Annex H

Report of the Sub-Committee on the Comprehensive Assessment of North Atlantic Humpback Whales

Members: Hammond (Chair), Allen, Allison, Baba, Baker, Bannister, Berggren, Best, Borchers, Bravington, Brown, Brownell, Butterworth, Carlson, Childerhouse, Cipriano, Clapham, Clark, C., Clark, E., Forde, Friday, Fulford-Gardener, Gillespie, Goodman, Goto, Hakamada, Hatanaka, Haug, Hester, Jann, Joseph, Kimiwada, Kingsley, Komatsu, Larsen, Lawrence, Lens, Lyrholm, Mate, Matsuoka, Mattila, Morishita, Nagahata, Nishiwaki, Ohsumi, Okamura, Øien, Oosthuizen, Palazzo, Palsboll, Pastene, Perrin, Perry, Polacheck, Punt, Read, Reeves, Rennie, Robbins, Robineau, Rogan, Rose, Sakamoto, Shimada, Simmonds, J., Skaug, Smith, Stevick, Taylor, Thiele, Urban, Wade, Walløe, Walters, Witting, Yamamura, Yoshida, Hideyoshi, Zeh.

1. CONVENER'S OPENING REMARKS

Hammond welcomed the participants. He reminded the sub-committee that the aim of a Comprehensive Assessment was to assess the status of a stock (or stocks) and to provide management advice to the Commission by conducting an in-depth and in-breadth review of the available information. He noted that the preparatory work done during the intersessional period, financially supported in part by the Commission, was intended to facilitate the completion of the Comprehensive Assessment at this meeting, although this would not preclude recommendations for future work being made.

2. ELECTION OF CHAIRMAN AND APPOINTMENT OF RAPPORTEURS

At last year's meeting, the Committee had agreed that Hammond would Chair the sub-committee. Clapham and Stevick undertook the duties of rapporteur.

3. ADOPTION OF AGENDA

The adopted agenda is given as Appendix 1.

4. REVIEW OF DOCUMENTS

Documents identified as containing information relevant to the sub-committee included: SC/53/NAH1-26, SC/53/IA21, Reeves *et al.* (2001), Swartz *et al.* (2001), Gabriele *et al.* (2001), Baker and Medrano-Gonzalez (2001), Larsen and Hammond (2000) and Larsen and Bérubé (2000).

5. POPULATION STRUCTURE AND STOCK IDENTITY

The humpback whale is a cosmopolitan species and is found in all oceans, including the North Atlantic. It has been observed in the Mediterranean Sea, but its occurrence there is considered rare or aberrant (Aguilar, 1989). The species is commonly found in coastal or shelf waters throughout its range, although it frequently travels across deep water during migration (Dawbin, 1966; Clapham and Mattila, 1990).

The humpback whale is highly migratory, thus its distribution changes with the seasons. This whale spends spring, summer and autumn on feeding grounds in temperate or high-latitude waters (Mackintosh, 1942; Dawbin, 1966), and there are records of the species above latitude 75° in the Northern Hemisphere (Christensen *et al.*, 1992). In winter, animals migrate to mating and calving grounds in tropical or subtropical waters, where they are generally found associated with islands or offshore reef systems (Mackintosh, 1942; Dawbin, 1966; Whitehead and Moore, 1982; Baker *et al.*, 1986). Many of the major breeding concentrations occur close to latitude 20° in both hemispheres, but the winter range of some whales extends to equatorial waters.

In the western North Atlantic, humpback whales feed in summer from the eastern coast of the United States to West Greenland (Katona and Beard, 1990; Smith *et al.*, 1999). Other feeding grounds occur off Iceland and northern Norway, including off Bear Island and Jan Mayen (Christensen *et al.*, 1992; Palsbøll *et al.*, 1997). Whales from all of these areas have been assumed to mate and calve primarily in the West Indies in winter (Katona and Beard, 1990; Clapham *et al.*, 1993; Palsbøll *et al.*, 1997). Some whales of unknown northern origin migrate to the Cape Verde Islands, where the existing population is considerably smaller than it appears to have been in the 19th century (Reiner *et al.*, 1996, SC/53/NAH18). Humpback whale distribution in the North Atlantic is summarised in Fig. 1.

The largest scientific effort directed at North Atlantic humpback whales was a two-year (1992/93), seven-nation project known as Years of the North Atlantic Humpback (YoNAH). Much of the data for this Comprehensive Assessment derives from this project; this information is summarised in SC/53/NAH1, with additional detail in other papers presented to the meeting. Information on items (e.g. the mating system) not discussed during the meeting is contained in SC/53/NAH3, SC/53/NAH4 and SC/53/O15.

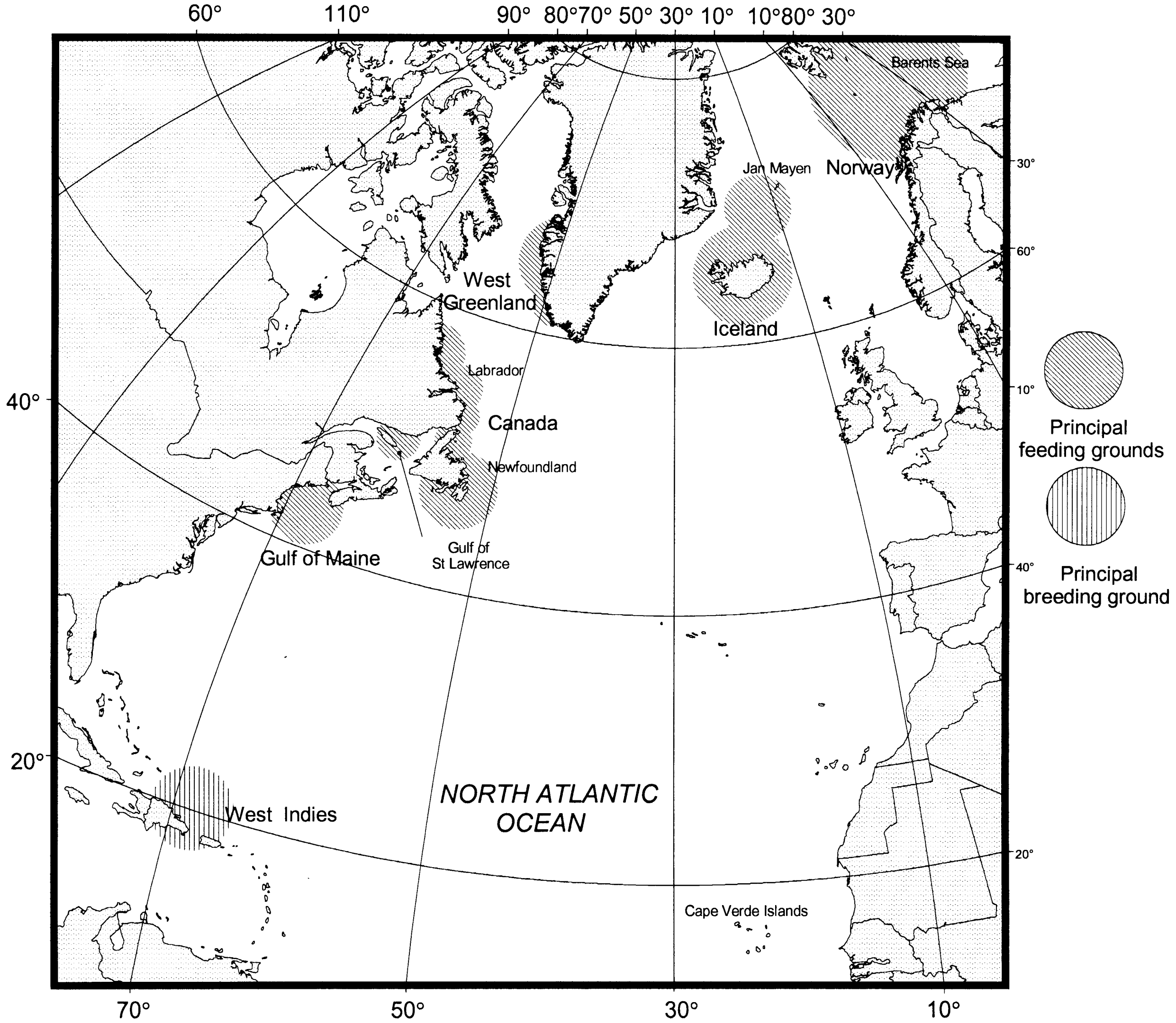

Fig. 1. North Atlantic Ocean showing principal humpback feeding grounds and breeding ground.

5.1 Feeding grounds

SC/53/NAH8 analysed population structure on and among feeding grounds in the North Atlantic using data from YoNAH. The principal known grounds are the Gulf of Maine, the waters off eastern Canada (Gulf of St Lawrence, Newfoundland and Labrador), West Greenland, Iceland and Norway. Photo-identification data indicate that individual whales exhibit high fidelity to specific feeding grounds and that this fidelity is maternally directed; there is little exchange between the major feeding grounds. Rates of movement appear to be a function of distance and are also affected by changes in the availability of food resources. The Gulf of Maine and West Greenland were distinct from other feeding grounds, as was eastern Canada (including Newfoundland and the Gulf of St Lawrence). More movement was detected between Iceland and Norway. In discussion, it was noted that any estimates of exchange rates among areas need to be calculated using a standardised measure that accounts for different levels of abundance in the areas that have been defined.

SC/53/NAH11 presented genetic analyses of mitochondrial DNA (mtDNA) and nuclear loci in samples collected from all known feeding grounds. Low but significant degrees of heterogeneity were observed in the distribution of the variation in mtDNA between all feeding grounds (except Newfoundland/Labrador) as well as between all feeding grounds and the West Indies breeding grounds. In contrast, heterogeneity at nuclear loci was detected only between the central North Atlantic (Iceland and Jan Mayen) and the western North Atlantic feeding grounds as well as the West Indies samples. The same was found for samples collected in the Barents Sea. Humpbacks from the Strait of Belle Isle clearly grouped with those from Newfoundland and Labrador, while the Gulf of St Lawrence showed low but significant differences from other areas of eastern Canada.

SC/53/NAH10 examined stock definition in Gulf of Maine humpback whales, using data on 53 individually identified whales observed in 1998 and 1999 in the previously unstudied Scotian Shelf area. The results gave a match rate of approximately 25% between the Scotian Shelf and the Gulf of Maine, with evidence that many of the matches were transient animals. This suggests that the range of most whales from the Gulf of Maine usually does not extend as far east as the Scotian Shelf or Newfoundland. Comparison of the 1998 sample to the North Atlantic Humpback Whale Catalogue (NAHWC) and to the YoNAH collection found no matches to feeding grounds outside the Gulf of Maine; comparisons of 1999 photographs are incomplete. No inter-year matches were found in the Scotian Shelf sample, suggesting that the abundance of humpback whales there is larger than previously suspected.

SC/53/NAH12 examined Gulf of Maine population structure on the basis of photo-identification data from seven areas across the region. The proportion of animals matching one intensively-studied area (Stellwagen Bank) decreased significantly with distance from that area. However, exchange between areas increased with time. Cluster analysis also suggested that individuals tend to use a few adjacent habitats at a higher frequency than the other areas available to them. Some population structure relating to age, sex and reproductive condition was evident in the data, with males, mature whales and females without calves more likely to be found in the northern (rather than the southern) Gulf of Maine.

SC/53/NAH20 used photo-identification data to examine the origin of humpback whales found in the waters of the US mid-Atlantic states (New Jersey to North Carolina), where humpbacks have appeared with apparently increased frequency in recent years and where a high rate of mortality has been observed. Comparison of photographs from 23 live and 20 dead whales to catalogues from the Gulf of Maine and other areas of the North Atlantic revealed a high number of matches with the Gulf of Maine. Five of the live animals were matched to eastern Canada (Newfoundland and the Gulf of St Lawrence). This, combined with the lack of sampling in Newfoundland after 1993 and variable levels of effort prior to 1992, suggest that these results may under-represent the true presence of Canadian animals in the mid-Atlantic states region. Overall, it is clear that mixing of whales from at least three feeding grounds (the Gulf of Maine, Newfoundland and the Gulf of St Lawrence) occurs in the mid-Atlantic states region, which may represent a supplemental winter feeding ground for some whales.

SC/53/NAH21 reviewed the distribution of humpback whales in the Barents and Norwegian Seas using sightings data from a variety of sources. These data show that humpbacks are widely distributed in the region, with major concentrations occurring around Bear Island and Hopen Island. The primary distribution appeared to shift from the Norwegian Sea in the late 1980s to the Bear Island region in the mid-1990s; this may have been related to the distribution of capelin.

SC/53/NAH26 summarised records of humpback whales in Irish waters. Overall, there have been few sightings of this species in the region; there were catches of only six humpback whales off the Irish coast (between 1908 and 1914), and recent surveys for cetaceans or seabirds have seen very few whales. In discussion, it was noted that 70 humpback whales were killed off the coast of Scotland between 1903 and 1929; it is not known whether this relatively small number of takes reflected earlier depletion of the stock elsewhere, or unsuitability of the British Isles region as humpback whale habitat.

5.2 Migration

SC/53/NAH13 used photo-identification data from the YoNAH project to examine migration in North Atlantic humpback whales. Results indicated that all of the known feeding grounds were represented in the West Indies in proportion to feeding ground sample sizes. Humpbacks from the Gulf of Maine and eastern Canada were sighted in the West Indies significantly earlier in the winter than those from West Greenland, Iceland and Norway. Males were observed earlier than females on the breeding grounds; this pattern was observed for animals from all feeding grounds. Data in SC/53/NAH3 indicated that dates of sighting of individually identified females observed in two consecutive years (1992 and 1993) in the West Indies were correlated; this correlation between dates of observation was not found in males. Overall, the data suggest that most females do indeed migrate; contradictory data suggesting that many females in the Southern Hemisphere do not migrate each year (Brown *et al.*, 1995) may reflect an inter-population difference.

Another paper from the YoNAH study (SC/53/NAH20) examined the age composition of Gulf of Maine whales observed in the West Indies, and found that these whales were significantly older than the overall Gulf of Maine population, with two and three year-olds under-represented in the West Indies. Winter sightings of young animals off the USA mid-Atlantic states (SC/53/NAH20) may be evidence of over-wintering by juveniles, but the residency periods of the whales in question are unknown.

Charif *et al.* (2001) summarised the results of acoustic monitoring conducted in deep-water areas off the British Isles. Twelve monitoring areas encompassed the region from the Shetland and Faeroe Islands southwest through offshore waters west of Ireland, and south to a region west of the Bay of Biscay. Singing humpbacks were consistently detected between November and March in all but the southeasternmost region (west of Biscay). From the earliest autumn detections through February in both years, groups of singing humpbacks were tracked travelling on generally southwesterly courses. Movement patterns exhibited a southwesterly trend over the course of the winter, but with no corresponding northward trend later in the season. There were no confirmed humpback detections in July, August or September, and very few in June; this was not surprising in view of the infrequency with which singing occurs at this time, and the fact that humpbacks were likely to be feeding in shallower shelf water where they would not be detected by the methods employed in the study. A review of historical data from this area, together with the present results, suggests that the offshore waters of the British Isles represent a migratory pathway for humpbacks, at least some of which originate in Norwegian (and possibly eastern Icelandic) waters. The migratory destination of the detected animals remains unknown, but the limited movement data suggest that these whales were bound primarily for the West Indies rather than the Cape Verde Islands.

C. Clark reported additional unpublished information from the same acoustic monitoring programme. An additional group of song detections is located off northwestern Norway in early autumn, moves towards the east coast of Iceland through autumn, then moves in a counter-clockwise direction into the southern portion of the Norwegian Sea, where it remains during the winter. The daily number of singers detected in this area is comparable to that recorded in the eastern Caribbean, and exceeds those reported by Charif *et al.* (2001) off the British Isles. Clark reported that the Norwegian Sea group of singers appears to be spatially distinct from the group that apparently migrates off the British Isles. It is not known whether the animals that overwinter and sing in the Norwegian Sea constitute a breeding population. Nineteenth century catches of humpback whales off Norway in winter, including pregnant females with near-term foetuses (Ingebrigtsen, 1929) are consistent with this hypothesis but do not provide positive evidence of a breeding population in this region.

5.3 Breeding grounds

5.3.1 West Indies

SC/53/NAH11 summarised genetic analyses of population structure in North Atlantic humpback whales, primarily using a large sample set obtained by the YoNAH project.

Mitochondrial and nuclear DNA were analysed from 3,276 samples. There was clear evidence for the existence of at least two breeding stocks in the North Atlantic, with western North Atlantic whales migrating primarily to the West Indies, and Barents Sea whales mainly breeding in one or more other unknown locations. The humpback whales that feed in the central North Atlantic come from more than one breeding stock, one of which is known to be the West Indies.

