Abundance estimate of striped dolphins (*Stenella coeruleoalba*) in the Pelagos Sanctuary (NW Mediterranean) by means of line transect surveys.

GIANCARLO LAURIANO[1], SIMONE PANIGADA[2], ROBERTA CANNERI[1], MARTA MANCA ZEICHEN[1]

[1] *ISPRA, Via di Casalotti 300, 00166 Rome – Italy*

[2] *Tethys, c/o Acquario Civico, Viale G.B. Gadio 2, 20121 Milano - Italy*

Corresponding author, e-mail: giancarlo.lauriano@isprambiente.it

Abstract

To assess cetacean densities in the Pelagos Sanctuary and generate baseline data to provide insight on possible trends, a survey was carried out in the Ligurian-Provençal Sea (NW Mediterranean) in August 2008. An area of 58,000 km^2 was surveyed in eight days with equally spaced zigzag transects, covering 1,255 km in favorable conditions. Track-lines were designed using *Distance 5.0* to allow for homogeneous coverage probability over the selected area. Fifty three sightings of four cetacean species were made: striped dolphins (n=37), fin whales (12), sperm whales (3) and Cuvier's beaked whales (1). The best model and detection function, selected with the lowest Akaike's Information Criteria (AIC) values, had a half normal function with cosine adjustments. Striped dolphin populations size resulted to be 13,232 (%CV=35.55; 95% C.I.=6,640.0-26,368), with a density of 0.23 individuals km^{-1} (%CV=35.55; 95% C.I.=0.11-0.45). The central value of the 2008 estimate was almost half of that of a survey conducted in 1992 in the same area with comparable effort and platform (N=25,614; %CV=25.3; 95% C.I.=15,377-42,658). These results raise the concern that cetacean abundance in the Sanctuary - an MPA specifically designated to protect cetaceans - over the past 16 years may be declining and urge for further systematic monitoring. Considering that recent Red List assessments for Mediterranean striped dolphins is *Vulnerable*, we stress the need for urgent conservation measures in the high seas throughout the Basin.

Introduction

The Pelagos Sanctuary is the world's first high-seas Marine Protected Area (MPA) (Hoyt, 2005). It has been established by Italy, France and Monaco principality, after a long process started in the early '90s by recognising the high productivity of the area coupled with unusual cetacean concentrations (Notarbartolo di Sciara et al., 2003). The 87.500 km^2 of the Pelagos Sanctuary encompass pelagic and neritic regions, representing areas suitable both for breeding and foraging needs of the cetacean species found in the Western Mediterranean Sea (Notarbartolo di Sciara et al., 2007). Among these, Fin whales (*Balaenoptera physalus*) and Striped dolphins (*Stenella coeruleoalba*) are the most common species regularly present in the Pelagos area (Forcada et al., 1998). The area faces a complex of anthropogenic pressure: the recreational importance of the Pelagos coastal regions is responsible for a heavy touristic presence and high concentrations of pleasure boats during summer. These elements, coupled with presence of coastal run off and sewage, chemical pollution, ferry and merchant traffic may represent a threat for the biological features of the area. Despite the importance of the region for cetaceans' presence and the management issue related to the existence of an MPA with such high levels of human pressure, no regular cetaceans monitoring programmes have been conducted.

Striped dolphins' abundance was estimated with a line transect survey carried out during summer 1992 (Forcada et al., 1995). The population was assessed at 25,614 individuals (95% CV=25,34; C.I.=15,377-42,658); this number may have been perceived wrongly by the public as a witness of a good status of the population and may have induced a lack of conservation measures (Fortuna et al., 2007). Besides factors responsible for general habitat degradation, which may lead to declining populations in some Mediterranean species (Gomez de Segura et al., 2006), direct impacts have also been registered in the last 20 years. High by-catch rates were reported in all the Mediterranean Sea in the '90s and despite the EU driftnets ban since 2001 (EC Reg. 1239/98) illegal driftnetting was recently reported (Tudela et al., 2005); moreover, a mass mortality due to a viral epizootic hit the striped dolphin Mediterranean sub-population in the 1990-92 period (Aguilar and Raga, 1993) causing the death of over 1.000 animals. Moreover, numbers are believed to be higher and a reliable assessment of the mass mortality was not possible (Aguilar, 2000). Information on striped dolphin abundance is therefore needed to assess current estimates and highlight eventual trends in the populations.

