# Occurrence and distribution of cetaceans off northern Angola, 2004/05

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ABSTRACT

The occurrence and distribution of cetacean species off northern Angola was examined using dedicated survey data and incidental sighting records. Dedicated surveys for cetaceans were carried out during two geophysical seismic surveys off northern Angola between August 2004 and September 2005. A total of 3,268hr of survey effort data were collected, resulting in 779 on-effort cetacean sightings. There were 263 sightings reported off-effort and incidentally from other platforms and sports fishermen. With 21 cetacean species confirmed, the cetacean community off northern Angola is diverse and primarily tropical in characteristic, comprising four species of baleen whale, two sperm whale species, at least two beaked whale species, and 13 species of delphinid. Humpback and sperm whales were the most frequently recorded cetaceans. The occurrence of humpback whales was significantly higher within neritic waters, and during the winter and spring months in association with seasonal occupancy of their West African breeding grounds. Sperm whales were recorded in water depths exceeding 1,000m and demonstrated significant seasonality, with peak occurrence during the summer and autumn. Atlantic spotted dolphins and common dolphins (*Delphinus* sp.) were the most numerous delphinids recorded, with spotted dolphins showing a significant seasonal peak during the spring and summer, and common dolphins in the winter. Other species recorded included fin whale, sei whale, Bryde's whale, dwarf sperm whale, Cuvier's and *Mesoplodon* beaked whales, killer whale, short-finned pilot whale, false killer whale, melon-headed whale, Atlantic humpback dolphin, rough-toothed dolphin, Risso's dolphin, bottlenose dolphin, Pantropical spotted dolphin, spinner dolphin, Clymene dolphin and striped dolphin. Further research is required to document the cetacean community in Angola, particularly given the unknown threat from fishery bycatch and the increasing level of oil and gas exploration in the region.

KEYWORDS: CETACEANS; DISTRIBUTION; HABITAT; SCHOOL SIZE; ANGOLA; ATLANTIC OCEAN; SURVEY-VESSEL; INCIDENTAL SIGHTINGS; FIN WHALE; SEI WHALE; BRYDE'S WHALE, DWARF SPERM WHALE; HUMPBACK WHALE; COMMON DOLPHIN; CUVIER'S BEAKED WHALE; KILLER WHALE; SHORT-FINNED PILOT WHALE; FALSE KILLER WHALE; MELON-HEADED WHALE; ATLANTIC HUMPBACK DOLPHIN; ROUGH-TOOTHED DOLPHIN; RISSO'S DOLPHIN; BOTTLENOSE DOLPHIN; PANTROPICAL SPOTTED DOLPHIN; SPINNER DOLPHIN; CLYMENE DOLPHIN; STRIPED DOLPHIN

## INTRODUCTION

There is a paucity of information on the occurrence of cetaceans off Angola, located on the west coast of Africa in the southeastern Atlantic Ocean (Fig. 1). The historical occurrence of large whales off Angola is documented via whaling records (Best, 1994; De Figueiredo, 1958; Townsend, 1935). Rigorous exploitation of whales on the west coast of Africa commenced towards the end of the 18th century, with whalers working in the Gulf of Guinea during 1763 and arriving at Angola before 1770 (Best, 1981). Between 1909 and 1916 modern shore-based and floating whaling stations were established at Lobito, Baia dos Elefantes, Mossamedes, Porto Alexandre and Baia dos Tigres (Best and Ross, 1986; De Figueiredo, 1958). The whaling charts of Townsend (1935) show large catches of sperm whales (*Physeter macrocephalus*) and humpback whales (*Megaptera novaeangliae*) off the coast of Angola between 1761 and 1920, while the review by Best (1994) also indicates catches of blue (*Balaenoptera musculus*), fin (*B. physalus*), sei (*B. borealis*) and Bryde's whales (*B. edeni*)[1] off Angola between 1909 and 1928. Whaling records from nearby waters in Gabon, extending to 5°S also testify to the frequent occurrence of large rorquals and sperm whales in the region (Budker, 1952;1953; Budker and Collignon, 1952; Budker and Roux, 1968), and a traditional hunt of humpback whales continued at Annobon Island off central Gabon into at least the 1970s (Aguilar, 1985). Current knowledge of large whales off Angola is limited to the humpback whale, which was the focus of a 12-day study in coastal waters off northern Angola during September 1998 (Best *et al*., 1999) and this species is also the subject of a long-term photo-identification and genetic capture-recapture study in nearby Gabon (Rosenbaum *et al*., 2002).

In contrast to large whales, the distribution of smaller cetaceans off Angola remains almost completely unknown. A review of small odontocetes off West Africa by Jefferson *et al*. (1997) did not include Angolan waters and the scarce literature available comprises only opportunistic sightings (Morzer Bruyns, 1968; Perrin *et al*., 1994b; van Waerebeek *et al*., 2004; Weir, 2006a;2006b).

There is growing interest in the cetacean fauna inhabiting the waters off Angola, where industrial activity including geophysical seismic surveys is increasing. The planning of industrial activities and the mitigation of potential effects from anthropogenic sound sources upon cetaceans requires an understanding of the occurrence of species within the region. This paper presents results from dedicated cetacean survey work carried out off northern Angola during 2004 and 2005.

## METHODS

### Study area

The topography of the marine environment off Angola differs between the northern and southern regions (Fig. 1). In the north, the continental shelf is wide extending around 50km from the coast, with water depths of 1,000m generally occurring around 90km offshore. The shelf is much narrower (8km) to the west of Luanda and also in the region of the Congo Canyon off Soyo where water depths of over 1,000m occur around 50km from the coast. The southern

[1] Bryde's whale off Angola are likely to be *B. brydei* rather than *B. edeni* (IUCN, 2006).

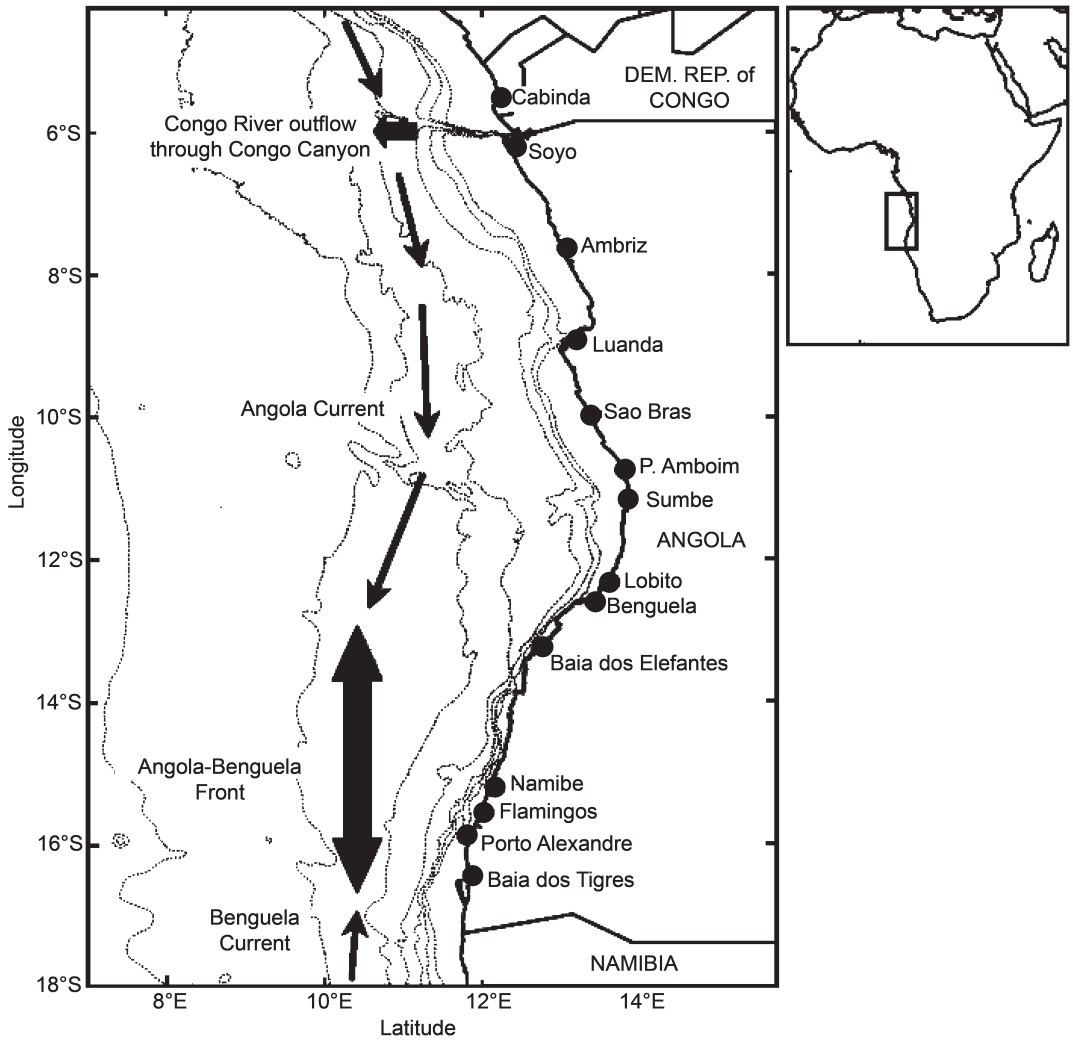


Fig. 1. Location, bathymetry and principal oceanographic features of the study area.

portion of Angola from Benguela south to Tombwa is characterised by a very narrow continental shelf (<10km) which slopes steeply into 1,000m only around 15km from the coast. Offshore, the seabed slopes gradually to water depths exceeding 5,000m in the Angola Basin.

There is also oceanographic variation between northern and southern Angola due to the influence of two large marine ecosystems (LMEs): the Benguela Current LME; and the Gulf of Guinea LME (Fig. 1). The cold-water Benguela Current is the primary oceanographic influence in Angola's marine environment, being one of the strongest locally wind-driven coastal upwellings in the world (Hardman-Mountford *et al*., 2003). This current extends northwards along the west coast of southern Africa, bringing colder, nutrient-rich water from the south. Off Namibia the current diverges, with the smaller branch continuing to flow northwards along the coast and into southern Angola (Hardman-Mountford *et al*., 2003). In northern Angola, warm water flows southwards from the Gulf of Guinea as the Angola Current, a fast and narrow band of warm water that extends along the Angolan coast between 9°S and 16°S (Hardman-Mountford *et al*., 2003; Moroshkin *et al*., 1970). The coastal northward-flowing cold Benguela Current and the southward-flowing warm Angola Current dominate the eastern Angola Basin, converging at latitudes of between 17°S and 13°S (depending on season) to form the Angola-Benguela front (Moroshkin *et al*., 1970).

The Congo River is the largest freshwater input to any worldwide eastern ocean boundary (Hardman-Mountford *et al*., 2003) and has a significant impact on Angola's marine environment. Freshwater outflow (the 'Congo River Plume') extends as a sediment-laden surface current primarily in the upper 5-15m of the water column (Eisma and van Bennekom, 1978). This outflow of turbid freshwater is detectable at ranges of 800km offshore during the monsoon months between November and April (Eisma and van Bennekom, 1978; Van Bennekom and Berger, 1984), causing peaks in primary productivity around 150-200km from the river mouth (Van Bennekom and Berger, 1984).

## Survey methodology

Two categories of data were used to examine the distribution of cetaceans in the region: (1) dedicated survey data; and (2) incidental sighting records.

## Dedicated surveys

Cetacean data were collected during two geophysical seismic surveys between August 2004 and September 2005. These surveys comprised dedicated cetacean watches where an associated measure of effort was recorded. Most marine mammal data were collected from the *Geco Triton* at 18.5m eye height (1 August 2004 to 15 May 2005), which conducted two consecutive large-scale 3D seismic surveys

using airgun arrays of 5,085 and 3,147cu. in. respectively. The *Sea Trident* at 10.75m eye height (10 August to 27 September 2005) conducted a high-resolution seismic survey that utilised a low volume airgun array of 70cu. in. Most data were collected at survey speed (4-5 knots or 8km $hr^{-1}$), with a small portion of data collected during transits between survey sites (7 knots or 13km $hr^{-1}$).

