This article appeared in a journal published by Elsevier. The attached copy is furnished to the author for internal non-commercial research and education use, including for instruction at the authors institution and sharing with colleagues.

Other uses, including reproduction and distribution, or selling or licensing copies, or posting to personal, institutional or third party websites are prohibited.

In most cases authors are permitted to post their version of the article (e.g. in Word or Tex form) to their personal website or institutional repository. Authors requiring further information regarding Elsevier’s archiving and manuscript policies are encouraged to visit:

http://www.elsevier.com/copyright
Skin diseases in Guiana dolphins (Sotalia guianensis) from the Paranaguá estuary, Brazil: A possible indicator of a compromised marine environment

M.-F. Van Bressem a,*, Marcos César de Oliveira Santos b, Júlia Emi de Faria Oshima b

a Cetacean Conservation Medicine Group (CMED), Peruvian Centre for Cetacean Research (CEPEC), Museo de Delfines, Pucusana, Lima 20, Peru
b Projeto Atlantis, Laboratório de Biologia da Conservação de Cetáceos, Departamento de Zoologia, Instituto de Biociências, Universidade Estadual Paulista "Júlio de Mesquita Filho" (UNESP), Campus Rio Claro. Av 24-A, 1515, Bela Vista, Rio Claro, SP 13506-900, Brazil

1. Introduction

Caused by the fungal pathogen known as Lacazia loboi (Taborda et al., 1999) (syn. Loboa loboi; Caldwell et al., 1975), lobomycosis (or lacaziosis) naturally affects humans, common bottlenose dolphins (Tursiops truncatus) and Guiana dolphins (Sotalia guianensis) (de Vries and Laarman, 1973; Caldwell et al., 1975; Simões-Lopes et al., 1993; Reif et al., 2006; Van Bressem et al., 2007). The natural reservoir of L. loboi is unknown but soil and vegetation seem to be likely sources of infection for humans (Honda et al., 2007). Lobomycosis in dolphins is characterized by grayish, whitish to slightly pink, verrucous lesions, often in pronounced relief that may ulcerate (Migaki et al., 1971). T. truncatus from the Indian River Lagoon (IRL), Florida, affected by cutaneous lobomycosis, were found to have significant impairment in adaptive immunity possibly related to chronic exposure to environmental stressors (Reif et al., 2008). Variation in salinity and water temperature may also play a role in the infection (Reif et al., 2006). Lobomycosis and lobomycosis-like disease (LLD), a disease very similar to lobomycosis but for which a histological diagnostic is missing, have been reported in inshore dolphins from several South American countries with the first case reported in a S. guianensis caught in the estuary of the Surinam River in 1971 (de Vries and Laarman, 1973; Simões-Lopes et al., 1993; Van Bressem et al., 2007). Photo-identification was shown to be a useful tool to detect and monitor these diseases (Van Bressem et al., 2007; Murdoch et al., 2008).

Two communities of S. guianensis inhabit the Lagamar estuary (Fig. 1), Brazil. One dwells in the coastal waters surrounding the island of Cananéia (25°03′S; 47°55′W) and the other lives along the northern coast of the Paranaguá state (25°22′S; 48°25′W). The first one has been studied since 1996 (e.g. Santos and Rosso, 2007, 2008; Santos et al., 2000, 2001, 2002, 2003) while photo-identification surveys of the second one started in April 2006. In the Cananéia and Paranaguá areas 200 and 103 dolphins were photo-identified, respectively. Approximately 180 km long, the Lagamar estuary is located between the states of São Paulo and Paranaguá and is in close contact with the Southwest Atlantic Ocean. It is surrounded by large mangrove forests and was designated a National Protected Area in 1984 (Schaeffer-Novelli et al., 1990). It is, however, severely impacted by anthropogenic factors. A channel dug at the end of the 1880s to connect its northern limit to the Ribeira do Iguape River has caused dramatic changes in its fauna composition and structure (Tommassi, 1985). Though prohibited by law in Brazil since 1985, chlorinated hydrocarbons were vastly used till
the end of the 1990s and still contaminate the estuary (Ferreira et al., 1980; Mattos, 2002). In the southern portion of the estuary, Paranaguá harbour, Brazil’s second most important port, was built in 1935. Oil spills are common in this area as well as shipwrecks inside and outside local estuarine waters (Wiczorek, 2006). As top predators, small cetaceans are exposed to, and affected by, persistent organic pollutants (POP) including polychlorinated biphenyls (PCBs), dibenzo-p-dioxins (PCDDs), dibenzofurans (PCDFs) and related compounds (Ross et al., 1996; Ross, 2002).

