Report

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Skin Lesions and Physical Deformities of Coastal and Offshore Common Bottlenose Dolphins (*Tursiops truncatus*) in Santa Monica Bay and Adjacent Areas, California

Skin lesions and physical deformities on coastal and offshore bottlenose dolphins (*Tursiops truncatus*) were assessed during a photo-identification study conducted between 1997 and 2007 in Santa Monica Bay and adjacent areas in California. During 425 boat surveys, 647 individuals were identified based on marks on their dorsal fins. Of 637 individuals examined for skin lesions and deformities, 79.0% exhibited at least one type of lesion. Offshore animals showed more lesions than coastal animals (offshore: 87.8%, n = 209; coastal: 73.4%, n = 270). Only one individual showed a physical deformity. Results show that skin lesions affect a large portion of the coastal and offshore dolphin populations in the study area. When considering that lesions and physical deformities can be a sign of disease and may be related to anthropogenic factors, their high presence on dolphins must be a cause of concern.

INTRODUCTION

In the eastern North Pacific Ocean, there are 2 forms of common bottlenose dolphins (hereafter bottlenose dolphins, *Tursiops truncatus*): a coastal and offshore form (1–4). Coastal bottlenose dolphins are currently estimated to number about 320 individuals along the California shoreline (5), whereas the offshore population is approximately 3000 individuals within the United States Exclusive Economic Zone of the West Coast (3).

In the years 1997–2007, during cetacean surveys in the waters of Santa Monica Bay and adjacent areas in California, it was determined that coastal and offshore populations of bottlenose dolphins were present in all seasons, making the area suitable for a long-term study of the social ecology of this species (6). Although resighting rates of coastal and offshore individuals in the study area were generally low, coastal individuals were present over one or more seasons and/or year to year, and were using the area for foraging and feeding (6). The study area is also of conservation interest, because it is subject to urban runoff from the adjacent metropolis of Los Angeles.

From 1997 to 2007, a variety of dermal lesions and physical deformities were observed on live, free-ranging bottlenose dolphins in Santa Monica Bay and other areas in California (D. Maldini pers. comm.), which raises concerns about the health status of this species and potential negative effects on the entire coastal and offshore populations.

Studies of skin lesions and physical deformities in wild bottlenose dolphins are generally scarce and localized (7–14), and the majority of investigations were focused on dead or captive animals (15–21). The cause of these lesions, which may signify epidermal diseases (8), is still unknown, but the few studies on wild bottlenose dolphins suggest that lesions and deformities may be anthropogenically induced (9–11, 15).

Because this is the first study to investigate dermal lesions and physical deformities on bottlenose dolphins on the West Coast of the United States, this research provides an important step toward assessing their presence on already identified animals in the area. Further, it offers data for comparison with other study areas in which these types of lesions have been investigated and new ground for discussion on the health of these animals and the impact of anthropogenic activities.

MATERIALS AND METHODS

Study Area

The Santa Monica Bay study area (approximately 460 km^2) is a shallow shelf 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 contains 3 submarine canyons: Dume and Redondo canyons head in shallow water, whereas Santa Monica Canyon begins at a depth of about 100 m. The mean depth is about 55 m, and the maximum depth is 450 m. A shallow shelf between Santa Monica Canyon and Redondo Canyon extends as a plateau from the 50-m contour. Surveys were also conducted outside Santa Monica 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. The entire area in which surveys were conducted is illustrated in Figure 1. Mild temperatures, short rainy winters, and long, dry summers are usual weather conditions for the area. Normal water surface temperatures range from 11 to 22°C.

Data Collection and Analysis

Field Surveys. Inshore (distance from shore up to 1 km) and offshore (distance from shore >1 km) surveys were conducted from February 1997 to June 2002 and from June 2005 to July 2007, with an average of 5.2 days on the water per month (n = 425) in Santa Monica Bay and adjacent areas. No data were collected: December 1999, October 2000, July 2001, September 2001, July 2005, December 2005, May 2006, February–April 2007. Routes were covered 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 were collected with laptop computers and occasionally with tape recorders. When dolphins were spotted, data on the number of animals, behavior, and aggregations with other species were recorded at 5-min intervals throughout the sighting (6). The number of dolphins and size classes were verified later through photo-identification analysis.

