

Distribution and relative abundance of oceanic cetaceans in Colombia's Pacific EEZ from survey cruises and platforms of opportunity

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ABSTRACT

We compiled cetacean sighting data collected under various programs in Colombian Pacific waters with the goal of assessing the distribution and abundance patterns of the most common species throughout the exclusive economic zone (EEZ). Distribution maps are presented for 19 species and one genus based on 548 sightings collected between 1986 and 2008. Concentrations of sightings were observed in two areas: the continental shelf (depths <2,000m) and over the Malpelo Ridge, an oceanic bathymetric feature. Ordered by sighting frequency, these species were: striped dolphin (*Stenella coeruleoalba*), common bottlenose dolphin (*Tursiops truncatus*), pantropical spotted dolphin (*Stenella attenuata*), humpback whale (*Megaptera novaeangliae*), sperm whale (*Physeter macrocephalus*), Risso's dolphin (*Grampus griseus*), common dolphin (*Delphinus delphis*), rough-toothed dolphin (*Steno bredanensis*), beaked whales (*Mesoplodon* spp. and unidentified ziphiid whales), short-finned pilot whale (*Globicephala macrorhynchus*), false killer whale (*Pseudorca crassidens*), melon-headed whale (*Peponocephala electra*), spinner dolphin (*Stenella longirostris*), Cuvier's beaked whale (*Ziphius cavirostris*), killer whale (*Orcinus orca*), dwarf sperm whale (*Kogia sima*), Bryde's whale (*Balaenoptera edeni*), pygmy killer whale (*Feresa attenuata*), dense beaked whale (*Mesoplodon densirostris*) and minke whale (*Balaenoptera acutorostrata*). 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 differences and because several factors that affect sightability were not accounted for in these estimates. Our results provide useful information for ongoing regional research and conservation initiatives aimed at determining population status and connectivity within adjacent EEZs. Future activities should focus on conducting dedicated surveys designed for estimating abundance and monitoring trends in areas of special interest (*i.e.*, the continental shelf and the Malpelo Ridge). More research is also needed in terms of quantifying the sources and impact of anthropogenic mortality on population size. Finally, studies characterizing genetic diversity and stock discreteness in coastal species (*i.e.*, pantropical spotted dolphin and common bottlenose dolphin) would help inform local management strategies.

KEYWORDS: SOUTHEAST PACIFIC OCEAN; SURVEY - VESSEL; INCIDENTAL SIGHTINGS; DISTRIBUTION; ABUNDANCE ESTIMATE; INDEX OF ABUNDANCE

INTRODUCTION

On 23 May 2007, Colombia's government 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 (CPPS, 2008). 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) (Shillinger, 2004). These international instruments reflect the country's commitment to the conservation of biological diversity. In this context, knowledge about the distribution and abundance of protected resources such as cetaceans is essential for the development of adequate management plans. For the humpback whale (*Megaptera novaeangliae*), extensive biological information and a comprehensive conservation strategy now exist as a product of more than 20 years of study (Flórez-González *et al.*, 2007). In addition, efforts 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.*, 2004a) and Malpelo

(Herrera *et al.* 2007). However, little is known about the occurrence of cetaceans outside these locations, in particular for those species occurring in offshore waters.

Colombia's exclusive economic zone (EEZ) in the Pacific Ocean covers an area of about 330,000km² (Fig. 1). At least 23 cetacean species are known to occur in these waters (Table 1) (Vidal, 1990; Flórez-González and Capella, 1995; Flórez-González *et al.*, 2004b). Abundance estimates for nine of these species and for the beaked whales (family Ziphiidae) as a group were provided by Gerrodette and Palacios (1996), based on line-transect surveys conducted between 1986 and 1993 (Table 2). However, no comprehensive maps of cetacean distribution have ever been published. Here we present, for the first time, distributional maps for 19 cetacean species and one genus occurring in oceanic waters of Colombia's EEZ, based on a compilation of sightings collected aboard survey cruises and platforms of opportunity between 1986 and 2008. We also report encounter rates for several of these sources. Finally, we discuss what has been learned from these efforts and identify gaps in knowledge and research needs.

DATA SOURCES

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

NOAA/NMFS/SWFSC line-transect cruises

The Southwest Fisheries Science Center (SWFSC), part of the National Marine Fisheries Service (NMFS) of the US National Oceanic and Atmospheric Administration (NOAA), has conducted systematic line-transect surveys for cetaceans throughout the eastern tropical Pacific since 1986. 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.*, Wade and Gerrodette, 1993; Kinzey *et al.*, 2000), but briefly, the surveys were conducted from late July to early December using two 52m research vessels, the *McArthur* and the *David Starr Jordan* (an additional ship, the R/V *Endeavor*, was used in 1998), following pre-determined random tracklines at a nominal cruising speed of 10 knots (18.5km/h). A team of three observers conducted visual searching for cetaceans during daylight hours (dawn to dusk) from the ship's flying bridge, 11m above the water line. Angle and radial distance to each sighting were recorded upon initial sighting, and the ship was then diverted to approach the animals in order to obtain species identity and group size. The surveys have taken place in international waters as well in EEZ waters of several Central and South American countries. The data set extends through 2006, and, within Colombia's EEZ, it contains 355 sightings of at least 17 species and covers 7,784km of effort (Appendix 1). A map showing the survey tracklines is presented in Figure 2a.

The *Siben* and *Odyssey* Expeditions

Two expeditions to study cetaceans in South American waters were conducted by the Ocean Alliance (under the former names of Long-term Research Institute and Whale Conservation Institute). The *Siben* Expedition operated in Colombian waters between May and July 1998 (Torres *et al.*, 1988), and the *Odyssey* Expedition at various times during 1993 (February, September, October) and 1994 (April) (D.M. Palacios, B.J. Brennan and P.L.R. Brennan, unpublished data). These expeditions were conducted aboard the R/Vs *Siben* and *Odyssey* (both sailboats), respectively, with the purpose of studying various aspects of the biology of sperm whales (*Physeter macrocephalus*) and humpback whales (*Megaptera novaeangliae*). Observations were conducted atop the ship's pilothouse or from the crow's nest on the main mast. Sightings of other cetacean species were recorded but the associated search effort data are not available. The *Siben* Expedition in Colombian waters consisted of three legs during which 11 sightings of six species were recorded (Appendix 2). The *Odyssey* Expedition consisted of four legs during which eight sightings of four species were collected (Appendix 2). These routes are shown in Figure 2b.

Colombian Navy oceanographic cruises

Fundación Malpelo has placed marine mammal observers aboard oceanographic ships of the Colombian Navy taking part in a study of the El Niño phenomenon (ERFEN cruises) as well as other in oceanographic studies (PACIFICO cruises). Four cruises were conducted aboard R/Vs *Providencia* and *Malpelo* throughout Colombia's Pacific EEZ between 2004 and 2008. Observation effort took place during travel between oceanographic stations at a speed of 12 knots (22.2km/h). Typically one or some times two observers searched for cetaceans from the ship's flying bridge 10m above the water line. Unlike the SWFSC surveys, sightings were not closed on, so only cetacean groups that occurred near the ship could be identified and counted. For this

reason, searching was only done under acceptable viewing conditions (no fog or rain, and in Beaufort sea state <4). A total of 378h of effort and 159 sightings belonging to 13 species were recorded (Appendix 3). The cruise tracks while on effort are shown in Figure 2c.

