Cetacean distribution and relative abundance in Colombia's Pacific EEZ from survey cruises and platforms of opportunity

Daniel M. Palacios[1,2], Julio C. Herrera[3], Tim Gerrodette[4], Carolina García[5,6], Germán A. Soler[5], Isabel C. Avila[7,8], Sandra Bessudo[5], Elizabeth Hernández[3], Fernando Trujillo[9], Lilián Flórez-González[3] and Iain Kerr[10]

Contact e-mail: Daniel.Palacios@noaa.gov

ABSTRACT

Cetacean sighting data collected under various programmes in Colombian Pacific waters were collated with the goal of assessing the distribution and abundance patterns of all species occurring in the exclusive economic zone (EEZ). Distribution maps are presented for 19 species and one genus based on 603 sightings collected between 1986 and 2008. Ordered by sighting frequency, these species were: humpback whale (*Megaptera novaeangliae*); striped dolphin (*Stenella coeruleoalba*); common bottlenose dolphin (*Tursiops truncatus*); pantropical spotted dolphin (*Stenella attenuata*); common dolphin (*Delphinus delphis*); Risso's dolphin (*Grampus griseus*); sperm whale (*Physeter macrocephalus*); rough-toothed dolphin (*Steno bredanensis*); short-finned pilot whale (*Globicephala macrorhynchus*); mesoplodont whales (*Mesoplodon* spp.); Cuvier's beaked whale (*Ziphius cavirostris*); melon-headed whale (*Peponocephala electra*); false killer whale (*Pseudorca crassidens*); killer whale (*Orcinus orca*); spinner dolphin (*Stenella longirostris*); dwarf sperm whale (*Kogia sima*); Bryde's whale (*Balaenoptera edeni*); pygmy killer whale (*Feresa attenuata*); minke whale (*Balaenoptera acutorostrata*) and fin whale (*Balaenoptera physalus*). Concentrations of sightings were observed in three geographic areas: (1) the continental shelf (depths <200m) and the contiguous continental slope (200–2,000m); (2) over the Malpelo Ridge, an offshore bathymetric feature and (3) the northeast corner of the EEZ between Golfo de Cupica and the border with Panamá, although we do not rule out that these patterns could be an artefact of non-random effort. In inshore waters, the most frequently seen species were pantropical spotted dolphin, common bottlenose dolphin and humpback whale. For several of the data sets we provide encounter rates as indices of relative abundance, but urge caution in their interpretation because of methodological limitations and because several factors that affect sightability could not be accounted for in these estimates. Our results provide useful information for ongoing regional research and conservation initiatives aimed at determining occurrence, population status and connectivity within adjacent EEZs in the eastern tropical Pacific. Suggested research priorities include conducting dedicated surveys designed for estimating abundance and monitoring trends throughout the EEZ and focused studies in areas of special interest like the continental shelf, the Malpelo Ridge and the vicinity of Cupica and Cabo Marzo. More research is also needed in terms of quantifying the sources and impact of anthropogenic mortality on population size. Studies characterising genetic diversity and stock discreteness in coastal species (pantropical spotted dolphin and common bottlenose dolphin) would help inform local management strategies.

KEYWORDS: SOUTH AMERICA; EASTERN TROPICAL PACIFIC OCEAN; SURVEY-VESSEL; INCIDENTAL SIGHTINGS; ABUNDANCE ESTIMATE; INDEX OF ABUNDANCE; DISTRIBUTION; HABITAT; BREEDING GROUNDS

INTRODUCTION

On 23 May 2007, Colombia's government, through its Ministries of Environment and Foreign Affairs, announced its intention to adhere to the International Convention for the Regulation of Whaling of 1946, motivated by the country's policies in regard to the non-lethal use of cetacean species[11]. This initiative was passed into law by Congress as Ley 1348 of 31 July 2009 (Anon., 2009) and on 19 May 2010 it received the approval of the Constitutional Court (Anon., 2010). Additionally, through the San José Declaration of 2 April 2004, Colombia, together with the governments of Ecuador, Costa Rica and Panamá, agreed to the establishment of the 'Eastern Tropical Pacific Seascape,' an initiative for the integrated management of the rich biological resources within the marine protected areas around the islands of Cocos (Costa Rica), Coiba (Panamá), Malpelo and Gorgona (Colombia), and Galápagos (Ecuador) (Anon., 2005; Shillinger, 2005; *http://www.cmarpacifico.org/*). These international instruments reflect the country's commitment to the conservation of its biological diversity in the Pacific Ocean. In this context, scientific information on the distribution and abundance of protected resources in its waters is essential for the development of adequate management plans.

Colombia's coastline along the Pacific Ocean has an extent of 1,300km and its exclusive economic zone (EEZ) covers an area of about 330,000km^2 (DIMAR, 1988) (Fig. 1). The continental shelf (depths <200m) and slope (200–2,000m) are wide south of 4°N but very narrow to the north, especially between Cabo Corrientes and the border with Panamá (Fig. 1). The Mapelo Ridge, a submarine mountain range running on a southwest-northeast axis, rises to the surface from depths greater than 2,000m at Malpelo Island and is the most prominent feature in the offshore region (Fig.

[1]*Joint Institute for Marine and Atmospheric Research, University of Hawaii at Manoa, 1000 Pope Road, MSB 312, Honolulu, HI 96822, USA.*
[2]*NOAA/NMFS/Southwest Fisheries Science Center, Environmental Research Division, 1352 Lighthouse Avenue, Pacific Grove, CA 93950-2097, USA.*
[3]*Fundación Yubarta, Apartado Aéreo 33141, Cali, Colombia.*
[4]*NOAA/NMFS/Southwest Fisheries Science Center, Protected Resources Division, 8604 La Jolla Shores Drive, La Jolla, CA 92037-1508, USA.*
[5]*Fundación Malpelo, Carrera 11 No. 87–51, Local 4, Bogotá, Colombia.*
[6]*Fundación MarViva, Calle 98 No. 8–19, Bogotá, Colombia.*
[7]*Departamento de Biología, Facultad de Ciencias, Universidad del Valle, Apartado Aéreo 24560, Cali, Colombia.*
[8]*Fundación Cabo Mar, Carrera 26 No. 6A–23, Cali, Colombia.*
[9]*Fundación Omacha, Diagonal 86A No. 30–38, Bogotá, Colombia.*
[10]*Ocean Alliance, 191 Weston Road, Lincoln, MA 01773, USA.*
[11]*http://www.minambiente.gov.co/contenido/contenido.aspx?conID=786&catID=433.*

Table 1
List of 23 cetacean species whose presence has been confirmed within Colombian Pacific waters.

Common name	Scientific name	Source
Pantropical spotted dolphin	*Stenella attenuata*	Vidal (1990); Flórez-González and Capella (1995)
Spinner dolphin	*Stenella longirostris*	Vidal (1990)
Striped dolphin	*Stenella coeruleoalba*	Vidal (1990)
Rough-toothed dolphin	*Steno bredanensis*	Vidal (1990)
Common dolphin	*Delphinus delphis*	Vidal (1990); Flórez-González and Capella (1995)
Common bottlenose dolphin	*Tursiops truncatus*	Vidal (1990); Flórez-González and Capella (1995)
Risso's dolphin	*Grampus griseus*	Vidal (1990); Flórez-González and Capella (1995)
Fraser's dolphin	*Lagenodelphis hosei*	Vidal (1990)
Melon-headed whale	*Peponocephala electra*	Vidal (1990)
Pygmy killer whale	*Feresa attenuata*	Vidal (1990)
False killer whale	*Pseudorca crassidens*	Vidal (1990); Flórez-González and Capella (1995)
Short-finned pilot whale	*Globicephala macrorhynchus*	Vidal (1990); Flórez-González and Capella (1995)
Killer whale	*Orcinus orca*	Vidal (1990); Flórez-González and Capella (1995)
Sperm whale	*Physeter macrocephalus*	Vidal (1990); Flórez-González and Capella (1995)
Dwarf sperm whale	*Kogia sima*	Vidal (1990); Flórez-González and Capella (1995)
Blainville's beaked whale	*Mesoplodon densirostris*	Flórez-González and Capella (1995)
Cuvier's beaked whale	*Ziphius cavirostris*	Vidal (1990); Flórez-González and Capella (1995)
Minke whale	*Balaenoptera acutorostrata*	Vidal (1990)
Bryde's whale	*Balaenoptera edeni*	Vidal (1990); Flórez-González and Capella (1995)
Sei whale	*Balaenoptera borealis*	Vidal (1990)
Humpback whale	*Megaptera novaeangliae*	Vidal (1990); Flórez-González and Capella (1995)
Fin whale	*Balaenoptera physalus*	Vidal (1990)
Blue whale	*Balaenoptera musculus*	Mora-Pinto *et al*. (1995); Van Waerebeek *et al*. (1997)

1). At least 23 cetacean species are known to occur in these waters (Flórez-González and Capella, 1995; Flórez-González *et al.*, 2004a; Vidal, 1990) (Table 1). Extensive biological information and a comprehensive conservation strategy exist for the humpback whale *(Megaptera novaeanglieae)* as a product of more than 20 years of study (Flórez-González *et al.*, 2007). Efforts also have been undertaken to document the cetacean fauna inhabiting the waters around the islands of Gorgona (Flórez-González and Capella, 2001; Flórez-González *et al.*, 2004b) and Malpelo (Herrera *et al.*, 2007). However, much less is known about the occurrence of cetaceans outside these locations, in particular for those species occurring in offshore waters. Abundance estimates for selected species have been presented by Gerrodette and Palacios (1996) based on regional-scale line-transect surveys for the period 1986–1993 (Table 2), but no more recent estimates are available and no comprehensive maps of cetacean distribution have ever been published for Colombia's EEZ. This paper presents, for the first time, distributional maps for 19 species and one genus occurring in Colombian waters, based on a compilation of sightings collected aboard survey cruises and platforms of opportunity between 1986 and 2008. It also provides, with some important caveats, group encounter rates and typical group sizes to give a more complete picture of the occurrence patterns of these species. Finally, the paper discusses what has been learned from these efforts and identifies gaps in knowledge and research needs.

DATA SOURCES

Since the purpose was to obtain as complete a picture as possible of the patterns of cetacean occurrence in Colombia's Pacific EEZ, sightings data were compiled from dedicated cetacean surveys as well as from platforms of opportunity operating in these waters between 1986 and 2008. Details of these programmes are as follows.

