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# Behavioural changes in female Indo-Pacific bottlenose dolphins in response to boat-based tourism

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ABSTRACT: We investigated the behavioural changes of Indo-Pacific bottlenose dolphins *Tursiops aduncus* in response to boat-based tourism at both group and individual levels. The behaviour, movement and dive patterns of nursing females off the south coast of Zanzibar were investigated between January and March 2000 to 2002 and statistical comparisons were made between observations made at different levels of tourist activity. Behavioural data was collected during boat surveys using scan sampling of groups and focal individual follows of 5 female dolphins with calves. The movement patterns of dolphin groups were not affected by the presence of a few (1 to 2) tourist boats without swimmers. However, the groups displayed a significantly larger proportion of erratic (non-directional) movements as tourist activities increased and when swimmers were present. The proportion of active, peduncle, tail-out and porpoise dives also increased as tourist activity increased. Further, females travelled more frequently as tourist activities increased; this may have a negative effect on the time available for females to nurse their calves. Intense non-regulated dolphin tourism in this area may lead to a shift in habitat use by nursing females, and the apparent changes in dolphin behaviour due to the increased levels of tourism may ultimately reduce fitness at both individual and population levels. We urge that the guidelines already issued by the Department of Fisheries and Marine Products, Zanzibar, be implemented and complied with as a first important step towards sustainable dolphin tourism.

KEY WORDS: Dolphin watching · Tourism · Swim-with-dolphin tourism · *Tursiops aduncus* · Behaviour



## INTRODUCTION

Whale and dolphin watching is an expanding tourism industry that yearly exceeds US$ 1 billion in total expenditure worldwide (Hoyt 2001). In developing countries, an increased interest in whales and dolphins on the part of tourists has provided a new source of income for local communities that potentially could replace that lost through unsustainable fishing methods and could help raise awareness of the marine environment. However, whale and dolphin watching in developing countries is often unregulated, and concern has been raised for the welfare of these mammals (Spradlin et al. 2001). Tourist activities may have a negative impact on these animals and should therefore be managed and regulated. The impact of dolphin watching activity and boat traffic on dolphins has been studied at several locations around the world (Wells & Scott 1997, Bejder et al. 1999, Constantine 2001, Williams et al. 2002, Hastie et al. 2003, Lusseau 2003a,b, 2004, Scarpaci et al. 2003). Several studies have shown that these activities can affect dolphin behaviour (Lusseau 2003a, Constantine et al. 2004), breathing rate (Janik & Thompson 1996, Lusseau 2003b), inter-individual distance (Bejder et al. 1999, Nowacek et al. 2001), and can increase swimming speed (Nowacek et al. 2001) and change swimming direction (Au & Perryman 1981, Nowacek et al. 2001), breathing synchrony (Hastie et al. 2003) and residency patterns (Lusseau 2005).

Dolphin tourism off the south coast of Zanzibar, East Africa, has been increasing rapidly since its inception in 1992 (Amir & Jiddawi 2001). The main target of dolphin tourism is a population of Indo-Pacific bottlenose

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dolphins *Tursiops aduncus* resident in the area (Stensland et al. 2006). Initially only a few boats participated in the dolphin watching activity. However, by 2001 a total of 35 dolphin tourist boats were active, based in 2 villages, Kizimkazi-Dimbani and Kizimkazi-Mkungoni (Amir & Jiddawi 2001). Dolphin tourism has gradually replaced the previous dolphin hunting in the area, where dolphin meat was used as shark bait and for local consumption, and dolphin blubber for waterproofing boats (Amir & Jiddawi 2001). The last hunt took place in 1996 when 23 dolphins were killed. Since then, dolphin tourism has become more valuable than the previous hunting activity, supplying new job opportunities and other sources of income to the villagers. The south coast of Zanzibar is one of the first areas reported where a cetacean hunt has been replaced directly by cetacean watching activity.

To date dolphin tourism activity remains unregulated, although field observations of dolphin behaviour in the presence of tourist boats in the area have indicated that the dolphins are potentially disturbed by such activity (authors' pers. obs.). For example, dolphins subjected to tourist activity were observed to move erratically, and regularly displayed behaviour that could be stress-related, such as tail slapping and coughing (authors' pers. obs.). In November 1998, in an attempt to minimise tourism impact on the dolphins, guidelines were issued by the Institute of Marine Sciences, University of Dar es Salaam, setting out the requirements that need be following to ensure minimum disturbance to the dolphins. These guidelines specified the maximum number of boats per dolphin group and also how boats and swimmers should behave around the dolphins. A study comparing dolphin behaviour when the guidelines were followed with their behaviour when these were not followed showed changes in dolphin behaviour and increased frequency of stress-related behaviour in the case of non-compliance (Englund & Berggren 2002). Dolphin groups approached by tourist boats violating the guidelines changed their behaviour from resting to travelling (Englund & Berggren 2002).