Dedicated watches for marine mammals were carried out throughout daylight hours and in all weather conditions on each day at sea. During 'search mode' a single dedicated observer scanned 360° around the vessel using the unaided eye and 8-10× binoculars. Effort logs (comprising the position, time, water depth and environmental data including Beaufort sea state, swell height and visibility) were completed for every watch. Whenever a cetacean was sighted, the species, number (and age class where possible) of animals, behaviour, position, distance from the vessel, water depth and associated environmental data were recorded. While subject to some error, the two experienced observers recorded a 'best estimate' of cetacean group size by eye, a method often relied upon during cetacean field surveys (Moreno *et al*., 2005). Where possible, animals were photographed in the field to confirm identification using a Canon Single Lens Reflex (SLR) camera and a 100-400mm Canon zoom lens. However the nature of the survey meant that animals could not often be approached to confirm species identification or group size.

Cetacean data were collected in a non-random manner, with the distribution of the survey effort determined by the geophysical survey work. Most of the survey work was concentrated over two deep-water areas: 120km off the Congo River mouth in water depths of 1,400-2,700m; and 150km north-west of Luanda in water depths of 1,200-1,500m. Limited survey data were also collected over the continental shelf and slope. The northern limit for data presented here is 5°S at the northern edge of the Angolan province of Cabinda and some data offshore Democratic Republic of Congo (DRC) are therefore also included. A total of 779 cetacean sightings were recorded during the dedicated survey work.

**Incidental sightings**

Cetacean sightings were classified as 'incidental' if no measure of effort was recorded. This category contained records reported 'off effort' during dedicated surveys (e.g. sightings at night) and records from several marine mammal surveys where the data collection methods were not rigorous enough for inclusion as dedicated surveys (e.g. no record of vessel position, incomplete data forms). A total of 264 incidental cetacean sightings were reported from a range of offshore platforms including seismic survey, guard, underwater vehicle, benthic and electromagnetic survey vessels, sports fishing trips operating out of Luanda (1991-2006), and during a kayak trip along the coast from the Cunene River to Luanda during 2004. Incidental records were only included in the analyses when the species identification could be confirmed via adequate descriptions on the data form, during discussion with the author, or from submitted photographs.

**Data analysis**

Prior to analysis, the effort, dedicated sightings and incidental sightings data were combined into single standardised databases. For a small number of incidental sightings a GPS position was not available, and these data were looked up from an electronic nautical chart (*C-Map World* for Windows, Version 3) according to descriptions of sighting locations provided by the observers. Where necessary, water depths were also looked up from a nautical chart. The depths recorded at the start and end of each dedicated watch were averaged to produce a mean water depth for each watch. Intermediate sea states (e.g. Beaufort 2-3) recorded in the field were rounded up to the higher value for analysis. The species identification provided by observers was checked and verified using written descriptions and photographs. In the majority of cases ($n$=39) the verification process involved downgrading sightings from a specific species to a category (e.g. 'dolphin species'). This occurred where the animals were judged to be too distant from the vessel to allow definite identification (>2km for *Stenella*/*Delphinus* dolphins), where an inadequate species description was provided, where the description/behaviour/location seemed inconsistent with the stated species, or where a sighting of an uncommon/rare species was not supported by adequate information. In limited cases sightings were 'upgraded' to species level ($n$=9), usually where photographs existed. Where mixed-species schools of cetaceans were encountered, data for each species were analysed as separate sightings.

The water depth distribution of cetacean species was described using the following terms: coastal (marine waters immediately adjacent to land, usually <20m depth); continental shelf (waters less than 200m depth); slope (200-1,000m); and deep oceanic (seaward of 1,000m). The terms 'neritic' and 'pelagic' were used to refer to areas over and seaward of the continental shelf respectively. For the four cetacean species for which sample size exceeded 15 dedicated survey sightings the relative abundance (Beaufort sea state 0-4) was examined in four water depth categories (<200m, 200-999m, 1,000-2,000m, >2,000m). Due to low sample size in several of the depth categories, statistical analysis of cetacean occurrence related to depth categories was not feasible.

The seasonal occurrence of each species was examined as relative rather than absolute abundance (using only 'on effort' sightings recorded during dedicated surveys) since the survey effort was spatially uneven, an effective strip width method was not used, sample size was small for many species, and there was an unknown potential influence from the airguns. The relative abundance was calculated as $(N/E)\times 100$, where $N$ is the number of animals recorded and $E$ is the total survey effort (min), and only effort and sightings recorded in Beaufort sea states $\leq 4$ (Beaufort $\leq 2$ for beaked and *Kogia* whales) were used. Seasonal analysis was carried out according to: spring (Sep-Nov); summer (Dec-Feb); autumn (Mar-May); and winter (Jun-Aug). For humpback and sperm whales (with over 100 dedicated survey sightings in Beaufort sea states 0-4), a Chi-squared Goodness of Fit test was used to determine whether the number of encounters recorded differed from that expected in each season.

There is relatively little published information on the responses of cetaceans to open-water seismic exploration and most published studies have examined responses to airgun arrays of much lower volume than those utilised during actual geophysical seismic surveys (e.g. 20 cu. in. used during playback experiments on humpback whales by McCauley *et al*. (2000)). The exact effects of seismic survey upon cetaceans are unknown, but potentially include masking of communication signals and echolocation, altered behaviour, temporary or permanent hearing/tissue damage, stress and displacement from habitat (Gordon *et al*., 2003; Richardson *et al*., 1995). The data presented here are therefore potentially influenced by unknown reactions of

each cetacean species to airgun sound produced during the survey, and such impacts should be borne in mind when considering spatio-temporal trends within the dataset.

## RESULTS AND DISCUSSION

A total of 3,268hr (196,063min) survey effort data were collected during dedicated survey work in 2004 and 2005. Effort occurred in all survey months except for June and July, with the largest amount occurring during August and September (Table 1). While the summer and autumn seasons received similar amounts of survey coverage, the spring months received 38% of the total effort and the winter only 17% (Table 1). Survey coverage occurred over a greater spatial scale during the spring and summer, with effort as far south as Porto Amboim (Fig. 2). Most effort occurred in pelagic slope and oceanic waters, with the percentage of total effort distributed as: <200m (0.6%); 200-999m (1.7%); 1,000-1,499m (5.8%); 1,500-1,999m (46.5%); 2,000-2,499m (37.6%); and >2,499m (7.8%). Some 26% (50,520min) of effort occurred in Beaufort sea state 0-2, 45% (88,154min) during Beaufort 3, 26% (51,298min) during Beaufort 4, and 3% (6,091min) during Beaufort 5-6. Daily water temperature data collected between August 2004 and May 2005 varied between 21.8°C and 30.3°C (Weir, 2006d).

Table 1
Seasonal distribution of dedicated survey effort, 2004/05.

| Month/season | Survey effort (min) | Percentage of total effort |
|---|---|---|
| Sep. | 36,035 | 18.4 |
| Oct. | 19,691 | 10 |
| Nov. | 18,420 | 9.4 |
| *Spring total* | *74,146* | *37.8* |
| Dec. | 13,855 | 7.1 |
| Jan. | 17,037 | 8.7 |
| Feb. | 17,600 | 9 |
| *Summer total* | *48,492* | *24.7* |
| Mar. | 16,070 | 8.2 |
| Apr. | 16,935 | 8.6 |
| May | 8,080 | 4.1 |
| *Autumn total* | *41,085* | *21.0* |
| Jun. | 0 | 0 |
| Jul. | 0 | 0 |
| Aug. | 32,340 | 16.5 |
| *Winter total* | *32,340* | *16.5* |
| **Survey total** | **196,063** | **100** |

A total of 1,042 dedicated and incidental cetacean sightings were recorded off Angola, comprising at least 39,883 animals. Of these, 779 sightings occurred during the dedicated survey work. The cetacean community off Angola was diverse with at least 21 species recorded (Table 2), comprising four species of baleen whale, two sperm whale species, at least two beaked whale species, and 13 species of delphinid. A large number of animals, particularly dolphins, remained unidentified at sea due to a combination of distance from the vessel, adverse weather (choppy sea state and sun glare), brevity of the sighting, uncertainty over mixed-species groups, and the close similarity in external appearance of many species within the region (particularly *Balaenoptera* and *Stenella* species). Much of the data within the following species accounts are summarised in Tables 2 and 3, with an overview of the seasonal occurrence of each species in Angolan waters presented in Fig. 3.

### Fin whale (*Balaenoptera physalus*)

Conclusively separating between fin, sei and Bryde's whales proved difficult at sea, and a total of 21 encounters were logged as being one of these three species. There were four confirmed sightings of fin whales between 2003 and 2006, comprising two on-effort and two incidental sightings (Table 2). All records involved single or pairs of animals, distributed in deep water pelagic areas of 1,500-1,739m depth (Table 2, Fig. 4). Fin whales were sighted only in August (3) and September (1) during the winter and spring, which is consistent with the theory of a seasonal migration of this species between summer Antarctic feeding areas and winter low-latitude breeding grounds (Gambell, 1985).

### Sei whale (*Balaenoptera borealis*)

Only one sighting was positively identified as sei whale during the survey work, a pair of animals recorded in 1,691m water during August 2004 (Fig. 4). The seasonality of this record agrees with the proposed southward seasonal migration towards summer feeding grounds (Best and Lockyer, 2002). The status of this species off Angola remains unclear.

### Bryde's whale (*Balaenoptera edeni*)

Bryde's whales were the most numerous of the *Balaenoptera* species recorded off Angola, with a total of 19 sightings (Table 2). However, group size was small (mean ($\bar{\chi}$)=1.3 animals) and the overall relative abundance of this species off Angola was low (Table 3). Bryde's whales occurred in distinctly separate habitats, with 42% of sightings in waters of <100m depth and the remaining 58% of sightings in deep oceanic waters exceeding 1,600m depth (Figs 5 and 11). The apparent divide in Bryde's whale distribution between neritic and pelagic habitat is consistent with Best's (2001) proposal of distinct 'offshore' and 'inshore' forms off the west coast of Africa.

There was some suggestion of seasonality in Bryde's whale occurrence off Angola, with most sightings recorded between June and November (Fig. 3). Observations from sports fishermen suggest that Bryde's whales are seen most frequently inshore off Luanda during August and September (Ian Austin, pers. comm.). However, three incidental sightings of Bryde's whale from coastal waters in southern Angola during January 2004 testify to some presence of this species in Angolan waters during other seasons. While it is generally considered that inshore Bryde's whales inhabit the west coast throughout the year, the offshore form is thought to make extensive migrations between South Africa (Jan-Feb) and Gabon (May-Jul) (Best, 1996; Best, 2001). More work is required to determine the exact status of Bryde's whales off Angola; however, it seems reasonable to conclude that this species is reasonably common within the region and may occur year-round.

### Humpback whale (*Megaptera novaeangliae*)

The whaling charts of Townsend (1935) show a distinct area of humpback whale abundance off West Africa extending primarily from northern Angola to Gabon. The present-day occurrence of humpback whales in this region has been confirmed via short surveys in northern Angola (Best *et al*., 1999), Congo (Weir, 2006d), São Tomé and Príncipe (Carvalho *et al*., 2003) and Gabon (Walsh *et al*., 2000; Weir, 2006d), and by a long-term population study off Gabon since 1997 (Rosenbaum *et al*., 2002). Humpback whales were the most frequently recorded cetacean species during survey work in 2004/05, with a total of 205 sightings