SWFSC line-transect cruises

The Southwest Fisheries Science Center (SWFSC), part of the National Marine Fisheries Service (NMFS) of the U.S. National Oceanic and Atmospheric Administration (NOAA), has conducted systematic line-transect surveys for cetaceans throughout the eastern tropical Pacific (in international waters as well in the EEZs of several Central and South American

Table 2
Estimates of cetacean abundance (N, in number of animals) and density (D, in number of animals per 1,000km^2) for Colombia's Pacific EEZ, with lower (N_{low}) and upper (N_{up}) limits of the 95% confidence intervals, based on SWFSC line-transect surveys conducted between 1986 and 1993 (source: Gerrodette and Palacios, 1996).

Common name	Scientific name	N	N_{low}	N_{up}	D
Pantropical spotted dolphin	*Stenella attenuata*	3,934	1,755	8,820	11.9
Striped dolphin	*Stenella coeruleoalba*	25,785	17,324	38,379	78.3
Rough-toothed dolphin	*Steno bredanensis*	4,366	1,869	10,200	13.3
Common dolphin	*Delphinus delphis*	12,369	4,136	36,989	37.5
Common bottlenose dolphin	*Tursiops truncatus*	7,171	3,548	14,493	21.8
Risso's dolphin	*Grampus griseus*	7,266	3,599	14,668	22.1
Short-finned pilot whale	*Globicephala macrorhynchus*	1,140	450	2,892	3.5
Beaked whales	*Ziphius cavirostris* and *Mesoplodon* spp.	30,784	10,633	89,119	93.4
Sperm whale	*Physeter macrocephalus*	1,248	643	2,422	3.8
Bryde's whale	*Balaenoptera edeni*	109	37	321	0.3

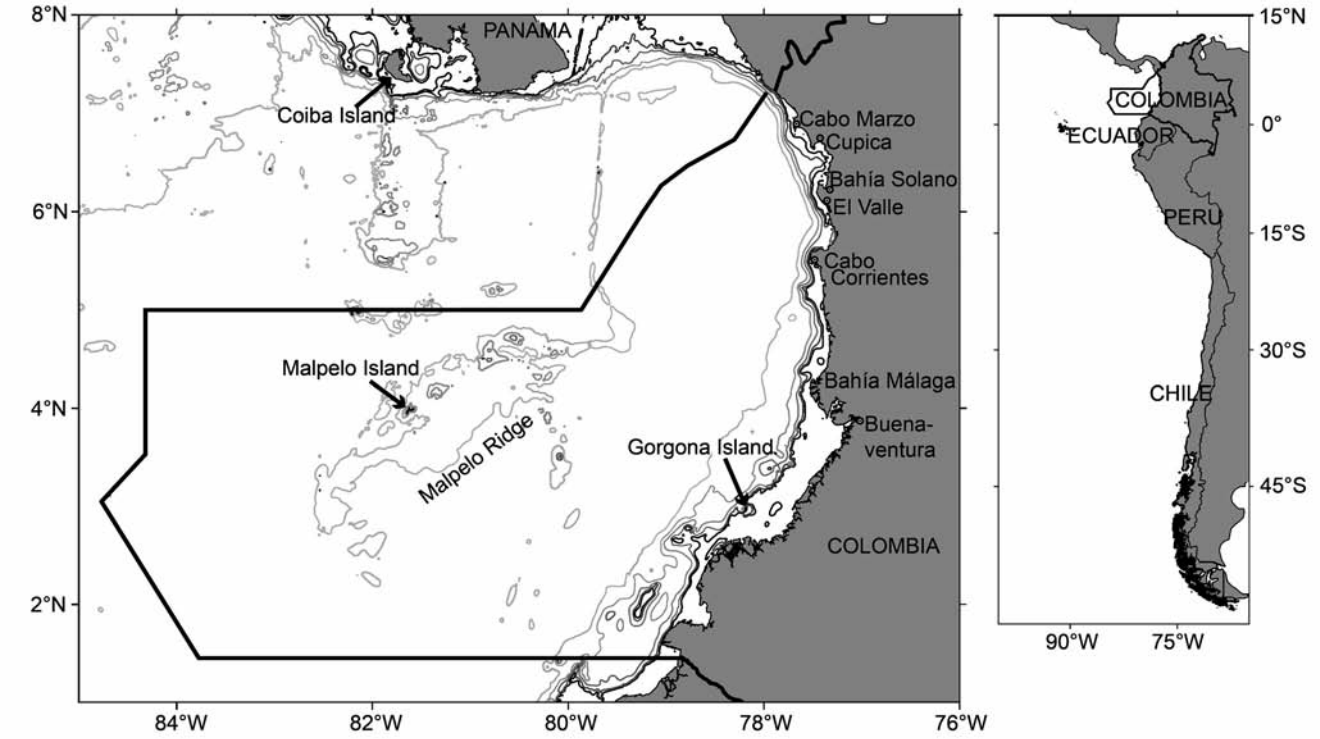

Fig. 1. Left: Colombia's exclusive economic zone (EEZ) in the Pacific Ocean (source: DIMAR, 1988). Localities mentioned in the text are labelled. Bathymetric contours correspond to the 100, 200, 500, 1,000 and 2,000m isobaths (source: SRTM30_PLUS global topography v.6.0, available from *http://topex.ucsd.edu/*). Right: Political boundaries of Colombia and its location in the Southeast Pacific.

countries) every few years between 1986 and 2006 (1986–1990, 1992, 1998–2000, 2003 and 2006). The purpose of these surveys is to estimate population size and to monitor trends in the abundance of several dolphin stocks that have been affected by incidental mortality in the international purse-seine fishery for tuna (Gerrodette, 2002). The methodology has been documented in detail elsewhere (e.g. Gerrodette and Forcada, 2005; Kinzey *et al.*, 2000; Wade and Gerrodette, 1993), but briefly, the ship-based surveys take place from late July to early December following pre-determined random tracklines at a nominal cruising speed of 10 knots (18.5km/h). A team of three observers conduct visual searching for cetaceans during daylight hours (dawn to dusk) from the ship's flying bridge using 25x150mm pedestal-mounted binoculars in sea state conditions ranging from 0 to 6 in the Beaufort scale. Angle and radial distance to each sighting are recorded upon initial sighting, and the ship is then diverted to approach the animals in order to obtain species identity and group size. Between 1986 and 2000, two 52m research vessels, the *McArthur* and the *David Starr Jordan*, were used, both having an observation height of 11m above the water line. An additional ship, the 57m R/V *Endeavor*, with an observation height of 10m, was used during the 1998 survey. Starting with the 2003 survey, the *McArthur* was replaced with the 68m *McArthur II*, with an observation height of 15m.

The *Siben* and *Odyssey* expeditions

Two expeditions to study cetaceans in South American waters were conducted under the joint auspices of the Ocean Alliance (under the former names of Long-term Research Institute and Whale Conservation Institute) and the Interpolar Research Society. The purpose of these expeditions was to study the biology of the sperm whale (*Physeter macrocephalus*) and the humpback whale while providing training in cetacean research techniques to local scientists (see also Pardo *et al.*, 2009). The first expedition operated in Colombian waters aboard the R/V *Siben*, a 25.9m sailboat, between May and July 1998 (Torres *et al.*, 1988), while the second one took place at various times during 1993 (February, September, October) and 1994 (April) aboard the R/V *Odyssey*, a 28.4m sailboat (Ocean Alliance, unpublished data). On both ships, two observers maintained visual watches during daylight hours (07:00–18:00h, weather permitting), using the naked eye or hand-held binoculars. On the *Siben,* the observation was conducted from the bow and the stern (3–4m above the waterline), while on the *Odyssey* observers were positioned atop the ship's pilothouse (4m above the waterline) and in the crow's nest on the main mast (18m above the waterline). Sightings of other cetacean species were recorded while searching for the target species but the associated search effort data were not available.

DIMAR oceanographic cruises

The Dirección General Marítima de Colombia (DIMAR), through its Centro de Control de Contaminación del Pacífico (CCCP), conducts long-term studies of the El Niño phenomenon in Colombia's Pacific EEZ with a series of biannual oceanographic cruises known as 'Pacífico' (normally in February or March) and 'ERFEN' (in September). Each cruise uses one of two ships, either R/V *Providencia* or R/V *Malpelo*, both 50.9m long, and takes about 20 effective sea days to complete. Two national non-profit organisations, *Fundación Yubarta* and *Fundación Malpelo*, have placed marine mammal observers on seven of these cruises between 2004 and 2008. Observation effort takes place during travel

between oceanographic stations at a cruising speed of 10 knots for *Malpelo* (18.5km/h) and 11 knots (20.4km/h) for *Providencia*. An observer searches for cetaceans from the ship's flying bridge 10m above the water line using 7x50mm hand-held binoculars. Unlike the SWFSC surveys, sightings are not closed on, so only cetacean groups that occur near the ship can be identified and counted. For this reason, search effort is only conducted under acceptable viewing conditions (no fog or rain, and in Beaufort sea states of 3 or less).

Dive and Seascape charter trips

Fundación Malpelo and *Fundación Yubarta* have also placed marine mammal observers on 39 chartered trips to the offshore islands of Malpelo and Gorgona between 2004 and 2008. Twenty-four of these were dive trips organised by the company *Embarcaciones Asturias* and 17 were dedicated research trips conducted under the auspices of Conservation International's 'Eastern Tropical Pacific Seascape Program.' One additional dive charter trip in 2008 organised by Fundación Cabo Mar covered the coastal segment from Cabo Marzo-Buenaventura. All trips used M/V *Maria Patricia*, which has a cruising speed of 8 knots (14.8km/h). Observations took place during transit between the originating port (Buenaventura) and the island destinations as well as during transit between destinations. Searching was conducted by one to three observers from the vessel's top deck at a height of 4m above the waterline under acceptable viewing conditions (no fog or rain, and in Beaufort sea states of 3 or less). The vessel was diverted to approach sightings when conditions allowed during the Seascape trips but not during the dive trips. Sightings collected at the dive sites (i.e. at anchor or while circumnavigating the islands) were removed from the data set to avoid introducing bias by island-associated communities at these biologically rich localities.

Sports-fishing charter trips

Cetacean observations were collected on coastal sports-fishing trips organised by Fundación Cabo Mar between 2000–2001 and 2004–2008. During these periods, 20 daily trips were conducted along one of three coastal routes: Buenaventura-Bahía Solano, Bahía Solano-Cupica and Cupica-Cabo Marzo. An additional route between the locality of El Valle and offshore waters was covered on one occasion. Two fiberglass boats with outboard engines were used: M/V *La Cotizada* (23ft long, two 40hp engines) between 2000 and 2005; and M/V *El Gran Blanco* (32ft, two 115hp engines) between 2006 and 2008. Two observers located near the boat's bow collected sighting data at a height of 2.2m and 2.7m above the water line, respectively for each boat. Travel speed was variable, ranging between 12 and 30km/h depending on navigation conditions.

