LEATHERWOOD, S., R. R. REEVES, W. F. PERRIN AND W. E. EVANS. 1982. Whales, dolphins and porpoises of the eastern North Pacific and adjacent arctic waters. NOAA Technical Report NMFS Circular 444.

PERRIN, W. F. 1972. Variation and taxonomy of spotted and spinner porpoises (genus *Stenella*) of the eastern tropical Pacific and Hawaii. Ph.D. dissertation, University of California, Los Angeles. 490 pp.

PERRIN, W. F. 1975*a*. Variation of spotted and spinner porpoise (genus *Stenella*) in the Eastern Tropical Pacific and Hawaii. Bulletin of the Scripps Institution of Oceanography 22:1–206.

PERRIN, W. F. 1975*b*. Distribution and differentiation of populations of dolphins of the genus *Stenella* in the Eastern Tropical Pacific Ocean. Journal of the Fisheries Research Board of Canada 32:1059–1067.

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RELATIVE ABUNDANCE OF CETACEA IN THE CANAL DE BALLENAS, GULF OF CALIFORNIA

The Gulf of California, México, is a 1,000-km-long, enclosed, subtropical sea with relatively high primary productivity and extremely dynamic oceanography (Alvarez-Borrego 1983). There have been a number of cruises to count cetaceans in the Gulf of California and several publications on the distribution and numbers of cetaceans there (see review by Vidal *et al.*, in press). These studies provide excellent data on the large-scale distribution and relative abundance of cetaceans throughout the Gulf of California, and more limited data on seasonal distribution.

We made counts of all cetaceans during a three-year study of the behavior and ecology of *Balaenoptera* whales in the Canal de Ballenas, central Gulf of California (Tershy *et al.* 1990, Tershy 1992). Here, we provide data on the relative abundance of cetacea by season for 1985–1986, our most complete year of field work, and supplement this with behavior and group size data from 1983 and 1984.

The study area was a 20 × 40-km section of the Canal de Ballenas (29°00′N, 113°20′W) including Bahía de los Angeles and Bahía de las Animas (see Tershy *et al.* 1991 for a detailed description). It is characterized by (1) three main habitat types: shallow sandy bays, rocky points and islands, and near-shore

waters over 1,500 m deep; (2) extreme temporal habitat variability with temperate water conditions (<15°C) and prevailing northwest winds in winter and spring, and tropical water conditions (>26°C) with southeast winds in the summer and fall; and (3) strong tidal currents (>3 m/sec) which cause extensive vertical mixing and sustained year-round primary productivity comparable to major upwelling zones (Alvarez-Borrego 1983).

To estimate relative abundance we used data from 167 d between April 1985 and April 1986 during which we conducted 1,378 h of observations in a 4.5-m inflatable skiff with an observation height of ≤2 m. We counted all cetaceans regardless of distance and did not estimate the distance at which different species could be seen. We used a consistent but non-random search method (Tershy *et al.* 1990) and attempted to cover all three major habitat types on a weekly basis. Counts were made only when visibility was greater than 5 km and wind speed less than 11 km/h (sea state 2 or less on the Beaufort scale). Therefore, we did not correct for differences in weather or interspecific differences in sightability. At least once a day we measured the sea surface temperature 1 m below the surface.

Observer bias was relatively consistent because one of us (B.R.T.) collected the data on over 95% of census days. Only days with >2 h of effort, and weeks with more than two days of observations, are included in the analysis. We did not make counts during the first week of June, third and fourth week of September, first week of October, fourth week of November, all of December, and last three weeks of February.

We separated the study year into four periods which roughly encompass the season of southwest winds and tropical conditions (June–August = 555 h boat time), the fall transition season (September–November = 234 h), the season of northwest winds and temperate conditions (December–February = 125 h), and the spring transition period (March 1986 and April–May 1985 = 464 h) (Alvarez-Borrego 1983). During each period we divided the number of cetaceans sighted by the number of boat hours.

