

SPERM WHALE ABUNDANCE ESTIMATES FROM ACOUSTIC SURVEYS OF THE IONIAN SEA AND STRAITS OF SICILY IN 2003

REPORT TO ACCOBAMS

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INTRODUCTION

There are no population estimates of sperm whales in the Mediterranean at present (Whitehead 2002), the population status is classed as ‘unknown’ (Notarbartolo di Sciara 2002), and limited data are available on historical population size from whaling records. However, sperm whales in the Mediterranean are impacted by a number of anthropogenic threats. Information is therefore needed to assess current abundance, particularly in view of the likely isolation and uncertain status of the population (Notarbartolo di Sciara 2002, Annex 1). This study provides abundance estimates of sperm whales for the Ionian Sea and the Straits of Sicily based on acoustic line-transect surveys carried out between 10th August and 17th October 2003. Further details of sightings results and field methods for the surveys can be found in Lewis *et al.* 2003.

SURVEY AREA AND TRACKLINE DESIGN

The two survey blocks (red polygons) and the formal survey transects (green) followed by the survey vessel are shown in fig. 1a. The track lines were designed to provide roughly even coverage probabilities in each block. The areas of the Ionian Sea block and the Straits of Sicily block were 271 500 km² and 62100 km², respectively.

Sperm whale abundance estimates for Ionian Sea & Straits of Sicily from IFAW's 2003 survey

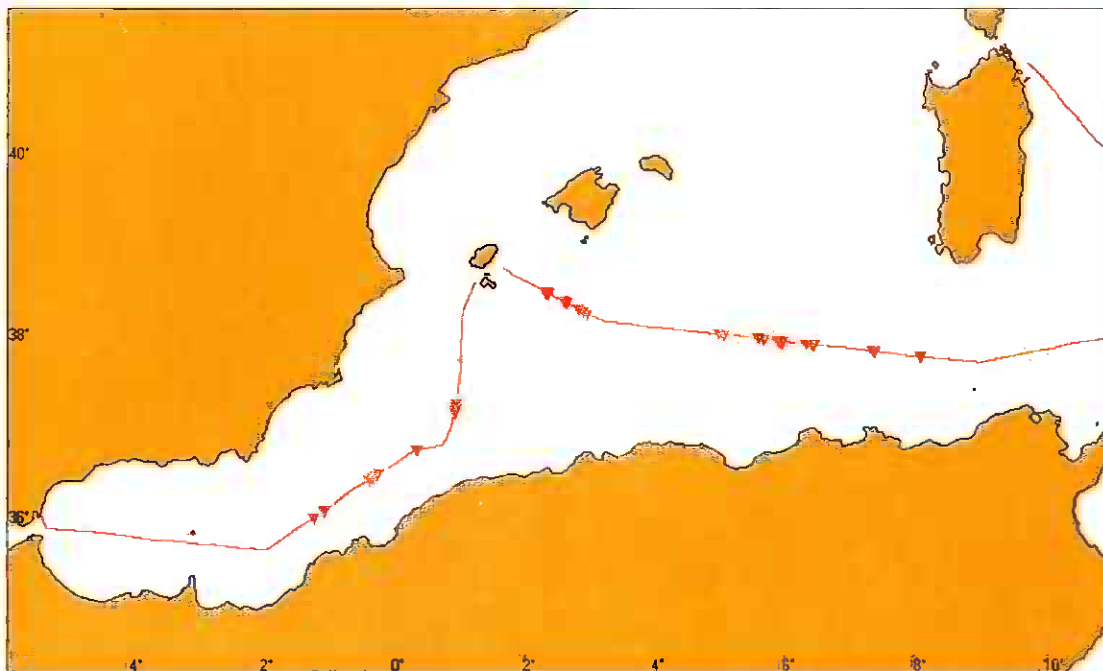
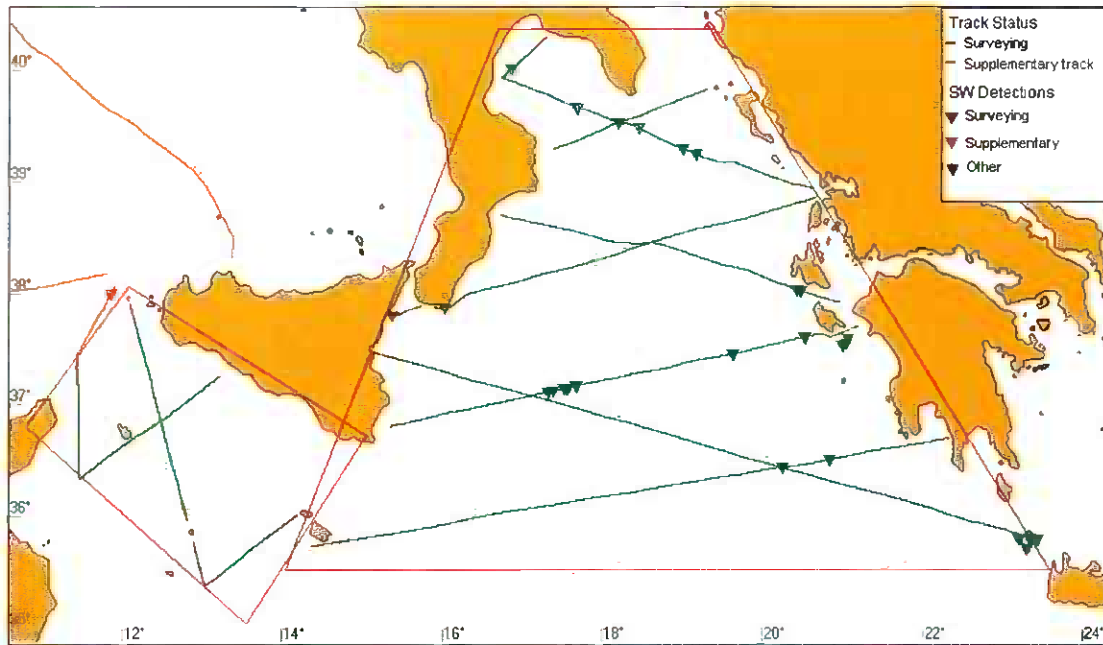