DATA ANALYSIS

Sighting categories

In the field, sightings were classified under 38 different identification categories including subspecies, species and higher taxonomic levels such as genus, family, etc. For analysis purposes, several of these categories were pooled into more manageable or meaningful species groupings as follows. Species having several recognised subspecies or sighting categories (see Dizon *et al.*, 1994) were pooled into a single species. Thus, a single 'pantropical spotted dolphin (*Stenella attenuata*)' category was created from three categories: offshore; coastal and unidentified subspecies. Similarly, a 'spinner dolphin (*Stenella longirostris*)' category was created by pooling four categories: eastern; whitebelly; Central American and unidentified subspecies. Conversely, sightings possibly belonging to several related species were combined into a single category when field identification to species level was not possible due to inconspicuous behaviour and/or lack of easily distinguishable features. This was the case for unidentified sightings in the genus *Mesoplodon,* for which a 'mesoplodont whales (*Mesoplodon* spp.)' category was created by pooling sightings of Blainville's beaked whale (*M. densirostris*) with sightings identified to the genus level only.

A single-species category was created by pooling confirmed sightings of the target species with sightings belonging either to the target species or to a related species when the two are difficult to separate in the field. This was done only in cases where biogeographic evidence indicates that the presence of the related species in the study area is unlikely or extremely rare. Thus, a 'Bryde's whale (*Balaenoptera edeni*)' category was created by pooling sightings positively identified as Bryde's whales (i.e., when the auxiliary ridges on the head of the animal were clearly seen) with those identified as 'either sei (*B. borealis*) or Bryde's whales' (i.e. when a very close examination at the animal's head was not obtained and therefore identification remained uncertain). Positive identification of the sei whale in the field can be very difficult, but no confirmed sightings of this species have been made anywhere in the eastern tropical Pacific during the long-standing surveys by the SWFSC. In a similar manner, a 'dwarf sperm whale (*Kogia sima*)' category was created by pooling sightings positively identified as dwarf sperm whales with those identified as *Kogia* sp. In this case, it is possible that some of the *Kogia* sp. sightings belonged to the pygmy sperm whale (*K. breviceps*), although only one confirmed sighting of this species has been reported south of 24°N by the extensive SWFSC surveys.

Sightings classified under nine 'unidentified' categories: unidentified beaked whale; unidentified rorqual (*Balaenoptera* sp.); unidentified dolphin; unidentified small whale; unidentified large whale; unidentified cetacean; unidentified whale; unidentified small delphinid and unidentified medium delphinid, were not used in this study. In this manner, 20 sighting categories are reported here: 19 individual species and the genus *Mesoplodon*.

Encounter rates

Species encounter rates were computed for each data source separately (except for the *Siben* and *Odyssey* expeditions, which lacked effort data), based on the sightings recorded while search effort was being conducted. These are reported as group sightings per unit search effort in Appendices 1–5 using the original measurement unit recorded (i.e. kilometers or hours). Since the methodology for group size estimation was variable among the different sources (see section on 'Biases and caveats'), average group size was not used in the calculation of relative abundance to avoid introducing further bias. For ease in presentation and discussion, the estimated encounter rates for all sources are summarised in Table 3 in

the same units (groups per km scaled by 1,000). This was accomplished by multiplying the effort hours collected by the dive/Seascape and the sports-fishing trips by the vessel speed (14.8km/h and an average 21km/h, respectively).

Due to methodological differences, direct comparison of the estimated encounter rates between sources would be problematic (see 'Biases and caveats' in the next section). Nevertheless, we attempt to provide interpretation by according each species a qualitative rank based on the average encounter rate from all sources, where 'low' corresponds to species with encounter rates of less than 1 group per 1,000km, 'intermediate' to species with encounter rates between 1 and 3 groups per 1,000km and 'high' to species with encounter rates greater than 3 groups per 1,000km (Table 3).

Sighting frequency and group size statistics

All identified on-effort sightings were pooled into a single data set containing a total of 488 records. Sighting frequency is reported as the number of sightings for each species in this data set. Group size statistics (range, average, median and standard deviation) for each species were computed from this data set.

Distribution

Identified sightings from all sources, including those collected during non-effort periods or from sources with no search effort data and in all Beaufort sea state conditions, were combined into a single data set containing a total of 603 records belonging to the 20 sighting categories. Species distribution maps were created based on these data.

RESULTS AND DISCUSSION

Effort and associated sightings

SWFSC (*1986–2006*)

A total of 7,784km of visual effort were traversed by NOAA vessels during the SWFSC line-transect surveys in Colombian waters (Fig. 2a). A total of 238 identified sightings were made while on-effort belonging to 16 species and the genus *Mesoplodon* (see Appendix 1).

Siben and Odyssey expeditions (*1988, 1993, 1994*)

The *Siben* Expedition in Colombian waters consisted of three legs during which 11 sightings of six species were collected, while the *Odyssey* Expedition consisted of four legs during which eight sightings of four species were collected (see Appendix 2). The routes followed by both expeditions are shown in Fig. 2b.

DIMAR (*2004–2008*)

A total of 8,587km of effort and 178 sightings belonging to 14 species and the genus *Mesoplodon* were recorded aboard DIMAR vessels during on-effort periods (see Appendix 3). A map of the cruise tracks while on effort is shown in Fig. 2c.

Dive and Seascape trips (*2004–2008*)

A total of 264hr (3,907km) of effort and 46 sightings belonging to 13 species were recorded during the transits between Buenaventura and the diving destinations (see Appendix 4). A map of the effort segments for these trips is shown in Fig. 2d.

Sports-fishing trips (*2000–2001 and 2004–2008*)

A total of 108hr (2,268km) of observation were conducted during which 26 cetacean sightings belonging to four species were recorded (see Appendix 5). A schematic map of the daily routes is presented in Fig. 3.

Patterns of cetacean occurrence

The compiled sightings data set contained records for 19 cetacean species and one genus within Colombia's Pacific EEZ. Distribution maps for these taxa are presented in Figs 4–6. Of the 23 species previously reported in these waters (Table 1) only three were absent from our data set: Fraser's dolphin (*Lagenodelphis hosei*); sei whale and blue whale

Table 3

Estimated encounter rates (in groups per 1,000km) by source for 19 cetacean species and one genus, based on the on-effort sightings. The ranked encounter rate (low < 1, 1 ≤ intermediate < 3, and high ≥ 3 groups per 1,000km) is based on the average from all sources (in parenthesis) and is arbitrary.

Common name	Species name	SWFSC	DIMAR	Dive/seascape	Sports-fishing	Ranked encounter rate
Pantropical spotted dolphin*	*Stenella attenuata*	1.93	1.86	1.28	4.08	Intermediate (2.29)
Spinner dolphin*	*Stenella longirostris*	0.39		0.26		Low (0.32)
Striped dolphin	*Stenella coeruleoalba*	8.99	2.21	1.54		High (4.25)
Rough-toothed dolphin	*Steno bredanensis*	1.54	0.47	0.26		Low (0.76)
Common dolphin	*Delphinus delphis*	1.67	0.70	2.82		Intermediate (1.73)
Common bottlenose dolphin	*Tursiops truncatus*	3.21	2.45	2.82	5.44	High (3.48)
Risso's dolphin	*Grampus griseus*	3.21	0.35	0.26		Intermediate (1.27)
Melon-headed whale	*Peponocephala electra*	0.64		0.26		Low (0.45)
Pygmy killer whale	*Feresa attenuata*	0.26				Low (0.26)
False killer whale	*Pseudorca crassidens*		0.23	0.77	0.45	Low (0.48)
Short-finned pilot whale	*Globicephala macrorhynchus*	0.77	0.70	0.51		Low (0.66)
Killer whale	*Orcinus orca*	0.26	0.12	0.51		Low (0.30)
Sperm whale	*Physeter macrocephalus*	3.47	0.23			Intermediate (1.85)
Dwarf sperm whale*	*Kogia sima*	0.51				Low (0.51)
Mesoplodont whales*	*Mesoplodon* spp.	1.41	0.12			Low (0.77)
Cuvier's beaked whale	*Ziphius cavirostris*	0.51	0.23	0.26		Low (0.33)
Minke whale	*Balaenoptera acutorostrata*		0.12			Low (0.12)
Bryde's whale*	*Balaenoptera edeni*	0.51				Low (0.51)
Fin whale	*Balaenoptera physalus*		0.12			Low (0.12)
Humpback whale	*Megaptera novaeangliae*	1.28	10.83	0.26	1.81	High (3.55)

*Pooling of related sighting categories was done for these species as described in the text.

