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Occurrence of the Barnacle (*Xenobalanus globicipitis*) on Coastal and Offshore Common Bottlenose Dolphins (*Tursiops truncatus*) in Santa Monica Bay and Adjacent Areas, California

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Abstract.—Occurrence and distribution of pseudostalked barnacle (*Xenobalanus globicipitis*) on bottlenose dolphin (*Tursiops truncatus*) were assessed during a 1997–2007 study in Santa Monica Bay and nearby areas, California. During 425 surveys, 647 individuals were observed to assess presence and prevalence of barnacles; 92 barnacles on 56 individual (8.66%) were observed. On average, one barnacle was found on individuals, usually on top of dorsal fins (97.83%). No significant difference between barnacles' numbers on coastal versus offshore sightings was recorded. A significant difference on their occurrence on dolphins was recorded between seasons and years. Barnacles affect a small portion of the dolphin population in the study area.

Introduction

The pseudostalked barnacle (*Xenobalanus globicipitis*) is a cosmopolitan species that has been associated with 34 different cetacean species (Spivey 1981; Rajaguru and Shantha 1992; Kane *et al.* 2008 for a review). The presence of this barnacle on common bottlenose dolphin (hereafter bottlenose dolphin), *Tursiops truncatus*, have been studied in the eastern tropical Pacific Ocean (Kane *et al.* 2008), in the western Pacific Ocean (Orams and Schuetze, 1998), in the northwest Atlantic Ocean (Toth-Brown and Hohn 2007), in the southwest Atlantic Ocean (Di Benedetto and Ramos 2000) and in the Indian Ocean (Rajaguru and Shantha 1992; Karuppiyah *et al.*, 2004).

Pseudostalked barnacles attach themselves to dorsal fins (generally trailing edges), pectoral flippers and tail flukes of dolphins (Dhermain *et al.* 2002; Seilacher 2005; Toth-Brown and Hohn 2007) and, in rare cases, they can be found on rostra and in between their teeth (Samaras, 1989). These barnacles are obligate commensals - that “use” dolphins for transportation (Toth-Brown and Hohn 2007) - sometimes creating drag or causing irritation to their host (Dhermain *et al.* 2002; Fertl and Newman 2008). Their presence varies greatly with host species, ranging from one to over 100 barnacles per host (Aznar *et al.* 2005; Toth-Brown and Hohn 2007).

Unhealthy cetaceans are usually more susceptible to attachment by barnacles due to impairment of their immune system and/or presence of skin diseases (Aznar *et al.* 1994; Aznar *et al.* 2005). Barnacles are also commonly found on stranded cetaceans (Dailey and Walker 1978; Dhermain *et al.* 2002; Karuppiyah *et al.* 2004; Aznar *et al.* 2005). Considering that unhealthy cetaceans carry more barnacles than healthy ones, the high presence of these barnacles in wild cetacean populations is likely to be an indication of the overall health of the host population (Aznar *et al.* 2005). Factors such as age and swimming speed of host individuals, and oceanographic conditions (e.g., water temperature, primary productivity), however, have also been suggested to affect the settlement of barnacles on dolphins (Van Waerebeek *et al.* 1993; Aznar *et al.* 1994; Orams and Schuetze 1998; Toth-Brown and Hohn 2007; Kane *et al.* 2008).

Data on presence, prevalence and distribution of this barnacle on cetaceans like bottlenose dolphins are keys in understanding the cause and effect of settlement and the ecological relationships between these species. Only two studies, however, have been published on this subject (Toth-Brown and Hohn 2007; Kane *et al.* 2008). This study, conducted between 1997–2007 as a part of a larger systematic photo-identification and ecological investigation on bottlenose dolphins (Bearzi 2005; Bearzi *et al.* 2009), reports the occurrence of *Xenobalanus* on wild bottlenose dolphins frequenting the coastal and offshore waters of Santa Monica Bay and adjacent waters in California. This investigation provides the first report on presence, prevalence and distribution patterns of *Xenobalanus* on dolphins in the study area over a ten year-period. This investigation also offers data for comparison with other study areas in which these barnacles have been recorded on dolphin.