Figure 1a (top): Survey track lines (green) and acoustic detections of sperm whales while surveying (dark green triangles) and off-effort (light green triangles). The Straits of Sicily block is on the left, and the Ionian Sea block on the right (red polygons).

Figure 1b (bottom): Examples of pseudo-random passages (orange lines) in the western Mediterranean providing supplementary detection data (orange triangles).

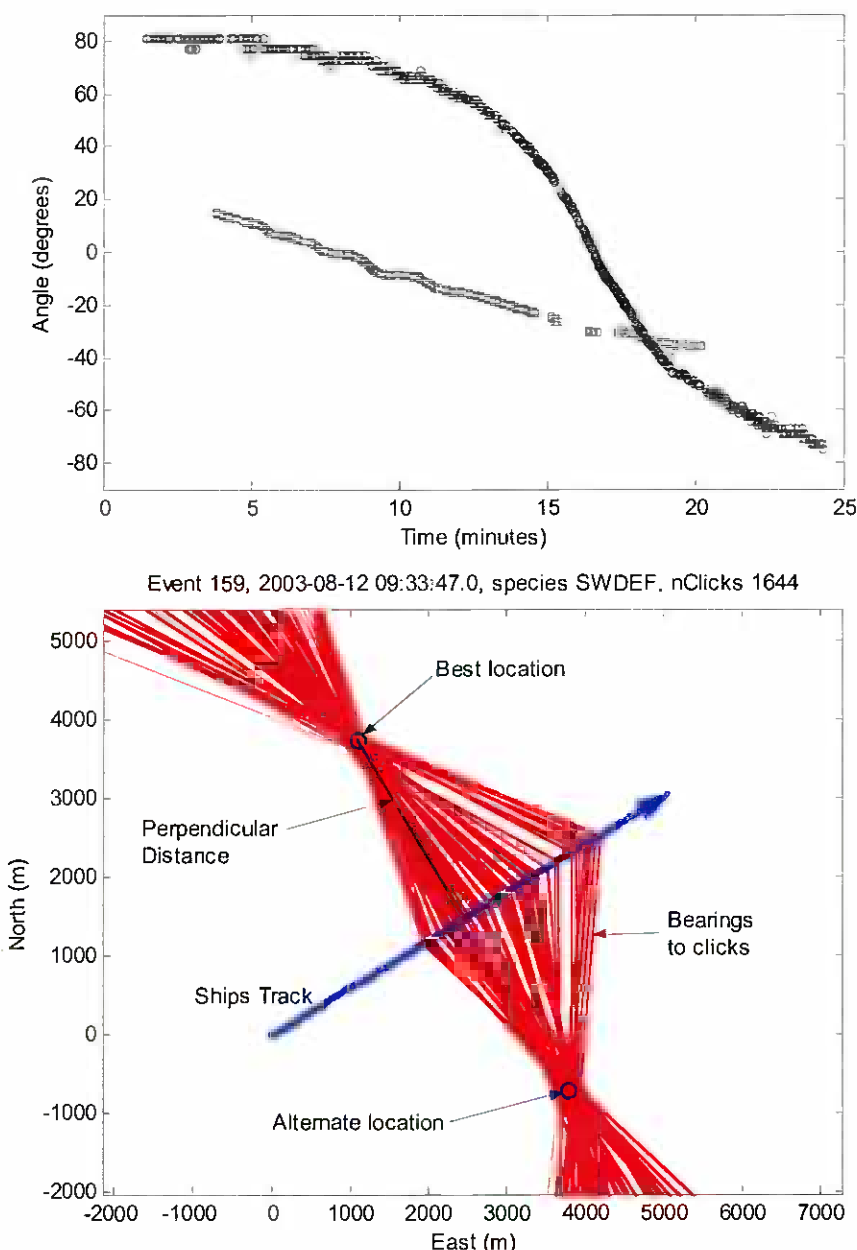


Figure 2a (top): Tracks of two sperm whales as the vessel passed by.
2b (bottom): Reconstruction of one whale's position to estimate perpendicular distance.

ACOUSTIC DATA COLLECTION AND ANALYSIS

Acoustic data were collected using a 200 m long towed hydrophone array which contained two hydrophone elements (100 Hz – 22 kHz bandwidth) spaced 3 m apart. Time of arrival differences of sperm whale clicks on the two hydrophones were used to determine bearings to whales and target-motion analysis was used to estimate their locations.

Signals from the hydrophone were digitized using a sound card (Creative Labs Extigy). RainbowClick software (www.ifaw.org/sotw) automatically scanned incoming signals for candidate clicks, which were stored on disk for later analysis. Automated recordings (WAV files) were also made when the system detected potential sperm whale sounds. The algorithm used to detect clicks was similar to that described in Gillespie (1997) except for the addition of a 4th order Butterworth-response high-pass digital filter with a corner frequency at 2 kHz.

Assignment of individual clicks to individual whales was carried out manually using the graphical user interface of RainbowClick, based on click bearings, inter-click intervals, spectral characteristics and positions of whales. Once click trains had been identified, the least squares fit was used to calculate the best position for each animal. Since the calculated bearings to whales contain a rotational ambiguity about the array axis, it is not known whether the animal is to the left or the right of the track line. The fit was therefore carried out for both sides, and the side with the best fit (based on a χ^2 statistic) taken (fig. 2b). When the vessel track was reasonably straight, there would be no difference between the fit for the positions on either side, however, if there were significant heading changes, one position would have a much better fit than the other.

