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Fin Whale Abundance in the Eastern North Atlantic, Estimated From Spanish NASS-89 Data

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ABSTRACT

Applying standard line transect analysis to the Spanish NASS-89 sightings survey data, the abundance of fin whales in the eastern Atlantic west of Iberia and south-west of the British Isles is estimated as 17,335 whales (CV=0.266; 95% confidence interval (10,400, 28,900) whales).

KEYWORDS: FIN WHALE; NORTH ATLANTIC; SURVEY-SHIPBOARD; ASSESSMENT.

INTRODUCTION

Large-scale line transect surveys of the North Atlantic to assess whale abundance were carried out in 1987 and 1989 (North Atlantic Sightings Surveys, NASS-87 and NASS-89). Between 5 July and 9 August 1989, a Spanish vessel participating in NASS-89 surveyed that part of the eastern Atlantic bounded by 25°W to the west, the European continental shelf to the east, 42°N to the south and 52°N to the north. For logistic reasons, the area was covered in two parts, the Atlantic area, spanning 244,390 n.miles^2, and the Bay of Biscay area, spanning 170,900 n.miles^2 (Lens, 1991; see Fig. 1). We analyse the fin whale (*Balaenoptera physalus*) data from this survey.

Most of the surveyed area was within the limits of the International Whaling Commission's 'Spain-Portugal-British Isles' stock of fin whales (Donovan, 1991), but the area west of 18°W, out to 25°W, was also covered. To estimate abundance of different stocks in the North Atlantic, the sightings data should be considered together with data from other surveys carried out during NASS-89.