Dolphin groups that include females and calves are regarded as more vulnerable to disturbance (e.g. Constantine 2001), and in many locations where dolphin tourism is conducted, boats are not allowed to interact with such groups. Groups containing mothers and calves are common off the south coast of Zanzibar (authors' pers. obs.), indicating that this may be an important nursing area for these dolphins.

To assess the impact of dolphin tourism, we investigated the group size, behaviour, movement and dive patterns of female Indo-Pacific bottlenose dolphins by comparing observations made at different levels of tourism activity.

## MATERIALS AND METHODS

**Study area.** This study was conducted on a population of Indo-Pacific bottlenose dolphins inhabiting the waters off the south coast of Zanzibar (6° 29′ S, 39° 29′ E), East Africa (Stensland et al. 1998). The core of the study area is about 26 km$^2$ (Fig. 1). The latest abundance estimate for the population is 136 individuals (log-normal 95% confidence interval 124 to 172), generated using mark–recapture analysis on data collected in 2002 (Stensland et al. 2006). The population is considered a resident one, based on regular resightings of photographically identified individuals both within and between years (Stensland et al. 2006).

**Data collection.** Boat surveys were conducted in the study area between January and March 2000 to 2002. During this part of the year the northeast monsoon is predominant, with light winds and minimum rainfall. When a group of dolphins was encountered, we estimated the number of individuals in the group as well as the number of calves present. We attempted to identify all the individuals in the group by photo-identification, comparing identified individuals against an existing catalogue of known dolphins in the area (Würsig & Jefferson 1990). We determined the sex of the individuals by visual inspection of the genital area when they were swimming close to the research

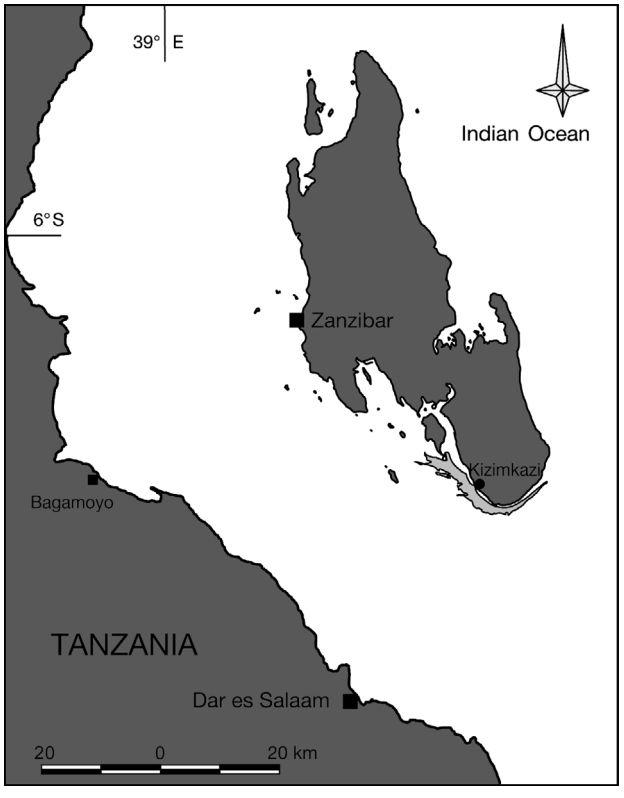


Fig. 1. Core study area (light grey)

boat, or by the presence of dependent calves during repeated sightings.

We studied the behaviour of female bottlenose dolphins with dependent calves (calves not yet weaned and observed swimming in infant position in which they are nursed by their mothers; after Mann & Smuts 1998) from a 5 m outboard-powered boat using focal individual follows and scan sampling of focal female groups. We used point sampling techniques (Altmann 1974, Martin & Bateson 1993, Mann 1999) and recorded the behaviour and dive types of the focal females at 1 min intervals. Group scans were conducted at the same time intervals to determine the movement patterns and general behaviour of the focal female groups. Definitions of the recorded behavioural activities are shown in Table 1 (after Mann & Smuts 1999, Mann & Sargeant 2003).

The number of tourist boats and presence of human swimmers within 50 m of the dolphin groups were also recorded. The dolphin tourist boats are mainly traditional wooden fishing boats (about 6 m long) equipped with outboard engines. They carry up to 15 people, who watch and/or swim with the dolphins during encounters lasting up to 1 h. Dolphin tourism take place year round, weather permitting.

