) of the 190 examined stomachs contained some food remains. In total 14 prey species were found in the stomachs including 10 species of fish and 2 species of euphausids. The diet was primarily (> 90%) composed of fish, with krill contributing only 8.6% in terms of Weighted frequency of occurrence (WFO) and 8.2% in terms of Reconstructed weight (RW) to the diet. Sandeel was the single most important prey type overall with 45% and 47% prevalence in terms of WFO and RW, respectively. Other common prey species were herring, capelin, haddock and cod. Together, large benthic fish (gadoids) constituted 24% and 23% of the diet respectively according to these measures. Overall, haddock and cod were the most important gadoids, contributing 9.77 and 7.93% of the reconstructed weight respectively.

The size range of fish prey for the minke whale was wide. Overall the prey ranged from 1 to 93 cm in total length. All age classes of capelin (0-4 yrs) and sandeel (0-6 yrs) were found in the stomachs and the age of cod prey ranged from 0 to 14, with a mean of 6 years.
The results show pronounced spatial and temporal variation in the diet. Sandeel dominated the diet in the southern and western areas, while the diet was more diverse off northern and eastern Iceland. Cod consumption was largely confined to the northern area where it constituted up to 29% of the diet.
Of the pelagic fish prey capelin appeared to form a steady part of the diet in the northern area throughout the observation period while being hardly detected in the southern area (see SC/F13/SP2 Fig. 3). The importance of herring in the diet however increased from being non-existent in the stomachs from 2003 to constituting nearly 80% of the diet in the southern area during 2007
Cod consumption was largely confined to the northern area where it constituted up to 29% of the diet.
The temporal changes include a decrease in the proportion of sandeel in the diet over the study period and a corresponding increase in herring and gadoids. The diet also differed markedly from the limited previously available data from Icelandic waters. In the present study the proportion of large, benthic fish (notably cod and haddock) was much higher while planktonic crustaceans and capelin accounted for much smaller proportion of the diet.

Conclusion

These changes in diet composition are consistent with recent changes in the Icelandic continental shelf ecosystem including high sea temperatures and changes in distribution of several fish species including sandeel and capelin. The results therefore do not indicate any strong prey preference but rather seem to reflect prey availability in the Icelandic continental shelf area. However, a concomitant decrease in abundance of minke whales in this area may reflect shifts in whale distribution following a northward shift in distribution of prey species s.a. capelin due to increase in sea temperatures. Although natural fluctuations cannot be ruled out at this stage, these dietary changes, together with decreased abundance in coastal waters, may thus reflect the responses of minke whales to a changed environment possibly driven by global warming.

◊ **Paper of reference:** SC/F13/SP3

Analyses on stable carbon and nitrogen isotope ratios in soft tissues of common minke whale (*Balaenoptera acutorostrata*) in Icelandic waters and its prey.

Materials and methods

A total of 94 and 92 tissue samples were analysed for $\delta^{13}C$ or $\delta^{15}N$, respectively. The samples consisted of four tissue types (blood, muscle D4, skin M4.5, skin D4) and were obtained from 36 whales landed in Icelandic waters in June to September in 2003, 2004 and 2006 (Table 1). For further description on the sampling procedure see (SC/F13/SP1).

Samples of common prey species of the minke whale were collected for the study in various research excursions in Icelandic waters in the years 2003 to 2007. Each sample consisted of five whole fish that were homogenized before the isotope analyses. Results on isotope levels for various fish species obtained from Pétursdóttir and Gíslason (2009) were included in the comparison.
Stable isotopes ratios were analysed at the Institute for Energy Technology (IFE), Kjeller, Norway. After drying the samples at 80°C to constant weight, they were homogenized in a mortar and finally defatted by Soxhlet extraction for 2 h using 93% dichloromethane and 7% methanol. Stable isotopes ratios ($\delta^{13}C$ and $\delta^{15}N$) were analysed on a Horizon Isotope Ratio Masspectrometer from NU-Instruments, Wales. The isotope enrichment (‰) relative to international isotopic standards is given by the following equation:

$$\delta X = \left[\left(R_{sample} / R_{standard} \right) - 1 \right] \times 1000$$

where δX is $\delta^{13}C$ or $\delta^{15}N$ and R is the ratio of either $^{13}C/^{12}C$ or $^{15}N/^{14}N$. Pee Dee Belemnite (PDB: USGS 24) is the standard for $\delta^{13}C$, while atmospheric air (IAEA-n-1 and IAEA-n-2) is the standard for $\delta^{15}N$.

Relationship between stable isotope ratios in skin D4 compared to blood, muscle-M4 and skin-M4.5 were evaluated using linear regression model in the R package (R Core Team 2012). Models fitting the relationship of isotope ratios to a set of explanatory variables were built using generalised linear mixed model (glmmADMB package in R) (Skaug *et al*. 2011) with a Gaussian link function. The variability of the model parameters were assessed by running *post hoc* Markov chain of 50,000 MCMC iterations.
The explanatory variables used in the models were tissue type (blood, muscle d4, skin-D4, skin-M4.5), body length, period (2003/2004 and 2006) and region (SW: Látrabjarg south and east to Hornafjörður; NE: Látrabjarg north and east to Hornafjörður). Models testing for interactions between region and period were evaluated. To model the measurement correlation the ID of the whale was used as a random effect in the models tested.

Results
The results of the $\delta^{13}C$ and $\delta^{15}N$ (average +/- SD) in various tissues, regions and periods for the minke whale as well as common prey species are shown in Fig. 1 (see SC/F13/SP3).
Paired t-test of isotope levels in skin-D4 samples compared to blood, muscle-D4 and skin-M4.5 respectively showed significant difference in $\delta^{15}N$ to blood and muscle-D4 at the 1% level and in $\delta^{13}C$ to blood at the 5% level (see SC/F13/SP3 Table 2). Of the groups with significant difference in the t-test only skin-D4~muscle-D4 showed significant intercept in the regression analyses for $\delta^{15}N$ (see SC/F13/SP3 Table 2, Fig. 2 a, b).

The glm model fitting best to the $\delta^{13}C$ data was based on the tissue type, region, length and period and for the $\delta^{15}N$ data was based on the tissue type and length (see SC/F13/SP3 Table 3).

Conclusion
The overall level of $\delta^{15}N$ in minke whale tissues is at the level of herring, above the levels of krill and sand eel and below adult cod fishes (see SC/F13/SP3 Fig. 1). Taking into account 3‰ to 4‰ enrichment between trophic levels this may lead to the assumptive conclusion that krill and small sand lance are of significant importance in the minke whale diet. The overall level of $\delta^{13}C$ in the minke whale tissues is at level with adult codfishes but lower than krill, sand eel and the pelagic herring and capelin. These somewhat contradictory results may suggest that the minke whale diet consists of prey species or populations not fully covered in the present study.

The low significant difference in the paired comparison of $\delta^{13}C$ in skin-D4 samples and blood, muscle-D4 and skin-M4.5 respectively suggest that biopsy samples may give representative information on the isotope levels of the individual whale. Significance was only detected in comparison of $\delta^{13}C$ in skin-D4 and blood. Paired comparison of $\delta^{15}N$ in skin-D4 to other tissues showed significance at the 1% level for blood and muscle-D4. These results indicate that biopsy samples are less suitable to represent N isotope values in other tissues of the minke whale.

The glmm model fitting best to the isotope data suggest that $\delta^{13}C$ values are highly dependent on tissue type, region and period and to a lesser extent the whale length. Interactions between regions or periods did not improve the fit. The best model for $\delta^{15}N$ suggests that tissue type and body length are the main explanatory parameters.

These results suggest that the average trophic level of the minke whale diet is stable and does not vary geographically or by the size of the predator. Furthermore the consequent levels observed in the different tissue types and the two periods (2003/04 *vs* 2006) suggest little change in the average trophic level over shorter and longer time scale.

The somewhat more complex results of the $\delta^{13}C$ analyses suggest that the diet in the NE region is by larger extent of pelagic origin than in the SW region. Furthermore, some shift towards diet of pelagic origin seems to have occurred from 2003/04 to 2006.

Comparison of the results from the stable isotope and stomach content analyses showed a considerably lower trophic level in the isotope study (SC/F13/SP2). Thus the large proportion of large gadoids (codfish) in the northern areas (20-30% of the diet) found in the stomachs is not indicated in the $\delta^{15}N$ isotope data. This might be explained by the fact that while stomach contents are a measure of recent feeding activities, isotopes reflect a past period. On the other hand, the spatial and temporal difference observed in the $\delta^{13}C$ is in line with the stomach content analyses, and suggest larger importance of prey of coastal origin in the SW and in 2003/04 compared to larger proportions of pelagic diet in the NE region and in 2006.

In general it may be impossible to draw firm conclusions on the diet based solely on stable isotope signatures in a highly generalist predator as the minke whale. The diet of minke whale consists of wide spectrum of prey species from different trophic levels and therefore it will be difficult to interpret the isotope data without information from other sources. The isotope levels may however prove useful as a monitoring tool and provide signals of changes in the minke whale diet or of further down the food chain.

◊ **Paper of reference:** SC/F13/SP4

Fatty acids in the blubber and blood of common minke whales (*Balaenoptera acutorostrata*) and relation to their diet in Icelandic waters.

Summary

Fatty acid (FA) profiles of the total lipids of 23 minke whales (*Balaenoptera acutorostrata*) were analysed in tissues of outer blubber, inner blubber and blood and in some of the minke whales potential prey the years 2003, 2004 and 2006 in the waters around Iceland. The main objective was to study how FA profiles reflect the diet of minke whales around Iceland. These three tissues were tissue-specific (i.e. samples from each tissue group together in multivariate analysis) and the inner blubber best reflected diet. The FA profiles did not reflect the stomach contents of the minke whales. However, the large variance in FA composition of the inner blubber indicates a diverse diet of the minke whales in agreement with the stomach contents. The FA profiles indicated that before the collapse of the sandeel stock around 2005 the food variety of minke whales was more diverse than in the year 2006 when the sandeel stock had collapsed. In 2006 the *Calanus* based food-web was of higher importance than in 2003. The use of FA analysis in trophic studies of whales are promising but must be interpreted with care and with their limitations in mind.

◊ **Paper of reference:** SC/F13/SP6

Changes in minke whale distribution and abundance by season and over time in aerial surveys of Iceland 1986-2009. Previously submitted as *SC/64/RMP4 revised*, June 2012, Panama City, Panama.

Results
The off season component of these surveys was a part of the Icelandic Research Program of common minke whales, but the results of all aerial surveys covering most of the continental shelf waters of the Icelandic economic zone at intervals 1987 to 2009 were summarized with respect to temporal and seasonal features given recent observed ecosystem changes. The same observers have participated in only a few of these surveys, but it is found that although there are some observer differences the changes in minke whale sighting rates between years are fairly consistent for the two primary observers (on the left and right side of the plane) and consistent in repeated coverage of the same blocks within survey. The observers differ more in their detection functions and therefore the estimates of abundance derived from the fit of these to the data, also when including corrections for animals missed by the observers based on limited independent observer data. Sighting rates of the smallest whales (harbour porpoises) differ greatly by observers and the sighting rates of large whales are inflated when the observer has more effort at greater distances from the track line. Sighting rates of minke whales are a more robust index of relative presence in the areas in particular when comparing the off-season surveys, during times of low density and therefore few sightings. Sighting rates were lowest in the spring (late April-early May). The sighting rates in September are 1/3 of the midsummer rates, but variation between years is even greater and there is an observable change over time in species distribution in the area.

Conclusion
The aerial surveys sighting rates give a good overview of distribution changes over time and season. The survey area is too limited, in particular to the North where the densities are similarly high at the outer edges of the survey area, for any conclusions to be drawn about the total abundance of the population feeding in the Central Atlantic. The high variation observed during the surveys and difficulties with surveying off season, resulted in less surveying than had been initially planned. The IO data need to be augmented with video or photographing, which would ensure comparability to future surveys. These might be conducted entirely by such means.

3. ENERGETICS

Studies on body condition of minke whales are closely related to those on feeding ecology. The aim of these studies was to investigate the building up of energy reserves throughout the summer using both direct (Lockyer and Waters 1986; Víkingsson *et al*. 1988) and indirect (Lockyer 1987; Víkingsson 1995) estimates of increase in weight and energy content of different tissues.

The energetic studies included analyses of blubber thickness and girths (SC/F13/SP5, SC/F13/SP8), energetic contents of various tissues (SC/F13/SP10), weightings of tissues and organs and estimation of food ingestion rates from physiological parameters (SC/F13/SP11). In the original proposal, feasibility of estimating field metabolic rates from measurements of lung capacity and respiratory frequencies was suggested as done by Folkow and Blix (1992). However, this last objective was abandoned due to logistical constraints and the low likelihood of such experiments to add significantly to the above mentioned research on the same species off Norway.