Photo identification. Photo identification followed Würsig and Jefferson (22) and Bearzi, Notarbartolo di Sciara, and Politi (23). For each sighting of dolphin schools, an attempt was

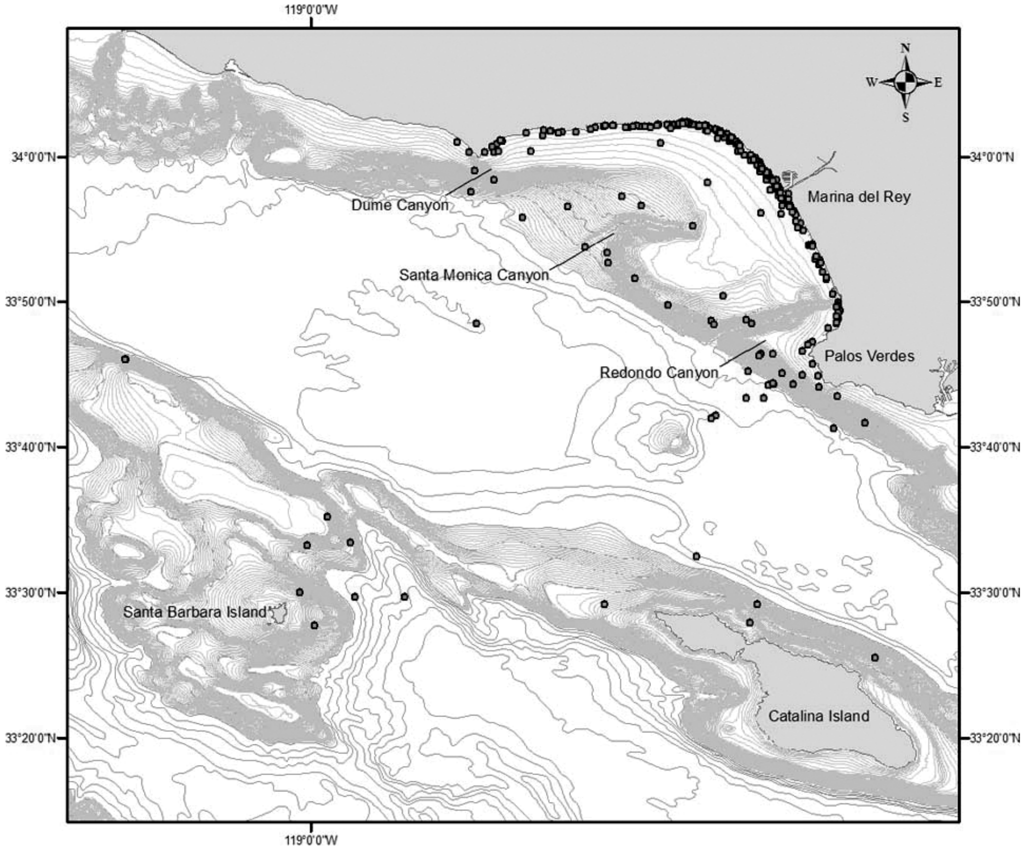

Figure 1. The study area and the distribution of coastal and offshore bottlenose dolphins selected for skin disease and physical deformity analyses. Each symbol represents initial global positioning satellite coordinates of photo-identified bottlenose dolphin sightings.

made to photograph all individuals present in the group. Color photographs were taken with 35-mm Canon EOS1N and A2 cameras equipped with 75–300-mm lenses, and a digital Canon 5D equipped with 400-mm lens. For the years 1997–2002, a total of 810 images were scanned and matched by using a computer-assisted identification system (*Finscan*) (24). For the years 2005–2007, a total of 464 digital images were cataloged and matched with ACDSee software by using techniques described in Kreho et al. (25) and modified. During matching, marks, and scars likely to have been inflicted by sharks were also documented. Adult individuals consistently accompanied by a calf over a 2-month period were assumed to be females.

To identify distinct coastal and offshore individual dolphins for the study area, matching procedures focused on 195 sightings (88.2% of total bottlenose 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.

Skin Disease and Physical Deformities Analyses. Images of dolphin dorsal fins and bodies taken during photo-identification studies offer an excellent tool to assess the presence and prevalence of epidermal diseases because of their visibility (7). Of the 647 distinct individuals, the best digital images of 637 individuals (98.5%) were analyzed for prevalence and extent of skin lesions and the presence of physical deformities by using the software Acdsee Pro (each image was enlarged to observe dermal lesions in detail). In addition, slides of the same individuals previously cataloged in the years 1997–2002 were also analyzed to ensure documentation of all visible lesions on an individual. All 637 images taken into analysis were suitable in quality for assessing skin lesions and physical deformities. Calves were excluded from this analysis.