Thus the original hypothesis that North Atlantic humpbacks constitute a single panmictic population was rejected by the analysis. The locations of the breeding ground(s) other than the West Indies are unknown; one obvious possibility from historical and contemporary data is the Cape Verde Islands, but there are currently no data with which to test this.

Reeves *et al.* (2001) used data from 19th century American whaling logbooks to examine the historical distribution of humpback whales in the West Indies, notably the eastern and southern Caribbean. Data were extracted from 19h century American whaling logbooks and journals covering 48 voyages by 29 vessels to the West Indies from 1823-1889. Humpback whale records in these documents came from a geographical area that encompassed Haiti to southern Trinidad, the Gulf of Paria and the coast of Venezuela. Of 807 records in which whales were mentioned (as sightings, strikes or catches), the largest number was from the Windward Islands and Venezuela, especially St Vincent and the Grenadines, Guadeloupe, Dominica/Martinique/St Lucia and Venezuela. However, the data should be regarded only as approximate indicators of the relative abundance of whales since the effort involved cannot be meaningfully quantified. Similarly, effort-uncorrected data suggest that the peak months for humpback whales in the Windward Islands were February, March and April. Few sightings were recorded off the Dominican Republic after March, but this may reflect a lack of effort there in April and May. However, humpbacks apparently were abundant in the Windward Islands in April and even May, which is not the case in the major present-day wintering areas off Hispaniola.

With one notable exception, there is little evidence in the logbooks and journals that humpbacks were taken on a more than opportunistic basis in waters off Hispaniola, where the major aggregations are found today. The reason for this is not clear, but it is possible that the present situation reflects a major shift in distribution within the breeding range (Clapham and Hatch, 2000).

The whaling logbook data did not address the possibility that humpback whales from the Southern Hemisphere cross the equator and enter the southern Caribbean. It is assumed that any such movements today do not occur in the boreal winter, but the possibility that some overlap (and thus inter-hemispheric mixing) occurs at the extremes of the seasons cannot be excluded.

Swartz *et al.* (2001) summarised results of a visual and acoustic survey of the eastern and southern Caribbean in February and March 2000. Despite considerable effort, relatively few humpbacks were detected. This result stands in sharp contrast to the situation in this area in the 19th century as summarised in Reeves *et al.* (2001). Only a few humpback whales were photo-identified on this cruise; no matches were made to either the NAHWC or the YoNAH collection. Thus, the only high-latitude feeding ground match recorded to date from the southeastern Caribbean is one from Grenada to Greenland (Stevick *et al.*, 1999), although another match between Dominica and Puerto Rico indicates some exchange with the major breeding grounds in the northern West Indies. While it seems unlikely that humpback whales from the eastern and southern Caribbean are part of a breeding population that is separate from animals observed in the northern West Indies, further data are required to confirm this.

Another survey from the eastern Bahamas to the Virgin Islands (SC/53/NAH17) in February/March 2001 generally confirmed existing knowledge about the occurrence and distribution of whales in this region.

5.3.2 Cape Verde Islands

An historical study based upon whaling logbooks (SC/53/NAH18) examined the occurrence of humpback whales in the Cape Verde Islands. Data came from 23 logbooks covering the period 1826-1902. There were 396 records of an estimated 1,105 humpback whales (catches, strikes and sightings). The largest numbers of whales were from the islands of Sal, Sao Vicente and Sao Nicolau; peak occurrence appears to have been March, with many records from February and April. A crude analysis of encounter rates from the logbook data suggested that humpback whale density in the Cape Verde Islands was comparable to that in the major 19th century West Indies whaling grounds (Reeves *et al.*, 2001).

Observations of humpback whales in the Cape Verde Islands in the winters of 1999-2001 (SC/53/NAH19) included mothers with calves, singers and competitive groups. Photographs of 26 individual humpback whales recorded by this study have been compared to both the NAHWC and the YoNAH collection, with no matches made. The significance of this lack of matches is unclear.

5.4 Summary of information on population structure

Photo-identification and genetic data strongly suggest that population structure in North Atlantic humpback whales is characterised by relatively discrete feeding sub-stocks, with strong fidelity to specific feeding grounds by individual whales and low rates of exchange among them. Strong site fidelity also influences movement patterns within feeding grounds; the extent of intra-area movement also declines with distance.

The only other breeding ground known from historical and contemporary data is the Cape Verde Islands, but to date there is no direct evidence to support the idea that this is a breeding ground used by central and eastern North Atlantic animals. That there is a separate breeding population in the Norwegian Sea (as suggested by Ingebritsen, 1929, and the results presented by C. Clark under Item 5.2) raises the possibility that there are three separate breeding grounds in the North Atlantic. Sightings of (presumably Southern Hemisphere) humpback whales off western Africa as late as November (Larsen and Bérubé, 2000) may mean that there is some mixing of whales from the North and South Atlantic, but this possibility cannot be evaluated with existing data.

6. CATCHES AND INCIDENTAL TAKES

6.1 Commercial catches

A review of catches by Mitchell and Reeves (1983) focussed largely on the western North Atlantic. SC/53/NAH15 attempted to provide a more comprehensive overview of humpback takes from all known fisheries in this ocean, with an emphasis on defining and delineating fisheries, describing the nature of data sources and identifying gaps in coverage. Supplemental information about sources, estimation methods and underlying assumptions was given by Smith. SC/53/NAH15 included estimates of minimum catches from the Cape Verde Islands (SC/53/NAH18), where the peak of whaling appears to have been in the 1850s to 1860s; perhaps 1,000-1,200 removals can be documented for the Cape Verde Islands from whaling logbook data and supplemental sources, most of these occurring during the peak period in mid-century.

Thirteen ‘fisheries’ were defined in SC/53/NAH15 based largely on whaling methods (e.g. non-mechanised, transitional or mechanised, and pelagic versus shore-based), nationalities of the whalers and areas of operations. Three of these fisheries were sub-divided into a total of 20 regional ‘sub-fisheries’. For each fishery and sub-fishery, the authors noted total years of activity, approximate cumulative numbers of humpbacks taken and whether humpbacks were or were not among the principal target species. Data were incorporated from a variety of sources, most notably the IWC catch database and Mitchell and Reeves (1983). For all western and central North Atlantic fisheries, the methods used by Mitchell and Reeves (1983) to estimate removals post-1850 were noted and evaluated. Catch data were considered reasonably complete for eight of the 11 sub-fisheries of the Norwegian mechanised shore fishery. The North Norway, Iceland and Faeroes sub-fisheries included large catches of whales unspecified to species in the late 19th and early 20th centuries, and there is reason to believe that these could represent hundreds, or thousands in the case of Iceland, of humpbacks in addition to those specified in the catch statistics. In discussion, it was pointed out that a major portion of the North Norway catch took place in winter months (February to March; Ingebrigtsen, 1929).

Other fisheries that took large numbers of humpback whales, but with large amounts of uncertainty associated with the catch history, are the Canada non-mechanised/transitional pelagic fishery based on the Gaspe Peninsula during the 19th century, the West Indies non-mechanised shore fisheries during the late 19th and early 20th centuries and the American non-mechanised/transitional pelagic fishery centred in the Cape Verde Islands and West Indies during the 19th century. In addition to these, the Cape Verdes non-mechanised shore fishery is of particular relevance because it is known to have continued for at least several decades after the collapse of the American pelagic fishery for humpbacks in that area (Hazevoet and Wenzel, 2000).

SC/53/NAH15 identified several sources of data that merit further examination to improve the catch history, including the daily journals of West Greenland shore stations during the late 18th and 19th centuries, British colonial records for Bermuda and possibly one or more islands in the West Indies, and Portuguese archival and other records on Cape Verdes shore whaling. It was also emphasised that a detailed account of Sigurjónsson’s (1988) method of estimating 2,800 humpbacks taken at Iceland prior to 1915 would be useful.

The sub-committee expressed its thanks to Reeves and Smith for the considerable amount of work invested in the production of the catch information.

Questions were raised regarding allocation of sex composition to the 19th century catch data from the Cape Verde Islands and West Indies. An *ad hoc* Working Group was established to examine data from ‘clean’ logbooks, i.e. those for which catch or strike information was almost always accompanied by a comment. Results were similar for the two grounds; the combined sample of catches (142) showed that 18% consisted of mothers, 10% were calves and 72% were unspecified whales. The combined proportion of 28% for mothers and calves should be regarded as a minimum value since it is likely that the ‘unspecified’ category included some cows and calves which were not identified as such in the logbooks. The sub-committee requested that these data might be used to generate an alternative estimate of composition to that derived from Price (1985) and applied to non-mechanised shore-based catches in the breeding grounds. There is reason to believe that the Yankee ship-based whalers were much more mobile than the shore-based whalers and therefore encountered a more representative sample of the humpback whale population. Thus, the catches by the Yankee whalers may well have included a larger proportion of non-calf males than those of the shore-based whalers. The sex ratio of the unspecified portion of the catches could be allocated using information from the YoNAH project in the West Indies.

Another need identified in discussion was for a way to allocate estimated breeding ground catches by the American whalers between the West Indies and Cape Verde Islands. Reeves tallied the voyages identified by Mitchell and Reeves (1983) as humpbacking in the West Indies from 1850-87 and the voyages identified in SC/53/NAH18 as humpbacking in the Cape Verde Islands during the same period. The resulting data suggest that the two fisheries developed more or less in parallel, both peaking between about 1865-70. Prior to 1867 more voyages appear to have been made to the Cape Verde Islands than the West Indies, while after 1867 the vast majority of humpbacking voyages in the North Atlantic were to the West Indies. Even though these data suffer from a variety of essentially intractable biases, they can be considered to provide a reasonable basis for allocating catches between the two breeding grounds over this roughly 40-year period.

Appendix 2 gives further details of the methods used to allocate catches and shows the total estimated landings by fishery, and the total estimated removals from feeding and breeding grounds calculated using agreed struck and lost rates.

6.2 Aboriginal catches

Aboriginal catches from locations in the North Atlantic are included in the catch series summarised in SC/53/NAH15. The sub-committee agreed to complete the catch series through 2000 using reports filed with the Commission by St Vincent and the Grenadines.

6.3 Incidental takes

Information on incidental takes of humpback whales is available on a continuous basis only from the Gulf of Maine, and from Newfoundland in earlier years. At least 94 entanglement mortalities occurred in Newfoundland and Labrador between 1979 and 1990 (Lien, 1994). A further 19 fishery-related mortalities were recorded between 1969 and 1977 (Perkins and Beamish, 1979). Both figures should be considered minima since not all deaths will have been reported. Although this mortality was high, by 1990 it was reduced to approximately 15% of entanglements by a whale release programme operated by Memorial University. Furthermore, since most of the entanglements occurred in groundfish gear (notably inshore cod traps), the closure of this fishery in 1992 has presumably resulted in a major decrease in humpback whale mortality.

The sub-committee noted that incidental mortality (from both entanglement and ship strikes) is theoretically taken account of in the survival estimates for the Gulf of Maine (SC/53/NAH10). The sub-committee agreed that known entanglement mortalities from Newfoundland/Labrador should be included (as minimum values) in the assessment. Mortalities for the two years (1991 and 1992) for which there are no data would be included as the average of the series from 1979-1990.

7. ABUNDANCE AND TRENDS

7.1 Methodological issues

The results of a double-marking experiment were presented in SC/53/NAH5, in which natural markings and microsatellite genetic markers were used to identify individual whales. The results confirmed that natural markings are a reliable means of identifying humpback whales on a large scale. The error rates identified in individual photo-identification were stratified by image quality. A modification to the two-sample Petersen estimator to account for errors in identification was presented. This correction reduces the bias in estimates made using poorer quality photographs to a negligible level.

SC/53/NAH14 examined potential biases in Petersen estimates of abundance using an individual-based model which simulated the sample probabilities of individual whales under different assumptions about behaviour and population dynamics. These results demonstrate that the inverse-variance weighted Petersen estimate presented in Smith *et al.* (1999) was likely negatively biased due to a correlation between the weighting and the magnitude of the estimated abundance. Estimates based only on feeding ground data are negatively biased because of spatial heterogeneity among feeding regions. Estimates which include data from both years are positively biased because they violate the assumption of a closed population, however the magnitude of this bias is small given the likely mortality and increase rates. The magnitude of the positive bias due to an open population is comparable in both the pooled estimate proposed by SC/53/NAH2 and the mean of four breeding-feeding estimates from Smith *et al.* (1999). When a second, unsampled breeding ground is modelled as being populated by a portion of the Iceland and Norway feeding grounds, the ocean-basin estimates are negatively biased. However, when abundance is estimated without samples from the Iceland and Norway feeding grounds, the result is an unbiased estimate of the West Indies breeding ground. When the density of whales in the West Indies breeding ground was modelled according to the density described in Whitehead (1982), and female arrival date was the same in both years but male arrival date was not, estimates based only on breeding ground data are negatively biased. This bias increases as the length of female occupancy decreases and as the difference between the length of female and male occupancy increases. As expected, individual heterogeneity negatively biased all abundance estimates.

A query was made regarding the effect on abundance estimation of animals not migrating. The author indicated that this was only an issue where both samples were from the breeding grounds.

7.2 Feeding ground estimates

7.2.1 Gulf of Maine

A mark-recapture abundance estimate for the Gulf of Maine of 652 (CV = 0.29) was presented based upon YoNAH sampling cruises in 1992 and 1993 (SC/53/NAH10). This estimate may be biased by heterogeneity in animal distribution patterns and in sampling effort. Minimum numbers of individually identified animals known to be alive were presented for 1992 (501 whales) and 1997 (497 whales).

Line transect estimates for the Gulf of Maine were presented based upon shipboard and aerial surveys conducted in 1999. These yielded estimates of 816 (CV = 0.45), or 902 (CV = 0.41) including areas of the Scotia Shelf. It was pointed out that while the shipboard estimates account for $g(0)$, the estimates of $g(0)$ did not account for dive time heterogeneity and estimates may thus remain negatively biased. Aerial surveys did not account for $g(0)$ and are thus negatively biased, perhaps significantly so.

Ignoring the biases identified above, the sub-committee noted that the estimates using the different methods were consistent with one another given the seven year difference in dates and the rate of increase presented in the paper.

7.2.2 Canada

SC/53/NAH1 presented a mark-recapture estimate using YoNAH data for eastern Canadian waters of 1,807 (CV = 0.053). Sampling within eastern Canada was highly variable spatially, however, and this estimate is likely to be seriously negatively biased. Attempts to overcome this problem by stratifying the data into three regions within which effort was more consistent resulted in an estimate of 2,509 (CV = 0.077). This estimate does not account for movement of individuals between strata, and almost certainly still suffers from significant negative bias due to spatial heterogeneity in sampling.

7.2.3 West Greenland

Mark-recapture estimates of abundance for West Greenland from 1988-1993 ranged from 362-615 (Larsen and Hammond, 2000). The estimate from 1990-1991 was anomalously large and was based upon less representative geographic sampling coverage. An inverse-CV^2 weighted mean of the remaining four estimates was 385 (SE = 24).

The concern was raised that some segregation of mothers with calves may occur in the feeding grounds and that this behavioural heterogeneity could potentially bias abundance estimates. Specifically, it was suggested that the frequency of observations of calves in Greenland was low, and could indicate that some such areas were not being sampled. Larsen indicated that there was no evidence for areas of humpback whale concentrations in the West Greenland region that were not sampled.

A preliminary analysis of data from humpback whale sightings made during aerial surveys for minke whales in July/August 1993 was presented in SC/53/NAH23. Line-transect analysis of the humpback whale observations gave a preliminary estimate for West Greenland of 599 (CV = 0.50) surface visible humpback whales.

The sub-committee noted concerns about the survey and its results. These included, firstly, that neither component of visibility bias had been corrected for (or even estimated) and that therefore the estimate could be expected to be negatively biased; the authors had noted this. This concern was exacerbated by an apparent loss of visibility, evidenced by a lack of recorded sightings, close to the trackline. Secondly, the survey had been intended as a cue-counting survey, not a line-transect survey, and it had targeted species other than humpback whales. Thirdly, its estimated CV was large. The sub-committee agreed with the author that, as the analysis was preliminary, the results should not be used as an estimate of abundance at this time.

7.2.4 Iceland

Data from shipboard line-transect surveys from Iceland conducted during 1995 (SC/53/NAH24) were analysed to give an estimate of humpback whale abundance of 14,600 (95% CI = 5,100-41,500). A number of issues were raised concerning this estimate. It is highly imprecise and appears implausible given earlier estimates for this region and for the North Atlantic overall. The majority of sightings were derived from a small number of transects in a sparsely sampled block. Additionally, two vessels covered the area and the large estimate could have resulted from the same large group being recorded by both vessels. It was noted also that the confidence limits were estimated in a manner not appropriate for estimates of low precision and that the distribution of search effort was not optimised for humpbacks.

