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NOTE

Increase in cetacean and seabird numbers in the Canal de Ballenas during an El Niño-Southern Oscillation event

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ABSTRACT: El Niño-Southern Oscillation (ENSO) events cause a decline in upwelling-based primary productivity throughout the California Current system and southern Gulf of California. However, in the Canal de Ballenas, central Gulf of California, primary productivity is based on tidal mixing and appears unaffected by ENSO events. Between the ENSO year of 1983 and the anti-ENSO year of 1985 we censused 4 piscivores (Bryde's whale *Balaenoptera edeni*; common dolphin *Delphinus delphis*; blue-footed booby *Sula nebouxii* and brown booby *S. leucogaster*) and 3 planktivores (fin whale *B. physalus*; black storm-petrel *Oceanodroma melania*; and least storm-petrel *O. microsoma*). For all species the number of individuals sighted per hour declined by 77 to 94 % over the 3 yr period. This suggests that during ENSO events the Canal de Ballenas may serve as a refugium of high productivity and prey abundance for these highly mobile marine animals.

El Niño-Southern Oscillation (ENSO) events severely reduce primary productivity throughout most of the coastal eastern Pacific (Barber & Chavez 1983, Cane 1983). This causes a decline in the growth, reproduction and survivorship of zooplankton and small schooling fish (Barber & Chavez 1983), and the larger predators that feed on them, including seabirds (Boersma 1978, Schreiber & Schreiber 1983), pinnipeds (Trillmich et al. 1986), and cetaceans (Manzanilla 1989). Some species of highly mobile, long-lived marine animals experience less excess adult mortality during ENSO events than expected from the apparent reductions in localized prey density. Little is known about what measures adults take at sea to compensate for decreased prey density.

Mee et al. (1985) proposed that because productivity in part of the central and northern Gulf of California is based on tidal current mixing it would not be affected by ENSO events. They suggested this could protect local fauna from ENSO-associated ecological catastrophes.

Oceanography of study area and effects of ENSO events. Alvarez-Borrego (1983) and Alvarez-Borrego & Lara-Lara (in press) describe the oceanography of the study area in detail. The canal is narrow and deep (Fig. 1). It undergoes a seasonal change from temperate water conditions (as low as 14 °C) and prevailing northwest winds in winter and spring, to tropical water conditions (as high as 28 °C) with southeast winds in summer and fall. Tidal ranges of up to 4 m generate strong currents (up to 3 m s^{-1}; Alvarez et al. 1984) which cause extensive vertical mixing (Roden 1964). As a result the canal has the lowest sea surface temperatures (Robinson 1973), and highest nitrate and silicate surface concentrations in the Gulf (Alvarez-Borrego et al. 1978). Within the tropical or temperate season surface temperatures appear unaffected by the direction or intensity of wind (Badan-Dangon et al. 1985).

Positive mean sea level anomalies show the onset of the strongest recorded ENSO event in the Gulf of California at the end of 1982 (Robles-Pacheco & Christensen 1984). Mee et al. (1985) used temperature and chlorophyll *a* time series data from the entrance to the Gulf to show that the ENSO event occurred there from September 1982 through June 1984. Their temperature data indicate enhanced upwelling in 1981 and suppressed upwelling in 1983. In 1981 there was a large standing crop of phytoplankton with average surface value 12 mg m^{-3}. In 1983 there was no large seasonal chlorophyll *a* maximum and average surface values were < 2 mg m^{-3}. In contrast, Lara-Lara et al. (1984) found that surface nutrient concentrations were not limiting photosynthesis in the Guaymas Basin (just