Skin Lesion Classification. Skin lesions were grouped into 6 categories and others (8): *i)* black, *ii)* pale (white, cream, white fin-fringe, abraded fin tips), *iii)* cloudy, *iv)* lunar, *v)* dark and white fringed spots, *vi)* orange (hue, patches), and *vii)* others. Lesions that result from physical injury and dorsal-fin notches were excluded from the study.

Prevalence was defined as the proportion of photo-identified individuals that exhibited skin lesions (26). Two types of skin-lesion prevalences were calculated based on their presence on dorsal fin or body of the animal:

i) dorsal fin: the prevalence of skin lesions was calculated as a percentage of animals that exhibit any skin lesion on the dorsal fin. The lower margin of the dorsal fin was defined as "the horizontal line where the plane of the dorsal fin changed to that of the body" (8);

ii) body and dorsal fin: a minimum, rather than actual, prevalence was calculated to include the portion of the individual not captured in the image. The minimum prevalence was defined as the minimum number of individuals that exhibit at least one skin lesion on both dorsal fin and body. All images that show >10% of the tail stock and/or rib section, as defined by Weaver (27), were included.

Extent coverage by skin lesion, defined as the "percentage of each individual's epidermis covered by lesions" (9), was visually determined: low (<20% of visible epidermis), medium (20–50% of visible epidermis), and high (>50% of visible epidermis).

Physical Deformities Classification. Physical deformities were classified as conformational deformities (humpbacked, bent dorsal fins, lumps) (9), and as spinal malformations (kyphosis, kyphoscoliosis, and lordosis) (10). The presence of physical deformities was calculated as the percentage of individuals that exhibited either feature.

Data Analyses. Data analyses were performed by using Statview 5.0, Minitab 13.30 and Microsoft Excel 2003; data on species distribution were plotted with ArcGis 9.2. Because no genetic analysis was performed, data on coastal and offshore bottlenose dolphins for statistical analysis was divided exclusively based on their distance from shore: all bottlenose dolphins observed during coastal surveys conducted at 0.5 km from shore

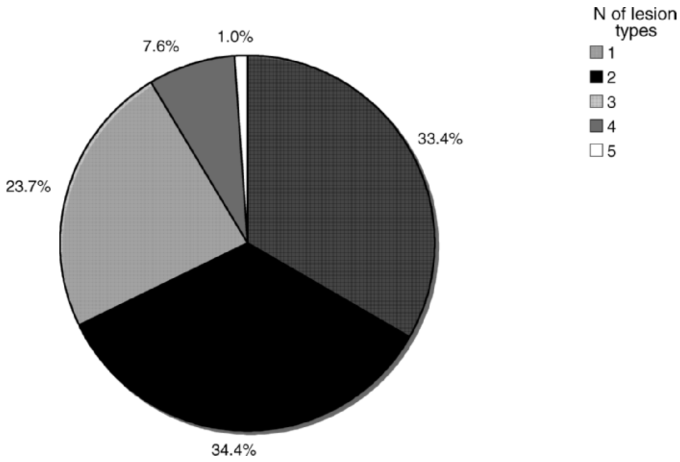

Figure 2. Percentage of individuals exhibiting one or more types of skin lesions.

(which includes animals occasionally observed up to 1 km from shore) were considered coastal; all bottlenose dolphins observed during surveys conducted at >1 km from shore were considered offshore, as also suggested by Defran and Weller (2).

RESULTS

Field Effort

Data were collected during 204 inshore and 221 offshore surveys in the study area for the years 1997–2007. A total of 823 hr were spent searching for cetaceans in good weather conditions (Beaufort scale ≤ 2). A total of 221 bottlenose dolphin schools were encountered during sightings lasting, on average, about 1 hr (mean = 59.0 min, SD = 39.63, SE = 2.70, range 3–262 min, calculated on a subset of data n = 215). One hundred eighty coastal bottlenose dolphin schools were encountered during sightings lasting on average 59 min (SD = 38.94, SE = 2.94, range 3–262 min, n = 175), whereas 41 offshore bottlenose dolphin schools were observed during sightings that lasted on average 57 min (SD = 43.02, SE = 6.81, range 4–166 min, n = 40).

Skin Lesions

Of the 637 photo-identified dolphins examined in this study, 79.0% (n = 503) exhibited at least one type of skin lesion on the portion of the dolphin visible in the image. The maximum number of lesion types seen on any individual was five (Fig. 2). Of the 503 dolphins with lesions, 335 (66.6%) exhibited more than one lesion type. Only 2 dolphins exhibited lesion types not falling into our categories.

