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Research

Behavior and salivary cortisol of captive dolphins (*Tursiops truncatus*) kept in open and closed facilities

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ABSTRACT

Few studies have been carried out on the welfare of captive bottlenose dolphins (*Tursiops truncatus*). Of these, most include information on animals kept in closed facilities or pools. The aim of this study was to assess the welfare of captive bottlenose dolphins in open and closed facilities by measuring states of individual behavior and salivary cortisol concentrations. A total of 23 bottlenose dolphins were studied in 4 different dolphinaria. Dolphinaria A and B have closed facilities, whereas dolphinaria C and D have open facilities. A total of 152 hours of behavioral observations were analyzed using a combination of behavior and scan sampling to obtain information on individual time budgets. Salivary cortisol concentrations were measured using radioimmunoassay in 96 and 180 saliva samples of dolphins kept in closed and open facilities, respectively. In general, the results found that dolphins kept in open facilities spent less time floating ($P < 0.05$) and swimming in circular patterns than linear ones ($P < 0.05$) compared with dolphins in closed facilities. Dolphins kept in open facilities also had lower salivary cortisol concentrations than dolphins kept in closed facilities ($P < 0.05$). For this reason, we suggest that further research should include other welfare indicators such as reproductive function and health measurements to know more about the relationships between the design of pools and dolphin welfare.

Introduction

The behavior of any wild species is the result of many generations of natural selection and adaptation to the environment. The ability to cope with changes in the environment such as those related to captivity depends on a complex interplay of biological factors (Mason, 1990; Shepherdson, 1994; Carlstead, 1996; Poole, 1998). The welfare of many species of terrestrial mammals has been studied (Carlstead, 1996), but little information is available on marine mammals in captivity (Pedernera-Romano et al., 2006; Luna, 2008). Bottlenose dolphins (*Tursiops truncatus*) in captivity are still used for entertainment and assisted therapy in several countries. It is known that these animals have to adapt to changes in their physical and social environments as a result of the design of the enclosures where they are kept, changes in food presentation, and also because of changes in their social structure (Pedernera-Romano et al., 2006).

It is well known that stress induces behavioral changes (Fowler, 1986; Dierauf, 1990; Waples and Gales, 2000) that could be related to prolonged adrenal activity and long-term welfare and health problems (Moberg, 1985; Broom and Johnson, 1993; Fowler, 1995; Chrousos et al., 1998; Sapolsky et al., 2000; Reeder and Kramer, 2005).

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Some studies carried out with bottlenose dolphins have been useful for understanding general aspects of their maintenance behaviors in captivity (Gygax, 1993; Sobel et al., 1994; Small and DeMaster, 1995; Bassos and Wells, 1996; Galhardo et al., 1996; St. Aubin and Dierauf, 2001; Sekiguchi and Kohshima, 2003; Ugaz et al., 2009). Fewer studies, however, have assessed adrenal function through measurements of plasma, serum, and salivary cortisol (Thomson and Geraci, 1986; St. Aubin, 1996; Ortiz and Worthy, 2000; St. Aubin, 2001; Suzuki et al., 2003; Pedernera-Romano et al., 2006; Noda et al., 2007). Salivary cortisol of dolphins has proven to be a noninvasive procedure of great value when repeated sampling is necessary as its collection is potentially stress free and practical (Pedernera-Romano et al., 2006). So far, most of this information has been obtained from dolphins kept in dolphinaria with closed pools. A recent study that compared the behavior of 10 dolphins that were kept in pools and moved to open sea enclosures showed that the behavior of dolphins varies according to the type of facilities (Ugaz et al., 2009). The results show that when dolphins were kept in closed facilities they spent less time swimming and more time floating than when in open facilities. Dolphins in closed facilities tend to swim in circles, whereas those in open facilities spend more time swimming in linear patterns. Furthermore, dolphins kept in closed facilities spent more time interacting socially than those in open facilities. For these reasons, the aim of this study was to compare individual and social behaviors, as well as salivary cortisol, of different groups of captive bottlenose dolphins kept in open and closed facilities. This information can enhance our knowledge of how the characteristics of open facilities for captive dolphins may influence their behavior and adrenal activity in comparison to closed pools.