◊ **Paper of reference:** SC/F13/SP5

Female body condition affects foetal growth in a capital breeding mysticete

Summary

Understanding how female body condition (FBC) influence foetal development, and hence offspring production, is fundamental for our understanding of species reproductive physiology and life history. In this study we demonstrate for the first time that FBC can affect foetus growth in minke whales, a capital breeding K-strategy species. Pregnant minke whales were sampled around Iceland during the summer feeding seasons between 2003 and 2007 and the length and weight of their foetuses were measured. FBC was modelled as the relative difference between measured blubber volume and the average expected blubber volume of individual whales. Linear models were used to test the effect of FBC on foetus length, while accounting for the daily growth in foetus size through gestation, as well as other covariates. Similar to previous studies, foetus length increased linearly through the study period at a rate of 0.918 cm day^{-1} (SE = 0.111). The effect of FBC on foetal length was nonlinear, showing an almost linear positive relationship for females in poorer body condition (FBC < 0), which levelled off at better body conditions (FBC > 0). This curvilinear relationship was confirmed by fitting a generalized additive model and by running separate analyses on two subsets of data containing females in poorer and better condition. Our findings suggest that females that are in poorer body condition reduce their energetic investment in their foetus proportionately to their condition, in order to maintain high adult survival. That foetus length did not continue to increase at better body condition suggest that maternal size causes physiological constraints to the maximum length that the offspring can attain at birth, in order to avoid labour complications. Reducing the size at birth by reducing the gestation period is unlikely, since the reproductive cycle of balaenopterids is strongly linked to their seasonal migration between feeding grounds and breeding grounds.

◊ **Paper of reference:** SC/F13/SP8

Minke whales maximise energy storage on their foraging grounds.

Summary

Seasonal trends in energy storage of minke whales (*Balaenoptera acutorostrata*), as a capital breeder, were investigated by estimating blubber volume (SC/F13/SP8). Total blubber volume was modelled, using blubber thickness and morphometric measurements of individual whales. Total blubber volume was strongly influenced by the length of the animal, and there was a difference between reproductive classes, with pregnant females having a higher blubber volume than mature animals. Whereas there was no seasonal variation in the blubber volume for immature whales (n = 4 males, 12 females), mature (n = 61 males, 5 females) and pregnant whales (n = 49) showed a strong linear increase in blubber volume through the feeding season. The rate of blubber increase did not differ between mature (0.0028 m^3 day^{-1}, s.e.m = 0.00103) and pregnant whales (0.0024 m^3 day^{-1}, s.e.m = 0.00100). This suggests that immature whales could be investing a large proportion of their excess into growth, to reach the length of sexual maturity faster and start reproducing earlier, whereas mature and pregnant whales tended to reserve this energy for breeding. That the rate of increase in blubber for mature and pregnant whales did not level off through feeding season, further showed that minke whales aim to maximize energy storage, and consequently food intake, while on the feeding grounds. The total amount of blubber accumulated over the feeding season was about 0.51 m^3 for mature whales, and 0.43 m^3 for pregnant whales. Being a capital breeder, this amount, together with the energy stored as muscles and intra-abdominal fats, constitute the total amount of

energy that minke whales have available to finance the costs of reproduction (foetus development and lactation) on the breeding grounds, and to cover the costs of migration as well as daily field metabolic rates, growth and body maintenance.

◊ **Paper of reference:** SC/F13/SP9

Report on predicted urine production and food ingestion rate and salt balance of the common minke whale (*Balaenoptera acutorostrata*) off Iceland. Previously submitted as *SC/56/O11*, Sorrento, Italy.

Results

Blood and urine samples were obtained from 30 animals for scientific purposes. Both blood and urine samples were obtained from 16 common minke whales (*Balaenoptera acutorostrata)* caught off the coast of Iceland August-September 2003, 4 nonpregnant females and 12 males. The animal weight was derived from their length, which gave a mean weight of 4,571 kg (S.D. = 1,337). Na^{+}, K^{+}, Cl", Mg^{++}, Ca^{++}, creatinine, urea, and uric acid were measured in blood and urine as well as pH and osmolarity. Utilizing allometry of creatinine clearance in relation to body weight and the serum and urinary concentrations of creatinine the average urine volume was predicted to be 214 L/day. From this volume and the known water content of the ingested food the average daily food ingestion was estimated to be about 280 L.

Conclusion

The estimated ingestion is considerably greater in volume than reported earlier by most workers. Energy calculations suggest considerable heat loss as this metabolic rate is over three times that of an equally heavy terrestrial mammal. Concentrations of electrolytes in urine are compatible with the fact that the minke whale is a piscivorous animal and are quite different from those of the krill eating fin whale. The high sodium and magnesium levels in urine suggest some sea water ingestion. Whole body salt concentrations of the fishes preyed on are not known, but these, including all extracellular spaces in blood vessels, entrails, gills etc., are needed for further balance studies.

◊ **Paper of reference:** SC/F13/SP10

Energy storage in common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters 2003-2007. –Chemical composition of tissues and organs.

Summary

No systematic studies have been conducted on body condition or energetics of common minke whales in Icelandic waters. Therefore energetic studies were included as an important part of the Icelandic minke whale research program (Marine Research Institute 2003). Here, we report on chemical analysis of various tissues, believed to be important in energy storage. Individuals sampling methods can be found in the original paper.

This study demonstrates that in addition to the increase in mass of important energy storage tissues, s.a. blubber and visceral fat (SC/F13/SP8, SC/F13/SP11), common minke whales store significant amounts of energy by increasing the lipid content of various tissues, thereby increasing the energy density per unit weight. The results are consistent with previous studies on balaenopterids in that the most important blubber storage sites lie dorsally in the posterior part of the body. Significant amounts of energy are also stored in the posterior dorsal muscles as in fin whales (Lockyer *et al*. 1985; Vikingsson 1990, 1995) and supports indications detected by Næss *et al*. (1998) regarding minke whales. In addition, large amounts of energy are apparently stored as visceral fats and within bone tissue. The pattern of variation among reproductive classes is broadly similar to that found for larger Balaenoptera with highest levels of lipids found in pregnant females. The study has also shown interesting spatial variation within the Icelandic continental shelf area, which can be explained by corresponding variation in diet composition. A significant decrease over the research period 2003-2007 in lipid content of posterior dorsal muscle could be a result of a decrease in prey availability. This is supported by the concurrent feeding ecology studies and recent changes in abundance of minke whales in the area. Thus, a massive decrease in the Icelandic sandeel population around or before 2005 explains decreased proportion of sandeels (apparently the preferred prey species) in the minke whale stomachs during 2003-2007. Decreased abundance of minke whales in sightings surveys during 2007-2009, as compared to 2001, could thus reflect a shift in distribution or/and a result of food shortage.

This study has demonstrated the feasibility of using carcass analysis for estimating total energy storage throughout the season which would establish an important parameter for estimating food requirements as an input for multispecies modelling. Larger sample sizes (e.g. in connection with the commercial minke whaling operations) are however obviously required to increase the precision of such estimates.

◊ **Paper of reference:** SC/F13/SP11

Spatial and temporal variation in body mass and the blubber, meat and visceral fat content of North Atlantic minke whales.

Summary

Subsamples from both Icelandic and Norwegian research catches were weighed for total weight and a larger sample for part weights of blubber, meat and visceral fat. Regression found in all cases a significant increase (for a given length) over the season, in particular for the mature animals, and also in the girth measurements, more so towards the caudal part of the body, but the girth measurements do not fully capture the increase in weight. This fattening (increased weight for a given length) is in addition to any increase in weight due to growth (lengthening) or maturation of the animals and the increased energy content found in other studies comes on top of this increased mass/volume. Pregnant females are fatter and have in particular significantly more blubber. The results agree with studies on blubber thickness measurements and tissue energy content and are in time and space in line with observed changes in the ecosystem around Iceland during the research period.

4. BIOLOGICAL PARAMETERS

Research on biological parameters of common minke whales in Icelandic waters have been limited to studies in conjunction with the commercial fishery during the last few years before the onset of the moratorium in 1986 (Sigurjónsson 1980, 1988; Sigurjónsson *et al*. 1990; Víkingsson and Sigurjónsson 1998). These studies included estimates of standard biological parameters such as age at sexual maturity, length at sexual maturity and apparent pregnancy rates. As other studies on the biology of common minke whales these have suffered from lack of reliable methods for age determination. Various methods have been attempted, including the use of growth layers in ear plugs, tympanic bullae and jaw bones but none of these have produced satisfactory results. The feasibility of using ear plugs for age determination was examined. Attempts were made to collect ear plugs from all animals. Earplugs (one or two) were collected from around 80% of the animals and fixed in formalin. Preparation of microscope slides from these proved however unsuccessful, both at the MRI and at the institute for experimental pathology, University of Iceland. These poor results are in concordance with most other attempts to use earplugs for age determination of common minke whales (Sergeant 1963; Mitchell and Kozicki 1975). This method was therefore deemed infeasible as a reliable method for age determination. Attempts were also made to use bullae for age determination as described in Christensen (1981). The results did not suggest this to be a useful method for age determination. This is in line with previous studies. Age of the common minke whales from Icelandic waters was therefore estimated by the aspartic acid racemization (AAR) technique (see SC/F13/SP15).

The objective of the study of the biological parameters was to collect and analyse new information on age and reproduction in minke whale in Icelandic waters (SC/F13/SP12, SC/F13/SP13, SC/F13/SP14, SC/F13/SP15).

◊ **Paper of reference:** SC/F13/SP12

Growth and reproduction of minke whales in Icelandic waters.

Results

The overall (female/male) sex ratio was 1.30/1 and 1.20/1, for foetus and 0+ whales respectively, not significantly different from 1:1.

Standard length at birth was estimated with the von Bertalanffy growth model as about 2 (95% CI 0 – 7) meters and females grew faster and attained lager size than males. Asymptotic standard length was 795 (SE 13.48) and 842 (SE 12.30) cm for males and females respectively. Estimated age and standard length at sexual maturity was 7 and 10 years and 639 and 713 cm for males and females. Pronounced seasonality was observed in testes weight and in the diameter and cover of seminiferous tubules, indicating a continuing testes development throughout the summer and autumn. Lack of data from the winter makes the exact timing of parturition and mating unknown. About 91% of mature females were reproducing and 9% anoesterous, indicating a predominantly annual reproductive cycle. The study confirmed earlier findings of parturition and conception occurring in mid-winter and gestation about 11 months. However, there was great temporal variability in parturition and conception, indicated by high variability of standard length of foetus in relation to day of the year. One minke whale female of total of 72 pregnant females had twin foetuses (1.4%).

Conclusion

From the outset, it was recognized that a total sample size of 200 animals would hardly be sufficient for precise estimation of biological parameters. However, results of the study are broadly in line with previous indications and have therefore strengthened the data basis for determining the biological parameters of Central North Atlantic minke whales. In particular, the new method of age determination is promising and throws new light on some of the previously assumed biological parameters such as age at sexual maturity. It is clear that a larger sample size is needed for more precise determination of biological parameters, but the study has confirmed the feasibility of systematic collection of biological data onboard minke whale catcher boats. This might be achieved in connection with the commercial minke whaling operations.

◊ **Paper of reference:** SC/F13/SP13

Report on blood testosterone and oestrogen concentrations of the north Atlantic minke whales (*Balaenoptera acutorostrata*) during the feeding season in Icelandic waters from research catches 2003-2006. Previously submitted as *SC/64/RMP4 revised*, June 2012, Panama City, Panama.

Results

Sex hormone measurements from the North Atlantic minke whale (common minke whale, *Balaenoptera acutorostrata*) in Icelandic coastal waters were obtained from frozen blood serum samples collected fresh post-mortem from 23 females and 47 males caught during June–September 2003–2007 as a part of the Icelandic Research Program of Common Minke Whales. Respectively serum progesterone (P) and testosterone (T) concentrations were measured and compared with anatomical data. The frequency distribution of female serum P measurements in Norwegian catches has been shown to have two clusters, one consisting mainly of immature animals and the second of pregnant ones, with mean serum values of about 0.49 ± 0.04 (S.E.) and 44.2 ± 2.84 nmol/L, respectively. Therefore only females that had no observed foetus and in some cases one or both ovaries missing were measured to provide information on the reproductive status. The Norwegian frequency distribution of male serum T did not show any group-specific distribution during the hunting season. Only males longer than 5.70 m were measured here. Contrary to earlier reports on the Antarctic minke whale (*Balaenoptera bonaerensis*), serum T values rose during the hunting season in the mature males as also observed in the Norwegian sample. This increase agrees with the predominantly annual reproduction cycle of minke whales. However the rise in the T measurements in the Icelandic sample happens during the days 215-243 of the year while the rise in the Norwegian measurements appears during days 180-220 of the year or earlier.