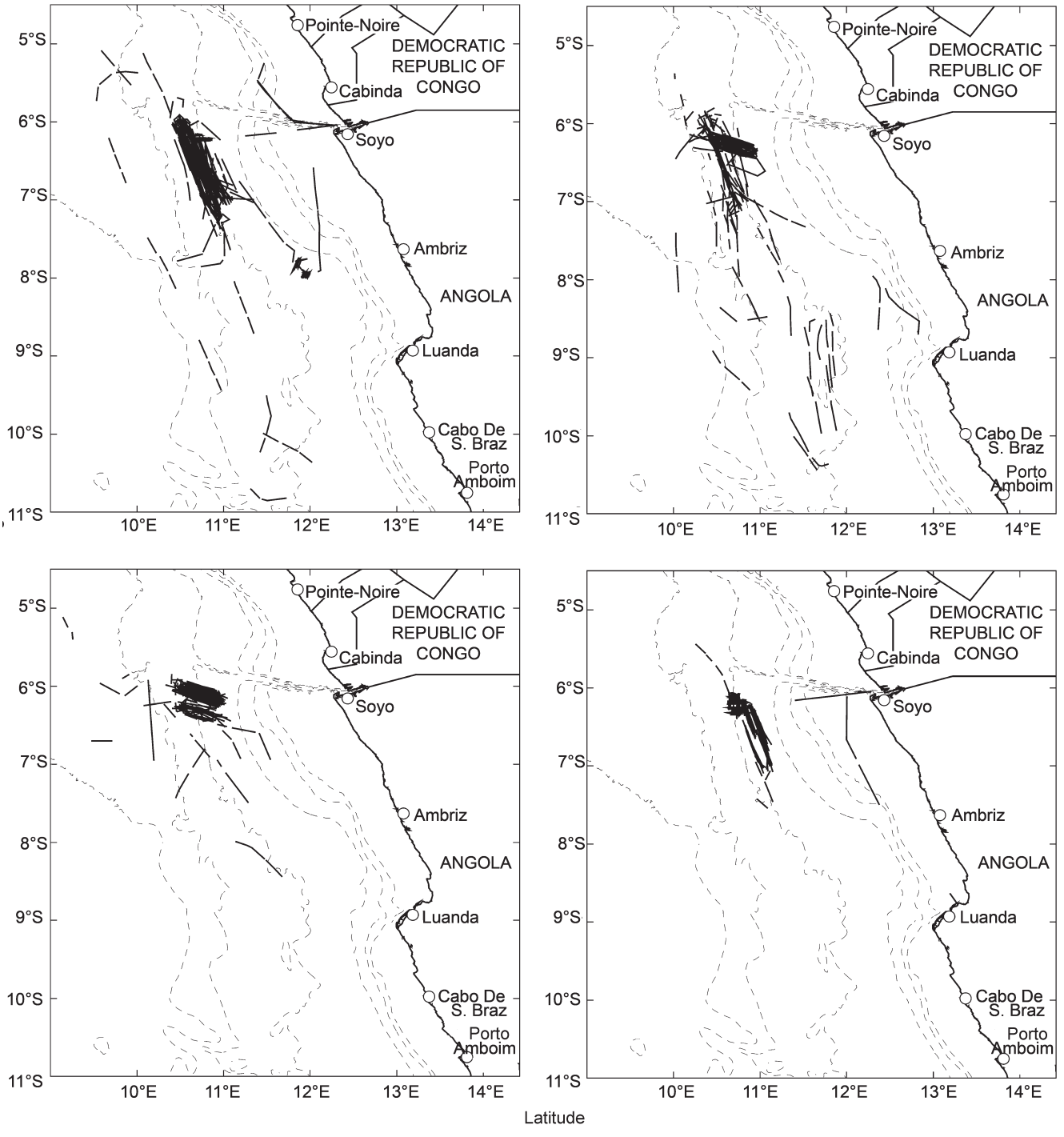


Fig. 2. Seasonal distribution of survey effort in (A) spring, (B) summer, (C) autumn and (D) winter.

including 157 on-effort records (Table 2). The majority of sightings were recorded off northern Angola (Fig. 6), with clusters of records over both of the deep-water study sites and in the vicinity of the Congo Canyon. Relative abundance of humpback whales was five times higher in depths of <200m (5.09 animals 100min$^{-1}$) than over the shelf edge (1.07 animals 100min$^{-1}$) or in depths >1,000m (0.08 animals 100min$^{-1}$).

There was a significant difference in the number of humpback whale encounters ($\chi^2$=141.6, d.f.=3, $p$=<0.001) recorded according to season. Significantly more humpback whales were recorded during the winter and spring, and significantly fewer during the summer and autumn (Table 3). The earliest seasonal record was an individual sighted on 7 May. Although there was no dedicated survey effort during June and July, incidental sightings over this period testified to the occurrence of humpback whales. Moderate densities remained into October, but then decreased sharply with few sightings recorded in November (2), December (1) and January (3). The seasonality of humpback whales in Africa is also apparent from the mid-May to October timing of whaling catches off Gabon (Budker and Roux, 1968), although most modern whaling activities in West Africa were anyway confined to the June-November period (Best and Ross, 1986). The seasonal pattern relates to their use of the region as a calving and mating ground during the winter months (Best *et al*., 1999), as indicated by sightings of surface-active whale groups and mother-calf pairs in Angolan waters. Of 157 groups of humpback whales where age composition was recorded, single ($n$=62) and pairs

Table 2

Cetacean species recorded in Angola (listed in decreasing order of number of dedicated survey sightings) showing group size and water depth.

| | Dedicated surveys | | Incidental sightings | | School size | | | Water depth (m) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Species | Sightings | Animals | Sightings | Animals | Mean | SD | Range | Mean | SD | Range |
| Unid. dolphin | 293 | 21,426 | 75 | 6,296 | 75.3 | 91.8 | 1–500 | 1,845 | 420.5 | 10–3,300 |
| Humpback whale | 157 | 289 | 48 | 85 | 1.8 | 0.9 | 1–6 | 1,464 | 810.5 | 40–4,036 |
| Sperm whale | 126 | 1,219 | 13 | 53 | 9.2 | 8.8 | 1–65 | 1,977 | 327.7 | 1,349–2,917 |
| Unid. whale | 39 | 68 | 14 | 23 | 1.7 | 2.7 | 1–20 | 1,928 | 479.8 | 61–3,578 |
| Unid. baleen whale | 27 | 28 | 11 | 18 | 1.2 | 1 | 1–7 | 1,853 | 411.8 | 183–2,693 |
| Atlantic spotted dolphin | 20 | 2803 | 18 | 1,146 | 103.9 | 125.1 | 1–500 | 1,633 | 329.6 | 1,000–2,266 |
| Common dolphin sp. | 19 | 1,172 | 19 | 2,165 | 87.8 | 109.7 | 1–500 | 1,601 | 627.0 | 74–2,385 |
| Dwarf sperm whale | 14 | 23 | 0 | 0 | 1.6 | 0.6 | 1–3 | 1,760 | 199.7 | 1,290–2,009 |
| Fin/sei/Bryde's whale | 13 | 16 | 8 | 9 | 1.2 | 0.4 | 1–2 | 1,815 | 695.1 | 77–2,795 |
| Pilot whale sp. | 11 | 216 | 11 | 603 | 37.2 | 56 | 4–200 | 2,014 | 606.9 | 1,206–3,400 |
| Bryde's whale | 11 | 13 | 8 | 12 | 1.3 | 0.7 | 1–4 | 1,246 | 1,103.0 | 15–1,903 |
| Bottlenose dolphin | 8 | 96 | 7 | 128 | 14.9 | 9.3 | 1–30 | 1,187 | 1,018.8 | 10–2,585 |
| Striped dolphin | 7 | 309 | 2 | 225 | 59.3 | 62.9 | 8–200 | 1,785 | 229.2 | 1,612–2,385 |
| False killer whale | 5 | 82 | 4 | 30 | 12.4 | 11.4 | 1–35 | 1,930 | 327.9 | 1,467–2,561 |
| Killer whale | 5 | 32 | 2 | 7 | 5.6 | 2.5 | 3–9 | 1,714 | 1,067.5 | 20–2,609 |
| Unid. beaked whale | 5 | 9 | 1 | 1 | 1.7 | 0.5 | 1–2 | 1,870 | 218 | 1,477–2,091 |
| Spinner/Clymene dolphin | 5 | 310 | 0 | 0 | 62 | 51.7 | 20–150 | 2,101 | 446.4 | 1,614–2,809 |
| Risso's dolphin | 4 | 36 | 3 | 22 | 8.3 | 3.9 | 4–15 | 1,770 | 374.9 | 1,391–2,375 |
| Unid. cetacean | 2 | 2 | 10 | 49 | 4.3 | 5.7 | 1–20 | 1,601 | 429.9 | 1,240–1,834 |
| Fin whale | 2 | 2 | 2 | 3 | 1.3 | 0.5 | 1–2 | 1,611 | 99.7 | 1,500–1,739 |
| Melon-headed whale | 2 | 350 | 1 | 300 | 216.7 | 104.1 | 100–300 | 1,915 | 509.6 | 1,330–2,265 |
| Cuvier's beaked whale | 2 | 6 | 0 | 0 | 3.0 | 0 | 3 | 1,984 | 376.9 | 1,717–2,250 |
| Rough-toothed dolphin | 1 | 25 | 1 | 10 | 17.5 | 10.6 | 10–25 | 2,095 | 62.9 | 2,050–2,139 |
| Sei whale | 1 | 2 | 0 | 0 | 2 | 0 | 2 | 1,691 | 0 | 1,691 |
| Atlantic humpback dolphin | 0 | 0 | 4 | 14 | 3.5 | 0.5 | 2–4 | 11 | 2.5 | 10-15 |
| Pantropical spotted dolphin | 0 | 0 | 2 | 170 | 85.0 | 49.5 | 50–120 | 1,900 | 0 | 1,900 |

Table 3

Relative abundance (individuals/100min) of cetacean species according to season (Beaufort 0–4), listed in decreasing order of overall abundance.

| | On effort (Beaufort 0–4)* | | Total relative abundance* | Seasonal relative abundance (effort (min)) | | | |
|---|---|---|---|---|---|---|---|
| Species | Sightings | Animals | | Spring (72,766) | Summer (47,412) | Autumn (37,454) | Winter (32,340) |
| Unid. dolphin | 288 | 21,101 | 11.107 | 10.708 | 5.336 | 8.749 | 23.197 |
| Atlantic spotted dolphin | 19 | 2,768 | 1.457 | 1.568 | 2.130 | 1.354 | 0.340 |
| Common dolphin sp. | 19 | 1,172 | 0.617 | 0.449 | 0.348 | 0.000 | 2.103 |
| Sperm whale | 118 | 1,167 | 0.614 | 0.054 | 0.584 | 2.179 | 0.108 |
| Melon-headed whale | 2 | 350 | 0.184 | 0.344 | 0.211 | 0.000 | 0 |
| Spinner/Clymene dolphin | 5 | 310 | 0.163 | 0.082 | 0.380 | 0.053 | 0.155 |
| Striped dolphin | 6 | 301 | 0.158 | 0.240 | 0 | 0.120 | 0.250 |
| Humpback whale | 155 | 285 | 0.150 | 0.210 | 0.015 | 0.003 | 0.383 |
| Pilot whale sp. | 11 | 216 | 0.114 | 0.103 | 0.287 | 0.013 | 0 |
| Bottlenose dolphin | 8 | 96 | 0.051 | 0.080 | 0.042 | 0.000 | 0.056 |
| False killer whale | 5 | 82 | 0.043 | 0.071 | 0 | 0.021 | 0.068 |
| Dwarf sperm whale* | 13 | 21 | 0.042 | 0.022 | 0 | 0 | 0.117 |
| Unid. whale | 35 | 64 | 0.034 | 0.038 | 0.006 | 0.024 | 0.074 |
| Risso's dolphin | 4 | 36 | 0.019 | 0.026 | 0 | 0.000 | 0.053 |
| Killer whale | 5 | 32 | 0.017 | 0.021 | 0.036 | 0.000 | 0 |
| Unid. baleen whale | 27 | 28 | 0.015 | 0.023 | 0 | 0.016 | 0.015 |
| Rough-toothed dolphin | 1 | 25 | 0.013 | 0.034 | 0 | 0.000 | 0 |
| Unid. beaked whale* | 3 | 6 | 0.012 | 0 | 0.018 | 0 | 0.026 |
| Fin/sei/Bryde's whale | 13 | 16 | 0.008 | 0.010 | 0.013 | 0.008 | 0 |
| Bryde's whale | 11 | 13 | 0.007 | 0.014 | 0.002 | 0.000 | 0.006 |
| Cuvier's beaked whale* | 1 | 3 | 0.006 | 0 | 0 | 0.029 | 0 |
| Fin whale | 2 | 2 | 0.001 | 0 | 0 | 0.000 | 0.006 |
| Sei whale | 1 | 2 | 0.001 | 0 | 0 | 0.000 | 0.006 |

*Beaked and *Kogia* whales calculated at sea state Beaufort 0-2, total effort = 50,520min

(*n*=41) of adult animals were most frequently observed. Forty-eight groups (31%) contained immature animals of which 28 (18%) groups included calves, a similar proportion to the 21% of groups containing calves recorded by Best *et al*. (1999) in this area. However, it is likely that the proportion of groups containing calves was greatly underestimated during the current survey work due to the distance of many sightings from the survey vessel.