Here we report on the presence of LLD and possibly related nodular skin disease (NSD) in S. guianensis from the Paranaguá estuary and on their absence in the community inhabiting the Cananéia area.

2. Materials and methods

2.1. Image and data collection

Photo-identification boat-based (15 and 30hp motorized vessels) surveys were conducted from May 1996 to August 2007 in the Cananéia estuary and from April 2006 to September 2007 in the northern portion of the Paranaguá state. The survey path followed a zig-zag pattern to maximize chances of encountering dolphins. Surveys were conducted in good sea conditions (Beaufort scale = 0–2). A 35 mm reflex camera using printed films and with a 300 mm zoom lens was used till May 2004 and subsequently replaced by digital cameras with 300 and 400 mm lenses. Photographs were taken at distances ranging from 2 to 10 m with shutter speeds ranging between 1/500 s and 1/2000 s.

2.2. Dolphins

All dolphins were individually identified from natural marks present on the dorsal fin and body (Würsig and Würsig, 1977; Würsig and Jefferson, 1990). About 100,000 and 26,000 pictures of dorsal fins were examined for the Cananéia and Paranaguá dolphins, respectively. On most occasions, all individuals from a group including calves were photographed. Females were identified on the basis of an accompanying calf. Calves are defined as individuals whose body length (BL) ranged from one-third to one-half the BL of large dolphins in the area and that usually remain close to their mothers in the infant position (Mann and Smuts, 1999; Mann et al., 2000). Adults are large, robust dolphins.

2.3. Nodular skin disease and lobomycosis-like disease

Nodular skin disease is characterized by circumscribed, raised, grey, orange or reddish, sometimes ulcerated, skin lumps. Lobomycosis-like disease consists in raised, gray-white to slightly pink, verrucous, at times ulcerated, proliferating lesions that may form large plaques, and grossly most closely resemble those caused by L. loboi in T. truncatus.

The lesions were counted and their broadest size estimated on the basis of a mean dorsal fin base length of 23 cm in adults (Santos et al., unpublished data). They were further classified as small (<10 mm), medium (>10 mm and <30 mm) and large (>30 mm). Severity of the disease was scored as follows: 1 = one small to medium-sized lesion, 2 = two to seven, small to medium-sized, localized nodules, 3 = five or more, small to large lesions affecting more than one body areas, 4 = more than 10 lesions, aggregating, affecting several body areas and covering approximately 10% or more of the visible body surface.

3. Results

In the Paranaguá estuary we observed LLD and NSD in 18 (17.4%) of the 103 dolphins photo-identified in 2006–2007. Four (3.9%) dolphins including a calf, an adult female and two adults of unknown sex had LLD with severity scores ranging from 2 to 4 (Table 1). In two adults, including the female, the lesions were extensive and proliferating and affected the back, flanks and tailstock (Fig. 2a). Individual lesions ranged from an approximate 5 to 50 mm in their broadest dimension (Table 1). When congregating the sores formed large plaques in adult female J’ (approximately 355 × 25 mm, 283 × 16 mm and 119 × 8 mm) and in adult L’ of unknown sex (about 180 × 80 mm-the sizes of the

![Map of the Lagamar estuary, Brazil, including the Cananéia and Paranaguá estuaries.](image-url)
two other visible plaques could not be measured). In the calf the disease was apparently restricted to the back and dorsal fin (Fig. 2b). The elevated white lumps measured around 8 till 20 mm in their broadest dimension. All dolphins were seen in Guaraqueçaba bay (25° 16' S, 48° 21' W, Fig. 1) and surrounding areas in February–August 2007. On the only picture available, the calf’s mother had a small white and round mark on her right side that was not considered to be LLD or NSD but may represent a very early stage of these diseases (Fig. 2b).

NSD was seen in 14 (12.6%) dolphins including 13 adults and a large calf with severity scores ranging from 1 to 3 (Table 1). The nodules were seen on the flanks, back and tailstock. They ranged from an estimated 5 to 45 mm in their broadest dimension, were occasionally ulcerated (Fig. 3a, Table 1) and were sometimes associated with skin traumas (Fig. 3b) suggesting that wounds may play a role in the pathogenesis of this disease. In two adult dolphins of unknown sex, the lumps evoked the beginning of LLD: though still circumscribed they were grouped on a small area behind the dorsal fin and had a tendency to form plaques (Fig. 4).