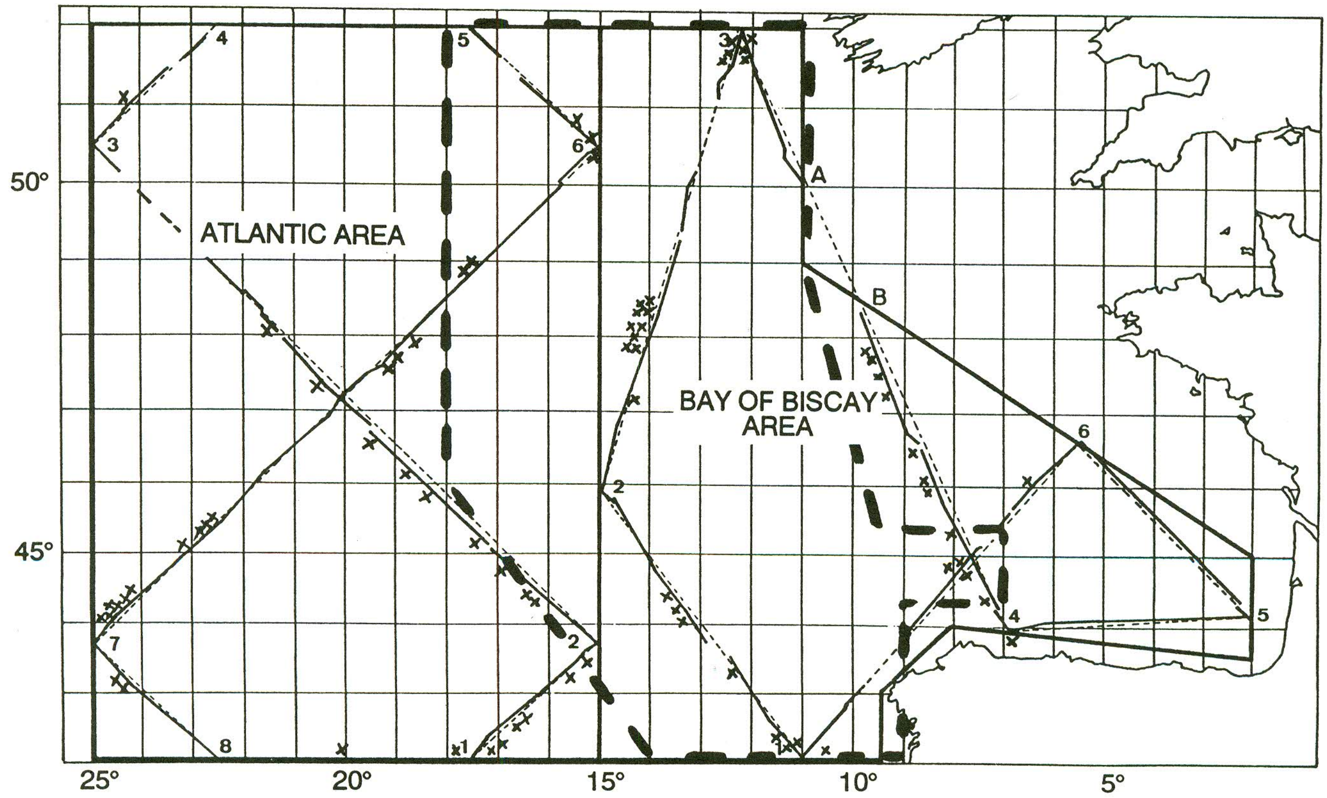

Fig. 1. Spanish cruise tracks in NASS-89. The broken lines show the planned track and the solid lines actual effort. Approximate positions of confirmed fin whale sightings are shown by crosses. The heavy broken line delineates the area surveyed by the Spanish vessel in NASS-87.

Table 1

Number of sightings (after truncation but before smearing), *esw*, encounter rate and mean school size by sea state, Spanish fin whale data, NASS-89. Standard errors in parentheses. Values in the same column with different superscript letters are significantly different ($p < 0.05$).

Beaufort	Number of sightings, n	*esw* (n.miles)	Encounter rate (schools/100 n.miles)	Mean school size, s
0-2	16	0.275 (0.153)[a]	1.93 (0.53)[ab]	2.06 (0.35)[a]
3	23	0.268 (0.110)[a]	1.33 (0.27)[a]	1.52 (0.18)[ab]
4-7	29	0.452 (0.128)[a]	3.01 (0.64)[b]	1.31 (0.12)[b]

Table 2

Number of sightings (after truncation but before smearing), *esw*, encounter rate and mean school size by area, Spanish fin whale data, NASS-89. Standard errors in parentheses. Values in the same column with different superscript letters are significantly different ($p < 0.05$).

Block	Number of sightings, n	*esw* (n.miles)	Encounter rate (schools/100 n.miles)	Mean school size, $\bar{s}$
Atlantic	31	0.269 (0.089)[a]	1.92 (0.31)[a]	1.39 (0.14)[a]
Bay of Biscay	37	0.429 (0.106)[a]	1.90 (0.35)[a]	1.70 (0.18)[a]

METHODS

As far as possible, the methods used by Buckland *et al.* (1992) to analyse Icelandic and Faroese NASS fin whale data were applied. Thus the hazard-rate model was fitted to smeared perpendicular distances. The smearing method was method 2 of Buckland and Anganuzzi (1988). Detections were considered to correspond to schools for the purpose of analysis, although an analysis in which individual animals were taken as the detections was also carried out. The latter strategy has been adopted by the IWC Scientific Committee for Southern Hemisphere minke whales (IWC, 1988), in an attempt to avoid the bias associated with estimating average school size from detected schools only, which might for example be larger on average than undetected schools. Another solution to this problem is to stratify the sightings data by school size, and this approach is also attempted.

Three potential stratification factors were identified: geographic block, Beaufort and school size. Ideally stratification should be by all three factors, but sample size considerations preclude this. To assess say the effect of Beaufort, each of average school size, encounter rate and effective search half-width (denoted here by *esw*) are estimated for each Beaufort category in turn, pooling across all other possible stratification factors. Standard errors are calculated for each estimate, and z-tests carried out to assess whether there are significant differences in estimates at different Beauforts. Standard error for school size is calculated as sample standard deviation divided by square root of sample size. For encounter rate, the rate per day is calculated, and the sample variance of these rates, weighted by daily effort, is used to calculate the standard error, as described for the empirical method by Burnham, Anderson and Laake (1980). The standard error for *esw* is obtained from likelihood methods, via the information matrix.