Dive-charter trips

Fundación Malpelo has also placed marine mammal observers on 13 diving trips to Malpelo and Gorgona Islands organized by the company Embarcaciones Asturias aboard M/V *Maria Patricia* between 2004 and 2007. Observations took place during transit between the port of Buenaventura and Malpelo Island and during transit between Malpelo and Gorgona islands, at a speed of 8 knots (14.8km/h). Searching was conducted from the boat's top deck at a height of 4m above the waterline under acceptable viewing conditions (no fog or rain, and in Beaufort sea state <4). Sighting data were recorded without diverting the boat. A total of 167h of effort and 68 sightings belonging to 13 species were recorded (Appendix 4). The on-effort segments of these trips are shown in Figure 2d.

Sports-fishing charter trips

Cetacean observations were collected on coastal sports-fishing trips organized by the company Pacífico Extremo between 2001 and 2008. During this period, 20 daily trips were conducted along one of three 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. At least 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. Travel speed was variable, ranging between 12 and 30km/h. A total of 108h of effort were logged, during which 26 cetacean sightings belonging to four species were recorded (Appendix 5). A map showing the daily routes is presented in Figure 3.

DATA ANALYSIS

In the field, sightings were classified under 37 different identification categories (*i.e.*, species or lower taxonomic level, genus, family and other). For analysis purposes, sightings falling under several of these categories were pooled as follows. A single 'pantropical spotted dolphin (*Stenella attenuata*)' category was created from three categories (offshore, coastal and unidentified subspecies). The category 'spinner dolphin (*Stenella longirostris*)' was similarly created by pooling four categories (eastern, whitebelly, Central American and unidentified subspecies). The category 'Bryde's whale (*Balaenoptera edeni*)' was created by pooling sightings positively identified as Bryde's whales with those identified as either sei (*B. borealis*) or Bryde's whales. The 'dwarf sperm whale (*Kogia sima*)' category was created by pooling sightings positively identified as dwarf sperm whales with those identified as *Kogia* sp. Finally, a 'beaked whales' category was created by pooling sightings identified as *Mesoplodon* sp. with sightings only identified to the family level (Ziphiidae). Sightings classified under nine unidentified categories ('unidentified rorqual', 'unidentified dolphin', 'unidentified small whale', 'unidentified large whale', 'unidentified cetacean', 'unidentified whale', 'unidentified small delphinid', 'unidentified medium delphinid' or 'unidentified large delphinid') were not used in this study. In this manner, 20 sighting categories are reported here (19 individual species and the beaked whales; see Table 3).

Species encounter rates were estimated for each data set separately, 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). For ease in discussion, the estimated encounter rates are also listed comparatively in Table 3 for all data sets for which effort data were available. Mean group size for each species was computed for each data set separately, using the on-effort sightings only (Appendices 1-5).

For study of distribution, sightings from all sources, collected both during search effort periods as well as at other times (or for sources with no search-effort data), were combined into a single data set containing a total of 548 records belonging to the 20 sighting categories described above. Species distribution maps are presented in Figures 4-6.

DISCUSSION

Occurrence patterns

Patterns of cetacean distribution and relative abundance in Colombia's Pacific EEZ are discussed in this section for each species. We consider occurrence in inshore and offshore waters, given the distinct characteristics of

these habitats, arising from the presence of the continental shelf (depths <2,000m) and the more coastal environments. In the offshore region, we note apparent associations with the Mapelo Ridge, a large submarine bathymetric feature running southwest-northeast and rising to the surface at Malpelo Island (Fig. 1). Although the estimated encounter rates are not comparable among data sets (as discussed in the next section), we consider the general trends in encounter rates among them in qualitative terms to assess relative abundance between species (*i.e.*, low, moderately low, moderately high and high).

Pantropical spotted dolphin (*Stenella attenuata*)

This species was well represented in inshore waters, but there also were multiple sightings scattered throughout the offshore region (Fig. 4a). 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 dolphins had moderately high encounter rates, especially in the inshore region, covered by the sports-fishing trips (Table 3).

Spinner dolphin (*Stenella longirostris*)

There were only a few spinner dolphin sightings, and they were found in both the inshore and offshore regions (Fig. 4a). Three subspecies or forms of this species were reported: 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). Encounter rates were low for this species (Table 3).

Striped dolphin (*Stenella coeruleoalba*)

The species was well distributed in offshore waters and absent from inshore waters (Fig. 4b). Striped dolphins are probably the most abundant dolphin species in Colombia's EEZ (Table 2; Gerrodette and Palacios, 1996), and they had high encounter rates in this study (Table 3).

Rough-toothed dolphin (*Steno bredanensis*)

The species occurred in the offshore region, mostly south of 5°N (Fig. 4c). Rough-toothed dolphins had moderately low encounter rates (Table 3).

Common dolphin (*Delphinus delphis*)

This species had a somewhat contrasting distribution with respect to that of rough-toothed dolphins, mostly occupying the northeastern part of the EEZ (Fig. 4c). Common dolphins were found primarily in offshore waters and had moderately high encounter rates (Table 3).

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.*, 2003). Most of the sightings occurred north of 4°N, and in the offshore region several occurred over the Mapelo Ridge (Fig. 4d). The species had high encounter rates in all data sets (Table 3).

Risso's dolphin (*Grampus griseus*)

This dolphin was found primarily in offshore waters, including over the Mapelo Ridge (Fig. 4d), and had moderately high encounter rates (Table 3).

Melon-headed whale (*Peponocephala electra*), *pygmy killer whale* (*Feresa attenuata*) and *false killer whale* (*Pseudorca crassidens*)

These species had very few sightings, which were primarily found in the offshore region (Fig. 5a). There were three false killer whale sightings near Cabo Marzo, at the northeastern corner of the EEZ. Encounter rates were generally low, with the exception of that for the dive trips, which was high (Table 3). This encounter rate, however, was driven by several sightings being made on one day in the offshore region (near 4°N, 79°W; Fig. 5a), which may have been part of a large aggregation spread out over many kilometers.

Short-finned pilot whale (*Globicephala macrorhynchus*)

This species was not very common, but it was well distributed throughout the offshore region, including over the Malpelo Ridge (Fig. 5b). Encounter rates were moderately low (Table 3).

Killer whale (*Orcinus orca*)

The few sightings of this species were scattered in the offshore region (Fig. 5b). Killer whale encounter rates were generally low (Table 3).

Sperm whale (*Physeter macrocephalus*)

Sperm whales were distributed primarily in the offshore region, including over the Malpelo Ridge (Fig. 5c). The encounter rate was high (Table 3), but they were only sighted during SWFSC surveys, with four additional sightings contributed by the *Siben* and *Odyssey* expeditions (Appendix 2).