The percentages of skin lesions are illustrated in Figure 2, the prevalence of different types of lesions in Table 1, and the extent and their locations on body and dorsal fin in Table 2. The extent coverage on both body and dorsal fin was usually low (<20%). The location on the body (dorsal fin/body/both dorsal fin and body) was significantly linked to lesion type for black, white, and cloudy lesions ($\chi^2 = 54.048$, DF = 4, $P < 0.5$). Other lesion types were omitted from this analysis because of low presence in our sampling. Dark fringed spot, lunar lesions, and cream lesions were observed mostly on the body (91.7%, n = 11; 83.7%, n = 36; 80.0%, n = 4, respectively). Black lesions were present both on body and dorsal fins (30.9%, n = 101), whereas orange patches were most common on dorsal fins (78.9%, n = 15). Examples of some types of skin lesions observed in this study are showed in Figure 3a,b. The percentage of offshore individuals that displayed skin lesions was significantly higher than the percentage of coastal individuals with skin lesions (offshore: 87.8%, n = 209; coastal: 73.4%, n = 270; $\chi^2 = 18.21$, DF = 1, $p < 0.5$).

Physical Deformities

Only one dolphin, 0.2% of those studied (Table 1), exhibited a physical deformity in the form of a hump on the rib section. This dolphin also exhibited both black and white lesions. No spinal malformations were observed on any of the photo-identified animals.

DISCUSSION

Bottlenose dolphins were regularly observed in Santa Monica Bay and adjacent areas (6), in agreement with data for the Southern California Bight (3, 28). Coastal and offshore individuals in the study area show a high prevalence and extent of skin lesions in agreement with other areas worldwide (7, 11–14). For instance, lesions and deformities have been found on 95% of dorsal fins and backs of sampled individuals in the Moray Firth, Scotland (8); comparative data for 10 coastal populations of bottlenose dolphins worldwide showed that epidermal lesions were common on all populations and affected >60% of individuals (14). Comparisons with offshore popula-

Table 1. Prevalence of skin lesions and physical deformities in coastal and offshore bottlenose dolphins.

	Inshore	Offshore	Both	Total
Skin lesions				
Black	180 (28.3%)	133 (20.9%)	14 (2.2%)	327 (51.3%)
Pale				
White	140 (22.0%)	129 (20.3%)	18 (2.8%)	287 (45.1%)
Cream	1 (0.2%)	3 (0.5%)	1 (0.2%)	5 (0.8%)
White fin fringe	94 (14.8%)	114 (17.9%)	6 (0.9%)	214 (33.6%)
Abraded	5 (0.8%)	2 (0.3%)	0	7 (1.1%)
Cloudy	52 (8.2%)	50 (7.8%)	8 (1.3%)	110 (17.3%)
Lunar	32 (5.0%)	8 (1.3%)	3 (0.5%)	43 (6.8%)
White fringe spots	12 (1.9%)	4 (0.6%)	2 (0.3%)	18 (2.8%)
Dark fringe spots	7 (1.1%)	4 (0.6%)	1 (0.2%)	12 (1.9%)
Orange				
Hue	3 (0.5%)	1 (0.2%)	0	4 (0.6%)
Patches	8 (1.3%)	10 (1.6%)	1 (0.2%)	19 (3.0%
Other	1 (0.2%)	1 (0.2%)	0	2 (0.3%)
Conformational deformities				
Hump	1 (0.2%)	0	0	1 (0.2%)
Bent dorsal fin	0	0	0	0
Lumps	0	0	0	0
Total	368	238	31	637

Table 2. Extent of skin lesion coverage and locations of lesions on bodies and dorsal fins.