95% confidence intervals for population abundance were obtained by assuming that estimated abundance N is log-normally distributed (Burnham *et al.*, 1987, p.212):

$$(\hat{N}/C,\ \hat{N}.C),$$

where

$$C = exp[1.96\ .\ \sqrt{\{\hat{v}ar(log_e\hat{N})\}}]$$

and

$$\hat{v}ar(log_e\hat{N}) = log_e[1 + \frac{\hat{v}ar(\hat{N})}{N^2}].$$

Table 3

Number of sightings (after truncation but before smearing), *esw* and encounter rate by school size, Spanish fin whale data, NASS-89. Standard errors in parentheses. Values in the same column with different superscript letters are significantly different ($p < 0.05$).

School size	Number of sightings, n	*esw* (n.miles)	Encounter rate (schools/100 n.miles)
1	44	0.347 (0.088)[a]	1.25 (0.24)[a]
2-6	24	0.346 (0.117)[a]	0.67 (0.18)[a]

RESULTS

The *esw* did not differ significantly by sea state, area or school size (Tables 1–3), although it was relatively large in high Beaufort. Since this is the reverse of what might be expected, and the difference is not significant, pooling across sea state categories seems justified. We therefore fit a single detection curve to all primary sightings for the preferred analysis (Fig. 2). Relatively more effort was carried out in high Beaufort conditions in the Bay of Biscay area, for which the estimated *esw* was 60% higher than for the Atlantic area. Although the difference is non-significant, analyses were carried out by fitting a detection curve separately to the data from each area (method 2), in addition to the preferred method (method 1). Table 4 indicates that precision is relatively poor for method 2.

The encounter rate was significantly lower at Beaufort 3 than at Beauforts 4–7, and mean school size was significantly higher at Beauforts 0–2 than at Beauforts 4–7. For our preferred analysis, we therefore estimate both encounter rate and mean school size for each of two sea state categories: 0–3 and 4–7. Although neither encounter rate nor mean school size differed significantly by area, we estimate them separately by area, since there is little loss

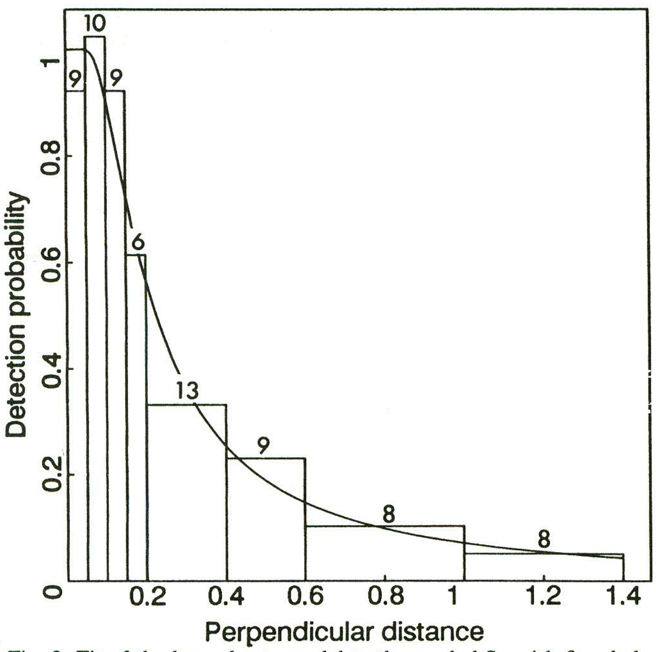

Fig. 2. Fit of the hazard-rate model to the pooled Spanish fin whale NASS-89 data.

from doing so, and it is then unnecessary to assume the parameters are equal for the two areas.

