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REPORT OF THE STUDY GROUP ON LONG-FINNED PILOT WHALES

Copenhagen, 30 August - 3 September 1993

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*General Secretary
ICES
Palægade 2-4
DK-1261 Copenhagen K
DENMARK

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1 INTRODUCTION

1.1 List of Participants

Dorete Bloch	Faroe Islands
Solange Brault	USA
Doug Butterworth (Chairman)	South Africa
Genevieve Desportes	Faroe Islands
Thorvaldur Gunnlaugsson	Iceland
Toshio Kasuya	Faroe Islands
Finn Larsen	Greenland
Nils Øien	Norway
Johann Sigurjonsson	Iceland
Tim Smith	USA
Steve Swartz	USA

Henrik Gislason (Denmark) and Henrik Sparholt (ICES Fisheries Assessment Scientist) participated in part of the discussion on multispecies interactions.

1.2 Terms of Reference

It was decided at the 80th Statutory Meeting in 1992 that the Study Group on Long-Finned Pilot Whales would meet at ICES Headquarters from 30 August - 3 September 1993 (C.Res. 1992/2:31). Prof. D. Butterworth was subsequently appointed to chair the meeting. The terms of reference were to:

a) conduct an evaluation of the status of long-finned pilot whales in the North Atlantic (i.e., population size and trends, population dynamics parameters), including the importance of behavioural factors and accounting for multispecies interactions;

b) identify key information gaps and critical long-term information needs.

1.3 Working Papers

The Study Group made substantial use of a number of papers in its deliberations - some prepared specifically for the meeting, and others in press or published. These are listed in Section 10 according to the reference numbers allocated during the meeting. Section 10 also lists other documents referenced in this report.

1.4 Terminology

The words "pilot whales" as used in this report refer to long-finned pilot whales, (*Globicephala melas*) unless specific indication is given to the contrary. Groups of animals sighted at sea are referred to as "schools". Aggregations driven ashore in the Faroes fishery are termed "*grinds*".

2 POPULATION IDENTITY AND SEASONAL MOVEMENTS

A number of the working papers submitted were relevant to the discussions under this section. These are WP-2,3, 6,8, 11, 13, 16, 17, 19, 22 and 29-33. This item was covered by structuring the discussions into distributional, genetic, morphometric and other evidence.

2.1 Distributional Evidence

WP-6 summarizes information on the distribution of pilot whales throughout the North Atlantic, using data from sightings surveys, catches, strandings, by-catch, and oceanographic studies. This species occurs broadly, from roughly 35° to 65°N in the western Atlantic and 40° to 75°N in the eastern Atlantic, with no indication of breaks in the distribution which might suggest separation into distinct populations. Pilot whales occur in some areas throughout the year, for instance in the Faroe Islands and along the US coast from the mid-atlantic to Cape Cod. In the northern part of their range they occur more seasonally, especially in western Greenland and perhaps in Iceland.

It was noted that the searching effort corresponding to the sightings data presented in WP-6 varies spatially, and this has yet to be taken into account quantitatively. The lack of sightings of pilot whales in the area south of Greenland between 40° and 50°W appears to be caused by a gap in searching effort.

WP-19 summarizes information on the distribution and movements of pilot whales in US waters based on sighting surveys conducted there from 1978 to 1988, and identifies the overlap in the ranges of the short-finned and long-finned species. These data were also used in WP-6. The authors note pronounced seasonal shifts in density of long-finned pilot whales, but note that these whales occur throughout the area all year round. They also note that this species occurs seaward of the continental shelf, especially in the shelf break region; these areas have not been included in most of the surveys reported. This lack of survey coverage in offshore waters occurs throughout the western Atlantic, resulting in a major gap in information on distribution from the shelf break east to 42°W.

WP-16 reports on the occurrence of mass strandings and drive-fisheries of long-finned pilot whales around Iceland. Forty events were identified from written sources in the period 1800-1993, of which at least 28 were drive-fisheries and the remaining 12 were considered to be non-human-influenced events. All the strandings/drive events occurred on the southwest, west and north coasts of Iceland. The seasonal distribution of the strandings showed a clear peak in August with no events in the period January-June inclusive. A less marked peak in late July to early September was reported from sightings records made on board whaling vessels west and south-west of Iceland.

The conclusions from the distributional information were drawn at two levels; the large scale (i.e. the whole North Atlantic), and the local scale. At the large scale, it was agreed that these data provided no direct evidence for there being more than one population in the North Atlantic.

Regarding the local scale there was a discussion as to whether all-year-round occurrence of pilot whales in some areas and seasonal occurrence in other areas could be used as evidence of more than one stock. Some argued that the possible seasonality at Iceland, in contrast to the year-round occurrence off Norway, in the Faroe Islands and in the western Atlantic, indicate some form of stock differentiation. The discussion centred around whether a direct proportionality between abundance and the number of strandings in a given area would be expected. For Icelandic waters it was suggested by some that such a proportionality exists because there is a similarity in the seasonal distribution of sightings and strandings. It was argued that natural strandings would better reflect the local abundance as they are not affected by visibility, in contrast to "assisted" strandings (cf Icelandic and Faroese samples). On the other hand the data from the western Atlantic indicate that, although pilot whales are present all year round, strandings occur in certain periods of the year only. This could indicate that mechanisms other than local abundance might be important.

Recommendations for future work:

a) The distributional map based on sightings (Figure 4.1.1 based on Figure 1 of WP-6) shows a gap in effort in offshore waters south of Greenland. Collection of effort-related information from this area is encouraged.

b) The sightings data should be presented with some form of effort and weather adjustment to reveal gradients in abundance. For example, the distributional data from the Icelandic NASS surveys (WP-16) may reveal longitudinal differences in pilot whale density. Further, the effort data in WP-19 should be analysed quantitatively.

2.2 Genetic evidence

WP-2 presents a study of genetic variability in samples from pilot whales stranded at Cape Cod, taken as by-catch in US waters, or stranded in Newfoundland, Nova Scotia, Scotland and England. The study is based on sequence data from part of the D-loop of the mitochondrial DNA (mtDNA). The results of the study indicate that North Atlantic long-finned pilot whales have low levels of mitochondrial genetic variation. A similar study (WP-3) comparing material collected from the Faroe Island drive fishery and pilot whales taken as by-catch in U.S. waters of the western Atlantic also demonstrated a low variation in mtDNA.

WP-17 presents genetic analyses made on a limited sample (n=12) of pilot whales stranded on the coast of Iceland on one occasion in 1986. The genetic studies conducted were based on polyacrylamide gel electrophoresis of enzymes, and on restriction enzyme analysis of mtDNA. Genetic variation was found in four of 18 loci examined in the allozyme study, but was low for mtDNA. The author suggests that the allozyme studies might be a useful approach, but that mtDNA needs further investigation to prove its usefulness in population studies of pilot whales. The results found in WP-17 with low mtDNA variation were consistent with the findings in WP-2 and WP-3.

WP-29 presents the results of a study of allozymes using ordinary starch gel electrophoresis on pilot whale samples collected in the western North Atlantic. The results are compared to the results of similar analyses made on pilot whales from 31 Faroese schools. The study demonstrates a large variability, but did not detect any significant genetic differences between pilot whales from the two areas. At least one of the loci was the same as one of those presented in WP-17, and showed the same degree of polymorphism, indicating that this locus could be used for comparisons.

There was agreement that the results presented above are not inconsistent with the hypothesis of a single North Atlantic stock of pilot whales, but that they are too limited to substantiate such a conclusion.

Recommendations for future work:

a) The possibility that the low mtDNA variability compared to that in other delphinid species (WP-20) is related to the cohesive social structure should be investigated.

b) Further genetic analyses should be conducted using methods other than analysis of mtDNA to determine reproductive relationships within and among different family groups, and to compare animals from different regions.

2.3 Morphometric Evidence

The paper WP-13 is based on body part measurements of 25 male and 21 female pilot whales caught in drive fisheries in Newfoundland during 1951-1954, and 97 male and 131 female pilot whales from two *grinds* caught in the Faroe Islands in 1988 and 1992 (WP-37). Flipper measurements were taken on an additional 509 whales (214 males and 295 females) from 22 *grinds* from the Faroe Islands. The preliminary analyses show a difference between the two localities investigated in that the male flipper length relative to total body length is greater in Newfoundland than in Faroese pilot whales, regardless of total length. Furthermore, pilot whales from Newfoundland showed longer skulls and shorter torsos than Faroese pilot whales. The authors of WP-13 also indicated that samples from France and Iceland are available but have not been included in the preliminary analyses because of the very small sample size.

Since the genetic evidence presented so far is not inconsistent with the hypothesis of one stock, the conclusion of WP-13, that there might be one eastern and one western stock, is very important for the interpretation of population identity of North Atlantic long-finned pilot whales. This led to broad discussions which focused on two items: whether the measurement methods used in the two areas were the same, and whether the analyses had taken changes in proportions during growth into account.

On the first point, the author informed the Group that Faroese measurements had been made following the standard methods of Norris (1961), and that those methods were also used for the Newfoundland material. The reliability of the length measurements in the Faroese material had been tested (WP-25) and was found to represent only a minor problem, if any. A closer examination of the paper by Sergeant (WP-37) suggested that, in that study, the sample had been taken evenly over the entire range of body lengths. Two problems were identified in the measurements used in that study: one was that there was some confusion as to whether standard length (tip of upper snout to fluke notch) or maximum length (forehead to fluke notch) had actually been used; the other was that the measurements had been taken on a segmental basis, implying that there was no confirmation that the sum of the segments equalled the total body length. The Study Group therefore thought that caution should be exercised when comparing measured segments of the body, but since the flipper length, and also the first segment measurement of the skull, are probably independent of the above caveats, these could probably be used. It was, however, noted that the proportion of the head region decreases with age while the tail region increases and the flipper length:total length ratio increases with length. Rough calculations made during the meeting indicated that, although differences in measurements of total length may arise because the furthest extent of the melon is sometimes used instead of the tip of the upper snout, the effect of this on the estimates of proportions would be minor.