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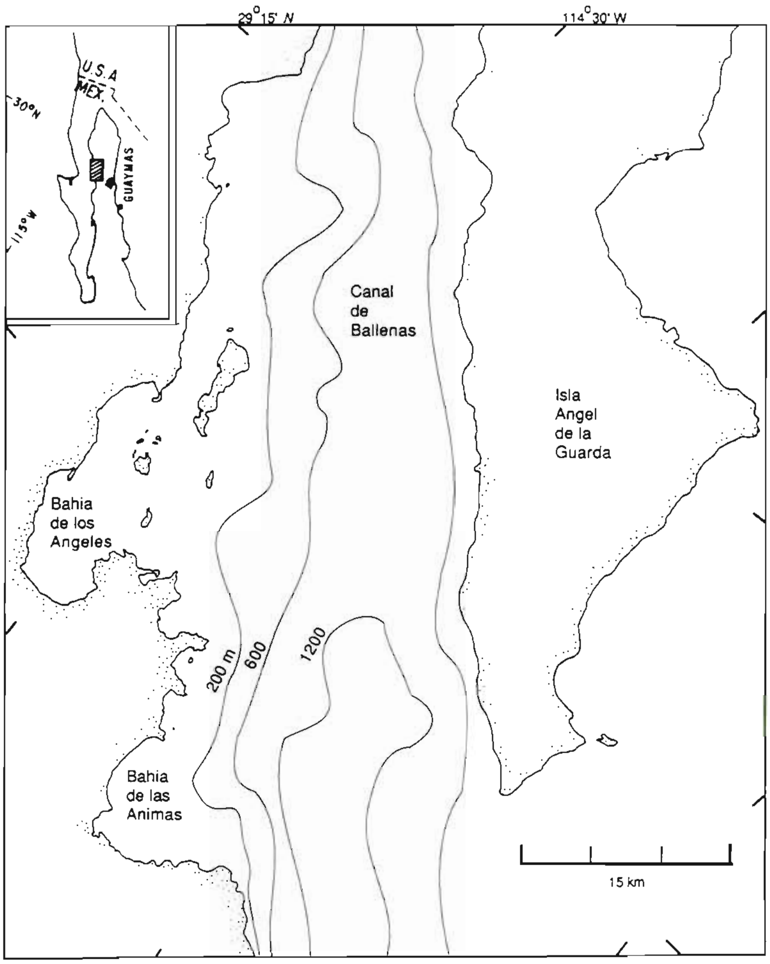

Fig. 1. Study area

south of the Canal de Ballenas) during March and October 1983. In addition, the primary productivity data of Lara-Lara et al. (1984) are similar to those reported for 1981 and 1982 by Gaxiola-Castro & Alvarez-Borrego (1986) for the same area.

Thus, with the scarce data available, El Niño events do not appear to decrease primary productivity in the central Gulf of California where there is intense mixing by tides, and where nutrient concentrations remain high in the euphotic zone. Unfortunately, there are no primary productivity data for 1983 from the Canal de Ballenas, but it has the most intense physical dynamics of the entire Gulf. Therefore, it is where we would expect ENSO events to have the least effect on nutrient input to the surface waters.

Materials and methods. From May through August in 1983, 1984, and 1985 we counted cetaceans and seabirds in the Canal de Ballenas whenever visibility was greater than 5 km and wind speed less than 11 km h^{-1} (Beaufort 2 or less) – about 74 % of the days in each year. Because we only conducted counts under these conditions it is unlikely that differences in weather between years affected our ability to sight cetaceans or seabirds. We used a consistent but non-random search method in which we ran our 4.2 m inflatable boat in a straight line at planing speed (ca 17 km h^{-1}) for 5 or 10 min then shut off the engine for 15 min to listen for the blows or exhalations of whales and do a 360° binocular scan. All cetaceans, regardless of distance from the boat, and all seabirds, within an estimated 100 m radius around our boat, were counted. Distance estimates were periodically calibrated using landmarks of known distance. We made no attempt to randomize the search effort on a daily basis. However, on a weekly basis we covered most of the study area (Fig. 1) and all 3 major habitat types (Tershy et al. in press). The relatively small size of the study area and long period of time over which daily counts were averaged (4 mo) minimizes potential interannual differences in area covered. Furthermore, planktivores and piscivores used different parts of the study area (unpubl.) but both groups showed similar changes in relative abundance between years. Observer reliability was high because one of the authors (B.R.T.) was present and consistently collected data on over 95 % of the census days.

Mixed species feeding aggregations were common and several species had similar seasonal distributions. However, there was no significant correlation in the daily counts of any 2 species (unpubl.), suggesting that the movements of each species were relatively independent.