Dwarf sperm whale (*Kogia sima*)

There were only a handful of sightings of dwarf sperm whales, and they were found in the offshore region, although one sighting was made near Cabo Marzo, at the northeastern corner of the EEZ (Fig. 5c). This species had a low encounter rate and was only sighted during SWFSC surveys.

Beaked whales (*Mesoplodon sp. and other ziphiids*)

Beaked whales were well distributed in the offshore region, including over the Malpelo Ridge (Fig. 5d). Two sightings were also made near Cabo Marzo, at the northeastern corner of the EEZ (Fig. 5d). Although this group had only moderately high encounter rates in this study (Table 3), when combined with the next two species they are probably the most abundant medium-sized cetaceans in Colombia's EEZ (Table 2; Gerrodette and Palacios, 1996).

Dense beaked whale (*Mesoplodon densirostris*)

This species was positively identified only twice during SWFSC surveys (Fig. 5d), and consequently it had a low encounter rate.

Cuvier's beaked whale (*Ziphius cavirostris*)

The handful of sightings for this species was made offshore, mainly in the western part of the EEZ including over the Malpelo Ridge (Fig. 5d). It had a low encounter rate (Table 3).

Minke whale (*Balaenoptera acutorostrata*)

This species was only sighted once during the Colombian Navy's oceanographic cruises, in the northeastern part of the EEZ (Fig. 6).

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). It had a low encounter rate (Table 3). However, the combined data set included 20 sightings that could only be identified as *Balaenoptera sp.*, and therefore, it is possible that this and other rorquals like minke and sei whales are more common than what the positively identified sightings indicate.

Humpback whale (*Megaptera novaeangliae*)

This was primarily an inshore species, common south of 4°N and with fewer sightings to north (Fig. 6). A few offshore sightings were also recorded, including over the Malpelo Ridge (Fig. 6). Humpback whale encounter rates were moderately high. Most sightings were made during the second part of the year and probably belong to the Southeast Pacific stock (Breeding Stock G) during their winter migration to low latitudes (Flórez-González *et al.*, 2007). However, a few sightings from March and April suggest that Northeast Pacific animals may also use the Colombian EEZ (cf. Calambokidis *et al.*, 2000; Acevedo-Gutiérrez and Smulter, 1995; Rasmussen *et al.*, 2007).

Biases and caveats

Although the overall trends in species encounter rates were qualitatively similar among data sources covering similar regions (*e.g.*, SWFSC and Colombian Navy cruises, see Table 3), use of these encounter rates as quantitative indices of relative abundance, for instance to compare relative abundance in inshore *vs.* offshore regions, is problematic for several reasons arising from methodological differences in data collection. The observation height varied widely among platforms (2-10m), as did vessel speeds (14-30km/h). 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. Finally, the Navy cruises and the dive-charter 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).

Further, the use of simple encounter rates as indices of relative abundance does not take into account the effects of species behavior, sea state and swell height (which were not recorded for all data sources) on detectability. Because these are known to impact the estimation of perpendicular sighting distances in more rigorous methods for estimating abundance, 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 perpendicular sighting distances are collected as part of the survey protocol (Barlow *et al.*, 2001).

CONCLUSIONS

The patterns of cetacean occurrence in Colombia’s Pacific EEZ presented here are composites of effort from several sources over many years. Even the SWFSC surveys, which had the greatest spatial and temporal coverage, only spent a few days within Colombia’s EEZ on any given year. Nevertheless, two areas of interest emerge from these data that should receive further attention in the future. One is the inshore area, bounded by the coastline and the 2000m isobath, where significant stocks of coastal species (*i.e.*, pantropical spotted dolphins, bottlenose dolphins and humpback whales) may be found. The second one is the Malpelo Ridge, an oceanic bathymetric feature, where a significant diversity of offshore species appears to be present. These two areas are probably where most fishing effort by the Colombian fleet takes place, and where detrimental cetacean-fishery interactions are more likely to occur. Therefore, future efforts focusing on line-transect surveys in these two areas would yield the most valuable information about the population status of cetacean stocks found within them. Considering the marked seasonal oceanographic variability of the region and the seasonal presence of some species (*e.g.*, the humpback whale) in Colombian waters, we recommend that these surveys be conducted twice a year, in February and in August, to capture the seasonal peaks. Additionally, more localized studies of coastal species, focusing on residence patterns (*e.g.*, Suárez, 1994), genetic structure (*e.g.*, Escorza-Treviño *et al.*, 2005), interactions with fisheries and directed catches (*e.g.*, Mora-Pinto *et al.*, 1995; Palacios and Gerrodette, 1996; Capella-Alzueta *et al.*, 2001; Avila *et al.*, 2008) should yield additional information for management strategies at the local level.

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Table 1. List of 23 cetacean species whose presence has been confirmed within Colombian Pacific waters (sources: Vidal, 1990; Flórez-González and Capella, 1995; Flórez-González *et al.*, 2004b).

Common name	Scientific name	Source
Pantropical spotted dolphin	<i>Stenella attenuata</i>	Vidal (1990); Flórez-González and Capella (1995)
Spinner dolphin	<i>Stenella longirostris</i>	Vidal (1990)
Striped dolphin	<i>Stenella coeruleoalba</i>	Vidal (1990)
Rough-toothed dolphin	<i>Steno bredanensis</i>	Vidal (1990)
Common dolphin	<i>Delphinus delphis</i>	Vidal (1990); Flórez-González and Capella (1995)
Common bottlenose dolphin	<i>Tursiops truncatus</i>	Vidal (1990); Flórez-González and Capella (1995)
Risso's dolphin	<i>Grampus griseus</i>	Vidal (1990); Flórez-González and Capella (1995)
Fraser's dolphin	<i>Lagenodelphis hosei</i>	Vidal (1990)
Melon-headed whale	<i>Peponocephala electra</i>	Vidal (1990)
Pygmy killer whale	<i>Feresa attenuata</i>	Vidal (1990)
False killer whale	<i>Pseudorca crassidens</i>	Vidal (1990); Flórez-González and Capella (1995)
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	Vidal (1990); Flórez-González and Capella (1995)
Killer whale	<i>Orcinus orca</i>	Vidal (1990); Flórez-González and Capella (1995)
Sperm whale	<i>Physeter macrocephalus</i>	Vidal (1990); Flórez-González and Capella (1995)
Dwarf sperm whale	<i>Kogia sima</i>	Vidal (1990); Flórez-González and Capella (1995)
Blainville's beaked whale	<i>Mesoplodon densirostris</i>	Flórez-González and Capella (1995)
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	Vidal (1990); Flórez-González and Capella (1995)
Minke whale	<i>Balaenoptera acutorostrata</i>	Vidal (1990)
Bryde's whale	<i>Balaenoptera edeni</i>	Vidal (1990); Flórez-González and Capella (1995)
Sei whale	<i>Balaenoptera borealis</i>	Vidal (1990)
Humpback whale	<i>Megaptera novaeangliae</i>	Vidal (1990); Flórez-González and Capella (1995)
Fin whale	<i>Balaenoptera physalus</i>	Vidal (1990)
Blue whale	<i>Balaenoptera musculus</i>	Flórez-González <i>et al.</i> (2004)