Materials and methods

Survey design

The study area was located in the western part of the Sanctuary and encompassed 58,000 km^2 of the Pelagos Sanctuary (Fig. 1). The survey design was made considering previous experiences by Forcada and colleagues (1995) using similar platform and comparable methodology. The survey design was selected using the software Distance 5 (http://www.ruwpa.st-and.ac.uk/distance/) (Thomas et al., 2003).

We tried to achieve a good level of precision estimated as 0.30 CV (Coefficient of Variation) (Dawson et al., 2008); in order to achieve the CV desired, we estimated the amount of transect lengths required according to Buckland and colleagues (2001). Nevertheless, limited ship time available and logistics requirements, obliged us to choose a balance between the two constrains. Design class was "equal spaced zig-zag". The study area was stratified in two strata of 15,916 (strata 1) and 42,013 (strata 2) Km^2 respectively, in order to optimise the expected variability in cetaceans density between strata and to minimise the one within-stratum (Thomas et al., 2007). The vessel used was the 54 metres-long *Arctic sunrise* provided by Greenpeace International; survey speed was set between 8 and 10 knots (15 and 18.5 Km h^{-1} respectively). Observation point was set at the highest accessible area for the observers team, at 7.98 m above sea level on the main deck. The observation team consisted of three people (at least one with specific previous experience in visual surveys); the port and starboard observers searched (with the naked eye) a sector from the track-line to 90°, while the third person was involved in data entry. Once a group was sighted, 7x50 binoculars were used to indentify species and assess group size. Observer team rotated every 90 minutes. Primary effort was maintained under conditions of ≤ 3 on the Beaufort scale. The radial angle from the track line to the school was measured with an angle board (Buckland *et al*., 2001) mounted on the deck fence; the distance was estimated with personal measuring sticks, made according to the protocol used for Scans II (SCANS-II, 2008). In order to save searching time, sighting data such as radial angle, distance, species and school size estimate were collected on passing mode (Dawson et al., 2008).

Schools sighted while off effort were not considered in the density and abundance analyses. Geographical positions were registered with a Global Positioning System (GPS) connected to the computer, equipped with the *Logger2000* software (Logger 2000, www.ifaw.org). The GPS was set to register position every 1 min, the computer operator entered navigation data every 15 min and/or every time a change in conditions, such as weather, ship speed, course, sighting conditions occurred.

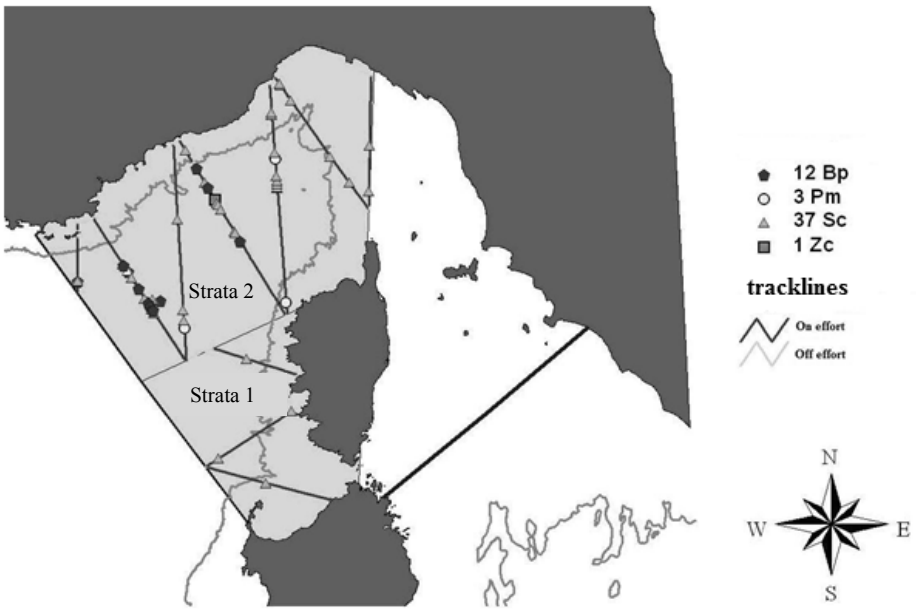

Fig. 1 - The study area, the transects made (on and off effort) and the encounters.