Ten different focal females were followed, but only 5 of these (Chelsea, CHA; Hook, HOK; Jackie, JAE; Spike, SPE; Stumpan, STN) provided sufficient replicates (≥4 focal follows) for use in the analyses. The follows varied in duration from 45 min to 4 h 30 min. All focal females had distinct marks on their dorsal fins and were considered resident in the study area, based on high frequencies of re-sightings within and between years. The selected females had dependent nursing calves of similar age, all older than 10 mo (i.e. all calves were sighted in the year prior the start of this study), to avoid heterogeneities due to the dramatic development changes that calves experience during their first few months of life (Mann & Smuts 1999).

We were unable to control for potential effects by the research boat. However, in order to minimise disturbance, we operated the boat at slow speed, staying parallel or slightly behind the group of dolphins studied. Focal females were observed nursing and engaging in other social behaviours (such as petting and sexual interactions) close to the research boat, indicating that they were habituated to its presence (Mann & Smuts 1999). Typical dolphin–boat distance was 5 to 25 m during focal follows. The identification of individual dolphins in encountered groups and recordings of their general behaviour served as an habituation period (approximately 30 min) prior to the start of focal sampling.

**Data reduction and analyses.** We determined the proportion of the dolphin population that had been subjected to tourist activities by recording the number of marked individuals (individuals with distinctive dorsal fins: see Stensland et al. 2006) that had been observed in groups with tourist boats present. We also determined how often marked individuals and the focal females were subjected to tourist boat encounters by recording the number of times each individual had been identified in groups with or without tourist boats. Further, we determined the proportion of time focal females spent near tourist boats during focal follows.

**Follow events.** The focal follow data were divided into periods of time with different levels of tourist activity (hereafter called 'follow events'). In the analyses we used the following categories or combinations of these categories for various levels of tourist activity: (1) no tourist boat present (TB 0), (2) few (1 to 2) tourist boats and no swimmers (TB 2 n), (3) few tourist boats

Table 1. *Tursiops aduncus.* Definitions of behavioural activities of studied females

| Behaviour | Definition |
|---|---|
| Rest | Low level of activity, dolphins moving slowly (speed < 2 knots). Slow surfacings 3 to 4 times before diving for extended period of time |
| Travel | Persistent movement (speed >2 knots). Dolphins may meander, but still move in a general direction |
| Forage | Rapid energetic surfacings, frequent directional changes, fish chases and observations of dolphins with fish in mouths. Peduncle and tail-out dives common |
| Social | Petting, rubbing, mounting, chasing, genital inspections, play, displays and other physical contact between individuals |
| Nursing | Calf rostrum in contact with mammary slit for >2 s |
| Regular dive | Dolphin leaves surface by sinking at end of a breathing series without arching peduncle or raising flukes out of water |
| Tail out dive | Deep dive; flukes raised out of water |
| Peduncle dive | Peduncle arched at dive; flukes do not leave water |
| Porpoise | Rapid surfacing, whereby dolphin almost clears surface in horizontal position but ventrum remains on surface |
| Leap | Rapid surfacing, whereby whole dolphin clears water surface |

with swimmers in the water (TB 2 s), (4) many (3 or more) tourist boats and no swimmers (TB 3+ n), (5) many tourist boats with swimmers in the water (TB 3+ s). The data used for tourism category TB 0 comprised only data recorded during follows without tourist boats present or before tourist boats had arrived. During a focal follow, a focal female (and her associated group) could encounter no, few, or many tourist boats. A single follow could therefore be divided into several follow events. If a follow contained more than 1 tourism category, the data for the respective categories were analysed as separate follow events. All follow events shorter than 5 min were excluded from the analyses. All time periods when focal females were not sighted for >5 min and whose behaviour and associated data could not be recorded were also excluded from the analyses. When females were resighted, the data recordings were resumed and were added to the follow event. As the studies were carried out at the same time of the year in all 3 years the data were pooled for all 3 years. Several previous studies analysing the behaviour of dolphins have pooled data for focal groups or individuals across years in a similar way (Waples 1995, Mann & Smuts 1999, Lusseau 2003a).

**Group size and composition.** To test for differences in group sizes for 4 of the 5 tourist boat categories, (there were too few data points for TB 3+ n to include this category in the analyses) in the behavioural category 'travel' we used an analysis of variance (ANOVA in STATISTICA, StatSoft 1999).

We determined the proportion of calves in the population by comparing the estimated number of calves with the estimated total number of individuals in each group and calculating a mean for each year separately.