Methods

Study area

Santa Monica Bay (approximately 460 km²) is bounded by the Palos Verdes Peninsula to the south (33°45'N, 118°24'W), Point Dume to the north (33°59'N, 118°48'W), and the edge of the escarpment to the west. The bay is characterized by three submarine canyons: Dume and Redondo Canyons head in shallow water (50 m), whereas Santa Monica Canyon begins at a depth of about 100 m. The mean depth is about 55 m and the maximum depth 450 m. Surveys were also conducted outside the bay, both along the coast (at 0.5 km from shore) to the south (33°43'N, 118°15'W) and to the north (34°5'N, 119°6'W), and in pelagic waters off Catalina (33°23'N, 118°41'W) and Santa Barbara Islands (33°27'N, 119°3'W), up to 65 km offshore in the Southern California Bight (Fig. 1). The bay has mild temperatures, short rainy winters and long, dry summers. Normal water surface temperatures range from 11 to 22°C.

Data collection and analyses

Data on barnacle occurrence on bottlenose dolphins for this study were collected from marine mammal surveys conducted between February 1997–June 2002 and June 2005–July 2007 (Bearzi *et al.* 2009). Only data collected on photo-identified bottlenose dolphins were analyzed to assess barnacle presence on each individual.

Field surveys.—Coastal (distance from shore up to 1 km) and offshore (distance from shore >1 km) surveys were conducted with an average of 5.2 days on the water per month ($n = 425$) in Santa Monica Bay and adjacent areas (Bearzi *et al.* 2009). No data were collected: Dec. 1999, Oct. 2000, July 2001, Sep. 2001, July 2005, Dec. 2005, May 2006, Feb.–Apr. 2007. Routes, planned for an even coverage of the study area, were surveyed from 7-m (1997–2000) and 10-m power boats (2001–2002, 2006–2007), and a 17-m sailboat (2005), at an average speed of 18 km hr⁻¹. Data on dolphin behaviour were collected with laptop computers and recorded at 5-min intervals throughout each sighting (Bearzi 2005).

Photo-identification.—For each sighting of dolphin schools, we attempted to photograph all individuals. An effort to take high quality close-up images of bodies and dorsal fins of dolphins in each school was made to ensure a significant dataset to analyze skin lesions and physical deformities (Bearzi *et al.* 2009) and barnacle presence (this study) on dolphins. Color photographs were taken with 35-mm Canon EOS1N and A2 cameras equipped with 75–300mm lenses, and a digital Canon 5D equipped with 400mm lens. A total of 810 images were scanned and matched using a computer-assisted

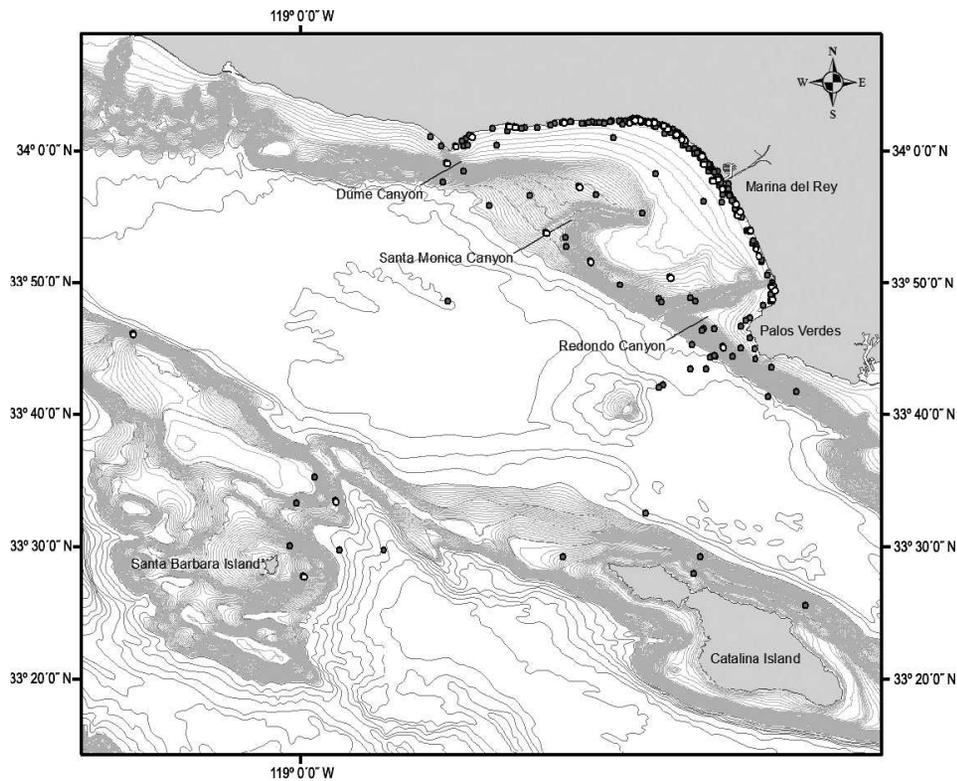


Fig. 1. The study area and the distribution of coastal and offshore bottlenose dolphins in Santa Monica Bay and adjacent waters. Each symbol (white circle: sightings with barnacles; grey circle: sightings without barnacles) represents initial GPS coordinates of photo-identified bottlenose dolphin sightings.