However, these lesions were only sighted once and their evolution is unknown. Nine of the 13 adults with lumps were seen in Guarapequeba bay and surroundings. The mother of the calf with the reddish lump did not have visible skin lesions but only one picture was available. None of the 200 Cananéia dolphins had LLD or NSD in the period 1996–2007, a highly significant ($\chi^2 = 37.32, df = 1, P = 10^{-26}$) difference.

### Table 1

<table>
<thead>
<tr>
<th>Dolphin</th>
<th>Sex</th>
<th>Age class</th>
<th>Date</th>
<th>NSD</th>
<th>LLD</th>
<th>Nber</th>
<th>Severity</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>J</td>
<td>Female</td>
<td>Adult</td>
<td>8 August 07</td>
<td>No</td>
<td>Yes</td>
<td>Several</td>
<td>4</td>
<td>Dark gray and brownish, at times ulcerated, small to large nodules forming plaques on flanks and back</td>
</tr>
<tr>
<td>L</td>
<td>Indet</td>
<td>Adult</td>
<td>8 February 07</td>
<td>No</td>
<td>Yes</td>
<td>Several</td>
<td>4</td>
<td>Extensive, small to large, nodular lesions forming plaques on dorsal fin, back and tailstock</td>
</tr>
<tr>
<td>G</td>
<td>Indet</td>
<td>Calf</td>
<td>8 July 06</td>
<td>No</td>
<td>Yes</td>
<td>3</td>
<td>2</td>
<td>Two whitish, small to medium, verrucous lesions on back behind dorsal and one on dorsal fin</td>
</tr>
<tr>
<td>V</td>
<td>Indet</td>
<td>Adult</td>
<td>2 August 07</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Small to medium lesions on the back, apparently associated with a skin trauma</td>
</tr>
<tr>
<td>A</td>
<td>Indet</td>
<td>Adult</td>
<td>30 July 06</td>
<td>Yes</td>
<td>No</td>
<td>5</td>
<td>3</td>
<td>In relief small to large lesions on dorsal fin and left flank</td>
</tr>
<tr>
<td>B</td>
<td>Female</td>
<td>Adult</td>
<td>30 July 06</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>Small to medium nodules on back and left flank</td>
</tr>
<tr>
<td>C</td>
<td>Indet</td>
<td>Adult</td>
<td>8 July 06</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
<td>2</td>
<td>Ulcerated, medium-sized nodules on the back below dorsal</td>
</tr>
<tr>
<td>D</td>
<td>Indet</td>
<td>Adult</td>
<td>8 July 06</td>
<td>Yes</td>
<td>No</td>
<td>3</td>
<td>2</td>
<td>Small to large, grouped nodules on left flank</td>
</tr>
<tr>
<td>E</td>
<td>Indet</td>
<td>Adult</td>
<td>8 July 06</td>
<td>Yes</td>
<td>No</td>
<td>2</td>
<td>2</td>
<td>A small nodule on the back and a medium on tailstock</td>
</tr>
<tr>
<td>F</td>
<td>Female</td>
<td>Adult</td>
<td>8 July 06</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Medium-size, ulcerated nodule on left flank</td>
</tr>
<tr>
<td>H</td>
<td>Indet</td>
<td>Calf</td>
<td>8 August 07</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Heart shaped, medium, reddish nodule on the back before dorsal fin</td>
</tr>
<tr>
<td>M</td>
<td>Indet</td>
<td>Adult</td>
<td>8 February 07</td>
<td>Yes</td>
<td>No</td>
<td>1–3</td>
<td>2</td>
<td>One medium-size reddish nodule on tail stock, two in relief lesions associated with skin traumas on left flank</td>
</tr>
<tr>
<td>N</td>
<td>Indet</td>
<td>Adult</td>
<td>8 January 07</td>
<td>Yes</td>
<td>No</td>
<td>~7</td>
<td>2</td>
<td>Small to medium nodules associated with scars and evoking the beginning of LLD on the back behind dorsal fin</td>
</tr>
<tr>
<td>O</td>
<td>Indet</td>
<td>Adult</td>
<td>31 July 06</td>
<td>Yes</td>
<td>No</td>
<td>5</td>
<td>2</td>
<td>Medium, whitish nodules evoking the beginning of LLD on the back behind dorsal fin</td>
</tr>
<tr>
<td>P</td>
<td>Indet</td>
<td>Adult</td>
<td>8 August 07</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Reddish, medium-size nodule on right flank</td>
</tr>
<tr>
<td>Q</td>
<td>Indet</td>
<td>Adult</td>
<td>8 August 07</td>
<td>Yes</td>
<td>No</td>
<td>5</td>
<td>2</td>
<td>Medium-size, whitish nodules on the left flank and back behind dorsal fin</td>
</tr>
<tr>
<td>R</td>
<td>Female</td>
<td>Adult</td>
<td>8 August 07</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Medium-size nodule on the back behind head</td>
</tr>
<tr>
<td>S</td>
<td>Indet</td>
<td>Adult</td>
<td>2 August 07</td>
<td>Yes</td>
<td>No</td>
<td>1</td>
<td>1</td>
<td>Small nodule on the back behind dorsal</td>
</tr>
</tbody>
</table>