**Movement patterns.** We determined the proportion of time that focal groups spent in different movement patterns during the behavioural category 'travel'. We recorded the movement patterns by scan sampling the group during focal follows. The movement patterns were classified as directional (dolphins clearly heading in one direction) or non-directional (dolphins meandering or milling). During meandering, the movements of all dolphins were coordinated and the direction changed repeatedly. During milling, the movements of the dolphins were not coordinated and individual dolphins changed direction at almost every surfacing. In the analysis of the movement patterns we used the tourism activity categories TB 0, TB 2 n, TB 2 s and TB 3+ s. We analysed the impact of the number of tourist boats by comparing the proportion of time dolphin groups were engaged in non-directional movements for the 4 different tourist boat categories using ANOVA. We transformed the proportions with a modified Freeman-Tukey arcsine-transformation (Zar 1996) in order to meet the assumption of homogeneity of variances. Tukey's honestly significant difference (HSD) test (unequal n) was used as a post hoc test to examine differences between tourism categories.

**Behaviour.** During focal follows, detailed behavioural information was collected for the focal females (e.g. swim speed and nursing events). In order to analyse the data statistically, all behaviours were classified into 4 general categories: (1) rest, (2) travel, (3) forage, (4) social. However, if the focal female was not sighted for a maximum of 4 min and the next recorded behaviour was the same as that previously recorded, we assumed that the female had been engaged in the same behaviour during the intervening period. If the behaviour had changed between successive recordings the behaviour was assumed to have changed at the midpoint.

Behavioural budgets were calculated for each focal female by summarising the total time engaged in the 4 general behavioural categories during all follows, but separating time periods when no (TB 0), few (TB 2 n, TB 2 s) and many (TB 3+ n, TB 3+ s) tourist boats were present.

We analysed the proportion of time the focal females spent in different behavioural categories during follow events in a 2-way ANOVA with focal female and tourism activity as independent variables. If the variances were not homogenous, we used a Kruskal-Wallis analysis of variances. We used 4 of the focal females (CHA, HOK, JAE and SPE) and 3 tourism activity categories (no [TB 0], few [TB 2, TB 2 s], and many [TB 3+ n, TB 3+ s] tourist boats present). Female STN was excluded from this analysis as her data did not include sufficiently long follow events from all tourism categories. The proportions were transformed using a modified Freeman-Tukey arcsine-transformation (Zar 1996). Tukey's HSD test (unequal n) was used as a post hoc test to examine differences between tourism categories.

**Dive patterns.** We examined whether tourist activity affected the proportion of time focal females spent in different dive patterns during the behavioural category 'travel' (dive types given in Table 1). In this analysis we reduced the recorded dive types to 2 categories: regular dives and active dives. Active dives were peduncle, tail-out and porpoise dives. These dives are normally used when dolphins dive deeply, move actively or while foraging (e.g. Mann & Sargeant 2003). The dive patterns during the behavioural categories 'foraging' and 'socialising' were not investigated as dive types normally vary considerably during these behaviours and are therefore difficult to interpret in relation to disturbance. Dive patterns during resting were not analysed because the time periods that dolphins were observed resting during intense tourist activities were too short.

We analysed the proportion of time spent performing active dives per follow event for 3 focal females, i.e. CHA, JAE, and SPE, and 3 tourism categories, i.e. TB0, TB ≥ 2 n (TB 2 n and TB 3+ n), or TB ≥ 2 s (TB 2 s and TB 3+ s), using a 2-way ANOVA (StatSoft 1999) with modified Freeman-Tukey arcsine-transformed proportions (Zar 1996). Tukey's HSD test (unequal n) was used as a post hoc test. Females STN and HOK were excluded from this analysis as they did not have long enough follow events during travel for all tourism categories.

All analyses were made in STATISTICA (StatSoft 1999) or Microsoft Excel with a significance level of $\alpha = 0.05$.

## RESULTS

### Time subjected to tourist activities

All marked individuals identified in the study area, except one, were identified in dolphin groups subjected to tourist activities. Tourist boats were present during 45% (64 of 142) of all dolphin group sightings and in 80% of these groups nursing calves were present. Data were collected for a total 61.5 h of focal follows of the 5 focal females and their groups (Table 2).

The 5 focal females were found in groups subjected to tourist activities during 45% (on average) of the sightings compared to 36% for males (based on 8 positively identified males) and 37% for all marked individuals. During focal follows the females were accompanied 43% (on average) of the time by tourist boats. Swimmers were present in the water during 28% of the follow time.

### Group size and composition

There was no significant difference in focal group size between the different tourism categories ($F = 0.35$, df = 3, p = 0.79). The median group size for all encountered groups during 2000 to 2002 ranged between 8 and 13 and the mean proportion of calves ranged between 19 and 24% (Table 3).