DETECTION FUNCTION ESTIMATION

The number of detections gathered in the two survey blocks was low (17 in the Ionian Sea and 0 in the Straits of Sicily) and insufficient for detection function estimation. It was therefore necessary to use supplementary detection data, gathered on pseudo-random passages made in the same year using the same platform, equipment, software and settings. These supplementary passages were selected to ensure they were straight-line passages in directions unrelated to coastal margins, bathymetry, or to any prior knowledge of whale distribution. Supplementary passages are shown in figs. 1a and 1b. This procedure provided 63 detections in total, and the resulting perpendicular distance data are shown in figure 3.

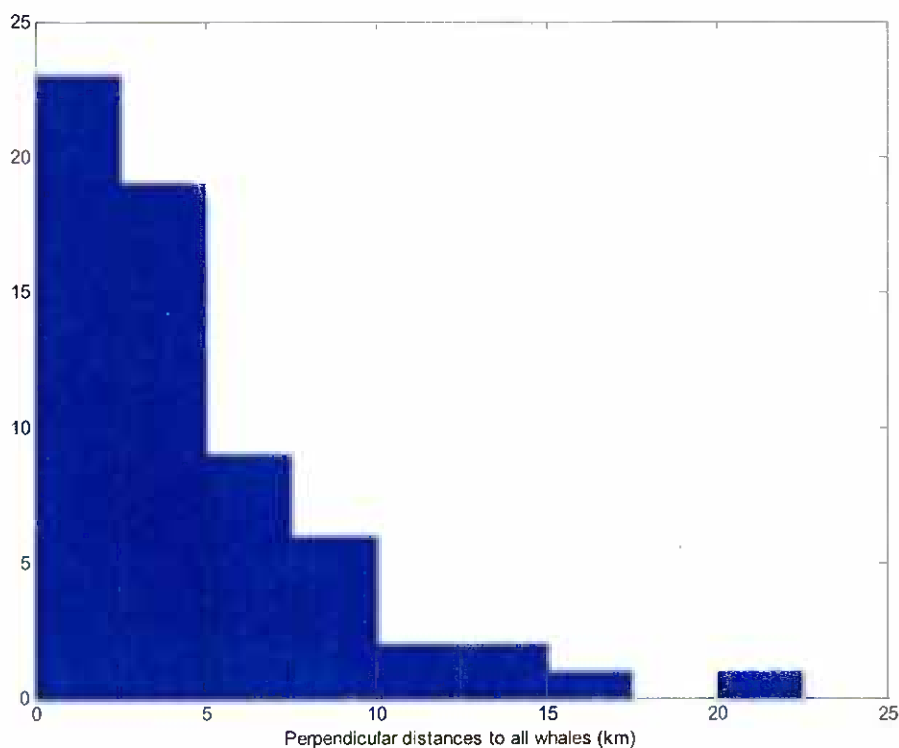


Fig. 3 Histogram of perpendicular distances to all located sperm whales.

Examination of the nearest-neighbour distances between whales indicated a heap at inter-animal distances of less than 1 km (fig. 4), which we interpret to show a division of sperm whale aggregations into relatively dispersed animals and tighter clusters. Accordingly animals were stratified as either dispersed or clustered based on this 1 km nearest-neighbour distance and histograms of the perpendicular distances at which individual whales in these two strata were detected are shown in fig. 5. These show much smaller perpendicular distances to

animals that are part of clusters, mostly within 5 km, while distances to dispersed animals extend further - to the truncation distance of 20 km.