Specimens are ordered by disease and code. Abbreviations are: Indet, indeterminate; Nber, number.

Fig. 2a. Extensive lobomycosis-like disease in adult female S. guianensis ‘J’.

Fig. 2b. Localised lobomycosis-like disease in calf S. guianensis ‘G’.
4. Discussion

This photo-identification study reports for the first time on the presence of LLD and NSD in a community of *S. guianensis* inhabiting the Paranaguá estuary, Brazil. It is also the first time that LLD is observed in a calf. The epidemiological status of LLD and NSD in *S. guianensis* from the Lagamar estuary is unknown. The presence of extensive lobomycosis-like lesions in two adults, and minor lesions in a third, suggests that the disease has been present for at least some months in this community. Prevalence of LLD was 3.9% in 103 dolphins photo-identified in 2006–2007. In inshore *T. truncatus* from South America, prevalence levels of this syndrome varied from 1.6% (Gulf of Guayaquil, Ecuador) to 20% (Tramandaí estuary, Brazil) in the period 1990–2007 (Van Bressem et al., 2007). The role of *L. loboi* as the aetiological agent of LLD was confirmed by histology in a dead *T. truncatus* from the Tramandaí estuary, Brazil, visually diagnosed as positive when still alive (Van Bressem et al., 2007; Moreno et al., 2008). Further studies will examine whether this fungus is also the causal agent of LLD in *S. guianensis* from the Paranaguá estuary.

Though the ‘nodular skin disease’ observed in the Paranaguá dolphins suggests an early form of LLD, it may represent another disorder. Besides, *L. loboi* at least four other pathogens are known to cause skin nodules in small cetaceans. *Streptococcus iniae*, primarily a bacteria of fishes, triggered ‘golf ball disease’, a condition characterized by multiple subcutaneous abscesses in botos (*Inia*...
5. Conclusions

The high prevalence of LLD and NSD in the S. guianensis from the Paranaguá estuary and their absence in the well-studied community of the Cananéia estuary is striking. These diseases may be indicators of environmental changes. Their aetiology, pathogenesis, epidemiology, evolution and impact on survival of coastal dolphins should be further explored.

Acknowledgements

Long-term photo-identification studies in the Lagamar estuary have been sponsored by the Cetacean Society International (CSI), the Whale and Dolphin Conservation Society (WDCS), The Humane Society of the United States (HSUS), The Society for Marine Mammalogy (SMM), the Earthwatch Institute (EWI), and the Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP, process numbers 01/05128-8, 05/59439-5, 05/54149-9). M. Santos received a fellowship from FAPESP and J. de Faria obtained a fellowship from Agência Nacional do Petróleo (ANP). Financiadora de Estudos e Projetos (FINEP), Ministério da Ciência e Tecnologia (MCT), Programa de Recursos Humanos da ANP for the setor de petróleo e gás – PRH–ANP/MCT. Logistical support was provided by the Instituto Oceanográfico da Universidade de São Paulo (Cananéia research station) and the Núcleo Prê-Ação de Guararapesca da Pontifícia Universidade Católica do Paranaguá. Ednison da Silva and Eduardo Pacífico helped in fieldwork surveys. The work of M.-F. Van Bressem was funded by the WDCS and CSI. We kindly thank two anonymous reviewers for their constructive comments on the manuscript.

References


