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Some Reproductive Parameters of an Estuarine Population of Indo-Pacific Bottlenose Dolphins (*Tursiops aduncus*)

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Abstract

The Port River estuary (Adelaide, South Australia) supports a population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) despite its heavily modified habitat. This paper reports the calving season, birth rate, calf mortality, and inter-birth interval of the resident population, all factors important in the conservation of this population. Between 1989 and 2005, 1,176 boat surveys were undertaken, covering all seasons for each year. All dolphins encountered were photographed, and their location, number, age category, and behaviour were recorded. Dolphin identity was determined *a posteriori* using photo-identification. Results indicated a calving season from December to March, which coincided with the maximum surface water temperature of the estuary. Inter-birth intervals were consistent with the literature—3.8 y when the previous calf was weaned and 1.7 y when the previous calf died—with the exception of one special case. Forty-five calves were born to resident females between 1989 and 2005, and the average crude birth rate was 0.064, which is similar to that found for other bottlenose dolphin populations. First-year calf mortality (30%) and mortality rate for calves prior to weaning (46%) were higher than mortality rates described for other locations. Minimal predation is thought to occur in the estuary, and there was no evidence of poor condition in the mothers, suggesting that the high mortality rates were caused by direct impacts on calves such as entanglements, boat strikes, deliberate attacks, or exposure to toxic pollution.

Key Words: Indo-Pacific bottlenose dolphin, *Tursiops aduncus*, inter-birth interval, reproduction, seasonality, birth rate, calf mortality, Port River estuary, Adelaide, South Australia

Introduction

The highly modified environment of the Port River estuary in Adelaide, South Australia, associated with port development and industrialisation, supports a population of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*). This population has been studied for the past 18 y (Kemper et al., in press). A dolphin sanctuary was proclaimed in 2005 by the Government of South Australia to protect the dolphins and their habitat (Adelaide Dolphin Sanctuary Act, 2005). The protection and conservation of these dolphins requires knowledge of their population dynamics, including reproductive parameters such as calving season, birth rate, calf mortality, and inter-birth interval.

Calving season in bottlenose dolphins (*Tursiops* sp.) varies greatly between different populations (Urian et al., 1996). Most of the populations studied showed a diffuse calving seasonality, with a uni- or bimodal distribution of births (e.g., Scott et al., 1990; Mann et al., 2000; Thayer et al., 2003) and with some births possible during other months. No simple relationship between environmental factors, such as sea temperature or latitude, and calving season has been found (Urian et al., 1996).

Birth and death rates of calves have been determined for other *Tursiops* populations. "Crude birth rate" (Wells & Scott, 1990, p. 410, Table 2a)—the number of calves born to identified females divided by the total number of identified animals—ranged between 0.046 and 0.071 (Wells & Scott, 1990; Bearzi et al., 1997; Wilson et al., 1999; Kogi et al., 2004). For some study populations, the mortality of calves during their first year ranged from 13 to 24% (Wells & Scott, 1990; Mann et al., 2000; Kogi et al., 2004) and reached 40 to 46% by the age of separation from the mother (Connor et al., 2000; Mann et al., 2000).

Inter-birth intervals for the bottlenose dolphin (*Tursiops* sp.) in the wild are generally described as 3 y or more (Reynolds et al., 2000; Perrin et al., 2002). This figure has mostly been derived from observational photo-identification studies, but at least one study used ovarian scars examined during necropsies (Cockcroft & Ross, 1990). Bearzi et al. (1997) undertook a photo-identification study of common bottlenose dolphins (*T. truncatus*) in the Kvarneric area of the northern Adriatic Sea and described mother-calf associations lasting 3 to 4 y and longer. While these data are not strictly for inter-birth interval, the mother-calf associations found by Bearzi et al. generally mirror the inter-birth interval of bottlenose dolphins in the Kvarneric. A long-term study of Indo-Pacific bottlenose dolphins in Shark Bay, Australia (Mann et al., 2000) reported inter-birth intervals from 3 to 6.2 y, with a median of 4.07 y and a mean of 4.55 y. Kogi et al. (2004) studied Indo-Pacific bottlenose dolphins at Mikura Island in Japan and reported a range of 1 to 6 y, with a median of 3 y and a mean of 3.4 y. However, the shortest intervals of 1 and 2 y involved females which had lost their calves and became pregnant the same or following year. Bearzi et al. (1997) also reported two inter-birth intervals shorter than 2 y associated with pre-weaning mortality. The only report listing inter-birth intervals of 2 y with a surviving calf was for *T. truncatus* in Sarasota, Florida (Connor et al., 2000), but the authors commented that intervals of 3 to 6 y were more common. No interval shorter than 3 y with a previous surviving calf has been reported for *T. aduncus*.