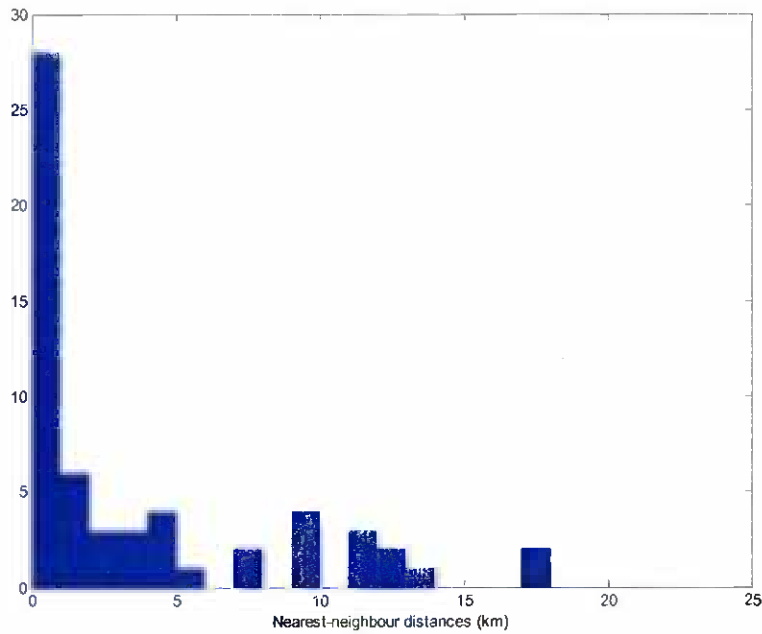


Figure 4. Histogram of nearest-neighbour distances. Four distances extended beyond the upper limit of the x-axis shown here.

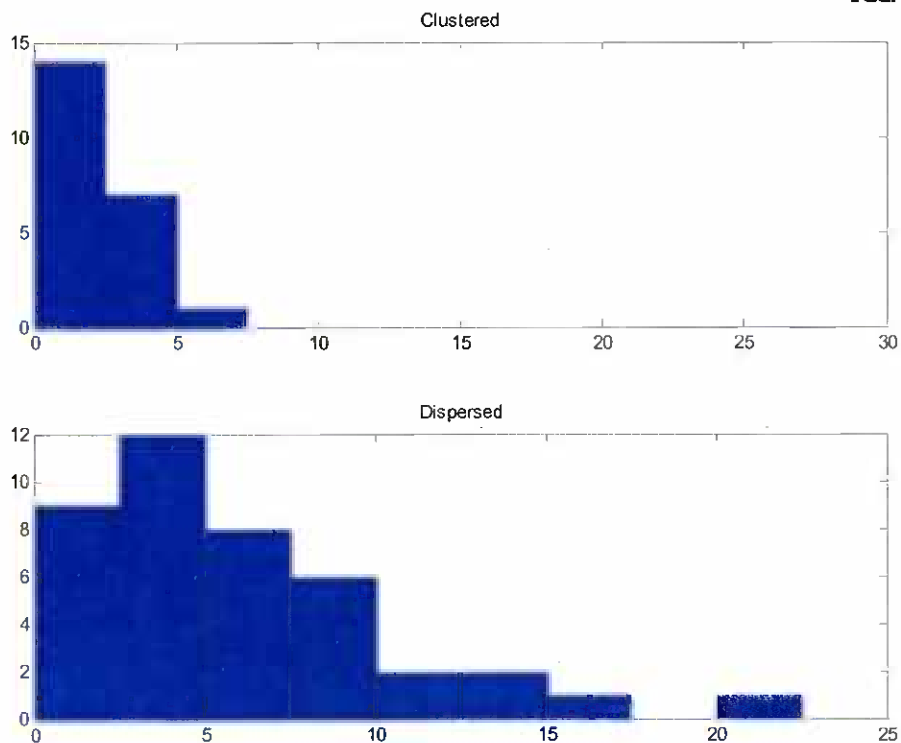


Figure 5. Histograms of distance data to individuals, stratified as clustered or dispersed.