The sub-committee concluded that while this survey indicates the presence of a substantial number of humpback whales in the Iceland region, the presented estimate and the associated confidence intervals should not be considered to represent abundance in the area and should not be used in the assessment. The author was encouraged to consider further analysis, including post-stratification of the data.

7.2.5 Norway

Estimates of humpback whale abundance from extensive line transect surveys conducted principally for minke whales in the Norwegian and Barents Seas were presented in SC/53/NAH21. In addition to previously published estimates of 1,126 (CV = 0.31) for 1988 and 689 (CV = 0.59) for 1989, a new abundance estimate of 889 (CV = 0.32) for 1995 was presented. The estimate covered the same area as was surveyed in 1989, but was slightly different from that surveyed in 1988. There was no spatial overlap between these surveys and the survey presented in SC/53/NAH24.

It was noted that $g(0)$ was not estimated for humpback whales on these surveys, and that the estimates were therefore likely to be negatively biased but not as much as for aerial surveys.

A summary of mark-recapture estimates reviewed by the sub-committee and their potential biases is given in Appendix 3.

7.3 Breeding ground/ocean basin estimates

SC/53/NAH2 provided abundance estimates for the North Atlantic from 1979-1993, based on several methodological improvements. These included application of the error rate correction presented in SC/53/NAH5 and sample pooling. Pooling of samples increases precision and is not subject to the bias resulting from inverse-variance weighting. All estimates were based upon two (pooled) feeding ground samples and two (pooled) breeding ground samples. The estimates presented were larger and more precise than those previously published. The ocean-basin abundance in 1992-1993 was estimated at 11,570 (CV = 0.069). For Petersen two-sample mark-recapture abundance estimates to be unbiased, only one sample is required to be representative with respect to any potential source of bias. Thus if sampling on the feeding grounds had been completely representative with respect to breeding ground origin, the estimate using (1) data from all feeding grounds; and (2) the West Indies breeding ground would have been an unbiased estimate of the whole ocean basin, even though the second breeding ground had not been sampled. However, sampling in the feeding grounds was not representative so this estimate of 11,570 is a negatively biased estimate of the whole ocean basin.

A series of estimates was calculated for 1979-1993 which excluded samples collected off Iceland and Norway and so represents the West Indies breeding population. Because sampling on the West Indies breeding grounds appears to have been representative with respect to feeding ground origin, there should be no bias in these estimates of the West Indies breeding population due to whales from Iceland and Norway not being sampled in the feeding grounds. Note, however, that there is (positive) bias in this estimate of the West Indies breeding population if some animals from another breeding ground migrate to the western North Atlantic. A total of 24 estimates was calculated for the West Indies breeding population spanning 14 years. Estimates ranged from 6,920-12,580 with CVs from 0.070-0.039.

There was considerable discussion of the possible biases resulting from different combinations of data from feeding and breeding grounds included in the estimates, differences in animal distribution, and timing of presence in the breeding ground. Appendix 4 shows the distribution of photographic samples by sampling area and date (year and additionally week within year for the West Indies). This confirms that West Indies data are representative with the exception of 1988/89 to 1990/91, for which sampling was temporally limited and therefore unrepresentative. The sub-committee concluded that the series of estimates for the West Indies breeding stock should be used in the assessment with the exception of the four estimates utilising breeding ground samples for 1988/89 to 1990/91.

There was also discussion of whether animals over-wintering in the feeding grounds and variability in this pattern by sex could potentially bias abundance estimates. It was noted that records of animals wintering in high latitudes were uncommon in the North Atlantic and that within the Gulf of Maine there was no observed sex bias in winter sightings. Additionally, it was noted that using feeding-breeding estimators, sex bias would not influence abundance estimates unless there was also a sampling bias related to sex in high latitudes.

Some line-transect surveys for years prior to 1979 were examined, the spatial coverage of which was principally in the West Indies. These were found not to be comparable with the mark-recapture estimates and the sub-committee concluded that these should not be considered in the assessment.

7.4 Trends in abundance

SC/53/NAH2 presented an estimate of trends in abundance from 1979-1993 based upon the series of abundance estimates presented in Item 7.3 above. The average rate over this period was 0.031 (SE = 0.005).

A question was raised concerning whether each of the separate areas sampled in the West Indies could be regarded as representative, such that estimates of abundance based upon data from feeding grounds together with those from a limited area of the breeding grounds would be reliable. This was addressed by calculating separate estimates of abundance for 1992-93 (the YoNAH years), using the feeding grounds sample and each of the four surveyed breeding habitats (Puerto Rico, Navidad Bank, Samana Bay and Silver Bank). The resulting four estimates were reasonably consistent (see Appendix 4), suggesting that limited-area estimates in other years are reliable.

Another question was raised regarding pooling of samples from consecutive years in both feeding and breeding grounds, and whether this introduced serial correlation. Covariance in pooled estimates presented in Smith *et al.*

(1999) was found to be not significantly different from zero, but it is probable that the variance of the trend derived from the estimates in SC/53/NAH2 is negatively biased. This may not be important in the assessment model because it does not estimate variance of the output parameters. However, to assess the degree of this problem it was agreed to run the assessment using the entire series of abundance estimates, and additionally using alternate estimates (to ensure independence); if no significant difference is apparent in the results, the entire series would be used.

The sub-committee agreed to accept the trends estimated in SC/53/NAH2, which excluded the four estimates spanning 1988/89 to 1990/91, as discussed under Item 7.3.

8. BIOLOGICAL PARAMETERS

8.1 Age at sexual maturity

Average age at attainment of sexual maturity (ASM; or more accurately, age at first birth minus one year) has been estimated only for the Gulf of Maine population. Clapham (1992) estimated ASM at five years for the period 1979 through 1991. This estimate was derived from resightings of females of known age (i.e. those first observed as calves). Because these females were resighted every year from birth to first parturition and all females in the sample had calved by the end of the study period, the estimate is unlikely to be biased by precocious animals. An alternative estimate of ASM derived from the same data set through an interbirth interval model gave a similar result (Barlow and Clapham, 1997). An updated analysis of ASM from 1979 through 1999 showed no change in this parameter (Robbins, unpublished data); however, the result was heavily weighted towards in the period analysed by Clapham (1992), with only a small sample of animals from later years. The substantially less complete resighting histories available from the 1990s would make it difficult to reliably detect a recent change in this parameter.

8.2 and 8.3 Fecundity and survival

In SC/53/NAH10, the growth rate for the Gulf of Maine population was estimated using an interbirth interval model using data from 1992-2000. The estimate was either 1.00 (using a calf survival rate of 0.51) or 1.04 (using a calf survival rate of 0.875). Although confidence limits were not available (because maturation parameters could not be estimated), both estimates of population growth rate are outside the 95% confidence intervals of the previous estimate of 1.065 for the period 1979-1991 (Barlow and Clapham, 1997). Most of the difference appears to be the result of a reduction in calf survival rates between 1992 and 1995; however, reduced adult female survival and increased interbirth intervals may also have contributed.

The possibility that the apparent reduction in calf survival was related to a shift in distribution cannot be rejected; indeed, such a shift occurred during exactly the period (1992-95) in which estimates of survival rates declined. It is possible that this shift resulted in calves born in those years imprinting on (and thus subsequently returning to) areas other than those in which intensive sampling occurs. If the apparent decline was in part real, it may be related to known high mortality among young-of-the-year whales in the waters of the USA mid-Atlantic states (SC/53/NAH20). However, calf survival appears to have increased since 1996, presumably accompanied by an increase in population growth. It was noted that the 4% estimate of growth rate was consistent with growth implied by the two Gulf of Maine abundance estimates for 1992 and 1999, presented elsewhere in SC/53/NAH10.

A survival estimate for the Gulf of Maine of 0.96 (SE = 0.008) was available to the sub-committee (Barlow and Clapham, 1997).

8.4 Comparison to other populations

Estimates of first-year humpback whale calf mortality in the eastern and central North Pacific were given by Gabriele *et al.* (2001), who used photo-identification data to examine apparent loss of calves to mature females observed in both the Hawaiian breeding grounds and feeding grounds in southeast Alaska. The best estimate was 18.2% (95% CI = 2.3-51.8%); this ignored late-season sightings, to exclude cases of early weaning.

9. ENVIRONMENTAL CONCERNS

A variety of environmental issues potentially affecting humpback whales was discussed. Robbins summarised a study of 19 chlorinated organic compounds in humpback whales and sand lance off the northeastern coast of the USA (Lake *et al.*, 2001). As found in previous studies, contaminant burdens were significantly higher in male humpbacks than in females. Samples collected from humpback whales in the Gulf of St Lawrence showed similar contaminant levels in most of the studied compounds.

Coastal development and the attendant increase in runoff, pollution, tourism, boat traffic and other factors was discussed as a potential threat to humpback whale habitats, especially in nearshore waters. Areas of particular concern were identified as the breeding grounds in the Caribbean and the Cape Verde Islands, as well as the southern Gulf of Maine which is preferentially used by mothers with calves (SC/53/NAH12). High levels of noise from oil and gas operations in the Gulf of Paria were detected by the acoustic survey summarised in Swartz *et al.* (2001); the absence of humpback whales from this region contrasts sharply with data from American whaling logbooks which, Reeves noted, show significant numbers of animals in this area in the 19th century (Reeves *et al.*, 2001). Whether the current paucity of humpback whales in the Gulf of Paria reflects abandonment of this habitat because of the noise there is unknown, but this issue represents a concern.

SC/53/NAH25 described a study of humpback whale entanglement in the Gulf of Maine. Caudal peduncle photographs of 261 free-ranging whales were blind coded to reflect the presence or absence of wrapping scars, notches and other injuries believed to be entanglement-related. These assumptions were successfully tested against whales with documented entanglements during the study period. Between 48% and 65% of each annually collected sample exhibited scarring that was likely to have resulted from a prior entanglement. Males were more likely than females to exhibit entanglement-related scars. Yearlings exhibited the highest rate of entanglement, although whales continued to become entangled when mature. Calves had a significantly lower rate of entanglement than all other age classes. As a group, females exhibiting evidence of a prior entanglement produced significantly fewer calves during the study period than did females with no evidence of a prior entanglement. Thirty-one percent of the animals sampled in 1997 and re-sampled in 1999 acquired entanglement-related scars between events, while severe entanglement-related injuries were detected at an average rate of 1-2%.

10. ASSESSMENT

10.1 Specification of assessment

SC/53/NAH16 provided a framework for the assessment of North Atlantic humpback whales. The underlying population dynamics model for this framework is density-dependent as well as age- and sex-structured. It allows for up to two breeding stocks and multiple discrete feeding sub-stocks (see Item 5). The model is fitted to data on absolute abundance, trends in relative abundance, rates of increase and information about the proportions of animals in each feeding sub-stock from each breeding stock (including details of catches of males, females and calves). The model does not include depensation. Given the uncertainty in various aspects of the input to the assessment model, the sub-committee agreed that there should be tests of the sensitivity of model output to a range of values in some input data. These, and general considerations regarding values to be used, are discussed below.

10.1.1 Breeding stocks and feeding sub-stocks

It was agreed that because there are at least two breeding stocks in the North Atlantic (see Item 5.3), the assessment should include two breeding stocks (the maximum number that can be accommodated by the assessment model). One clearly overwinters in the West Indies. Two scenarios would be used for the second: (1) that the second breeding population overwinters in the Cape Verde Islands; and (2) that the West Indies and Cape Verde Islands should be treated as a single breeding stock, with a second breeding stock which, for the purpose of this assessment, was assumed to over-winter in the southern Norwegian Sea (see Item 5.2).

The number of feeding sub-stocks in the North Atlantic depends on how one treats the Gulf of St Lawrence, Iceland and Norway. In photo-identification comparisons, the former region shows higher levels of exchange with Newfoundland and Labrador than to other feeding grounds, but also has low but significant levels of difference in genetic analyses. In light of this, it was agreed that the assessment should be structured considering all of eastern Canada as a single sub-stock and alternatively with the Gulf of St Lawrence and Newfoundland/Labrador considered as two separate feeding sub-stocks.

With regard to Iceland and Norway, given the size of the areas concerned and the difficulty of assigning animals in region to a particular breeding stock, it was decided that they should be treated separately for the purpose of the assessment.

The sub-committee agreed to allocate the proportions of animals from Iceland and Norway to the two breeding stocks using figures derived from the genetic data (SC/53/NAH11). The proportions of humpback whales from the second breeding stock off Iceland and Norway were estimated from nuclear as well as mitochondrial loci, assuming that the samples from the Gulf of Maine contained only individuals from the West Indies breeding stock. The CV of the proportions was estimated assuming a binomial distribution, which ignores the contribution of variance from the genetic basis of the estimation. These values are given in Appendix 5.

10.1.2 Assignment of catches

The methods and rationale for the assignments of catches to specific areas are given in Appendix 2.

The situation with the Scotian Shelf is unclear (SC/53/NAH10), but the number of catches from this area was too small to be significant. Based upon their location (off Blandford, Nova Scotia), it was decided to assign these catches to the Gulf of Maine.

Allocation of catches from the eastern North Atlantic to the hypothesised Norwegian breeding stock requires information on the seasonal and spatial distribution of those catches. Information was not available to the meeting to allow this and this hypothesis was not considered further at this time.

Appendix 2 gives the catch series to be used in the assessment runs.

10.1.3 Rates of increase

It was agreed to run the assessment model using the estimated rate of increase of 0.063 (SD = 0.11) for the Gulf of Maine for the period 1979-1991 (Barlow and Clapham, 1997). The alternative, more recent values for the Gulf of Maine from SC/53/NAH10 were compromised by possible sampling problems, did not have an associated standard deviation (which is necessary for the model), and were not used. To reflect uncertainty over this, it was agreed to include a model run without information on rate of increase in the Gulf of Maine.

10.1.4 Estimates of abundance

Estimates of abundance used in the assessment are given in Appendix 5. A series of estimates for the West Indies breeding population was used, as discussed in Item 7.4. No estimate was used for eastern Canada given that the only available estimates are known to be unreliable and to have unrealistically small CVs (see Item 7.2.2). The existing estimate for the Gulf of St Lawrence was regarded as unreasonably small; however, it would be used in the assessment model to explore its impact on results. For West Greenland, the series of estimates discussed in Item 7.2.3 was used, with the exception of the estimate for 1990 which was based upon poor and probably unrepresentative spatial coverage. In discussion, an earlier West Greenland estimate by Perkins *et al.* (1984) was rejected as being unreliable because of unrepresentative sampling. For Iceland, the 1987 sighting survey estimate for Iceland given by Gunnlaugsson and Sigurjónsson (1990) was used. For Norway, the line-transect survey estimates given in Item 7.2.5 were used.

10.1.5 Estimates of relative abundance

The relative abundance series for Iceland given in Appendix 5 was used in the assessment.

10.1.6 Survival rate

Based upon data from the Gulf of Maine (Barlow and Clapham, 1997; SC/53/NAH10), and considering possible differences in other areas, it was agreed to adopt a value of 0.96 for survival rate of age 1+ whales, and to test the sensitivity of the model to a range of 0.94-0.98. It was recognised that application of the Gulf of Maine estimate to the entire North Atlantic, as is assumed by the model, may not be appropriate

Punt noted that the input value for first-year survival was unimportant as it was used simply to scale fecundity rate in a single parameter incorporating fecundity and survival through the first year of life. The sub-committee agreed that model output should include a series of the estimated values of this parameter, that is, the number of calves surviving to age one per mature female, that could be compared with data from the Gulf of Maine on the number of calves surviving to approximately six months per mature female, for diagnostic purposes.

10.1.7 Sex ratio of calves

It was agreed to use an even sex ratio for calves in both catches and births based upon data in Smith *et al.* (1999) and other published sources.

Appendix 5 gives a complete list of the (non-catch) data included as input to the assessment model.

10.2 Results

Using the input data described in Item 10.1, Appendix 2 and Appendix 5, attempts to fit the model outlined in SC/53/NAH16 to the hypothesis of separate breeding populations in the Cape Verde Islands and the West Indies did not identify a single set of parameter values that is able to reconcile all of the information (catches, abundance estimates, mixing rates, rates of increase, etc). This lack of a satisfactory result meant that it was not possible to complete the Comprehensive Assessment at this meeting. The lack of model fit was further explored by attempting to fit the data after down-weighting selected input datasets.

Two sets of results were selected to illustrate the behaviour of the model. One model included all of the absolute and relative abundance estimates as input but excluded the Gulf of Maine rate of increase. For this fit of the model, the population in most feeding grounds and both breeding grounds were shown to be in the process of recovering. The model-estimated current rate of increase in each area was lower than the rate of increase estimated from data for the Gulf or Maine or the West Indies. Given that commercial humpback whaling in the North Atlantic declined in most areas due to reduced whale availability, the minimum abundances estimated by the model appeared improbably high, particularly in eastern Canada and the West Indies.