Table 2. Estimates of cetacean abundance (N , in number of animals) and density (D , in number of animals per 1,000km²) 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	<i>Stenella attenuata</i>	3,934	1,755	8,820	11.94
Striped dolphin	<i>Stenella coeruleoalba</i>	25,785	17,324	38,379	78.26
Rough-toothed dolphin	<i>Steno bredanensis</i>	4,366	1,869	10,200	13.25
Common dolphin	<i>Delphinus delphis</i>	12,369	4,136	36,989	37.54
Common bottlenose dolphin	<i>Tursiops truncatus</i>	7,171	3,548	14,493	21.76
Risso's dolphin	<i>Grampus griseus</i>	7,266	3,599	14,668	22.05
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	1,140	450	2,892	3.46
Beaked whales	<i>Ziphius cavirostris</i> and <i>Mesoplodon</i> spp.	30,784	10,633	89,119	93.43
Sperm whale	<i>Physeter macrocephalus</i>	1,248	643	2,422	3.79
Bryde's whale	<i>Balaenoptera edeni</i>	109	37	321	0.33

Table 3. Estimated encounter rates by source for 19 species and one genus, based on the on-effort sightings. Note that encounter rates for SWFSC are in groups per 1000km and in groups per 100h for the other sources.

Common name	Species name	SWFSC (groups per 1000km)	Navy cruises (groups per 100h)	Dive charters (groups per 100h)	Fishing charters (groups per 100h)
Pantropical spotted dolphin*	<i>Stenella attenuata</i>	1.93	3.96	2.84	8.57
Spinner dolphin*	<i>Stenella longirostris</i>	0.39	0.26	0.57	0.00
Striped dolphin	<i>Stenella coeruleoalba</i>	8.99	2.38	3.97	0.00
Rough-toothed dolphin	<i>Steno bredanensis</i>	1.54	0.79	0.57	0.00
Common dolphin	<i>Delphinus delphis</i>	1.67	3.17	3.40	0.00
Common bottlenose dolphin	<i>Tursiops truncatus</i>	3.21	4.23	3.97	11.43
Risso's dolphin	<i>Grampus griseus</i>	3.21	1.06	0.57	0.00
Melon-headed whale	<i>Peponocephala electra</i>	0.64	0.00	0.57	0.00
Pygmy killer whale	<i>Feresa attenuata</i>	0.26	0.00	0.00	0.00
False killer whale	<i>Pseudorca crassidens</i>	0.00	0.79	5.10	0.95
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	0.77	1.32	0.57	0.00
Killer whale	<i>Orcinus orca</i>	0.26	0.26	1.13	0.00
Sperm whale	<i>Physeter macrocephalus</i>	3.47	0.00	0.00	0.00
Dwarf sperm whale*	<i>Kogia sima</i>	0.51	0.00	0.00	0.00
Beaked whales*	<i>Mesoplodon</i> spp. and ziphiid whale	2.31	1.59	1.13	0.00
Dense beaked whale	<i>Mesoplodon densirostris</i>	0.26	0.00	0.00	0.00
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	0.51	0.26	0.57	0.00
Minke whale	<i>Balaenoptera acutorostrata</i>	0.00	0.26	0.00	0.00
Bryde's whale*	<i>Balaenoptera edeni</i>	0.51	0.00	0.00	0.00
Humpback whale	<i>Megaptera novaeangliae</i>	1.28	6.34	0.00	3.81

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

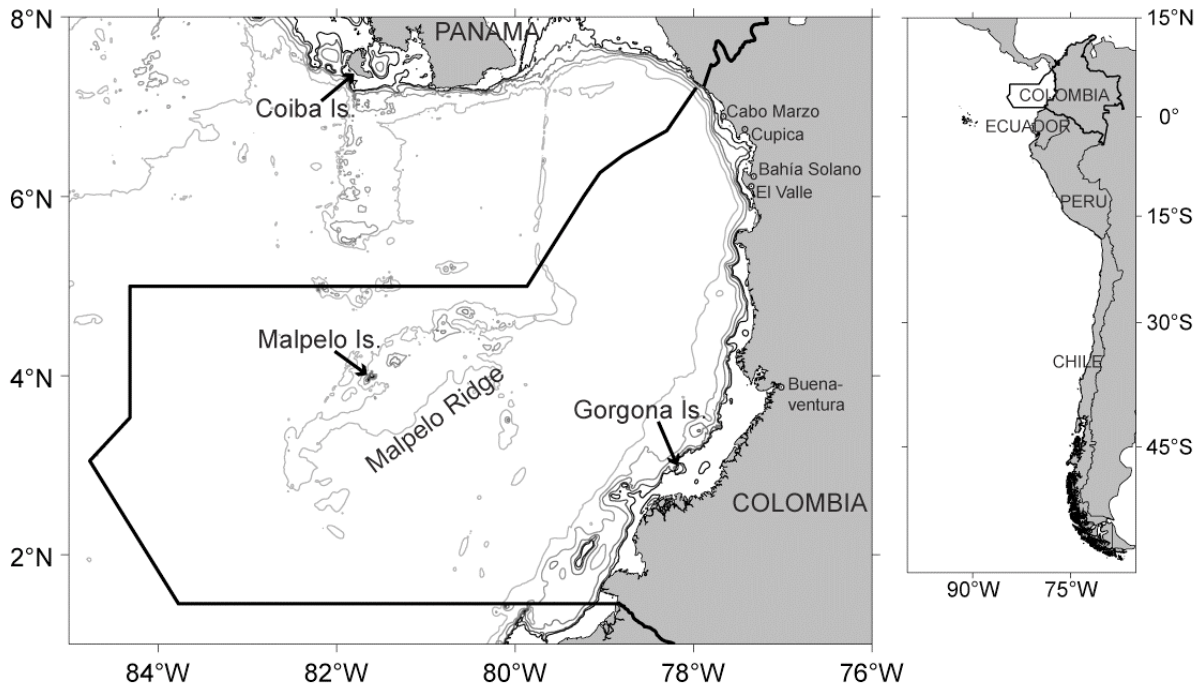


Figure 1. Left: Colombia's exclusive economic zone (EEZ) in the Pacific Ocean (source: DIMAR, 1988). Localities mentioned in the text are labeled. Bathymetric contours correspond to the 100, 200, 500, 1000 and 2000m isobaths (source: SRTM30_PLUS global topography v.3.0, available from <http://topex.ucsd.edu/>). Right: Political boundaries of Colombia and its location in the Southeast Pacific.