This paper reports calving season, birth rate, calf mortality, and inter-birth intervals from a long-term photo-identification study of the population of coastal bottlenose dolphins in the Port River estuary, with particular reference to one inter-birth interval of less than 2 y, which was not the result of the death of the previous calf. Dolphins in the Port River estuary are *T. aduncus* (Kemper, 2004).

Materials and Methods

Study Area

The Port River estuary (Figure 1) is 15 km from central Adelaide, a city of approximately one million people. The estuary is impacted in numerous ways by human activity (Edyvane, 1999; Wade, 2002). Shipping channels are dredged regularly, and much of the shoreline has been modified for housing and industry. The waters receive discharges from industrial wastes, storm water, sewage effluent, and heat effluent from three power stations. The estuary is extensively used by commercial and recreational boats, with speedboat racing also occurring. A number of introduced species also have become established, including a toxic dinoflagellate and the invasive algae *Caulerpa taxifolia* (Bryars, 2003). The estuary is known to be polluted with toxic chemicals, particularly PCBs and heavy metals (Harbison, 1986; Edwards et al., 2000; EPA, 2000; Wade, 2002).

Data Collection

A long-term photo-identification study has been underway in the Port River estuary since 1989, comprising 1,176 boat surveys up to 31 December 2005, with an average of 69 surveys/y (min = 41, max = 93). Surveys were conducted throughout the year for each year of data collection when the sea state was 3 or less (Beaufort scale). M. Bossley was the observer on all surveys, although volunteers were also present on the vessel at times. Surveys were conducted during both mornings and afternoons. A standard survey route (Figure 1) was introduced in 1992, and standard surveys averaged 29% (min = 10%, max = 51%) of the total surveys undertaken from 1992 to 2005. Each time dolphins were encountered, the sea state, location, number of animals of each age category, and their behaviour were recorded. Age category was designated as follows: adults were fully grown animals (estimated to be more than 1.8 m in length); subadults were dolphins less than full size (between 1.5 and 1.8 m) and not consistently accompanied by an adult; juveniles were smaller dolphins (between 1 and 1.5 m) that were spending most of their time with an adult; and neonates were very small animals (approximately 1 m) that were always close to an adult, identified by the presence of foetal folds and by their characteristic head-out swimming style (McBride & Kritzler, 1951). Each group encountered was observed for a minimum of 10 min in an attempt to ensure all individuals present were photographed to permit identification (e.g., Würsig & Würsig, 1977; Würsig & Jefferson, 1990).

Data Analysis

Data from photo-identification showed that individual bottlenose dolphins differed greatly in how frequently they used the estuary, with some individuals observed frequently and some occasionally or only once. Individuals sighted more than 20% of the months it was possible to observe them (i.e., from the first sighting of an individual to its last sighting or to the end of the study period) were considered as residents (Bossley et al., in prep.).