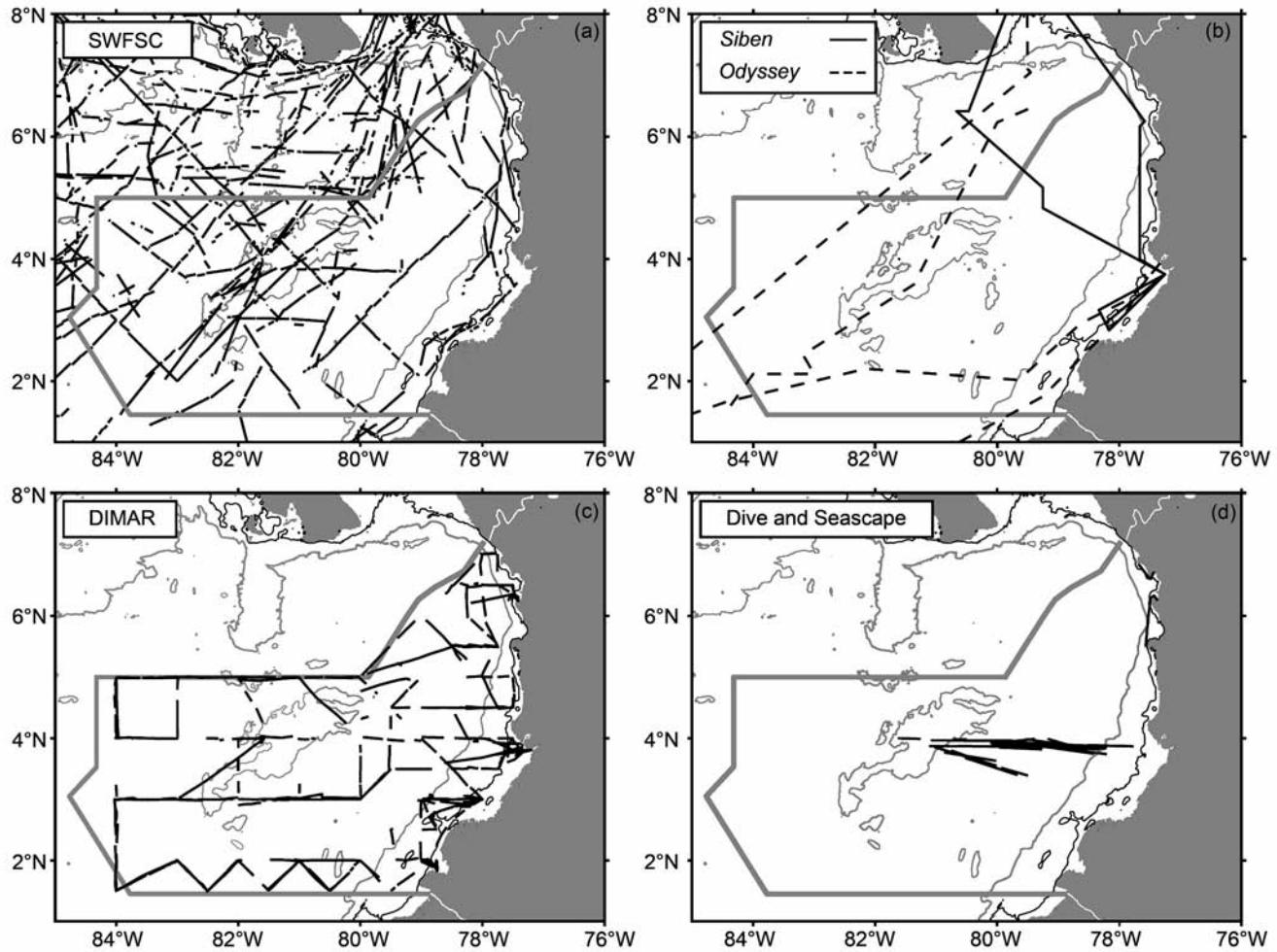

Fig. 2. (a) On-effort segments of trackline followed by NOAA vessels during SWFSC line-transect surveys (1986–2006). (b) Tracks followed by the *Siben* Expedition (May–July 1988) (solid black line) and the *Odyssey* Expedition (February 1993, September–October 1993 and April 1994) (dashed black line). (c) On-effort segments of trackline followed by DIMAR vessels during oceanographic cruises (2004, 2006–2008). (d) On-effort segments of trackline followed by M/V *Maria Patricia* during dive and Seascape charter trips (2004–2008). For clarity, only the bathymetric contours corresponding to the 100m (black) and 2,000m (gray) isobaths are shown (source as in Fig. 1).

(*Balaenoptera musculus*), suggesting they are exceedingly rare in the region. The estimated encounter rates for the 19 species are summarised in Table 3 for all sources for which effort data were available. Although density was not estimated, the following species accounts include a comparison of the density values reported by Gerrodette and Palacios (1996) for selected species in Colombia's EEZ with the corresponding density estimates for the neighbouring waters of Panamá and Ecuador, to give a regional context. The aim is to provide a synthesis of information on cetacean occurrence in Colombia's Pacific EEZ, while warning about its biases and limitations.

Pantropical spotted dolphin (*Stenella attenuata*)

This species was well represented in inshore waters, where sightings tended to occur in clusters around Gorgona Island (where it is a year-round resident; Flórez-González and Capella, 2001), outside Bahía de Buenaventura and from Golfo de Cupica to the Panamá border (Fig. 4a). Multiple scattered sightings also occurred throughout the offshore region. This pattern probably corresponds to the coastal and offshore subspecies (Dizon *et al.*, 1994; Escorza-Treviño *et al.*, 2005), as both were reported in the data. Pantropical spotted dolphin had an intermediate ranked encounter rate (Table 3) and it was the fourth most frequently sighted species (Table 4). Average group size was 94 and the range was 2–400 (Table 4). Based on an earlier data set, Gerrodette and Palacios (1996) reported a density estimate for Colombia's EEZ of 11.9 pantropical spotted dolphins per 1,000km^2 (Table 2). This number is substantially lower than the density estimate for Panamá's EEZ (58.8 animals per 1,000km^2) to the north, but higher than that for Ecuador's EEZ (8.3 animals per 1,000km^2) to the south (Gerrodette and Palacios, 1996).

Spinner dolphin (*Stenella longirostris*)

The few spinner dolphin sightings in the data set were made on the slope and over the Malpelo Ridge (Fig. 4a). Three subspecies or forms of this species were reported within Colombia's EEZ: eastern (*S. l. orientalis*); whitebelly (a presumed hybrid between *S. l. longirostris* and *S. l. orientalis*) and Central American (*S. l. centroamericana*) (Dizon *et al.*, 1994). The ranked encounter rate was low for this species (Table 3). Average spinner dolphin group size was 96 and the range was 1–226 (Table 4).

Striped dolphin (*Stenella coerueoalba*)

The species was well distributed in offshore waters and absent from inshore waters (Fig. 4b). Striped dolphin had a high ranked encounter rate (Table 3) and it was the second

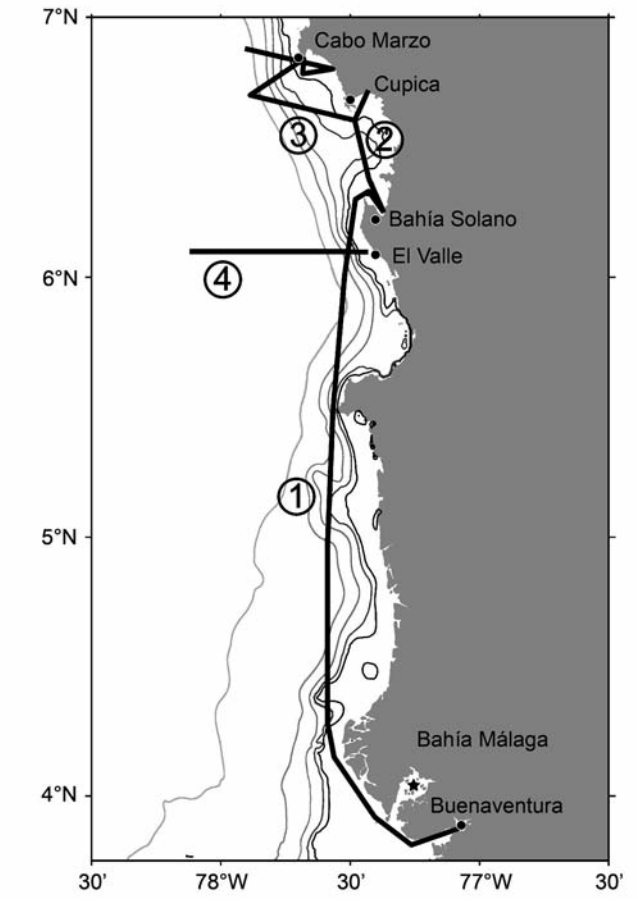

Fig. 3. Typical daily routes followed by the coastal sports-fishing trips (2000–2001, 2004–2008). Encircled numbers correspond to: (1) Buenaventura-Bahía Solano route; (2) Bahía Solano-Cupica route; (3) Cupica-Cabo Marzo route and (4) El Valle-offshore route. Bathymetric contours correspond to the 100, 200, 500, 1,000 and 2,000m isobaths (source as in Fig. 1).

most frequently sighted species in the data set (Table 4). Average group size was 71 and the range was 3–1,500 (Table 4). According to Gerrodette and Palacios (1996), striped dolphin is probably the most abundant dolphin species in Colombia's EEZ (Table 2). The existing density estimate for this species in Colombia's EEZ (78.2 animals per 1,000km^2; Table 2) is somewhat higher than that reported for Panamá (64.3 animals per 1,000km^2) or Ecuador (72.6 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Rough-toothed dolphin (*Steno bredanensis*)
The species occurred in the offshore region, mostly south of 5°N (Fig. 4c). Rough-toothed dolphin had a low ranked encounter rate (Table 3). Average group size was 35 and the range was 5–90 (Table 4). The existing density estimate for the species in Colombia's EEZ (13.3 animals per 1,000km^2; Table 2) is higher than that reported for Panamá (6.9 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Common dolphin (*Delphinus delphis*)
Common dolphins were found primarily in offshore waters, especially in the northeastern part of the EEZ (including the vicinity of Cabo Marzo) (Fig. 4c). This species had an intermediate ranked encounter rate (Table 3) and it was the fifth most frequently sighted in the data set (Table 4). Average group size was 155 and the range was 3–800 (Table 4). The existing density estimate for this species in Colombia's EEZ (37.5 animals per 1,000km^2; Table 2) is substantially lower than that reported for Panamá (129.4 animals per 1,000km^2) or Ecuador (402.2 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Common bottlenose dolphin (*Tursiops truncatus*)
Like the pantropical spotted dolphin, this species was well represented in inshore waters, with multiple sightings scattered throughout the offshore region as well (Fig. 4d). This suggests the occurrence of inshore and offshore ecotypes known from around the world (e.g. Natoli *et al.*, 2004). Most of the inshore sightings occurred north of 4°N, especially between Bahía Solano and Cabo Marzo, and in the offshore region several occurred over the Mapelo Ridge (Fig. 4d). Bottlenose dolphin had a high ranked encounter rate (Table 3) and it was the third most frequently sighted species in the combined data set (Table 4). Average group size was 25 and the range was 1–300 (Table 4). The existing density estimate for common bottlenose dolphin in Colombia's EEZ (21.8 animals per 1,000km^2; Table 2) is substantially lower than that reported for Panamá (53.3 animals per 1,000km^2), and somewhat lower than that reported for Ecuador (26.5 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Risso's dolphin (*Grampus griseus*)
This dolphin was found primarily in offshore waters, including over the Mapelo Ridge (Fig. 4d). Ranked encounter rate was intermediate for this species (Table 3). Average group size was 13 and the range was 1–59 (Table 4). The existing density estimate for Risso's dolphin in Colombia's EEZ (22.1 animals per 1,000km^2; Table 2) is higher than that reported for Panamá (12.7 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Melon-headed whale (*Peponocephala electra*)
The handful of sightings of melon-headed whale in the database were made south of 5°N just offshore of the continental slope (Fig. 5a). Ranked encounter rate was low for this species (Table 3). Average group size was 206 and the range was 10–434 (Table 4).