Data analysis

Given the relative low number of sightings and associated variables, Conventional Distance Sampling (CDS) (Thomas et al., 2007) was used to analyse the data. Moreover, it was possible to produce abundance estimate for striped dolphins only. Different detection functions, given by the combination of the uniform and half normal key functions and the cosine expansion term, were fitted to the data and the model with the smallest Akaike's Information Criteria (AIC) values was selected.

Results

58,000 km^2 were surveyed in 8 days, with a total of 1,255 km covered in favorable conditions (out of 1,370 km of transect length (91.6%)). A total of 53 sightings of four cetacean species were made: striped dolphins (n=37), fin whales (12), sperm whales (3) and Cuvier's beaked whales (1) (Table 1).

Table 1. Summary of group size and composition.

Species	N	Mean group size	[range]
Stenella coeruleoalba	37	7,51 ±7,396	[1 – 35]
Balaenoptera physalus	12	1,08 ± 0,288	[1 – 2]
Physeter macrocephalus	3	1	
Ziphius cavirostris	1	1	

Striped dolphins were found in offshore area, in both strata. Thirty four out of 37 striped dolphin sightings were primary and have been taken into account for the abundance estimate. Only three *Stenella coeruleoalba* sightings occurred in the strata 2, therefore Distance analyses were made pooling both strata together. Size of the dolphin schools observed ranged from 1 to 35 (mean 7.51 SD=7.40); the frequency distribution of all the striped dolphin sightings is shown in Figure 2. In order to estimate the detection function, sightings were truncated at the perpendicular distance of 800 m and the best model had a half normal function with cosine adjustment. Group size was estimated regressing the natural log of group size against estimated detection probability (Fig. 3). Estimates for striped dolphin are presented in Table 2.

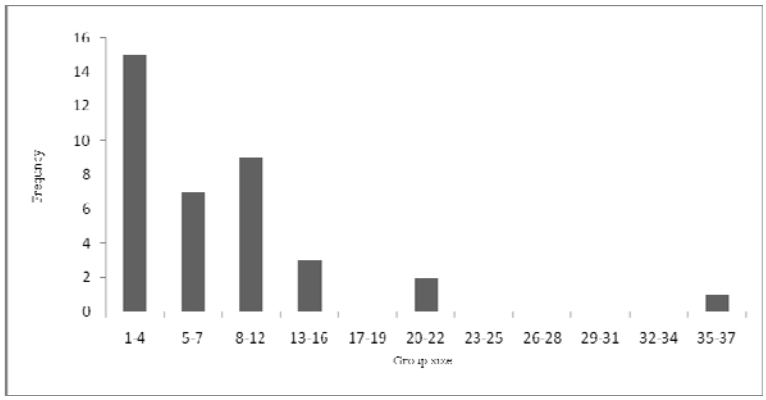

Fig. 2 – frequency distribution of all the striped dolphin groups.