Table 2. *Tursiops aduncus.* Number of focal follows (n), duration of total follow time and percentage of time accompanied by tourist boats (TB) for the 5 focal females investigated

| Focal female | Focal calf | n | Follow time (h min) | % with TB |
|---|---|---|---|---|
| CHA | MAR | 9 | 16 23 | 17 |
| HOK | HAY | 4 | 8 22 | 69 |
| JAE | JAM | 8 | 16 54 | 59 |
| SPE | JUP | 6 | 11 56 | 41 |
| STN | NDI | 4 | 7 58 | 30 |

Table 3. *Tursiops aduncus.* Median, minimum and maximum group size and mean proportion of age groups of Indo-Pacific bottlenose dolphins off south coast of Zanzibar. Old calves: small dolphins swimming in calf position next to adult dolphin (Mann & Smuts 1999). YOY: young-of-the-year dolphins <1 yr old (determined from relative size, surfacing behaviour and/or presence of foetal folds)

| Year | Group size | | Adults + juveniles (%) | Old calves (%) | YOY (%) |
|---|---|---|---|---|---|
| | Median | Min.–max. | | | |
| 2000 | 8 | 1–38 | 78 | 18 | 4 |
| 2001 | 11 | 1–50 | 76 | 21 | 3 |
| 2002 | 13 | 2–65 | 81 | 13 | 6 |

### Movement patterns

The movement patterns of focal groups differed significantly between categories of tourism (Table 4, Fig. 2). The proportion of non-directional movements increased significantly as tourist activity increased (Table 4). There was no significant difference in the proportion of non-directional movement for groups accompanied by few tourist boats compared to those accompanied by few tourist boats with swimmers, although there was a trend for more non-directional movements when swimmers were in the water (p = 0.07) (Table 4, Fig. 2).

### Behaviour

The data showed variation in the behavioural budgets of the 4 focal females (Fig. 3). The proportion of travel increased significantly as tourist activities

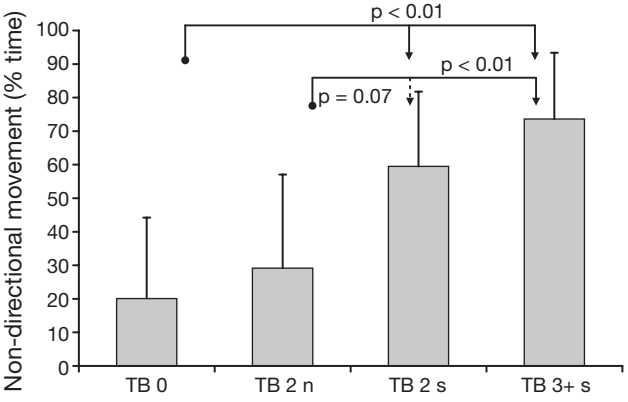


Fig. 2. *Tursiops aduncus.* Mean (+SD) time that focal groups made non-directional movements during travel without tourist boats (TB 0), and when accompanied by few (1 or 2) tourist boats and no swimmers (TB 2 n), by few tourist boats and swimmers (TB 2 s) and by many tourist boats and swimmers (TB 3+ s). ANOVA test performed on arcsine-transformed data

Table 4. *Tursiops aduncus.* Results of ANOVA tests on proportion of non-directional movements, travel and active dive patterns at different levels of tourist activity. TB 0: no tourist activity; TB 2 n: few (1 to 2) tourist boats, no swimmers; TB 2 s: few tourist boats with swimmers; TB 2: few tourist boats (with and without swimmers); TB 3+ s: many (3 or more) tourist boats with swimmers; TB 3+: many tourist boats (with and without swimmers); TB ≥ 2 n: tourist boats without swimmers; TB ≥ 2 s: tourist boats with swimmers. HSD: honestly significant difference

| | df | MS | *F* | p | Tukey's HSD: p | | | |
|---|---|---|---|---|---|---|---|---|
| Non-directional movements | (1-way) Arcsine-transformed | | | | | TB 0 | TB 2 | TB 2 s |
| Tourist activity | 3 | 0.76 | 11.40 | <0.001 | TB 2 n | 0.80 | | |
| Residual | 34 | 0.07 | | | TB 2 s | 0.005 | 0.07 | |
| | | | | | TB 3+ s | <0.001 | 0.004 | 0.53 |
| Travel | (2-way) Arcsine-transformed | | | | | TB 0 | TB 2 | |
| Tourist activity | 2 | 0.63 | 5.77 | < 0.01 | TB 2 | 0.046 | | |
| Female | 3 | 0.18 | 1.64 | 0.20 | TB 3+ | <0.01 | 0.36 | |
| Tourist activity × Female | 6 | 0.03 | 0.26 | 0.94 | | | | |
| Residual | 29 | 0.11 | | | | | | |
| Active dive pattern | (2-way) Arcsine-transformed | | | | | TB 0 | TB ≥ 2n | |
| Tourist activity | 2 | 0.30 | 4.94 | 0.02 | TB ≥ 2 n | 0.40 | | |
| Female | 2 | 0.14 | 2.31 | 0.13 | TB ≥ 2 s | 0.01 | 0.16 | |
| Tourist activity × Female | 4 | 0.01 | 0.17 | 0.95 | | | | |
| Residual | 18 | 0.06 | | | | | | |