Lesion types	Extent of coverage*			
	Low	Medium	High	Total
Black	74.6% (n = 244)	18.7% (n = 61)	6.7% (n = 22)	327
White	81.9% (n = 235)	15.0% (n = 43)	3.1% (n = 9)	287
Cream	80.0% (n = 4)	20.0% (n = 1)	0% (n = 0)	5
White fin fringe	70.1% (n = 150)	28.5% (n = 61)	1.4% (n = 3)	214
Cloudy	60.9% (n = 67)	30.9% (n = 34)	8.2% (n = 9)	110
Lunar	81.4% (n = 35)	16.3% (n = 7)	2.3% (n = 1)	43
White fringe spots	94.4% (n = 17)	5.6% (n = 1)	0% (n = 0)	18
Dark fringe spots	100.0% (n = 12)	0% (n = 0)	0% (n = 0)	12
Orange hue	75.0% (n = 3)	25.0% (n = 1)	0% (n = 0)	4
Orange patches	84.2% (n = 16)	10.5% (n = 2)	5.3% (n = 1)	19
Not identified	0% (n = 0)	50,0% (n = 1)	50.0% (n = 1)	2
	Locations			
	Body	Dorsal fin	Body, dorsal fin	Fin edge
Black	36.1% (n = 118)	33.0% (n = 108)	30.9% (n = 101)	0% (n = 0)
White	59.2% (n = 170)	15.3% (n = 44)	25.1% (n = 72)	0% (n = 0)
Cream	80.0% (n = 4)	0% (n = 0)	20.0% (n = 1)	0% (n = 0)
White fin fringe	0% (n = 0)	76.6% (n = 164)	0% (n = 0)	23.4% (n = 50)
Cloudy	63.6% (n = 70)	10.0% (n = 11)	26.4% (n = 29)	0% (n = 0)
Lunar	83.7% (n = 36)	7.0% (n = 3)	9.3% (n = 4)	0% (n = 0)
White fringe spots	44.4% (n = 8)	44.4% (n = 8)	11.1% (n = 2)	0% (n = 0)
Dark fringe spots	91.7% (n = 11)	0% (n = 0)	8.3% (n = 1)	0% (n = 0)
Orange hue	75.0% (n = 3)	0% (n = 0)	25.0% (n = 1)	0% (n = 0)
Orange patches	21.1% (n = 4)	78.9% (n = 15)	0% (n = 0)	0% (n = 0)
Not identified	0% (n = 0)	100.0% (n = 2)	0% (n = 0)	0% (n = 0)

* Low = <20% of visible epidermis, medium = 20–50% of visible epidermis, high = >50% of visible epidermis.

tions, which showed an even higher presence of skin lesions than the coastal population in our study area, were difficult because of the lack of comparative studies in other locations. In the study area, as well as previously published data, the presence of multiple lesions on an individual was not uncommon (this study: 25.4% had 3 or more types of lesions; Wilson, Thompson, and Hammond [8]: 61% had 3 or more types of lesions).

In Santa Monica Bay and adjacent areas, pale lesions were the most commonly observed (80.5% for both coastal and offshore dolphins), followed by black lesions (51.3%). This result is consistent with data found for Scotland waters (8), where there was also a higher prevalence of pale lesions (88%) in comparison with black lesions (72%). In the study area, the least observed lesions were orange hue (0.6%), also in agreement with data for the Scotland waters (8), where they were found on 1% of photographed individuals.

Dark-fringed spots observed on some individuals in our study (1.9%, n = 12) are of concern for these animals' health status because they are believed to result from infection of dolphin pox virus (7, 16, 29). To avoid terminology confusion, other investigators defined dark-fringed spots as ring lesions (7) and as tattoo lesions (16, 29). The low presence of physical deformities on the examined individuals is likely an underestimate of their actual presence on the animals' bodies, when considering that only the rib sections were clearly observed on the images and analyzed for deformities. Opportunistic videos on photo-identified schools for the years 1997–2007 confirm that physical deformities were present on several individuals. Further photo-identification studies that include photographs of the entire upper section of these animals' bodies are necessary for a more accurate figure.

Implications for Conservation and Management

Fungal, viral, and bacterial infections; vitamin deficiencies; diatom growth; and reaction to parasites have been identified among the main causes of skin lesions and physical deformities in cetacean species (8). Studies on wild bottlenose dolphins, however, suggest that these lesions and deformities may also be anthropogenically induced (8, 9, 13, 16). The severity of some viral outbreaks among different species of marine mammals has been linked to anthropogenic pollution (30, 31), and anthropogenic activities are likely to influence the course of diseases and/or directly cause lesions (32, 33).

Figure 3. Some types of skin lesions analyzed during this study. Logan (observed 14 August 2006) has black lesions on dorsal fin and white-fringe spots on body (a). Cassell (observed 23 January 2007) shows black and white lesions on body and dorsal fin, and white fringe spots on body (b). (Photos: M. Bearzi)

Studies show that infectious diseases are likely to have harmful impacts on population abundance, either by increasing dolphins' natural mortality (e.g., morbilloviruses and, perhaps, poxviruses) or by negatively affecting their reproduction (e.g., *Brucella*) (17, 13, 34). Other noninfectious diseases and lesions may also have a negative effect on reproduction, impair feeding abilities and, potentially, cause the death of an individual (32, 33). There are reports in which captive cetaceans died after developing several body skin diseases (15). Stressful conditions may also have affected the immune responses of 2 captive bottlenose dolphins that showed recurrent diseases (16, 35). Captive animals are usually more susceptible to these type of lesions, and the lesions appear to regress when the dolphins are transferred to better water conditions (16).