**Sperm whale (*Physeter macrocephalus*)**

Townsend's (1935) charts show a significant year-round sperm whale ground off Angola, and sperm whales were by far the most numerous large whale species recorded in Angolan waters, with a minimum of 1,219 individuals recorded during survey work (Table 2). This is partly a facet of their large group size ($\bar{\chi}$=9.2 animals), since the total number of sightings was slightly lower than for humpback

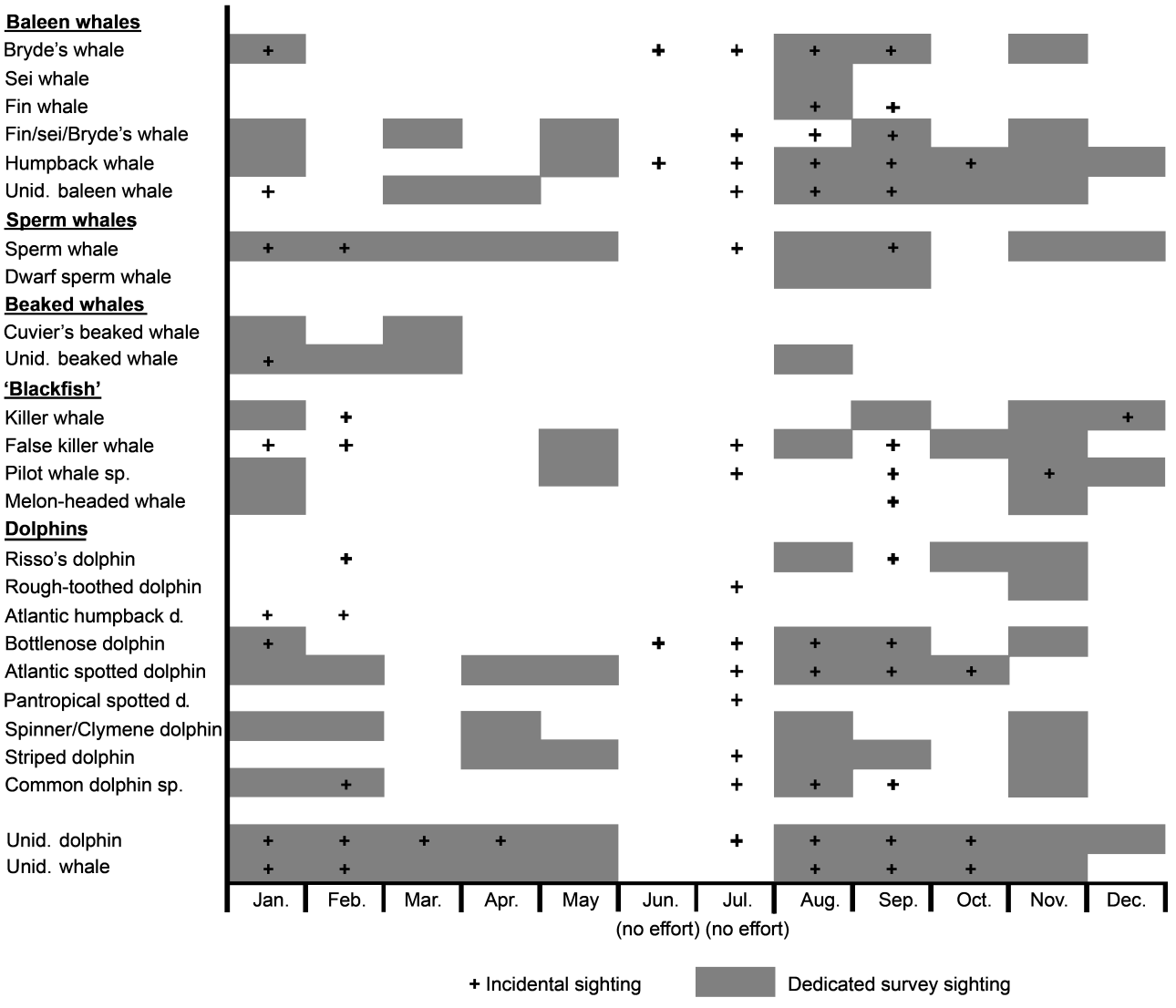


Fig. 3. Seasonal occurrence of cetaceans in Angolan waters.

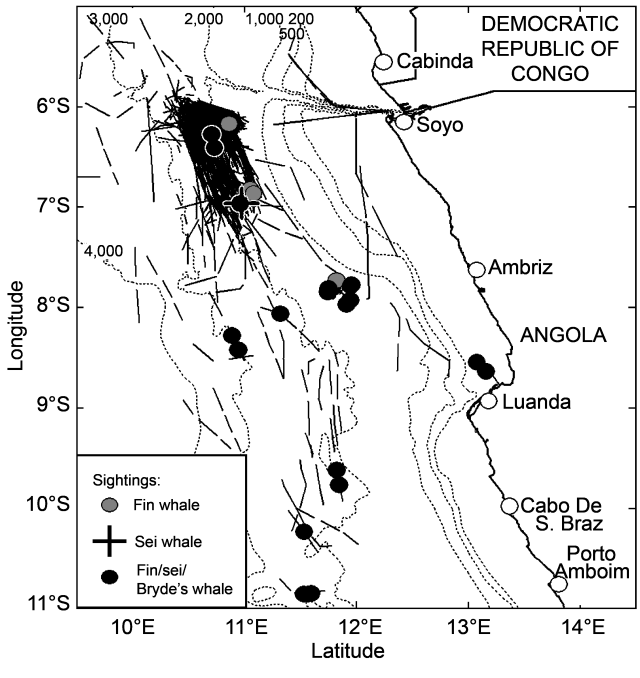


Fig. 4. Distribution of fin and sei whale sightings

whales. The overall relative abundance of sperm whales was 0.6 individuals/100min, making it the third most abundant cetacean species off Angola (Table 3). Sperm whales were sighted exclusively seaward of the shelf break (Table 2), which is consistent with their known preference for deep-water habitat and their relative abundance was similar (0.41-0.72 animals/100 min) across all depth categories exceeding 1,000m. Sightings were clustered particularly in the northeast region of the study area to the west of the Congo River mouth (Fig. 7), with a smaller number of sightings further south off central Angola.

The occurrence of sperm whales within the study area peaked between January and May, and there was a significant difference in the number of encounters ($\chi^2$=198.8, d.f.=3, $p$=<0.001) recorded according to season (Table 3). Significantly more encounters than expected were recorded during the autumn, and significantly fewer during the winter and spring. There was no significant difference between the number of observed and expected sperm whale encounters during the summer. It is currently unclear whether this seasonality represents animals moving into Angolan waters from elsewhere, or a more localised movement of sperm whales within Angola. The timing of peak seasonal abundance of sperm whales in the study area

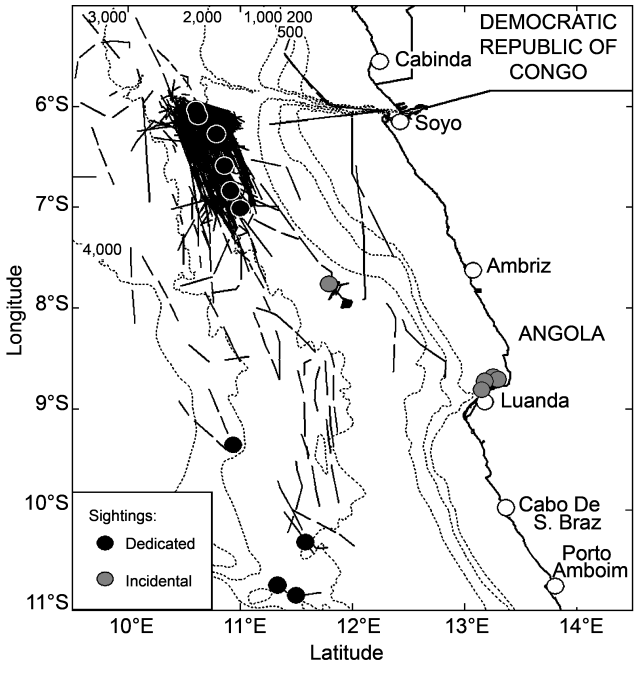


Fig. 5. Distribution of dedicated and incidental Bryde's whale sightings.

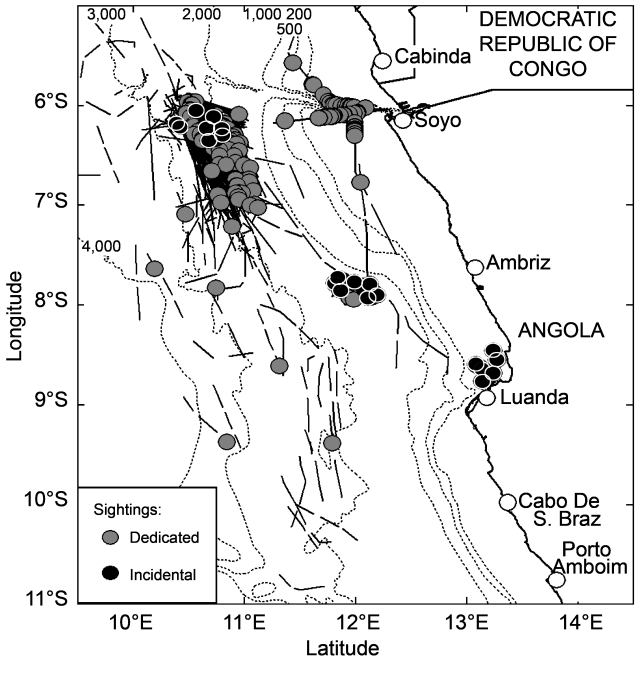


Fig. 6. Distribution of dedicated and incidental humpback whale sightings.

correlates with the monsoon season (Nov-Apr), and may be related to increased outflow and productivity from the Congo River. Large-scale correlations between sperm whales and productivity occur worldwide, and this association off Angola (based on Townsend's 1935 charts) has been previously inferred (Jaquet, 1996).

Sperm whales were often sighted at long range from the survey vessel, and age composition could only be confirmed in 47 of the encounters. Of these, 21 comprised adult-only groups, while 26 groups contained juveniles and/or calves. Mature bulls were seen on very limited occasions, with most pods comprising smaller animals considered to be females or immature males. The dorsal calluses often indicative of

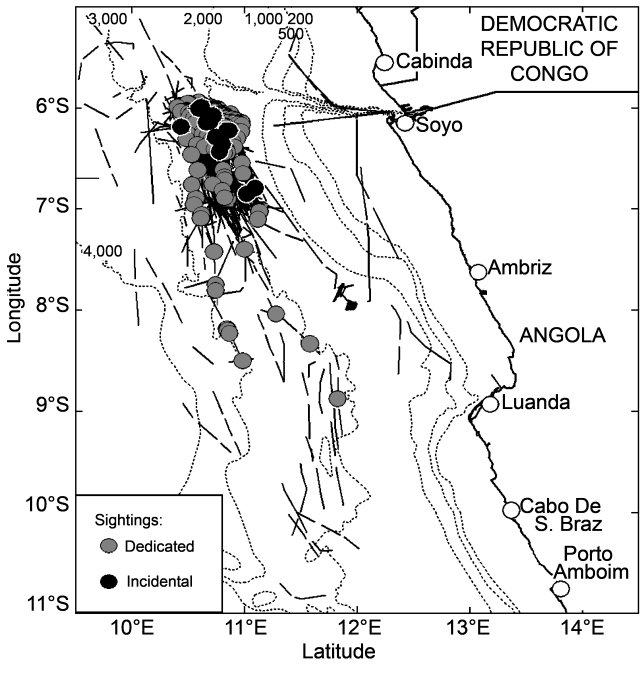


Fig. 7. Distribution of dedicated and incidental sperm whale sightings.

mature females (Kasuya and Ohsumi, 1966) were observed on some closer animals. These data confirm that sperm whale nursery groups regularly use Angolan waters on at least a seasonal basis.

