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DISTRIBUTION OF DOLPHINS IN GALÁPAGOS WATERS

The productive waters near the Galápagos Islands appear to contain a high abundance and diversity of cetaceans (Day 1994, Merlen 1995). In this note we use incidental sightings collected between 1985 and 1995 to describe the distributions and trends in abundance of several species of dolphins (family Delphinidae) around the islands (within a study area bounded by 2°N–2°S, 88°W–93°W) during the first half of the year.

Dolphin sightings were recorded opportunistically during sperm whale (*Physeter macrocephalus*) research in 1985 (18 February–24 April), 1987 (2 January–30 June), 1989 (4 April–23 May), 1991 (19 March–18 April), 1992 (28 June–13 July), and 1995 (5 April–6 June). A total of 3,975 daylight hours was spent at sea within the study area. *Elendil*, a 10-m sloop, was used for the 1985–1989 studies, and *Balaena*, a 12-m cutter, for those between 1991–1995. The speed of these vessels during the research ranged between 4–12 km/h. Every three hours, standard data were recorded, including position (using a Tracor Transtar Satellite Navigator prior to 1992 and a Trimble TRANSPAK GPS subsequently, although these instruments occasionally malfunctioned), sea-surface temperature (SST), and depth (from bathymetry of William Chadwick, Oregon State University, when a position accurate within a few km was available).

Observers with experience in cetacean identification alternated watches on deck and noted incidental sightings of dolphins. For each sighting, the dolphins were identified to the lowest taxonomic level possible, and the group size (minimum number of animals present), time, duration of sighting, and position were recorded. Depth was calculated later from bathymetry when an accurate position was available. SST was taken from the closest 3-h measurement. Sightings (separated by at least 15 min without observing an animal) were considered units for statistical tests and were assumed to be independent. We used the standard 3-h measurements taken in daylight as controls. During January–June the waters off Galápagos are almost invariably calm (wind less than 15 kn) and the visibility good.

The sightings of dolphins are summarized in Table 1. Three species were frequently sighted: the bottlenose dolphin (*Tursiops* spp.), Risso's dolphin (*Grampus griseus*), and common dolphins (*Delphinus* spp.). Short-beaked and long-beaked common dolphins were not distinguished, although D. Palacios believes that the only common dolphin species found in Galápagos waters is the shortbeak (*Delphinus delphis*).[1] Pilot whales (*Globicephala macrorhynchus*), killer whales (*Orcinus orca*), Fraser's dolphins (*Lagenodelphis hosei*), and three species of *Stenella* (striped dolphin, *S. coeruleoalba*; pantropical spotted dolphin, *S. attenuata*; and spinner dolphin, *S. longirostris*) were sighted so rarely (Table 1) that additional analyses were not warranted.

Day (1994) and Merlen (1995) reported the presence of the nine delphinid

Table 1. Summary of dolphin sightings.

Species	Number of sightings (sightings /h)	Day's (1994) abundance	Mean group size (SD)	Temperature range in °C	Depth range in m
Bottlenose dolphin	60 (0.014)	Frequent	24 (50)	20.8–31.0	12–3,510
Unidentified common dolphin	43 (0.010)	Frequent	125 (118)	20.7–31.0	1,160–3,580
Risso's dolphin	26 (0.006)	Present	13 (28)	20.8–27.9	280–3,370
Striped dolphin	6 (0.002)	Present	50 (28)	23.2–27.2	900–3,500
Spotted dolphin	2 (0.0005)	Present	33 (25)	25.5–26.5	2,000–3,500
Spinner dolphin	1 (0.0003)	?	100	25.8	1,100
Fraser's dolphin	1 (0.0003)	Rare	300	26.0	3,400
Pilot whale	18 (0.005)	Present	19 (15)	22.0–29.0	1,500–3,300
Killer whale	8 (0.002)	Present	5 (1.6)	24.2–28.9	1,100–3,250
3-h controls	1,265		—	18.0–31.2	3–3,720

species given in Table 1 from within the Galápagos Archipelago, and Day's qualitative indications of abundance generally match our sighting rates for these species (Table 1). However, he also listed the rough-toothed dolphin, *Steno bredanensis*, which was identified from skeletal remains, and three other members of the Globicephalinae: the melon headed whale (*Peponocephala electra*, termed "Rare" by Day), the pygmy killer whale (*Feresa attenuata*, "Rare"), and the false killer whale (*Pseudorca crassidens*, "Present"). The lack of sightings of these species in our studies may be partly due to the difficulties of positive identification (Day 1994)—during the study there were 272 sightings of dolphins in which species could not be determined, including at least one in which the animals were suspected to be false killer whales.

The general agreement between our results and Day's (1994) and Merlen's (1995) qualitative summaries of observations in all seasons suggests that during the second half of the year, when sea temperatures are about 3°C cooler (Jackson 1985), the dolphin community around the islands is not radically different from that indicated in Table 1.