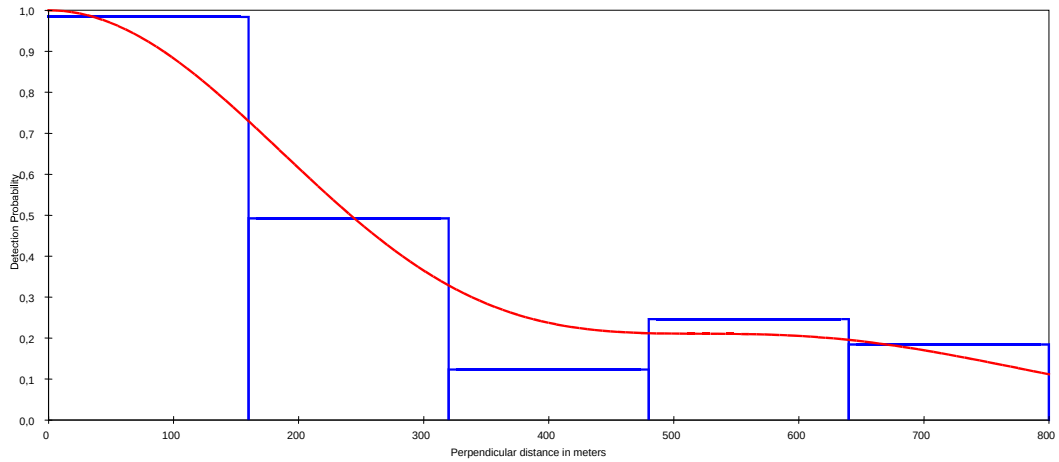

Fig. 3 – Detection function with a right truncation at 800 m.

Table 2 – Estimates for striped dolphins

Sample size	10 sample	33 encounters		
Estimated parameters	Point estimate	CV 95%	LCI	UCI
P	0.404	17.92		
ESW	324.7	17.92	225.94	466.62
Estimated parameters	Point estimate	CV	LCI	UCI
ER	0.026	0.158	0.18	0.37
E(s)	5.64	26.29	3.33	9.56
DS	0.40	23.92	0.25	0.65
D	0.228	35.55	0.11	0.45
N	13,232	35.55	6,640	26,368

CV, coefficient of variation; LCI and UCI lower and upper 95% confidence interval; P= probability to observe a dolphin in a defined area; ESW, effective stripe width (m); ER, encounter rate; E(S), estimated of expected value of group size; DS, estimate of density of groups; D, estimate density of animals; N, estimate abundance;

Differences between the 1992 estimate (N=25,614; %CV=25.3; 95% C.I.=15,377-42,658) and that from 2008 resulted significant (Z-test p: 0,0000).

Discussion

This study provides a striped dolphins' abundance estimate in the western portion of the Pelagos Sanctuary 16 years after the first one (Forcada et al. 1995) carried out within the same area, period and adopting almost the same methodology.

Despite the suggestions made by Forcada and colleagues (1995) to replicate the survey in order to monitor differences in cetacean presence and distribution according to season and prey availability, no further exhaustive information on abundance have been provided for the whole Sanctuary area. This could be considered as a drawback to the goals of the Pelagos itself, being monitor programmes one of the priorities of management objectives.

Striped dolphin abundance estimate and density resulted less than those detected during the 1992 survey. When comparing the data presented here with those presented by Forcada and Hammond (1998), density estimates are higher than those from the south western Mediterranean (D=0.12 CV=0.38) and Alboran Seas (D=0.20 CV=0.33), South Balearic area (D=0.08 CV=0.34) and the whole north western Mediterranean (D=0.20 CV=0.24), while they are lower than those from the Ligurian Sea (D=0.30 CV=0.35) and the Ligurian-Provencal Basin (D=0.24 CV=0.26). Moreover, density was lower than that recorded for the striped dolphin sub-population (D=0.26 CV=0.42) of the southern Tyrrhenian Sea (Fortuna et al., 2007).

Moreover, the number of years elapsed between the '92 and this estimate does not allow definitive conclusions on the status of the surveyed population and caution should be taken when interpreting these results.

It must be considered that several factors could have played a role in the different outputs of the surveys. Even if this study was intended to replicate as much is possible the '92 survey and parameters such as ship characteristics, speed, area, time of the year and methodology were chosen accordingly, some differences were inevitable.

Sightings distance measurements were dissimilar in the two surveys; during the first one distance was estimated and corrected after estimation experiments, while during the latter it was measured with *ad hoc* gear (measuring sticks). Moreover, since group size of cetaceans can be estimated accurately in close proximity to the group and is underestimated at greater distance (Dawson et al., 2008), the choice to operate in passing mode could have been responsible for an underestimation of the striped dolphin group size and therefore abundance and density.