**Dwarf sperm whale (*Kogia sima*)**

*Kogia* whales comprising the closely related dwarf (*K. sima*) and pygmy sperm whale (*K. breviceps*) inhabit tropical and warm temperate regions worldwide (Caldwell and Caldwell, 1989). There were 14 on-effort sightings of *Kogia* within the Angolan study area, comprising small groups of 1-3 animals (Table 2). One of these animals was identified simply as '*Kogia* sp.', but the remaining sightings were all positively identified as dwarf sperm whales based on the proportion and position of their dorsal fins, and verified from photographs taken in the field. This species was the fifth most commonly sighted cetacean in Angolan waters despite its detection being severely hindered by weather conditions (93% of sightings occurred in Beaufort sea state 0-2). Dwarf sperm whales were recorded only in deep oceanic waters ranging from 1,290-2,009m depth (Table 2). A cluster of sightings occurred in the north-east of the survey area offshore from the Congo River mouth (Fig. 8). Dwarf sperm whales were recorded only during August and September (Fig. 3), although this also corresponds with the period of greatest survey effort and calmest weather conditions. Although Maigret (1994) suggests that *Kogia* species are migratory off West Africa, sightings of dwarf sperm whales have also occurred off Angola during January (pers. obs.), and more year-round survey effort in suitable weather conditions is required prior to drawing conclusions on seasonality.

**Cuvier's beaked whale (*Ziphius cavirostris*)**

There were two confirmed sightings of Cuvier's beaked whales during dedicated survey work, and these are described in detail elsewhere (Weir, 2006b). Both encounters involved groups of three animals, located over deep water ($\bar{\chi}$=1,984m) in northern and central Angola (Fig. 8). The sightings occurred during January and March.

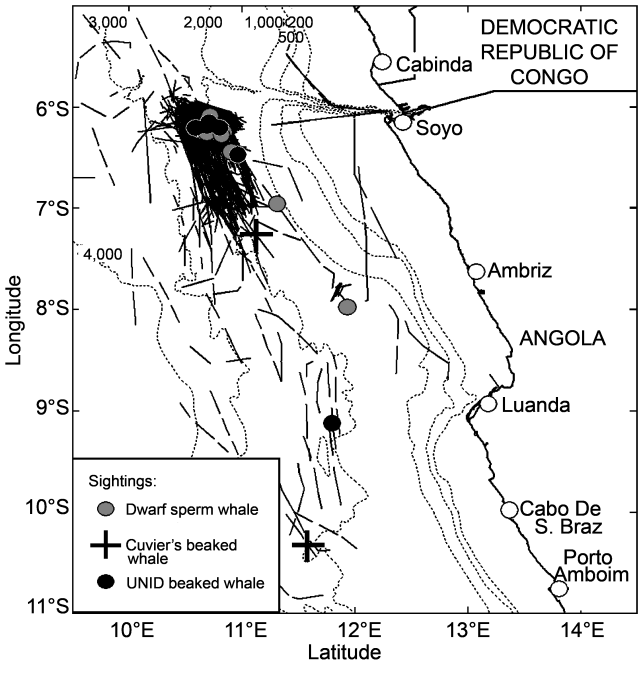


Fig. 8. Distribution of all dwarf sperm whale and beaked whale sightings.

### Unidentified beaked whales

The worldwide distribution of many beaked whale species has been determined primarily from strandings, since these species are elusive, difficult to distinguish between at sea and inhabit only deep-water areas (Mead, 1989). Records of beaked whales off the west coast of Africa have been summarised by Weir (2006b), with Cuvier's, Blainville's (*Mesoplodon densirostris*) and Gervais' (*M. europaeus*) beaked whales considered the most likely species to occur off Angola. Previous records off Angola include a sighting of three unidentified *Mesoplodon* whales reported in July 1966 (Morzer Bruyns, 1968), and an unidentified breaching *Mesoplodon* observed in March 2004 (Weir, 2006b).

A total of six sightings of unidentified beaked whales (either *Ziphius* or *Mesoplodon* sp.) were recorded (Table 2), comprising five on-effort records (Weir, 2006a) and one incidental sighting of an unidentified beaked whale during January 2006. All beaked whale sightings occurred over deep-water oceanic habitat ($\bar{\chi}$=1,870m). Most sightings occurred in the northern portion of the study area offshore from the Congo River mouth, with a single record west of Luanda (Fig. 8). Beaked whales were recorded between January and March, and in August (Fig. 3). The detection of beaked whales at sea is limited by increasing sea state, and it is likely that these species are more numerous off Angola than indicated by the dataset.

### Killer whale (*Orcinus orca*)

There were seven sightings of killer whales during the survey, of which five were on-effort (Table 2). Sightings were recorded in coastal waters ($n$=1), over the slope ($n$=1) and in deep oceanic habitat ($n$=5) (Fig. 9). All on-effort sightings involved groups of four to nine animals off northern Angola over water depths exceeding 2,000m. It was notable that the five killer whale sightings recorded from the seismic vessel occurred only during periods of airgun inactivity, and possible avoidance of the sound source by this species may have resulted in under-recording. The incidental records comprised three animals observed north of Luanda during December 1991, and a pod of four approximately 40km west of Luanda during February 1992 (Iain Nicolson, pers. comm.). At least three inshore sightings have been observed between Tombwa and Namibe (Bruce Bennett, pers. comm.), also testifying to the occurrence of this species in southern Angola.

Killer whales were recorded during five months of the year and there was a suggestion of seasonality in the offshore sightings with most records occurring between November and January (Fig. 3, Table 3). This corresponds with the timing of killer whale sightings off Angola in the 1960s/70s by Mikhalev *et al*. (1981) and with the migratory occurrence noted by Maigret (1994) for this species off West Africa.

The external appearance of killer whales off Angola is consistent with the Type A whales documented by Pitman and Ensor (2003). Killer whales in offshore waters were noted in proximity to sperm whales on three occasions, including observations of an apparent predatory attack upon sperm whales in January 2005.

### Pilot whales (*Globicephala macrorhynchus* and *G. melas*)

The distribution of the short-finned pilot whale (*G. macrorhynchus*) is assumed to be continuous along the west coast of Africa (Jefferson *et al*., 1997), although it is replaced off the coast of Namibia and South Africa by the closely related long-finned pilot whale (*G. melas*), which inhabits cold temperate and subpolar regions (Bernard and Reilly, 2000; Findlay *et al*., 1992). The exact distribution of these two species off the west coast of Africa is unclear (due to lack of previous survey effort, and difficulties in distinguishing between them at sea), and it is possible that some records off Angola might relate to long-finned pilot whales, particularly in southern areas and years when the cool Benguela Current pushes further northwards. However close views allowed some groups to be positively identified as short-finned pilot whales, and the tropical location of most sightings is strongly suggestive of this species.

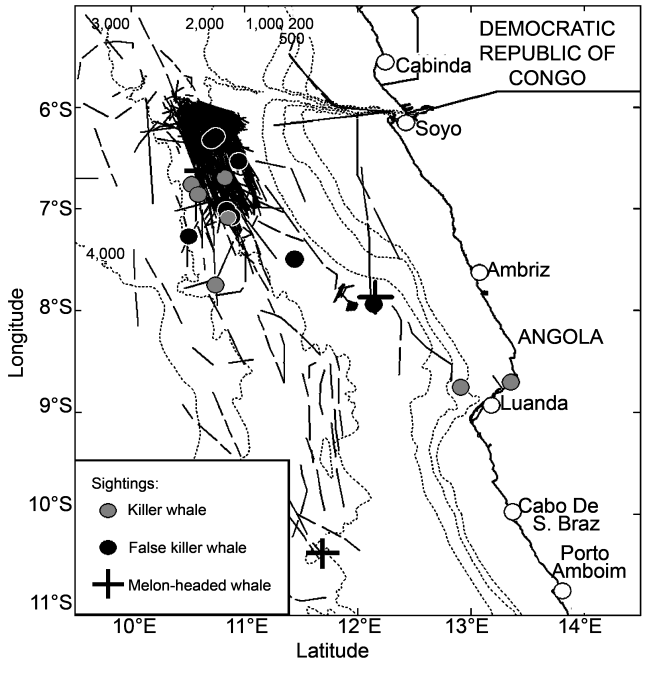


Fig. 9. Distribution of all killer, false killer and melon-headed whale sightings.

There were a total of 22 pilot whale sightings, that were evenly split between on-effort and incidental sightings (Table 2). The relatively large group size ($\bar{\chi}$=37.2 animals) resulted in a relative abundance of 0.1 animals/100min (Table 3), and pilot whales are therefore one of the more commonly occurring cetaceans off Angola. Pilot whale sightings were located exclusively seaward of the 1,000m isobath, with a mean water depth of 2,014m (Table 2). The majority of pilot whale sightings were recorded south of the main survey area with a relatively high number of sightings occurring west of Luanda (Fig. 10). In contrast only five pilot whale groups were observed within the area of prime survey effort off the Congo River mouth where they appeared to be comparatively scarce.

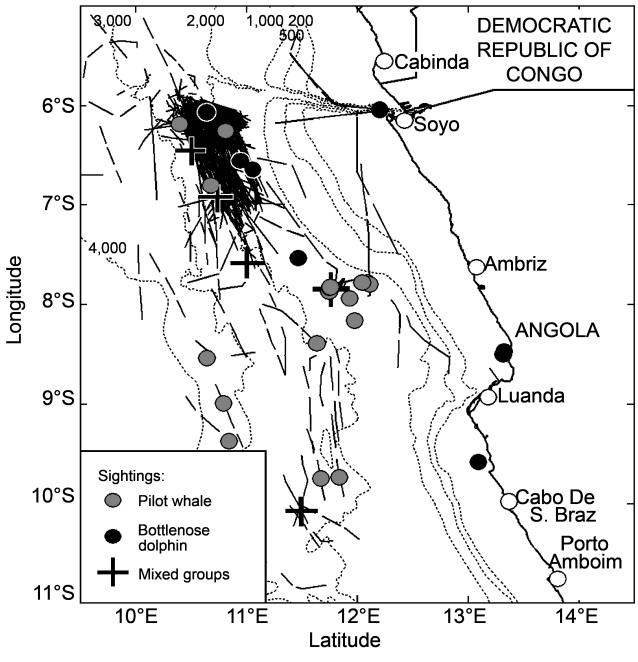


Fig. 10. Distribution of all pilot whale and bottlenose dolphin sightings.

Pilot whales were recorded during only four of the ten dedicated survey months (Fig. 3), but incidental sightings occurred during two other months and this species likely occurs year-round in Angolan waters. Groups consisted of four to 200 animals (Table 2), with the largest groups reported during incidental sightings to the west of Ambriz (Fig. 10). As is commonly observed in other areas (Bernard and Reilly, 2000), five of the sightings involved mixed-species assemblages with common bottlenose dolphins, and pilot whales have also been observed travelling with rough-toothed dolphins off Angola and Gabon (pers. obs.).

**False killer whale (*Pseudorca crassidens*)**

There were nine sightings of false killer whales off Angola, including five on-effort records (Table 2). The sightings were all located over deep-water areas seaward of 1,467m, with a mean water depth of 1,930m. False killer whales were sighted in eight months of the year (Fig. 3), and can be considered resident in deep, warm Angolan waters. The mean school size of false killer whales in Angolan waters was 12.4 animals (Table 2), and both calves and juveniles were recorded. All sightings occurred in single-species schools. Although unconfirmed (and not included in the analysis), a group of three to five large animals almost certainly of this species was observed feeding on a manta ray (*Manta birostris*) in deep water west of Luanda during the summer of 1990/91 (Iain Nicolson, pers. comm.).

**Melon-headed whale (*Peponocephala electra*)**

There were three confirmed records of melon-headed whales, and several additional sightings that were strongly suspected to be this species but could not be conclusively separated from the very similar pygmy killer whale (*Feresa attenuata*) which is also expected to occur throughout tropical West Africa (Caldwell and Caldwell, 1971; Jefferson *et al*., 1997). All sightings were recorded in deep oceanic water (Fig. 9), over depths of 1,330-2,265m (Table 2). Although there were only a small number of records, the large group size of this species (Table 2) made it one of the more abundant species recorded during the survey work (Table 3). Sightings occurred during January, September and November (Fig. 3).

**Atlantic humpback dolphin (*Sousa teuszii*)**

The Atlantic humpback dolphin is endemic to tropical and subtropical West Africa, where it occupies shallow, coastal waters from Morocco south to Angola (Jefferson *et al*., 1997; van Waerebeek *et al*., 2004). This species was not recorded during dedicated survey work, no doubt due to the predominantly offshore distribution of the survey effort. However, at least three Atlantic humpback dolphin groups are thought to be resident along the coast of Namibe Province, including two groups inhabiting the area between Namibe and Flamingos, and a third group off Inamagando located 130km north of Namibe (Bruce Bennett, pers. comm.). These dolphins are typically observed in groups of 4-6 animals (including calves), with sightings located in shallow water (<5m) over, or in close proximity to, rock reefs. Details were kept of four incidental sightings that occurred between 29 January and 7 February 2004 during a kayak trip through this region (Alex Vogel, pers. comm.) (Table 2). Three sightings (each of four animals) occurred off Flamingos to the south of Namibe, including one group that contained a calf. A single sighting of two animals was reported 2km south of Flamingos (Fig. 11).