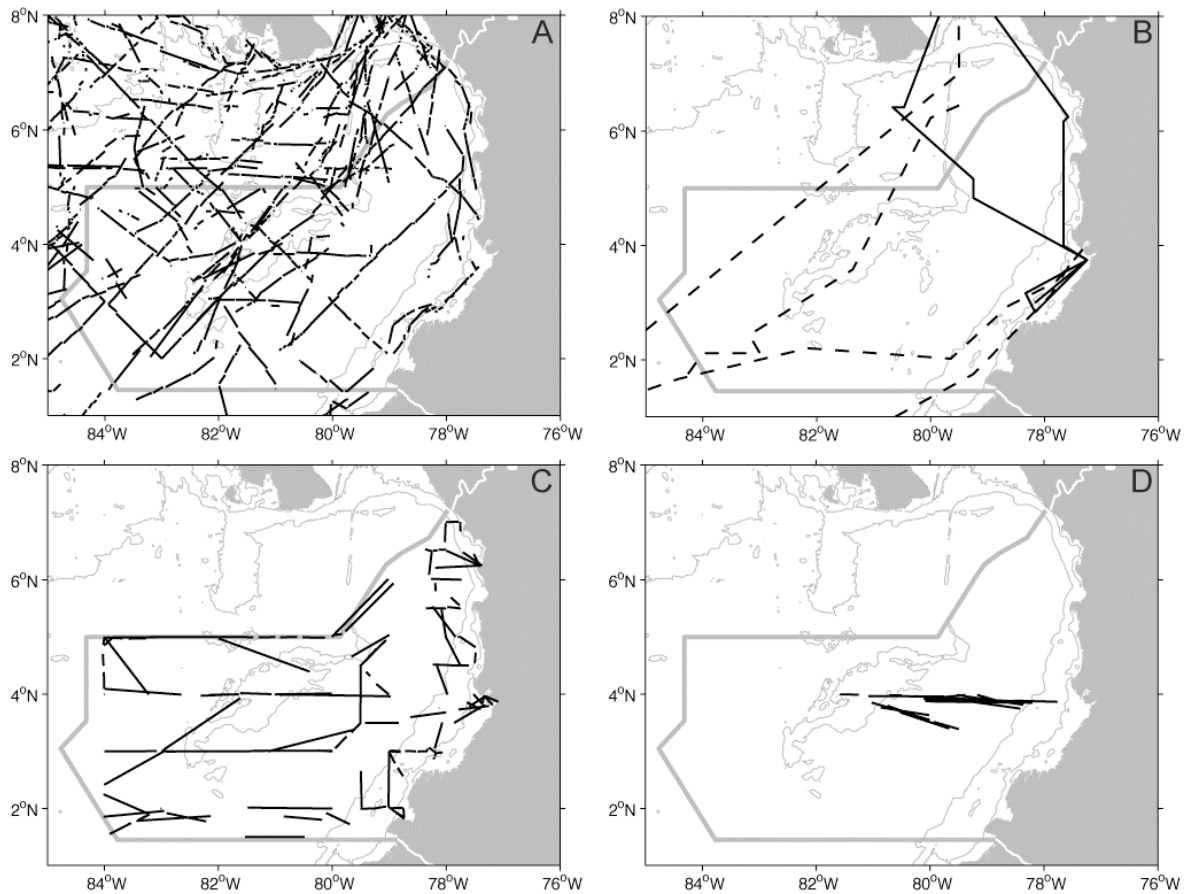


Figure 2. A) On-effort segments of trackline followed by NOAA vessels during SWFSC line-transect surveys (1986-2006). B) Tracks followed by the *Siben* Expedition (May-July 1988) (dashed black line) and the *Odyssey* Expedition (February 1993, September-October 1993 and April 1994) (solid black line). C) On-effort segments of trackline followed by Colombian Navy vessels during oceanographic cruises (2004, 2006-2008). D) On-effort segments of trackline followed by the dive charter vessel *M/V Maria Patricia* during transit between Buenaventura and Malpelo Island and between Malpelo and Gorgona Island (2004-2007). Bathymetric contours correspond to the 100 and 2000m isobaths (source as in Fig. 1).

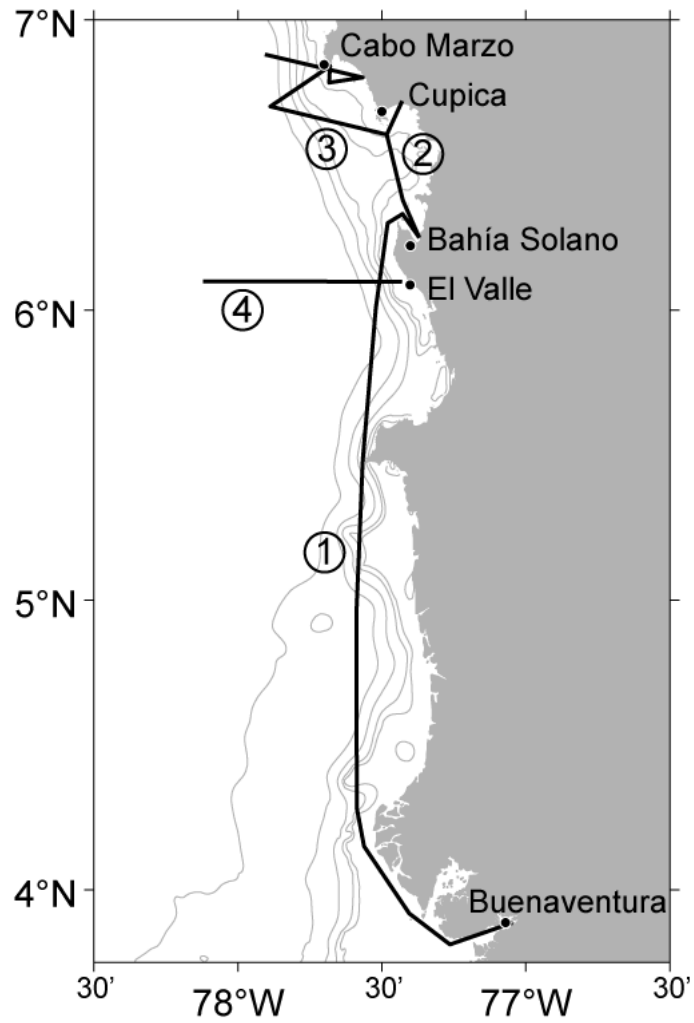


Figure 3. Typical daily routes followed by the coastal sports-fishing trips (2000-2001, 2004-2008). Encircled numbers correspond to (1) Buenaventura-Bahía Solano route, (2) Bahía Solano-Cupica route, (3) Cupica-Cabo Marzo route and (4) El Valle-offshore route. Bathymetric contours correspond to the 100, 200, 500, 1000 and 2000m isobaths (source as in Fig. 1).