The second model included as input all of the absolute and relative abundance estimates and the Gulf of Maine rate of increase, but with the precision of the Gulf of Maine rate of increase and the West Indies abundance estimates artificially increased in an attempt to force the model to fit to these data. This selective procedure led to a lack of model fit to data on abundance for all areas except the West Indies. However, the model only fitted the earlier part of the West Indies time series and did not reflect the observed increase. For this fit of the model, the populations in most feeding grounds and both breeding grounds were estimated to be at carrying capacity. Estimated time-series of abundance were highly variable from one area to another with minimum abundances appearing improbably high for most areas but improbably low for the Gulf of Maine.

The sub-committee thanked Friday and Punt for their efforts.

The sub-committee noted that while it was disappointing that the Comprehensive Assessment had not been completed at this meeting, considerable progress had been made. Furthermore, the assessment runs had illuminated some interesting questions and issues that should be explored further intersessionally (see Item 12), and it was anticipated that the Comprehensive Assessment would be successfully completed at the next meeting.

11. MANAGEMENT ADVICE

Given the inability of the sub-committee to complete the Comprehensive Assessment at this meeting, and the absence of any substantially new information regarding humpback whales in the southeastern Caribbean, the sub-committee reiterates its view of the last two years that a catch of up to three whales taken annually would be unlikely to harm this stock.

The sub-committee noted that the question of the abundance and population identity of humpback whales in the southeastern Caribbean remains unresolved.

Although it had been unable to complete the Comprehensive Assessment at this meeting, the sub-committee agreed that the in-depth and in-breadth review of information on humpback whales in the North Atlantic confirmed that the appropriate unit that should be considered for management was that of the feeding sub-stock. This is in agreement with the use by the sub-committee on Stock Definition (Annex I), of the term ‘feeding sub-stock’ as an example of either a ‘sub-stock’ or a ‘closed sub-stock’.

12. RECOMMENDATIONS FOR FUTURE WORK

12.1 Assessment model development

With regard to further development of the assessment model, there are several uncertainties in the model itself and in the input data that need to be further considered to determine how all the data may be reconciled. The sub-committee **recommends** that the following tasks be undertaken intersessionally. Model development: (1) allowance for different MSYR rates in different feeding grounds (constrained not to vary dramatically among such grounds); (2) allowance for temporary movement of animals between feeding grounds (i.e. an overlap hypothesis); (3) allowance for differences in survival rate among feeding grounds; (4) allowance of three breeding stocks. Model testing: (1) examination of the impact of depensation; (2) examination of the impact of removing each data source in turn; (3) examination of the effects of where density-dependence is assumed to act.

To facilitate this work, the software developed to implement the model needs to be re-parameterised to a more robust formulation, and additional software developed to allow more rapid graphical evaluation of the fits.

The sub-committee **recommends** that an Intersessional Steering Group be formed to oversee this work.

12.2 Historical catch data

The sub-committee recognised that it is important to obtain improved catch data to facilitate completion of the Comprehensive Assessment. The following areas would benefit from further work.

(1) Further examination of the American non-mechanised pelagic fishery catches from the West Indies and the Cape Verde Islands. Additional information is available in voyage logbooks, many held in public collections. The subset of logbooks used in this meeting was not a representative sample. It would be useful to examine a subset of logbooks, selected to be representative of the ‘Atlantic’ fleet, for voyage details such as species and area.

(2) Review of historical data sources for land station humpback catches in the Cape Verde Islands. A person has been identified who would be able to examine the historical sources in both Portugal and the Cape Verde Islands. Those sources are likely to improve understanding of the historical catches in this region.

(3) Examination of eastern North Atlantic catch data by season. Additional information is available in Norwegian land station logs, many held privately. Other

historical archives may also be useful in interpreting the catch data from the eastern North Atlantic.
(4) Review of additional historical data to allocate unidentified catches to species in the Faroe Islands and Iceland for the period approximately 1880-1930. J. Sigurjónsson (pers. comm.) had indicated to Smith that the data he had used earlier was available and that further analysis of this information was possible. The present allocation is not well documented and improvement is necessary.
(5) Further examination of Bermuda Blue Books and other colonial records on the Bermuda shore fishery. Additional sampling of the voluminous records on Bermuda history in the Public Record Office and in institutions in Bermuda would help resolve questions about scale of removals and fishery trends.
(6) Review of Blue Books for Grenada, St Lucia and other West Indies islands not previously covered in studies of whaling history. This matter was raised in sub-committee discussions, where it was noted that Grenada served as a major collecting point for whale oil to be shipped overseas, and that St Lucia and possibly other islands not previously identified as having substantial shore fisheries for humpbacks should be considered. The relevant data sources should be available in the Public Record Office.
(7) Examination of whaling station diaries from West Greenland. As noted in SC/53/NAH15, there should be useful information on humpback whaling activity in West Greenland from the late 1700s to the mid-1800s in the diaries kept at West Greenland shore whaling stations. Documentation of humpback catches in the Davis Strait during this period is otherwise poor. There is reason to believe that the primary source materials are available in Copenhagen; their use will require competence in Danish, but an individual has been identified who may be willing to assist with this effort.

In discussion, a question was raised regarding whether the assessment model was likely to be sufficiently sensitive to changes in catch data to justify considerable additional work on historical records. The answer to this question is unclear, and determination of the importance of this issue represents a modelling exercise in itself.

The sub-committee agreed that all of the items listed above should be pursued as practicable, with highest priority given to the first two items. Smith noted that funding for preliminary work under point (1) would be made available through the USA. The sub-committee **recommends** that should this preliminary work be successful, Commission funding should be sought for the remainder of this task.

The sub-committee expressed its hope that local scientists and/or historians would assist in the search for, and interpretation of, appropriate material under points (3), (4), (6) and (7). Lawrence informed the sub-committee that the work identified under point (6) above would be taken forward and the sub-committee looked forward to receiving the results.

Smith noted that his recent collaboration with the History of Marine Animal Populations Project (HMAPP, based at Southern Denmark University, the University of New Hampshire and Hull University) had been very helpful in facilitating work on historical whaling catches, and requested that the sub-committee accept HMAPP's offer to continue this collaboration. The sub-committee agreed and **recommends** that the Secretariat contact the HMAPP Steering Group to convey this.

12.3 Additional analyses and data collection

The sub-committee agreed that the highest priority for future data collection was obtaining additional photographic and genetic samples from the Cape Verde Islands to elucidate the question of the stock identity of the animals which breed there. A proposal by Jann, Allen and Palsbøll to conduct such work in the winter of 2002 (Appendix 6) was endorsed by the sub-committee. The sub-committee **recommends** that this proposal (value £8,000) be forwarded to the Scientific Committee for consideration for funding by the Commission.

The sub-committee also considered a USA proposal to conduct a large-vessel acoustic and visual survey in the eastern Caribbean, with emphasis on deeper-water areas away from the island chain (Appendix 7). The sub-committee considered that while humpback whales do occur in these offshore waters, albeit in low densities, the priority for additional information from such a survey was lower than for the Cape Verde Islands.

As noted in SC/53/NAH22, other research in coastal waters of the West Indies is planned. The sub-committee encouraged cooperative research in this area.

Carlson noted that opportunistic and/or dedicated surveys off Guadeloupe as well as off St Barthelemy and possibly Martinique would be conducted during the coming winter. The sub-committee welcomed this information.

The sub-committee identified a number of additional analyses that would be a valuable contribution towards the Comprehensive Assessment.

12.3.1 Life history

Because of uncertainties about applying Gulf of Maine survival rates to other areas, survival rates could be estimated from photo-identification datasets other than the Gulf of Maine (e.g. West Greenland; the entire YoNAH dataset). This would be aided by matching the YoNAH dataset to the NAHW Catalogue. In addition, survival rates for the Gulf of Maine including data for more recent years should be estimated.

Preliminary calculations from the Gulf of Maine catalogue held by the Centre for Coastal Studies suggest that mature females have produced an annual average of 0.32 calves surviving to approximately six months of age. Further analyses of these data are required to enable assessment model output to be interpreted (see Item 10.2).

The extent of individual heterogeneity in capture probabilities could be explored using the extensive Gulf of Maine dataset to evaluate the magnitude of potential effects on abundance estimates.

12.3.2 Migration and stock structure

Differences among animals from various feeding grounds in patterns of migration to the West Indies should be further evaluated. This would also benefit from matching the NAHWC to the YoNAH dataset.

Patterns of migration of the putative Norwegian breeding population could be investigated using historical records.

The present and previous distribution of humpbacks in waters around the British Isles and the Faroe Islands could be investigated from sighting and possibly historical records, especially because the present low abundance appears to be inconsistent with the historical catches.

The YoNAH sampling was restricted spatially to the main breeding grounds in the West Indies. Recent survey results (SC/53/NAH17) suggest that there are groups of humpbacks to the east of the YoNAH study site in the Greater Antilles. Further information on the relationships between the animals in those areas with animals on Silver Bank and other West Indies breeding grounds would allow the possibility that YoNAH abundance estimates are biased to be investigated.

The assumption that humpback whales found in the Lesser Antilles and those found in the Greater Antilles are all part of the same breeding population is based on limited information. Additional photographic and/or genetic samples from various island areas in the Lesser Antilles would allow this to be tested.

The sub-committee reiterated its request made in previous years that photographs and tissue samples for genetic analysis of animals taken in the St Vincent hunt be collected and analysed, and the results presented to the Committee.

13. ADOPTION OF REPORT

The report was adopted as amended at 22:50 on 12 July 2001. The Chairman thanked participants for their work intersessionally and at the meeting, and announced that the YoNAH project originally conceived in 1989 was now completed. Members thanked Hammond for Chairing the sub-committee.

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Appendix 1
AGENDA

1. Convenor's opening remarks
2. Election of Chairman and appointment of rapporteurs
3. Adoption of agenda
4. Review of documents
5. Population structure and stock identity
   - 5.1 Feeding grounds
   - 5.2 Migration
   - 5.3 Breeding grounds
6. Catches and incidental takes
   - 6.1 Commercial catches
   - 6.2 Aboriginal catches
   - 6.3 Incidental takes
7. Abundance and trends
   - 7.1 Methodological issues
   - 7.2 Feeding ground estimates
     - 7.2.1 Gulf of Maine
     - 7.2.2 Canada
     - 7.2.3 West Greenland
     - 7.2.4 Iceland
     - 7.2.5 Norway
   - 7.2 Breeding ground/ocean basin estimates
   - 7.3 Trends in abundance
8. Biological parameters
   - 8.1 Age at sexual maturity
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   - 8.4 Comparison to other populations
9. Environmental concerns
10. Assessment
    - 10.1 Specification of assessment
    - 10.2 Results
11. Management advice
12. Recommendations for future work
    - 12.1 Assessment model development
    - 12.2 Historical catch data
    - 12.3 Additional analyses and data collection
13. Adoption of report

Appendix 2

ESTIMATING HISTORICAL HUMPBACK WHALE REMOVALS FROM THE NORTH ATLANTIC

Tim D. Smith and Randall R. Reeves

Introduction

Humpback whales were harvested by some 13 fisheries operating throughout the North Atlantic, the earliest from the early 1600s. Data on numbers of humpback whales removed by these fisheries vary in completeness as described in SC/53/NAH15. Estimation of landings and other removals requires making many assumptions about the operations of some of these fisheries. This appendix describes the assumptions made and provides estimates of total removals by fishery, sub-fishery, and year, classified as calves or non-calves ('adults'), with the non-calves also broken down by sex. The estimates were prepared in a format suitable for use in the population model described in SC/53/NAH16. The procedure was intended to enable the Scientific Committee to explore different treatments of the data efficiently.

Methods

The data sources identified in SC/53/NAH15 were examined for each fishery and sub-fishery. Available information was insufficient for making catch estimates for two fisheries (Canada non-mechanised coastal and American non-mechanised coastal) and three sub-fisheries (St Lucia and Turks and Caicos sub-fisheries of West Indies non-mechanised shore, and Other Areas sub-fishery of American non-mechanised pelagic). For all others, estimates of some kind were obtained, drawing when necessary on ancillary information about the nature of the fishery, or in some cases on the nature of similar fisheries or sub-fisheries. The lack of detail for some fisheries and periods made it necessary to interpolate or extrapolate in order to fill gaps in the catch history.

Bounds on the interpolated or extrapolated values were derived from the range of known or estimated removals over periods in which the fisheries appeared essentially constant. Reported landings were converted to common units, depending on the fishery and the time period. In many cases, especially during the 20th century, landings were reported as number of individual humpbacks, sometimes with information on sex and size. Some of the landings of whales were not identified to species, and a proportion of these unspecified landings were allocated as humpbacks on the basis of species ratios in specified landings.

Conversions

When the available data were reported in barrels of whale oil (rarely specified as humpback oil), amounts were converted to number of whales using a mean yield derived from reports on individual whales in the same fishery or fishing area. Yields of humpbacks in the North Atlantic varied from five (small calves) to as much as 60 barrels (Mitchell and Reeves, 1983), with an average in breeding areas of 25. When catch information was expressed only in terms of monetary value, the relation between the volume of whale oil and monetary value was used for conversion into estimated barrels of oil. Uncertainties in the conversions from monetary values to barrels and from barrels to whales were ignored because of the large amounts of uncertainty in the data more generally.

Loss rates
Hunting loss is a feature of most hunting operations, including whaling. Perhaps the most obvious recognition of its importance is manifest in the IWC's quota scheme for bowhead whales, the so-called *Strike Limit Algorithm* (*SLA*). It is expected that some proportion of the whales that are struck will not be landed even though they are effectively lost to the population. Hunting loss occurs when animals sink after being killed, when the whalers are unable to secure a carcass because of bad weather or adverse sea conditions, or when a struck whale escapes alive only to die later from its wounds. A special case of hunting loss is when a dependent calf starves after being orphaned.

Although hunting loss has often been ignored in assessments using catch series from modern whaling (e.g. IWC, 1992a), it is generally accepted that an adjustment of some kind is needed for catch series involving pre-modern hunting methods (e.g. IWC, 1986; 1992b; 2001; IWC, 1993). Bannister *et al*. (1983) estimated maximum and minimum mortality factors as 1.6 and 1.2, respectively, in 19th century American sperm whaling. The higher value assumed that all struck-and-lost whales were dead or moribund, while the lower value assumed that only those whales lost 'spouting blood' were removed from the population. The IWC Right Whale Workshop in 1983 concluded that an average mortality factor between 1.2 and 1.6 was appropriate for fisheries using hand harpoons and non-explosive lances, and also that losses were higher in open-sea conditions than in bay whaling (IWC, 1986).

In the case of humpback whales in the North Atlantic, hunting loss is recognised as an important component of the catch history (see Mitchell and Reeves, 1983). Here, all catches were adjusted for hunting loss, using three values for 'correcting' data on landings (secured catch) in various types of fisheries as described below.

Mitchell and Reeves (1983) used samples of logbook data from three areas (West Indies, Cape Verdes and eastern South Pacific) to estimate correction factors for 19th century American humpback whaling (1.86, 2.12 and 1.92, respectively). They applied 1.85 to catch data for both pelagic and shore-based whaling in which pre-modern methods were employed on the calving grounds. Data from logbooks used by Mitchell and Reeves (1983) were analysed along with some additional logbooks. That analysis (reported below) confirms their results, and given that humpbacks were more likely to sink than either right whales or sperm whales, we consider 1.85 a reasonable 'best' estimate of hunting loss in pre-modern humpback fisheries in the calving grounds.

For pre-modern whaling in feeding areas, Mitchell and Reeves (1983) used correction factors that were derived more subjectively, i.e. from mostly anecdotal references in the literature. These ranged from 1.2 in the Canadian (Gaspé) non-mechanised (and transitional) pelagic fishery to 1.5 in the West Greenland non-mechanised (and possibly transitional) shore fishery from 1885-1923. The so-called American mechanised shore fishery from 1850-95 is an anomaly in that it involved improved killing power (explosive projectiles) and steam propulsion yet was much like 19th century whaling with respect to its efficiency in securing and processing whales. Mitchell and Reeves (1983) suggested that a loss rate factor of 2.0 was appropriate for this fishery. Here, for simplicity, we propose to apply a loss rate factor of 1.5 to all non-mechanised humpback fisheries outside the calving grounds, and the American 'mechanised' shore fishery is included in this category.

Fisheries using modern methods (engine-powered vessels and deck-mounted explosive harpoons) are relatively efficient in landing and processing struck whales. For example, Mitchell and Reeves (1983) used the report of a whaling inspector at Hawkes Harbour, Labrador, to estimate hunting loss as 5.6% of the landed catch. They therefore multiplied reported catches at modern shore stations in eastern Canada by 1.06 to 'correct' for loss. Reeves *et al.* (1985) used whaler logbook data to estimate the 'killed-but-lost component' for two modern North Pacific shore stations as 1.8% of the landed catch. They suggested multiplying catch data by 1.02 to account for hunting loss. Here, all humpback catches by modern whaling in the North Atlantic (except for the American shore fishery mentioned above) were adjusted by a loss rate factor of 1.02.