The sightings of Atlantic humpback dolphins in southern Angola imply a potential occurrence off both central and northern Angola. The author carried out watches specifically for this species during several port calls to Luanda and Soyo in Angola, and Pointe Noire in Congo, but no dolphins were recorded. Further coastal survey work is required to establish this species' exact distribution within Angola and adjacent waters.

**Rough-toothed dolphin (*Steno bredanensis*)**

Two sightings of rough-toothed dolphins were reported in Angola, of which one was on-effort (Table 2). A group of 25 animals was seen in a mixed-species assemblage with unidentified blackfish (melon-headed or pygmy killer whales) in November 2004, and a pod of ten was observed in July 2005. Both sightings were recorded in over 2,000m water (Table 2) in the northern portion of the study area (Fig. 12). Additional records of this species in Angola include a group of 12 animals photographed west of Luanda during March 2004, and 11 observed in a mixed-species school with bottlenose dolphins and pilot whales off Gabon during September 2005 (Weir, 2006c). All sightings of this species have occurred in shelf edge or oceanic waters.

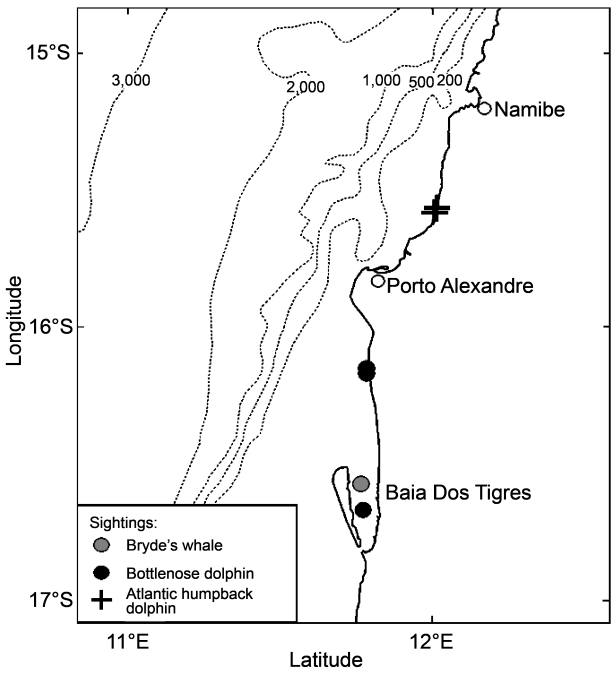


Fig. 11. Distribution of incidental cetacean sightings in southern Angola.

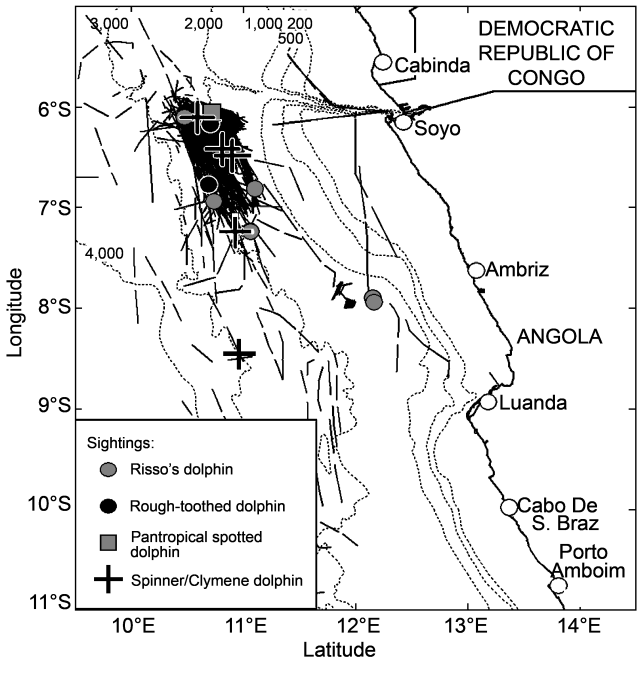


Fig. 12. Distribution of all Risso's, rough-toothed, Pantropical spotted and Spinner/Clymene dolphin sightings.

**Risso's dolphin (*Grampus griseus*)**

There were a total of seven sightings of Risso's dolphins, four of which were on-effort (Table 2). This species showed a deep-water pelagic distribution off Angola, with all sightings occurring in water depths exceeding 1,300m (Table 2). However a sighting of this species over the Gabon shelf in April 2004 (pers. obs.) suggests that Risso's dolphins might also occasionally occur in shallower habitat in Angola. Five of the sightings were located in the northern study area, while two occurred north-west of Luanda in around 1,400m water (Fig. 12). Risso's dolphins were observed in small groups of 15 or fewer animals (Table 2). Sightings occurred in five of the survey months and it has additionally been recorded during January (pers. obs.), indicating a likely year-round occurrence off Angola.

**Common Bottlenose dolphin (*Tursiops truncatus*)**

Although there were only eight sightings during dedicated survey work, a further seven sightings of this species were recorded incidentally making it the third most frequently sighted dolphin species in Angola (Table 2). Sightings were distributed throughout northern, central and southern Angola (Figs 10 and 11) and occurred in both neritic and oceanic waters (Table 2). This species has also been recorded inside Luanda harbour (pers. obs.). Sightings were divided into those distributed in depths of <100m ($\bar{\chi}$= 30.8m, $n$=6) and those in waters exceeding 1,000m depth ($\bar{\chi}$=1957.9m, $n$=9). Genetic studies have distinguished separate 'inshore' and 'offshore' populations of bottlenose dolphins in many areas worldwide (Duffield *et al*., 1983; Hoelzel *et al*., 1998) and this may also be the case in Angola.

Bottlenose dolphins are a year-round inhabitant of Angolan waters, being sighted in six of the survey months (Fig. 3, Table 3), and also recorded during other surveys in March and April (pers. obs.). Group size ranged from one to 30 animals (Table 2). A third of the sightings in Angola comprised mixed-species schools with pilot whales. The mean group size of bottlenose dolphins was higher within mixed-species ($\bar{\chi}$=19.0, $n$=5) rather than dolphin-only ($\bar{\chi}$=12.9, $n$=10) schools, and total group size (including pilot whales) was almost four times higher ($\bar{\chi}$=51.4, $n$=5) than that of dolphin-only ($\bar{\chi}$=12.9, $n$=10) groups. Although some dolphin-only groups were observed in deep water, the mean water depth of mixed-species associations was three times higher ($\bar{\chi}$=2,174m, $n$=5) than that of bottlenose dolphin-only ($\bar{\chi}$=694m, $n$=10) sightings. Rough-toothed dolphins were also present in one mixed-species group off Gabon during September 2005. The tendency for bottlenose dolphins to occur in mixed-species schools with increasing distance from shore has also been recorded in the eastern tropical Pacific Ocean, where pilot whales again form the majority of associations (Scott and Chivers, 1990).

Other notable observations of bottlenose dolphins in Angolan waters include a white (albino or leucistic) bottlenose dolphin sighted amongst a mixed bottlenose dolphin/pilot whale group west of Luanda on 27 December 2001 (photographed by Iain Nicolson), and the several-month residence of a sociable adult female bottlenose dolphin in Mussulo Bay, Luanda during late 2004 (photographed by Iain Nicolson), which frequently interacted with swimmers before eventually being killed.

**Pantropical spotted dolphin (*Stenella attenuata*)**

Although some sightings of unidentified *Stenella* dolphins recorded during dedicated surveys were strongly suspected to be pantropical spotted dolphins, none of these records could be confirmed. However, two incidental sightings were reported during July 2005, involving bow-riding groups seen at close range. The sightings occurred in close proximity in the north of the study area, over water depths of around 1,900m (Table 2). Three sightings were also recorded over the shelf edge off northern Angola during the autumn of 2004 (pers. obs.). The status of this species in Angola remains unclear.

**Atlantic spotted dolphin (*Stenella frontalis*)**

Gabon is currently recognised as the southern distributional limit of Atlantic spotted dolphins in the eastern Atlantic Ocean (Perrin *et al*., 1994a; Perrin *et al*., 1987). However,

Atlantic spotted dolphins were one of the most frequently sighted dolphin species in Angolan waters during survey work, with a total of 38 sightings including 20 on-effort records (Table 2). This species was also numerous, and at 1.5 individuals/100min$^{-1}$, the relative abundance of Atlantic spotted dolphins was more than double that of any other species in Angola (Table 3). The tendency of this species to approach survey vessels to bow-ride may have resulted in an over-recording of its frequency relative to other less interactive dolphin species. However, sightings of this species during the seismic surveys may also have been under-recorded, since Atlantic spotted dolphins appeared to show avoidance of active large-volume airgun arrays and only approached the vessel to bow-ride outside of periods of airgun use.

Although most numerous over continental shelf waters in the western Atlantic (Davis *et al*., 2002; Herzing, 1997; Moreno *et al*., 2005), this species clearly inhabits slope and oceanic waters seaward of the shelf break in Angola (Fig. 13, Table 2). Relative abundance was highest over depths of 1,000-1,499m (4.95 animals/100min$^{-1}$). Although no sightings were recorded over the slope (200-999m) during dedicated surveys, this depth category received rather little effort and opportunistic sightings pertain to the occurrence of this species over slope regions in both Angola and Gabon. Atlantic spotted dolphins were recorded in most months of the year (Fig. 3) and are likely to be year-round residents in Angolan waters. However, their relative abundance showed a clear peak during the summer months (Table 3).

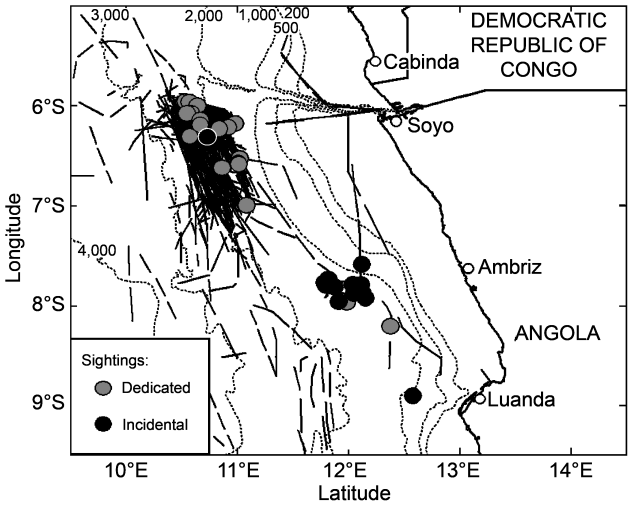


Fig. 13. Distribution of dedicated and incidental Atlantic spotted dolphin sightings.

Group size ranged from one to 500 individuals (Table 2), with pods of over 100 animals recorded on 12 occasions. This group size is notably higher than that reported in the western Atlantic (Davis *et al*., 2002; Herzing, 1997; Moreno *et al*., 2005), which together with the difference in habitat type is suggestive of a different ecology of this species in the south-east Atlantic compared to other parts of its range.

**Spinner dolphin (*Stenella longirostris*) and Clymene dolphin (*Stenella clymene*)**

Although no sightings of spinner or Clymene dolphins were confirmed during the survey work reported here, both species are known to occur in Angola (pers. obs.); (Weir, 2006a). In addition, five on-effort sightings were recorded as either spinner or Clymene dolphins (Table 2), since their characteristic behaviour of leaping from the water and spinning repeatedly around their longitudinal axis (Perrin and Gilpatrick, 1994; Perrin and Mead, 1994) was observed. The records were distributed over deep pelagic waters with a mean depth of 2,101m (Table 2). The status of spinner and Clymene dolphins in Angola is currently uncertain due to the low number of confirmed sightings, confusion with other species, and frequent observations that some of the smaller dolphin species (particularly *Stenella* sp.) exhibited avoidance and detoured around the survey vessel resulting in under-recording.

**Striped dolphin (*Stenella coeruleoalba*)**

The striped dolphin inhabits warm temperate and tropical waters worldwide, and there are two previous records from offshore Angola (Perrin *et al*., 1994b). Striped dolphins were recorded on nine occasions during the survey work, including seven on-effort sightings (Table 2). This species had one of the higher relative abundance values in Angola (Table 3), due to its occurrence in fairly large schools of up to 200 animals (Table 2). Striped dolphins were observed only in deep, oceanic waters (Fig. 14), over a mean water depth of 1,785m. Sightings occurred in six of the survey months (Fig. 3), and the species is potentially resident year-round in most of Angola's deep-water areas.