Data for group size and behavior for common dolphins and bottlenose dolphins are reported for 1985–1986 only; for all other species we combined data from all years of the study (25 May–29 August 1983, 588 h of boat time; 3 April–28 August 1984, 788 h of boat time) and included supplemental observations of behavior made from a 30-m coastal cliff. We estimated group size and general behavior of all cetaceans sighted. We photo-identified individual male killer whales using the same technique described for *Balaenoptera* whales in Tershy *et al.* (1990).

Seven odontocete species were sighted in 1985–1986; the most abundant was the common dolphin *Delphinus delphis* (Table 1). Mean weekly *Delphinus* numbers were correlated positively with water temperature (1984 $r = 0.74$, df = 17; 1985–1986 $r = 0.31$, df = 35; $P < 0.01$ for both field seasons). Group size was recorded consistently in 1985–1986 (n = 88 groups, $\bar{x}$ group size = 129.2 ± 137.78, range = 1–650), but several groups in 1983 were estimated to be ≥1,500. *Delphinus* were frequently found in mixed-species feeding aggregations with Bryde's whales, and were observed feeding on Pacific sardines

Table 1. Relative abundance of cetaceans in the Canal de Ballenas in 1985–1986, expressed as number sighted per hour of boat effort.

	Mar–May	Jun–Aug	Sep–Nov	Dec–Feb	Total number (% of sightings)
Common Dolphin *Delphinus delphis*	4.95	10.47	6.85	4.95	10,454 (87.5%)
Bottlenose Dolphin *Tursiops truncatus*	0.16	0.26	1.23	1.73	715 (6.0%)
Bryde's Whale *Balaenoptera edeni*	0.14	0.37	0.13	0.05	317 (2.7%)
Fin Whale *B. physalus*	0.40	0.10	0.05	0.27	291 (2.4%)
False Killer Whale *Pseudorca crassidens*	0.00	0.065	0.279	0.00	100 (0.84%)
Killer Whale *Orcinus orca*	0.017	0.013	0.043	0.016	27 (0.23%)
Minke Whale *B. acutorostrata*	0.022	0.009	0.008	0.0	17 (0.14%)
Blue Whale *B. musculus*	0.015	0.006	0.009	0.000	9 (0.08%)
Gray Whale *Eshrichtius robustus*	0.009	0.0	0.0	0.0	4 (<0.01%)
Humpback Whale *Megaptera novaeangliae*	0.006	0.0	0.0	0.0	3 (<0.01%)
Short-finned Pilot Whale *Globicephala macrorhynchus*	0.0	0.0	0.0	0.016	2 (<0.01%)
Sperm Whale *Physeter catodon*	0.0	0.0	0.0	0.016	2 (<0.01%)
Dwarf Sperm Whale *Kogia simus*	0.0	0.0	0.004	0.0	1 (<0.01%)
Total number cetaceans	2,652	6,082	2,003	1,205	11,942
Hours of effort	464	555	234	125	1,378
Number cetaceans/hour	5.72	10.96	8.56	9.64	8.67

(*Sardinops sagax*) which concentrated in the study area during the late summer (Lluch-Belda *et al.* 1986). When Pacific sardines were shoaling beneath the skiff, we captured them by rapidly pulling a small treble hook through the school and were also able to identify them by looking over the side with a skin diving mask and observing light reflecting off the characteristic striae on the operculum. Although the mean number of Bryde's whales and *Delphinus* sighted per week were positively correlated (Tershy 1992), there was no correlation between number of Bryde's whales and *Delphinus* sighted per day (Tershy *et al.* 1991).

Bottlenose dolphins (*Tursiops truncatus*) were the second most abundant cetacean in the study area. They were sighted in relatively equal numbers throughout the year. *Tursiops* have separate nearshore and offshore morphs, both of which have been recorded in the Gulf of California (Walker 1981). In 1985–1986, groups sighted <5 km from shore were smaller than groups sighted

≥5 km from shore (nearshore groups $n = 66$, $\bar{x} = 8.5 \pm 6.79$; offshore groups $n = 5$, $\bar{x} = 110 \pm 63.34$; $P < 0.001$ two tailed t test).