Conclusion

As no genetic divergence has been observed between the Icelandic and Norwegian samples and low diversity in the North Atlantic in general, the difference in the timing of the rise in T values is likely due to segregation by reproductive status as has been observed by sex and age, generally north-south. T value measurements later in the season would be valuable, but minke whales have not been caught then. The P measurements are valuable when other means of determining the reproductive status are inconclusive.

◊ **Paper of reference:** SC/F13/SP14

Geographic, temporal and size segregation of sexes of the common minke whale (*Balaenoptera acutorostrata*) in Icelandic waters based on catch data from 1974 to 2009.

Results

Results of the binomial GLM analyses of F/M ratio (F = 1 and M = 0) and available predictor variables, showed that seasons, years, areas and the interactions seasons×longitude, years×longitude and years×length of animals were significant. The females were increasingly dominating in the catch (p = 0.01) as the season progressed, and there was a significant interaction between season and latitude (p = 0.001). Also the F/M ratio was highly significantly different between the East and West area of Icelandic waters ($p < 0.001$), divided by the western 18° degree longitudinal arch. The F/M ratio increased with latitude, but this was dependent on the season ($p = 0.01$). There was also an increasing F/M ratio in relation to length of animals, but here again a significant interaction between years and length of animals was observed ($p = 0.002$). This indicates that F/M was different in the two areas West and East of Iceland, the ratio decreased with time and was influenced by longitude and length of animals. There was a negative relation between F/M and length of animals and some interaction between seasons and latitude.

Conclusion

The observed pattern in the catch-data of common minke whales in Icelandic waters, could be explained with males arriving later from the south to Icelandic waters, because their spring and summer distributions were observed to be more southerly (areas 1, SA and 10) than the distribution of females. Later in the summer and the autumn they have arrived to the northern part of Icelandic waters, dominating in the catch there too. The females may by then have left the Icelandic whaling area and moved even more northerly or to West and East Greenlandic waters. In all, the results not only suggested a complicated geographic and temporal segregation of minke whales, but also a size dependent one.

◊ **Paper of reference:** SC/F13/SP15

Estimation of age of minke whales (*Balaenoptera acutorostrata*) in Icelandic waters by aspartic acid racemization (AAR),-aspartic acid racemization and earplugs of minke whales from the Antarctic (*B. bonaerensis*) used as a reference.

Summary

Good estimates of age of animals is of great importance in all aspects of wildlife research as for example management of stocks, elucidating age structure, life-history, and catch-at-age history of populations (Olsen 2002). However, it has been found difficult to determine age of minke whales from the North Atlantic (*Balaenoptera acutorostrata*) by way of either earplugs (Sigurjónsson 1980) *or bulla tympanica* (Olsen 2002) in contrast to Antarctic minke whale (*B. bonaerenis*) and fin whales (*B. physalus*) for which earplugs are normally used for ageing. The estimate was based on the eye nuclei from 38 earplug-aged Antarctic minke whales and eye nuclei from 21 foetuses of Icelandic minke whales (*B. acutorostrata*). The age of the Icelandic minke whale was found from the regression of age of Antarctic minke whales and on transformed D/L-ratios for the Antarctic minke whales and the foetuses of Icelandic minke whale. The age interval found for the Antarctic minke whales was 2-48 years while the minimum and maximum age estimated for the Icelandic minke whales were 3 and 42 years, respectively. The standard prediction error is about 4 years while the SE of the left and right lens nuclei is on average between 2.6 and 3.1 years.

The racemization rate, *k*, of the Antarctic minke whale was found to be 0.00147 ± 0.00006/y (SE) which is higher than that obtained for Icelandic fin whales, bowhead whales, and harp seals but lower than that found for harbour porpoises. The ratio of D and L at birth, $(D/L)_0$, found for the Icelandic minke whale foetuses and the regression of the transformed D/L-ratio of the Antarctic minke whales on earplug readings was found to be 0.0196 ± 0.0009 (SE) which is in the lower range of values found for other marine mammals. Since Antarctic minke whale has more biological resemblance to the Icelandic minke whale than other marine mammalian species for which racemization rate has been estimated so far, the Antarctic minke whale is assumed to be the presently best model of the racemization behaviour in the lens nucleus of the Icelandic minke whale. However, further studies are needed to better understand what governs the values of racemization rate and $(D/L)_0$.

5. STOCK STRUCTURE

5.1. Genetics

Genetic studies of the stock structure, social structure and dispersal of North Atlantic baleen whales have traditionally been limited to research on harvested individuals from their feeding grounds. The main disadvantage of these studies was low sample sizes, in particular lack of samples from large areas where no whaling was ongoing. Traditionally, the management of the North Atlantic common minke whales has been based on four geographical subdivisions divided by the International Whaling Commission (Donovan 1991), namely the Canadian East coast stock, the West Greenland stock, the Central stock (Iceland) and the Northeastern stock (Norway). These management regions have been primarily established through studies based on catch statistics, biological characteristics and tagging. Genetic variation among potential (sub)populations of minke whale prior to the research program, have been investigated using isozyme (Daníelsdóttir *et al.* 1992, 1995) and human α-globin 3'HVR (Árnason and Spillaert 1991). Both types of markers revealed a significant genetic differentiation among samples collected at West Greenland, Icelandic and Norwegian feeding grounds; hence suggesting the potential existence of at least three different populations. However, genetic studies using more polymorphic and variable markers such as microsatellite loci have been highly recommended, hence the following section of the research program.

The objectives of the genetic approach were therefore four-fold:

1) To analyse the genetic composition of animals in Iceland with the same genetic methods as used in the Norwegian and Japanese individual identification registry,

2) to compare with reanalysed Icelandic samples collected in the past and samples from animals taken in nearby areas such as Greenland and Norway,

3) to analyse temporal variation and heterogeneity of Icelandic minke whales with respect to the possibility of a mixture of more than one breeding stock at the feeding grounds,

4) to compare available genetic samples collected prior to 1986, with samples from the present time in order to study the effect of protection for the past 18 years (stock expansion and/or decline).

All results related to the objectives mentioned above have been dealt with in SC/F13/SP17, and an additional study has been performed with part of the samples collected during the research program (SC/F13/SP16).

◊ **<u>Paper of reference:</u>** SC/F13/SP16

Possible cryptic stock structure for minke whales in the North Atlantic: Implications for conservation and management

<u>Summary</u>
The minke whale is the last of the great whale species to be hunted in significant numbers. Effective management must include an understanding of how genetic diversity is divided and distributed among

putative local populations, and as for many migratory species, this is complicated for the minke whale by large-scale seasonal movement among geographic regions. The problem is that the geographic identity of breeding populations is not known, and instead these whales are predictably found and hunted where different breeding stocks may mix on seasonal feeding grounds. Here we use microsatellite DNA and mtDNA markers to investigate minke whale population structure across the species' range in the North Atlantic. We found no evidence of geographic structure comparing putative populations in recognized management areas, though some limited structure had been indicated in earlier studies. However, using individual genotypes and likelihood assignment methods, we identified two putative cryptic stocks distributed across the North Atlantic in similar proportions in different regions. Some differences in the proportional representation of these populations may explain some of the apparent differentiation between regions detected previously. The implication would be that minke whales range extensively across the North Atlantic seasonally, but segregate to some extent on at least two breeding grounds. This means that established stock boundaries in the North Atlantic, currently used for management, should be re-considered to ensure the effective conservation of genetic diversity.

◊ **<u>Paper of reference:</u>** SC/F13/SP17

Genetic structure of the North Atlantic minke whale (*Balaenoptera acutorostrata*) at feeding grounds: a microsatellite loci and mtDNA analysis. Previously submitted as *SC/60/PFI10*, June 2008, Santiago, Chile.

<u>Results</u>

All the laboratory work and statistical methods employed during this study were previously described in *SC/60/PFI10* and followed the IWC guidelines (see Tiedemann *et al*. 2012, SC/64/SD4 for an update). The results are presented below in relation to the objectives of the research program.

1) To analyse the genetic composition of animals in Iceland with the same genetic methods as used in the Norwegian and Japanese individual identification registry.

All samples were therefore analysed with the same methods as the one developed for the Norwegian and Japanese individual identification registry. In 2010, a DNA-registry database was created in ORACLE at the Marine Research Institute of Reykjavík, containing all scientific samples (2003-2007) which have been used for this project.

2) To compare with reanalysed Icelandic samples collected in the past and samples from animals taken in nearby areas such as Greenland and Norway.

Icelandic samples from scientific permit (2003-2007) as well as from past hunting activity (1981-1985) were genetically analysed as planed and compared to samples from the Barents Sea, West Greenland, Norway coastal area, North Sea and Spitsbergen.

First, both genetic markers gave congruent results and showed no genetic differentiation among temporal samples collected in Iceland from 1981 to 2007 (see SC/F13/SP17 Appendix 2 and 3), therefore suggesting temporal stability.

In addition, samples collected from the six different geographical regions (see SC/F13/SP17 Appendix 2 and 3) were also not significantly different at both genetic markers.

An analysis based on the regional genetic partition among the four areas defined by Andersen et al. (2003) was performed using a hierarchical analysis of molecular variance (AMOVA) and confirmed the absence of genetic structure among the investigated regions (see SC/F13/SP17 Table 3).

3) To analyse temporal variation and heterogeneity of Icelandic minke whales with respect to the possibility of a mixture of more than one breeding stock at the feeding grounds.
Both genetic markers revealed the presence of temporal stability at the Icelandic feeding grounds (see paragraph above) from 1981 to 2007. None of the genetic variability indices have been varying significantly during the investigated period (see SC/F13/SP17 Table 6 and Appendix 1). All analyses performed did not give any indication of the presence of more than one breeding stock at the feeding grounds at the Icelandic feeding grounds. This can be due to the presence of only one breeding population at the Icelandic feeding grounds and/or to the fact that the genetic markers employed (the only one available to date for baleen whale) were not powerful enough to detect the presence of several breeding populations in our samples.

4) To compare available genetic samples collected prior to 1986, with samples from the present time in order to study the effect of protection for the past 18 years (stock expansion and/or decline).
As stated above, all genetic analyses suggested temporal stability at the Icelandic feeding grounds, and none of the genetic variability indices varied significantly over time. However, the haplotype mismatch distribution of the mtDNA suggested a historical expansion of minke whale in the North Atlantic (see SC/F13/SP17 Fig. 3).

Although the capture signal at the mtDNA might reflect older event (recolonisation after the last glacial maximum) than the current protection over the last 20 years, none of the genetic markers used during this project revealed a decline of the minke whale at the Icelandic feeding ground.

Additional information on the genetic structure of minke whale in North Atlantic was published by Anderwald *et al.* (2011) (see SC/F13/SP16). Part of the samples collected during 2003-2004 in Iceland was used during this study (60 animals). Although possible cryptic stock structure was suggested, the analyses clearly suggested that the most probable number of populations within the North Atlantic was one, e.g. suggesting the lack of structure among minke whales from the North Atlantic.

<u>Conclusion</u>
All genetic analyses performed during this project indicate temporal stability of the samples collected at the Icelandic feeding grounds over more than 20 years and reveal the absence of geographical genetic structure across the North Atlantic Ocean, therefore not confirming previous analyses performed with genetic markers (Árnason and Spillaert 1991; Daníelsdóttir *et al.* 1992, 1995; Andersen *et al.* 2003).

5.2. Telemetry

Satellite telemetry has, in recent decades, proven to be a useful technique to monitor movements of free ranging animals. The use of the technique for studying large cetaceans is, however, much more problematic than for terrestrial mammals. The additional problems include the need for remote deployment of the tags and short communication time between tags and satellite because of diving. Although the use of this method on whales cannot be considered to be beyond the experimental stage, the success rates have been increasing in recent years. We therefore intended to obtain information on autumn migration (including the location of wintering grounds) as well as movements within the summer feeding season by monitoring the movements of minke whales by satellite telemetry. In addition, this study was expected to provide data on respiratory frequency to be used in calculations on metabolic rates and in abundance estimation.

◊ **Paper of reference:** SC/F13/SP18

Migration and local movements of common minke whales tracked by satellite in the North Atlantic during 2001 – 2010.

Results

During 2001-2011, 12 minke whales were instrumented with satellite tags in Iceland. Of these, six provided information useful for describing movement and will be described in more details here (see SC/F13/SP18 Table 1). One 6m long minke whale was tagged at Skjálfandi Bay, north Iceland, on 12th August 2001 (#13280). The whale was tracked through 29th August where it travelled a minimum of 153 km along the coast of northern Iceland (see SC/F13/SP18 Fig. 1). Occasional signals were received through 6th September.