identification system (1997–2002; *Finscan*; Kreho *et al.* 1999). A total of 464 digital images were catalogued and matched utilizing ACDSee software (2005–2007; Mazzoil *et al.* 2004, modified).

Distinct coastal and offshore individuals for the study area were identified based on matching procedures focusing on 195 sightings (88.2% of total dolphin sightings, $n = 221$). A total of 647 distinct individuals (50.8% of total identified and resighted individuals, $n = 1274$) were recognized in the study area between 1997–2007 (Bearzi *et al.* 2009).

Images of dolphin dorsal fins, flukes and bodies taken during photo-identification studies offer a great tool to assess presence of barnacles (Speakman *et al.* 2006). All 647 distinct individuals were analyzed to assess *presence* and *prevalence* of barnacles (only the dorsal fins was considered for analysis in this study), using Acdsee Pro and Photoshop 8.0. Each image was enlarged to record barnacle number and position on fins. Scanned images of the same individuals catalogued in 1997–2002 were also analyzed to assess barnacle presence and prevalence. Calves were excluded from this analysis.

Barnacle presence analysis.—Barnacle *presence* was recorded as the total number of barnacles on the dorsal fin of an individual dolphin. For analysis, a subset of data of photo-identified and resighted individuals ($n = 1225$; 96.2% of entire data set, $n = 1274$) was used due to: 1) incomplete image data, and 2) avoid data replication of barnacle presence (only one image was considered of the same photo-identified dolphin per survey

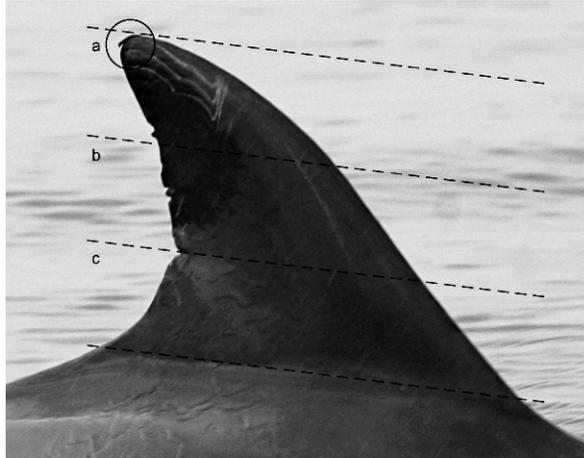


Fig. 2. Division of the dorsal fin into three segments of equal height: a) top, b) center, and c) bottom. A *Xenobalanus* specimen is visible on the top segment of the fin.

day). A total of 189 sightings were included in the analysis (85.5% of total dolphin sightings, $n = 221$).

Barnacle prevalence and position on dorsal fin.—Prevalence of *Xenobalanus* for each sighting was determined by dividing the number of photo-identified dolphins carrying one or more barnacles by the total number of dolphins photo-identified in that sighting (Kane *et al.*, 2008). To determine the *position* of barnacles on dorsal fins, the fin was divided into three segments of equal height (Fig. 2). The lower margin of the dorsal fin was defined as the straight line where the plane of the dorsal fin changes to that of the body.

Data analyses.—Data analyses were performed using Statview 5.0, Microsoft Excel 2007; data on species distribution were plotted with ArcGIS 9.2. Nonparametric statistics tests were performed due to non-normal distributions of data. Statistical significance was set at $P < 0.05$ and two-tailed P values were calculated. Kruskal-Wallis test was used both to determine whether barnacle presence varied significantly over the years and between the seasons. Dunn's comparison test was used as a post-hoc analysis to determine differences between years. To determine whether there was a significant difference between barnacle presence on coastal and offshore bottlenose dolphins, nonparametric Mann-Whitney U test was used. Chi-square (χ^2) test of independence was used to determine if there was a relationship between barnacle presence and survey type (coastal/offshore).