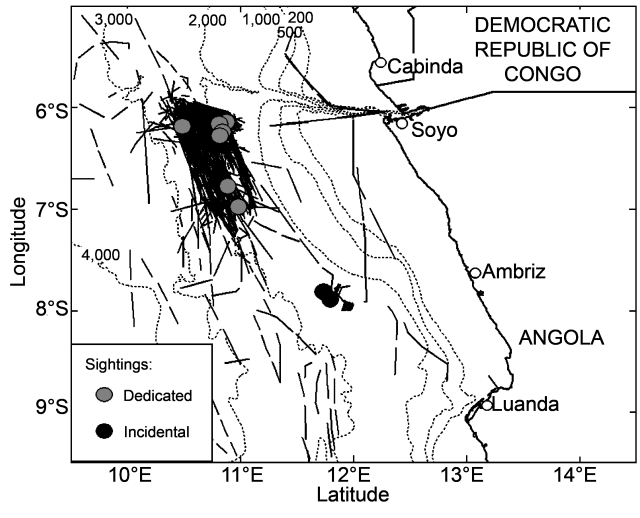


Fig. 14. Distribution of dedicated and incidental striped dolphin sightings.

**Common dolphins (*Delphinus delphis* and *D. capensis*)**

Together, the short-beaked (*D. delphis*) and long-beaked common dolphin (*D. capensis*) (Heyning and Perrin, 1994) are abundant throughout temperate and tropical areas worldwide. Jefferson *et al*. (1997) consider these to be the most common offshore delphinids in West Africa, while Van Waerebeek (1997) confirmed that both species occur off Gabon and Angola. However, they are analysed together here since most observers did not distinguish between the two species during the survey work, and due to uncertainties regarding their external appearance off Angola (Fig. 15). A total of 38 sightings of common dolphins (*Delphinus* sp.) were recorded, of which 19 were on-effort and 19 were incidental (Table 2). The overall relative abundance of 0.6 individuals 100min$^{-1}$ (Table 3) was lower than that of Atlantic spotted dolphins. However, 13 of the 16 groups that comprised over 80 animals occurred as incidental sightings and were not included in the calculation of relative

abundance. The mean group size of common dolphins was significantly higher in water depths of <1,000m ($\bar{\chi}$=231, standard deviation (SD)=204, *n*=5) compared with >1,000m ($\bar{\chi}$=66, SD=71, *n*=33) (Mann-Whitney *U*=26, *n*=38, *p*=<0.05), which suggests that this species may be more numerous in Angolan waters than indicated by the predominantly deep-water survey effort.

Fig. 15. External appearance of common dolphin (*Delphinus* sp.) photographed off Angola, showing shorter beak length than typically observed in *D. capensis* but colouration pattern more comparable to *D. capensis* than *D. delphis*.

Common dolphin sightings were recorded in all habitat types, including neritic (*n*=4), slope (*n*=1) and deep oceanic waters (*n*=33) (Fig. 16). However, although most sightings were recorded over deep water, when corrected for effort the relative abundance was much higher at depths <200m (33.89 animals/100min$^{-1}$) than over the shelf edge (1.63 animals/100min$^{-1}$) or in depths >1,000m (0.53 animals/100min$^{-1}$).

Relative abundance peaked during the winter months (Table 3) probably due to the relatively large number of sightings recorded during August 2005. Common dolphins are likely to be numerous year-round residents throughout Angolan waters, although clarification is needed on the relative occurrence of the two species in the region.

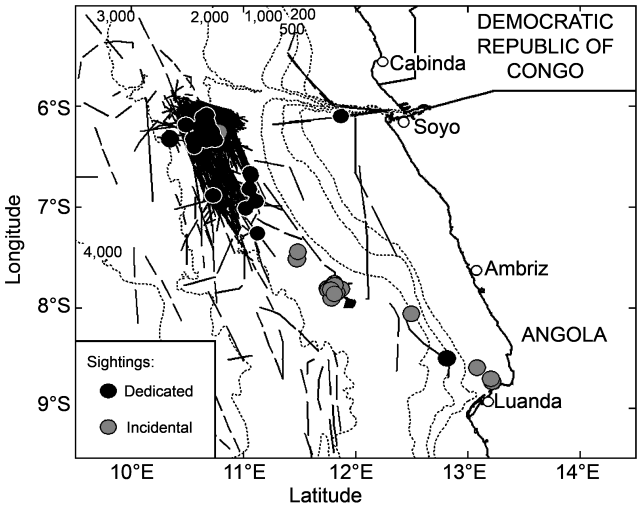


Fig. 16. Distribution of dedicated and incidental common dolphin (*Delphinus* sp.) sightings.

## CONCLUSIONS

These data provide preliminary information on the occurrence, habitat preferences and seasonality of cetaceans in Angolan waters, particularly in providing novel information on small odontocetes in the region. However, most data were collected from a seismic survey vessel and the potential reaction of particular individuals and/or species to airgun sound must be considered when describing the species' distribution.

Although most of the recorded species were previously unconfirmed in Angola, all were expected to occur based on their worldwide distribution. The cetacean community off northern Angola is similar to other tropical areas such as the eastern tropical Pacific, the Indian Ocean and the Gulf of Mexico (Anderson, 2005; Ballance and Pitman, 1998; Davis *et al*., 2002), containing both cosmopolitan species such as bottlenose dolphins, killer whales and sperm whales, and species restricted to warm temperate and tropical waters such as Pantropical spotted dolphin, rough-toothed dolphin and Bryde's whale. However it is important to note that variation in oceanographic conditions within Angola, and particularly the presence of the cold-water Benguela Current, is likely to result in a rather different species composition in southern Angola. Survey work is required in this area to properly document cetacean occurrence. Since the cetacean community recorded in Namibia comprises predominantly cold water and temperate species (Findlay *et al*., 1992), it is likely that many of the tropical cetaceans recorded off northern Angola will have their southernmost distributional limits somewhere in central or southern Angola.

The data revealed trends in both the seasonal occurrence and depth-related distribution of cetacean species in Angola. Although survey data were lacking for June and July, cetaceans were present in the region throughout the year and trends in seasonality were apparent for the most numerous species. Notable concentrations of sperm (summer and autumn) and humpback (winter and spring) whales occur on a seasonal basis, and the contrasting seasonal occurrence of these two species means that Angolan waters are of year-round importance for breeding whales. As noted in other areas (Davis *et al*., 1998; Moreno *et al*., 2005), water depth is a major factor influencing cetacean occurrence off Angola. The cetacean fauna can be broadly divided into separate neritic and deep-water communities. Humpback whale, Bryde's whale, killer whale, bottlenose dolphin and common dolphin were present in both communities; however there may be distinct inshore and offshore populations of the latter four species. Although survey effort was biased towards slope and deep oceanic waters, the highest diversity of cetaceans in Angola does appear to occur over deep water habitat with sperm whales, baleen whales, *Stenella* dolphins and large delphinids such as pilot whales and false killer whale all occurring exclusively seaward of the shelf break.

Owing to a lack of previous studies, the conservation status of cetacean species in Angola is unclear. Maigret (1981; 1994) reports the presence of purse seine fisheries in West Africa at artisanal, national and foreign commercial scales, and these fisheries are known to catch dolphins. Coastal West African species such as bottlenose and Atlantic humpback dolphins are particularly vulnerable to artisanal fisheries (Jefferson *et al*., 1997; van Waerebeek *et al*., 2000), while commercial purse seine fisheries are capable of

causing mass mortality of pelagic species, for example at least 125 Atlantic spotted dolphins killed in a purse seine operation off Mauritania in 1995 (Nieri *et al*., 1999).

Information on the occurrence and status of marine mammals in Angola is important for environmental impact assessments and mitigation of airgun sound by the oil and gas industry, and also for potential future development of whale-watching ecotourism in Angolan waters. Long-term monitoring throughout the region and the establishment of a proper stranding recording scheme are required to ensure conservation and management of cetaceans in Angola.

## ACKNOWLEDGEMENTS

I am grateful to British Petroleum (BP) Angola and their partners in Blocks 18 and 31 for sponsoring the marine mammal survey work, particularly Ann-Marie McLaughlin, Dan Touzel and Anne Walls of BP for their support. Many thanks to all field observers; Nathan Gricks, Richard Woodcock, Frank Vargas, Laura Colombo and Xana Teixeira; and to the captains and crews of the *Geco Triton, Sea Trident, Geo Prospector, Rig Supporter* and *Bucentaur*, particularly Ole Skogsholm, Hans Jacob Krogsrud, Piotr Sacewicz, Mark Olsen, Dave MacDonagh, Mark Maynard, Guy Wainwright, Ollie Harris, Wayne Smith, Izak Venter and Rudi Yulianto for their support during fieldwork. Ian Austin, Bruce Bennett, Iain Nicolson and Alex Vogel kindly provided information and photographs of cetaceans encountered off Angola. Numerous people answered my queries about Angolan cetaceans, particularly Peter Best, Trevor Branch, Inês Carvalho, Tim Collins, Ken Findlay, Cornelis Hazevoet, Miguel Morais, William Perrin, Robert Pitman, Rui Prieto, Kristin Reed, Francisco Reiner, Daniel Robineau, Tamar Ron, Howard Rosenbaum, Jean-Paul Roux, Vladimir Russo and Koen Van Waerebeek. Drafts of this paper were improved by Charles Anderson (formerly of Marine Research Centre, Maldives), Peter Best (Mammal Research Institute, University of Pretoria: based at Iziko South African Museum) and Robert Pitman (US National Marine Fisheries Service). Koen van Waerebeek and Howard Rosenbaum provided useful comments when reviewing this paper.

## REFERENCES

Aguilar, A. 1985. Aboriginal whaling off Pagalu (Equatorial Guinea). *Rep. int. Whal. Commn* 35: 385-86.

Anderson, R.C. 2005. Observations of cetaceans in the Maldives, 1990-2002. *J. Cetacean Res. Manage*. 7(2): 119-36.

Ballance, L.T. and Pitman, R.L. 1998. Cetaceans of the Western Tropical Indian Ocean: distribution, relative abundance, and comparisons with cetacean communities of two other tropical ecosystems. *Mar. Mammal Sci*. 14(3): 429-59.

Bernard, H.J. and Reilly, S.B. 2000. Pilot whales *Globicephala* Lesson, 1828. pp.245-79. *In*: Ridgway, S.H. and Harrison, R. (eds). *The Second Book of Dolphins and the Porpoises*. Academic Press, London. i-xix+486pp.

Best, P.B. 1981. The status of right whales (*Eubalaena glacialis*) off South Africa, 1969-1979. *Investl Rep. Div. Sea Fish. S. Afr*. 123: 1-44.

Best, P.B. 1994. A review of the catch statistics for modern whaling in southern Africa, 1908-1930. *Rep. int. Whal. Commn* 44: 467-85.

Best, P.B. 1996. Evidence of migration by Bryde's whales from the offshore population in the southeast Atlantic. *Rep. int. Whal. Commn* 46: 315-31.

Best, P.B. 2001. Distribution and population separation of Bryde's whale *Balaenoptera edeni* off southern Africa. *Mar. Ecol. Prog. Ser*. 220: 277-89.

Best, P.B. and Lockyer, C.H. 2002. Reproduction, growth and migrations of sei whales *Balaenoptera borealis* off the west coast of South Africa in the 1960s. *S. Afr. J. Mar. Sci* 24: 111-33.

Best, P.B., Reeb, D., Morais, M. and Baird, A. 1999. A preliminary investigation of humpback whales off northern Angola. Paper SC/51/CAWS33 presented to the IWC Scientific Committee, May 1999, Grenada, WI (unpublished). 12pp. [Paper available from the Office of this Journal].

Best, P.B. and Ross, G.J.B. 1986. Catches of right whales from shore-based establishments in southern Africa, 1792-1975. *Rep. int. Whal. Commn (special issue)* 10: 275-89.

Budker, P. 1952. Quelques considérations sur la campagne baleiniere 1951 au Cap Lopez (Gabon). *Mammalia* 14(4): 154-58. [In French].

Budker, P. 1953. Les campagnes baleinieres 1949-1952 au Gabon. (Note préliminaire). *Mammalia* 17(3): 129-48. [In French with English summary].