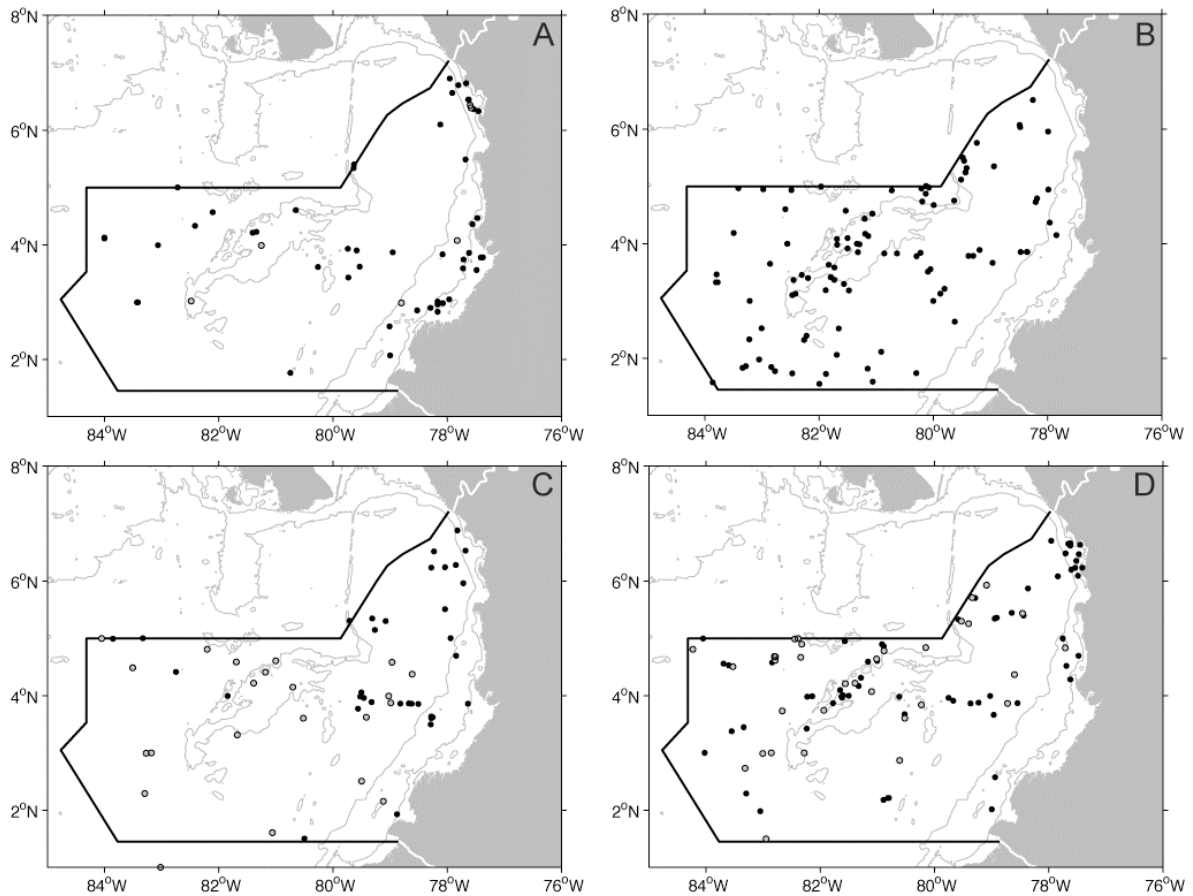


Figure 4. Distribution maps in Colombia's Pacific EEZ based on sightings from all sources combined (1986-2008) for: A) pantropical spotted dolphin (*Stenella attenuata*) (n = 55, black circles) and spinner dolphin (*Stenella longirostris*) (n = 7, gray circles); B) striped dolphin (*Stenella coeruleoalba*) (n = 97, black circles); C) common dolphin (*Delphinus delphis*) (n = 34, black circles) and rough-toothed dolphin (*Steno bredanensis*) (n = 31, gray circles); and D) common bottlenose dolphin (*Tursiops truncatus*) (n = 94, black circles) and Risso's dolphin (*Grampus griseus*) (n = 41, gray circles). Bathymetric contours correspond to the 100 and 2000m isobaths (source as in Fig. 1).

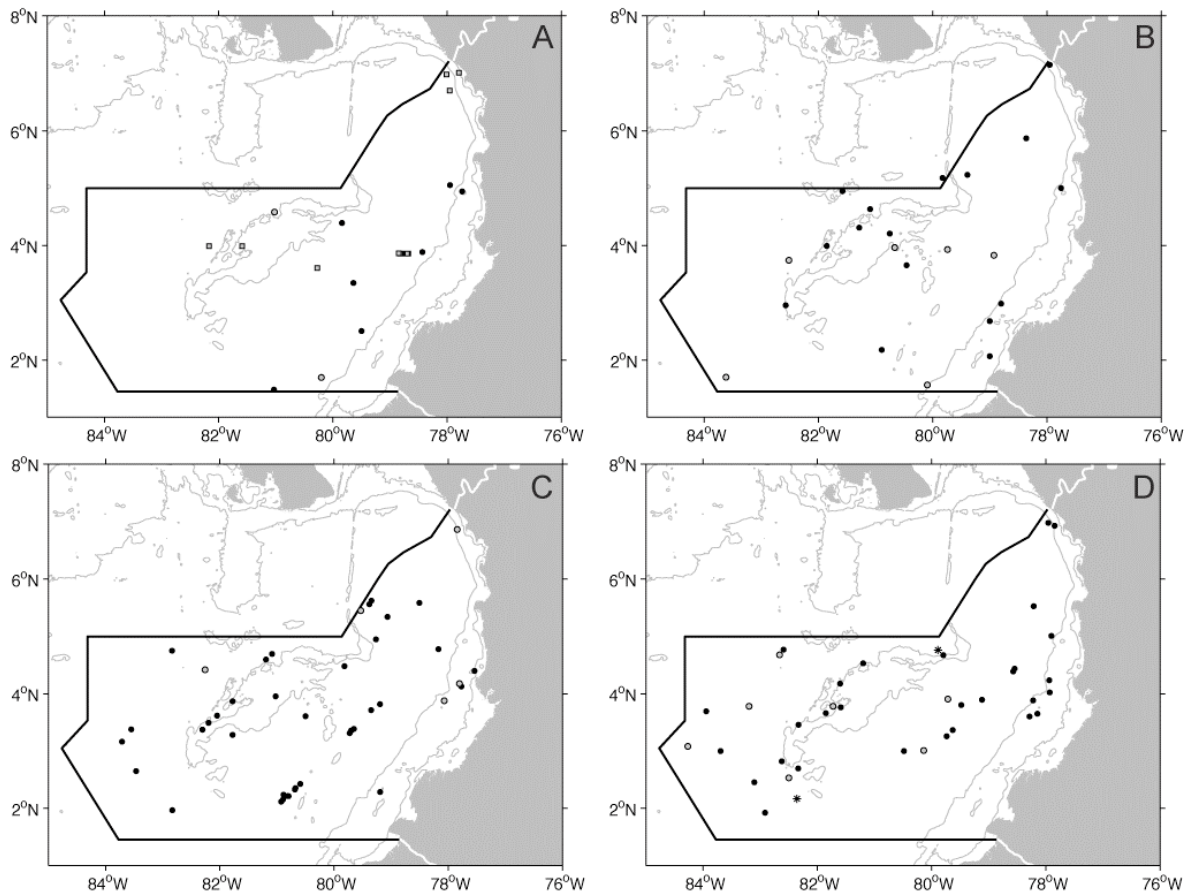


Figure 5. Distribution maps in Colombia's Pacific EEZ based on sightings from all sources combined (1986-2008) for: A) false killer whale (*Pseudorca crassidens*) (n = 14, gray squares), melon-headed whale (*Peponocephala electra*) (n = 8, black circles) and pygmy killer whale (*Feresa attenuata*) (n = 2, gray circles); B) short-finned pilot whale (*Globicephala macrorhynchus*) (n = 20, black circles) and killer whale (*Orcinus orca*) (n = 6, gray circles); C) sperm whale (*Physeter macrocephalus*) (n = 42, black circles) and dwarf sperm whale (*Kogia sima*) (n = 5, gray circles); and D) beaked whales (*Mesoplodon* spp. and unidentified ziphiids) (n = 29, black circles), dense beaked whale (*Mesoplodon densirostris*) (n = 2, black stars) and Cuvier's beaked whale (*Ziphius cavirostris*) (n = 7, gray circles). Bathymetric contours correspond to the 100 and 2000m isobaths (source as in Fig. 1).