Dolphin females were not observed giving birth; therefore, it was necessary to estimate date of birth from the sightings record. Accordingly, a neonate's date of birth was calculated as the middle date between the last sighting of the mother without calf and the first observation of

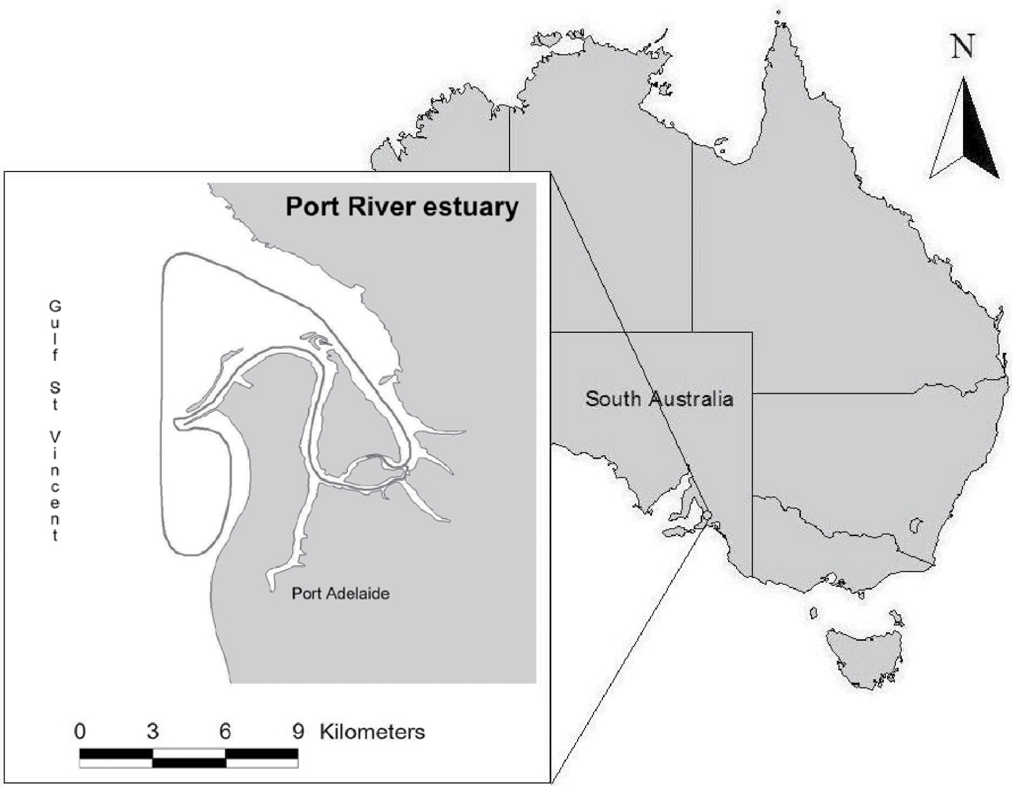

Figure 1. Study area showing the standard survey route (grey line)

the calf. To accurately determine the calving date of resident females, only those for which a sighting without a calf was made not more than 4 mo before the first sighting of the calf were used.

The calculation of a mean annual crude birth rate was based on the definition given by Wells & Scott (1990) as the number of calves born to known mothers divided by the number of known individuals. Here, it was calculated using only the resident individuals (i.e., the number of calves born to resident identified females divided by the total number of resident identified individuals). The mortality rate was calculated as the percentage of calves seen dead or which disappeared compared to the total number of calves of known fate. Calves disappearing before the birth of the next neonate of the mother were presumed to have died.

To assess the interval between births, only resident females seen regularly during the study were used. The birth date was estimated as defined earlier, when the interval between sightings of the mother without and with a calf was less or equal to 4 mo (21 calves). When the interval was between 5 and 10 mo (5 calves), the birth was assumed to have occurred in February, the middle of the calving season preceding the first sighting of the calf.

Results

From 1989 to 2005, 195 bottlenose dolphins were identified, with 74 (27 females, 22 males, and 25 individuals of unknown gender) considered as residents in the estuary. During the course of the study, 45 calves were known to be born to resident females. Of the 45, only 35 were used to determine calving season, 33 to assess mortality rate, and 26 to calculate inter-birth intervals.