increased (Table 4). There were no significant differences between females and there was no interaction between females and tourist activity (Table 4). The proportions of resting, socialising and foraging were not homogenous (despite transformation) for the focal females and were therefore analysed using a Kruskal-Wallis ANOVA. There were no significant differences between the proportion of resting ($H$ = 3.42, n = 41, df = 2, p = 0.21), foraging ($H$ = 4.31, n = 41, df = 2, p = 0.12) or socialising ($H$ = 0.44, n = 41, df = 2, p = 0.80) dolphins for the different tourism categories.

### Dive patterns

The proportion of time spent performing active dives, during travel, was significantly different for the different levels of tourism activity (Table 4, Fig. 4). The females made a higher proportion of active dives when subjected to swimmers (TB ≥ 2 s) than females not subjected to tourist activity (TB 0) (Table 4, Fig. 4). There were no significant differences between females and no interaction between females and tourist activity (Table 4). Further, there were no differences between presence and absence

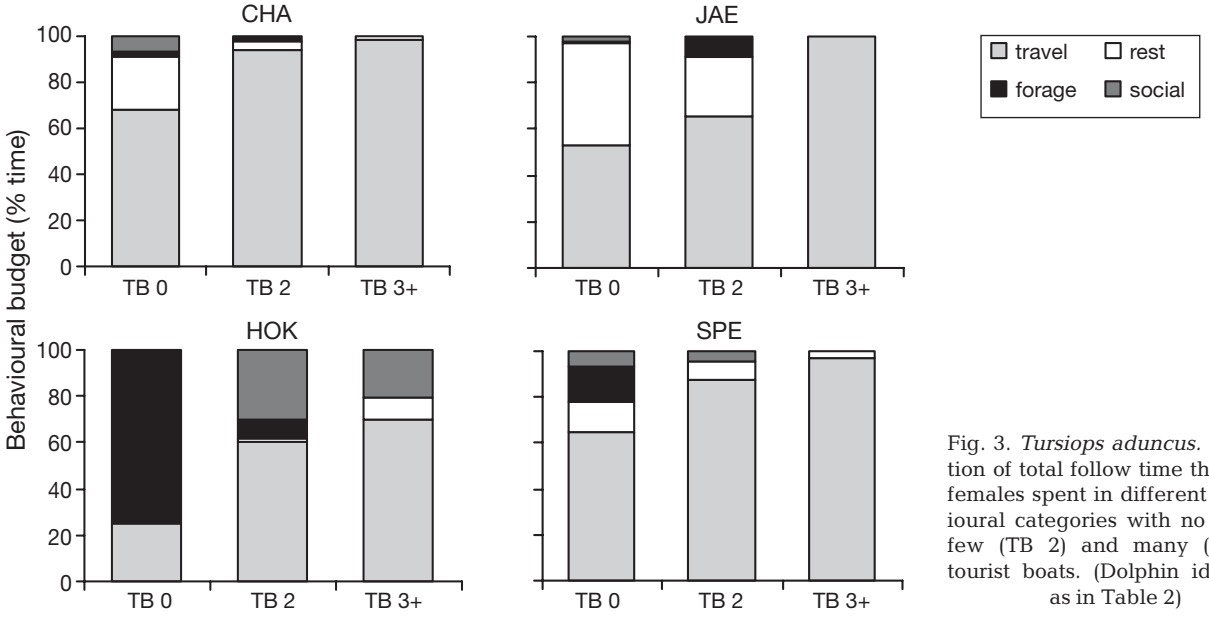


Fig. 3. *Tursiops aduncus.* Proportion of total follow time that focal females spent in different behavioural categories with no (TB 0), few (TB 2) and many (TB 3+) tourist boats. (Dolphin identities as in Table 2)

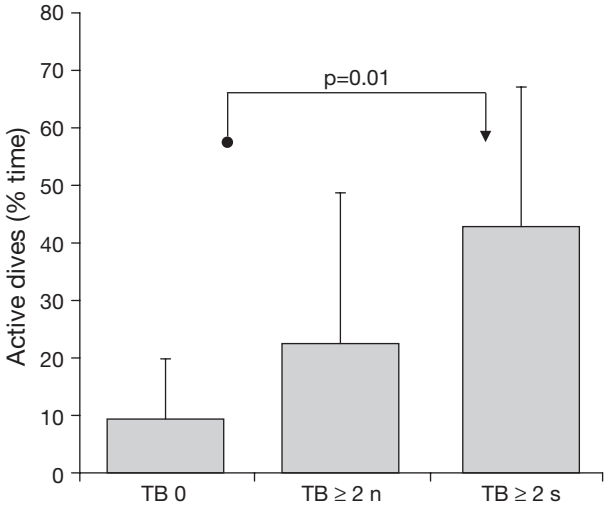


Fig. 4. *Tursiops aduncus.* Mean (+SD) time that focal females (here pooled) performed active dives during travel without tourist boats (TB 0), and when accompanied by tourist boats and no swimmers in the water (TB ≥ 2n) and by tourist boats and swimmers in the water (TB ≥ 2 s). ANOVA test performed on arcsine-transformed data

of tourist boats (without swimmers) or between tourist boats with and without swimmers (Table 4).