The relative abundance of the different delphinid species close to the islands is quite distinct from that in the offshore waters of the eastern tropical Pacific where Wade and Gerrodette (1993) used sightings from research vessel surveys between 1986 and 1990 to estimate cetacean abundance. Common dolphins seem to be the most abundant species both in the eastern tropical Pacific and off the Galápagos (where relative abundance is indicated by multiplying sighting rates by the mean group sizes shown in Table 1). However, Wade and Gerrodette (1993) estimated eastern tropical Pacific abundances of the three *Stenella* species to be an order of magnitude higher than those of bottlenose dolphins, Risso's dolphins, or pilot whales—a substantial contrast to the relative abundance of these species close to the Galápagos Islands (Table 1). The Galápagos dolphin community also seems to be distinct from that found in the inshore waters of tropical islands in the central and western Pacific (such

as Hawaii and Moorea) where the spinner dolphin is one of the most commonly observed species (*e.g.*, Norris *et al.* 1994). The relatively cooler and more productive upwelling waters of the Galápagos (Houvenaghel 1978) are likely a contributing factor in the presence of a dolphin fauna with different relative abundances from those found in other areas of the tropical Pacific.

Observed group sizes were highly variable both within and between species (Table 1). Common dolphins were sighted in much larger groups than the other two frequently observed species. Bottlenose dolphin groups were larger than those of Risso's dolphins. The group sizes given in Table 1 agree remarkably well with Merlen's (1995) general observations for Galápagos waters, and Wade and Gerrodette's (1993) mean school sizes for these species in the wider eastern tropical Pacific, with one exception. In contrast to the mean estimated group size of 125 in our research (n = 43), Wade and Gerrodette listed a mean school size of 472 (n = 92) for the 'southern' stock of common dolphins, whose range includes Galápagos waters, significantly larger (t = 4.475, 133 df, $P < 0.001$).

The distribution of effort (3-hourly positions) and sightings of the three frequently sighted dolphin species within our study area are shown in Figure 1. The dolphin distributions roughly follow effort, but there are some important differences. In order to examine these quantitatively, the Galápagos area was divided into 1° × 1° squares. To provide a reasonable effort in each area, the squares defined by 1°–2°S, 90°–91°W, and 1°–2°S, 91°–92°W were lumped into one area, and then all other squares with less than 100 h effort were discarded. Within the five remaining areas, all three species had distributions which were significantly different from the distribution of effort (using G tests: bottlenose dolphin, G = 40.0, 4 df, $P < 0.005$; common dolphin, G = 10.4, 4 df, $P < 0.05$; Risso's dolphin, G = 12.1, 4 df, $P < 0.05$). Bottlenose dolphins were concentrated inshore of the shelf break (indicated by the 1,000-m contour) south of the largest island of Isabela and had at least twice the relative abundance in the central and southern areas than in the other areas. Risso's dolphins were most common just off the shelf break both north and south of Isabela and had greatest abundance in the southern area. Common dolphins had highest abundance in the squares north and west of Isabela where upwelling is usually strongest (Houvenaghel 1978).

The principal distinction between the distributions of the three species and the distribution of effort was related to water depth (Table 1, Fig. 1, 2). Bottlenose dolphins were much more frequently sighted in waters less than 1,000 m deep than expected from the distribution of effort (Kolmogorov-Smirnov test, $P < 0.001$). Risso's dolphins were also distributed significantly different from effort, being sighted most frequently in slope waters 1,000–2,000 m deep (Kolmogorov-Smirnov test, P = 0.005). Although the sightings of common dolphins showed no statistically significant depth preference (Kolmogorov-Smirnov test, P = 0.39), all common dolphin sightings in our studies were in depths greater than 1,000 m (Table 1, Fig. 2). However, because of our relative lack of effort in waters less than 1,000 m deep, this did not