Another minke whale was tagged at Skjálfandi bay on 15 August 2001 (#13282). It was tracked through 18th October where it moved a minimum of 958 km with an average daily travel distance of 16km (range 2-38 km/day). Its movements mainly consisted of visits to fjords in northeast Iceland with no apparent offshore activities (see SC/F13/SP18 Fig. 1).

On 20th August 2002, two minke whales were instrumented with satellite transmitters. No signals with positions were received from one of these whales. The other whale was tracked until 8th November, for 88 days (#3960, see SC/F13/SP18 Fig. 2). Like the minke whale tracked in 2001, it was rather stationary in coastal Northern Icelandic waters beyond mid-October. On 31st October the whale had moved northeast of Iceland, and four days later signals were received more than 350 km further south. The last signals were received on 8th November at 56°N 27°W showing continuous fast southward movement (see SC/F13/SP18 Fig. 2).

During the period 27th August-23rd September 2004 seven minke whales were instrumented with satellite transmitters in Faxaflói Bay, Southwest Iceland, but useful information were only received from four of them (see SC/F13/SP18 Table 1). Two of these only transmitted data for few days while they were still in the area where they were tagged. One minke whale tagged on 14th September (#50683) 2004 stayed within the tagging area in Faxaflói Bay until 22nd September, when it moved west to the continental slope area where it stayed for about a week. On 30th September the animal turned southwards along the Reykjanes Ridge, at a mean speed of 10 km/hour. The last signal was received on 8th October at around 50°N, 34°W (see SC/F13/SP18 Fig. 2).

On 17th November 2004 signals were received from a minke whale that was tagged in Faxaflói Bay 27th August (#50686), the first data received from this animal. The position of the animal was then over the Mid-Atlantic Ridge, 900 km west of Northern Spain. The transmitter provided the next positions on 23rd November, where the whale had travelled some 700 km to the south, into the Azores area. No useable transmissions were received on the 30th November, but on 5th December the animal had moved further to the south, along the Canary Current and was 1,000 km northwest of the Cape Verde Islands. This area is 3,700 km away from Faxaflói Bay where the tag was deployed on the whale three months (101 days) earlier.

Tagging attempts during spring have yielded limited results with only one minke whale providing useful, albeit very limited data. This whale was tagged in Faxaflói Bay on May 6th and the first signals were received 45 days later close to the tagging site. During 20th June-8th July six positions were received, all in Faxaflói Bay except one, probably erroneous location off Greenland's east coast on 23rd June.

Conclusion

The experiments in 2001-2002, although few in numbers and limited in time, gave important information on the migration pattern of minke whales. It primarily indicated a rather stationary behaviour of minke whales in coastal North Icelandic waters during late summer and fall prior to the onset of migration. They also indicated a somewhat later start of the fall migration than previously assumed from catch data (e.g. Sigurjónsson and Víkingsson 1997) as neither one of the two "long-transmitting whales" had started migration by late-October. However, the only whale tagged in Faxaflói Bay for which the departure date could be determined did leave Icelandic waters one month earlier. The two animals tagged north of Iceland were both estimated as 6 m in length (corresponding to immature or pubertal individuals) while the “early” migrant was estimated as 8 m long and thus likely mature. Unfortunately no biopsies for determination of gender were obtained from the tagged animals.

In addition, the tracks of the three minke whales that departed from Icelandic waters provide the first indications of the migration route and possible winter destination of minke whales summering in Icelandic waters. All three followed an offshore route in the middle of the Atlantic heading south. Contact was lost early with two of the whales but they were all heading in the same direction. The third whale, where contact was maintained past the Azores, continued south to a position in the mid Atlantic at about 28^{o}N. This represents the longest tracking record for a minke whale worldwide both in terms of distance travelled (3,700 km) and time (100 days).

In all, tracking methods by telemetry remains a challenge as long as methods will not be developed further, but they still give important insight into the migration route of baleen whale such as the minke whale.

5.3. Other methods

The objectives of this section of the program research were to analyse other potentially useful indicators of stock structure. Below are presented results obtained with morphometric characteristics (SC/F13/SP19) and relatedness analyses using DNA profile (SC/F13/SP20).

◊ **<u>Paper of reference:</u>** SC/F13/SP19

Morphometric comparison of common minke whales *Balaenoptera acutorostrata* from different areas of the North Atlantic, including animals from Icelandic waters.

<u>Results</u>
Multivariate statistical analyses of 17 morphometric characters were performed in order to evaluate potential heterogeneity among predefined minke whale stock units area in the North Atlantic. Comparison tests were performed among data collected at West Greenland, East Greenland, North Sea, Norwegian and Barents Sea, and Iceland.
Results from principal component analyses (PCA), multivariate analyses of variance (MANOVA), linear discriminating analyses (LDA) and cluster analyses (CA), suggest that data cannot be regarded as random samples drawn from one uniform distribution. Males could best be divided into two clusters, eastern and western, however, females could best be divided into three groups; eastern, central and western, N-Atlantic common minke whales. The overlap between groups was too substantial, however, to allow a firm conclusion concerning the question of isolated breeding stocks versus a large common breeding pool.

<u>Conclusion</u>
Extensive analyses of the 17 morphological characters investigated revealed that no clear discrimination between groups separated by the current IWC area boundaries could be confirmed due to the high degree of overlap among groups.

◊ **Paper of reference:** SC/F13/SP20

Genetic study on close relatedness of minke whales in the Central and Northeast Atlantic.

Results

Detection of relatives was done by computing pairwise LOD scores for the 817 individuals in the sample, for each relatedness of interest. If Di and Dj were the genetic profiles of individuals i and j then the LOD score for their relatedness was calculated according to Skaug *et al*. (2010):

$$LOD_{i,j} = log(\frac{P(D_i, D_j \mid H_1 : related)}{P(D_i, D_j \mid H_0 : unrelated)})$$

Relatedness analyses were performed using the genetic profiles previously analyzed in SC/F13/SP17. In addition, 50 mothers-foetus pairs were collected from 2003-2007 and the foetus DNA profiles were added to the original dataset presented in SC/F13/SP17. Out of these 50 foetuses, five contained missing alleles at some loci and/or some non-common alleles with the mother (mutation) and were not considered for further analyzes. In addition, Norwegian minke whales collected from 2004-2006 and encompassed in the Norwegian minke whale DNA register (Glover *et al*. 2012), with validated genotyping error rates (Haaland *et al*. 2011) were also added in the dataset (with permission of the Norwegian DNA-registry managers), a total of 272 individuals. Because the techniques highly depends on matching of alleles, all individuals with missing alleles at certain loci were deleted from the dataset prior to the analyzes.

Out of the 333,336 (n(n-1)/2) pairwise-relatedness comparisons possible, 670 exhibited a high LOD score larger than zero (suggesting relatedness). After FDR corrections for multiple tests, only 124 remained significant (see SC/F13/SP20 Table 1). The correction procedure (FDR) was set-up to capture most of the mother-foetus pairs, e.g. the q values was set-up at 0.52 and only 5 mother-foetus pairs out of 45 were not detected (mainly because of too many common allele types) between the mother and the foetus, resulting in a low LOD score).

Among the 124 significant pairwise-relatedness comparisons, 40 were among mother-foetus pairs and 12 involved foetuses of different females and foetus and other females than their mother. No trio matches mother-foetus pairs – potential alleged father were found.

Few examples of relationships could be examined further due to available biological information such as age, sex and length, e.g. for example:

- A female of 17 years old captured in Iceland in 2004 was related to a female captured in Norway in 2006
- - A female of 20 years old captured in Iceland in 2007 was related to a male captured in Norway in 2004
- A male of 23 years old captured in 2006 in Iceland was related to a male of 19 years old captured in 2007 at the same location (potential brothers)
- A male of 22 years old captured in 2007 in Iceland was related to a male captured in 1984 at the same location (potential match father-son)
- A female of 14 years old captured in 2007 in Iceland was related to a male captured in the same location in 1982 (potential grand father-grand daughter)

Older relationships among Icelandic and Norwegian minke whales were detected such as the male captured in 2004 in Norwegian waters which was related to a female captured in 1983 in Iceland.

Conclusion
These results show that within and among generations, gene flow among groups separated by the current IWC area boundaries is quite high, therefore confirming previous genetic analyses (SC/F13/SP17). Relatedness analyzes seem to be promising for future investigation of relationships among these groups, but would crucially need to be complemented by other biological information which will help to assess the type of relationships observed.

6. POLLUTANTS

The results from the studies on persistent organic pollutants (POP's) and trace elements are presented in papers SC/F13/SP22 and SC/F13/SP23, respectively. In addition the research program has contributed to several cooperative studies on pollutant loads in marine mammals of the North Atlantic and the Arctic (SC/F13/SP21, SC/F13/SP24, SC/F13/SP25, SC/F13/SP26). These studies are summarized below. The aspects of the pollutant studies related to the usefulness of biopsies are discussed in section 8

◊ **Paper of reference:** SC/F13/SP21

Methoxylated polybrominated diphenyl ethers (MeO-PBDEs) are major contributors to the persistent organobromine load in sub-Arctic and Arctic marine mammals, 1986–2009.

Summary
A selection of MeO-BDE and BDE congeners were analyzed in pooled blubber samples of pilot whale (*Globicephala melas*), ringed seal (*Phoca hispida*), minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), harbor porpoise (*Phocoena phocoena*), hooded seal (*Cystophora cristata*), and Atlantic white-sided dolphin (*Lagenorhynchus acutus*), covering a time period of more than 20 years (1986–2009). The analytes were extracted and cleaned-up using open column extraction and multi-layer silica gel column chromatography. The analysis was performed using both low resolution and high resolution GC-MS. MeO-PBDE concentrations relative to total PBDE concentrations varied greatly between sampling periods and species. The highest MeOPBDE levels were found in the toothed whale species pilot whale and white-sided dolphin, often exceeding the concentration of the most abundant PBDE, BDE-47. The lowest MeO-PBDE levels were found in fin whales and ringed seals. The main MeO-BDE congeners were 6-MeO-BDE47 and 2′-MeO-BDE68. A weak correlation only between BDE47 and its methoxylated analog 6-MeO-BDE47 was found and is indicative of a natural source for MeO-PBDEs.

◊ **Paper of reference:** SC/F13/SP22

Concentrations of persistent organic pollutants (POP's) in minke whale from Icelandic waters.

Summary
The legacy POPs PCBs, DDTs, HCHs, HCB, chlordanes, toxaphenes (26, 50, and 62), and dieldrin were analysed in blubber, blubber biopsies (1.5 cm deep into the blubber), muscle tissue and livers from 25 minke whales from Icelandic waters caught in 2003 and 2004 (SC/F13/SP22). PBDEs (47, 99 and 100) were also analysed in these tissues. Dioxins and dioxin-like PCBs were analysed in 5 samples of ventral grooves. The animals selected represented the areas north and south of Iceland, equal sex ratios from both areas and as large a length span as was possible. Comparisons of levels between studies are often hampered by the use of sum parameters since these sums may represent different compounds from one study to another. PCBs (PCB7) were found to be similar in Icelandic minke whale blubber as the levels found in minke whales from the NW-Pacific and the Barents Sea while they were lower than those found in the North Sea. This was also the case for DL-PCBs in ventral grooves, similar levels were found in minke whales from the Barents Sea but lower than those found in the North Sea. Dioxins in ventral grooves of the Icelandic minke whales were somewhat lower than those found in Barents Sea and much lower than those found in the North Sea. The levels of DDTs in blubber tissue of the Icelandic minke whale were similar to the levels found in blubber of minke whales from the Barents Sea but lower than the levels found in the N-Pacific. However, the levels of DDTs in the Antarctic minke whale are much lower than those found in minke whales from Icelandic waters. HCB is found in similar levels in blubber of minke whales from the North Atlantic, N-Pacific and the Antarctic. HCHs are at low levels in the blubber of Icelandic minke whales, equal to the lowest found in the North Atlantic but much higher than the levels found in blubber of the Antarctic minke whales. However, levels of HCHs in blubber of minke whales from the N-Pacific are much higher than those found in the N-Atlantic. Toxaphenes, unlike other organic contaminants studied, are at higher levels in the blubber of Icelandic minke whales than in blubber of other minke whale populations in the N-Atlantic, where levels are lowest in SE and SW of Greenland. The spatial trend in N-Atlantic minke whale blubber indicates long range transport of toxaphenes from the southwest. Therefore, it may be concluded that the pattern of the legacy POPs in the blubber of Icelandic minke whales is different than that in other minke whale populations of the North-Atlantic and very different than that of the N-Pacific and Antarctic.