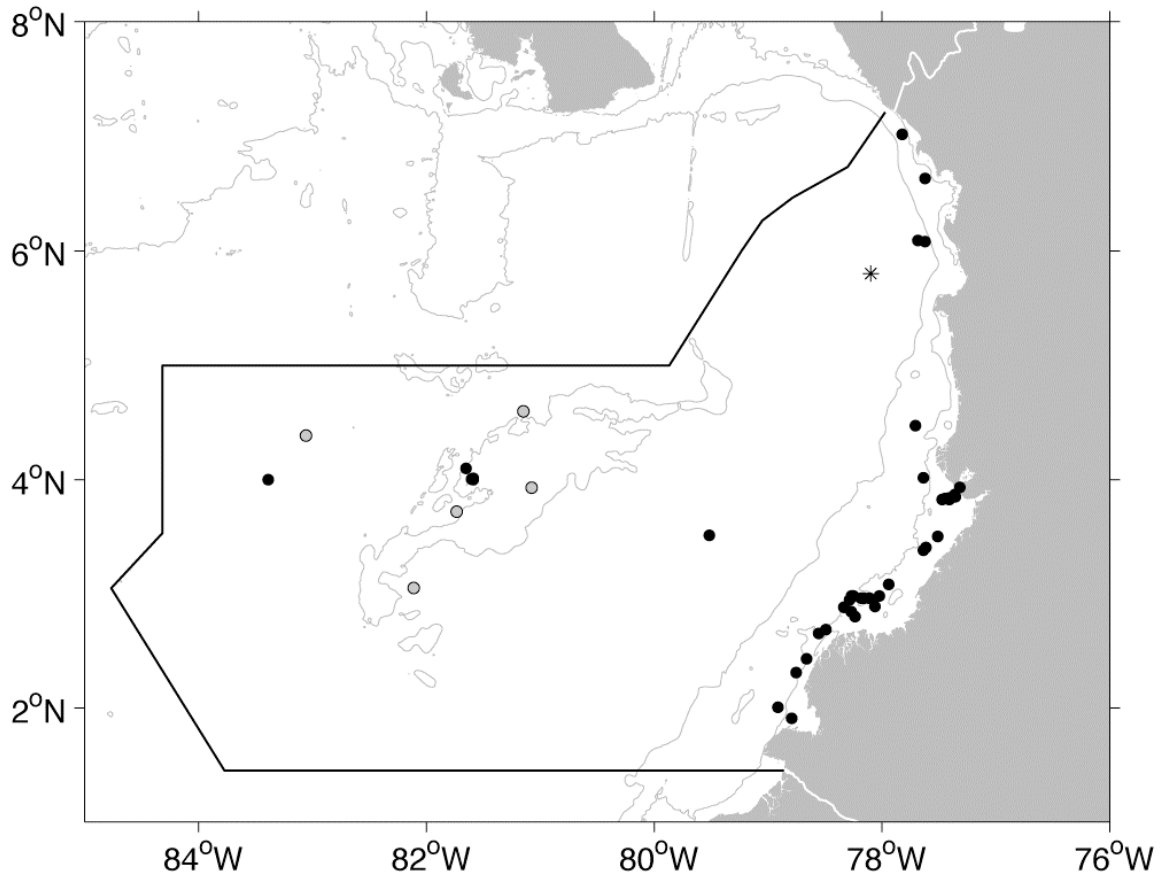


Figure 6. Distribution map for humpback whale (*Megaptera novaeangliae*) (n = 48, black circles), Bryde's whale (*Balaenoptera edeni*) (n = 5, gray circles) and minke whale (*Balaenoptera acutorostrata*) (n = 1, black star) in Colombia's Pacific EEZ based on sightings from all sources combined (1986-2008). Bathymetric contours correspond to the 100 and 2000m isobaths (source as in Fig. 1).

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 <i>David Starr Jordan</i>	252.2
1986	MOPS86	R/V <i>McArthur</i>	376.1
1987	MOPS87	R/V <i>McArthur</i>	782.2
1987	MOPS87	R/V <i>David Starr Jordan</i>	475.0
1988	MOPS88	R/V <i>David Starr Jordan</i>	334.8
1988	MOPS88	R/V <i>McArthur</i>	596.4
1989	MOPS89	R/V <i>David Starr Jordan</i>	373.2
1990	MOPS89	R/V <i>David Starr Jordan</i>	351.6
1992	PODS92	R/V <i>McArthur</i>	1,730.8
1992	PODS92	R/V <i>David Starr Jordan</i>	636.9
1998	SPAM98	R/V <i>McArthur</i>	127.7
1998	SPAM98	R/V <i>Endeavor</i>	480.9
1998	SPAM98	R/V <i>David Starr Jordan</i>	325.5
2000	STAR00	R/V <i>McArthur</i>	544.9
2006	STAR06	R/V <i>David Starr Jordan</i>	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)	# <i>Si</i>	<i>ER</i>
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	<i>#Si</i>	<i>G</i>	<i>ER</i>
Pantropical spotted dolphin*	<i>Stenella attenuata</i>	15	84.2	1.93
Spinner dolphin*	<i>Stenella longirostris</i>	3	77.4	0.39
Striped dolphin	<i>Stenella coeruleoalba</i>	70	48.4	8.99
Rough-toothed dolphin	<i>Steno bredanensis</i>	12	27.3	1.54
Common dolphin	<i>Delphinus delphis</i>	13	126.9	1.67
Common bottlenose dolphin	<i>Tursiops truncatus</i>	25	15.6	3.21
Risso's dolphin	<i>Grampus griseus</i>	25	12.2	3.21
Melon-headed whale	<i>Peponocephala electra</i>	5	245.5	0.64
Pygmy killer whale	<i>Feresa attenuata</i>	2	35.1	0.26
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	6	9.9	0.77
Killer whale	<i>Orcinus orca</i>	2	5.3	0.26
Sperm whale	<i>Physeter macrocephalus</i>	27	10.4	3.47
Dwarf sperm whale*	<i>Kogia sima</i>	4	1.6	0.51
Beaked whales*	<i>Mesoplodon</i> spp. and ziphiid whale	18	1.9	2.31
Dense beaked whale	<i>Mesoplodon densirostris</i>	2	4	0.26
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	4	1.5	0.51
Bryde's whale*	<i>Balaenoptera edeni</i>	4	1.5	0.51
Humpback whale	<i>Megaptera novaeangliae</i>	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 May 1988	Panamá-Bahía Solano-Buenaventura-Gorgona	R/V <i>Siben</i>
26 June - 12 July 1988	Buenaventura-Panamá	R/V <i>Siben</i>
24-27 July 1988	Buenaventura-Gorgona-Buenaventura	R/V <i>Siben</i>
9-16 February 1993	Panamá-Galápagos	R/V <i>Odyssey</i>
20-21 September 1993	Galápagos-Bahía Málaga	R/V <i>Odyssey</i>
5-9 October 1993	Bahía Málaga-Galápagos	R/V <i>Odyssey</i>
12-19 April 1994	Galápagos-Panamá	R/V <i>Odyssey</i>