Results

Field effort

Barnacle occurrence was analyzed on a dataset of 204 coastal and 221 offshore surveys conducted in the years 1997–2002 and 2005–2007 (Bearzi *et al.* 2009). A total of 823 h were spent searching for cetaceans in good weather conditions and 400 h observing 509 dolphin schools. Of these schools, 221 were bottlenose dolphins.

Presence, prevalence and position of barnacles on dolphins

A total of 92 barnacles on 56 distinct individual dolphins (8.66% of total number of distinct individuals, $n = 647$) were observed in the study area between 1997–2007

Table 1. Summary of barnacle presence on coastal and offshore bottlenose dolphins in Santa Monica Bay and adjacent areas between 1997–2007.

Survey type	Photo-identified dolphins	Number of photo-identified dolphins with barnacles	Total number of barnacles on photo-identified individuals	Distinct individual dolphins with barnacles
Coastal	924	64	77	44
Offshore	301	13	15	12
Total	1225	77	92	56

(Table 1). Photo-identified individuals carrying *Xenobalanus* were usually found with one barnacle (mean = 1.19, *SD* = 0.51, *SE* = 0.06, range = 1–4, *n* = 77; Fig. 3). There was no significant difference between the average number of barnacles found on coastal and offshore individuals (Mann-Whitney: *P* = 0.972; coastal: mean = 1.20, *SD* = 0.54, *SE* = 0.07, range = 1–4, *n* = 65; offshore: mean = 1.17, *SD* = 0.39, *SE* = 0.11, range = 1–2, *n* = 12).

Barnacles were observed in 54 different sightings (28.57% of total number of sightings, *n* = 189). Mean prevalence of *Xenobalanus* per sighting was 0.05 (*SE* = 0.008, *n* sightings = 189), and did not differ significantly between coastal and offshore sightings (Mann-Whitney: *P* = 0.889; coastal: mean = 0.05, *SD* = 0.12, *SE* = 0.01, range = 0–1, *n* = 161; offshore: mean = 0.04, *SD* = 0.07, *SE* = 0.01, range = 0–0.33, *n* = 28).

In total, 90 barnacles (97.83% of total number of barnacles, *n* = 92) were located on the top segment of the dorsal fin, two (2.17%) on the middle section and no barnacles were observed at the bottom. All of the barnacles were found along the trailing edge of the dorsal fin.

Occurrence and distribution of barnacles

Occurrence of barnacles on photo-identified bottlenose dolphins is shown in Table 2 and it differed significantly between years (KW = 33.40, DF = 8, *P* < 0.0001), with 1999 showing individuals with the greatest number of barnacles (Bonferroni-Dunn: *P* < 0.0001).

Overall, most barnacles were recorded in spring (*n* = 41). Winter had the fewest barnacles (*n* = 3) while a total of 31 and 17 barnacles were recorded respectively in summer and fall. Significant difference in barnacle occurrence was also observed between

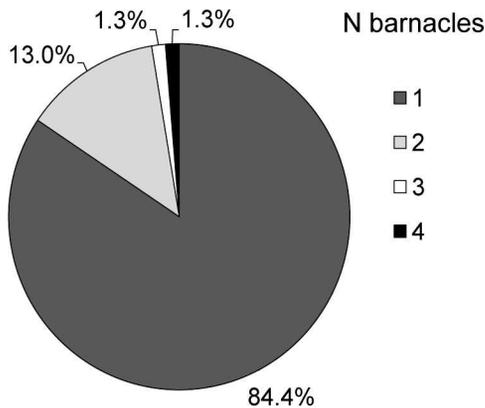


Fig. 3. Percentage of photo-identified dolphins carrying one or more barnacles.

Table 2. Summary of barnacle number and occurrence on photo-identified bottlenose dolphins recorded in Santa Monica Bay and adjacent areas. Data in parentheses represent the total number of distinct individual dolphins and the number of distinct individuals with barnacles, respectively.

Years	Photo-identified dolphins	Photo-identified dolphins with barnacles	Total number of barnacles
1997	61 (47)	1 (1)	1
1998	334 (170)	22 (15)	22
1999	178 (105)	28 (19)	39
2000	109 (77)	5 (3)	5
2001	69 (61)	2 (1)	3
2002	10 (10)	1 (1)	1
2005	90 (89)	5 (5)	6
2006	201 (188)	7 (7)	7
2007	173 (153)	6 (7)	8
Total	1225	77	92

seasons ($KW = 8.42$, $DF = 3$, $P = 0.038$) There was no significant difference between survey type (coastal/offshore) and barnacle occurrence ($\chi^2 = 2.197$, $DF = 1$, $P = 0.138$). The distribution of *Xenobalanus* on coastal and offshore bottlenose dolphins is presented in Figure 1.