Abundance is therefore estimated as 17,335 whales, with 95% confidence interval (10,400, 28,900). Few schools of more than two animals were detected. After truncation, there were 44 primary detections of single animals, 16 of two animals, four of three, three of four, and one of six animals. Table 3 indicates there would be no advantage in stratifying by school size. Furthermore, sample size would be small for estimating *esw*, so this option was not attempted. An analysis was also carried out with the individual whale as the sampling unit, and the abundance estimate increased to 18,369, although the confidence interval is very similar (Table 4).

Many large whales were detected but not identified. In the Atlantic area (Fig. 1), there were 38 sightings of fin whales (including secondary sightings), comprising 55 animals, and 45 sightings (61 animals) recorded as unidentified rorquals or baleen whales; for the Bay of Biscay area, these numbers were 38 (63 animals) and 57 (68 animals) respectively (Lens, 1991). If the unidentified animals are included in the analyses, the favoured method of analysis yields a total abundance estimate of 17,904 whales (SE=4,564), compared with 17,335 whales (SE=4,605) when only confirmed fin whale sightings are analysed. Despite the large number of unidentified sightings, the estimate and standard error are barely affected. This arises because the vessel operated in 'passing mode', and most unidentified large whales were detected some distance from the trackline. It is likely that most or all of the unidentified large whales were fin whales.

DISCUSSION

The NASS-87 survey covered an area of 193,947 n.miles^2, extending only to 18°W and spanning less of the Bay of Biscay than the NASS-89 cruise (Fig. 1). The earlier survey was described and the fin whale sightings data were analysed by Sanpera and Jover (1989). Correcting an error in their estimated standard error of mean school size and including the school of size five omitted by them, their analyses yield an abundance estimate of 4,618 whales (CV=0.0983; 95% CI (3,810, 5,600), which equates to 238 whales/(100 n.miles)^2; the corresponding estimate of takeable whales only is 4,249 (CV=0.109). By comparison, we obtain an estimate of 17,335 whales in 415,290 n.miles^2, or 417 whales/(100 n.miles)^2. Thus, estimated density was 43% lower in 1987, although this difference is not statistically significant ($p>0.1$).

Although estimated density was lower, the encounter rate with primary sightings of fin whale schools in 1987 was almost double that in 1989. The apparent discrepancy arises because mean school size was 16% higher in 1989, and because the *esw* was 2.8 times greater in 1987 than in 1989, partly because a high proportion of rorquals detected at some distance from the trackline was unidentifed in 1989, but not in 1987. If unidentified large whales are included, the encounter rate with schools was 9% lower in 1987 than in 1989, while the encounter rate expressed as number of animals (as distinct from schools) per unit distance was 21% lower.

Table 4

Abundance estimates, 'Iberian' fin whale stock, Spanish data, NASS-89. Method 1 is the preferred method defined in the text. Method 2 is the same as method 1, except the estimate of *esw* is stratified by area. Method 3 is the same as method 1, except that individual whales are taken as the sampling unit. Method 4 is the same as method 1, except records of unidentified large rorquals are included.

Method	Area	Beaufort		Average, weighted by effort	95% confidence interval
		Low (0-3)	High (4-7)		
1	Atlantic	6894 (2069)	17355 (7363)	9257 (2688)	(5300,16168)
	Biscay	8048 (3278)	8144 (2923)	8078 (2686)	(4282,15239)
	Both			17335 (4605)	(10391,28920)
2	Atlantic	8906 (3494)	22419 (11071)	11958 (4604)	(5770,24782)
	Biscay	6522 (2779)	6600 (2508)	6546 (2326)	(3330,12868)
	Both			18505 (5158)	(10826,31632)
3	Atlantic	7385 (1889)	18118 (6213)	9810 (2418)	(6095,15790)
	Biscay	8518 (3614)	8651 (2951)	8559 (2871)	(4513,16232)
	Both			18369 (4508)	(11435,29508)
4	Atlantic	6947 (2226)	15340 (5371)	8843 (2426)	(5216,14993)
	Biscay	9142 (3644)	8878 (3311)	9061 (2955)	(4859,16896)
	Both			17904 (4564)	(10949,29277)

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