The question was raised whether the Group was prepared to accept the results of the morphometric analyses despite the objections described above; in other words whether there has been an adequate demonstration that the relative male flipper length at Newfoundland is greater than that at the Faroe Islands. The Group agreed that a final answer should await the re-analysis indicated in the following paragraph.

With regard to the second point, worries were expressed about potential problems that might have arisen from the different timing of sampling of the Newfoundland material collected in the 1950s and the Faroese material collected around 1990. The basic question is whether the proportions measured are sensitive to different growth rates or changes in growth rates. Further, changes in growth might be correlated to density changes (for example, growth rates in sperm whales in the Pacific increased as the population was reduced by harvesting). WP-21 showed that the growth curves did not differ between the two study areas. It was also mentioned that apparent extension of the period over which animals grow could be an artefact of shifts in growth rates. In Figure 1 of WP-18, it was demonstrated that the flipper length:total body length ratio varied between sexes and maturation status. Although proportions might change with age, this could be dealt with by stratifying by length, or incorporating this aspect in the regression analysis.

Since conclusions on population structure hinge on the morphometric analyses, it was felt that some further studies should be undertaken to clarify matters. The Study Group recommends that the data presented should be reanalysed, specifically addressing how data collection is done. The existence of comparable morphometric measurements from pilot whales stranded on Cape Cod was noted in the report of the first meeting of this Study Group (ICES C.M.1992/N:3, p.23). These data are contemporaneous with the Faroe Islands data, and would probably allow stronger inferences to be made on population structure. Smith indicated that the US would endeavour to ensure that the collaborative analysis outlined in C.M.1992/N:3 is begun as soon as possible. Faroese scientists indicated their continuing strong interest in such a collaboration. Further, methods used to collect data should be identified to help in future collections of materials from these and other regions, whether through known catch operations as in Greenland, or through strandings. Faroese and US scientists would address these questions in a joint study.

It was suggested that a morphometric study of skulls, which might be available from museums and other similar sources, should be undertaken, especially since such measurements avoid possible bias problems identified in measurements on carcasses, like stretching during handling and treatment.

2.4 Other Evidence

Information in several papers tabled at the Study Group meeting was considered to provide potentially useful tools to determine population identity. The material presented was grouped into evidence from studies of pollutants, isotopes and teeth.

2.4.1 Pollutants and parasites

WP-22 presented a study of organochlorines in blubber from 114 long-finned pilot whales from five schools captured in the Faroe Islands during 1987. One pod could be distinguished from the other by a significantly higher PCB and tDDT content, and another by its higher p,p'-DDE/tDDT ratio.

WP-31 augmented by WP-12 (p.10) presented a study of heavy metals in the liver, kidney and muscle of 350 animals from eight schools captured in the Faroe Islands during 1986-1987. Two schools could be distinguished from the other by a significantly higher concentration of mercury and a lower concentration of cadmium and zinc. A third school could be distinguished by a significantly higher concentration of cadmium and zinc.

WP-33 presented a study of parasite loads in 170 animals from 13 schools caught in the Faroe Islands during 1987-1988. The examination of eight schools with respect to the abundance of helminth species showed that three schools could be distinguished by a significantly higher abundance of an acanthocephalan species while one school showed a significantly lower abundance of the same species and a significantly higher abundance of two other trematode species.

The authors of the different papers suggested that these variations may reflect the use of different food resources by different pods outside Faroese waters.

Based on these three studies the schools studied fall into three groups. One group is composed of most of the schools which could not be distinguished from each other by any of the methods. The remaining five schools fall into two groups.

These results indicated that although pods occur in the same area, they do not necessarily come from the same place. The results from these investigations could be understood as pods spending different portions of their time in different areas. The data negate the hypothesis of just one resident population at the Faroe Islands. The Faroe area might be a feeding ground shared by animals from several groups, but these groups must also occupy different areas away from this shared area.

2.4.2 Isotopes

WP-8 presented information on analyses of stable isotope ratios of nitrogen from tissue samples from two areas on the U.S. coast and the Faroe Islands. Four types of tissue were sampled: skin, muscle, blubber and teeth. Stable isotope ratios for skin and muscle differed between the eastern and western Atlantic samples, reflecting differences in recent diet. The ratios were similar for the two U.S. coastal areas for skin, muscle and teeth tissues, but differed for blubber. This suggests that the schools sampled had different longer-term diets. The interpretation of the difference for blubber is not clear, however, as the physiological dynamics of blubber in this species are not well understood. Taken together, the differences are consistent with animals being resident for extended periods on either side of the Atlantic, but suggest that animals sampled in close proximity can have different longer-term diets.

It was remarked that one problem in the interpretation of such results is that turnover rates for different tissues are unknown. There are additional difficulties with interpreting results from blubber: blubber is an energy source which itself has a high turnover, while the method measures ratios of N-isotopes, which are a more typical constituent of protein than of blubber. Within each of the sampled areas, variation was very low. If further analyses on isotopes from Faroese samples are conducted, the schools chosen for analysis should take the differences observed from the pollutant and parasite studies into account.

2.4.3 Teeth

A report on patterns of deposition of dentine and cement in teeth of pilot whales was given in WP-32. The material presented was from three schools, of which two had been stranded in Iceland (36 whales in 1982, and 108 whales in 1986) and one was a *grind* from the Faroe Islands (1986, 91 whales), a total of 235 whales. The paper concludes that one growth-layer-group is deposited each year, based on assessments of animals of known age. Several anomalous characters were recorded in the teeth and scored by sex, age, maturity etc. Appearance of pulp stones in the dentine seemed to be associated with the onset of puberty. Marker lines increased with age after one year and were significantly associated with certain calendar years in Icelandic samples. Mineralisation interference, dentinal resorption and cemental disturbance were all more common in the Faroese pod than in the two Icelandic pods.

The general comment was that the evidence from this study could also come from differences between pods, as indicated in other studies. It was speculated whether the different patterns observed in Icelandic and Faroese material could be based on physiological differences, genetic differences or local environmental effects.

The Group was informed that many more data exist; the material presented is just a subsample. Evidently, the Icelandic material was easy to read compared to the Faroese material. The basis for this was not clear. The Icelandic teeth, furthermore, showed more markerlines, and these were apparently formed synchronously among members within each school. The mechanism behind this is not understood. It was therefore *recommended* that more Faroese pods are investigated.

2.5 Overall conclusions - general discussion

It was considered useful in the discussions to try to formulate a small set of reasonable hypotheses and questions, which could then be examined on the basis of the information available to see whether they could be supported or rejected by the data.

Hypothesis I: There is only one North Atlantic population. If the morphometric findings are accepted, this hypothesis should be rejected and more than one population recognized. If the morphometric evidence is set aside, other findings (pollutants, teeth) indicate that there might not be one population with free mixing within it, but rather one or more populations consisting of schools with different histories.

Hypothesis II: There is more than one population in the North Atlantic. This immediately opens the question of where the boundary between these populations should be placed. The distributional data presented cannot give an answer to this question because there is no firm evidence on whether the apparent gap in the distribution south of Greenland is due to a real lack of pilot whales in the area or to lack of searching effort. It was argued that the boundary would probably be associated with some kind of physical feature like the mid-Atlantic Ridge or the boundary between the two ocean gyres, but there was no supporting evidence.

Hypothesis III: There is only one stock around the Faroe Islands. This can be rejected from the data presented in Section 2.4. A strong argument against this hypothesis was that virtually no pilot whales were observed around the Faroe Islands during NASS-89, while quite a lot of them were seen there during NASS-87. It was further mentioned that some information exists on short-term movements from a) experimental radio-tracking and b) rehabilitation of stranded animals. This indicates that the scale of movement is at least of the order of a few hundred nautical miles (the span of the Gulf of Maine).

The Study Group agreed that the pods occurring around the Faroe Islands had different histories in the short-term, but there was no evidence to support any genetic isolation.

Suggestions for future research:

Radiotracking of animals from multiple pods was considered essential, to gain insight into the movements of pods. It is strongly recommended that, after being tagged, the tagged animal be released together with the whole pod. Several individuals tagged within one school would provide interesting information on social behaviour. It is also recommended that the tagging study be coupled with other studies providing information on the history of the school (see Section 2.5).

There was some discussion on whether collecting biopsy samples for genetic and other analyses would be useful. This should be considered only when the adequacy of genetic techniques has been demonstrated.

It was also pointed out that additional developmental work would be necessary to demonstrate the usefulness of genetic methods in resolving population identity questions for this species. It was, however, appreciated that pelagic information is lacking and would perhaps merit priority in future data collection as coastal data are better represented.

Skull morphometrics based on existing collections, and on new material from harvested and incidentally caught animals, could contribute additional information on stock identification. It was considered important, for example, to try to obtain material from places where strandings or catches are known to occur. Samples from West Greenland were noted as especially useful because they would also contribute to analyses of data in relation to any north-south differentiation. In addition, studies of colour patterns and acoustic investigations of possible pilot whale dialects (e.g., as in studies of killer whale dialects) should also be considered.

3 SOCIAL STRUCTURE AND BEHAVIOURAL FACTORS

In WP-23 a total of 31 schools of pilot whales with 1948 individuals from the Faroe Islands were investigated for genetic variation by electrophoresis of three polymorphic enzyme loci. The males showed significant deviations from the Hardy-Weinberg equilibrium in some schools, which could be explained, either by a migration of males between schools, or by selection. A hypothesis based on the overall heterogeneity observed in the pooled material is that it could be generated by a regular pattern of fusion and fission of schools, combined with the migration of mature males between schools and a strong maternal family structure within the school, possibly consisting of several female lineages.