Discussion and Conclusions

Presence, prevalence and position of barnacles on dolphins

Presence of *Xenobalanus* on dorsal fins of coastal and offshore bottlenose dolphins in Santa Monica Bay was similar to other regions worldwide (Tangalooma, Australia: Orams and Schuetze 1998; Rio de Janeiro, Brazil: DiBeneditto and Ramos 2000; eastern tropical Pacific Ocean: Kane *et al.* 2008), and low in comparison to the northwest Atlantic Ocean (New Jersey coast: Toth-Brown and Hohn 2007). We recorded a maximum of four barnacles per individual while Toth-Brown and Hohn (2007) reported over 10 barnacles on bottlenose dorsal fins for the Atlantic Ocean.

In Santa Monica Bay, 29% of sightings had individuals carrying barnacles and a review by Kane *et al.* (2008) for the eastern tropical Pacific Ocean shows barnacle presence in less than 10% of sightings. Overall, these data show a lower presence of *Xenobalanus* on bottlenose dolphins in comparison to the Atlantic Ocean (Toth-Brown and Hohn 2007: 64% sightings with barnacles). Prevalence of *Xenobalanus* in the study area was also lower in comparison to the Atlantic Ocean (our study: 5%; New Jersey coast: 55%, Toth-Brown and Hohn 2007) and more similar to Kane *et al.* (2008) for the eastern tropical Pacific Ocean (0.2%). These differences in barnacle presence and prevalence between the Pacific and Atlantic Ocean may be related to habitat as suggested by Kane *et al.* (2008).

In this study, all barnacles were found along the trailing edge of the dorsal fin and, for the most part, attached to the top segment making them generally visible from both sides. In other studies where the presence of barnacles was generally high, however, *Xenobalanus* were recorded on all fin segments (Toth-Brown and Hohn 2007). It is possible that barnacles have a preference for settling on the top of dorsal fins when present in low number (as shown in our study area) but, when they are present in high numbers, they may also spread to other segments of the fin, as observed by Toth-Brown and Hohn (2007). Further, barnacles not settling along trailing edges are likely to be swept off (Rajaguru and Shantha 1992).

Occurrence and distribution of barnacles

No difference in barnacle occurrence and distribution was observed between coastal and offshore bottlenose dolphins in the study area, contrary to reports for the Northwest Atlantic Ocean (Rittmaster *et al.* 1999; Toth-Brown and Hohn 2007). These studies found more dolphins with barnacles in offshore waters than in estuarine or coastal waters (Beaufort, North Carolina: Rittmaster *et al.* 1999; New Jersey coastline: Toth-Brown and Hohn 2007). In these authors' opinion, diverse coastal and offshore habitats and habitat use were the reason for these differences. In Santa Monica Bay, a slight spatial overlap between coastal and offshore individuals (Bearzi *et al.* 2009) may be responsible for the lack of a significant difference in barnacle occurrence on coastal versus offshore dolphins.

Occurrence of barnacles on photo-identified dolphins for the study area varied between years, with the highest presence in 1998–1999 and the lowest in 1997 and 2002. Our study recorded most barnacles on dolphins during La Niña event in 1999. From April 1997 through March 1998, considered a warm El Niño period (Grover *et al.* 2002), no barnacles were recorded. From April 1998, barnacle occurrence increased again, while El Niño weakened, shifting into La Niña in July 1998 (Enfield 2001), showing a potential correlation between low barnacle occurrence and El Niño events. Kane *et al.* (2008) observed *Xenobalanus* in areas of increased primary productivity suggesting that it may indirectly limit barnacle presence in oligotrophic areas. Further studies are necessary to better understand the relationship between barnacle occurrence on dolphins and shifts in oceanographic conditions.

Xenobalanus occurrence also varied between seasons with most barnacles found in spring and fewest in winter. In Australian waters, True (1890) observed similar trends while Orams and Schuetze (1998) reported seeing more barnacles in cold temperatures than in warm. In the northern Atlantic Ocean, Toth-Brown and Hohn (2007) did not find changes in barnacle numbers between May and September. It is possible that spawning occurs at different times of the year (Van Waerebeek *et al.* 1993; Toth-Brown and Hohn 2007), or that barnacle occurrence is not primarily influenced by water temperature.

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