Sex/age composition of takes
Where the sex and size composition of some of the landings were reported (e.g. West Indies Non-mechanised Shore, American Non-mechanised Pelagic and Norwegian Mechanised Shore fisheries), these data were summarised and the ratios used to allocate total estimated landings to three classes: non-calf males, non-calf females and calves. Where such information was not available, rates for similar fisheries were applied, or in some cases a 50:50 sex ratio was assumed.

Results and discussion

Estimated humpback whale removals are given here, by year, for each fishery and sub-fishery in table 1 of SC/53/NAH15. Where relevant, the fishery-specific estimation procedures are described. Fig. 1 summarises removals (landed catch adjusted for hunting loss) for fisheries and sub-fisheries known to have taken substantial numbers of humpback whales. The estimated removals for each fishery or sub-fishery were assigned to the appropriate breeding or feeding areas according to their proximity, with those from the Norwegian mechanised shore sub-fisheries in the Faeroe Islands and in the British Isles allocated equally between the Iceland and Norway feeding areas (Table 1). Total estimated removals are tabulated by relative age (calves vs. non-calves) and sex (non-calves only), and by feeding or breeding area, and are given in Adjunct 1.

Norwegian mechanised shore fishery
Some data for all sub-fisheries of this fishery were included in the records of individual whales assembled by the Bureau of International Whaling Statistics (BIWS), and other aggregate records, that have been entered into the databases of the International Whaling Commission (C. Allison, pers. comm.). Those data that have been validated and finalised were analysed and assigned to the fisheries and sub-fisheries defined in SC/53/NAH15.

NORTH NORWAY SUB-FISHERY

This fishery operated non-continuously from 1868-1969, during which 1,172 humpback whales and 5,627 unspecified whales (all before 1896; Jonsgård, 1977) were reported landed. We have included under this sub-fishery the catch of 25 humpbacks along the Murman coast between 1885-89, and note that in 1883-84 one or two boats were operating on this coast but their catches are unknown (Jonsgård, 1977).

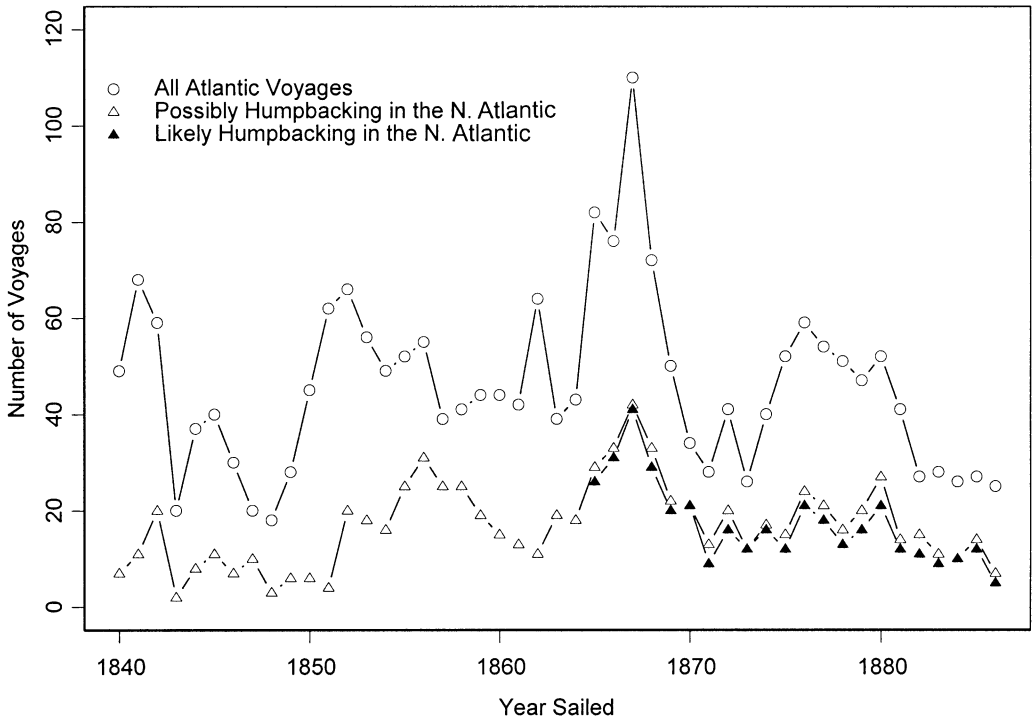

Fig. 1. Total estimated removals of humpback whales in the North Atlantic over time, for those fisheries or sub-fisheries that took substantial numbers.

Table 1

The breeding or feeding ground that catches by each of the North Atlantic whale fisheries or sub-fisheries in which humpback whales were taken.

Fisheries	Sub-fisheries	Breeding or feeding ground
Norwegian Mechanised Shore	N. Norway	Norway
	W. Norway	Norway
	Svalbard	Norway
	Iceland	Iceland
	Faroes	Norway (50%), Iceland (50%)
	British Isles	Norway (50%), Iceland (50%)
	Newfoundland	Canada
	Gulf of St Lawrence	Canada
	Nova Scotia	Gulf of Maine
	Grenada	West Indies
	Spain-Portugal	Cape Verde Islands
Norwegian Mechanised Pelagic		Greenland, Iceland, Norway
Greenland Non-mechanised Shore		Greenland
Greenland Mechanised Shore		Greenland
Canada Non-mechanised Shore		Canada
Canada Non-mechanised Pelagic (Gaspé)		Canada
American Non-mechanised Coastal		Gulf of Maine
American Mechanised Coastal		Gulf of Maine
Bermuda Non-mechanised Shore		West Indies
West Indies Non-mechanised Shore	Barbados	West Indies
	St Vincent and the Grenadines	West Indies
	Grenada	West Indies
	Trinidad	West Indies
	St Lucia	West Indies
	Turks and Caicos	West Indies
American Non-mechanised Pelagic	West Indies	West Indies
	Cape Verde Islands	Cape Verde Islands
	Other Areas	Not assigned
Cape Verde Islands Non-mechanised Shore		Cape Verde Islands
Madeira Non-mechanised Shore		Cape Verde Islands

The unspecified catches were allocated using the average ratio of humpbacks in the specified catches from the six surrounding years, three before and three after the periods of unspecified catches.

WEST NORWAY SUB-FISHERY

This fishery operated almost continuously from 1912-1969, during which 17 humpback whales were reported landed (plus 30 unspecified whales in 1912; Jonsgård, 1977).

SVALBARD SUB-FISHERY

This fishery operated non-continuously from 1903-27, during which 42 humpbacks were reported landed. Comments associated with the BIWS data suggest that very few, if any, of the 978 unspecified landings were humpbacks.

ICELAND SUB-FISHERY

This fishery operated almost but not quite continuously from 1883-1989. Landings of 219 humpbacks were reported, along with a large number (13,431, all between 1884-1912, according to Jonsgård, 1977) of unspecified animals. Allocation of the unspecified component was attempted by Sigurjónsson (1988) drawing on other Icelandic records. Although he did not describe his methods of analysis, he suggested that 2,800 humpbacks were taken prior to 1915. Few were taken subsequently. In the absence of detailed information from Icelandic scientists, Sigurjónsson's estimate of 2,800 (minus the 206 humpbacks specified for Iceland from 1890-1912) was used here, allocated in proportion to the reported unspecified catches by year from 1889-1915.

FAEROES SUB-FISHERY

Operating almost continuously from1894-1939, landings of 39 humpbacks were reported to the BIWS from 1920-26. Degerbøel (1940) indicated landings of 189 humpbacks from 1903-30. The 150 whales not accounted for in the BIWS data were allocated to the period 1903-16 in proportion to the total annual catches (specified and unspecified, combined). For the period 1894-1902, when all catches were unspecified, 40% of the total landings (1,215) were assumed to have been humpbacks based on Degerbøel's (1940) description of the fishery.

BRITISH ISLES SUB-FISHERY

Operating discontinuously from 1903-51, with 65 humpback landings reported between 1904-29 and 394 unspecified whales between 1910-14. Because the proportion of humpbacks in the specified catches was < 1%, it was decided that no allocation of the unspecified catches was necessary.

NEWFOUNDLAND SUB-FISHERY

From episodic operations between 1898-1971, 1,216 humpbacks were reported landed. In addition, 679 unspecified landings were reported for 1898-1902 in the IWC database. For these years, higher values (totalling 1,043) as reported by Mitchell and Reeves (1983) were used here, and it was assumed that 33% of landings were humpbacks based on the ratio in the 1903 IWC data. For 1906-07 and 1910-11, catches were entirely unspecified. These unspecified catches were allocated using the average ratio of humpbacks in the specified catches from the four surrounding years, two before and two after the periods of unspecified catches.

GULF OF ST LAWRENCE SUB-FISHERY

Operating from 1905-15, only three humpback whales were reported landed.

NOVA SCOTIA SUB-FISHERY

Operating from 1964-71, only seven humpback whales were reported landed (Mitchell, 1973).

GRENADA SUB-FISHERY

Operating only briefly in 1925-26, 174 humpbacks were reported landed.

SPAIN-PORTUGAL

Operating from 1924-85, only two humpbacks were reported from Spain and one from Portugal. In addition, the two reported from the catch of the *Sierra* in 1978 (Sanpera and Aguilar, 1992) are considered here.

Norwegian mechanised pelagic fishery

This fishery operated from 1911-37 but IWC data were available only from 1922 onward. Catches of 12 humpbacks in 1911-12 and 10 in 1919, all in Davis Strait, were summarised by Mitchell and Reeves (1983). A total of 451 humpbacks were taken from 1922-37, including 327 in Davis Strait from 1922-24. IWC data and information from Mitchell and Reeves (1983) were used to determine that the catches from 1930-34 were predominantly in Davis Strait and Bear Island/Svalbard (43% and 47%, respectively) and 10% in Denmark Strait/Iceland.

Greenland non-mechanised shore fishery

This fishery operated from the 1700s to 1923, apparently as an offshoot of the shore-based hunt for bowheads. The catch series provided by Kapel (1979) begins only in 1886, with annual landings ranging from one or less to 9 or 10. Mitchell and Reeves (1983) noted a catch of 15 humpbacks by a British vessel off West Greenland in about 1850 as well as single-year catches as high as 13 at one shore station in 1844 and 22 in an uncertain year before 1841. Here, catches of 5/year were arbitrarily assigned to this fishery from 1750-1840. Thereafter, interpolations and extrapolations following the procedures outlined above were used to estimate annual catches.

Greenland mechanised shore fishery

This fishery operated from 1924 to the present, with 300 humpback whales reported landed between 1926-94 according to the IWC database. Kapel (1979) also lists 18 humpbacks taken off West Greenland by the S/S *Sonja* in 1924-25.

Canada non-mechanised coastal fishery

The period of operation of this fishery is not well known but would be from the late 1700s to mid 1800s. No information was available on landings. Generally, the whaling covered under this heading involved vessels from Newfoundland and sites in Quebec outside the Gaspé.

Canada non-mechanised pelagic fishery (Gaspé)

Operating out of ports along the Gaspé Peninsula from 1804-93, landings for this fishery were estimated using the conversion and interpolation/extrapolation procedures described above, applied to the data in Mitchell and Reeves (1983). An average yield of 23bbl oil/whale was calculated from data on this fishery and it was assumed, based on descriptions of the fishery cited by Mitchell and Reeves (1983), that 75% of the catch consisted of humpbacks in the Gulf of St Lawrence, Strait of Belle Isle and Labrador coast.

American non-mechanised coastal fishery

This fishery operated along the American seaboard from the early 1700s to the mid 1800s, essentially as an adjunct to the fishery targeting right whales and to some extent sperm whales. It is poorly defined and documented, and estimation of catches has not been attempted here.

American mechanised coastal fishery

This fishery operated from about 1850-95 and was apparently centred in the Gulf of Maine. Annual landings for 1850-95 were estimated by applying the conversion and interpolation/extrapolation procedures, outlined above, to the data in Mitchell and Reeves (1983, their table 6, supplemented by information in SC/53/NAH15).

Bermuda non-mechanised shore fishery

Operating more or less continuously from 1606-1941 but with highly variable effort, the landings are poorly reported. The data in Reeves and Smith (2002) were used for a series of highly speculative interpolations and extrapolations to provide a complete but questionable catch series. The catch composition attributed to this fishery was the same as for the West Indies Non-mechanised Shore Fishery. Even though catches in any single year are not known to have exceeded about 20 individuals, estimates were made because of the long duration of the fishery and the possibility that catches were substantial. Examination of Blue Books and other colonial records would reduce this uncertainty.

West Indies non-mechanised shore fishery

The catch composition applied to all sub-fisheries was based on Price's (1985) Bequia sample for the years 1958-83, which consisted of 13% 'bulls', 46% cows and 41% calves.

BARBADOS SUB-FISHERY

Operating from 1868 to about 1913, catches for 1869-78 were estimated following the conversion and interpolation/extrapolation procedures outlined above and using data from Mitchell and Reeves (1983, table 13). For subsequent years, catches were estimated from British Blue Book data in SC/53/NAH15.

ST VINCENT AND THE GRENADINES SUB-FISHERY

Operating since 1876 at Bequia and several other sites to the south, whale oil export data from the British Blue Books (Mitchell and Reeves, 1983, table 15) were used (following the procedures outlined above) to estimate landings from 1876-1920. Landings in more recent years were reported in the IWC database.

GRENADA SUB-FISHERY

Shore whaling in Grenada is well documented for the period 1920-24 (Romero and Hayford, 2000).

TRINIDAD SUB-FISHERY

Annual landings for 1826-65 were estimated by applying the conversion and interpolation/extrapolation procedures, outlined above, to the data in Reeves *et al*. (2001).

ST LUCIA SUB-FISHERY

Although some shore whaling for humpbacks apparently took place at St Lucia during the late 19th or early 20th century, no information was available about catches or periods of operation.

TURKS AND CAICOS SUB-FISHERY

Although humpback whaling is said to have occurred near these small islands in the 1880s, no information was available about catches or periods of operation.

American non-mechanised pelagic fishery (West Indies and Cape Verde Islands sub-fisheries)

The Yankee whaling fleet sailing out of ports in New England caught humpback whales in several areas, including the West Indies and the Cape Verde Islands. Previous catch estimates for the West Indies (totalling somewhat more than 2,400 for the period 1866-88) were biased downward (Mitchell and Reeves, 1983). SC/53/NAH18 made crude estimates of catches (plus known struck-and-lost) at the Cape Verdes totalling close to 600 whales in 50 years. Correcting for losses, this would represent somewhat more than 1,000 whales removed.

Additional information on this fishery was assembled and analysed, as follows.

Data were extracted from Starbuck (1878) and Hegarty (1959) for the 1,048 Yankee whaling voyages with nominal 'Atlantic' or 'North Atlantic' destinations that departed between 1865-86 (inclusive) (Fig. 2). For each voyage, the following were recorded: vessel name and port, rigging (class), tonnage, sailing and arrival months and years, barrels of 'sperm oil', 'whale oil', and 'bone' brought back or sent home, and any comments by the compiler (e.g. damage to the vessel, sealskin returns, etc.). In addition to the detailed extractions from Starbuck (1878) and Hegarty (1959) described above, we tallied the number of voyages listed in Starbuck (1878), by year, from 1840-64 with nominal 'Atlantic' or 'North Atlantic' destinations (1,110 voyages). From these combined subsets of the total voyages, 1840-86, the number that returned with or sent home 20 or more bbls whale oil and no whalebone (called the Possibly Humpbacking subset; Fig. 2) were tallied.

These published voyage records were supplemented with information from 48 logbooks of voyages between 1865-86. The logbooks had been read by Reeves for other studies and selected originally for a variety of reasons, depending on the focus of the particular study. Selection was frequently intended to maximise the information that could be obtained on humpback whaling in the West Indies or the Cape Verde Islands, so the sample cannot be construed as random or representative for all voyages in those years. Information was recorded on locations fished (i.e. West Indies vs. Cape Verde Islands), humpback whales landed, killed-but-lost and struck-but-lost, and other whaling vessels sighted (or 'spoken') on the humpback whaling grounds. The amount of information varied widely among the logbooks depending on the amount of detail originally recorded and on the document's legibility. From the read logbooks, information was recorded on the whereabouts and activities (e.g. chasing, striking or taking humpback whales) of 107 other voyages (labelled 'sighted'). This made it possible to increase the number of voyages that were known to have been humpbacking in the North Atlantic breeding grounds.