The sightings of neonates in the area during the study period indicated resident females had a predictable calving season in summer and early autumn, with 32 births out of 35 (91.4%) taking place between December and March (Figure 2).

There were 45 calves known to be born to resident females between 1989 and 2005 (Table 1), giving an average of 2.6 calves born/y. The average crude birth rate was 0.064 (SD = 0.05). Of the 33 calves which were weaned, known to have died, or disappeared and presumed dead, 18 were weaned (54.5%) and 15 died or disappeared

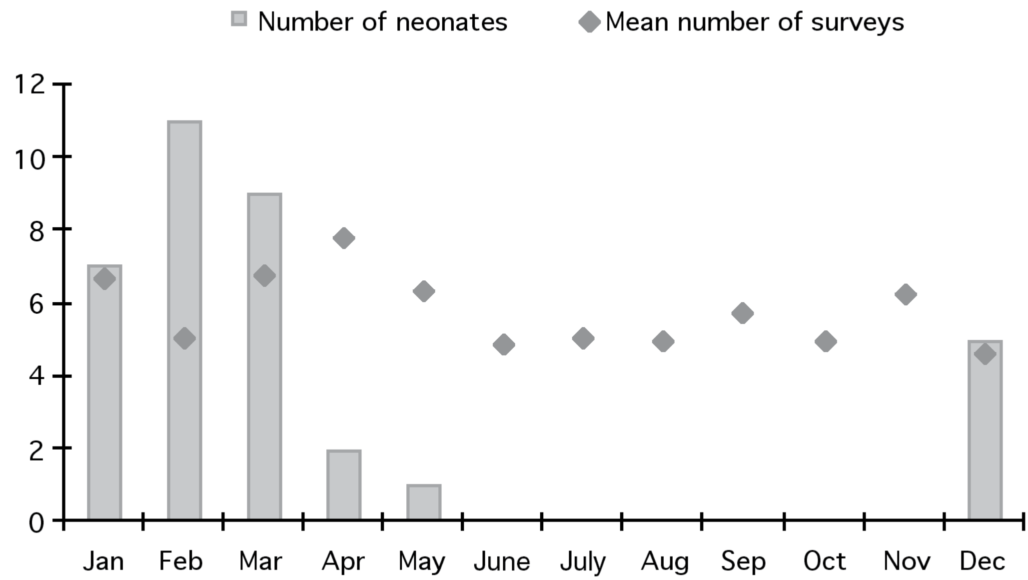

Figure 2. Sightings of *T. aduncus* neonates and monthly mean number of surveys conducted between 1989 and 2005 in the Port River estuary, Adelaide, South Australia

(45.5%), 10 of these (30.3% of 33) during their first year.

Inter-birth intervals were calculated for nine females (Table 2). The mean interval when the previous calf was weaned (except for the case of F200 described below) was 3.8 y (median = 3.2, SD = 1.1, n = 9, range = 2.9 to 6); five inter-birth intervals were of approximately 3 y, two of 4 y, one of 5 y, and one of 6 y. When the previous calf died, the interval averaged 1.7 y (median = 1.2, SD = 0.8, n = 5, range = 1.1 to 2.9).

The female F200 gave birth to a calf when its previous calf (M389) was only 1.9 y old and still alive (Table 2, note c). F200 gave birth to calf M389 between January and April 2001 (Table 3). M389 was recognizable because of several entanglements in fishing lines and ropes that cut deeply into its tail flukes and remained with its mother until the birth of a new calf in late January 2003. M389 was thus effectively weaned at 1.9 y old and was subsequently seen only occasionally with its mother and its mother's new calf. From January 2001 to December 2003, F200 was sighted on average four times a month and during every month except February and March 2001, December 2002, and September 2003—regularly enough to allow following this event accurately. From December 2003 to the end of the study period (December 2005), M389 was regularly observed in the area, but only occasionally with F200 and the new calf.