A selection of PBDE congeners was analyzed in pooled blubber samples of minke whales as well as several other marine mammals from the N-Atlantic (SC/F13/SP24). The levels found in minke whale blubbers from Norway, SW-Greenland, and Iceland were 82–389 ng/g lipid weight, 50–170 ng/g lipid weight and 64–111 ng/g lipid weight, respectively (sum of 10 congeners). These levels were slightly lower compared to minke whales caught of the Korean coast. One objective of that study was to see if any temporal trends in the levels of the PBDEs could be discerned although the minke whale samples could not be used for that purpose due to lack of samples in time series. The highest PBDE levels were found in samples from the late 1990s or beginning of 2000, possibly reflecting the increase in the global production of technical PBDE mixtures in the 1990s. The levels of BDE #153 and #154 increased relative to the total PBDE concentration in some of the species in recent years, which may indicate an increased relative exposure to higher brominated congeners. This study highlighted the importance of continuous monitoring of POPs such as PBDEs in the North-Atlantic.

A selection of MeO-BDE and BDE congeners were analyzed in pooled blubber samples of minke whales as well as several other marine mammals from the North-Atlantic (SC/F13/SP21). The main MeO-BDE congeners were 6-MeO-BDE47 and 2′-MeO-BDE68. Due to weak correlation between BDE47 and its methoxylated analog, 6-MeO-BDE47, in all species, the study indicated a natural source of MeO-PBDEs where levels in toothed whales may often exceed the concentration of the most abundant PBDE, BDE-47. The levels of 6-MeO-BDE47 and 2′-MeO-BDE68 were lower in Norwegian minke whale blubber than those found in minke whale blubbers from SW-Greenland and Iceland, the latter two being similar.

A selection of PCN congeners was analyzed in pooled blubber samples minke whales from the North-Atlantic as well as several other marine mammals (SC/F13/SP25). The sum of PCN congeners 52, 53, 66 and 69 were similar in minke whale blubber samples from Norway, Iceland and SW-Greenland and varied between 0.3 and 0.9 ng/g lipid weight. PCBs were also analyzed in minke whales from Iceland and the total PCN content accounted for 0.2 % or less of the total non-planar PCB content.

◊ **Paper of reference:** SC/F13/SP23

Concentrations of mercury and other trace elements in minke whales from Icelandic waters.

Summary
Trace elements (Hg, Cd, Pb, Se, As, Se, Cu, Zn, Fe, Mn, Cr and Ni) were analysed in muscle, skin, liver, and kidney of 25 minke whales (*Balaenoptera acutorostrata*) from Icelandic waters caught in 2003 and 2004 (SC/F13/SP23). Cadmium was also analysed in testes and ovaries. The animals selected represented the areas north and south of Iceland, equal sex ratios from both areas and as large a length span as was possible. The levels of mercury were found to be equal to or lower than the levels found in other minke whale populations in the North Atlantic while the hepatic levels are considerably higher than in livers from the Antarctic minke whales (*B. bonaerensis*). The levels of cadmium, however, were generally higher in livers and kidneys than in other North Atlantic minke whale stocks while the levels in muscle tissue were equal to or lower than in these stocks. The levels of cadmium in kidneys, which is the tissue showing highest concentrations, are about thousand times higher than in the muscle tissue. Log-transformed cadmium levels in gonads, especially the testes, were linearly related to levels in kidneys, livers and muscle tissue. In spite of high levels in livers and kidneys of the Icelandic stock, the cadmium levels in for example liver of minke whales from the Antarctic are considerably higher than in their Icelandic counterparts. Selenium concentrations in livers, kidneys and muscle tissue of the Icelandic minke whales were on average similar to mean levels found in other North Atlantic minke whale populations.
When comparing levels in skin and levels in other tissues, no correlation could be found in any of the trace elements studied except in the case of mercury (see section 8).

◊ **<u>Paper of reference:</u>** SC/F13/SP24

Polybrominated diphenyl ethers (PBDEs) in marine mammals from Arctic and North Atlantic regions, 1986–2009

<u>Summary</u>
A selection of PBDE congeners was analyzed in pooled blubber samples of pilot whale (*Globicephala melas*), ringed seal (*Phoca hispida*), minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), harbor porpoise (*Phocoena phocoena*), hooded seal (*Cystophora cristata*) and Atlantic white-sided dolphin (*Lagenorhynchus acutus*), covering a time period of more than 20 years (1986–2009). The analytes were extracted and cleaned-up using open column extraction and multi-layer silica gel column chromatography, and the analysis was performed on a GC-MS system operating in the NCI mode. The highest PBDE levels were found in the toothed whale species pilot whale and white-sided dolphin, and the lowest levels in fin whales and ringed seals. One-sided analyses of variance (ANOVA) followed by Tukey comparisons of means were applied to test for differences between years and sampling areas. Due to inter-year sampling variability, only general comparisons of PBDE concentrations between different sampling areas could be made. Differences in PBDE concentrations between three sampling periods, from 1986 to 2007, were evaluated in samples of pilot whales, ringed seals, white-sided dolphins and hooded seals. The highest PBDE levels were found in samples from the late 1990s or beginning of 2000, possibly reflecting the increase in the global production of technical PBDE mixtures in the 1990s. The levels of BDE #153 and #154 increased relative to the total PBDE concentration in some of the species in recent years, which may indicate an increased relative exposure to higher brominated congeners. In order to assess the effect of measures taken in legally binding international agreements, it is important to continuously monitor POPs such as PBDEs in sub-Arctic and Arctic environments.

◊ **<u>Paper of reference:</u>** SC/F13/SP25

Polychlorinated naphthalenes (PCNs) in sub-Arctic and Arctic marine mammals, 1986-2009

<u>Summary</u>
A selection of PCN congeners was analyzed in pooled blubber samples of pilot whale (*Globicephala melas*), ringed seal (*Phoca hispida*), minke whale (*Balaenoptera acutorostrata*), fin whale (*Balaenoptera physalus*), harbour porpoise (*Phocoena phocoena*), hooded seal (*Cystophora cristata*) and Atlantic whitesided dolphin (*Lagenorhynchus acutus*), covering a time period of more than 20 years (1986-2009). A large geographical area of the North Atlantic and Arctic areas was covered. PCN congeners 48, 52, 53, 66 and 69 were found in the blubber samples between 0.03 and 5.9 ng/g lw. Also PCBs were analyzed in minke whales and fin whales from Iceland and the total PCN content accounted for 0.2% or less of the total non-planar PCB content. No statistically significant trend in contaminant levels could be established for the studied areas. However, in all species except minke whales caught off Norway the lowest PPCN concentrations were found in samples from the latest sampling period.

◊ **Paper of reference:**SC/F13/SP26

"New" POPs in marine mammals in Nordic Arctic and NE Atlantic areas during three decades

Summary
The present report describes the findings from a Nordic study with the aim to show possible trends in "new" contaminants in marine mammals from Nordic Arctic waters and North-East Atlantic areas over a period of three decennia. The species analysed were ringed seal (Greenland), hooded seal (Norway – West Ice), harbour porpoise (Iceland and Norway), white-sided dolphin (Faroe Islands), pilot whale (Faroe Islands), minke whale (Greenland, Iceland and Norway) and fin whale (Iceland). The substances investigated were a wide suite of brominated flame retardants (BFRs), polybrominated dibenzo-p-dioxins/furans (PBDD /PBDF) and methoxylated PBDEs, perfluorinated compounds (PFCs) including PFOS and polychlorinated naphthalenes (PCNs). The BFRs and PCNs were analysed in blubber, whereas the PFCs were analysed in liver with one exception when muscle tissue was used. The study provides new and valuable insight into a series of "new" contaminants in a range of marine mammals from Nordic Arctic area and/or North-East Atlantic Ocean. A large number of samples were carefully selected and analysed within this study, but still only a limited number of sampling sites, species and time periods were covered. Notwithstanding, several statistical significant trends were revealed. Many of the "new" contaminants analysed in the present project appear to decline during the time period studied. This is true for the BDEs, PCNs and PFOS, the PFC that was found in the highest concentration. Rising levels of the larger PFCs were seen, and in addition several BFRs other than BDE were seen in the sample extracts. The highest concentrations of Σ10PBDEs were found in toothed whales, including the pilot whales (~1,200 ng/g LW), the white-sided dolphins (~650 ng/g LW) and the harbour porpoises (~250 ng/g LW). BDE-47 was the most abundant congener accounting for 30–75% of the total burden in the different marine mammals. Deca-BDE was analysed in samples of ringed seal, pilot whale and minke whale (Norway), but was not detected in any samples in levels above the detection limits (range 0.5–3.0 ng/g lipid). The methoxylated PBDEs which are at least partly naturally occurring compounds followed the decreasing trend as the PBDEs, but only weak correlation between the PBDEs and methoxylated BDEs was found. Highest levels of methoxylated PBDEs were found in pilot whales and remarkably 6MBDE47 was the most dominant compound. The temporal trend analysis of BFRs showed that the levels of Σ10PBDEs increased from the 1980s to the late 1990s, thereafter declined during the first part of the 2000s. This trend was seen in all the marine mammals studied and was significant for the fin whales and white side dolphins. A decline of Σ10PBDEs during the period 2000–2006 was observed in all species and was largest (44%) for the ringed seals from Greenland. A selected number of samples were screened for unknown organic brominated compounds and several unidentified bromine containing compounds were seen. In addition, selected samples were analysed for other brominated compounds than BDE including HBB, PBT, BTBPE and DBDPE, PBB-153, TBECH and brominated dioxin and furans. All compounds were below the current LOD except for PBB-153 and HBB. TBECH was tentatively found in pilot whale samples by using low resolution GC/MS, but these results could not be confirmed by using high resolution GC/MS. PCNs were found in much lower concentration than the PBDEs but are of concern due to their dioxin-like behaviour and toxicity. The highest concentrations of Σ14PCNs (~4 ng/g LW) were found in pilot whales. Differences in PCN-congener patterns were found between the different mammalian species. In general, no consistent temporal trend of decreasing PCNs in recent years was found for the marine mammals. However, in hooded seals and fin whale significant decreasing trends for Σ14PCNs were observed. For other species, the decrease could be seen for individual congeners only. Concentrations of PCNs in minke whale from the Norwegian coast in 1999 were not significantly different from those taken in 1993. Unlike other compounds in his study, which were analysed in blubber, PFCs were analysed in livers except for the fin whale samples where muscle tissue was analysed. Eighteen PFCs were analysed, of which PFOS was found in the highest concentrations. The highest PFOS concentrations were found in the white-sided dolphin (~110 ng/g WW), followed by similar concentrations in ringed seal (NW-

Greenland), hooded seal, pilot whale, minke whale (W-Greenland) and harbour porpoise (WIceland) (~50ng/g WW). The concentrations of PFOS in the fin whale muscle samples were very low (0.4 ng/g WW), and for most PFCs close to or below the detection limit. A significant decrease in PFOS was found in hooded seals (1990–2007). On the other hand, increasing trends of one or more PFCs were found in samples of ringed seals, in pilot whale, white-sided dolphins and harbour porpoise. For PFUnDA a significantly increasing trend was found for ringed seal, pilot whale and white-sided dolphins indicating that levels of the larger PFCs are still increasing. Generally, no regional differences were seen in these "new" contaminant distributions. However this could only be studied for the minke whales and the harbour porpoise which were sampled at more than one location.

7. Parasites and pathology

The objectives of the study were to provide baseline information on the species composition, geographic distribution and abundance of the epibiotic macrofauna on minke whales in Icelandic waters during the summer period. In the light of projected environmental changes in the world's oceans in the coming decades, the information may prove valuable as a basis for future comparisons.

◊ **Paper of reference:** SC/F13/SP27

Epibiotic macrofauna on common minke whales (*Balaenoptera acutorostrata* Lacépède 1804) in Icelandic waters.

Results

From the examination of 185 common minke whales (see SC/F13/SP27 Table 1), three ectoparasites *Cyamus balaenopterae* Barnard, 1931 (Amphipoda: Cyamidae) and *Caligus elongatus* Nordmann, 1832 (Copepoda: Caligidae) and its monogenean hyperparasite *Udonella caligorum* Johnston, 1835 (Udonellidae) were found; one mesoparasite species, *P. balaenopterae* Koren et Danielssen, 1977 (Copepoda: Pennellidae); three epizoics, *Conchoderma virgatum* Spengler, 1790, *C. auritum* (Cirripedia: Lepadidae), and, *Xenobalanus globicipitis* Steenstrup, 1851 (Cirripedia: Balanidae). On five occasions, a single live sea lamprey, *Petromyzon marinus* L. (Pisces: Petromyzontidae), were found attached to a whale, in addition, to fresh (*i.e.* open) and old feeding/attachment wounds which were commonly seen on the flanks of the whales (see SC/F13/SP27 Table 2, Fig. 1).

No significant relationship was observed between parasite intensity and host body length for neither *C. balaenopterae* nor *C. elongatus* while the proportion of infected hosts was higher in August-September than earlier in the summer for *C. balaenopterae* ($\chi2 = 13.69$, $p < 0.01$, d.f. = 1) and *C. elongatus* ($\chi2 = 28.88$, $p < 0.01$, d.f. = 1). The prevalence of *C. balaenoptera* was significantly higher on male than on female hosts ($\chi2 = 5.08$, $p < 0.05$, d.f. = 1) (see SC/F13/SP27 Table 2).