A review of genetic evidence relating to social organisation and breeding system in the long-finned pilot whale is given in WP-20. This study is based on two schools from the Faroese drive fishery which were analysed by DNA fingerprinting and microsatellite polymorphism. The authors conclude that the pods are matrifocal, containing related individuals, and that the adult males in a pod are rarely the fathers of the unborn foetuses in that pod. From detailed studies they conclude that there is little dispersal of either sex from the natal group. Mating apparently occurs reciprocally between pods at encounters.

Comments were made that both papers WP-20 and WP-23 concluded that the long-finned pilot whale schools are matrifocal, but that they differed somewhat with respect to the interpretation of male behaviour. In WP-20, the males were thought to stay in their natal pod and to mate only when the pod joined with another one such that reciprocal mating took place. It was remarked that the evidence for this was indirect, based on the fact that males within a group could have seldom fathered the foetuses within that group. In WP-23, it was hypothesised that males migrate between pods. The basic question is, then, whether the males return to their natal pod after mating or not.

In the discussions following the presentations of these papers an attempt was made to elucidate other information on pod structure that could be of help in interpreting the genetics results. WP-38 proposed two peaks of mating for pilot whales occurring around the Faroe Islands, one in May, which is the main season, and one in October. These peaks coincide with peaks in the size of the *grind* (the Faroese word for a pilot whale pod caught). This could support the hypothesis of schools joining for reciprocal mating. It was, however, commented that this behaviour could also have other explanations, for example aggregations of whales at times of peak availability of food.

A further point was made about the apparent differences between typical pod sizes of pilot whales recorded during sightings surveys, whether shipborne or aerial, and the sizes of *grinds*. While the former will often be in the range 20-30, the latter has a mode of around 110. In other words, the units recorded in drive fisheries are larger than those recorded during sightings surveys, and the question is then whether this can be (i) ascribed to problems of visibility during surveys or (ii) explained as a real phenomenon. To try to see whether the size of the pods were underestimated systematically during surveys, Bloch described some opportunistic observations at the Faroe Islands where *grinds* had been observed from as early as possible in the drive sequence to make an estimate of *grind* size which could subsequently be compared with the final catch. The first estimate turned out to be anything from 10% to nearly 100% of the final number. Larsen reported that pilot whales observed during aerial surveys off West Greenland usually occurred in groups of 20-50 animals, and that several such groups could be found within a distance of a few kilometres. Several members of the Group reported occasions when pilot whales made a sudden appearance or disappearance; the latter behaviour could be associated with feeding. These findings are, however, not inconsistent with the assumption that several smaller groups might live in relatively close proximity to each other. In fact, the spatial factors involved in school size estimation are not known, but the spatial distances between pods that are related, and that therefore might constitute a *grind*, could be larger than the average sightings distance.

In paper WP-9, attention is drawn to potential problems in estimation processes due to cohesive pod structures. Firstly, abundance estimation by sightings surveys may be affected by spatial diffusion of pods into subgroups. A second question is how a population structured into permanent pod units is affected by exploitation. In view of these questions, the implications of group structure for the ability of the population to support different levels of mortality should be explored. The types of studies needed include investigations of the nature of demographic implications on the behavioural processes which define and maintain the pod structures and produce new pods.

The discussion following this presentation again focused on pod size, but also on possible mechanisms for pod formation and implications for management. At present, no concrete mechanism has been demonstrated for pod splitting and formation, and these may not necessarily be discrete processes. It was suggested that a set of models should be formulated and their merits and eventual implications investigated if found reasonable. Given the relatively open-ended factual basis, this raised more questions than it answered. Schools might not be as cohesive as we suspect, implying that they may mix and separate. They may also split with growth, depending on the distribution and availability of prey items. When schools disappear, for example due to hunting, it is a question how density changes result in changes in food availability for other schools. One mechanism that was suggested was that groups may expand to a size where splitting is probable; in that case the effect might be that the density-dependent response is delayed. Pod structure will obviously have implications for management, although the relative importance is unknown. If males migrate between pods, a drive fishery taking whole pods (*grinds*) may change the age structure of the males, but not of the females (see Section 6.2).

The problems with determining what constitutes a pod and a *grind* were considered to be of high importance for future work, both with respect to sightings surveys, genetic structure and population dynamics modelling. It was recommended that spatial differences in group sizes should be investigated from sightings surveys (NASS-87 and NASS-89), especially to check for gradients in school sizes, for example around the Faroe Islands. However, there will be some limitations since these sightings surveys had most of the effort offshore, whereas the driving operations of *grinds* are purely coastal.

4 ESTIMATES OF ABUNDANCE

4.1 Eastern Atlantic

WP-24 provides an analysis of sightings data collected during the North Atlantic Sightings Surveys which were conducted in 1987 and 1989 (NASS-87 and NASS-89). The NASS-89 covered a greater area, and a summation of abundance estimates obtained from the Icelandic, Faroese and Spanish data (making appropriate allowance where coverage overlaps) yields a total abundance estimate of 778,000 whales (CV = 0.295). The area to which this estimate applies is indicated in Figure 4.1.1.

Tables 4.1.1 to 4.1.3 (reproduced from WP-24) provide abundance estimates on a finer spatial scale from both NASS-87 and NASS-89. Figures 4.1.2 to 4.1.4 indicate the sub-areas to which these estimates apply. The estimates for comparable areas from NASS-87 and NASS-89 do not differ significantly at the 5% level.

The estimate of total abundance is not particularly sensitive to alternative procedures for interpreting the information recorded for "high", "low" and "best" estimates of school size. It is based on the assumption that all schools on the trackline are sighted. This seems plausible for the larger schools (unless they can exhibit synchronous diving behaviour), but may not hold for smaller groups, with a consequent negative bias in the abundance estimate. WP-24 draws attention to a positive bias which may arise if the locations of large diffuse sub-groups are recorded as those of the first constituent sub-group sighted (which tend to be closer to the trackline). Attention should be given to the methodological suggestions made in WP-24 to overcome this problem when designing future surveys.

The school size estimates reported for these surveys, which have means of some 20 whales, are difficult to reconcile with *grind* data which reflect aggregations typically in excess of 50 animals. Estimation of school size during the surveys, which is based on the number of whales seen on the surface over a short time period, is difficult. Nevertheless the Group did not believe that these difficulties were so severe that the size of schools recorded as 30 whales or less were substantially underestimated. Two lines of further investigation were suggested to examine this apparent inconsistency further:

i) a *grind* may consist of several "schools" (as recorded on surveys); the survey data should be checked for evidence of sightings in close proximity, which would indicate that "schools" are predominantly components of larger aggregations;

ii) the survey data should be examined for a decreasing trend in school size with distance from the nearest coastline, to check the possibility that animals may aggregate differently in coastal and open sea conditions.

4.2 Western Atlantic

Past surveys for pilot whales in this region have had very limited areal coverage, with the result that the associated abundance estimates (of the order of 10,000 whales, e.g. WP-19 and Hay, 1982) give little indication of the abundance for the region as a whole. Indirect estimates based on population models have been attempted in the past (WP-35), but there are a number of reservations about such analyses (as discussed in Section 5). Nevertheless, the cumulative removals of some 54,000 animals from this region over the 1950s and 1960s provides a lower bound for the abundance at the start of that period.

A survey with complete coverage of the range of pilot whales west of 42°W is a clear priority. Synchrony of efforts to this end, with a likely NASS survey of the eastern Atlantic planned for mid-1995 (J. Sigurjonsson, pers.comm), should be strongly encouraged.

5 ESTIMATES OF TRENDS IN ABUNDANCE

5.1 Eastern Atlantic

The Study Group noted that since its meeting in Montreal in 1991, there had been no further modelling to explore the question of long-term sustainability of the population and catch of pilot whales. Two further pieces of information were discussed. First, Hoydal (1986) found no significant changes over the last 50 years in the mean size of pilot whales. This can be interpreted as an indication of absence of substantial change in fishing mortality and growth, assuming that the pod structure of the catches does not alter the standard relation between mortality and average age, and that individual growth rate does not increase to compensate for reduced numbers under higher fishing mortality. Second, WP-11 provided an analysis of the catch data series (1709-1992) of pilot whales and bottlenose whales from the Faroese drive fishery by number of whales and number of schools. The pilot whale catch series is compared to temperature series for the Dansgaard Greenland ice cores and for Faroese waters. The paper suggests that the variability observed in the number of both whales and schools can be connected to changes in the ocean around the Faroes. The catches of pilot whales are frequently (though not exclusively) related to the catches of squid and to the biomass of blue whiting in their feeding area, i.e., the Norwegian Sea. Accordingly, it was hypothesized that the migration route of pilot whales in the north Atlantic, and hence their abundance in Faroese waters, may vary in relation to changes in the North Atlantic currents.

A number of problems were found in relation to this interpretation of the relationship between the variation in temperature and catch fluctuations.

- The reversal in the sign of the correlation between the temperature time-series and the pilot whale catch time-series around 1920 was seen as weakening the usefulness of this relation in understanding and predicting trends in abundance.

- The overlap of the time-series for pilot whales and blue whiting is very short, and there is no information on squid availability around the Faroe Islands.

- Figure 7b of WP-11 shows a marked correlation between pilot whale catches and the abundance of blue whiting on its feeding ground. However, this is a purely empirical relationship for which the underlying mechanism is unclear. If pilot whale abundance is closely linked to blue whiting biomass, reduction in the latter would give rise to concern as regards pilot whales, but independent information is needed to corroborate this relationship before it can be regarded as well established.

- The correction factors given in Table 2 of WP-11, which are said to reflect changes in fishing effort, are estimated values of relative intensity of the pilot whale fishery rather than direct estimates. While the directions of the trends which they indicate are probably reliable, their quantitative accuracy is likely to be low. If the correlation between availability and abundance of pilot whales was constant over time, a time series of catches adjusted for effort changes would be useful as an index of abundance. However, given the observed changes in oceanographic features and in temperature, such an assumption about this expectation is probably incorrect.