Pygmy killer whale (*Feresa attenuata*)
Only two sightings were collected for this species, one of which occurred over the Malpelo Ridge (Fig. 5a). Ranked encounter rate was low for this species (Table 3). Average group size was 35 and the range was 25–45 (Table 4).

False killer whale (*Pseudorca crassidens*)
Of the eight false killer whale sightings in the combined data set, four were made offshore near the Malpelo Ridge and the remaining four were made near Cabo Marzo, in the northeast corner of the EEZ (Fig. 5a). Ranked encounter rate for this species was low (Table 3). Average group size was 62 and the range was 2–300 (Table 4).

Short-finned pilot whale (*Globicephala macrorhynchus*)
This species was well distributed throughout the offshore region, including over the Malpelo Ridge, but one sighting was made in the northeast corner of the EEZ near the border

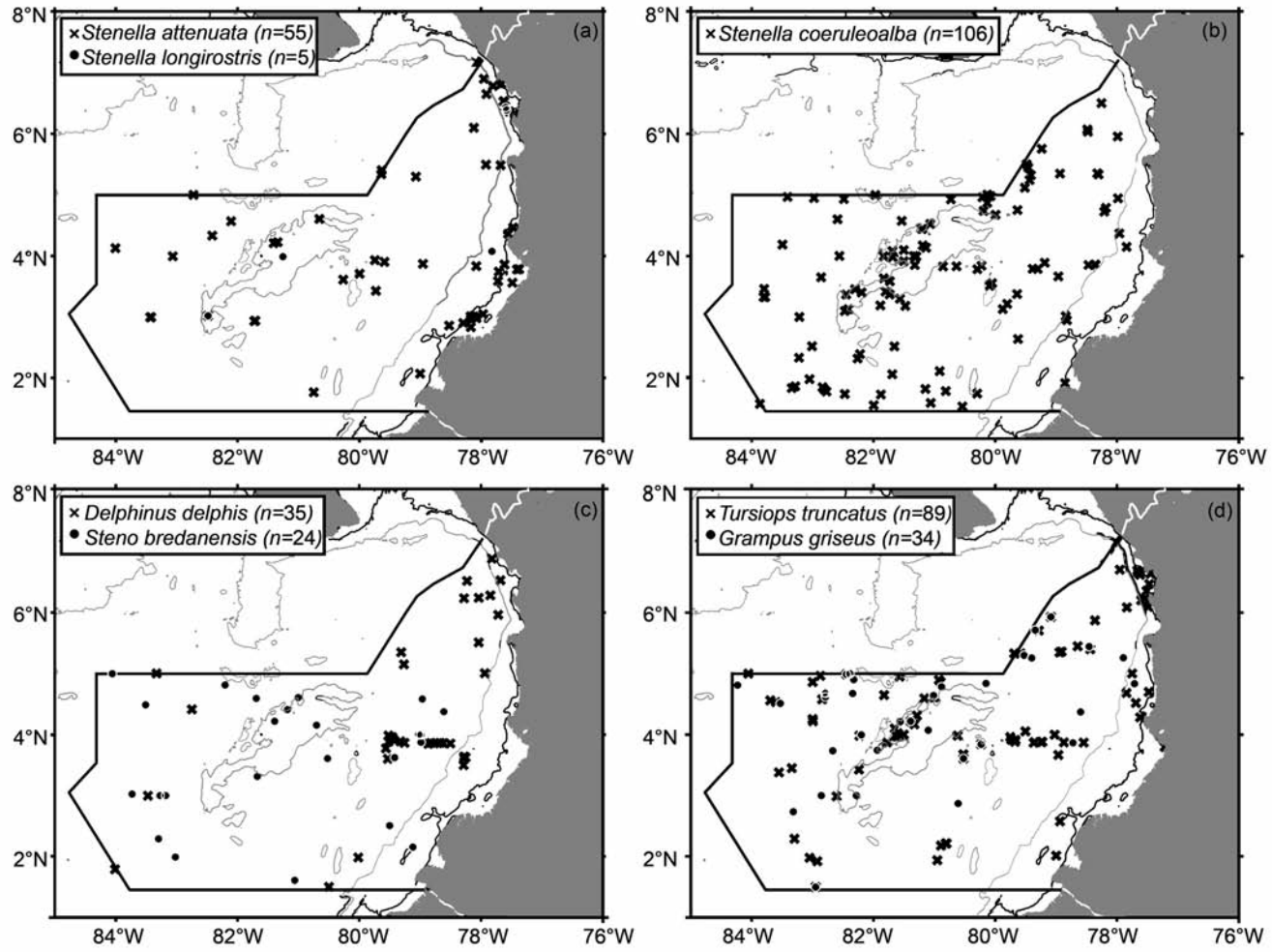

Fig. 4. Distribution maps in Colombia's Pacific EEZ based on sightings from all sources combined (1986–2008) for: (a) pantropical spotted dolphin *(Stenella attenuata)* and spinner dolphin *(Stenella longirostris)*; (b) striped dolphin *(Stenella coeruleoalba)*; (c) common dolphin *(Delphinus delphis)* and rough-toothed dolphin *(Steno bredanensis)* and (d) common bottlenose dolphin *(Tursiops truncatus)* and Risso's dolphin *(Grampus griseus)*. The number of sightings for each species is indicated. For clarity, only the bathymetric contours corresponding to the 100m (black) and 2,000m (gray) isobaths are shown (source as in Fig. 1).

with Panamá (Fig. 5b). Short-finned pilot whale ranked encounter rate was low (Table 3). Average group size was 16 and the range was 1–80 (Table 4). The existing density estimate for this species in Colombia's EEZ (3.5 animals per 1,000km^2; Table 2) is substantially lower than that reported for Panamá (15.2 animals per 1,000km^2) or Ecuador (13.1 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Killer whale (*Orcinus orca*)

The few sightings of this species were scattered in the offshore region south of 4°N (Fig. 5b). Killer whale ranked encounter rate was low (Table 3). Average group size was 5 and the range was 3–8 (Table 4).

Sperm whale (*Physeter macrocephalus*)

Sperm whale was distributed primarily in the offshore region, including over the Malpelo Ridge (Fig. 5c). Ranked encounter rate for this species was intermediate (Table 3). Average group size was 10 and the range was 1–34 (Table 4). It is worth noting that despite relatively continuous coverage between 1986 and 2008, all but two sightings were made prior to 1998, suggesting that sperm whale has shifted its distribution in recent years and that it is no longer present in the Colombian EEZ in the same numbers as in the early years of sampling. The home range of the sperm whale in the eastern tropical Pacific spans ~2,000km (Whitehead *et al.*, 2008), and hence it is possible that the observed trend is, at least in part, a reflection of the species' multi-year displacements throughout the region. The existing sperm whale density estimate in Colombia (3.8 animals per 1,000km^2; Table 2) is based on data for the period 1986–1993 and is somewhat lower than that reported for Panamá (5.3 animals per 1,000km^2) or Ecuador (5.4 animals per 1,000km^2) for the same period (Gerrodette and Palacios, 1996).

Dwarf sperm whale (*Kogia sima*)

There were few sightings of dwarf sperm whale, which were scattered over the slope and in the offshore region, although one sighting was made near Cabo Marzo, in the northeast corner of the EEZ (Fig. 5c). This species had a low ranked encounter rate (Table 3) and was only sighted during SWFSC surveys. Average group size was 2 and the range was 1–3 (Table 4).

Mesoplodont whales (*Mesoplodon spp.*)

Mesoplodont whales were well distributed in the offshore region south of 5°N, including over the Malpelo Ridge (Fig. 5d). Two sightings also were made near Cabo Marzo, in the