Conclusion

The most common epibiotic species were the ectoparasites *C. elongatus* and *C. balaenoptera*. *Caligus elongatus* is common parasite of various fishes and the present study reveals the first record of a cetacean

host. Increased intensity throughout the summer is in line with observation on fish hosts in Norway and suggests that the infections are local.
Observed difference in prevalence of *C. balaenoptera* between male and female hosts suggests sexual segregation at the time of infection. Increased prevalence throughout the summer may suggest that infections occur locally however smaller size of the lice at earlier life stages and preference for sheltered sites on the whale body may have led to unnoticed infections early in the summer.
Low abundance of the sessile copepod *P. balaenoptera* and the cirripeds, *C. vigratum*, *C. auritum* and *X. globicitis* suggest that the minke whale becomes infected during winter migrations and these epibiotics are brought into Icelandic waters from lower latitudes. However, observations late in the feeding season and in the colder waters off the north coast suggest that these species may survive in these waters and do not fall of the host immediately when arriving in the area.
The present study supports suggestions that *P. marinus* can survive in the waters south and southwest of Iceland and at least some of the attachments on the minke whale may be of local origin.
The long term impact of increased sea temperatures as observed in the world's oceans in recent years and projected subsequent rise in the near future (Bindoff *et al.* 2007) on the biota in the northern North Atlantic is unknown. Potential future changes in the epibiotic macrofauna on common minke whales may indicate the altered migration route of the host population or alterations to the survival rate of the epizoic species.

◊ **Paper of reference:** SC/F13/SP28

Anisakid nematodes from stomach of minke whales (*Balaenoptera acutorostrata*) off Iceland, collected in the period 2003-2007.

Results
The objective of this study was to examine quantitative infections of *Anisakis* complex in order to evaluate the importance of the host for the parasite.
From the examination of 16 common minke whales, Anisakid nematodes were treated as any other food items and therefore the methods are the same as in SC/F13/SP2. Most of the minke whale harboured less than 1 kg of Anisakid nematodes, with however some exception (maximum value observed 112 kg). Only two out of 16 whales did not exhibit infection. Intensity of infection varied from 23 to over 1.3 million nematodes.

Conclusion
The present results suggest that minke whale is highly infected with Anisakid nematodes and that infection levels can be quite high. However, the observed results were only collected from a limited number of individual.

◊ **Paper of reference:** SC/F13/SP29

Gross pathology, histo- and haemological logical findings and microbial examinations of minke whales in Icelandic waters.

Summary
The aim of present study was to evaluate the of health status of minke whales in Icelandic waters by veterinary dissections, histopathological, haematological and bacteriological examinations of animals caught in the period 2003-2005. Basic veterinary necropsy was performed on fourteen animals (8 males and 6 female) and total of 49 organ tissue samples from these 14 animals and 95 tissue samples from other 48 animals caught in the same period were collected for histological examination. A total of 140 animals were blood sampled for analyses of hemaglobulin, hematocrit and total leukocyte, neutrophils, lymphocytes, eosinophils and monocyte count. Bacteriological cultivation was made from a total of 135 swabs collected from 39 animals.
The gross pathological and histopathological findings in the studied animals were sporadic, usually mild and mainly due to parasites infestations. Large differences between animals were found in all white blood cell populations both in % and in absolute number. No pathological lesions were observed that could reflect infections with bacteria or viruses nor could pathogenic bacteria be isolated from blood and major organs of these animals.
In present study on health status of normal minke whales found in Icelandic waters, all animals examined were found to be in normal condition and with healthy appearance. However the few the pathological observations made, reflect high parasitic burden found in some of these animals.

8. APPLICABILITY OF BIOPSIES

The program provided a unique opportunity for evaluation of the use of biopsies in studies of feeding ecology and pollutant burden by comparisons of tissues normally included in biopsies (sub-dermal blubber) with samples deeper in the body, which require lethal sampling. In the following we summarize the results of these comparisons from the various subprojects.

Diet composition

Three methods to describe diet composition were tried out in the program, stomach content analysis (SC/F13/SP2), stable isotope ratios (SIR, SC/F13/SP3) and fatty acid profiles (FA, SC/F13/SP4). In general FA and stable isotope ratios are believed to reflect diet over a longer period than the stomach contents. However, the precise time scale is uncertain and seems to depend on several factors including species and tissue type. While each stomach only gives a snapshot of diet composition for a particular time and area, a temporally and spatially representative sampling scheme should give a good overview over the diet composition in the desired area. In addition, analysis of stomach contents should provide a much more detailed information on the prey (s.a. length and age) than the more indirect methods FA and SIR, which only provide a more generalized information s.a. trophic level and origin of fatty acids. These may be difficult to interpret for a top predator with wide and variable spectrum of prey species like the common minke whale.

Fatty acids
In general fatty acid profiles did not reflect diet composition as determined from stomach contents (SC/F13/SP4). This is likely due to different time period reflected by these two methods. Thus stomach

contents mainly reflect the diet composition of the last meal before sampling, or perhaps from the day before (e.g. Víkingsson 1997). However, the sampling distribution covered the period late April to early October, so the stomach contents analysis should be representative of that period. In addition the fatty acid profiles were tissue specific which makes the results hard to interpret. Of the three tissue types tested (blood, inner blubber and outer blubber), the inner blubber (closest to the muscle) appeared to best reflect the results from the diet analysis (SC/F13/SP2). In contrast, the outer blubber layer does not seem to be informative in this respect, indicating that results from biopsies (except perhaps full core biopsies) may give misleading information on the diet.

Stable isotope ratios

In general, the stable isotope ratios indicate a somewhat lower trophic level than the stomach contents (SC/F13/SP2). This may be due to different time periods reflected by these two methods. However, as for the fatty acid profiles, the isotope ratios appeared to tissue specific. Paired comparison of isotope levels in skin-D4 to other tissue types in the same individual revealed significant difference for $\delta^{13}C$ levels in muscle-D4 and for $\delta^{15}N$ levels in blood and muscle-D4 respectively. However, low significant difference in the intercept of the slopes suggests that biopsies may give representative information on the isotope levels in the other tissues and that the individuals' diet was relatively homogenous during a period prior to the sampling.

Pollutants

When comparing levels in skin and levels in other tissues, no correlation could be found in any of the trace elements studied except in the case of mercury. The mercury level in skin is proportional to the levels of mercury found in muscle tissue and a good correlation is obtained where a 1:1 relationship is found if levels in skin are expressed on a dry weight basis and the levels in muscle on a wet weight basis. There is also a fairly good correlation between levels of mercury in skin and levels in both livers and kidneys albeit the relationship is not 1:1. It may therefore be concluded that for the Icelandic minke whales at least, that skin biopsies are generally not valid for predicting trace element concentrations in internal organs except in the case of total mercury in muscle tissue.

There is a fairly good correlation between organic contaminants (on a lipid basis) in the whole core of the blubber and biopsy but all the organic contaminants except HCB are at 18-25% higher levels in the biopsy than in the whole core. The HCB levels in both the biopsy and the whole core are the same. Biopsies are therefore, strictly speaking, only applicable to HCB but biopsies give a good idea of the levels of other legacy POPs in the whole blubber core. However, it is not generally possible to predict the levels of organic contaminants in muscle or livers by their levels in biopsies. Exceptions are HCB and α-HCH although there is not a 1:1 relationship between levels in different tissues.

In conclusion, the above research on the applicability of using biopsies in studies of diet composition and pollutant levels has produced mixed results. Of the tested parameters, only mercury and HCB had the same levels (1:1) in the outer blubber layer (representing biopsies) and inner tissues. All the other parameters were tissue specific, making the use of biopsies without supplementary information problematic. However, in some cases linear relationships were found between the "biopsies" and inner layers. These relationships could be used in future studies based on biopsies although further studies may be needed to strengthen the relationships.

9. ADDITIONAL RESEARCH NOTES

This section presents a short summary of additional studies which have been performed on the request of partners in Iceland. Additional samples have therefore been collected, like the brain of six minke whales (below), to support partner's research in Iceland or tissues for analyses of radioactivity level (SC/F13/SP30 below).

Brain structure: sleep control system, neurogenesis and proteins in the brain.

Six minke whale brains collected in Iceland during 2005-2011 seasons are being used in a range of scientific projects, including those specifically focused upon the minke whale and those taking a broader comparative approach where the minke whale tissue represents an interesting, and perhaps even extreme, data point. Below, each project is listed and progress made on each project described. Where possible the conclusions we have come to are also provided.

(1) Anatomy of the neural systems controlling sleep in the minke whale. It is well known that whales and dolphins sleep with one half of their brain at a time, but how they accomplish this is unknown. By examining the sleep centres of the brain (in the hypothalamus and pons) of the minke whale, we can compare these to the well known sleep systems in other mammals. Differences that we find may inform us about how sleeping with half a brain at a time is possible in whales. To date we have sectioned and stained appropriate regions of two minke whale brain to reveal the sleep systems. The most interesting observation to date is that the minke whales have very high numbers of orexinergic neurons (a neuronal type that promotes wakefulness) when compared to other mammals. The analysis of this tissue is ongoing.

(2) Adult hippocampal neurogenesis in the minke whale. As part of a broader comparative study of adult hippocampal neurogenesis, we have examined this in the brains of 2 minke whales to compare with another 60 mammalian species we have studied. While most mammals possess adult hippocampal neurogenesis (believed to enhance cognitive processes in these animals), the minke whale, harbour porpoise and manatee (three fully aquatic mammals) lacked this feature of the brain. The minke whale and harbour porpoise also had very small hippocampi compared to other mammals. These findings indicate that one of the central structures involved in all higher cognitive functioning is compromised in the whales and dolphins, indicating that it is likely that they are not cognitively complex as often thought and portrayed in the media. This project is currently being written up for publication.

(3) Uncoupling proteins in the minke whale brain. Again as part of a broader study, blocks of cerebral cortex from 2 minke whale brains were used in a study examining the presence and location of uncoupling proteins in the neurons and glia of the brain. Uncoupling proteins short circuit the ATP cycle within the cell and release all the energy as heat. In the minke whale, humpback whale and harbour porpoise brain we observed 100% of cortical neurons to contain UCP1, 45% of cortical glia cells to contain UCP4 and 5, and 65% of white matter glia cells to contain UCP4 and 5. In the closely related artiodactyls we found that only 45% of cortical neurons contained UCP1 and no glia cells contained any UCPs. This data strongly supports the thermogenetic basis of large brain evolution in cetaceans and indicates that they are not intelligent as commonly thought. This project is in the last phases of analysis and will be written up for publication in the next few months.

◊ **Paper of reference:** SC/F13/SP30

A short note on radioactivity in minke whale meat (*Balaenoptera acutorostrata)* from Icelandic waters

Summary

Several samples of minke whale meat were analyzed at the Icelandic Radiation Safety Authority. The samples were measured in 200-ml polyethylene boxes. Sample size ranged from 100 to 200 ml. Uncertainty in the Cs-137 activity concentration measurements, due to counting statistics, were relatively high in general due to the small sample sizes and the low Cs-137 activity. The Cs-137 activity concentration was measured using Ortec HPGe gamma detectors of 48.6% and 55.4% relative efficiency for the 1.33-MeV peak of 60Co and calculated in Becquerels per kilogram fresh weight. The analysis was carried out using software developed at IRSA in the early 1990s and validated in numerous intercomparisons. The Cs-137 activity concentration in the samples was very low (in all cases below 1

Bq/kg fresh weight; some below detection limits), and far below the guideline levels of 1000 Bq/kg set for food moving in international trade set in Codex General Standard For Contaminants And Toxins In Food And Feed (1995). In comparison to other routinely measured food, the numbers in Icelandic fish are below 0.25 Bq/kg, in Icelandic lamb the range is 0.5-150 Bq/kg with average of 11.7 from 2005 to 2011 (Guðnason *et al*. 2012), but in sea around Iceland the numbers are from 1.1 to 2.3 Bq/m^{-3} (Ólafsdóttir 2005).

Reference list

Andersen L.W., Born E.W., Dietz R., Haug T., Oien N., and Bendixen C., 2003. Genetic population structure of minke whales *Balaenoptera acutorostrata* from Greenland, the North East Atlantic and the North Sea probably reflects different ecological regions. *Marine Ecology Progress Series* 247, 263-280.

Anderwald P., Daníelsdóttir A.K., Haug T., Larsen F., Lesage V., Reid R.J., Víkingsson G.A., and Hoelzel A.R., 2011. Possible cryptic stock structure for minke whales in the North Atlantic: implications for conservation and management. *Biological Conservation* 144, 2479-2489.