Table 1. Calves born from resident female *T. aduncus* between 1989 and 2005 in the Port River estuary, Adelaide, South Australia

Calf's fate	Number of calves
Weaned	18
Still with mother at the end of 2005	9
Still with mother at its last sighting	2
Died or disappeared	15
Fate not known	1

Discussion

Resident females in the Port River estuary showed a distinct calving season, with calves born only from December to May each year over 17 y. Of those, 91.4% were born between December and March. This calving season corresponded to the maximum surface water temperature measured at nine sites within the estuary from 1997 to 2000 (Wade, 2002). It is possible that resident females coordinate neonate births with the warmer conditions in the estuary. Bottlenose dolphins show a great variability in the seasonality of their reproduction in different areas, and no simple relationship between temperature and calving season was found (Urian et al., 1996). Urian et al. hypothesized that "the different seasons of birth of populations of bottlenose dolphins are responses to seasonal patterns of availability of local resources" (p. 401). However, the structure composition and abundance of the dominant fish species in the

Table 2. Inter-birth intervals of resident female *T. aduncus* regularly followed between 1989 and 2005 in the Port River estuary, Adelaide, South Australia

Female	Birth date	Calf's fate	Inter-birth interval (y)[b]
F001	2/1995	Disappeared; presumed dead	First known calf
	4/1996	Miscarriage[a]	*1.17*
	12/1998	Weaned	*2.67*
	12/2002	Seen dead	**4.00**
	1/2004	Disappeared; presumed dead	*1.08*
	2/2005	Still with mother	*1.08*
F005	1/1992	Disappeared; presumed dead	?
	1/1995	Weaned	*2.92*
	2/2001	Still with mother	**6.08**
F019	3/1994	Weaned	?
	5/1997	Seen dead	**3.17**
F028	3/1997	Weaned	?
	12/2001	Seen dead	**4.75**
	1/2003	Still with mother	*1.08*
F033	2/2002	Weaned	?
	2/2005	Still with mother	**3.00**
F076	12/1995	Weaned	?
	1/2000	?	**4.08**
F108	1/1998	Weaned	?
	1/2001	?	**3.00**
F165	3/1998	Weaned	?
	2/2001	Seen dead	**2.92**
	1/2003	Seen dead	*2.00*
F200	12/1997	Weaned	?
	2/2001	Weaned	**3.17**
	1/2003	Still with mother	1.92[c]

[a]Presumed miscarriage as dolphin observed bleeding heavily from the genital area; [b]bold is the inter-birth interval after a successful weaning, and italic is the interval when the previous calf died or disappeared; [c]see text

Port River estuary showed little monthly variation and were only weakly correlated with water temperature (Jackson & Jones, 1999). It is therefore unlikely that food resources influenced the timing of birth in the estuary. In the Port River estuary, the calving season corresponded to the period where the estuary is mostly used for recreational purposes, with many boats present in the area.

The mean annual crude birth rate of 0.064 was consistent with those calculated for other populations of bottlenose dolphins using photo-identification data, ranging between 0.046 and 0.071 (Wells & Scott, 1990; Bearzi et al., 1997; Wilson et al., 1999; Kogi et al., 2004). As noted by those researchers, this rate was probably underestimated as some calves could have been born and died before being recorded. However, the estimation made by Cockcroft & Ross (1990) using catch statistics gave similar results (0.043 to 0.065).

First-year calf mortality of 30% was higher than reported elsewhere, with 19% in Sarasota (Wells & Scott, 1990), 24% for nonprovisioned females in Shark Bay (Mann et al., 2000), and 13% around Mikura Island (Kogi et al., 2004). The mortality rate for calves at weaning of 46% was also higher than the 40% reported for nonprovisioned females in Shark Bay (Mann et al., 2000), but the same as in Sarasota (46%; Connor et al., 2000). The mortality rate was assessed from direct observation of dead calves (6 out of 15) or calves disappearing (9). It is possible that some calves which disappeared from the area were still alive. However, weaned calves were always observed with the mother until the birth of the next calf or until only a couple of months before. In the cases of disappearances, the females were always observed without a calf for at least 1 y, corresponding to the gestation period of bottlenose dolphins (Perrin et al., 2002). It is thus probable that the calf died, making the female receptive for another pregnancy. The total death rate of calves prior to weaning would have been even higher in the Port River estuary population if rescues of entangled animals had not occurred. Three rescued animals had entanglements, which would almost certainly have been fatal, with two of these occurring in the animals' first year of life.