Sperm whale abundance estimates for Ionian Sea & Straits of Sicily from IFAW's 2003 survey

Comparisons between the Ionian Sea survey data and the supplementary data showed that based on the 1 km nearest-neighbour distance the Ionian Sea survey detections were all dispersed (Table 1). It should be noted that within the Ionian Sea some animals did appear to be loosely aggregated, however they were not close enough to be classified as clustered. The present analysis therefore proceeds by estimating a detection function for the dispersed stratum only, which is then used for abundance estimation in the Ionian Sea block.

	Ionian Sea survey	Supplementary track
Clustered	0	28
Dispersed	17	25

Table 1. Number of detections by aggregation stratum (clustered/dispersed) and data source.

The truncation width was set at 20 km (resulting in two individuals being excluded), after which there were 40 dispersed detections available for detection function estimation. The function used was a Fourier-series model, fitted to the truncated distance data (fig. 6).

The estimated strip half-width $\hat{\mu} = 10.0$ km

with

$$\text{var}(\hat{\mu}) = 1.466$$

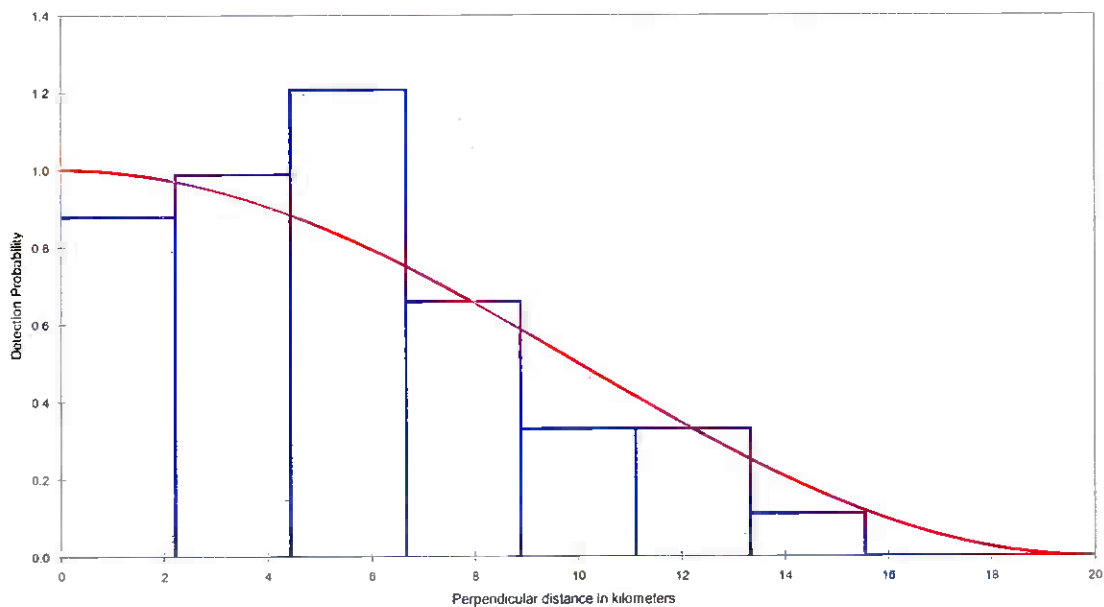


Figure 6. Histogram of perpendicular distances to dispersed sperm whales, and fitted detection function.

DENSITY AND ABUNDANCE ESTIMATION

Abundance estimation is based on the assumption that for acoustic methods $g(0) = 1$. This assumption is supported by data from joint visual and acoustic surveys where sperm whales were never detected visually without being detected acoustically (Leaper *et al.* 2000, Barlow and Taylor, 2005). Because of the small number of transects (8) in the Ionian Sea, variance estimation in the abundance estimates was carried out using the Satterthwaite approximation (Buckland *et al.* 2001).

Straits of Sicily

No sperm whales were encountered here in 892 km of survey transects, so $\hat{N} = 0$.