Árnason A., and Spillaert R., 1991. A study of variability in minke whale (*Balaenoptera acutorostrata*) in the North Atlantic using a human hypervariable region probe alpha-globin 3'HRV. *Report of the International Whaling Commission* 41, 439-443.

Bindoff N.L., Willebrand J., Artale V., Cazenave A., Gregory J., Gulev S., Hanawa K., Le Quéré C., Levitus S., Nojiri Y., Shum C.K., Talley L.D., and Unnikrishnan A., 2007. "Observations: Oceanic Climate Change and Sea Level." In: *Climate Change 2007: The Physical Science Basis. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* [Solomon, S., Qin D., Manning M., Chen Z., Marquis M., Averyt K.B., Tignor M., and Miller H.L. (eds.)] (Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press, 2007).

Bolker B., and R Development Core Team, 2012. bbmle: Tools for general maximum likelihood estimation. R package version 1.0.5.2. http://CRAN.R-project.org/package=bbmle

Borchers D.L., Pike D.G., Gunnlaugsson T., and Víkingsson G.A., 2009. Minke whale abundance estimation from the NASS 1987 and 2001 aerial cue–counting surveys taking appropriate account of distance estimation errors. *NAMMCO Scientific Publications* 7, 95-110.

Christensen I., 1981. Age determination of minke whales, *Balaenoptera acutorostrata*, from laminated structures in the tympanic bullae. *Report of the International Whaling Commission* 31, 245-253.

Christiansen F., Víkingsson G.A., Rasmussen M.H., and Lusseau D., in press. Minke whales maximise energy storage on their feeding grounds. *Journal of Experimental Biology*.

CODEX GENERAL STANDARD FOR CONTAMINANTS AND TOXINS IN FOOD AND FEED (Codex Standard 193-1995)

Dalerum F., and Angerbjörn A., 2006. Resolving temporal variation in vertebrate diets using naturally occurring stable isotopes. *Oecologia* 144, 647-658.

Daníelsdóttir A.K., Duke E.J., and Árnason A., 1992. Genetics variation at enzyme loci in North Atlantic minke whale, *Balaenoptera acutorostrata*. *Biochemical Genetics* 30, 189-202.

Daníelsdóttir A.K., Halldórsson S.D., Guðlaugsdóttir S., and Árnason A., 1995. Genetic variation in northeastern Atlantic minke whales (*Balaenoptera acutorostrata*). In: Whales, seals and man, eds Blix AS, Walløe L, Ulltang Ø, pp105-118.

Donovan G.P., 1991. A review of IWC stock boundaries. *Report of the International Whaling Commission*, (special issue 13), 39-68.

Folkow L.P., and Blix A.S., .1992. Metabolic rates of minke whales (*Balaenoptera acutorostrata*) in cold water. *Acta Physiologica Scandinavica* 146, 141–150.

Glover K.A., Haug T., Øien N., Walløe L., Lindblom L., Seliussen B.B., and Skaug H.J., 2012. The Norwegian minke whale DNA register. *Fish and Fisheries* 13, 313-332.

Guðnason K., Pálsson S.E., Halldórsson Ó., Ólafsdóttir E.D., and Gunnarsdóttir S., 2012. Vöktunarmælingar Geislavarna ríkisins 2011. Radioactivity in the environment and food in Iceland 2011. Geislavarnir ríkisins, GR 12:03, 18 s.

Gunnlaugsson Þ., Pike D., and Víkingsson G.A., 2012. Changes in minke whale distribution and abundance by season and over time in aerial surveys off Iceland 1986-2009. Paper *SC/64/RMP4 revised* presented to the IWC Scientific Committee, June 2012, Panama City, Panama.

Haaland Ø.A., Glover K.A., Seliussen B.B., and Skaug H.J., 2011. Genotyping errors in a calibrated DNA-register: implications for identification of individuals. *BMC Genetics*, 12, 36.

International Whaling Commission (2004) Report of the Scientific Committee. J Cetacean Res Manage 6 (SUPPL.)

Lockyer C., 1987. The relationship between body fat, food resource and reproductive energy costs in north Atlantic fin whales (*Balaenoptera physalus*). *Symposium zoological Society of London* 57, 343-361.

Lockyer C.H., McConnell L.C., and Waters T.D., 1985. Body condition in terms of anatomical and biochemical assessment of body fat in North Atlantic fin and sei whales. *Canadian Journal of Zoology* 64, 279-284.

Lockyer C., and Waters T., 1986. Weights and anatomical measurement of northeastern Atlantic Fin (*Balaenoptera physalus*, Linnaeus), and sei (*B. borealis*, Lesson) whales. *Marine Mammal Science* 2, 169-185.

Marine Research Institute 2003. A programme for a two year feasibility study on cetaceans in Icelandic waters. IWC SC/55/O2-revised:63.

Mitchell E., and Kozicki V.M., 1975. Supplementary information on minke whale (*Balaenoptera acutorostrata*) from Newfoundland fishery. *Journal of the Fisheries Board of Canada* 32, 985-994.

Næss A., Haug T., and Nilssen E.M., 1998. Seasonal variation in body condition and muscular lipid contents in northeast Atlantic minke whale *Balaenoptera acutorostrata*. *Sarsia: a Norwegian Journal of Marine Biology* 83, 211–218.

Olsen E., 2002. Errors in age determination of North Atlantic minke whales when counting growth zones in bulla tympanica. Journal of the Cetacean Research Management 4, 185-191.

Ólafsdóttir E.D., 2005. Mælingar á 137Cs í sjó við Ísland – samvinnuverkefni í 15 ár. In: Þættir úr vistfræði sjávar 2004. Hafrannsóknastofnunin, fjölrit nr. 116: 19-22

Pampoulie C., Daníelsdóttir A.K., and Víkingsson G.A., 2008. Genetic structure of the North Atlantic minke whale (*Balaenoptera acutorostrata*) at feeding grounds: a microsatellite loci and mtDNA analysis. Paper *SC/60/PFI10* presented to the IWC Scientific Committee, June 2008, Santiago, Chile.

Pétursdóttir H., and Gíslason Á., 2009. Trophic interactions and energy flow within the pelagic ecosystem in the Iceland Sea**.** ICES CM 2009/A:08.

Pike D.G., Gunnlaugsson T., and Víkingsson G.A., 2011a. Icelandic aerial survey 2009: Survey report and a preliminary abundance estimate for minke whales. IWC SC/60/PFI12:29 pp.

Pike D.G., Gunnlaugsson T., Elvarsson B., Víkingsson G.A., 2011b. Correcting perception bias for Icelandic aerial surveys, 2007 and 2009. NAMMCO SC/18/AESP/08.

R Core Team, 2012. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, Austria. ISBN 3-900051-07-0, URL http://www.R-project.org/.

Sergeant D., 1963. Minke whales, *Balaenoptera acutorostrata* Lacepede, of the western North Atlantic. *Journal of the Fisheries Board of Canada* 20, 1489-1504.

Sigurjónsson J., 1980. A preliminary note on ear plugs from Icelandic minke whales. *Report of the International Whaling Commission* 30, 193-194.

Sigurjónsson J., 1988. Studies on age and reproduction in minke whales (*Balaenoptera acutorostrata*) in Icelandic waters (abstract). *Report of the International Whaling Commission* 39, 461-462.

Sigurjónsson J., Halldórsson S.D., and Konráðsson A., 1990. New information on age and reproduction in minke whales (*Balaenoptera acutorostrata*) in Icelandic waters. *Report of the International Whaling Commission* 41, 588.

Sigurjónsson J., and Víkingsson G.A., 1997. Seasonal abundance of and estimated food consumption by cetaceans in Icelandic and adjacent waters. *Journal of the Northwestern Atlantic Fisheries Sciences* 22, 271-287.

Sigurjónsson J., Galan A., and Víkingsson G.A., 2000. A note on stomach contents of minke whales (Balaenoptera acutorostrata) in Icelandic waters. In: *Minke whales, harp and hooded seals: Major predators in the North Atlantic ecosystem.* [Víkingsson G.A., and. Kapel F.O. (eds)]. *NAMMCO Scientific Publications* 2, 82-90.

Skaug H.J., Bérubé M., and Palsbøll P.J., 2010. Detecting dyads of related individuals in large collections of DNA-profiles by controlling the false discovery rate. *Molecular Ecology Resources* 10, 693-700.

Skaug H.J., Fournier D., Nielsen A., Magnusson A., and Bolker B., 2011. Generalized Linear Mixed Models using AD Model Builder. R package version 0.7.2.12.

Stefánsson G., Sigurjónsson J., and Víkingsson G.A. 1997. On dynamic interactions between some fish resources and cetaceans off Iceland based on a simulation model. *Journal of the Northwestern Atlantic Fisheries Sciences* 22, 357-370.

Tiedemann R., Cipriano F., Morin P. A., Hoelzel A. R., Palsbøll P., Waples R., Natoli A., Bachmann L., Postma L., Double M., Pampoulie C., Skaug H., Baker C. S., and Jackson J., 2012. Updated guidelines for DNA data quality control and error rate estimation, for genetic studies relevant to IWC management advice. (First presented at IWC-SC60; updated by RT, FC, PM, RW, and JJ April/May 2012), Paper *SC/64/SD4* presented at the IWC, Panama City, Panama.

Vikingsson G.A., 1990. Energetic Studies on Fin and Sei Whales Caught off Iceland. *Report of the International Whaling Commission* 40, 365–373.

Víkingsson G.A., 1995. Body condition of fin whales during summer off Iceland. *In:* Blix, A.S., Walløe, L. and Ulltang, Ø. (eds). *Developments in Marine Biology 4. Whales, seals, fish and man*. Elsevier, Science, B.V. Amsterdam, the Netherlands. pp361-369

Víkingsson G.A., Sigurjónsson J., and Gunnlaugsson Th., 1988. On the relationship between weight. length and girth dimensions in fin and sei whales caught off Iceland. *Report of the International Whaling Commission* 38, 323-326.

Víkingsson G.A., and Sigurjónsson J., 1998. Hrefna. Lífríki Sjávar – Námsgagnastofnun.

Víkingsson G., Ólafsdóttir D., Gunnalugsson Þ., Halldórsson S., Galan A., Svansson V., Jörundsson E., Kjeld M., Daníelsdóttir A., Gíslason D., Auðunsson G.A., Þorgilsson B., Stefánsson M., 2004. Research programme on common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters-A progress report. IWC SC/56/O10.

Víkingsson G., Ólafsdóttir D., Gunnalugsson Þ., Halldórsson S., Galan A., Svansson V., Jörundsson E., Kjeld M., Daníelsdóttir A., and Gíslason D., 2005. Research programme on common minke whales (*Balaenoptera* *acutorostrata*) in Icelandic waters-A progress report May 2005. IWC SC/57/O14.

Víkingsson G., Ólafsdóttir D., Gunnlaugsson T., Halldórsson S., Galan A., Svansson V., Jörundsson E., Kjeld M., Daníelsdóttir A., Gíslason D., Auðunsson G., Pálmadóttir H., Gunnlaugsdóttir H., Þorgilsson B., Stefánsson M., Hjartardóttir S., and Pike D.G., 2006. Research programme on common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters-A progress report May 2006. IWC SC/58/O20.

Víkingsson G., Ólafsdóttir D., Gunnlaugsson T., Halldórsson S., Galan A., Svansson V., Kjeld M., Pampoulie C., Gíslason D., Auðunsson G., Pálmadóttir H., Gunnlaugsdóttir H., Stefánsson M., Hjartardóttir S., and Pike D.G., 2007. Research programme on common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters-A progress report May 2007. IWC SC/59/O16.

Víkingsson G., Ólafsdóttir D., Gunnlaugsson T., Pampoulie C., Halldórsson S., Galan A., Svansson V., Kjeld M., Auðunsson G., and Daníelsdóttir A., 2008. Research programme on common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters-A progress report May 2008. IWC SC/60/O13.

Víkingsson G., Ólafsdóttir D., Gunnlaugsson T., Pampoulie C., Halldórsson S., Galan A., Svansson V., Kjeld M., Auðunsson G., and Daníelsdóttir A., 2009. Research programme on common minke whales (*Balaenoptera acutorostrata*) in Icelandic waters-A progress report May 2009. IWC SC/61/O10.

Appendix

Appendix 1. Temporal and spatial distribution of the sampled common minke whales in 2003-2007. The total number of hunted animals including struck and lost is given in brackets.