5.2 Western Atlantic

Discussion in this section was based on WP-35, upon which comments in Nelson and Lien (1991) are based. In WP-35, landings of pilot whales in Newfoundland from 1952-1972, corrected for availability which is related to squid landings, were used to estimate the initial population size of the pilot whales exploited. The Delury model utilized for this calculation made a number of critical assumptions, such as that of constant fishing effort and the absence of immigration or emigration. The initial pilot whale population estimated in this manner is less than 60,000, with the number remaining at the end of the period less than 19,000.

The analysis in WP-35 accordingly indicates a sharply decreasing trend in local abundance in the Newfoundland region. However, the extent to which this trend was indeed fishery induced (i.e., arising from a change in abundance) or related to movements of animals out of the area (i.e., a change in availability) is not clear. It was also suggested that the fluctuations in catches in Newfoundland over this period are not dissimilar to variations found within the long-term Faroese catch data, which seem unlikely to reflect trends in abundance alone.

The interpretation of a real change in abundance by the author of WP-35 thus hinges on assumptions which have still to be validated. The use of squid landings to estimate pilot whale abundance from catch also depends on assumptions of constant availability and fishing effort on squid. Given the general observation that squid distribution is variable due to extensive movement (in contrast, for example, to cod, which is more localised), these constancy assumptions may not hold true.

If direct estimates of current abundance were available, would these help in interpreting the stock estimates from WP-35? It was noted that estimates of abundance and vital rates would allow estimation of the rate of population increase, so that an estimate of current abundance could be projected backwards to relate to Mercer's analysis. In summary, direct estimates of abundance from surveys and stock identification would provide information needed for a sounder interpretation of the local decline in catch in Newfoundland.

6 POPULATION DYNAMICS PARAMETERS, MODELS AND HISTORIC CATCH ESTIMATES

6.1 Population Dynamics Parameters

Estimates of standard parameters describing the life history of pilot whales were presented in several papers available to the meeting, including working papers and papers already published.

Because specific population models have yet to be selected, and because of limited time, the Study Group did not review these estimates in detail to select "best" estimates. Rather, the available estimates were assembled in Table 6.1.1, separately for eastern and western Atlantic data sources, and some specific comments were made on them as set out below. Estimates of statistical precision are available for most of these estimates, although they have not been included in this table. Cognisance should be taken of this uncertainty if these estimates are used in a population modelling context.

Estimates of the age of first ovulation were available only from Faroes samples, and were in the range of 8.0 to 8.7 years, depending on the method used. The method which produced the estimates at the upper end of this range was thought to be better. Desportes reported preliminary analyses of four *grinds* where she had measured age of first lactation based on the history of the mammary glands. For those *grinds*, the average age of first lactation was roughly double the average age of first ovulation (14.1 versus 7.6 years). It was noted that this did not appear to be consistent with the observed pregnancy rates for younger females, but that if this is a general pattern it would have important implications for the population dynamics and should be investigated further.

The gestation period appears to be about one year for the Faroe Islands animals (WP-38). An alternative estimate of 13 months in WP-38 was made using a method comparable to that used for the estimate for the western Atlantic (Newfoundland) samples. The higher western Atlantic value (15.5 months) may result from seasonal biases in those samples. The value of 12 months is partially confirmed by a different method of estimation of the length of the linear growth period in WP-4.

Two different methods were used for estimating calving interval and the western Atlantic estimate, at least, depends on an estimate of gestation period which is possibly biased. The eastern Atlantic estimate appears to depend on somewhat arbitrary values selected for some parameters; the estimates of calving interval and first year survival would change reciprocally for different selections of these parameters. Further examination of the material is needed to verify and compare estimates of this parameter for the two data sets.

Estimates of post-birth survival rates have been developed based on the sample age compositions in WP-21. The estimates may reflect both natural and harvesting mortality rates; the possible implications of harvesting whole family groups on the age composition of the catch is discussed in WP-10. Further, if the populations or family groups do not have an equilibrium age composition then the estimates of survival rate may be biased. The degree to which these potential difficulties apply to these data was not investigated because of lack of time.

The estimates of age-averaged survival rates are similar for the two methods shown in Table 6.1.1, with males having lower survival rates than females. However, the available data from both the eastern and western Atlantic suggest that survival changes with age, and the methods used to obtain the estimates in the table may not be appropriate because of this age dependency. It was noted, however, that the apparent age dependency in survival in the eastern Atlantic sample could be the result of systematic variation in recruitment to the population over periods approaching a decade or so. Age specific estimates for both sexes are available in WP-5, WP-21, WP-38, and Kasuya *et al.* (1988), using four different methods. Several questions about the results and the appropriateness of the methods used were raised. For example, in WP-38 the estimates for small ranges of ages do not appear to be consistent with the average estimates over all ages, especially for those based on the Chapman-Robson procedure. Further, the log regression method used can be less robust than the Chapman-Robson procedure, especially for small sample sizes. Estimates of survival rates by age were made by fitting a five parameter Siler model in WP-38 and WP-5, and also by means of a non-parametric model in WP-5. The latter paper suggested that the results from the Siler model may be sensitive to the fitting procedure used, especially if the solution space has multiple optima, and also notes that the non-parametric procedure used appeared to give satisfactory estimates. The estimates for the western Atlantic could not be compared easily with those from the eastern Atlantic because different age grouping had been used. Additional consideration of the methodology involved is needed to obtain satisfactory estimates.

Foetal mortality rates were estimated in WP-4 using size-classified cohort analysis. The estimates are for the later part of the gestation period, after the foetuses are large enough to be detected consistently (i.e., the last 300 days of gestation) and show a marked difference by sex. Female survival is lower earlier in the gestation period. Time did not permit a thorough discussion of these estimates. The sex ratio at birth favours females in both the eastern and western Atlantic samples. This imbalance is evident six months after conception.

Broadly speaking, there are three types of human-induced mortality in the North Atlantic: drives, harpooning or shooting, and by-catch. Age composition data do not suggest substantial age-specificity in the Faroes and Newfoundland drive fisheries although it is possible that there is a lower selectivity for older males if they are less vulnerable. This may be due either to their physically escaping the drive, or to a tendency to move away from family groups. Length data are available for the Norwegian harpoon fishery and the US by-catches, and could be examined to determine age selectivity, if any, in these sources of mortality.

6.2 Population Modelling

The Study Group identified three areas in which modelling initiatives need to be pursued:

i) A fishery based on assisted strandings of pilot whales removes cohesive schools (at least in respect of females) from the population. The differences (if any), in terms of population dynamics and population age structure, from the situation in a fishery on animals which mix freely, require examination under various hypotheses about school formation and density dependence mechanisms;

ii) Potential rates of population increase should be evaluated from the data available on population dynamics parameters, with an emphasis on accounting for statistical and model uncertainty;

iii) Population models should be implemented to evaluate historic population trajectories based upon current estimates of abundance, historic catches, and values of population dynamics parameters.

In the longer term, development of multispecies models appropriate to this situation might be considered, in cooperation with the ICES Multispecies Assessment Working Group.

Time did not permit a more detailed discussion of these matters.

6.3 Historic Catch Estimates

Tables 6.3.1-6.3.6 present information on the numbers of long-finned pilot whales harvested in direct fisheries, killed in natural and assisted strandings, and taken as by-catch in other fisheries. While this information is not comprehensive for all areas, the Group believed that it would be useful for future analyses of historic population trajectories.

7 MULTI-SPECIES INTERACTIONS

The terms of reference for the Study Group include accounting for multi-species interactions in evaluating the status of pilot whales in the North Atlantic.

The Group focused on predation processes, specifically prey availability and preferences. Information is available from stomach samples from drive fisheries in the Faroe Islands and Newfoundland, and from animals in the by-catches of mackerel and squid trawl fisheries in the U.S.A. Squids of different species appear to be the preferred prey in all areas (Table 7.1).

A variety of fish species, both pelagic and demersal, are also eaten but in lesser proportions than squid. However, the proportions of fish are greater in larger animals (WP-39). There are commercial fisheries on some of these species. Depending on the availability of preferred squid species, pilot whales will switch to other squid species (WP-39) and to fish species such as cod (WP-35) and blue whiting (WP-39).

The available data on diet are limited to localized areas (Faroes, Newfoundland) and to animals taken as by-catch in a fishery for a prey species (U.S.A.); the diet in other areas, especially offshore, is not known. The primary diet information is from hard parts of the prey. Differential retention of squid beaks and fish otoliths may result in overestimation of the frequency of squid in the diet.

Several lines of research were identified to address these uncertainties. Improved information on distribution and relative abundance of both the whales and their main prey species would be useful to determine the representativeness of the available data on diet. Because pilot whales seem to be associated with areas of high productivity such as the shelf edge and frontal zones, mapping of oceanographic processes and the distribution of other large predators such as swordfish, tunas, sharks, beaked whales and sperm whales would be informative (WP-36; Waring *et al.*, 1993). Additional stomach sampling would also be helpful. To design such a program, further analyses of existing stomach samples and dietary data are needed to identify optimum sample sizes for statistical variability and to identify a limited range of variables to measure. Measuring stable isotope ratios in whale and prey tissues may provide additional information on trophic levels and possibly prey species (WP-8). Further testing of the application of stable isotope methods to cetaceans, and the development of biopsy sampling methodology is needed.

The work of the ICES Multispecies Assessment Working Group was summarised by Henrik Gislason. In the North Sea the focus of this Group has been the estimation of predation mortality rates on fish by five fish species using fine spatial and temporal scale diet and abundance data. The results suggest that the level of the mortality caused by these five species is similar to that caused by fishing, and also to that caused by other sources of predation. In the latter category, the predation by one marine mammal species, the grey seal, was estimated from abundance and consumption rates to be small. It was noted, however, that marine mammal predation may be more important in other ecosystems. For example, Bax (1991) suggests that a much higher proportion of fish mortality is caused by marine mammals in the western Atlantic along US and Canadian coasts and in the Barents Sea. It was also noted that recent estimates of abundance of minke whales in the northern North Sea are relatively large so that the total predation by this species may be higher than that of grey seals. In this regard, it is important to note that even a low percentage contribution by a prey species in cetacean diets can correspond to large absolute predation in circumstances where cetacean abundance is high.