Ionian Sea

A total of 16 whales were detected within the truncation distance of 20 km along 3846 km of survey transects.

The estimated abundance is:

$$\hat{N} = A \times \frac{n}{2L\hat{u}} = 271500 \times \frac{16}{2 \times 3486 \times 10.0} = 62$$

with variance from :

$$\text{vâr}(\hat{N}) = A^2 \times \text{vâr}(\hat{D}) = A^2 \times \hat{D}^2 \left\{ \frac{\text{vâr}(n)}{n} + \frac{\text{vâr}(\hat{f}(0))}{\hat{f}(0)^2} \right\} = 751$$

using $\text{vâr}(n) = 46.2$.

The abundance estimate is thus 62 with lognormal 95% confidence limits of [24, 165] using the Satterthwaite approximation. The corresponding density estimate is $\hat{D} = 0.23 \times 10^{-3}$ with 95% confidence limits of $[0.869 \times 10^{-4}, 0.606 \times 10^{-3}]$.

DISCUSSION

The analysis given here provides the first sperm whale abundance estimates for parts of the Mediterranean Sea.

Two difficulties arose that required non-standard analysis:

Firstly, the small number of detections whilst on survey in the Ionian Sea ($n=17$) required that supplementary data were obtained from passages elsewhere in the western Mediterranean, in order to estimate the detection function. Although these transects were carried out from the same vessel using the same equipment there is the possibility that different acoustic propagation conditions may make such pooling of data inappropriate. However, we believe that the likely variation in background noise and propagation within the survey blocks would be greater than between blocks.

Secondly, the data were stratified into clustered and dispersed animals, because the distance data for clustered animals (as found in the supplementary data) appeared to be of a different shape, with a smaller strip-width. Because the Ionian Sea survey detections were all classified as dispersed, only the detection function for the dispersed stratum was required in the current analysis.

The histogram of distances for clustered animals (fig. 5a) may be an indication of differences in acoustic behaviour or some aspect of the detection process when a number of whales are in association. But it should also be noted that while the histogram shows the perpendicular distances to 28 individual whales, these whales were encountered within only about five clusters. Thus figure 5a does not represent a robust detection function for clusters, because of the small sample size. These data were not required for the abundance estimates presented.

The stratification into clustered/dispersed animals is a rather crude oversimplification of the behaviour of sperm whales, which are known to aggregate over a range of spatial scales (Whitehead 2003). There is likely some degree of spatial dependence even between animals classed here as dispersed. A consequence for surveys is possible underestimation of the confidence limits on abundance.

The assumptions about $g(0)$ also have implications for the confidence limits. Although we believe that the bias introduced by assuming $g(0) = 1$ is small, there have been behavioural studies in which sperm whales did not vocalise for periods of several hours (Barlow and Taylor, 1998). On the other hand, Teloni (2005) tracked sperm whales in the Mediterranean, and did not report any silent periods greater than about 40 minutes. Periods when whales do not vocalise regularly may also be related to grouping behaviour involving social activity at the surface. The small probability that a group of whales may not be detected may also lead to an underestimation of the upper confidence limit even if the bias related to assumptions regarding $g(0)$ is small.

There are two potential sources of errors in the analysis process that should be noted. Firstly the manual assignment of clicks to individual whales may be liable to mis-assignments when the following circumstances occur together: animals are close together (relative to their distance from the track line), their clicks have similar characteristics, and click trains are broken or asynchronous (animals not echo-locating at the same time). Probabilistic solutions to this problem are being investigated. Secondly the calculation of the nearest-neighbour distance, on which stratification is based, depends on locating animals using the least-squares fit. As the track of the platform approaches a straight line then it becomes more difficult to resolve which side of the track line whales are located, and hence there may be some ambiguity in the nearest-neighbour distances.