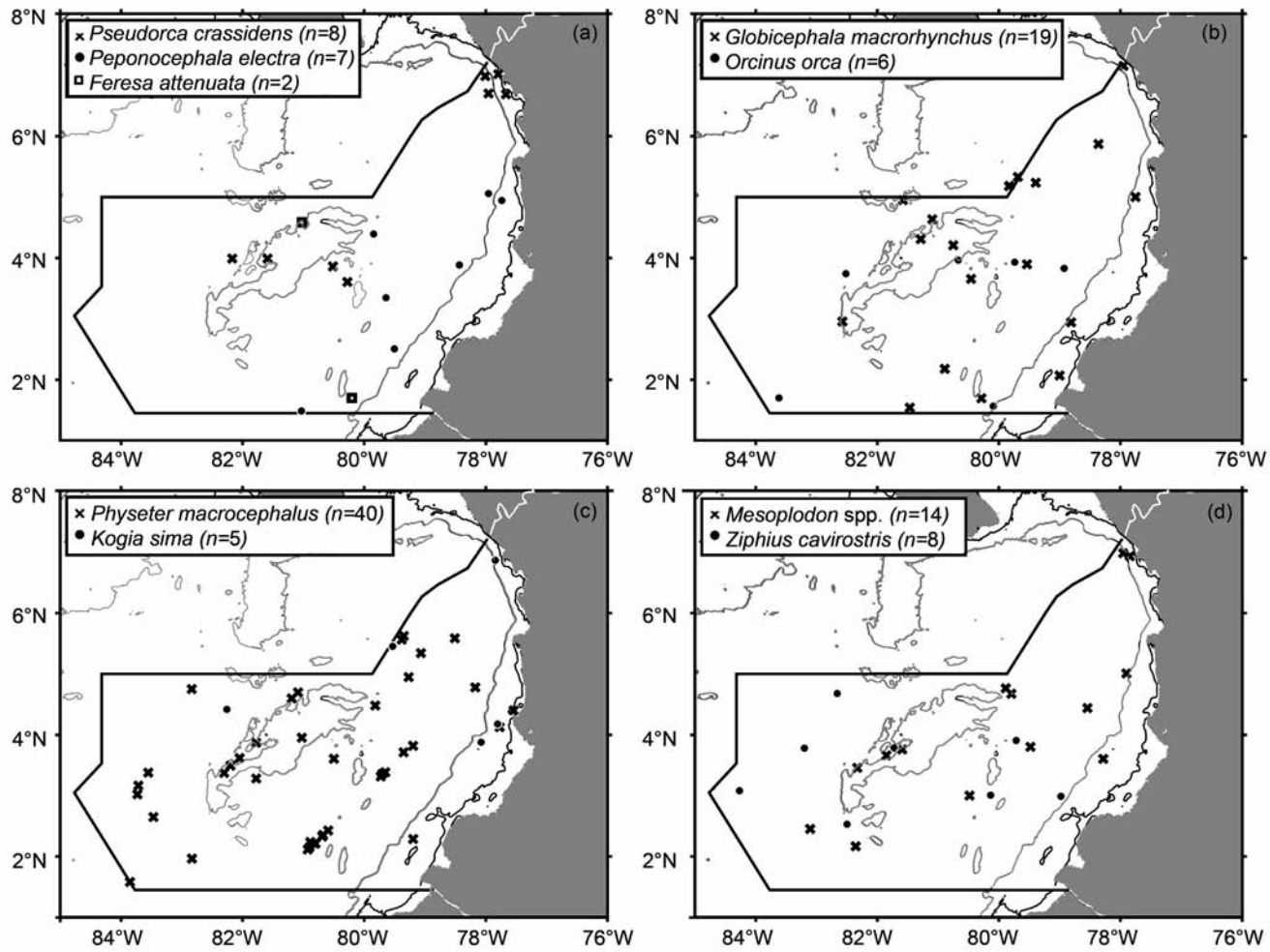

Fig. 5. Distribution maps in Colombia's Pacific EEZ based on sightings from all sources combined (1986–2008) for: (a) false killer whale (*Pseudorca crassidens*), melon-headed whale (*Peponocephala electra*) and pygmy killer whale (*Feresa attenuata*); (b) short-finned pilot whale (*Globicephala macrorhynchus*) and killer whale (*Orcinus orca*); (c) sperm whale (*Physeter macrocephalus*) and dwarf sperm whale (*Kogia sima*); and (d) mesoplodont whales (*Mesoplodon spp.*) and Cuvier's beaked whale (*Ziphius cavirostris*). The number of sightings for each species is indicated. For clarity, only the bathymetric contours corresponding to the 100m (black) and 2,000m (gray) isobaths are shown (source as in Fig. 1).

northeast corner of the EEZ (Fig. 5d). The only mesoplodont species with positive identifications in the data set was Blainville's beaked whale (n = 2). Although this genus had a low ranked encounter rate in this study (Table 3), the original combined data set contained 17 sightings of 'unidentified beaked whales,' some of which were probably mesoplodonts. Therefore, when combined with Cuvier's beaked whale (*Ziphius cavirostris*) (as done in Gerrodette and Palacios, 1996), the beaked whales as a group are probably the most abundant medium-sized cetaceans in the Colombian EEZ (Table 2). Average group size was 3 and the range was 1–5 (Table 4). The existing density estimate for all the beaked whales combined (*Z. cavirostris, Mesoplodon* spp. and unidentified beaked whales) for Colombia (93.4 animals per 1,000km^2; Table 2) is higher than that reported for Panamá (69.7 animals per 1,000km^2), but lower than that for Ecuador (117.6 animals per 1,000km^2) (Gerrodette and Palacios, 1996).

Cuvier's beaked whale (*Ziphius cavirostris*)

The few sightings for this species occurred offshore, mainly in the western part of the EEZ including over the Malpelo Ridge (Fig. 5d). Cuvier's beaked whale had a low ranked encounter rate (Table 3). Average group size was 1 and the range was 1–2 (Table 4).

Minke whale (*Balaenoptera acutorostrata*)

This species was only sighted once during the DIMAR cruises in the northeastern part of the EEZ (Fig. 6) and it had a low ranked encounter rate (Table 3). The group size for this sighting was 1 (Table 4).

Bryde's whale (*Balaenoptera edeni*)

The few offshore sightings of this species were made in the western part of the EEZ, including over the Malpelo Ridge (Fig. 6). Bryde's whale had a low ranked encounter rate (Table 3). However, the original combined data set contained 16 sightings of 'unidentified rorquals (*Balaenoptera sp.*),' some of which could have belonged to this species. Therefore, it is possible that this rorqual is more common than indicated by the positively identified sightings. Average group size was 2 and the range was 1–2 (Table 4). The existing density estimate for Bryde's whale in Colombia's EEZ (0.3 animals per 1,000km^2; Table 2) is the same as that reported for Panamá (Gerrodette and Palacios, 1996).

Fin whale (*Balaenoptera physalus*)

This species was only sighted once during the DIMAR cruises in the southwestern corner of the EEZ (Fig. 6) and it had a low ranked encounter rate (Table 3). The group size for this sighting was 1 (Table 4).

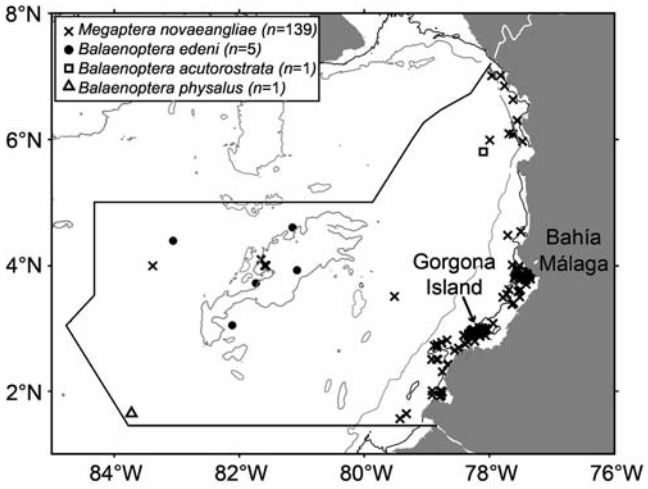

Fig. 6. Distribution map for humpback whale (*Megaptera novaeangliae*), Bryde's whale (*Balaenoptera edeni*), minke whale (*Balaenoptera acutorostrata*) and fin whale (*Balaenoptera physalus*) in Colombia's Pacific EEZ based on sightings from all sources combined (1986–2008). The number of sightings for each species is indicated. For clarity, only the bathymetric contours corresponding to the 100m (black) and 2,000m (gray) isobaths are shown (source as in Fig. 1).

Humpback whale (*Megaptera novaeangliae*)

This was primarily an inshore species, common south of 4°N and with fewer sightings to the north (Fig. 6). This distribution pattern has been related to the decreasing width of the continental shelf toward the north (Herrera *et al.*, 2008). Two sites that showed high concentration of humpback whale sightings were the waters surrounding Gorgona Island and the vicinity of Bahía Málaga (Fig. 6). These two sites have been previously identified as important for the species in Colombian waters (e.g. Flórez-González *et al.*, 2007). A few offshore sightings also were recorded, including over the Malpelo Ridge (Fig. 6). Most sightings were made during the second part of the year and probably belong to the Southeast Pacific stock (IWC Breeding Stock G) during their winter migration to low latitudes (Flórez-González *et al.*, 2007). However, a few sightings north of 4°N from March, April and May suggest that Northeast Pacific animals may also use the Colombian EEZ (cf. Acevedo-Gutiérrez and Smultea, 1995; Calambokidis *et al.*, 2000; Rasmussen *et al.*, 2007).

Humpback whale had a high ranked encounter rate (Table 3) and it was the most frequently sighted species in the combined data set (Table 4). Average group size was 2 and the range was 1–6 (Table 4). Photo-identification based population estimates exist for Gorgona Island (1,366 individuals in 2003, 95% CI = 775–3366; Escobar, 2009) and for Bahía Málaga (575 individuals in 2001, 95% CI = 474–676; Flórez-González *et al.*, 2003). Group composition and behaviour at these two sites is quite different (Escobar, 2009; Flórez-González *et al.*, 2003), however, highlighting the importance of determining the provenance and the segments of the population using the various concentration sites along the breeding range of the Southeast Pacific stock, which extends from northern Peru to western Panama and into Costa Rica (Flórez-González *et al.*, 2007). The most recent population-wide estimates for this stock are ~6,000–7,000 animals (Félix *et al.*, 2011; Johnston *et al.*, 2011), although these estimates are based on photo-identification studies conducted in Ecuador only.

Biases and caveats

The depictions of cetacean occurrence in the Colombian EEZ presented above assume implicitly that sampling was random. None of the studies used here were designed for this specific purpose (the SWFSC surveys were randomised at the regional level but coverage within the Colombian EEZ was not necessarily random) and therefore it is possible that these patterns could be an artefact of non-random effort. Further, although the overall trends in species encounter rates were qualitatively similar among data sources covering similar regions (e.g. SWFSC and DIMAR), we urge caution in the use of these encounter rates as quantitative indices of abundance for several reasons arising from methodological differences in data collection. First, the observation height

Table 4

Sighting frequency (*#Si*) and group size statistics (G_{rng}: range; G_{avg}: average; G_{med}: median; G_{sd}: standard deviation) for 19 cetacean species and one genus based on all on-effort sightings (*n*=488) recorded in Colombia's Pacific EEZ between 1986 and 2008.

Common name	Scientific name	*#Si*	G_{rng}	G_{avg}	G_{med}	G_{sd}
Humpback whale	*Megaptera novaeangliae*	108	1–6	1.9	2.0	1.1
Striped dolphin	*Stenella coeruleoalba*	95	3–1,500	70.5	38.1	157.7
Common bottlenose dolphin	*Tursiops truncatus*	69	1–300	25.0	7.0	50.9
Pantropical spotted dolphin*	*Stenella attenuata*	45	2–400	93.7	50.0	104.7
Common dolphin	*Delphinus delphis*	30	3–800	155.1	66.9	211.6
Risso's dolphin	*Grampus griseus*	29	1–59	12.9	10.2	12.5
Sperm whale	*Physeter macrocephalus*	29	1–34	10.0	5.8	9.6
Rough-toothed dolphin	*Steno bredanensis*	17	5–90	34.9	32.8	24.4
Short-finned pilot whale	*Globicephala macrorhynchus*	14	1–80	15.8	7.8	20.8
Mesoplodont whales*	*Mesoplodon spp.*	12	1–5	2.6	2.5	1.2
Cuvier's beaked whale	*Ziphius cavirostris*	7	1–2	1.4	1.2	0.5
Melon-headed whale	*Peponocephala electra*	6	10–434	206.2	206.6	158.7
False killer whale	*Pseudorca crassidens*	6	2–300	61.5	20.0	117.1
Killer whale	*Orcinus orca*	5	3–8	5.3	5.0	2.1
Spinner dolphin*	*Stenella longirostris*	4	1–226	95.5	77.5	111.2
Dwarf sperm whale*	*Kogia sima*	4	1–3	1.6	1.2	0.8
Bryde's whale*	*Balaenoptera edeni*	4	1–2	1.5	1.2	0.6
Pygmy killer whale	*Feresa attenuata*	2	25–45	35.1	35.1	13.9
Minke whale	*Balaenoptera acutorostrata*	1	1	1.0	1.0	0.0
Fin whale	*Balaenoptera physalus*	1	1	1.0	1.0	0.0

*Pooling of related sighting categories was done for these species as described in the text.

varied widely among platforms (2–15m), as did vessel speeds (14–30km/h). Second, the number of observers onboard these platforms varied between one and three, they used different sighting methods (25x binoculars, 7x binoculars, unaided eye) for scanning the area in front of the vessels and they had different levels of experience in species identification and group size estimation. Third, some of the sources (e.g. DIMAR and dive trips) collected observations in 'passing mode' (i.e. when the ship is not diverted from the trackline to approach a distant sighting), which severely limits species identification and accurate group size estimation (Barlow and Forney, 2007; Dawson *et al.*, 2008). Finally, the use of simple encounter rates as indices of relative abundance does not take into account the effects of group size, species behaviour, sea state and swell height on detectability. These variables are known to impact the estimation of perpendicular sighting distances in studies designed to estimate abundance based on line-transect methodologies, and therefore it is recommended that encounter rates be adjusted to the effective half-strip width, which can be estimated for several sighting categories and sea states if radial distances (sighting to ship) are appropriately collected as part of the survey protocol (Barlow *et al.*, 2001; Dawson *et al.*, 2008). It is because of these shortcomings in the data that we did not compute density.