Mortalities among neonates and calves of wild dusky dolphins and Burmeister's porpoises from Peru, without protective immunity, have been linked to the presence of skin lesions (34). Polyhalogenated aromatic hydrocarbons (PHAH) are immunotoxic environmental contaminants that can contribute to the severity of diseases in marine mammals (31, 36). Specifically, organocholorines have been associated with a high prevalence of skin lesions, both in coastal and offshore adult species of dolphins (13). In the wild, large, rounded lesions on dolphins from South America were suggested to be related to poor water quality (37). Dolphin pox, observed on free-ranging bottlenose dolphins, appeared to be linked to environmental conditions and to the general health of the animal (16).

In the study area, any of the above-mentioned factors may be responsible for the high prevalence and extent of skin lesions on offshore and coastal bottlenose dolphins. Bottlenose dolphins are apex predators and vulnerable to indirect threats, such as chemical pollution, acoustic pollution, and marine debris (38). Coastal bottlenose dolphins, for instance, are particularly susceptible to harmful threats, because they inhabit near-shore regions where pollution is usually abundant (39, 40). The poor quality of local waters raises particular concern regarding the effect of human impact on the health status of these animals, especially coastal populations. The Southern California Bight has been subjected to large amounts of pollution that enter the coastal and offshore environment from many sources for decades (41). Further, Santa Monica Bay, the area in which many anthropogenic sources commingle, has shown significantly higher concentrations of contaminants relative to other regions of the Bight (42). A contaminated sediment that contains dichloro-diphenyl-trichloroethane (DDT) and polychlorinated biphenyls (PCBs) covers a 17 square mile area of ocean floor off Palos Verdes Peninsula, DDT, now banned, was manufactured by the Montrose Chemical Corp, Torrance, California, from 1947 to 1982. This entire area contains submarine canyons known as primary foraging and feeding ground for offshore, as well as coastal bottlenose dolphins (6), which may explain the high prevalence of skin lesions found on these animals.

Future Studies

Regular monitoring and photo identification of coastal and offshore populations of bottlenose dolphins in Santa Monica Bay and adjacent areas, and comparison with other areas along the California coast, are necessary to assess changes in skin lesion presence and extent over time at both the population and individual levels. Stranded and by-caught bottlenose dolphins along the California coast may also provide additional data on skin-lesion presence and changes over time if individuals were photo identified and images compared with already examined individuals.

Laboratory studies should examine the concentration of DDT, PCB, PHAHs and other organocholorines in bottlenose dolphin tissues. When considering that different types of lesions may be stages of the same disease (e.g., dark lesion may be a precursor of pale lesions) (9) or a sign of completely different disorders (14), histologic examination will be helpful in better understanding skin diseases on these animals.