Although the sperm whales detected in the Ionian Sea while formally surveying were relatively dispersed, it is doubtful that this is a reliable characterisation of the general behaviour of whales in the area, because two larger aggregations were observed on passage (i.e., not surveying) on the eastern side. A speculative interpretation might be that the whales tend to aggregate in larger groups in the Hellenic Trench, making occasional more solitary forays into the basin of the Ionian Sea. It would be advisable in future surveys to consider the Hellenic Trench as a separate stratum, particularly in the light of the distribution results given by Frantzis *et al.* (2003).

Overall sperm whale density appears to be very low in the Ionian Sea and the Straits of Sicily, compared to results obtained in other regions of sperm whale habitat (summarised by Whitehead, 2003). Further surveys should be carried out in the future to monitor the status of sperm whales in this area. In the meantime research should be carried out to determine whether the low densities are a result of human induced mortality. If this were the case then population numbers are so low that measures to reduce threats may be urgently required.

SELECTED REFERENCES

- Song of the Whale Research Team. 2004. *Results of 2003 Pilot Survey and Remarks on Proposed Basin-Wide Sperm Whale Survey*. IFAW report to ACCOBAMS 2nd Meeting of Parties, Palma de Mallorca; 9-11th November 2004.
- Barlow, J. and Taylor, B.L. 1998. Preliminary abundance of sperm whales in the northeastern temperate Pacific estimated from a combined visual and acoustic survey. Paper SC/50/CAWS20 presented to IWC Scientific Committee, Oman, 1998.
- Barlow, J. and Taylor, B. 2005 Estimates of sperm whale abundance in the northeastern temperate Pacific from a combined acoustic and visual survey. *Marine Mammal Science* 21: 429-445.
- Buckland, S., Anderson, D., Burnham, J., Laake, J., Borchers, D. and Thomas, L. 2001. *Introduction to Distance Sampling*. Oxford University Press.
- Frantzis, A., Alexiadou, P., Paximadis, G., Politi, E., Gannier, A. and Corsini-Foka. M. 2003. Current knowledge on the cetacean fauna of the Greek Seas. *J. Cet. Res. Manage.* 5: 219-232.
- Gannier, A., Drouot, V. and Goold, J. 2002. Distribution and abundance of sperm whales in the Mediterranean Sea. *Marine Ecology Progress Series* 243: 281-293.
- Leeper, R., Gillespie, D. and Papastavrou, V. 2000. Results of passive acoustic surveys for odontocetes in the Southern Ocean. *J. Cetacean Res. Manage.* 2(3): 187-196.
- Gillespie D. 1997. An acoustic survey for sperm whales in the southern ocean sanctuary conducted from RSV Aurora Australis. *Reports of the International Whaling Commission* 47:897-906.
- Lewis, T., et al. 2003. *Report of the summer 2003 sperm whale survey by the International Fund for Animal Welfare; preliminary findings and some considerations for a Mediterranean-wide survey*. Report presented to the SC meeting of ACCOBAMS, Istanbul, November 2003. IFAW. 14 pp.
- Notarbartolo di Sciara, G. 2002. *Cetaceans of the Mediterranean and Black Seas: State of Knowledge and Conservation Strategies*. Report to ACCOBAMS Secretariat, Monaco.
- Notarbartolo di Sciara, G., Bearzi, G., Canadas, A. and Frantzis, A. 2004. *High mortality of sperm whales in the north-western Mediterranean, 1971-2003*. Paper SC/56/BC10 presented to IWC Scientific Committee, Sorrento, Italy, June 2004.
- Teloni, V. 2005 Patterns of sound production in diving sperm whales in the northwestern Mediterranean. *Marine Mammal Science*, 21(3):446-457.
- Whitehead, H. 2002. *Estimates of the current population size and historical trajectory for sperm whales*. *Marine Ecology Progress Series*. 242: 295-304.
- Whitehead, H. 2003. *Sperm Whales: Social Evolution in the Ocean*. University of Chicago Press.

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