CONCLUSIONS AND RECOMMENDATIONS

Shortcomings notwithstanding, the general picture of cetacean relative abundance in Colombia's EEZ suggests that common bottlenose dolphin, humpback whale and striped dolphin are the most regularly encountered species, followed by pantropical spotted dolphin, sperm whale, common dolphin and Risso's dolphin. In terms of distribution, apparent concentrations of sightings were observed in three geographic areas: (1) the inshore area from the coastline to the continental shelf (depths <200m) and the contiguous continental slope (200–2,000m), where significant stocks of coastal species may be found; (2) the Malpelo Ridge, an offshore bathymetric feature where several oceanic species were observed; and (3) the northeast corner of the EEZ near the border with Panamá, centred around Cupica and Cabo Marzo, where both coastal and oceanic species may occur due to the presence of deep water very close to the coast. These apparent 'hot spots' and their underlying environmental drivers should be formally tested in an ecological framework as was done recently for the DIMAR data set by Herrera (2009), who found that the area to the southwest of Malpelo Island had the highest species richness and relative abundance of the entire EEZ, at least during the first part of the year.

With some modifications to the current data collection protocols more accurate estimates of abundance could be obtained. These would involve conducting appropriately randomised and stratified surveys and collecting and incorporating sighting parameters in the estimation of encounter rate. These surveys should also consider the marked oceanographic seasonality of the region (e.g. Rodriguez-Rubio *et al.*, 2003) in order to capture any seasonal differences in species occurrence patterns (cf. Herrera, 2009). Additionally, long-term monitoring will be useful in detecting population trends and in documenting distributional shifts (as appears to have occurred with sperm whale) in response to climatic variation or otherwise. In this regard, the biannual DIMAR cruises are in a unique position to fill some of these knowledge gaps.

The use of passive acoustics for documenting occurrence could be a complementary approach in some specific areas and for selected species. Although this technology has its own limitations, it has been demonstrated to be effective for the long-term monitoring of the calling behaviour of both mysticete and odontocete species (e.g. Johnston *et al.*, 2008; Mellinger *et al.*, 2007; Rayment *et al.*, 2009; Soldevilla *et al.*, 2010). As an example, a network of sea-floor mounted hydrophone instrument packages could be deployed over the Malpelo Ridge to monitor species like sperm, humpback and beaked whales at this important but remote area.

Finally, localised studies of coastal species, focusing on residence patterns (e.g. Suárez, 1994), genetic structure (e.g. Escorza-Treviño *et al.*, 2005), and population impacts arising from interactions with vessel traffic, fisheries and directed catches (e.g. Avila *et al.*, 2008; Capella *et al.*, 2001; Mora-Pinto *et al.*, 1995; Palacios and Gerrodette, 1996) should yield additional information for management strategies at the local level.

ACKNOWLEDGEMENTS

We thank the many SWFSC scientists, marine mammal observers and personnel of NOAA ships *McArthur, David Starr Jordan* and *McArthur II* that were involved in the line-transect surveys. The catalysts of the *Siben* and *Odyssey* expeditions in Colombian waters were R. Payne, I. Kerr, J. Reynolds, A. Vélez-Sierra, J.S. Uribe, A. Vejarano, M. Obregón, F. Ospina-Navia and the organisations *Grupo para las Investigaciones Submarinas* (Cartagena) and *Seguimiento de Corazón de Ballenas Vía Satélite* (Bogotá). Participants for Colombia included D.F. Torres, C. Obregon, F. Trujillo, P.L.R. Brennan and D.M. Palacios. We thank the other scientists and crew on board and the office support staff, including T. Lyrholm, L. Galley, D. Day, B.J. Brennan, C. Rogers, R. Wallace and K. Marshall-Tilas. Fundación Yubarta and Fundación Malpelo wish to thank CCCP and its past directors, Captains J.M. Soltau and R. Molares, for their kind invitation to participate in the DIMAR oceanographic cruises. We also thank J.J. Capella (Fundación Yubarta) for assistance with sampling design and E. Rodríguez-Rubio (CCCP), J. Donoso, the scientific personnel and the officers and crews of the R/Vs *Providencia* and *Malpelo* for ensuring a successful operation. Finally, we thank H. Botero (*Embarcaciones Asturias*, Cali, Colombia) and A. Parra-Vidal (Fundación Cabo Mar, Cali, Colombia) for making available their platforms for marine mammal observation, and F.J. Álvarez-Vargas and the crews of M/Vs *Maria Patricia, La Cotizada* and *El Gran Blanco* for field assistance and logistical support. DMP was supported by funding from the Gordon and Betty Moore Foundation and from the NASA Applied Sciences Program, Earth Science Division, through a grant provided by Research Announcement NNH07ZDA001N, Research Opportunities in Space and Earth Sciences (ROSES-2007), Program Element A.20:

Decision Support through Earth Science Research Results. Fundación Malpelo received field equipment and supplies from IDEA WILD and financial support from the Seascape Program of Conservation International, the Walton Family Foundation and UNESCO. Funding for Fundación Yubarta's participation in the DIMAR cruises was provided by WWF. Earlier drafts of this paper benefited from comments from M.C. Díazgranados (Conservation International Colombia) and two anonymous reviewers.

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Date received: July 2010
Date accepted: October 2010

Appendix 1

DETAILS OF SURVEY EFFORT AND SIGHTING STATISTICS FOR SWFSC LINE-TRANSECT SURVEYS (1986–2006).

Table A1.1

Survey effort by year conducted by the SWFSC within Colombia's Pacific EEZ (1986–2006).

Year	Cruise	Vessel	Effort (km)
1986	MOPS86	R/V *David Starr Jordan*	252.2
1986	MOPS86	R/V *McArthur*	376.1
1987	MOPS87	R/V *McArthur*	782.2
1987	MOPS87	R/V *David Starr Jordan*	475.0
1988	MOPS88	R/V *David Starr Jordan*	334.8
1988	MOPS88	R/V *McArthur*	596.4
1989	MOPS89	R/V *David Starr Jordan*	373.2
1990	MOPS89	R/V *David Starr Jordan*	351.6
1992	PODS92	R/V *McArthur*	1,730.8
1992	PODS92	R/V *David Starr Jordan*	636.9
1998	SPAM98	R/V *McArthur*	127.7
1998	SPAM98	R/V *Endeavor*	480.9
1998	SPAM98	R/V *David Starr Jordan*	325.5
2000	STAR00	R/V *McArthur*	544.9
2006	STAR06	R/V *David Starr Jordan*	396.2

Table A1.2

Summary of effort, number of sightings (*#Si*) and encounter rate (*ER*, in sightings per 1,000km) collected under various sea state conditions (Beaufort scale) and swell height (in feet) during SWFSC line-transect surveys within Colombia's Pacific EEZ (1986–2006).

	Effort (km)	*#Si*	*ER*
Total	7,784.4	300	38.54
By sea state			
0	14.2	1	70.55
1	113.7	18	158.31
2	404.6	65	160.65
3	601.3	53	88.15
4	1,315.7	91	69.16
5	1,818.6	69	37.94
6	31.1	3	96.38
By swell height*			
0	7.2	0	0.00
1	138.2	8	57.87
2	357.8	30	83.84
3	1,476.1	76	51.49
4	1,209.7	27	22.32
5	365.7	11	30.08
6	444.8	11	24.73
7	81.2	4	49.24
8	117.6	4	34.01

*Number of sightings with no swell height recorded = 129.

Table A1.3

Number of on-effort sightings (*#Si*), average group size (*G*) and encounter rate (*ER*, in number of groups per 1,000km) for all identified species within Colombia's Pacific EEZ, from SWFSC line-transect surveys (1986–2006).

Common name	Scientific name	*#Si*	*G*	*ER*
Pantropical spotted dolphin*	*Stenella attenuata*	15	84.2	1.93
Spinner dolphin*	*Stenella longirostris*	3	77.4	0.39
Striped dolphin	*Stenella coeruleoalba*	70	48.4	8.99
Rough-toothed dolphin	*Steno bredanensis*	12	27.3	1.54
Common dolphin	*Delphinus delphis*	13	126.9	1.67
Common bottlenose dolphin	*Tursiops truncatus*	25	15.6	3.21
Risso's dolphin	*Grampus griseus*	25	12.2	3.21
Melon-headed whale	*Peponocephala electra*	5	245.5	0.64
Pygmy killer whale	*Feresa attenuata*	2	35.1	0.26
Short-finned pilot whale	*Globicephala macrorhynchus*	6	9.9	0.77
Killer whale	*Orcinus orca*	2	5.3	0.26
Sperm whale	*Physeter macrocephalus*	27	10.4	3.47
Dwarf sperm whale*	*Kogia sima*	4	1.6	0.51
Mesoplodont whales*	*Mesoplodon* spp.	11	2.7	1.41
Cuvier's beaked whale	*Ziphius cavirostris*	4	1.5	0.51
Bryde's whale*	*Balaenoptera edeni*	4	1.5	0.51
Humpback whale	*Megaptera novaeangliae*	10	2.6	1.28

*Pooling of related sighting categories was done for these species as described in the text.

Appendix 2

DETAILS OF ROUTES COVERED AND SIGHTINGS COLLECTED DURING THE *SIBEN* AND *ODYSSEY* EXPEDITIONS (1988, 1993, 1994).