Budker, P. and Collignon, J. 1952. Trois campagnes baleinieres au Gabon (1949-1950-1951). *Bulletin Institut d'Études Centrafricaines* 3: 75-100. [In French].

Budker, P. and Roux, C. 1968. The 1959 summer whaling season at Cape Lopez (Gabon). *Norsk Hvalfangsttid*. 6: 141-5. N.

Caldwell, D.K. and Caldwell, M.C. 1971. The pygmy killer whale *Feresa attenuata*, in the western Atlantic, with a summary of world records. *J. Mammal*. 52(1): 206-09.

Caldwell, D.K. and Caldwell, M.C. 1989. Pygmy sperm whale, *Kogia breviceps* (de Blainville, 1838); dwarf sperm whale, *Kogia simus* (Owen, 1866). pp.235-60. *In*: Ridgway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales*. Academic Press, London and San Diego. 442pp.

Carvalho, I., Brito, C., Reiner, F. and Dos Santos, M.E. 2003. Records of cetaceans around Ilheu Das Rolas, Sao Tome and Principe. *European Cetacean Society Conference Guide and Abstracts* 17: 268-69. Paper presented to the 17th Conference of the European Cetacean Society, Las Palmas de Gran Canaria, 9-13 March 2003.

Davis, P.W., Ortega-Ortiz, J.G., Ribic, C.A., Evans, W.E., Biggs, D.C., Ressler, P.H., Cady, R.B., Leben, R.R., Mullin, K.D. and Würsig, B. 2002. Cetacean habitat in the northern oceanic Gulf of Mexico. *Deep-Sea Res. I* 49: 121-43.

Davis, R.W., Fargion, G.S., May, N., Leming, T.D., Baumgartner, M., Evans, W.E., Hansen, L.J. and Mullin, K. 1998. Physical habitat of cetaceans along the continental slope in the north-central and western gulf of Mexico. *Mar. Mammal Sci*. 14(3): 490-507.

De Figueiredo, J.M. 1958. Pescarias de baleia nas Provincias Africanas Portuguesas. V Congresso Nacional de Pesca. [In Portugese].

Duffield, D.A., Ridgway, S.H. and Cornell, L.H. 1983. Hematology distinguishes coastal and offshore forms of dolphins (*Tursiops*). *Can. J. Zool*. 61(4): 930-33. LFS.

Eisma, D. and van Bennekom, A.J. 1978. The Zaire River and estuary and the Zaire outflow in the Atlantic Ocean. *Neth. J. Sea Res*. 12: 255-72.

Findlay, K.P., Best, P.B., Ross, G.J.B. and Cockcroft, V.G. 1992. The distribution of small odontocete cetaceans off the coasts of South-Africa and Namibia. *S. Afr. J. Mar. Sci* 12: 237-70.

Gambell, R. 1985. Fin whale – *Balaenoptera physalus* (Linnaeus, 1758). pp.171-92. *In*: Ridgway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 3. The Sirenians and Baleen Whales*. Academic Press, London and Orlando. xviii+362pp.

Gordon, J.C., Gillespie, D., Potter, J.J., Frantzis, A., Simmonds, M.P., Swift, R. and Thompson, D. 2003. A review of the effects of seismic surveys on marine mammals. *Mar. Tech. Soc. J*. 37(4): 16-34.

Hardman-Mountford, N.J., Richardson, A.J., Agenbag, J.J., Hagen, E., Nykjaer, L., Shillington, F.A. and Villacastin, C. 2003. Ocean climate of the south east Atlantic observed from satellite data and wind models. *Prog. Oceanogr*. 59: 181-221.

Herzing, D.L. 1997. The life history of free-ranging Atlantic spotted dolphins (*Stenella frontalis*): Age classes, color phases and female reproduction. *Mar. Mammal Sci*. 13(4): 576-95.

Heyning, J.E. and Perrin, W.F. 1994. Evidence for two species of common dolphins (Genus *Delphinus*) from the eastern North Pacific. *Contrib. Sci. [Los Angeles]* 442: 1-35.

Hoelzel, A.R., Potter, C.W. and Best, P.B. 1998. Genetic differentiation between parapatric 'nearshore' and 'offshore' populations of the bottlenose dolphin. *Proc. R. Soc. Lond. Ser. B*. 265(1402): 1177-83.

World Conservation Union. 2006. *Balaenoptera edeni*, *Cetacean Specialist Group 1996. 2006 IUCN Red List of Threatened Species*. [Available at *www.iucnredlist.org*].

Jaquet, N. 1996. How spatial and temporal scales influence understanding of sperm whale distribution: a review. *Mammal Rev*. 26(1): 51-65.

Jefferson, T.A., Curry, B.E., Leatherwood, S.E. and Powell, J.A. 1997. Dolphins and porpoises of West Africa: a review of records. *Mammalia* 61(1): 87-108.

Kasuya, T. and Ohsumi, S. 1966. A secondary sexual character of the sperm whale. *Sci. Rep. Whales Res. Inst., Tokyo* 20: 89-94.

Maigret, J. 1981. Rapports entre les Cétacés et la pêche thoniere dans l'Atlantique tropical oriental. *Notes Afr*. 171: 77-84. [In French].
Maigret, J. 1994. Marine mammals and fisheries along the west African coast. *Rep. int. Whal. Commn (special issue)* 15: 307-16.
McCauley, R.D., Fewtrell, J., Duncan, A.J., Jenner, C., Jenner, M.N., Penrose, J.D., Prince, R.I.T., Adhitya, A., Murdoch, J. and McCabe, K. 2000. Marine seismic surveys – a study of environmental implications. *APPEA Journal* 2000: 692-708.
Mead, J.G. 1989. Beaked whales of the genus *Mesoplodon*. pp.349-430. *In*: Ridgeway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 4. River Dolphins and the Larger Toothed Whales*. Academic Press Inc., London and San Diego. i-xix+442pp.
Mikhalev, Y.A., Ivashin, M.V., Savusin, V.P. and Zelenaya, F.E. 1981. The distribution and biology of killer whales in the Southern Hemisphere. *Rep. int. Whal. Commn* 31: 551-66.
Moreno, I.B., Zerbini, A.N., Danilewicz, D., Santos, M.C.O., Simões-Lopes, P.C., Lailson-Brito, J. and Azevedo, A.F. 2005. Distribution and habitat characteristics of dolphins of the genus *Stenella* (Cetacea: Delphinidae) in the southwest Atlantic Ocean. *Mar. Ecol. Prog. Ser.* 300: 229-40
Moroshkin, K.V.A., Bubnov, V.A. and Bulatov, R.P. 1970. Water circulation in the eastern South Atlantic. *Oceanology* 10: 27-34.
Morzer Bruyns, W.F.J. 1968. Sight records of Cetacea belonging to the genus *Mesoplodon* Gervais, 1850. *Z. Saugetierkd*: 106-07.
Nieri, M., Grau, E., Lamarche, B. and Aguilar, A. 1999. Mass mortality of Atlantic spotted dolphins (*Stenella frontalis*) caused by a fishing interaction in Mauritania. *Mar. Mammal Sci.* 15(3): 847-53. [In Notes].
Perrin, W.F., Caldwell, D.K. and Caldwell, M.C. 1994a. Atlantic Spotted Dolphin – *Stenella frontalis* (G. Cuvier, 1829). pp.173-90. *In*: Ridgway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 6. The Second Book of Dolphins and the Porpoises*. Academic Press, London and San Diego. 416pp.
Perrin, W.F. and Gilpatrick, J.W., Jr. 1994. Spinner dolphin, *Stenella longirostris* (Gray, 1828). pp.99-128. *In*: Ridgway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 5. The First Book of Dolphins*. Academic Press, London and San Diego. 416pp.
Perrin, W.F. and Mead, J.G. 1994. Clymene Dolphin – *Stenella clymene* (Gray, 1846). pp.161-71. *In*: Ridgway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 5. The First Book of Dolphins*. Academic Press, London and San Diego. 416pp.
Perrin, W.F., Mitchell, E.D., Mead, J.G., Caldwell, D.K., Caldwell, M.C., van Bree, P.J.H. and Dawbin, W.H. 1987. Revision of the spotted dolphins, *Stenella* spp. *Mar. Mammal Sci.* 3(2): 99-170.
Perrin, W.F., Wilson, C.E. and Archer, F.I. 1994b. Striped dolphin *Stenella coeruleoalba* (Meyen, 1833). pp.129-59. *In*: Ridgway, S.H. and Harrison, R. (eds). *Handbook of Marine Mammals. Vol. 5. The First Book of Dolphins*. Academic Press, London and San Diego. 416pp.
Pitman, R.L. and Ensor, P. 2003. Three forms of killer whales (*Orcinus orca*) in Antarctic waters. *J. Cetacean Res. Manage.* 5(2): 131-39.
Richardson, W.J., Greene Jr, C.R., Malme, C.I. and Thomson, D.H. 1995. *Marine Mammals and Noise*. Academic Press, San Diego. 576pp.
Rosenbaum, H.C., Ersts, P.J., Razafindrakoto, Y., Sounguet, G., Pomilla, C., Ngouessono, S., Rasoamampianina, V. and White, L. 2002. Population characteristics, distribution, and relative abundance of humpback whales off the coasts of Madagascar and Gabon: an update on recent and planned research. Paper SC/54/H20 presented to the IWC Scientific Committee, April 2002, Shimonoseki, Japan. 13pp. [Paper available from the Office of this Journal].
Scott, M.D. and Chivers, S.J. 1990. Distribution and herd structure of bottlenose dolphins in the eastern tropical Pacific Ocean. pp.387-402. *In*: Leatherwood, S. and Reeves, R.R. (eds). *The Bottlenose Dolphin*. Academic Press, San Diego. 653pp.
Townsend, C.H. 1935. The distribution of certain whales as shown by logbook records of American whaleships. *Zoologica (NY)* 19(1-2): 1-50+6 maps.
Van Bennekom, A.J. and Berger, G.W. 1984. Hydrography and silica budget of the Angola basin. *Neth. J. Sea Res.* 17: 149-200.
Van Waerebeek, K. 1997. Long-beaked and short-beaked common dolphins sympatric off central-west Africa. Paper SC/49/SM46 presented to the IWC Scientific Committee, September 1997 Bournemouth (unpublished). 5pp. [Paper available from the Office of this Journal].
Van Waerebeek, K., Barnett, L., Camara, A., Cham, A., Diallo, M., Djiba, A., Jallow, A.O., Ndiaye, E., Samba Ould Bilal, A.O. and Bamy, I.L. 2004. Distribution, status and biology of the Atlantic humpback dolphin, *Sousa teuszii* (Kukenthal, 1892). *Aquat. Mamm.* 30: 56-83.
Van Waerebeek, K., Ndiaye, E., Djiba, A., Diallo, M., Murphy, P.F., Jallow, A.O., Camara, A., Ndiaye, P. and Tous, P.T. 2000. *A Survey of the Conservation Status of Cetaceans in Senegal, The Gambia and Guinea-Bissau*. UNEP/CMS Secretariat, Bonn, Germany. 80pp.
Walsh, P.D., Fay, J.M., Gulick, S. and Sounguet, G.P. 2000. Humpback whale activity near Cap Lopez, Gabon. *J. Cetacean Res. Manage.* 2(1): 63-68.
Weir, C.R. 2006a. First confirmed records of Clymene dolphin *Stenella clymene* (Gray, 1850) from Angola and Congo, south-east Atlantic Ocean. *African Zoology* 41(2): 297-300.
Weir, C.R. 2006b. Sightings of beaked whales (Cetacea: Ziphiidae) including first confirmed Cuvier's beaked whales *Ziphius cavirostris* from Angola. *African Journal of Marine Science* 28: 173-75.
Weir, C.R. 2006c. Sightings of rough-toothed dolphins (*Steno bredanensis*) off Angola and Gabon, south-east Atlantic ocean. Abstract SD24 presented at the 20th Annual Conference of the European Cetacean Society, 2-7 April 2006, Gdynia, Poland. [Available from the author].
Weir, C.R. 2006d. The temporal and spatial distribution of marine mammals, turtles and other marine fauna off northern Angola, September 2003-March 2006. Unpublished report to BP (Angola) Exploration Ltd. Ketos Ecology, UK. May 2006. 157pp. [Available from BP (Angola)].

Paper received: August 2006
Paper accepted: April 2007