•

Area*	April	May	June	July	August	September/October	Total
2003							
Area 1					4	6	10
Area 2					2	3	5
Area 3					1		1
Area 4					2	1	3
Area 5					1	1	2
Area 6					2(3)	2	4(5)
Area 8					1	1	2
Area 9					3	2	5
Area 10					2	2	4
Total 2003		**0**	**0**	**0**	**18(19)**	**18**	**36(37)**
2004							
Area 1			8				8
Area 2			2	1			3
Area 3			2				2
Area 4			1				1
Area 5							0
Area 6			1				1
Area 8				2			2
Area 9			2	6			8
Area 10							0
Total 2004		**0**	**16**	**9**	**0**	**0**	**25**
2005							
Area 1				5(6)	6(7)		11(13)
Area 2				2	5		7
Area 3				0(1)	2		2(3)
Area 4				1			1
Area 5				2	1		3
Area 6				2			2
Area 8							0
Area 9				4(6)	2		6(8)
Area 10				1	1		2
Total 2005		**0**	**0**	**17(21)**	**17(18)**	**0**	**34(39)**
2006							
Area 1			1	6	8		15
Area 2			1	3	2		6
Area 3			4(5)	4			8(9)
Area 4			2	3			5
Area 5			2	2			4
Area 6			1	3	4		8
Area 8							0
Area 9				4	4(5)		8(9)
Area 10			2		2		4
Total 2006		**0**	**13(14)**	**25**	**20(21)**	**0**	**58(60)**
2007							
Area 1		3(4)	1			1	5(6)
Area 2	2	1	2		4(5)		9(10)
Area 3			1				1
Area 4	1		5				6
Area 5			2				2
Area 6		2	6				8
Area 8							0
Area 9		1					1
Area 10			5				5
Total 2007	**3**	**7(8)**	**22**	**0**	**4(5)**	**1**	**37(39)**
Grand total 2003-2007	**3**	**7(8)**	**51(52)**	**51(55)**	**59(63)**	**19**	**190(200)**

Areas: see Fig. 1.

Appendix 2. Photos from the sampling activities during the research program 2003-2007.

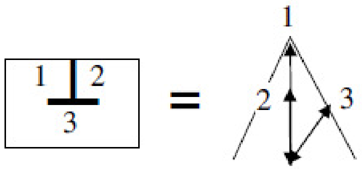
Hafrannsóknastofnunin – hvalarannsóknir

Blubber, girths and mammary gland

Blubberr

Tot	outer

Measurements: D4-D5-D6

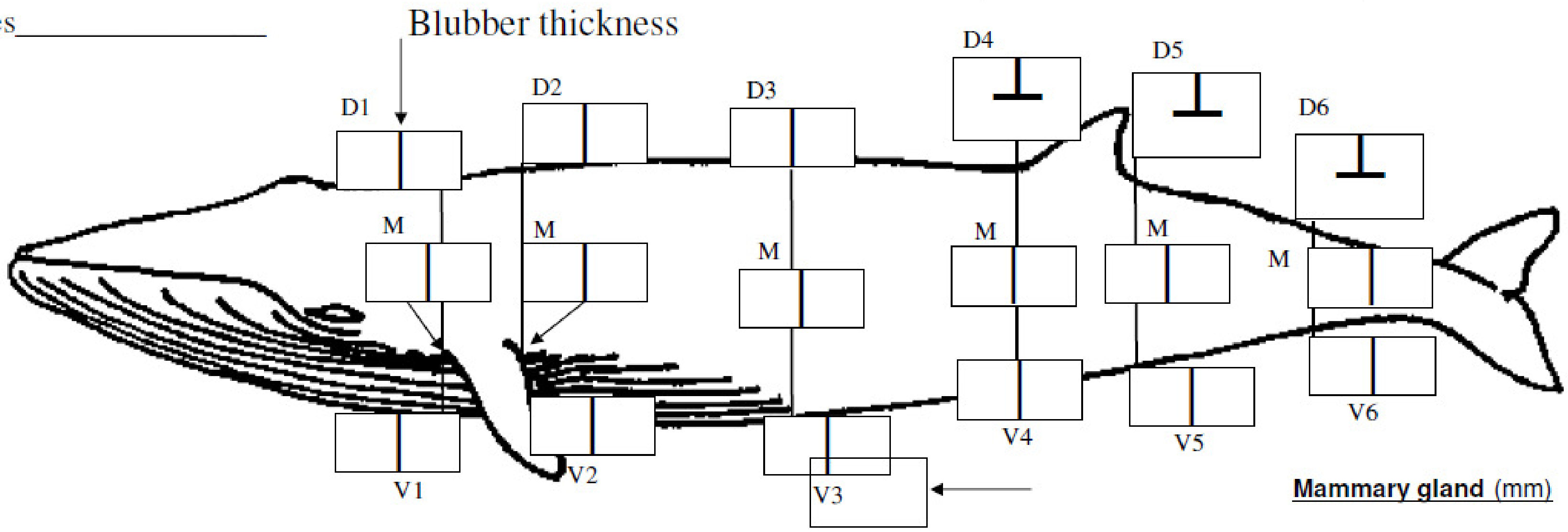


Boat________________________

Date________________________

Whale ID_________________

Species_________________



Girth (cm) → G1 – G2 – G3 – G4 – G5 – G6

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Baleen whale – Morphometry

Whale No________________________________Species:_________________________

Date___________________________________Taken by:________________________

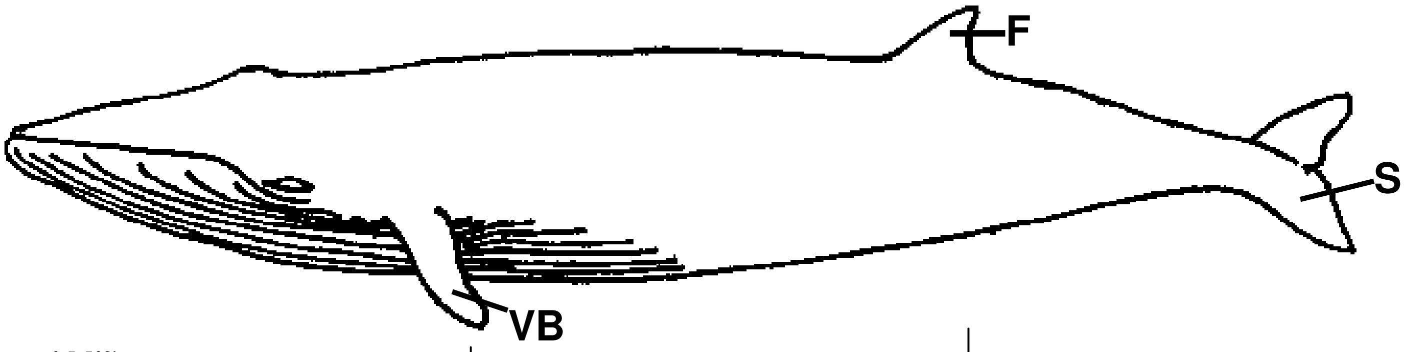
- Tip of upper jaw to anterior end of blowhole …………………………….. ________
- -----------------------posterior end of blowhole ………………………….. ________
- -----------------------middle of eye ……………………………………….. ________
- -----------------------angle of gape ……….…………………………….. ________
- -----------------------external auditory meatus…………………………….. ________
- -----------------------anterior insertion of flipper ………………………….. ________
- -----------------------posterior insertion of flipper ..……………………….. ________
- -----------------------anterior edge of dorsal fin …...……………………….. ________
- -----------------------posterior end of dorsal fin base ……………………… ________
- -----------------------notch of flukes ……………………………………….. ________
- Notch of flukes to center of anus ………………………………………….. ________
- -----------------------center of genetial aperture ..………………………….. ________
- -----------------------center of umbicilus …….………………………….. ________
- -----------------------end of ventral grooves ……………………………….. ________
- Depth of fluke notch …………………………………………………….. ________
- Notch of flukes to nearest point of leading edge of flukes …………………. ________
- Notch of flukes to tip of fluke ……………..…………………………….... ________
- Genital slit length ……………………………………………………..... ________
- Mammary slit length …………………………………………………….. ________
- Penis diameter at insertion ………………..…………………………….. ________
- Penis diameter midway along length ………..…………………………….. ________
- Penis length ……………………………..…………………………….. ________
- Flipper length, anterior insertion to tip …………………………………….. ________
- Flipper length posterior insertion to tip ……...…………………………….. ________
- Flipper maximum width …………………..…………………………….. ________
- Blowhole maximum width ………………..…………………………….. ________
- Projection of lower jaw beyond upper jaw …….…………………………….. ________
- Dorsal fin height ………………………..…………………………….. ________
- Anterior edge of dorsal fin to tip of fin …………………………………….. ________
- Base of the filtration apparatus …………………… off ________ …..on. ________
- Max length of filtration apparatus (inside) ……………………………….. ________
- Length of longest baleen plate (outer edge) ……………………………….. ________
- Mad breadth of longest baleen plate ……………………………………….. ________
- Max length of skull ……………………..…………………………….. ________

Max width of skull ………………………..…………………………….. ________

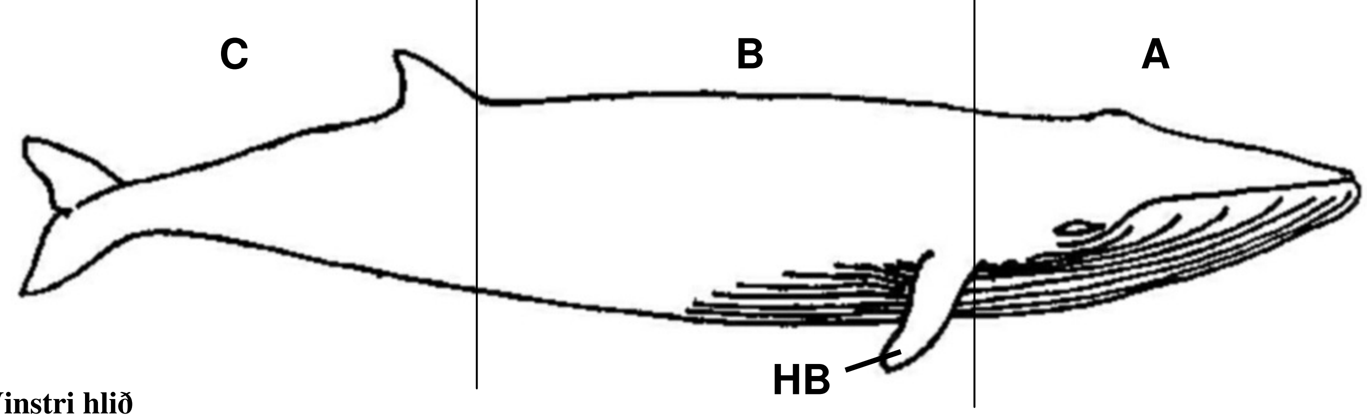
Baleen whales – Scarring and external Parasites

Whale number _______________ Species: __________________

Date _________________ Dissected by:____



Hægri hlið



Vinstri hlið

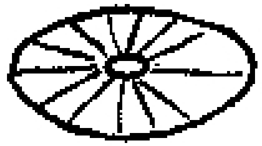
Ör/sár	**Svæði**		
	A	**B**	**C**
1. Lamprey			
2. Inf. lampr			
3. Hákarl			
4. Penella			
5. Blettir			
6. Tannaför			
7. Bit			

Ytri sníkjudýr	**Svæði**		
	A	**B**	**C**
a. Penella			
b. Hvallús			
c. Hrúðurkarl			
d. Hrúðurkarlslirfa			
e. Balaenophilus			
f. Diatom þörungar	%	%	%
g. cystur í spiki (kviðl)			

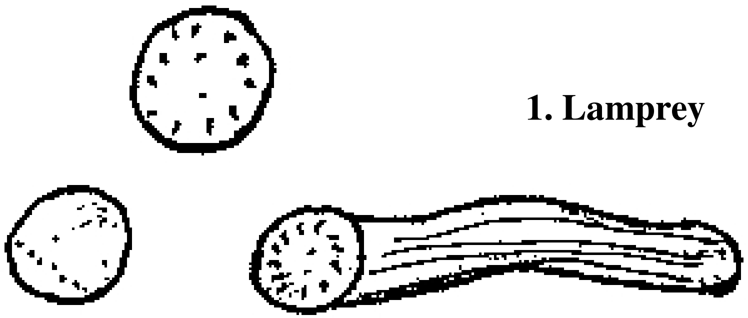
Ör:

2. Inf. lamprey

3. Hákarl



1. Lamprey



4. Penella - Húðin hörð stundum upphleypt; ör eftir gat ø ca. 1/2 cm
5. Blettir -Ekki harðari en húðin umhverfis; ø = 2-20 mm
6. Tannaför - tilgreina staði og taka myndir
7. Bit – VB: vinstra bægsli, **HB:** hægra bægsli, **S:** sporður, **F:** finni.; **I:** lítið, **II:** meðal, **III:** mikið

Snýkjudýr:

a. Penella
b. Hvallús
c. Hrúðurkarl
d. Hrúðurkarlslirfa
e. *Balaenophilus* copepod