References and Notes

1. Walker, W.A. 1981. *Geographical Variation in Morphology and Biology of Bottlenose Dolphins (*Tursiops*) in the Eastern North Pacific*. National Oceanic and Atmospheric Administration National Marine Fisheries Service (NOAA/NMFS) Southwest Fisheries Science Center Administrative Report N. LJ-81-03C, 52 pp.
2. Defran, R.H. and Weller, D.W. 1999. Occurrence, distribution, site fidelity, and school size of bottlenose dolphins (*Tursiops truncatus*) off San Diego, California. *Mar. Mamm. Sci. 15*, 366–380.
3. Carretta, J.V., Forney, K.A., Muto, M.M., Barlow, J., Baker, J., Hanson, B. and Lowry, M.S. 2006. *U.S. Pacific Marine Mammal Stock Assessments: 2005*. NOAA Technical Memorandum NMFS, NOAA-TM-NMFS-SWFSC-388, 318 pp.
4. Lowther, J.L. 2006. *Genetic Variation of Coastal and Offshore Bottlenose Dolphins,* Tursiops truncatus*, in the Eastern North Pacific Ocean*. Masters Thesis, University of San Diego, San Diego, CA. pp. 126.
5. Dudzik, K.J., Baker, K.M. and Weller, D.W. 2005. *Mark-recapture Abundance Estimate of California Coastal Stock Bottlenose Dolphins: February 2004 to April 2005*. Report Prepared Under Contract #AB133F-03-SE-7140 to the Southwest Fisheries Science Center, 13 pp.
6. Bearzi, M. 2005. Aspects of the ecology and behaviour of bottlenose dolphins (*Tursiops truncatus*) in Santa Monica Bay, California. *J. Cetacean Res. Manag. 7*, 75–83.
7. Thompson, P.M. and Hammond, P.S. 1992. The use of photography to monitor dermal disease in wild bottlenose dolphins (*Tursiops truncatus*). *Ambio 21*, 135–137.
8. Wilson, B., Thompson, P.M. and Hammond, P.S. 1997. Skin lesions and physical deformities in bottlenose dolphins in the Moray Firth: population prevalence and age-sex differences. *Ambio 26*, 243–245.
9. Wilson, B., Grellier, K., Hammond, P.S., Brown, G. and Thompson, P.M. 2000. Changing occurrence of epidermal lesions in wild bottlenose dolphins. *Mar. Ecol. Prog. Ser. 205*, 283–290.
10. Haskins, G.N. and Robinson, K.P. 2007. Visually detectable attributes of spinal malformations in free-ranging bottlenose dolphin calves in northeast Scotland. *European Research on Cetaceans 21*. (http://www.crru.org.uk/research/papers/haskins_&_robinson_ECS2007.pdf)
11. Harzen, S. and Brunnick, B.J. 1997. Skin disorders in bottlenose dolphins (*Tursiops truncatus*), resident in the Sado estuary, Portugal. *Aquat. Mamm. 23*, 59–68.
12. Van Bressem, M.F., Gaspar, R. and Javier Aznar, F. 2003. Epidemiology of tattoo skin disease in bottlenose dolphins (*Tursiops truncatus*) from the Sado estuary, Portugal. *Dis. Aquat. Org. 56*, 171–179.
13. Van Bressem, M.F., Van Waeerebeek, K., Raga, J.A., Gaspar, R., Di Beneditto, A.P., Ramos, R. and Siebert, U. 2003. *Tattoo Disease of Odontocetes as a Potential Indicator of a Degrading or Stressful Environment: A Preliminary Report*. Document SC/55/E1, International Whaling Commission, Berlin, 6 pp.
14. Wilson, B., Arnold, H., Bearzi, G., Fortuna, C.M., Gaspar, R., Ingram, S., Liret, C., Pribanic, S., et al. 1999. Epidermal disease in bottlenose dolphins: impacts of natural and anthropogenic factors. *Proc. R. Soc. Lond. B 266*, 1077–1083.
15. Sweeney, J.C. and Ridgway, S.H. 1975. Common disease of small cetaceans. *J. Am. Vet. Med. Assoc. 167*, 533–540.
16. Geraci, J.R., Hicks, B.D. and St. Aubin, D.J. 1979. Dolphin pox: a skin disease of cetaceans. *Can. J. Comp. Med. 43*, 399–404.
17. Medway, W. 1980. Some bacterial and mycotic diseases of marine mammals. *J. Am. Vet. Med. Assoc. 177*, 831–834.
18. Cowan, D.F., Walker, W.A. and Brownell, R.L. Jr. 1986. Pathology of small cetaceans stranded along southern California beaches. In: *Research on Dophins*. Bryden, M.M. and Harrison, R. (eds). Clarendon Press, Oxford, pp. 323–367.
19. Van Bressem, M.F. and Van Waerebeek, K. 1996. Epidemiology of pox virus in small cetaceans from the eastern South Pacific. *Mar. Mamm. Sci. 12*, 371–382.
20. Kirkwood, J.K., Bennet, P.M., Jepson, P.D., Kuiken, T., Simpson, V.R. and Baker, J.R. 1997. Entanglement in fishing gear and other causes of death in cetaceans stranded on the coast of England and Wales. *Vet. Rec. 141*, 94–98.
21. Smolarek Benson, K.A., Manire, C.A., Ewing, R.Y., Saliki, J.T., Townsend, F.I., Ehlers, B. and Romero, C.H. 2006. Identification of novel alpha-and gammaherpesviruses from cutaneous and mucosal lesions of dolphins and whales. *J. Virol. Methods 136*, 261–266.
22. Würsig, B. and Jefferson, T.A. 1990. Methods of photo-identification for small cetaceans. *Rep. int. Whal. Commn 12*, (special issue), 43–52.
23. Bearzi, G., Notarbartolo di Sciara, G. and Politi, E. 1997. Social ecology of bottlenose dolphins in the Kvarneric (Northern Adriatic Sea). *Mar. Mamm. Sci. 13*, 650–668.
24. Kreho, A., Kehtarnavaz, N., Araabi, B., Hillman, G., Würsig, B. and Weller, D. 1999. Assisting manual dolphin identification by computer extraction of dorsal ratio. *Ann. Biomed. Eng. 27*, 830–838.
25. Mazzoil, M., McCulloch, S.D., Defran, R.H. and Murdoch, M.E. 2004. Use of digital photography and analysis of dorsal fins for photo-identification of bottlenose dolphins. *Aquat. Mamm. 30*, 209–219.
26. Rothman, K.J. and Greenland, S. 1998. *Modern Epidemiology*. Lippincott-Raven Publishers, Philadelphia. pp. 737.
27. Weaver, A.C. 1987. *An Ethogram of Naturally Occurring Behavior of Bottlenose Dolphins,* Tursiops truncatus*, in Southern California Waters*. Masters Thesis, San Diego State University, San Diego, CA, pp. 180.
28. Bonnell, M.L. and Dailey, M.D. 1993. Marine mammals. pp. 604–681. In: *Ecology of the Southern California Bight*. Dailey, M.D., Reish, D.J. and Anderson, J.W. (eds). University of California Press, Berkeley, CA, p. 926.
29. Flom, J.O. and Houk, E.J. 1979. Morphological evidence of pox virus in "tattoo" lesions from captive bottlenosed dolphins. *J. Wildl. Dis. 15*, 593–596.
30. Hall, A.J., Law, R.J., Wells, D.E., Harwood, J., Ross, H.M., Kennedy, S., Allchin, C.R., Campbell, L.A., et al. 1992. Organocholorine levels in common seals (*Phoca vitulina*)