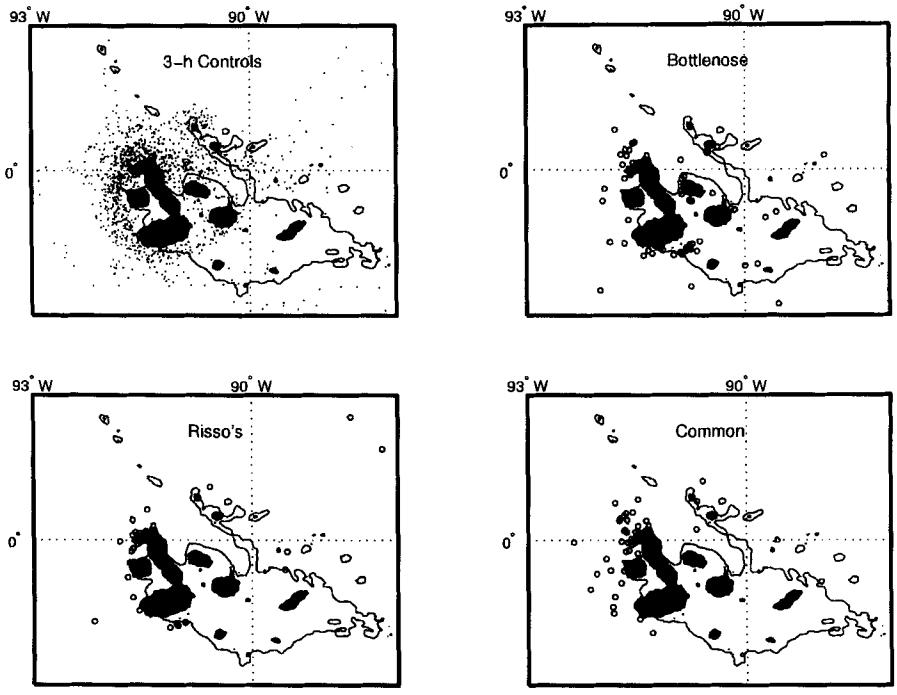

Figure 1. Distribution of effort (positions of 3-hourly environmental records made in daylight) and sightings of three most abundant dolphin species around Galápagos Islands (shaded) with 1,000-m contour (solid line). In western part of archipelago, where most effort occurred, 2,000-m contour is very close to 1,000-m contour, and 100-m contour very close to land. Thus 1,000-m contour roughly outlines shelf.

show up as a statistically significant effect. These depth preferences and distributions are also indicated on Merlen's (1995) charts.

The depth preferences of the three frequently sighted species found in our study are in general agreement with the results of studies from other areas. In the eastern tropical Pacific bottlenose dolphins are particularly abundant close to coasts and islands (Scott and Chivers 1990) and seem to have a more inshore distribution than other small cetacean species (Wade and Gerrodette 1993). Baumgartner (1997) showed that in the northern Gulf of Mexico, Risso's dolphins also use steep sections of the continental shelf, although in rather shallower waters (~350–975 m) than off the Galápagos (~1,000–2,000 m, Fig. 2). In the wider eastern tropical Pacific, Reilly (1990) found common dolphins to occupy upwelling-modified waters, in agreement with our Galápagos results.

None of the three frequently sighted dolphin species had a distribution of SSTs which was significantly different from that of effort (Kolmogorov-Smirnov tests: bottlenose dolphin $P = 0.13$; common dolphin $P = 0.48$; Risso's dolphin $P = 0.30$; Table 1). The eastern tropical Pacific and its biota are profoundly affected by the El-Niño-Southern-Oscillation phenomenon (*e.g.*,

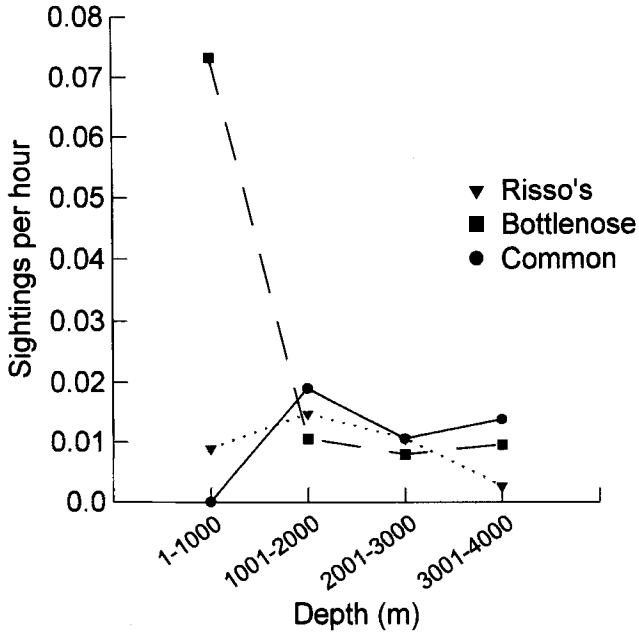

Figure 2. Sighting rates of three dolphin species with water depth off Galápagos Islands (1–1,000 m, n = 450 h; 1,001–2,000 m, n = 474 h; 2,001–3,000 m, n = 1,137 h; and 3,001–4,000 m, n = 1,158 h).

Merlen 1984, Arntz 1986). However, the three most abundant dolphin species were not sighted at significantly different rates in the years 1987 and 1991 in which El Niño raised sea temperatures by about 3°C compared with other years (t-tests with years as units, $P > 0.25$ for all species, excluding 1992 because of low effort).

Sperm whale densities in the Galápagos study area have declined dramatically (~20%/yr) between 1985 and 1995 (Whitehead *et al.* 1997). However, there was no statistically significant trend in sighting rates for any of the three most frequently observed dolphin species ($P > 0.15$ for all species; regressions of logged sighting rate on year, weighted by effort). In these analyses statistically significant ($P \leq 0.05$) results would have been generated by trends of ±7%/yr for bottlenose dolphins, ±13%/yr for common dolphins, and ±27%yr for Risso's dolphins.

In summary, the waters of the Galápagos Islands have a dolphin fauna with substantially different relative abundances from the wider eastern tropical Pacific. The three most abundant species off the Galápagos appear to have distinctive preferred habitats largely defined by depth: bottlenose dolphins are most abundant in shelf waters less than 1,000 m deep, Risso's dolphins in slope waters of 1,000–2,000 m, and common dolphins in deeper and generally more productive waters.

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