## DISCUSSION

Our data show that the behaviour, movement patterns and dive types of female bottlenose dolphins off the south coast of Zanzibar were affected by increased levels of tourism. In dolphin societies, the females have the main responsibility for caring for the calves. Like other social mammals, dolphins have a prolonged dependency period that extends beyond the first months of life when the calves are energetically dependent on their mothers. Calves of the bottlenose dolphin *Tursiops* sp. are nursed for 3 to 5 yr before they leave their mothers, usually when a new calf is born (Mann & Smuts 1998, Mann et al. 2000). It is possible that this prolonged nursing period has positive effects on survival, with calves obtaining cultural knowledge and social development (Grellier et al. 2003), in addition to learning their mothers' individual foraging techniques (Mann & Sargeant 2003, Sargeant et al. 2005). The survival of the calf is also dependent on the condition of the mother and her age, experience and foraging success (Mann & Watson-Capps 2005). The reproductive success of female bottlenose dolphins has been shown to be negatively correlated with the increased exposure to dolphin tourism vessels (Bejder 2005). In the face of all these facts, the consequences of disturbance, especially during important behaviours such as nursing and foraging, may be greater for females and calves than for other members of the dolphin society.

### Time subjected to tourist activities

A majority of the identified bottlenose dolphins are resident in the area off the south coast of Zanzibar (Stensland et al. 2006). Resident inshore populations may risk long-term effects from tourist activities, as the same individuals may be approached and disturbed day after day (Scarpaci et al. 2000). According to our analyses, all members of the population are subjected to interactions with tourist activities. Dolphin tourism occurs year round, with a peak season around Christmas and a low season during the rains in April to June, and generally occurs between 09:00 to 15:00 h, which represents about 50% of the daylight hours. Tourist activity mainly takes place within a small section (1.2 $km^2$) of the 26 $km^2$ core study area, and this is also the area where most of the bottlenose dolphin groups are encountered (Stensland et al. 2006). This part of the study area is primarily used by the dolphins for resting (30%) and foraging (32%) (Stensland et al. 2006). Such regular disturbance could result in decreased use of a preferred area and increased use of a suboptimal habitat, with unknown consequences for the dolphins. Changes in residency patterns by bottlenose dolphins have been found to be correlated with boat traffic and tourism in other geographical areas (Lusseau 2005, Bejder et al. 2006).

The focal females were subjected to tourist activity for almost half of the observation time (43% of the focal follow time and 45% of the group sightings). In comparison, 8 known males were encountered accompanied by tourist boats (averaging 36% of the sightings). This difference may be due to the fact that female bottlenose dolphins usually have smaller home ranges than males (Wells et al. 1987, Bearzi et al. 1997) and do not disperse far from their natal areas (Connor et al. 2000). However, the time that the focal females were subjected to tourist boats during follows may not be representative for the rest of the population. The tourist boats were likely attracted to the research boat, and hence detected the dolphins at greater distances than would have been the case had our boat not been present.

### Female behaviour and movement

The total proportion of time spent resting was higher without tourist boats present for most focal females, and the total proportion of travel increased for all

females as tourist activity increased (Fig. 3). The analyses also showed that females travelled for a larger proportion of time with increasing tourist activity (Table 4). This indicates that the dolphins try to avoid the tourist boats and possibly attempt to leave the area in which the tourist activities take place, as has also been shown at other study sites (Bejder et al. 2006). Females mainly nurse their calves during resting periods; nursing is less common during foraging and almost absent during socialising (J. Mann pers. comm.). An increase in the proportion of travel may therefore lead to less time for nursing and could potentially also affect the proportion of other important behaviours such as foraging. The mortality of calves is known to be high for bottlenose dolphins, e.g. in Shark Bay, Western Australia, 44% of the calves die before they are weaned (Mann et al. 2000). The condition of the mother as well as her experience and foraging success are factors that influence calf survival (Mann & Watson-Capps 2005). A reduction in time available for foraging and nursing may have a negative effect on the condition and survival of the calf. In Shark Bay, a negative correlation has also been found between reproductive success of females (defined as the number of offspring surviving to an age of 3 yr) and exposure to tourist boats (Bejder 2005). We were not able to measure calf survival in the present study, but nevertheless our findings should still raise concern.