The ICES Multispecies Assessment Working Group may be investigating other systems in the future, for example the cod-capelin interactions in the Barents Sea, Iceland, and Newfoundland. The abundance of pilot whales and other cetaceans, and their dietary reliance on the key species in such interactions, will need to be evaluated. The statistical precision and structural detail requirements of the MSVPA approach, however, probably cannot be met for species such as pilot whales. In this case alternative models which require less detail may be needed.

8 STATUS EVALUATION

The instruction to the Study Group to conduct an evaluation of the status of pilot whales amplified this by reference to "population size and trends, population dynamics parameters". The available information in this regard is discussed above: there is an estimate of 778,000 pilot whales over a large portion of the eastern Atlantic (see Figure 4.1.1) but no comprehensive estimate for the western regions; there is no directly measured information on trends; estimates of population dynamics parameters are given in Section 6.

The following discussion is separated for the eastern and western Atlantic purely for reasons of presentational convenience. This separation is not intended to imply rejection (or acceptance) of the hypothesis that there is one population only in the North Atlantic.

In relation to the eastern Atlantic, the Study Group noted that the following three considerations can be argued to be pertinent to an evaluation of status, in part because they relate in some way to current or likely future population trends.

The first consideration is the ratio of the present catch level to the current population size. "Population" in this context constitutes the reproductive unit(s) from which the catch (highly localised in this instance) is taken, and it is unclear at present how the extent of this population relates to the surveyed area (Figure 4.1.1). While pollutant and parasite data (see Section 2) exclude the possibility that pilot whales taken in the Faroes are drawn entirely from a localised and closed population, present data cannot distinguish between hypotheses ranging from an extent only marginally greater than the immediate vicinity of the Faroes to one in excess of the area of the eastern Atlantic covered in NASS-89. Thus estimates of the ratio in question would cover a wide range.

The second consideration relates to the use of population models to integrate information on historic catches, current abundance estimates and values of biological parameters to estimate trajectories (WP-35 provides a simple example of this). This approach provides indirect estimates of the ratio of the current population size to earlier population levels and of trends in population abundance. A difficulty with this approach lies in the interpretation of such ratios given the lengthy period of exploitation (some five centuries) in this particular instance. As in the previous paragraph, the problem of the relationship between current "population" size and the available estimate of abundance arises again. Calculations could be carried out over the range of possibilities in this regard, but the resulting range of estimated population trajectories might prove to be too broad to be informative.

Thirdly, given the difficulties in interpreting the ratios of current to earlier population levels noted above, and given the instructions to the Study Group to consider multispecies interactions, there is a need to evaluate the status of prey resources and how these are affected by the environment in the context of pilot whales.

The Study Group agreed that it had been unable to complete an evaluation of the status of pilot whales in the eastern Atlantic. Further refinements of the available information on population structure, abundance and population dynamics parameters are required, as discussed in Sections 2, 4 and 6 above. Time was insufficient to initiate the population modelling exercise described in the second consideration above, and further information on prey consumption and abundance is needed to address multispecies considerations, as indicated in Section 7.

The conclusions for the eastern Atlantic above apply also to the western region, except that the situation there is worse, principally because of the absence of a direct estimate of abundance (i.e. similar to that from NASS-89) for a wide area. Trend estimates are available from a population modelling exercise (WP-35), but these are very sensitive to variations in the wide-ranging assumptions which were necessary for that analysis. The bycatch information for this region also requires processing into a form suitable for input to population model analyses.

9 FUTURE RESEARCH REQUIREMENTS

The Study Group concluded that the main elements required for evaluating the status of pilot whales had been addressed. Due to time constraints, no new calculations or modelling exercises were carried out for the purpose of addressing the question of the status of the stock. Such work was considered to be one of the steps necessary fully to evaluate the status of pilot whales. However, this work would not necessarily lead to satisfactory answers relevant to the terms of reference owing to the gaps in information and methodologies used, uncertainties in key parameter values, and the need to apply additional methodologies, as identified above.

With regard to broader issues related to the status of the stock, the Study Group noted that several principal prey species had been identified in part of the distribution area of the pilot whale. For sound evaluation of the status and future prospects of the stock and its role in the ecosystem, one would need to explore the status and likely development of fisheries for these prey stocks. For this purpose, and to address broader ecological concerns, interaction is needed with relevant assessment working groups and the Multispecies Assessment Working Group.

The Study Group concluded that, although major progress had been made regarding the evaluation of the status, finality in this regard required at least two further steps to be taken. First, modelling evaluations conducted on the basis of the information presented above, and the results of further analyses detailed below, would help to address the terms of reference more fully. However, in the light of the uncertainties as regards population identity, this is unlikely to lead to definite answers.

The second step would be to evaluate the modelling results and to make proposals for the design and execution of future research which would improve the basis for overall evaluation of the status of pilot whales in accordance with the terms of reference of the Study Group.

These two steps could be accomplished at a meeting of the Study Group to be held following completion of certain preparatory tasks. These tasks are described below, organized in terms of the types of variables involved.

Population Dynamics Parameters:

1. Reanalysis of data to estimate calving intervals. Genevieve Desportes was nominated to coordinate this with Solange Brault and Toshio Kasuya, and to request assistance from A. Martin (Sea Mammals Research Unit, UK).

2. Reanalysis of data and methods for estimating survival rates. Solange Brault was nominated to coordinate this together with Toshio Kasuya, and to request assistance from Christina Lockyer (Sea Mammals Research Unit, UK).

Population size:

3. Reanalysis of sightings data to evaluate the proximity of other schools to primary sightings. Thorvaldur Gunnlaugsson was nominated to undertake this evaluation using NASS sightings data.

4. Analysis of average sighted group size at varying distances from islands or coastlines. Thorvaldur Gunnlaugsson was nominated to undertake this analysis.

Population identity:

5. Review of the potential value of different methods for detecting genetic variability. Liselotte Andersen was nominated to coordinate this review.

6. Reanalysis of morphometric data from the Faroe Islands and Newfoundland samples to take better account of different methods used for data collection and age-specific changes in allometric relationships. Dorete Bloch was nominated to coordinate this analysis together with Solange Brault.

7. Comparison of morphometric data from mass strandings on Cape Cod and data from other locations to detect population differences. Tim Smith was nominated to coordinate this together with Dorete Bloch, and to request assistance from the New England Aquarium.

8. Review of the present state, and likely development, of satellite tagging methodology, with the aim of being able to design an appropriate study to detect ranges of movement of individual groups of whales. Johann Sigurjonsson was nominated to coordinate this review.

9. Comparison of the Faroese *grinds* that are distinguished from others on the basis of pollutants and parasites, with the other *grinds*, on the basis of their carbon and nitrogen isotope ratios. Tim Smith was nominated to coordinate this study together with Dorete Bloch.

Multispecies interactions:

10. Review of information on the status of stocks of populations of prey species, drawing on ICES stock assessment working groups for squid and blue whiting and on other assessments in the North Atlantic. Doug Butterworth was nominated to coordinate this together with Tim Smith.

11. Review information on the relative detectability of squid beaks and fish otoliths in cetacean stomachs. Genevieve Desportes was nominated to coordinate this review.

Modelling:

12. Estimation of potential rates of population increase from available population parameters and evaluation of the impact of uncertainty in these parameters on this estimation. Solange Brault was nominated to coordinate this analysis, together with Doug Butterworth.

13. Development of population models to evaluate historic population trajectories. Solange Brault was nominated for this work, in conjunction with Doug Butterworth.

In addition to the tasks above, which need to be completed prior to the next meeting, several other tasks of high priority were identified, though these will probably take longer to complete.

Population dynamics parameters:

14. Comparison of age at first ovulation and age at first lactation to confirm preliminary results suggesting large differences. Genevieve Desportes was nominated for this analysis together with Toshio Kasuya.

Estimates of abundance:

15. Coordination of methodologies and coverage of future sightings surveys throughout the range of this species. Johan Sigurjonsson and Tim Smith were nominated to organize this activity jointly.

Population identity:

16. Further analysis of social structure using genetic methods, if population modelling suggests that social structure has important consequences for the population dynamics (see 19 below). Liselotte Andersen was nominated to coordinate this project.

17. Collation of skull measurements from museum collections for further research on population identity. Dorete Bloch was nominated for this, together with Steve Swartz.

18. Development of simplified methods for analysing marker structures in teeth to detect ranges of movement of pilot whale groups. Dorete Bloch was nominated to coordinate this, and to invite participation by Christina Lockyer (Sea Mammals Research unit, UK).

19. Evaluate the implication of cohesive social structure on the dynamics of populations, especially as regards the effects of exploitation, using modelling techniques. Solange Brault was nominated to coordinate this together with Doug Butterworth.

Finally, several other tasks were identified which would be useful to pursue, although they have lower priority than those listed above.

20. Development of stable isotope methods for determining trophic levels and prey requirements. Tim Smith was nominated to coordinate this.

21. Analysis of NASS, cetup and other sighting and effort data to identify spatial gradients and density patterns, to detect population structure. Tim Smith is nominated to coordinate this, together with Thorvaldur Gunnlaugsson and Genevieve Desportes.

22. Development of alternative models of multispecies interactions to evaluate population status.

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Table 4.1.1 Abundance estimates by block, Icelandic pilot whale data, NASS-87 and NASS-89.