Table 3. F200 sightings from January 2001 to December 2003

Years	2001												2002												2003											
Months	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O	N	D
With M389	0	x	x	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	x	0	0	0	0	1	0	0	0	x	0	1	1
With C	0	x	x	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	x	0	1	1	1	1	1	1	1	x	1	1	1

1 = F200 sighted with the calf (M389 or C = new calf) at least once during the month, 0 = F200 sighted without the calf, and x = no sighting of F200 during the month

Incorporating these rescued animals into the death rate for calves would increase it to 55% overall, with 36% dying in their first year, and thus correcting the bias caused by human rescue on the mortality rate. Causes for this higher mortality are unclear. Mann & Watson-Capps (2005) analysed breeding success in Shark Bay dolphins and concluded that the mother's feeding success was a major determinant of calf survival and that predation had minimal impact. Known predators of bottlenose dolphins are white sharks (*Carcharodon carcharias*), tiger sharks (*Galeocerdo cuvier*), bull sharks (*Carcharhinus leucas*), sixgill sharks (*Hexanchus griseus*), dusky sharks (*C. obscurus*; only an occasional predator), and killer whales (*Orcinus orca*) (Heithaus, 2001a; Perrin et al., 2002). Of those, only white sharks are occasional visitors to the estuary, but none were ever observed in the study area during the 18 y of the study. Another shark, the bronze whaler (*C. brachyurus*), visits the estuary occasionally. Evidence of shark attack was limited to one individual bearing a typical crescent shape scar (Heithaus, 2001b), representing a rate of 0.5% ($n = 195$). The occurrence of shark scars in bottlenose dolphins in the Port River estuary is at the very low end of shark scarring rates given at other locations: Shark Bay, Western Australia, 74.2% (Heithaus, 2001b); Moreton Bay, Queensland, 36.6% (Corkeron et al., 1987); Sarasota, Florida, 31.0% (Urian et al., 1998); central west coast of Florida, 22.0% of non-calves individuals (Wells et al., 1987); Natal, South Africa, 10.0 to 19.0% (Cockcroft et al., 1989); Galveston Bay, Texas, 2.0 to 5.0% (Fertl, 1994); coastal area off San Diego, California, 0.3% (Weller, 1991); and Kvarneric, Adriatic Sea, 0.0% (Bearzi et al., 1997). In the waters off San Diego, predators of bottlenose dolphins are infrequent visitors (Weller, 1991), and in the Kvarneric, Adriatic Sea, large sharks are known to be in decline (Bearzi et al., 1997), suggesting a low predation pressure possibly reflected by the low scarring rates found there. Thus, the predation pressure in the Port River estuary seems to be low, suggesting that females here might not feed themselves as successfully as females in other areas. However, there was no obvious evidence of emaciation in these females to suggest poor nutrition. If poor condition of the mothers was not the cause of calf mortality, it would appear there was some other factor acting directly on the calves. Direct impacts on calf survival possibly included undetected entanglements, boat strikes, toxic pollution, or possibly a combination of any or all of these factors. A number of anthropocentric impacts on the bottlenose dolphins were observed during the study. Fourteen entanglements (four involving calves) in fishing line, rope, or sail ties (some involving fishing hooks) were documented. Of these, seven led to the capture and disentanglement of the affected animal. Five boat strikes were documented, with two involving calves (one fatal). Direct attacks on dolphins involving spears, knives, and guns were also documented. There were 12 cases in all (four involving calves), with five fatalities. Three of these fatalities led to forensic investigations (Gilbert et al., 2000; Byard et al., 2001). This demonstrates human impacts on the bottlenose dolphins in the study area, and it is probable that many other cases were not detected, especially deaths, as the body needs to be found to determine the cause of the death. The Port River estuary waters are known to have elevated levels of several pollutants (EPA, 2000; Wade, 2002), and these could impact both prey and the dolphins (e.g., Jauniaux et al., 1997; Evans, 2003). PCBs are known to bioaccumulate in dolphins and are passed on to calves via the female, with a higher load passing to the first calf of a female (Wells et al., 2005), possibly leading to the morbidity or mortality of the calf (Reddy et al., 2001). Thus, human impact in the study area appears to play an important role in the mortality of these bottlenose dolphins. The proclamation of a dolphin sanctuary in 2005 should help reduce these impacts.