Table A2.1

Dates and routes of the *Siben* and *Odyssey* expeditions in Colombian Pacific waters. Effort information was not available for these data sets.

Date	Route	Vessel
23–27/05/88	Panamá-Bahía Solano-Buenaventura-Gorgona	R/V *Siben*
26/06–12/07/88	Buenaventura-Panamá	R/V *Siben*
24–27/07/88	Buenaventura-Gorgona-Buenaventura	R/V *Siben*
09–16/02/93	Panamá-Galápagos	R/V *Odyssey*
20–21/09/93	Galápagos-Bahía Málaga	R/V *Odyssey*
05–09/10/93	Bahía Málaga-Galápagos	R/V *Odyssey*
12–19/04/94	Galápagos-Panamá	R/V *Odyssey*

Table A2.2

Number of sightings (*#Si*) and average group size (*G*) for all identified species observed during the *Siben* Expedition in Colombian Pacific waters (May–July 1988).

Common name	Scientific name	*#Si*	*G*
Pantropical spotted dolphin	*Stenella attenuata*	2	45.0
Rough-toothed dolphin	*Steno bredanensis*	1	42.0
Common dolphin	*Delphinus delphis*	1	95.0
Short-finned pilot whale	*Globicephala macrorhynchus*	1	8.0
Sperm whale	*Physeter macrocephalus*	1	20.0
Humpback whale	*Megaptera novaeangliae*	5	2.4

Table A2.3

Number of sightings (*#Si*) and average group size (*G*) for all identified species observed during the *Odyssey* Expedition in Colombian Pacific waters (February 1993, September–October 1993 and April 1994).

Common name	Scientific name	*#Si*	*G*
Common bottlenose dolphin	*Tursiops truncatus*	1	20.0
Risso's dolphin	*Grampus griseus*	1	7.0
Sperm whale	*Physeter macrocephalus*	3	22.7
Humpback whale	*Megaptera novaeangliae*	3	1.7

Appendix 3

DETAILS OF SURVEY EFFORT AND SIGHTING STATISTICS FOR OCEANOGRAPHIC CRUISES ABOARD DIMAR VESSELS (2004, 2006–08).

Table A3.1

Visual effort conducted in passing mode, Beaufort sea states of 3 or less and good sighting conditions during oceanographic cruises aboard DIMAR vessels (2004, 2006–08).

Dates	Cruise	Vessel	Effort (km)
24/09–08/10/04	ERFEN-04	R/V *Providencia*	551.1
03–27/03/06	Pacífico-06	R/V *Malpelo*	1,703.4
15–26/09/06	ERFEN-06	R/V *Providencia*	811.3
24/01–18/02/07	Pacífico-07	R/V *Malpelo*	1,717.9
03–28/09/07	ERFEN-07	R/V *Providencia*	1,369.0
09–28/03/08	Pacífico-08	R/V *Providencia*	1,372.3
06–26/09/08	ERFEN-08	R/V *Malpelo*	1,061.9

Table A3.2

Number of sightings (*#Si*) and average group size (*G*) and encounter rate (*ER*, in number of groups per 1,000km) for all identified species, collected during oceanographic cruises aboard DIMAR vessels (2004, 2006–08).

Common name	Scientific name	*#Si*	*G*	*ER*
Pantropical spotted dolphin	*Stenella attenuata*	16	80.1	1.86
Striped dolphin	*Stenella coeruleoalba*	19	142.1	2.21
Rough-toothed dolphin	*Steno bredanensis*	4	53.8	0.47
Common dolphin	*Delphinus delphis*	6	185.5	0.70
Common bottlenose dolphin	*Tursiops truncatus*	21	9.1	2.45
Risso's dolphin	*Grampus griseus*	3	18.0	0.35
False killer whale	*Pseudorca crassidens*	2	104.7	0.23
Short-finned pilot whale	*Globicephala macrorhynchus*	6	24.2	0.70
Killer whale	*Orcinus orca*	1	5.0	0.12
Sperm whale	*Physeter macrocephalus*	2	4.5	0.23
Mesoplodont whales	*Mesoplodon* spp.	1	1.0	0.12
Cuvier's beaked whale	*Ziphius cavirostris*	2	1.0	0.23
Minke whale	*Balaenoptera acutorostrata*	1	1.0	0.12
Fin whale	*Balaenoptera physalus*	1	1.0	0.12
Humpback whale	*Megaptera novaeangliae*	93	1.8	10.83

Appendix 4

DETAILS OF SEARCH EFFORT AND SIGHTING STATISTICS FOR DIVE AND SEASCAPE CHARTER TRIPS (2004–08).

Table A4.1

Daily visual effort conducted in passing mode, Beaufort sea states of 3 or less and good sighting conditions aboard M/V *Maria Patricia* during dive and Seascape charter trips (2004–08).

Date	Effort (hr)	Route	Date	Effort (hr)	Route
14 February 2004	9.0	Buenaventura-Malpelo	11 March 2006	10.0	Gorgona-Malpelo
22 February 2004	10.0	Malpelo-Buenaventura	14 March 2006	10.0	Malpelo-Buenaventura
15 March 2004	9.8	Buenaventura-Malpelo	8 April 2006	10.7	Buenaventura-Malpelo
16 March 2004	4.0	Malpelo-Buenaventura	15 April 2006	10.6	Malpelo-Buenaventura
20 June 2004	2.0	Malpelo-Buenaventura	27 August 2006	4.0	Gorgona-Malpelo
18 December 2004	9.0	Malpelo-Buenaventura	18 March 2007	7.8	Buenaventura-Malpelo
24 March 2005	9.0	Gorgona-Malpelo	27 March 2007	4.3	Malpelo-Buenaventura
31 March 2005	11.7	Malpelo-Buenaventura	3 April 2007	6.2	Gorgona-Malpelo
12 April 2005	9.7	Buenaventura-Malpelo	10 April 2007	3.0	Malpelo-Buenaventura
13 April 2005	4.5	Malpelo-Buenaventura	21 March 2008	1.3	Buenaventura-Malpelo
21 April 2005	8.0	Malpelo-Buenaventura	30 March 2008	9.2	Malpelo-Buenaventura
10 August 2005	6.0	Gorgona-Malpelo	26 May 2008	9.0	Cabo Marzo-Buenaventura
14 August 2005	12.5	Malpelo-Buenaventura			

Table A4.2

Number of sightings (*#Si*) and average group size (*G*) and encounter rate (*ER*, in number of groups per 100hr) for all identified species, collected aboard M/V *Maria Patricia* during dive and Seascape charter trips (2004–08).

Common name	Scientific name	*#Si*	*G*	*ER*
Pantropical spotted dolphin	*Stenella attenuata*	5	54.0	1.90
Spinner dolphin	*Stenella longirostris*	1	150.0	0.38
Striped dolphin	*Stenella coeruleoalba*	6	101.6	2.28
Rough-toothed dolphin	*Steno bredanensis*	1	50.0	0.38
Common dolphin	*Delphinus delphis*	11	245.7	4.17
Common bottlenose dolphin	*Tursiops truncatus*	11	28.9	4.17
Risso's dolphin	*Grampus griseus*	1	15.0	0.38
Melon-headed whale	*Peponocephala electra*	1	10.0	0.38
False killer whale	*Pseudorca crassidens*	3	6.0	1.14
Short-finned pilot whale	*Globicephala macrorhynchus*	2	15.0	0.76
Killer whale	*Orcinus orca*	2	5.5	0.76
Cuvier's beaked whale	*Ziphius cavirostris*	1	2.0	0.38
Humpback whale	*Megaptera novaeangliae*	1	2.0	0.38

Appendix 5

DETAILS OF ROUTES COVERED AND SIGHTINGS COLLECTED DURING DAILY COASTAL SPORTS-FISHING TRIPS ORGANISED BY FUNDACIÓN CABO MAR (2000–01, 2004–08).

Table A5.1

Visual effort conducted during 21 daily coastal sports-fishing trips organised by Fundación Cabo Mar (2000–01, 2004–08).

Dates	Route	Vessel	Effort (hr)
July 2000*	Buenaventura-Bahía Solano	M/V *La Cotizada*	7
28 May 2001	Cupica-Cabo Marzo	M/V *La Cotizada*	7
July 2001*	Bahía Solano-Cupica	M/V *La Cotizada*	2
July 2001*	Cupica-Cabo Marzo	M/V *La Cotizada*	6
July 2001*	Bahía Solano-Cupica	M/V *La Cotizada*	3
29 December 2004	Buenaventura-Bahía Solano	M/V *La Cotizada*	9
30 December 2004	Cupica-Cabo Marzo	M/V *La Cotizada*	2
3 January 2005	Cupica-Cabo Marzo	M/V *La Cotizada*	5
4 January 2005	Cupica-Cabo Marzo	M/V *La Cotizada*	2
7 January 2005	Bahía Solano-Cupica	M/V *La Cotizada*	3
3 May 2005	Cupica-Cabo Marzo	M/V *La Cotizada*	6
January 2006*	Cupica-Cabo Marzo	M/V *El Gran Blanco*	8
1 March 2007	Bahía Solano-Cupica	M/V *El Gran Blanco*	4
6 March 2007	El Valle-offshore	M/V *El Gran Blanco*	4
10 April 2007	Buenaventura-Bahía Solano	M/V *El Gran Blanco*	4
15 April 2007	Buenaventura-Bahía Solano	M/V *El Gran Blanco*	7
11 May 2007	Buenaventura-Bahía Solano	M/V *El Gran Blanco*	5
11 May 2007	Bahía Solano-Cupica	M/V *El Gran Blanco*	3
2 January 2008	Cupica-Cabo Marzo	M/V *El Gran Blanco*	8
3 February 2008	Bahía Solano-Cupica	M/V *El Gran Blanco*	4
6 February 2008	Buenaventura-Bahía Solano	M/V *El Gran Blanco*	9

*The specific date for these trips was not available.

Table A5.2

Number of sightings (*#Si*) and average group size (*G*) and encounter rate (*ER*, in number of groups per 100h) for all identified species, collected during 21 daily coastal sports-fishing trips (2000–01, 2004–08).

Common name	Scientific name	*#Si*	*G*	*ER*
Pantropical spotted dolphin	*Stenella attenuata*	9	155.8	8.57
Common bottlenose dolphin	*Tursiops truncatus*	12	72.8	11.43
False killer whale	*Pseudorca crassidens*	1	2.0	0.95
Humpback whale	*Megaptera novaeangliae*	4	2.0	3.81