Methods

Locations and animals

A total of 23 bottlenose dolphins were studied in 4 different dolphinaria.

Dolphinaria A and B have closed facilities, whereas dolphinaria C and D have open facilities (Table 1). A closed facility was defined as a pool with no access to the sea and with treated water, whereas an open facility was defined as a pen, usually designed as a dock, with access to the sea and seawater and contained within a fence.

The average age of the dolphins studied was 16.3 years old (age range, from 11 to 24 years) with 6 males and 17 females (Table 1). All individuals were adults and healthy at the time of the study. All were captured in the Gulf of Mexico, and they had an average of 9.5 years in captivity (range, from 8 to 15 years). All dolphins, both in closed and open facilities, were fed with the same species of fish: capelin (*Mallotus villosus*), Atlantic Herring (*Clupea harengus*), and squid (*Loligo patagonica*, *Loligo gahi*, or *Loligo vulgaris*). The aquariums were opened to the public and regularly hosted interactive swimming sessions. The 4 dolphinaria had 5 interactive sessions per day, each lasting 40 minutes to every 80 minutes. The first interactive program is at 9:30 AM and the last one at 15:00. The observations were not conducted during an interaction or performance session.

Table 1
Individual dolphins kept in the 4 dolphinaria studied

Dolphinaria	Facilities	ID	Sex	Age (y)	Time in captivity (y)
A	C	1	Female	12	+8
A	C	2	Male	18	+15
B	C	3	Female	12	+8
B	C	4	Female	14	+8
B	C	5	Female	14	+8
B	C	6	Male	15	+8
B	C	7	Male	18	+8
B	C	8	Male	17	+8
C	O	9	Male	18	+10
C	O	10	Female	14	+10
C	O	11	Female	12	+9
C	O	12	Female	11	+8
C	O	13	Female	16	+8
D	O	14	Male	16	+10
D	O	15	Female	24	+10
D	O	16	Female	18	+10
D	O	17	Female	17	+10
D	O	18	Female	16	+10
D	O	19	Female	18	+10
D	O	20	Female	16	+10
D	O	21	Female	18	+10
D	O	22	Female	18	+10
D	O	23	Female	22	+10

Facilities are marked as C = closed and O = opened.

Closed facilities

Dolphinarium A is a round pool with a conical bottom reaching a maximum depth of 5 m and with a capacity of 1964 m^3. It is located in Mexico City at 2240 m above sea level. Dolphinarium B is a rectangular pool, with an average depth of 4 m, subdivided into a main area of 60 × 20 m and 4 small (5 × 10 m) holdings or pens, 2 at each end. It has total capacity of 5600 m^3 and is located on the Pacific coast of central Mexico.

Open facilities

Dolphinarium C is located on the east coast of the Yucatan Peninsula. It is an artificial breakwater with access to the sea allowing the exchange of seawater and small fish and other marine species. It has a maximum depth of 3.5 m, a total volume of 6074 m^3, and is subdivided into 2 areas of equal size with a dock separation and an oval rubble quay. Dolphinarium D is located in the north coast of the Yucatan Peninsula. It has 3 holdings or pens each of 33 × 10 m, separated by an open fence and with access to a central area of 100 × 35 m, with a maximum depth of 4 m, and an estimated total water capacity of 26,250 m^3 (Table 2).

Table 2
Size of the pools in each dolphinarium

Dolphinaria	Length (m)	Width (m)	Minimum depth (m)	Maximum depth (m)
A	25	25	3.5	5
B	70	20	4	4
C	75	30	3	3.5
D	100	45	3.5	4