Our results showed that focal female groups changed their movement patterns (during travel) when subjected to many tourist boats and presence of swimmers. When only a few (1 to 2) tourist boats were present, there were no significant differences in movement patterns, but when many tourist boats and/or swimmers were present, the proportion of non-directional movements increased (Fig. 2). However, our relatively small sample size precludes the assumption that a low number of tourist boats has no effect at all on the movement patterns of dolphins. Before any such conclusion can be reached, more data and more studies are required.

In accordance with our results, female killer whales *Orcinus orca* subjected to boat interactions increase their swimming speed and change to more erratic movement patterns to evade pursuing boats (Williams et al. 2002). These changes are comparable to models of behavioural responses for evading predators (Williams et al. 2002), whereby a successful escape involves simultaneous variation in turning radius and velocity (Howland 1974, Weihs & Webb 1984). Nowacek et al. (2001) showed that there is a higher probability of changes in swimming direction and inter-individual distance when boats approach dolphin groups erratically than when they approach at constant speed. Those tourist boats in Zanzibar that violated the guidelines often intersected the dolphins' course, approaching them in an erratic way, and allowing swimmers to jump into the water and/or chase the dolphins (E. Stensland pers. obs.). In addition to changed movement patterns we also found that the females altered their diving behaviour during encounters with swimmers. Altering dive patterns may be a direct response to a close distance threat. A higher proportion of active dives as well as changes in movement patterns may further indicate that the dolphins are trying to avoid tourist activities. In Doubtful Sound, New Zealand, female bottlenose dolphins *Tursiops* sp. increased their diving intervals when tour boat guidelines were violated, indicating that females alter their diving behaviour when they find a situation threatening (e.g. high risk of injuries) (Lusseau 2003b). Similarly, in our study, we observed that the dolphins instantly altered their dive types when tourist boats and/or swimmers behaved erratically (e.g. by swimmers jumping into the water close to the dolphins; authors' pers. obs.). The unpredictable behaviour of tourist boats and swimmers may lead to the dolphins regarding these as threats and induce erratic or avoidance behaviour (Lusseau 2003b).

Consistent short-term changes in behaviour could lead to long-term consequences for the dolphins if these frequently use more energetic surfacing patterns or are precluded from important behaviours such as foraging (Hastie et al. 2003). The present study was restricted to the behaviour of dolphins at the surface, whereas dolphins sometimes make quick and subtle changes in directional heading and inter-individual distances which could be difficult to observe at the water surface (Nowacek et al. 2001). Such small behavioural changes were not investigated in the present study and it is possible that dolphin tourism altered the dolphins' behaviours before these could be registered at the surface. We propose that future studies include some level of underwater observation as part of the data protocol.

## CONCLUSIONS AND RECOMMENDATIONS FOR DOLPHIN TOURISM OFF ZANZIBAR

Our results showed that dolphins' behaviour, movement and dive patterns are affected by tourist activities. Although data on the long-term effects of such changes on dolphin survival, reproduction and growth are lacking, the short-term changes described in this study should suffice to raise concern and warrant regulation and enforcement of existing guidelines for dolphin tourism.

There is considerable potential for whale and dolphin tourism in Zanzibar and other areas in the East

African region, given the accessibility of these animals and the many tourists that visit the region, primarily to encounter wildlife (Hoyt 2001). However, if such tourism is not controlled, intrusive behaviour of boats and swimmers could lead to increased avoidance by dolphins (Constantine 2001), leading in turn to reduced tourism potential. In conclusion, our results indicate that females dolphins spend more time travelling when tourist boats are present, and that the presence of a few (1 to 2) tourist boats (without swimmers) results in no detectable changes in their movement or diving patterns, provided that the boats are steered with care and do not interfere with the course of the dolphins (i.e. provided they follow the published guidelines). Further, the results show that the movement and dive patterns of dolphins are affected by the presence of many boats and swimmers. These short-term responses to tourist activity may, if continued, lead to the long-term consequence that the dolphins leave the area of dolphin tourism.

The apparent changes in dolphin behaviour in response to increased tourism may reduce the time available for important behaviours such as foraging and nursing, and this ultimately may reduce fitness at both individual and population levels. Hence, we believe it is important to stress the need for a precautionary approach and encourage that the guidelines of the Department of Fisheries and Marine Products, Zanzibar, issued in 2003, be implemented and complied with. However, the current guidelines do not restrict the number of tour boats and/or swimmers that may interact with a group of dolphins. The results of the present study show that such restrictions are necessary to create a sustainable dolphin tourism that has no significant negative impact on dolphin behaviour.

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