Our estimates of inter-birth intervals were consistent with those found at other locations using photo-identification (Bearzi et al., 1997; Mann et al., 2000; Kogi et al., 2004) or ovarian scars and catch statistics data (Cockcroft & Ross, 1990). Most of the inter-birth intervals with a weaned previous calf were between 3 and 4 y, with only one of 5 y and one of 6 y. It is possible that the two longer intervals of 5 and 6 y involved miscarriages, still births, or calves dying very soon after birth but not detected by researchers. If this applied, those longer intervals could have been in the range mostly found in the estuary: 3 or 4 y.

Inter-birth intervals shorter than 3 y with a surviving calf have been reported for *T. truncatus* in Sarasota (Connor et al., 2000) but never for *T. aduncus*. The interval of 1.9 y with a surviving calf reported here is unusually short for this species. It is also the shortest interval with a surviving calf recorded for the dolphins in the study area. It was also not the norm for F200 as the interval between its preceding calf and M389 was 3.2 y, and data collected after the analysis period showed F200 with a new neonate in February 2006, making a 3-y interval between its last two calves. F200 was estimated to be around 16 y old when M389 was born, and she appeared healthy, without any sign of emaciation or disease. M389 was the third calf of F200; the first one disappeared, and the second one and the fourth one were successfully weaned. M389 is still present in the study area and appears healthy. The only obvious difference between M389 and F200's other calves was that M389 suffered from entanglements in marine litter twice before weaning: once at 9 mo old and once at 14 mo old. These entanglements required its capture to remove the material. One severe entanglement consisted of monofilament fishing line snagged from the flukes to the animal's mouth, preventing it from diving and swimming properly. There was little doubt it would have died within a few days if not rescued. F200 was always observed with M389. The rescue was extended over a 9-h period from the first observation of the calf to its release and presumably was very stressful for both dolphins. F200 remained in close contact with M389 during the whole rescue period. It is possible that the entanglement trauma suffered by M389 was sufficient to trigger a hormonal change in its mother (F200), resulting in an unusually early instigation of oestrus. The above entanglement occurred in late October 2001, which was 14 mo prior to the birth of the new calf and could thus be consistent with the proposition that the trauma to the calf triggered oestrus in its mother. No data on the hormonal status of the female were available to confirm this hypothesis, however.

Birth rate and inter-birth intervals in the Port River estuary were comparable to other populations. However, the calf mortality rate was higher, apparently mostly the result of human impacts. The fact that the calving season coincided with the peak in recreational use of the estuary potentially exposed the calves to greater threats. It is not clear what levels of calf mortality can be sustained. The proclamation of a dolphin sanctuary in 2005 by the Government of South Australia should help decrease human impacts on dolphins, with rangers now patrolling the area. The distribution of information about entanglements to recreational fishers in the area could help reduce the impact of litter on the dolphins. A reduction of boat speed during the breeding season could mitigate boat strikes on neonates. A reduction in the amount of pollution discharged into the estuary would be beneficial for the habitat and reduce the potential impact of toxins on the dolphins.

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