which were victims and survivors of the 1988 phocine distemper epizootic. *Sci. Total Environ. 115*, 145–162.
31. Aguilar, A. and Borrell, A. 1994. Abnormally high polychlorinated biphenyl levels in striped dolphins (*Stenella coeruleoalba*) affected by the 1990–1992 Mediterranean epizootic. *Sci. Total Environ. 154*, 237–247.
32. Flach, L. 2006. Photo-identification study reveals human threats towards estuarine dolphins in Southeast Brazil. In: *Workshop on Research and Conservation of the Genus Sotalia, Armacao dos Buzios*. Siciliano, S., Borobia, M., Barros, N.B., Marques, N., Trujillo, F. and Flores, P.A.C. (eds). Rio de Janeiro, Brazil, pp. 19–23.
33. Van Bressem, M.F., Van Waeerebeek, K., Montes, D., Kennedy, S., Reyes, J.C., Garcia-Godos, A.I., Onton-Silva, K. and Alfaro-Shigueto, J. 2006. Diseases, lesions and malformations in the long-beaked common dolphin (*Delphinus capensis*) from the Southeast pacific. *DAO 68*, 149–165.
34. Van Bressem, M.F., Van Waerebeek, K. and Raga, J.A. 1999. A review of virus infections of cetaceans and the potential impact of morbilloviruses, poxviruses and papillomaviruses on host population dynamics. *Dis. Aquat. Org. 38*, 53–65.
35. Fair, P.A. and Becker, P.R. 2000. Review of stress in marine mammals. *J. Aquat. Ecosyst. Stress Recov. 7*, 335–354.
36. Ross, P.S., De Swart, R.L., Van Loveren, H., Osterhaus, A.D.M.E. and Vos, J.G. 1996. The immunotoxicity of environmental contaminants to marine wildlife: a review. *Annu. Rev. Fish. Dis. 6*, 151–165.
37. Van Bressem, M.F., Van Waerebeek, K., Reyes, J.C., Feilix, F., Echegaray, M., Siciliano, S., Di Beneditto, A.P., Flach, L., et al. 2007. *A Preliminary Overview of Skin and Skeletal Diseases and Traumata in Small Cetaceans from South American Waters*. Paper SC/59/DW4 presented to the IWC Scientific Committee, May 2007, 26 pp. (http://www.iwcoffice.org/_documents/sci_com/SC59docs/SC-59-DW4.pdf)
38. Simmonds, M.P. and Hutchinson, J.D. 1996. *The Conservation of Whales and Dolphins: Science and Practice*. J. Wiley & Sons Ltd., London, UK, pp. 476.
39. Curry, B.E. 1997. *Phylogenetic Relationships among Bottlenose Dolphins (genus* Tursiops*) in a Worldwide Context*. PhD Thesis, Texas A&M University, College Station, TX, 138 pp.
40. Wang, J.Y., Chou, L.-S. and White, B.N. 1999. Mitochondrial DNA analysis of sympatric morphotypes of bottlenose dolphins (genus: *Tursiops*) in Chinese waters. *Mol. Ecol. 8*, 1603–1612.
41. Kennish, M.J. 1998. *Pollution Impacts on Marine Biotic Communities*. CRC Press LLC, Boca Raton, FL, 310 pp.
42. Schiff, K.C. 2000. Sediment Chemistry on the mainland shelf of the Southern California Bight. *Mar. Poll. Bull. 40*, 268–276.
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