Year	Block	Number of sightings, *n*	Size of block (nm^2)	Abundance estimate, *N*	CV(*N*)	95% confidence interval
1987	1	1	2542.1	136	1.079	(24, 763)
	2	1	18926.3	271	0.594	(92, 796)
	7	11	75215.1	4651	0.814	(1149, 18819)
	36	6	44172.5	5753	0.707	(1651, 20051)
	88	12	59848.0	11325	0.577	(3960, 32388)
	93	15	21760.7	17339	0.608	(5774, 52066)
	94	10	46092.4	14147	0.781	(3656, 54744)
	95	1	69396.1	4240	0.778	(1101, 16326)
	All	57	337953.2	57864	0.362	(29074, 115164)
1989	36	16	44172.5	47195	0.408	(21857, 101904)
	40	10	107842.0	74503	0.522	(28484, 194869)
	50	25	99750.0	217950	0.458	(92611, 512923)
	60	3	131458.0	112138	0.777	(29157, 431288)
	70	7	88571.0	42109	0.523	(16052, 110461)
	88	9	59848.0	31889	0.633	(10215, 99549)
	93	2	21760.7	1783	0.597	(604, 5260)
	94	9	46092.4	46786	0.579	(16314, 134171)
	95	9	69396.1	37026	0.550	(13528, 101340)
	All	90	668890.7	611378	0.354	(312023,1197933)

Table 4.1.2 Abundance estimates by block, Faroese pilot whale data, NASS-87 and NASS-89.

Year	Block	Number of sightings, *n*	Size of block (nm^2)	Abundance estimate, *N*	*CV(N)* interval	95% confidence
1987	17	15	29599	55112	0.521	(21108,143895)
	37	1	69394	4275	0.880	(968, 18871)
	47	3	73492	5392	0.732	(1495, 19453)
	All	19	172485	64779	0.454	(27752,151209)
1989	10	5	195560	26122	0.689	(7702, 88593)
	20	6	40625	22887	0.898	(5068,103357)
	All	11	236185	49009	0.614	(16186,148389)

Table 4.1.3 Abundance estimates by block, Spanish pilot whale data, NASS-89.

Year	Block	Number of sightings, *n*	Size of block (nm^2)	Abundance estimate, *N*	*CV(N)* interval	95% confidence
1989	21	15	244390	128080	0.571	(45241,362604)
	22	4	170900	12235	0.633	(3924, 38148)
	All	19	415290	140316	0.541	(52015,378518)

Table 6.1.1 Estimates of population dynamics parameters for pilot whales from samples from the eastern and western Atlantic. Estimates from different methods applied to the same data are separated by dashes.

Parameter	Location	
	Eastern	Western
Age of first ovulation(yr)	8.4[1,2]-(8.0[1], 8.1[2])-(8.5[1],8.7[3])	
Gestation period (months)	(12-13[3])	15.5[6]
Calving interval (years)	5.3[5]	3.3[6]
Survival rates		
Female-(0-58 yrs) (annual)	(0.93-0.94[7])	
-foetal (last 300 days)	0.51[8]	
Male-(0-49 yrs) (annual)	(0.92-0.93)[7]	
-foetal (last 300 days)	0.28[8]	
Proportion female		
birth period	0.60[9]	
age 0-6 months	0.57[10]	0.55[11]

[1] WP-38, Table 1.

[2] WP-21, Table 8.

[3] WP-38.

[4] WP-5, Appendix.

[5] WP-38, Table 5.

[6] Sergeant (1962), p.58.

[7] WP-21 Figure 3.

[8] WP-4, Table 2 and Appendix A.

[9] WP-34, Table 2.

[10] WP-34, Tablea 4.

Table 6.3.1 Reported catches of long-finned pilot whales (*Globicephala melas*) around Newfoundland for the period 1947 to 1972 (WP-35).

Year	Number
1947	0
1948	215
1949	0
1950	172
1951	3102
1952	3155
1953	3584
1954	2298
1955	6612
1956	9794
1957	7831
1958	789
1959	1725
1960	1957
1961	6262
1962	150
1963	221
1964	2849
1965	1520
1966	887
1967	739
1968	204
1969	123
1970	155
1971	4
1972	0

Table 6.3.2 Number of long-finned pilot whales (*Globicephala melas*) taken in the Faroe Islands drive fisheries for the periods 1584-1640 and 1709-1978 (Bloch, pers. commn.)[1]

Year	Males	Females	Total
1584			
	(To be supplied later)		
1640			
	(To be supplied later)		
1709			
1980			
1981			1725
1982			2773
1983			2973
1984			2652
1985			1689
1986			
1987			2606
1988			1709
1989			1422
1990			1690
1991			1258
1992			916
1993			

[1] Full dataset not available at time of report preparation.

Table 6.3.3 Directed catches of long finned pilot whales (*Globicephala melas*) in Greenland during the periods 1929 to 1939 and from 1952 to 1990 (Heide-Jorgensen and Bunch, 1991).

Year	Number
1921	126
1923	32
1924	13
1926	200
1928	185
1931	415
1932	120
1935	325
1937	28
1939	400

1954	28
1955	2
1956	2
1957	25
1958	48
1959	158
1960	10
1961	5
1962	12
1965	138
1966	38
1968	8
1970	10
1973	2
1974	16
1975	108
1976	50
1977	138
1978	100
1979	50
1980	10
1981	2
1982	2
1985	25
1986	10

Table 6.3.4 Strandings and drives of long-finned pilot whales (*Globicephala melas*) in Iceland from 1606 to 1990 (WP-16).

Year	Number Stranded	Number Driven
1606		40
1704		37
1800	45	
early 19th century		?
1809	1000	
1812	2714-2814	724
1818		100
1824		5-600
1852		65
1878		207
1927		2-3000
1928	75	5
1929		200
1933		3-400
1934		72
1935	225	219
1937		68
1938		140
1939		190
1941		524
1943	700	
1957		105
1958		300
1960		100
1966		3
1982	280	
1986	148	
1990	22	

Table 6.3.5 Norwegian directed catches of long-finned pilot whales (*Globicephala melas*) from 1938 to 1974 (Øien 1991).

Year	Males	Females	Total
1938	20	7	27
1939	21	7	28
1940	0	0	0
1941	4	0	4
1942	8	0	8
1943	6	2	8
1944	1	4	5
1945	11	2	13
1946	1	0	1
1947	6	1	7
1948	1	0	1
1949	6	0	6
1950	0	9	9
1951	5	3	8
1952	1	1	2
1953	2	1	3
1954	0	0	0
1955	10	3	13
1956	0	1	1
1957	53	27	80
1958	167	59	225
1959	159	65	224
1960	228	103	331
1961	224	71	295
1962	32	11	43
1963	53	18	71
1964	44	10	54
1965	21	11	32
1966	264	75	339
1967	111	6	117
1968	27	4	31
1969	22	5	27
1970	32	11	43
1971	0	0	0
1972	0	0	0
1973	0	0	0
1974	1	0	1

Table 6.3.6 Standings, direct catches, and incidental takes of long-finned pilot whales *(Globicephala melas)* in the Northeastern United States from 1620 to 1988 (McFee 1990, Waring *et al.* 1990).

Year	Number Stranded	Direct Catch	Bycatch
1620	3		
1682	?		
1770	?		
1793	400		
1809	?		
1820	?		
1828		49	
1829		40	
1832	7		
1833		100	
1834		600	
1837		36	
1839		32	
1843	70	95	
1844		194	
1845		200	
1846	189	711	
1847		40	
1850	75	330	
1852		28	
1853	82	262	
1854		100	
1855	60	466	
1856	?		
1860		846	
1861	100	300	
1863		234	
1865		1343	
1866		100	
1869		63	
1870	3	767	
1873	160	97	
1874	28	1457	
1875	2	1430	
1876		322	
1878		261	
1879		8	
1884		3493	
1907		44	
1912	160	100	
1913	191	32	
1914	275		
1915	110	103	
1916	657	82	
1918	149	268	
1923		16	
1926	68		
1928	500	500	
1929	195	350	
1930	98	1300	
1932	50		

Year	Number Stranded	Direct Catch	Bycatch
1934	173		
1935	53		
1936	50		
1937	103	250	
1938	71		
1940	20		
1941	12		
1942	150		
1943	320		
1948	108		
1949	11		
1950	12	36	
1952	3		
1954	4		
1957	105		
1958	170		
1963	46		
1965	2		
1966	2		
1968	23		
1977			
1979	2		
1981	30		
1982	90		
1983	23	59	
1984	120	30	
1985		121	
1986	87	93	
1987		46	
1988		184	

Figure 4.1.1 The distribution of long-finned pilot whales in the North Atlantic and Mediterranean Sea based on sighting data from 1952 to 1992 (from WP-6). The dashed line superimposed demonstrates the area covered by the Iceland, Faroes and Spanish components of the NASS-89 survey, to which the estimate of 778,000 pilot whales given in the text applies. The area north of this boundary was covered during the NASS-87 survey, but resulted in few sightings of pilot whales. An area west of the Iberian peninsula out to 15°W was covered in earlier Spanish surveys with only 2 sightings made outside the 1989 survey boundary.