Published information and logbook data were aggregated to identify the characteristics of the vessels and voyages whaling for humpbacks in the North Atlantic, such as the amount of whale oil landed or sent home, vessel size and rigging, and timing relative to the humpback breeding period. These criteria were used to eliminate from the Possibly Humpbacking subset voyages that were unlikely to have humpbacked in the North Atlantic. Thus, all voyages by 'ships' and all voyages spanning more than three North Atlantic humpback breeding seasons (February-April) were eliminated. Finally, all voyages from ports with no known history of humpback whaling in the North Atlantic (e.g. New London, Sag Harbour) were eliminated. The remaining subset of voyages is referred to as the Likely Humpbacking subset (Fig. 2).

Complete information on the number of humpbacks landed was available for 34 voyages by 21 vessels. During those voyages, 203 humpbacks were recorded landed in 39 vessel-seasons. Thirty-one of the vessel-seasons were in the West Indies and eight in the Cape Verdes. The number of humpback whales landed per vessel-season was not significantly different between the two areas ($P = 0.94$), with a mean of 5.2 whales ($n = 39$, SD = 3.58, SE = 0.57). When

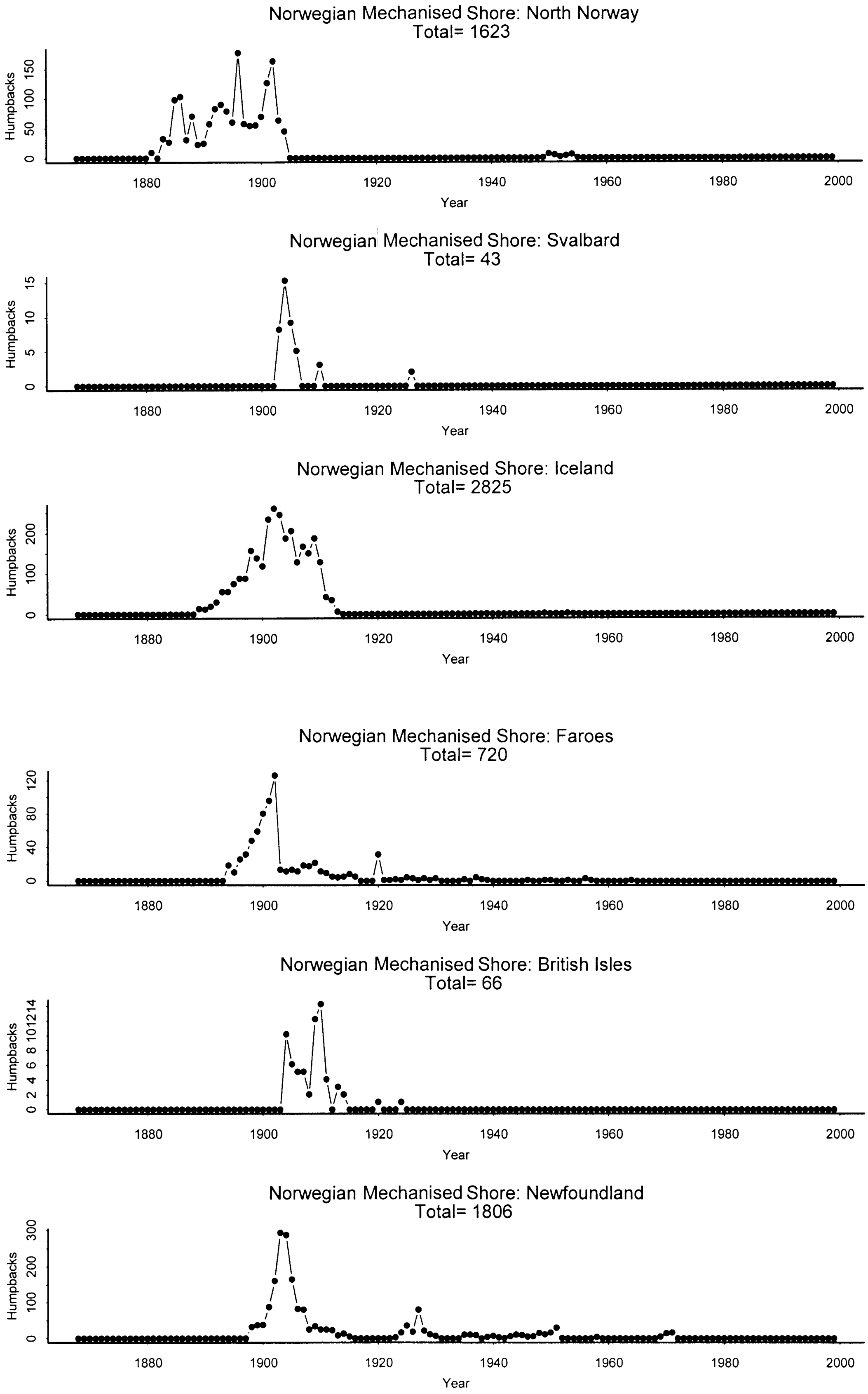

Fig. 2. Subsets of American whaling voyages, 1840-86, used to estimate humpback removals in the West Indies and Cape Verde Islands.

these same data were calculated on a per-voyage basis, the mean number of landed whales for the 34 voyages was 6.0 (SD = 4.37, SE = 0.75).

In 27 logbooks that appeared to contain a complete record of struck whales, 15 cows and 28 calves, along with an additional 80 animals unspecified to sex or relative age, were reported struck and lost (including killed animals that sank or were, for some other reason, not secured). In these 27 logbooks, 161 whales were reported landed, including 24 cows landed without their calves. It was assumed that all struck animals died, and that the calves of those 24 mothers also died. The struck/lost component was estimated as a proportion of the landed whales by regressing the estimated number of struck/lost (including orphaned calves) on the

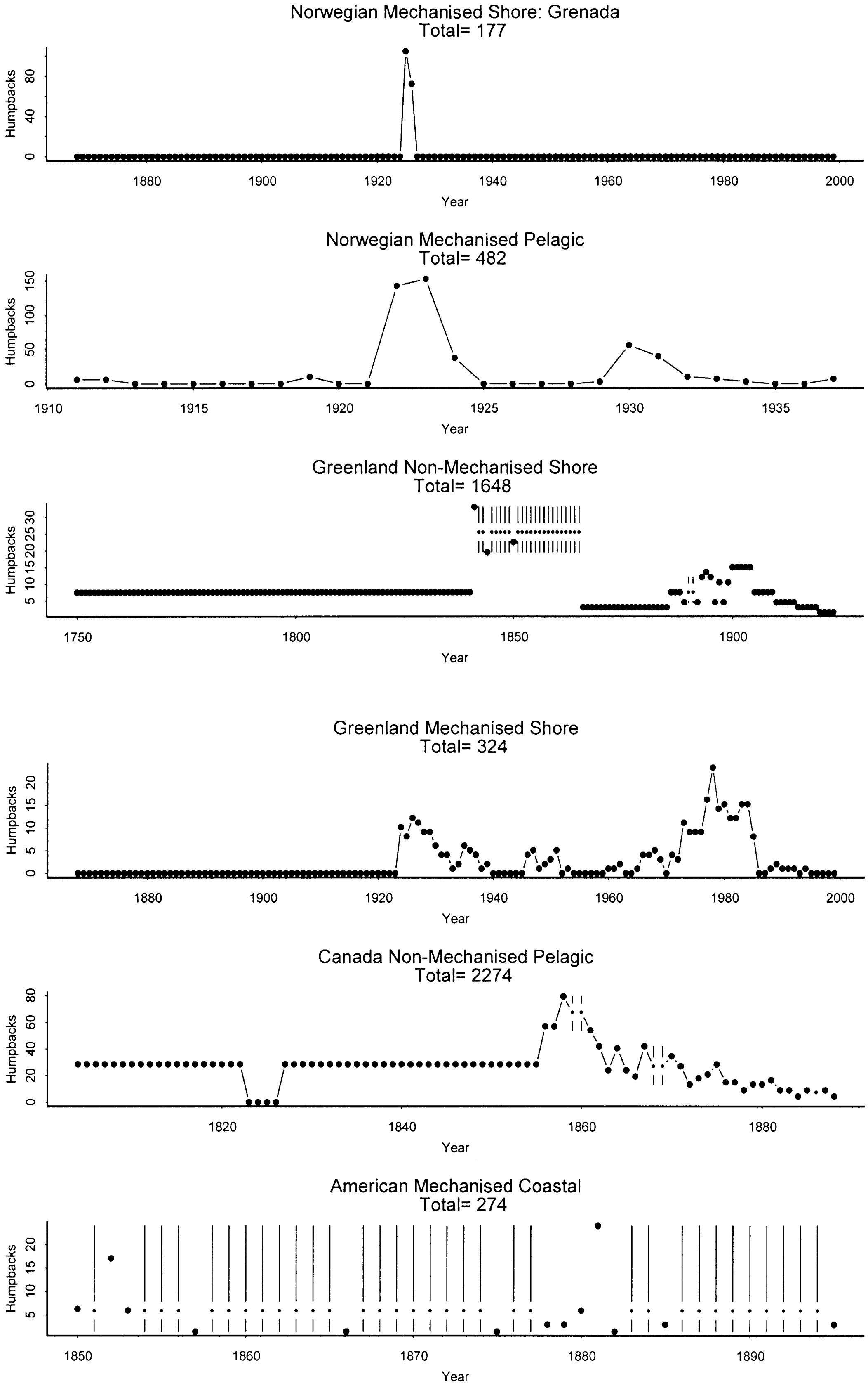

Fig. 2. *Continued*

landed number of whales, accounting for area (i.e. WI vs. CVI). The intercept and area were not significant, and the slope was 0.86 (SE = 0.117, R^2 = 67%). Although computed differently and with additional data, this result is consistent with the 'loss rate factor' (1.85) of Mitchell and Reeves (1983).

Composition of the catches in this fishery was estimated from logbook data as described in the text of the sub-committee's report.

Based on what is known about the fishery (e.g. Mitchell and Reeves, 1983; SC/53/NAH18), it was concluded that humpback whaling in the North Atlantic low-latitude

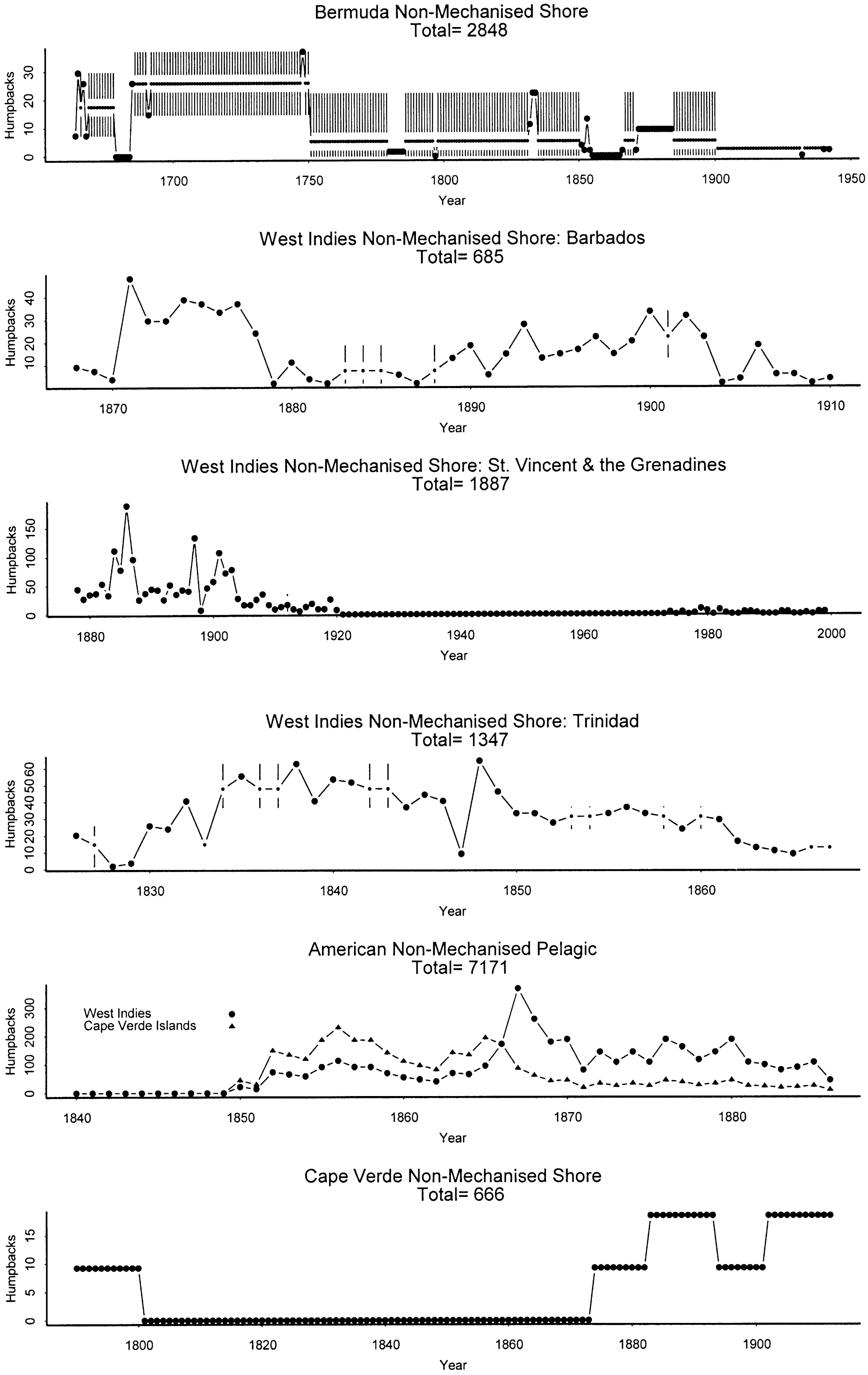

Fig. 2. *Continued*

breeding grounds between 1840-49 was negligible, and zero catches were therefore assumed for this period. It was equally clear from the literature and logbooks that by 1887 the American whalers had greatly reduced their effort at humpback whaling in both the West Indies and Cape Verde Islands, and zero catches were assumed for these two sub-fisheries from 1886 onwards.

The total numbers of humpbacks landed by the American fleet in the North Atlantic low-latitude breeding grounds were estimated by multiplying the Possibly Humpbacking subset from 1850-65 by 6.0, and the Likely Humpbacking subset from 1865-86 by 6.0. Allocation of these catches between the West Indies and Cape Verde Islands was based on a comparison of the number of voyages estimated to have been humpbacking in the West Indies (Mitchell and Reeves, 1983) vs. a similar estimate for the Cape Verde Islands (SC/53/NAH18). This comparison indicated that the following proportions should be assigned to the West Indies: 0.33 from 1850-65, 0.5 in 1866 and 0.81 from 1867-86.

Other areas sub-fishery

American pelagic whalers made voyages to northern areas for humpback whales, apparently beginning in the mid-18th century (SC/53/NAH15). For example, some 30 whales may have been taken off Newfoundland by seven Nantucket sloops in 1752, and other voyages to the Gulf of St Lawrence and Davis Strait probably included some humpbacking.

Sporadic hunting of humpback whales probably continued until the mid-19th century but there was no obvious method to estimate removals. SC/53/NAH15 suggests that at least hundreds of humpbacks were taken over the course of this sub-fishery (roughly 150 years).

Cape Verde Islands non-mechanised shore fishery

Humpback whales are thought to have been taken by shore stations in the Cape Verdes, perhaps from the late 18th century and into the early 20th. According to Hazevoet and Wenzel (2000) the first station opened at Brava in the late 1700s, and others at São Nicolau in 1874 and Sal in 1883. Stations at São Nicolau and Maio still existed in 1912 but ‘operations had all but ceased due to the scarcity of whales’ (Hazevoet and Wenzel, 2000). No data were available on the scale of effort or catches. Pending further historical research, these whaling stations were treated as equivalent to contemporary West Indies stations, with 3-5 boats and an annual secured catch of 4-7 whales (Adams, 1971, as summarised in Mitchell and Reeves, 1983). Five landings per year were assigned to each station for the period of known or assumed operation. The stations were assumed to have operated for a decade in those instances when the duration was uncertain. Further, the same catch composition was assigned for this fishery as for the West Indies Non-mechanised Shore Fishery (see above).

Madeira non-mechanised shore fishery

Operating from 1941-81, only five humpbacks were reported among the several thousand whales taken in this fishery primarily for sperm whales.

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Adjunct 1

Adjunct 1 tables follow

Table 1

Estimated numbers of North Atlantic humpback whales removed by whaling from 1664-1999, in two breeding grounds (West Indies and Cape Verde Islands) and in five feeding grounds (Gulf of Maine, Canada, West Greenland, Iceland and Norway), for males (M), females (F) and calves (C). This includes incidental catches in Canada from 1969-1992.