The most important assumption in line transect survey is that animals on the track line are always detected [i.e. g(0) = 1] (Buckland et al. 2001). This assumption can be met only when surveys are carried out under optimal conditions for detectability; whereas, schools or animals in the trackline could be diving and not observed (availability bias) or even if they are available, the observer fails to detect them (perception bias). The effect of these two biases in this study has not been corrected and logistic constraints did not allow the use of double platform method (Hammond et al., 2002; Buckland et al., 2004).

Considering the above mentioned issues, it is our opinion that the abundance estimate provided here may be slightly negatively biased.

Despite the above consideration, and the feasibility to detect differences in population estimates between 2 estimates (1992 and 2008), we warn about the possibility of a striped dolphins' abundance reduction since the '92 estimate, in a MPA expressly designed to protect cetaceans.

Stenella coeruleoalba have suffered several threats during the last decades. In particular, the *Morbillivirus* epizootic produced a massive mortality (Aguilar, 2000), reducing the population abundances of one third of the original levels (Aguilar, 2000). Moreover, questions about the permanence of the virus in the Mediterranean basin, as well as its periodic re-entrance in the Basin, are still unsolved (Di Guardo, 2008). The additional recent epizootic episodes along the Spanish coast (Raga et al., 2008), represents a warning on the possibility of new

epizootic events, which could threat striped dolphins again. Moreover, Mediterranean striped dolphins have suffered from a high level of mortality due to incidental capture in fishing gear; the level of bycatch in pelagic driftnets was declared unsustainable (Anonymous, 1995). Driftnetting have occurred until recent years (Cornax et al., 2006) despite a driftnet EU ban (reg. 1239/98) and was responsible for a persistence of high level of striped dolphins mortality in some areas in the western Mediterranean Sea (Tudela et al., 2005). Even if there are no reliable informations on the by-catch levels, there is a general consensus (e.g. Bjørge & Donovan, 1995) in assuming anthropogenic removal levels exceeding of 1% of the estimated population size, as a cause of concern. It is not unlikely, that by-catch reached this level also in the Pelagos Sanctuary and surroundings areas, according to the estimate inferred from the Spanish driftnet fishery (Forcada and Hammond, 1998) and from the Moroccan fleet (Tudela et al., 2005).
The Ligurian Sea was classified by D'Ortenzio and Ribera D'Alcalà (2008) as blooming area, being one of the most productive areas of the whole Mediterranean basin. This recurring bloom is crucial for sustaining the Pelagos Sanctuary's food web. Recent studies (Manca Zeichen et al., 2008; Finoia et al; 2007) conducted in order to study the inter-annual variability of chlorophyll concentrations (*chl*) within the Sanctuary area from 1997 to 2004, showed a sensible reduction of this geophysical parameter from 1997 to 2003. This could have been due to the reduced vertical mixing which fertilizes the surface waters with nutrient form the deeper layers, causing a diminished phytoplankton bloom intensity within the north western area of the Sanctuary.
According to these elements and considering the recent Red List assessment which proposed the *Stenella coeruleoalba* Mediterranean sub population as *Vulnerable* (Reeves and Notarbartolo di Sciara, 2006*)*, the outcomes of the study stress the need of conservation measures within the Pelagos Sanctuary as well as in the whole Mediterranean basin.

References

Aguilar A. 2000. Population biology, conservation threats and status of Mediterranean striped dolphins (*Stenella coeruleoalba*). *Journal of Cetacean Research and Management* 2 issue 1 17-26.

Aguilar, A. and A. Raga, 1993. The striped dolphin epizootic in the Mediterranean Sea. Ambio, 22: 524-528.

Bjørge, A. & Donovan, G.P. eds., 1995. Biology of the phocoenids. Report of the International Whaling Commission (Special Issue), 16, 1–552.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L., Borchers, D.L. & Thomas, L. 2001 *Introduction to Distance Sampling: Estimating Abundance of Biological Populations*. Chapman & Hall, New York, USA.