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	<i>#Si</i>	<i>G</i>
Pantropical spotted dolphin	<i>Stenella attenuata</i>	2	45.0
Rough-toothed dolphin	<i>Steno bredanensis</i>	1	42.0
Common dolphin	<i>Delphinus delphis</i>	1	95.0
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	1	8.0
Sperm whale	<i>Physeter macrocephalus</i>	1	20.0
Humpback whale	<i>Megaptera novaeangliae</i>	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	<i>#Si</i>	<i>G</i>
Common bottlenose dolphin	<i>Tursiops truncatus</i>	1	20.0
Risso's dolphin	<i>Grampus griseus</i>	1	7.0
Sperm whale	<i>Physeter macrocephalus</i>	3	22.7
Humpback whale	<i>Megaptera novaeangliae</i>	3	1.7

APPENDIX 3

Details of survey effort and sighting statistics for oceanographic cruises aboard Colombian Navy vessels (2004, 2006-2008).

Table A3.1. Visual effort conducted in passing mode, Beaufort sea state <4 and good sighting conditions during oceanographic cruises aboard Colombian Navy vessels (2004, 2006-2008).

Dates	Cruise	Vessel	Effort (h)
24 September - 3 October 2004	ERFEN-04	R/V ARC <i>Providencia</i>	38.4
3-27 March 2006	PACIFICO-06	R/V ARC <i>Malpelo</i>	130.0
25 January - 17 February 2007	PACIFICO-07	R/V ARC <i>Malpelo</i>	114.0
9-28 March 2008	PACIFICO-08	R/V ARC <i>Providencia</i>	96.0

Table A3.2. 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 oceanographic cruises aboard Colombian Navy vessels (2004, 2006-2008).

Common name	Scientific name	<i>#Si</i>	<i>G</i>	<i>ER</i>
Pantropical spotted dolphin	<i>Stenella attenuata</i>	15	67.0	3.96
Spinner dolphin	<i>Stenella longirostris</i>	1	6.0	0.26
Striped dolphin	<i>Stenella coeruleoalba</i>	9	290.0	2.38
Rough-toothed dolphin	<i>Steno bredanensis</i>	3	53.0	0.79
Common dolphin	<i>Delphinus delphis</i>	12	224.0	3.17
Common bottlenose dolphin	<i>Tursiops truncatus</i>	16	9.7	4.23
Risso's dolphin	<i>Grampus griseus</i>	4	14.0	1.06
False killer whale	<i>Pseudorca crassidens</i>	3	104.7	0.79
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	5	7.8	1.32
Killer whale	<i>Orcinus orca</i>	1	5.0	0.26
Beaked whale	<i>Mesoplodon</i> spp. and ziphiid whale	6	2.5	1.59
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	1	1.0	0.26
Minke whale	<i>Balaenoptera acutorostrata</i>	1	1.0	0.26
Humpback whale	<i>Megaptera novaeangliae</i>	24	1.4	6.34

APPENDIX 4

Details of search effort and sighting statistics for dive-charter trips (2004-2007).

Table A4.1. Daily visual effort conducted in passing mode, Beaufort sea state <4 and good sighting conditions aboard dive charter vessel *Maria Patricia* during transit between Buenaventura and Malpelo Island and between Gorgona Island and Malpelo (2004-2007).

Date	Effort (h)	Route
14 February 2004	9.0	Buenaventura-Malpelo
22 February 2004	10.0	Malpelo-Buenaventura
15 March 2004	9.5	Buenaventura-Malpelo
16 March 2004	4.0	Buenaventura-Malpelo
20 June 2004	2.0	Malpelo-Buenaventura
18 December 2004	9.0	Malpelo-Buenaventura
24 March 2005	9.0	Gorgona-Malpelo
31 March 2005	10.2	Malpelo-Buenaventura
12 April 2005	9.4	Buenaventura-Malpelo
13 April 2005	4.3	Buenaventura-Malpelo
21 April 2005	8.0	Malpelo-Buenaventura
10 August 2005	6.0	Gorgona-Malpelo
14 August 2005	12.3	Malpelo-Buenaventura
11 March 2006	9.6	Gorgona-Malpelo
14 March 2006	10.0	Malpelo-Buenaventura
8 April 2006	10.4	Buenaventura-Malpelo
15 April 2006	10.4	Malpelo-Buenaventura
27 August 2006	4.0	Gorgona-Malpelo
18 March 2007	7.5	Buenaventura-Malpelo
27 March 2007	4.2	Malpelo-Buenaventura
3 April 2007	5.8	Gorgona-Malpelo
10 April 2007	3.0	Malpelo-Buenaventura

Table A4.2. Number of sightings (*#Si*) and average group size (*G*) and encounter rate (*ER*, in number of groups per 100h) for all identified species, collected aboard a dive charter vessel during transit between Buenaventura and Malpelo Island and between Malpelo and Gorgona islands (2004-2007).

Common name	Scientific name	<i>#Si</i>	<i>G</i>	<i>ER</i>
Pantropical spotted dolphin	<i>Stenella attenuata</i>	5	56.6	2.84
Spinner dolphin	<i>Stenella longirostris</i>	1	150	0.57
Striped dolphin	<i>Stenella coeruleoalba</i>	7	87.4	3.97
Rough-toothed dolphin	<i>Steno bredanensis</i>	1	50.0	0.57
Common dolphin	<i>Delphinus delphis</i>	6	153.3	3.40
Common bottlenose dolphin	<i>Tursiops truncatus</i>	7	18.7	3.97
Risso's dolphin	<i>Grampus griseus</i>	1	15.0	0.57
Melon-headed whale	<i>Peponocephala electra</i>	1	10.0	0.57
False killer whale	<i>Pseudorca crassidens</i>	9	4.4	5.10
Short-finned pilot whale	<i>Globicephala macrorhynchus</i>	1	15.0	0.57
Killer whale	<i>Orcinus orca</i>	2	5.5	1.13
Beaked whales	<i>Mesoplodon</i> spp. and ziphiid whale	2	3.0	1.13
Cuvier's beaked whale	<i>Ziphius cavirostris</i>	1	2.0	0.57

APPENDIX 5

Details of routes covered and sightings collected during daily coastal sports-fishing trips (2000-2001, 2004-2008).

Table A5.1. Visual effort conducted during 21 daily coastal sports-fishing trips (2000-2001, 2004-2008).

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

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