	West Indies			Cape Verde Is.			Gulf of Maine			Canada			West Greenland			Iceland			Norway		
Year	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C
1664	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1665	4	14	12	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1666	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1667	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1668	1	3	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1669	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1670	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1671	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1672	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1673	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1674	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1675	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1676	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1677	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1678	2	8	7	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1679	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1680	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1681	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1682	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1683	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1684	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1685	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1686	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1687	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1688	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1689	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1690	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1691	2	7	6	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1692	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1693	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1694	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1695	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1696	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1697	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1698	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1699	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1700	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1701	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1702	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1703	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1704	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1705	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1706	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1707	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1708	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1709	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1710	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1711	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1712	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1713	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1714	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1715	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1716	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1717	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1718	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1719	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1720	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1721	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1722	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1723	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1724	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1725	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1726	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1727	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1728	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1729	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1730	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1731	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

cont...

Table 1 continued.

	West Indies			Cape Verde Is.			Gulf of Maine			Canada			West Greenland			Iceland			Norway		
Year	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C
1732	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1733	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1734	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1735	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1736	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1737	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1738	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1739	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1740	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1741	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1742	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1743	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1744	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1745	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1746	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1747	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1748	5	17	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1749	3	12	11	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1750	3	12	11	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1751	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1752	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1753	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1754	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1755	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1756	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1757	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1758	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1759	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1760	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1761	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1762	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1763	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1764	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1765	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1766	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1767	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1768	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1769	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1770	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1771	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1772	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1773	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1774	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1775	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1776	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1777	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1778	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1779	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1780	0	1	1	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1781	0	1	1	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1782	0	1	1	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1783	0	1	1	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1784	0	1	1	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1785	0	1	1	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1786	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1787	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1788	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1789	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1790	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1791	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1792	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1793	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1794	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1795	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1796	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1797	0	0	0	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1798	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1799	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1800	1	2	2	1	4	4	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1801	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1802	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1803	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0

cont...

Table 1 continued.

	West Indies			Cape Verde Is.			Gulf of Maine			Canada			West Greenland			Iceland			Norway		
Year	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C
1804	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1805	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1806	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1807	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1808	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1809	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1810	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1811	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1812	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1813	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1814	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1815	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1816	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1817	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1818	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1819	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1820	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1821	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1822	1	2	2	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1823	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1824	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1825	1	2	2	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1826	3	12	10	0	0	0	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0
1827	3	9	8	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1828	1	3	3	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1829	1	4	4	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1830	4	14	13	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1831	4	13	12	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1832	7	24	21	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1833	5	17	15	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1834	9	32	29	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1835	8	28	25	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1836	7	25	22	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1837	7	25	22	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1838	9	31	28	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1839	6	21	19	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1840	8	27	24	0	0	0	0	0	0	14	14	0	4	4	0	0	0	0	0	0	0
1841	7	26	23	0	0	0	0	0	0	14	14	0	16	16	0	0	0	0	0	0	0
1842	7	25	22	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1843	7	25	22	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1844	5	19	17	0	0	0	0	0	0	14	14	0	10	10	0	0	0	0	0	0	0
1845	6	23	20	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1846	6	21	19	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1847	2	7	6	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1848	9	32	29	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1849	7	24	21	0	0	0	0	0	0	14	14	0	13	13	0	0	0	0	0	0	0
1850	16	26	18	23	17	4	3	3	0	14	14	0	11	11	0	0	0	0	0	0	0
1851	12	23	17	15	12	3	3	3	0	14	14	0	13	13	0	0	0	0	0	0	0
1852	41	42	19	76	58	15	9	9	0	14	14	0	13	13	0	0	0	0	0	0	0
1853	40	46	25	69	52	13	3	3	0	14	14	0	13	13	0	0	0	0	0	0	0
1854	34	38	20	61	46	12	3	3	0	14	14	0	13	13	0	0	0	0	0	0	0
1855	51	51	23	95	72	19	3	3	0	14	14	0	13	13	0	0	0	0	0	0	0
1856	63	61	27	118	89	23	3	3	0	28	28	0	13	13	0	0	0	0	0	0	0
1857	51	51	23	95	72	19	1	1	0	28	28	0	13	13	0	0	0	0	0	0	0
1858	51	50	22	95	72	19	3	3	0	40	40	0	13	13	0	0	0	0	0	0	0
1859	39	38	17	72	55	14	3	3	0	34	34	0	13	13	0	0	0	0	0	0	0
1860	32	36	18	57	43	11	3	3	0	34	34	0	13	13	0	0	0	0	0	0	0
1861	28	32	17	50	37	10	3	3	0	27	27	0	13	13	0	0	0	0	0	0	0
1862	23	23	11	42	32	8	3	3	0	21	21	0	13	13	0	0	0	0	0	0	0
1863	37	33	12	72	55	14	3	3	0	12	12	0	13	13	0	0	0	0	0	0	0
1864	35	31	11	69	52	13	3	3	0	20	20	0	13	13	0	0	0	0	0	0	0
1865	50	41	13	99	75	19	3	3	0	12	12	0	13	13	0	0	0	0	0	0	0
1866	90	73	23	88	67	17	1	1	0	10	10	0	2	2	0	0	0	0	0	0	0
1867	191	151	44	44	33	9	3	3	0	21	21	0	2	2	0	0	0	0	0	0	0
1868	136	108	32	31	24	6	3	3	0	14	14	0	2	2	0	0	0	0	0	0	0
1869	94	75	23	22	16	4	3	3	0	14	14	0	2	2	0	0	0	0	0	0	0
1870	98	77	23	23	17	4	3	3	0	17	17	0	2	2	0	0	0	0	0	0	0
1871	48	54	29	10	7	2	3	3	0	14	14	0	2	2	0	0	0	0	0	0	0
1872	79	74	30	17	13	3	3	3	0	7	7	0	2	2	0	0	0	0	0	0	0
1873	60	60	27	13	10	3	3	3	0	9	9	0	2	2	0	0	0	0	0	0	0
1874	80	78	34	19	17	7	3	3	0	10	10	0	2	2	0	0	0	0	0	0	0
1875	61	63	30	14	14	6	1	1	0	14	14	0	2	2	0	0	0	0	0	0	0

cont...

Table 1 continued.

	West Indies			Cape Verde Is.			Gulf of Maine			Canada			West Greenland			Iceland			Norway		
Year	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C
1876	102	93	36	24	21	8	3	3	0	8	8	0	2	2	0	0	0	0	0	0	0
1877	89	84	35	21	19	8	3	3	0	8	8	0	2	2	0	0	0	0	0	0	0
1878	70	81	44	15	15	7	2	2	0	4	4	0	2	2	0	0	0	0	0	0	0
1879	79	74	30	19	17	7	2	2	0	7	7	0	2	2	0	0	0	0	0	0	0
1880	104	99	42	24	21	8	3	3	0	7	7	0	2	2	0	0	0	0	0	0	0
1881	62	65	31	14	14	6	12	12	0	8	8	0	2	2	0	0	0	0	5	3	0
1882	59	68	36	13	13	6	1	1	0	4	4	0	2	2	0	0	0	0	0	0	0
1883	48	54	29	12	16	9	3	3	0	4	4	0	2	2	0	0	0	0	19	12	2
1884	63	94	61	13	17	10	3	3	0	2	2	0	2	2	0	0	0	0	16	10	1
1885	67	83	48	15	18	10	2	2	0	4	4	0	2	2	0	0	0	0	58	35	5
1886	49	109	86	8	13	9	3	3	0	4	4	0	4	4	0	0	0	0	61	37	5
1887	13	48	42	2	9	8	3	3	0	4	4	0	4	4	0	0	0	0	18	11	1
1888	5	18	16	2	9	8	3	3	0	2	2	0	4	4	0	0	0	0	42	25	3
1889	7	25	23	2	9	8	3	3	0	0	0	0	2	2	0	8	5	1	13	8	1
1890	9	31	28	2	9	8	3	3	0	0	0	0	4	4	0	7	4	1	14	9	1
1891	7	25	22	2	9	8	3	3	0	0	0	0	4	4	0	11	7	1	34	21	3
1892	6	21	19	2	9	8	3	3	0	0	0	0	2	2	0	17	11	1	49	30	4
1893	11	39	35	2	9	8	3	3	0	0	0	0	6	6	0	33	20	3	53	33	4
1894	7	25	22	1	4	4	3	3	0	0	0	0	7	7	0	38	23	3	52	32	4
1895	8	29	26	1	4	4	2	2	0	0	0	0	6	6	0	47	29	4	39	24	3
1896	8	29	26	1	4	4	0	0	0	0	0	0	2	2	0	59	36	5	112	69	9
1897	21	74	66	1	4	4	0	0	0	0	0	0	5	5	0	61	37	5	43	26	3
1898	4	13	11	1	4	4	0	0	0	19	11	1	2	2	0	106	65	8	46	28	4
1899	9	33	29	1	4	4	0	0	0	22	13	2	5	5	0	99	61	8	50	31	4
1900	12	44	39	1	4	4	0	0	0	22	14	2	8	8	0	94	57	7	65	40	5
1901	17	61	54	1	4	4	0	0	0	52	32	4	8	8	0	166	102	13	103	63	8
1902	14	49	43	2	9	8	0	0	0	95	58	8	8	8	0	191	117	15	134	82	11
1903	13	47	42	2	9	8	0	0	0	173	106	14	8	8	0	149	91	12	41	25	3
1904	4	15	13	2	9	8	0	0	0	169	104	13	8	8	0	117	71	9	33	20	3
1905	3	10	9	2	9	8	0	0	0	97	59	8	4	4	0	127	78	10	6	4	0
1906	5	17	15	2	9	8	0	0	0	49	30	4	4	4	0	80	49	6	5	3	0
1907	4	16	14	2	9	8	0	0	0	48	29	4	4	4	0	105	64	8	7	4	1
1908	6	20	18	2	9	8	0	0	0	14	9	1	4	4	0	94	58	8	6	4	0
1909	3	10	8	2	9	8	0	0	0	20	12	2	4	4	0	120	74	10	10	6	1
1910	2	7	6	2	9	8	0	0	0	14	9	1	2	2	0	83	51	7	8	5	1
1911	2	7	6	2	9	8	0	0	0	14	9	1	6	5	0	29	18	2	4	2	0
1912	2	9	8	2	9	8	0	0	0	13	8	1	6	5	0	22	13	2	2	1	0
1913	1	5	5	0	0	0	0	0	0	5	3	0	2	2	0	6	4	0	2	1	0
1914	1	4	3	0	0	0	0	0	0	8	5	1	2	2	0	2	1	0	2	1	0
1915	2	7	6	0	0	0	0	0	0	3	2	0	2	2	0	2	1	0	2	1	0
1916	3	10	8	0	0	0	0	0	0	0	0	0	2	2	0	2	1	0	2	1	0
1917	1	5	5	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
1918	1	5	5	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	1	0	0
1919	4	13	12	0	0	0	0	0	0	0	0	0	8	5	1	0	0	0	2	1	0
1920	4	13	12	0	0	0	0	0	0	0	0	0	1	1	0	10	6	1	10	6	1
1921	1	2	2	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
1922	1	5	4	0	0	0	0	0	0	0	0	0	85	53	7	0	0	0	0	0	0
1923	1	5	5	0	0	0	0	0	0	2	1	0	91	56	7	1	0	0	1	0	0
1924	1	2	2	0	0	0	0	0	0	10	6	1	27	19	2	1	0	0	1	0	0
1925	84	21	3	0	0	0	0	0	0	21	13	2	4	4	0	1	1	0	1	1	0
1926	58	15	2	0	0	0	0	0	0	11	7	1	6	6	0	1	1	0	2	1	0
1927	0	1	1	0	0	0	0	0	0	48	29	4	5	6	0	0	0	0	0	0	0
1928	0	1	1	0	0	0	0	0	0	13	8	1	4	5	0	1	1	0	2	1	0
1929	0	1	1	1	1	0	0	0	0	7	4	1	5	5	0	0	0	0	1	1	0
1930	0	1	1	0	0	0	0	0	0	4	3	0	18	12	1	5	3	0	17	11	1
1931	0	1	1	0	0	0	0	0	0	0	0	0	13	9	1	3	2	0	11	7	1
1932	0	0	0	0	0	0	0	0	0	0	0	0	5	4	0	1	1	0	4	3	0
1933	0	1	1	0	0	0	0	0	0	0	0	0	3	2	0	1	1	0	3	2	0
1934	0	1	1	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	1	1	0
1935	0	1	1	0	0	0	0	0	0	6	4	0	3	3	0	1	0	0	1	0	0
1936	0	1	1	0	0	0	0	0	0	6	4	0	2	3	0	0	0	0	0	0	0
1937	0	1	1	0	0	0	0	0	0	5	3	0	7	5	1	2	1	0	1	1	0
1938	0	1	1	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	1	0	0
1939	0	1	1	0	0	0	0	0	0	2	1	0	1	1	0	1	1	0	1	1	0
1940	0	1	1	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	0	0	0
1941	0	1	1	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
1942	0	1	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0
1943	0	0	0	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	1	1	0
1944	0	0	0	0	0	0	0	0	0	6	4	0	0	0	0	0	0	0	0	0	0
1945	0	0	0	0	0	0	0	0	0	5	3	0	0	0	0	0	0	0	0	0	0
1946	0	0	0	0	0	0	0	0	0	3	2	0	2	2	0	0	0	0	1	1	0
1947	0	0	0	0	0	0	0	0	0	4	2	0	2	3	0	0	0	0	0	0	0

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Table 1 continued.

	West Indies			Cape Verde Is.			Gulf of Maine			Canada			West Greenland			Iceland			Norway		
Year	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C	M	F	C
1948	0	0	0	0	0	0	0	0	0	9	6	1	0	1	0	0	0	0	0	0	0
1949	0	0	0	0	0	0	0	0	0	7	4	1	1	1	0	2	1	0	1	1	0
1950	0	0	0	0	0	0	0	0	0	10	6	1	1	2	0	0	0	0	5	3	0
1951	0	0	0	0	0	0	0	0	0	17	11	1	2	3	0	1	0	0	3	2	0
1952	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	1	0
1953	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	1	0	3	2	0
1954	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	4	2	0
1955	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0
1956	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	1	1	0
1957	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1958	0	0	0	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	0	0	0
1959	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1960	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1961	0	0	0	2	2	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1962	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0
1963	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1964	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1965	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
1966	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
1967	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0
1968	0	0	0	0	0	0	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0
1969	0	0	0	0	0	0	1	1	0	4	3	0	1	2	0	0	0	0	0	0	0
1970	0	0	0	0	0	0	1	0	0	9	6	1	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	2	1	0	11	7	1	2	2	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	1	1	0	1	2	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	1	1	0	5	6	0	0	0	0	0	0	0
1974	0	2	2	1	1	0	0	0	0	1	1	0	4	5	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	1	1	0	4	5	0	0	0	0	0	0	0
1976	0	2	2	1	1	0	0	0	0	1	1	0	4	5	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	1	1	0	8	8	1	0	0	0	0	0	0
1978	0	1	1	1	1	0	0	0	0	4	4	0	11	12	1	0	0	0	0	0	0
1979	1	4	4	0	0	0	0	0	0	6	6	0	7	7	1	0	0	0	0	0	0
1980	1	3	2	0	0	0	0	0	0	8	8	0	7	8	1	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	4	4	0	6	6	0	0	0	0	0	0	0
1982	1	3	3	0	0	0	0	0	0	2	2	0	6	6	0	0	0	0	0	0	0
1983	0	1	1	0	0	0	0	0	0	2	2	0	7	8	1	0	0	0	0	0	0
1984	0	0	0	0	0	0	0	0	0	3	3	0	7	8	1	0	0	0	0	0	0
1985	0	0	0	0	0	0	0	0	0	4	4	0	4	4	0	0	0	0	0	0	0
1986	0	2	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
1987	0	2	2	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0
1988	0	1	1	0	0	0	0	0	0	6	6	0	0	1	0	0	0	0	0	0	0
1989	0	0	0	0	0	0	0	0	0	2	2	0	1	1	0	0	0	0	0	0	0
1990	0	0	0	0	0	0	0	0	0	5	5	0	0	1	0	0	0	0	0	0	0
1991	0	0	0	0	0	0	0	0	0	4	4	0	0	1	0	0	0	0	0	0	0
1992	0	2	2	0	0	0	0	0	0	4	4	0	0	1	0	0	0	0	0	0	0
1993	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1994	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0
1995	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1996	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1997	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1998	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1999	0	2	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Appendix 3

DISTRIBUTION OF PHOTOGRAPHIC SAMPLES BY AREA AND DATE

Table 1

Number of samples by area and year.