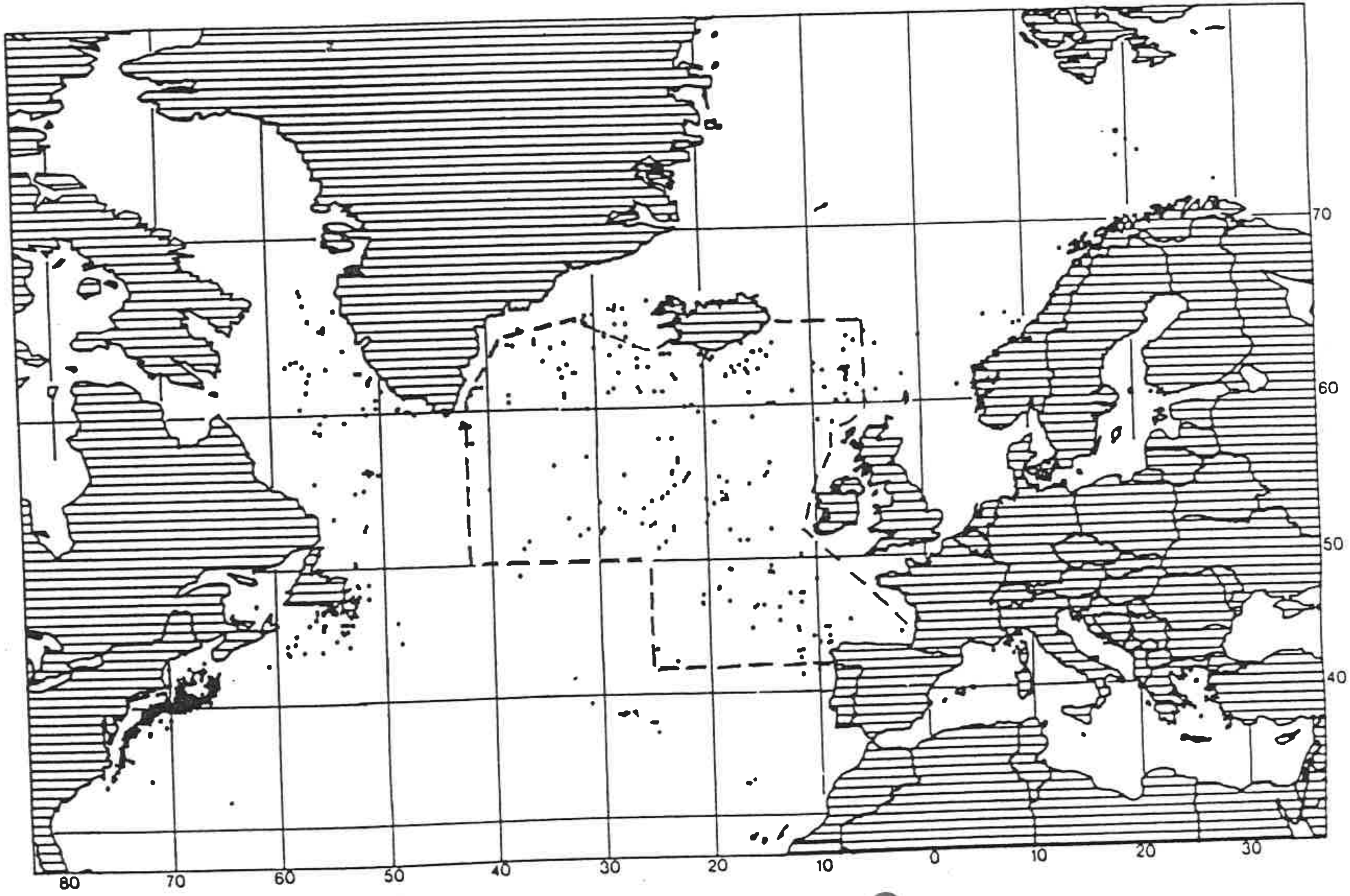


Figure 4.1.2   Survey blocks for NASS-87.

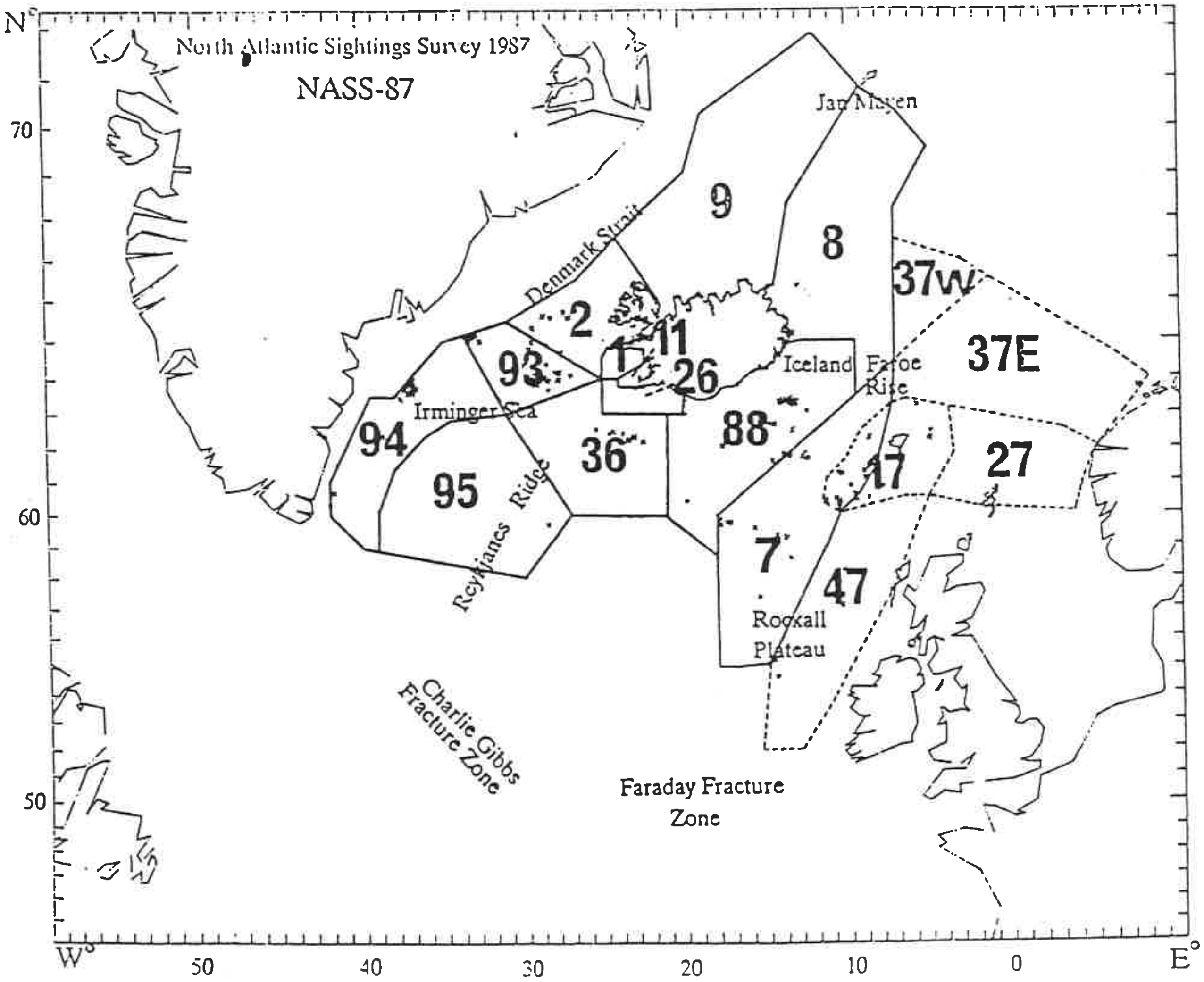


Figure 4.1.3 Survey blocks for NASS-89.