Bryde's (*Balaenoptera edeni*) and fin (*B. physalus*) whales were counted in all years. The numbers of seabirds and common dolphins *Delphinus delphis* were estimated during each day of observations in 1983 and 1984, but counted in 1985. We conducted a crude test of the relative accuracy of these estimates for seabirds on 2 days in July 1984. One observer counted seabirds while another estimated their numbers; on the next count observers switched positions. Taking the mean of the 2 days, estimates of the number of 18 seabird species combined were 89 % of counts (brown booby *Sula leucogaster* estimates 94 % of counts; blue-footed booby *S. nebouxii* estimates 131 % of counts; black storm-petrel *Oceanodroma melania* estimates 94 % of counts; least storm-petrel *O. microsoma* estimates 191 % of counts). Tripling the 1985 counts would not change the significance level of the decline in number sighted per hour for any species. For each species we used chi-square goodness of fit to test if the number of individuals sighted in each year was in the same ratio as the number of hours of censuses, and if the number of days on which sightings occurred was in the same ratio as the number of days of censuses.

Results and discussion. All 4 species of piscivores (blue-footed and brown boobies, common dolphins and Bryde's whales) and all 3 species of planktivores (black and least storm-petrels and fin whales) were relatively more abundant and were seen on a higher percentage of census days during the strong ENSO year of 1983 than during the anti-ENSO year of 1985 (Tables 1 & 2). The weak ENSO year of 1984 was a year of intermediate abundance for all species except brown booby and black storm-petrel.

Table 1. Number of planktivorous and piscivorous cetaceans and seabirds in the Canal de Ballenas between the 1983 ENSO and the 1985 anti-ENSO. Values are no. sighted (no. h^{-1}). All species show a significant decline ($p < 0.001$) in each successive year except for brown boobies which showed no significant change between 1983 and 1984 and black storm petrels which increased ($p < 0.001$) between 1983 and 1984

	1983	1984	1985
Time spent searching	(588 h)	(497 h)	(562 h)
Piscivores			
Bryde's whale	755 (1.28)	381 (0.77)	205 (0.39)
Common dolphins	58016 (98.67)	25961 (52.24)	5463 (9.72)
Blue-footed booby	28116 (47.82)	18781 (37.39)	2043 (3.88)
Brown booby	13186 (22.43)	11005 (22.14)	749 (1.42)
Planktivores			
Fin whale	272 (0.46)	61 (0.12)	57 (0.10)
Black storm petrel	5433 (9.24)	5625 (11.32)	1211 (2.30)
Least storm petrel	6562 (11.16)	5080 (10.22)	1438 (2.73)

Table 2. Number and percent of days when planktivorous and piscivorous cetaceans and seabirds were observed in the Canal Ballenas between the 1983 ENSO and the 1985 anti-ENSO. The decline, between 1983 and 1985, in the proportion of days sighted was significant for Bryde's whale, fin whale, common dolphin, brown booby ($p < 0.001$), and black storm petrel ($p < 0.05$), but not for blue-footed booby, and least storm petrel ($p > 0.05$)

	1983	1984	1985
No. days spent searching	(76)	(60)	(72)
Piscivores			
Bryde's whale	70 (92.1 %)	44 (73.3 %)	37 (51.4 %)
Common dolphins	62 (81.6 %)	44 (73.3 %)	33 (45.8 %)
Blue-footed booby	76 (100 %)	60 (100 %)	57 (79.2 %)
Brown booby	66 (86.8 %)	57 (95.0 %)	40 (55.6 %)
Planktivores			
Fin whale	38 (50.0 %)	16 (26.7 %)	14 (19.4 %)
Black storm petrel	71 (93.4 %)	55 (91.7 %)	52 (72.2 %)
Least storm petrel	71 (93.4 %)	52 (86.7 %)	54 (75.0 %)

These data cannot prove a causal relationship between the relative abundance of these pelagic animals in the Canal de Ballenas and ENSO-induced oceanographic conditions. However, they are at least consistent with the hypothesis that during ENSO events these long-lived, highly mobile marine animals leave areas of reduced productivity in the southern Gulf, and perhaps the adjacent Pacific, and concentrate in the Canal de Ballenas area where productivity and prey abundance remain high.

This hypothesis can be tested with long-term counts of cetaceans and seabirds spanning ENSO events. The most conclusive evidence would be the movement of photo-identified cetaceans or banded seabirds from other areas into the Canal de Ballenas during ENSO events.

Similar ENSO refugia may occur in other parts of the Pacific. For example, Aid et al. (1985) proposed that the Gulf of Panama may have been important to Peruvian (*Sula variegata*) and blue-footed boobies during the 1983 ENSO event because of the relatively cool sea surface temperatures and abundance of birds they observed. The existence of high productivity refugia could ultimately be important for highly mobile, long-lived marine animals during ENSO events.

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