Year	Gulf of Maine	Canada	Greenland	Iceland	Norway	Silver Bank	Navidad Bank	Samana Bay	Puerto Rico	Virgin Islands
1978	32	279	0	0	0	33	9	0	11	0
1979	79	493	0	0	0	11	0	3	68	0
1980	131	279	0	0	0	108	4	2	107	0
1981	122	53	70	2	2	28	0	2	91	0
1982	155	255	66	17	3	179	4	4	56	2
1983	159	296	60	0	1	163	0	0	97	4
1984	225	55	7	0	5	475	0	2	58	0
1985	273	75	0	0	0	134	0	0	0	32
1986	232	8	0	1	1	74	0	0	0	70
1987	294	49	0	0	0	15	0	8	0	20
1988	389	27	75	0	3	0	0	133	0	1
1989	265	45	133	0	0	3	16	151	0	1
1990	359	96	112	0	0	0	0	82	0	0
1991	349	193	46	0	3	0	0	54	0	0
1992	152	439	117	44	36	448	65	76	17	0
1993	108	593	83	105	49	453	16	82	38	0

Table 2

Distribution of West Indies samples by week beginning Jan 1.

Week	78/79	79/80	80/81	81/82	82/83	83/84	84/85	85/86	86/87	87/88	88/89	89/90	90/91
1	11	0	0	3	3	0	0	0	0	0	7	7	0
2	0	0	0	13	17	6	3	3	2	6	6	0	0
3	0	8	11	18	46	31	0	0	0	4	8	4	0
4	25	53	48	26	24	29	19	6	6	14	40	26	1
5	7	35	53	23	27	57	53	32	13	1	9	11	3
6	27	43	42	56	62	29	23	40	26	42	48	62	82
7	9	50	54	36	94	109	62	49	33	26	45	41	34
8	4	22	22	31	41	125	125	41	34	20	47	33	0
9	14	32	32	25	59	94	75	37	11	2	10	8	0
10	14	21	17	28	37	84	74	22	17	18	21	3	0
11	7	4	9	22	19	59	76	21	0	5	5	0	0
12	0	8	8	23	23	99	102	4	1	0	9	9	0
13	2	1	1	7	7	3	8	5	0	0	0	0	0
14	3	5	3	0	0	0	14	14	0	0	0	0	0
15	2	2	0	0	0	0	0	0	0	0	0	0	0
Total	125	284	300	311	459	725	634	274	143	138	255	204	120
>7	46	95	92	136	186	464	474	144	63	45	92	53	0
%	0.368	0.335	0.307	0.437	0.405	0.640	0.748	0.526	0.441	0.326	0.361	0.260	0.000
>8	42	73	70	105	145	339	349	103	29	25	45	20	0
%	0.336	0.257	0.233	0.338	0.316	0.468	0.550	0.376	0.203	0.181	0.176	0.098	0.000
>9	28.000	41.000	38.000	80.000	86.000	245.000	274.000	66.000	18.000	23.000	35.000	12.000	0.000
%	0.224	0.144	0.127	0.257	0.187	0.338	0.432	0.241	0.126	0.167	0.137	0.059	0.000

Table 3

Abundance estimates using different sub-areas of the West Indies sample.

Area	$n1$	$n2$	$m2$	N	Var.	CV
Puerto Rico	1,520	55	7	10,646	10,739,274	0.308
Navidad Bank	1,520	80	9	12,319	12,015,570	0.281
Samana Bay	1,520	155	26	8,787	2,240,312	0.170
Silver Bank	1,520	907	123	11,137	786,998.9	0.080

Appendix 4

PETERSEN TWO-SAMPLE MARK-RECAPTURE ESTIMATES OF ABUNDANCE CONSIDERED BY THE SUB-COMMITTEE

Area/population to which estimate applies	Year of estimate	Estimate	CV	Source	Samples	Potential biases
West Indies breeding population	1992/93	10,752	6.8%	SC/53/NAH2	1. West Indies breeding grounds 2. Western feeding grounds only (not Iceland or Norway)	(a) Positive bias of ~5%? Due to open population (b) Negative bias of unknown (but small?) magnitude due to individual heterogeneity (c) Negative bias of unknown (but small?) magnitude if some animals from 2nd breeding ground migrate to western NA feeding grounds
West Indies breeding population	Series from 1979/80 to 1988/89	See SC/53/NAH2 table 2 6,920-12,582	10.3-39.1%	SC/53/NAH2	1. West Indies breeding grounds 2. Western feeding grounds only (not Iceland or Norway)	(a) Positive bias of ~5%? Due to open population (b) Negative bias of unknown (but small?) magnitude due to individual heterogeneity (c) Negative bias of unknown (but small?) magnitude if some animals from 2nd breeding ground migrate to western NA feeding grounds
Whole North Atlantic	1992/93	11,570	6.9%	SC/53/NAH2	1. West Indies breeding grounds 2. All feeding grounds	(a) Positive bias of ~5%? Due to open population (b) Negative bias of unknown but small(?) magnitude due to individual heterogeneity (c) Negative bias of unknown magnitude because whales in 2nd breeding ground not sampled
West Greenland	1988/89 1989/90 1990/91 1991/92 1992/93	373 362 615 430 406	14% 10% 29% 20% 11%	SC/52/IA1	1. + 2. West Greenland	(a) Positive bias of ~5%? Due to open population (b) Negative bias of unknown but small(?) magnitude due to individual heterogeneity
Gulf of Maine	1992/93	652	29%	SC/53/NAH10	1. + 2. Gulf of Maine	(a) Positive bias of ~5%? due to open population (b) Negative bias of unknown but small(?) magnitude due to individual heterogeneity (c) Negative bias of unknown magnitude due to remaining spatial heterogeneity
Eastern Canada	1992/93	2,509	7.7%	SC/53/NAH1	1. + 2. Eastern Canada (3 strata)	(a) Positive bias of ~5%? due to open population (b) Negative bias of unknown but small(?) magnitude due to individual heterogeneity (c) Negative bias of unknown (but possibly large) magnitude due to remaining spatial heterogeneity (d) Positive bias of unknown magnitude due to not accounting for exchange between strata

Appendix 5

SPECIFICATION OF STOCK STRUCTURE HYPOTHESES AND INPUT DATA FOR THE ASSESSMENT MODEL

Table 1
Breeding stocks and feeding substocks.

Number of breeding stocks (2)	
West Indies Cape Verde Islands	
Number of feeding substocks	
(5)	(6)
Gulf of Maine Eastern Canada West Greenland Iceland Norway	Gulf of Maine Newfoundland/Labrador Gulf of St Lawrence West Greenland Iceland Norway

Table 2
Proportion of each feeding substock in each breeding stock.

Feeding Areas	Breeding Areas: West Indies	Breeding Areas: Cape Verde
Gulf of Maine	1	0
Eastern Canada	1	0
West Greenland	1	0
Iceland	0.60 (SD=0.050)	0.40 (SD=0.050)
Norway	0.13 (SD=0.057)	0.87 (SD=0.057)

Table 3
Sex ratio of calves (at birth and in catch): 50:50 (Smith et al. 1999).

ROI	Years	R (SD)	Source
Gulf of Maine	1979-91	0.063 (0.011)	Barlow and Clapham (1997) - ln(1)

Table 4
Survival and age at sexual maturity.

Age	Survival, S_a Barlow and Clapham (1997)	Fraction, 'mature', M_a Barlow and Clapham (1997)	Fraction recruited, Q_a
0	0.875	0	0
1	0.96	0	1
2	0.96	0	1
3	0.96	0	1
4	0.96	0.23	1
5	0.96	0.468	1
6	0.96	0.501	1
7	0.96	1	1
8	0.96	1	1
9+	0.96	1	1

Table 5
Abundance.

Year	*n* (CV)	Source
West Indies		
1979	7,260 (0.16)	SC/53/NAH2
1979	6,918 (0.15)	SC/53/NAH2
1980	9,439 (0.22)	SC/53/NAH2
1980	8,119 (0.20)	SC/53/NAH2
1981	7,234 (0.18)	SC/53/NAH2
1981	9,695 (0.19)	SC/53/NAH2
1982	8,864 (0.15)	SC/53/NAH2
1982	7,064 (0.10)	SC/53/NAH2
1983	7,603 (0.12)	SC/53/NAH2
1983	7,309 (0.13)	SC/53/NAH2
1984	9,200 (0.18)	SC/53/NAH2
1984	9,948 (0.29)	SC/53/NAH2
1985	10,310 (0.31)	SC/53/NAH2
1985	8,100 (0.36)	SC/53/NAH2
1986	11,185 (0.39)	SC/53/NAH2
1986	9,083 (0.36)	SC/53/NAH2
1987	10,297 (0.32)	SC/53/NAH2
1987	11,144 (0.25)	SC/53/NAH2
1988	12,582 (0.25)	SC/53/NAH2
1992	10,752 (0.07)	SC/53/NAH2
Gulf of Maine		
1992	652 (0.29)	SC/53/NAH10
1999	902 (0.41)	SC/53/NAH10
Gulf of St Lawrence		
1992	62 (0.08)	Unpublished YoNAH results
West Greenland		
1988	373 (0.14)	Larsen and Hammond (2000)
1989	362 (0.10)	Larsen and Hammond (2000)
1991	430 (0.20)	Larsen and Hammond (2000)
1992	406 (0.11)	Larsen and Hammond (2000)
Iceland		
1987	1,816 (0.18)	Gunlaugsson and Sigurjónsson (1990)
Norway		
1988	1,126 (0.31)	Øien (1990) and SC/53/NAH21
1989	698 (0.59)	Christensen *et al*. (1992) and SC/53/NAH21
1995	889 (0.32)	SC/53/NAH21

Table 6
Relative abundance.

Year	Animals/day	Source
Iceland		
1970	0.11	Sigurjónsson and Gunnlaugsson (1990, table 2)
1971	0.37	Sigurjónsson and Gunnlaugsson (1990, table 2)
1972	0.25	Sigurjónsson and Gunnlaugsson (1990, table 2)
1973	0.31	Sigurjónsson and Gunnlaugsson (1990, table 2)
1974	0.64	Sigurjónsson and Gunnlaugsson (1990, table 2)
1976	0.16	Sigurjónsson and Gunnlaugsson (1990, table 2)
1977	0.59	Sigurjónsson and Gunnlaugsson (1990, table 2)
1978	0.63	Sigurjónsson and Gunnlaugsson (1990, table 2)
1979	0.66	Sigurjónsson and Gunnlaugsson (1990, table 2)
1980	0.54	Sigurjónsson and Gunnlaugsson (1990, table 2)
1981	0.88	Sigurjónsson and Gunnlaugsson (1990, table 2)
1982	1.01	Sigurjónsson and Gunnlaugsson (1990, table 2)
1983	0.33	Sigurjónsson and Gunnlaugsson (1990, table 2)
1984	1.20	Sigurjónsson and Gunnlaugsson (1990, table 2)
1985	0.87	Sigurjónsson and Gunnlaugsson (1990, table 2)
1986	1.34	Sigurjónsson and Gunnlaugsson (1990, table 2)
1987	1.93	Sigurjónsson and Gunnlaugsson (1990, table 2)
1988	1.83	Sigurjónsson and Gunnlaugsson (1990, table 2)

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Appendix 6

PROPOSAL FOR RESEARCH ON HUMPBACKS OF THE CAPE VERDE ISLANDS

B. Jann, J. Allen and P. Palsbøll

Introduction

During the meeting of the sub-committee on the Comprehensive Assessment of North Atlantic humpback whales, the need for further research on the identity of the breeding population of the Cape Verde Islands was identified as a high priority issue. Although some attempts were made in the recent past (SC/53/NAH19; Carrillo *et al*., 1999; Hazevoet and Wenzel, 2000), the allocation of this population of whales to any feeding ground has not been successful.

There is a clear indication through genetic analysis, that the humpback whales present in the North Atlantic feeding grounds derive from different breeding populations (SC/53/NAH11). It is well known that the West Indies represent one important breeding ground for all feeding grounds (Stevick *et al.*, 1998; 1999). Most humpbacks feeding in the Barents Sea, however, originate from another breeding ground (SC/53/NAH11). Although females with very young calves, competitive groups and singing whales have been observed around the Cape Verde Islands and their presence in winter and early spring in these waters suggests that they are part of the North Atlantic population (SC/53/NAH19), no direct evidence exists that these waters represent a breeding ground for North Atlantic humpbacks. Until now, none of the 28 fluke ID photographs taken in the Cape Verde Islands could be matched with any other animal previously photographed in the North Atlantic (SC/53/NAH19; Carrillo *et al*., 1999). Therefore two main questions have to be answered.

(1) Where do these animal feed?
(2) Are they distinct from those present in the West Indies?

Methods

Previous work (SC/53/NAH19; Carrillo *et al*., 1999) has demonstrated the feasibility of such studies in this area, given the appropriate logistic support. To continue and improve the investigation of the identity of this population of whales and to ascertain their numbers and their relationship to the other whales present in the North Atlantic feeding grounds, the activities needed include the following.

(1) Collection and analysis of photographic material;
(2) Collection and analysis of genetic material; and
(3) Recording and analysis of songs.

Satellite tagging does not appear feasible at this time, according to expert advice.

An appropriate vessel is stationed in the Cape Verde Islands and has donated six weeks of ship-time to the principal researcher.

Photo-identification

This will be done using a 35mm camera with a 75-300mm zoom lens using 400 ASA colour slide film. The digitised pictures will be deposited at the North Atlantic Humpback Whale Catalogue in Bar Harbour, Maine and matched with those already present in the collection as well as those from the YoNAH Catalogue and the photographs of animals from the Western Equatorial region present in the Antarctic Catalogue. The expected number of photo-identification samples is about 20, according to the experience gained in previous studies.

Genetic material

The samples will be collected either as sloughed skin samples or as biopsies and processed according to the directions given by Palsbøll. Then they will be compared with the genetic database of individual profiles of *ca* 2,550 individual animals known from the North Atlantic. The expected number of samples lies between 10 and 15.

Acoustic recordings

The acoustics work is the focus of a separate, ongoing project.

The expected costs for the collection and analysis of photographic and genetic material in 2002 are in the order of £8,000.

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Appendix 7

LARGE VESSEL HUMPBACK WHALE RESEARCH POSSIBILITIES IN THE CARIBBEAN

Tim Smith

To address several uncertainties about the distribution, abundance and biology of the North Atlantic humpback whale, many of which were discussed at this meeting, a large vessel survey is proposed to be undertaken by scientists from eastern Caribbean nations and the USA in coordination with and to complement nearshore sighting surveys planned for local waters undertaken by individual eastern Caribbean nations.

This possibility was discussed at a January 2001 Workshop held in Miami, Florida on the coordination of research on humpback whales in the eastern Caribbean (SC/53/NAH22). The workshop participants concluded that the inclusion of passive acoustics in the survey methodology increased the detection rate of humpback whales in this region over visual based surveys alone, and that local nearshore surveys should be complemented by large vessel surveys of the offshore areas.

The workshop was attended by 24 scientists and fisheries managers with broad expertise in whale survey methods and the current state of information concerning cetaceans in the Eastern Caribbean. They encouraged cooperative research among the eastern Caribbean nations who share an interest in the status of humpback whales in the region.

Possible objectives of a large vessel survey include:

(1) survey deep offshore waters around the island nations of the Eastern Caribbean to complement local surveys of the nearshore waters conducted by national research teams from each country;
(2) include surveys of areas not covered by the 2000 survey to completely identify the winter range of humpback whales in this region;
(3) collect additional genetic and photographic samples from individual whales to determine their relationship to the North Atlantic population;
(4) further refine the acoustic methods used to detect humpback whales, and from data collected, determine the seasonal abundance (i.e. regional density) of whales utilising the eastern and southern Caribbean during the winter; and
(5) characterise the marine habitats currently preferred by humpback whales to determine why there has been a shift in the whales' use of habitats since commercial whaling ceased in this region.

The USA would make available the NOAA RV *Gordon Gunter*, an 85m oceanographic research vessel which has been used for marine mammal acoustic and sightings surveys in this region previously. Field sampling methods that could be effectively employed from this platform include visual sighting and passive acoustic surveys using a towed array, and deployment of sonobouys. Photographic and biopsy sampling might also be attempted, but this may be more efficiently done with smaller vessels.

The survey might follow the same general track as that used in an earlier survey conducted in 2000. That is, the first leg would begin at the Turks and Caicos and, moving from north to south, focus on the waters around the eastern islands of the Greater Antilles and the Lesser Antilles, including the Dominican Republic, Puerto Rico, Virgin Islands, Anguilla, St Martine, St Barthelemy, Saba, St Kitts and Nevis, Antigua and Barbuda, Montserrat, Guadeloupe, Dominica, Martinique, St Lucia, St Vincent and the Grenadines, Barbados, Grenada, Trinidad and Tobago, and the north shore of Venezuela. The second leg would work its way from south to north following the track of the first leg. In this way, two replicates of each area would be obtained.

The major cost of the survey would be born by the USA in providing the vessel time and operating costs. Additional expenses of travel for the scientific staff would be roughly \$30,000, to facilitate allowing for participation by scientists from the interested nations.