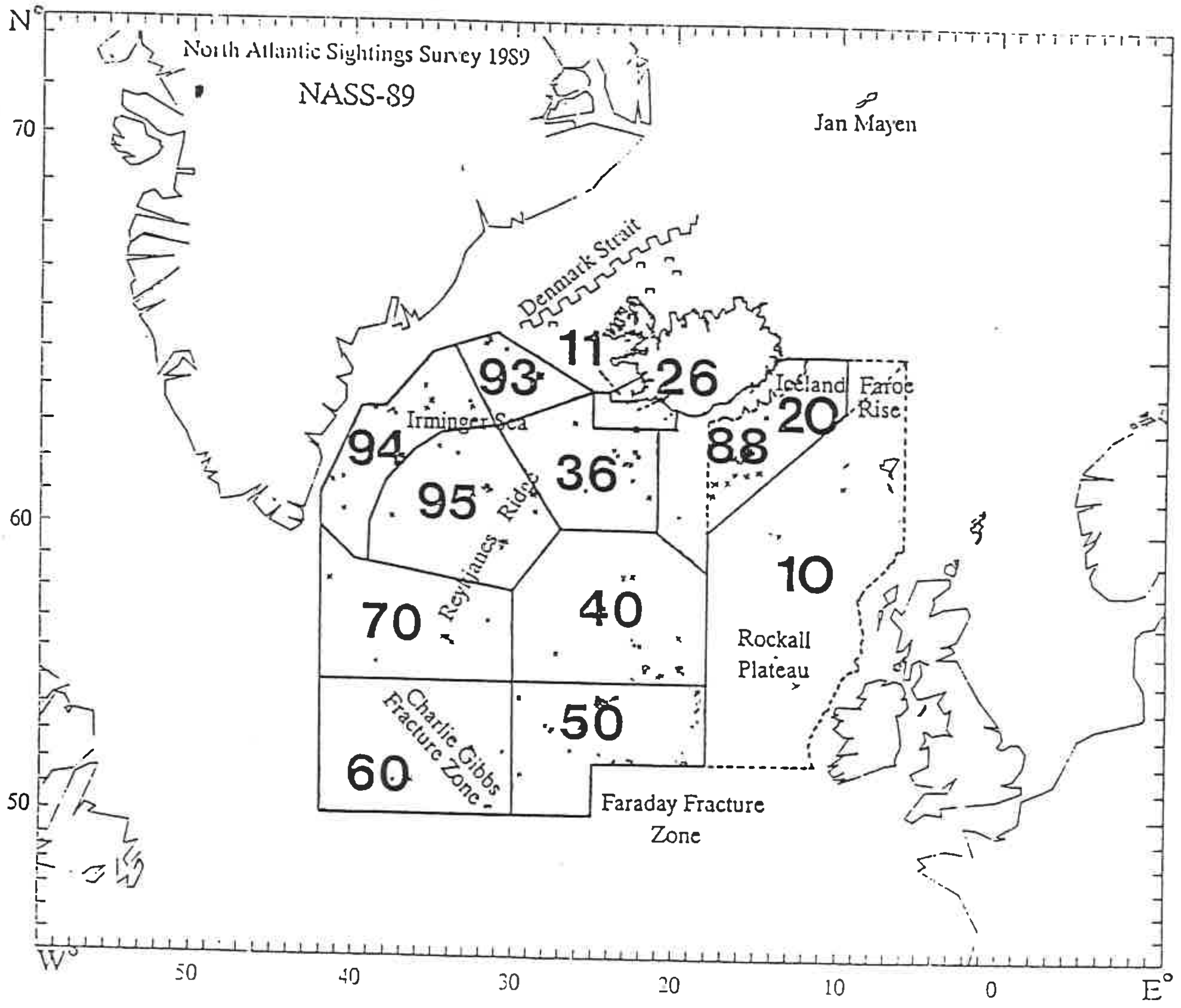
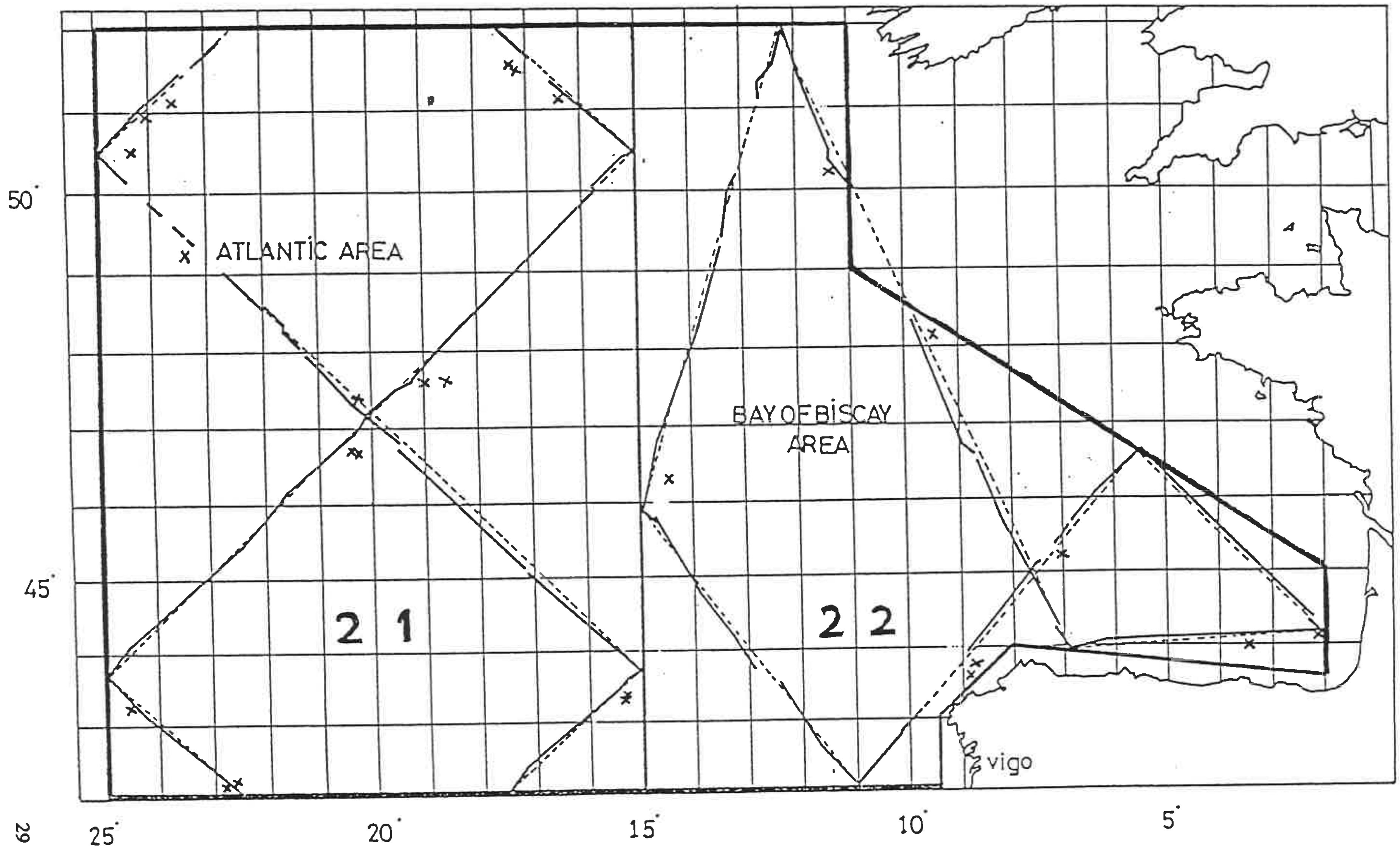


Figure 4.1.4 Survey blocks for the Spanish component NASS-89.



ADDENDUM TO ICES DOC. C.M.1993/N:5

Report of the Study Group on Long-Finned Pilot Whales,
Copenhagen, 30 August - 3 September 1993

Table 7.1 Principal prey species from stomach samples collected in three areas, with indication of relative importance (primary or alternative) and if a fishery for each species occurs in the corresponding area.

Area	Prey species	Relative importance	Fishery
Faroe Islands	*Todarodes sagittatus*	primary	Yes
	Gonatus sp.	alternate	No
	Argentina silus	alternate	Yes
	Micromesistius poutassou	alternate	Yes
	Reinhardtius hippoglossoidas	alternate	Yes
Newfoundland	*Illex illecebrosus*	primary	Yes
	Gadus morhua	alternate	Yes
	Reinhardtius hippoglossoides	alternate	Yes
Mid-Atlantic Bight	*Loligo pealei*	primary	Yes
	Scomber scombrus	primary (?)	Yes

Table 6.3.2 Number of long-finned pilot whales (*Globicephala melas*) taken in the Faroe Islands drive fisheries for all years in which data are available from 1584-1992 (Bloch, pers. comm.)

Year	Whales	Year	Whales	Year	Whales	Year	Whales	Year	Whales	Year	Whales	Year	Whales
1584	4	1723	1,320	1800	53	1838	1,332	1876	986	1917	263	1957	2,083
1588	115	1724	1,063	1801	154	1839	1,614	1877	383	1918	848	1958	2,619
1599	90	1725	1,359	1802	752	1840	2,193	1878	329	1919	153	1959	1,787
1600	24	1726	688	1803	1,063	1841	1,651	1879	2,018	1920	802	1960	1,796
1602	60	1727	835	1804	953	1842	636	1880	615	1921	1,076	1961	1,892
1613	80	1728	236	1805	206	1843	3,142	1881	367	1922	473	1962	1,813
1614	159	1729	1,423	1806	550	1844	2,171	1882	516	1923	1,047	1963	2,204
1615	392	1730	915	1807	367	1845	2,541	1883	135	1925	468	1964	1,364
1616	280	1731	2,188	1808	1,145	1846	1,039	1884	355	1926	348	1965	1,620
1617	120	1732	277	1809	226	1847	2,675	1885	977	1928	480	1966	1,465
1618	230	1733	1,186	1810	429	1848	1,181	1886	702	1929	17	1967	1,973
1619	135	1734	696	1811	510	1849	769	1887	833	1930	266	1968	1,649
1620	291	1735	559	1812	834	1850	502	1888	476	1931	2,386	1969	1,395
1621	1,200	1736	391	1813	281	1851	474	1889	695	1932	1,282	1970	388
1623	32	1737	350	1814	261	1852	2,230	1892	34	1933	958	1971	1,015
1624	180	1738	214	1815	543	1853	1,120	1893	840	1934	178	1972	511
1626	103	1739	313	1816	812	1854	794	1894	498	1935	652	1973	1,050
1628	200	1741	1,460	1817	652	1855	1,369	1895	542	1936	1,633	1974	673
1629	20	1743	622	1818	917	1856	411	1896	128	1937	886	1975	1,086
1630	87	1744	1,017	1819	1,447	1857	328	1897	342	1938	2,095	1976	531
1635	400	1746	100	1820	787	1858	757	1898	1,316	1939	3,362	1977	898
1637	60	1747	647	1821	263	1859	836	1899	2,380	1940	2,853	1978	1,195
1638	56	1748	165	1822	1,641	1860	640	1900	788	1941	4,448	1979	1,673
1664	1,000	1749	212	1823	1,098	1861	343	1902	481	1942	1,930	1980	2,775
1709	1,448	1752	194	1824	442	1862	1,129	1903	204	1943	1,037	1981	2,973
1710	1,430	1754	172	1825	1,935	1863	709	1904	566	1944	1,386	1982	2,652
1711	715	1770	16	1826	714	1864	574	1905	221	1945	1,555	1983	1,689
1712	385	1776	743	1827	711	1865	1,277	1906	410	1946	1,040	1984	1,921
1713	1,090	1781	434	1828	725	1866	1,758	1907	302	1947	1,939	1985	2,580
1714	635	1782	50	1829	556	1867	398	1908	1,793	1948	587	1986	1,677
1715	625	1787	262	1830	1,147	1868	478	1909	734	1949	955	1987	1,451
1716	728	1792	152	1831	695	1869	716	1910	1,324	1950	561	1988	1,690
1717	720	1793	148	1832	391	1870	846	1911	1,650	1951	2,835	1989	1,258
1718	409	1794	288	1833	1,455	1871	782	1912	669	1952	1,243	1990	916
1719	726	1796	545	1834	1,569	1872	2,315	1913	168	1953	2,099	1991	720
1720	803	1797	100	1835	1,338	1873	1,670	1914	291	1954	2,034	1992	1,572
1721	905	1798	91	1836	1,182	1874	652	1915	1,203	1955	895		
1722	317	1799	1,370	1837	1,221	1875	780	1916	397	1956	1,815		