Killer whales (*Orcinus orca*) were sighted in every month of field work (n = 21 sightings of a minimum of 5 different groups; $\bar{x}$ group size = 6.4 ± 4.16, range 1–14; $\bar{x}$ number of adult males per group = 1.2 ± 0.40, range 1–2; average percent adult males per group = 28.7%, range 9.1%–100%). Five adult males were identified photographically from 1–5 times ($\bar{x}$ identifications per individual = 2.6 ± 1.67) during the three years of the study. Two of these males were also identified in photographs given to us by other investigators from five killer whale sightings in the study area between 1982 and 1986. Photographs of a group of killer whales 120 km to the east of the study area, off the coast of Bahía Kino, Sonora, identified it as the most frequently sighted group in the Canal de Ballenas study area.

Killer whales in the Gulf of California have been observed hunting blue, fin, and Bryde's whales (Tarpy 1979, Vidal and Pechter 1989, Silber *et al.* 1990). We observed killer whales pass within 100 m of both California sea lions (*Zalophus californianus*) (n = 5 occasions), and *Balaenoptera* whales (n = 9 occasions including 2 females with calves). The killer whales did not noticeably alter their own behavior or that of the other species (except for two immature Bryde's whales which approached and swam with a group of 3 killer whales for >20 min). However, when killer whales were within ~500 m of common dolphins, the common dolphins traveled at high speed away from the killer whales (n = 3 events). Two killer whale predation attempts on common dolphins in the study area, one documented with photos, have been observed by other researchers (G. Meyer and A. Reséndiz, personal communication).

During the three years of the study all sightings of false killer whales (*Pseudorca crassidens*) were when water temperatures were above 21°C (n = 11 groups, $\bar{x}$ group size = 42.3 ± 23.92, range 20–100). Pilot whales (*Globicephala macrorhynchus*), in contrast, were sighted throughout the year, albeit rarely (n = 8 groups, $\bar{x}$ group size = 6.4 ± 2.33, range = 2–9).

Sperm whales (*Physeter catodon*) were sighted in August 1983 (1 group) and January–February 1986 (4 groups). All eleven individuals sighted appeared to be mature males, based on their size. Our study was conducted during a prolonged period of low giant squid (*Dosidicus gigas*) abundance (Ramirez-R and Klett-T 1985), and local fishermen reported that sperm whales were sighted much more frequently when squid were abundant.

One dwarf sperm whale (*Kogia simus*) was sighted on 4 November 86. There was no wind (sea state 0 on a Beaufort scale) or swell, and the *Kogia* rafted at the surface for about 2 min between dives, much like a sperm whale. Therefore, we were able to record four dive times to the nearest 1 min: 15, 43, 19, and 30 min. These may be the only recorded dive times for *Kogia*, because they are rarely sighted, and there is little published information on their behavior (Caldwell and Caldwell 1989).

Six mysticete species were sighted during 1985–1986 (Table 1). In 1985–1986 as well as 1983 and 1984, Bryde's whales (*Balaenoptera edeni*) were the most common mysticete as indicated by number sighted per hour and number

of individuals using the study area. Their numbers were positively correlated with water temperature (Tershy *et al.* 1990). They were primarily piscivorous, and relatively solitary except when aggregating at concentrations of food (Tershy 1992). Fin whale (*B. physalus*) numbers were negatively correlated with water temperature (Tershy *et al.* 1990); they were only observed feeding on zooplankton, often in large aggregations, and most individuals were in groups of 2–10 (Tershy 1992). Blue whales (*B. musculus*) were regular visitors to the Canal de Ballenas from April to June, while minke whales (*B. acutorostrata*) appeared to be year-round residents with sightings in all months in which there were more than 100 h of search effort (Tershy *et al.* 1990).

Gray whales (*Eshrichtius robustus*) were regular post-breeding season visitors and, on one occasion, were observed bottom feeding (Tershy and Breese 1992). Of the six humpback whales (*Megaptera novaeangliae*) sighted during the three years of study, five were thought to be immature individuals based on their size and were sighted in March and April, just after the dispersal of breeding aggregations south of the Gulf of California (J. Urban, personal communication). Only one of the humpback whales was adult size, sighted in August 1983.