Cornax, M.J., Pastor, X. & Aguilar, R., 2006. *Italian driftnetters: the Oceana report*. Madrid, Spain: OCEANA

D'Ortenzio F. and Ribera d'Alcalà M., 2008. On the trophic regimes of the Mediterranean Sea. *Biosciences Discussions*, 5: 2959-2983.

Dawson, S. Wade, P. Slooten E. and J. Barlow. 2008. Design and field methods for sighting surveys of cetaceans in coastal and riverine habitats**.** *Mammal Rev*. 2008, Vol 38, N°. 1, 19–49

Finoia M.G **,** Manca Zeichen M., Barale V., 2007. Phytoplankton dynamics in the *Pelagos* Sanctuary: a satellite approach. Ozhan E. (Editor), *Proceedings of the Seventh International Conference on the Mediterranean Coastal Environment*', *MEDCOAST 07*, 13-17 November 2007, Alexandria Egypt, MEDCOAST Middle East Technical University, Ankara, Turkey, 2: 1407-1418.

Forcada J. Notarbartolo Di Sciara G. and Fabbri F.1995Abundance of fin whales and striped dolphins summering in the Corso-Ligurian Basin. *Mammalia* 59 (1):127-140

Forcada J, Hammond PS (1998) Geographical variation in abundance of striped and common dolphins of the western Mediterranean. *J Sea Res* 39:313–325

Fortuna C., Canese S., Giusti M., Revelli E., Consoli P., Florio G., Greco S., Romeo T., Andaloro F., Fossi M. C. and Lauriano G. 2007. An insight into the status of striped dolphins (Stenella coeureoalba) of the southern-Tyrrhenian sea. *J. Mar. Biol. Ass.* U.K. 87:1321-1326

Gomez de Segura A., Crespo E.A., Pedraza S.N., Hammond, P.S., Raga J.A. 2006. Abundance of small cetaceans in the waters of the central Spanish Mediterranean. Marine Biology, 150, 149–160.
Notarbartolo di Sciara G., Agardy T., Hyrenbach D., Scovazzi T., Van Klaveren P. 2008. The Pelagos sanctuary for Mediterranean marine mammals. Aquatic Conservation: Marine and Freshwater Ecosystems 18:367-391.

Hoyt E. 2005. Marine Protected areas for whales, dolphins and porpoises. 492 pp.

Manca Zeichen M., Finoia M.G., S. Donfrancesco, Barale V., 2008. On the Use of Optical Remote Sensing to Assess Phytoplankton Dynamics in the *Pelagos* Sanctuary (Ligurian-Provençal Sea). Ocean Optics XIX, 5 -10 October.

Reeves R., Notarbartolo di Sciara G. (compilers and editors). 2006. The status and distribution of cetaceans in the Black Sea and Mediterranean Sea. IUCN Centre for Mediterranean Cooperation, Malaga, Spain. 137 pp.

SCANS-II (2008). Small Cetaceans in the European Atlantic and North Sea. Final Report to the European Commission under project LIFE04NAT/GB/000245. Available from SMRU, Scottish Oceans Institute, University of St Andrews, St Andrews, Fife KY16 8LB, UK.

Thomas L., Williams R., Sandilands D., 2007. Designing line transect surveys for complex survey regions. *J. Cetacean Res. Manage*. 9(1):1-13.

Tudela, S., Kai Kai, A., Maynou, F., El Andalossi, M. & Guglielmi, P., 2005. Driftnet fishing and biodiversity conservation: the case study of the large-scale Moroccan driftnet fleet operating in the Alboran Sea (SW Mediterranean). *Biological Conservation*, 121, 65–78.

Acknowledgements

We are grateful to the colleagues who participated to data collection: Alessandro Giannì, Elisabetta De Maio, Silvia Maltese, Pierdavide Pasotti. Greenpeace International and Greenpeace Italy offering the use of the Arctic Sunrise. Len Thomas (RUWPA, St. Andrews University) and Phil Hammond (SMRU, St. Andrews University) provided useful hints in survey design and data analysis and Laura Caramanna (Caspur) for advice in the statistics. Thank to IFAW for the Logger software.