The data we have presented are only a snapshot of cetacean relative abundance during a one-year period and it is likely that this will change over time. For example: there is evidence for several species that the number of individuals sighted per hour increases during El Niños (Tershy *et al.* 1991); as mentioned above, the number of sperm whales may respond to changes in the abundance of giant squid (*Dosidicus gigas*); and the recent decline of Pacific sardines and their replacement by northern anchovies (*Engraulis mordax*) (Hammann 1989, Lluch-Belda *et al.* 1989) may affect the distribution and relative abundance of common dolphins and Bryde's whales. Nevertheless, this is the only systematic survey of the cetacean fauna of the Canal de Ballenas, Gulf of California.

The combination of high year-round productivity with tremendous spatial and temporal habitat variability makes the Canal de Ballenas area an important marine habitat. This is reflected by the high species diversity and numbers of Cetacea recorded in the Canal de Ballenas area during our study.

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Literature Cited

Alvarez-Borrego, S. 1983. Gulf of California. Pages 427–449 *in* B. H. Ketchum, ed. Estuaries and enclosed seas. Elsevier Press, Amsterdam.

Caldwell, D. K., and M. C. Caldwell. 1989. Pygmy sperm whale *Kogia breviceps*: dwarf sperm whale *Kogia simus*. Pages 235–260 *in* S. H. Ridgeway and R. Harrison, eds. The handbook of marine mammals. Volume 4 River dolphins and the larger toothed whales. Academic Press, London.

Hammann, M. G. 1989. Range extension and commercial capture of the northern anchovy, *Engraulis mordax* Girard, in the Gulf of California, Mexico. California Fish and Game 75:49–53.

Lluch-Belda, D., F. J. Magallon and R. A. Schwartzlose. 1986. Large fluctuations in the sardine fishery in the Gulf of California: possible causes. California Cooperative Investigative Fisheries Reports 27:136–140.

Lluch-Belda, D., R. J. M. Crawford, T. Kawasaki, A. D. MacCall, R. H. Parrish, R. A. Schwartzlose and P. E. Smith. 1989. World-wide fluctuations of sardine and anchovy stocks: the regime problem. South African Journal of Marine Science 8:195–205.

Ramirez-R, M., and A. Klett-T. 1985. Composición de tallas de la captura de calamar gigante en el Golfo de California durante 1981. CIBCASIO Transactions (Scripps Institution of Oceanography) 10:124–137.

Silber, G. K., M. W. Newcomer and H. Pérez-Cortéz M. 1990. Killer whales (*Orcinus orca*) attack and kill a Bryde's whale (*Balaenoptera edeni*). Canadian Journal of Zoology 68:1603–1606.

Tarpy, C. 1979. Killer whale attack. National Geographic Magazine 155:542–545.

Tershy, B. R. 1992. Body size, diet, habitat use, and social behavior of *Balaenoptera* whales in the Gulf of California. Journal of Mammalogy 73:477–486.

Tershy, B. R., and D. Breese. 1992. Sightings and feeding of gray whales in the northern Gulf of California. Journal of Mammalogy 72:830–831.

Tershy, B. R., D. Breese and C. S. Strong. 1990. Abundance, seasonal distribution and population composition of balaenopterid whales in the Canal de Ballenas, Gulf of California, México. Reports of the International Whaling Commission (Special Issue 12):369–375.

Tershy, B. R., D. Breese and S. Alvarez-Borrego. 1991. Increase in cetacean and seabird numbers in the Canal de Ballenas during an El Niño-Southern Oscillation event. Marine Ecology Progress Series 69:299–302.

Vidal, O., L. T. Findley and S. Leatherwood. In press. Annotated checklist of marine mammals of the Gulf of California. San Diego Natural History Society Bulletin.

Vidal, O., and G. Pechter. 1989. Behavioral observation on fin whale, *Balaenoptera physalus*, in the presence of killer whale, *Orcinus orca*. Fishery Bulletin 87:370–373.

Walker, W. A. 1981. Geographical variation in morphology and biology of bottlenose dolphins (*Tursiops*) in the eastern North Pacific. NOAA Administrative Report No. LJ-81-03C. National Marine Fisheries Service, Southwest Fisheries Center, La Jolla, CA.

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