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Abundance of the Indo-Pacific bottlenose dolphin *Tursiops aduncus* off south-west Mauritius

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The abundance of Indo-Pacific bottlenose dolphins *Tursiops aduncus* off the south-west coast of Mauritius was estimated using capture-mark-recapture modelling. Over the past two decades this population has been subjected to ongoing anthropogenic disturbance in the form of extensive coastal development. Furthermore, daily dolphin tourism, which started in 1998, has rapidly increased in intensity. Identification photographs were collected between April 2008 and June 2010 from dolphins occurring along a 30 km length of coast where a dolphin tourism industry is concentrated. A total of 137 groups were encountered over 229 survey days. Over 5 000 photographs were taken, from which 35 individuals were considered to be sufficiently distinctively marked to use in mark-recapture analyses. The majority (85.7%) were seen more than once and resighting frequencies indicated a resident population. Three newborn calves were recorded during the study. Open population models produced abundance estimates of <100 individuals in the population. These results will be used to make recommendations for the conservation and management of this small, resident population, which is a valuable economic resource for the island but is currently under threat from high levels of human activity.

Keywords: dolphin watching, photo-identification, population estimate, residency

Introduction

Bottlenose dolphins *Tursiops* spp. are among the most widely distributed cetacean species (Connor et al. 2000). The common bottlenose dolphin *T. truncatus* is found in both coastal and offshore waters worldwide, whereas the Indo-Pacific bottlenose dolphin *T. aduncus* has a more restricted coastal range (Hale et al. 2000). The latter (hereafter referred to as the bottlenose dolphin) is found in the tropical and subtropical coastal waters of the Indian Ocean (including oceanic islands), the Red Sea, Persian Gulf, East and southern Africa, the western Pacific and throughout the Indonesian archipelago (Rice 1998; Hale et al. 2000). Bottlenose dolphins are reliant on nearshore waters, generally in water <30 m deep (Ross et al. 1987). They occur in coastal and estuarine environments and have been found in tidal creeks and in rivers (Connor et al. 2000; Fury 2009).

Within the Western Indian Ocean region, bottlenose dolphins are thought to be the most frequently observed coastal delphinids (Kiszka et al. 2009). They have been reported to inhabit the coastal waters of Mayotte (Kiszka et al. 2012), Réunion (Dulau-Drouot et al. 2008) and Madagascar (Rosenbaum 2003), as well as to have an almost-continuous distribution along the coast of East Africa and South Africa (Peddemors 1999; Amir et al. 2005; Stensland et al. 2006). With their inshore distribution, populations of *T. aduncus* have often become the target of tourism operations.

There is growing evidence that anthropogenic activities, particularly whale and dolphin watching, may interfere with and influence the activities and behaviour of whales and dolphins (e.g. Constantine et al. 2004; Lemon et al. 2006; Stensland and Berggren 2007). In addition, there is evidence that these animals will avoid areas of heavy boat traffic (Lusseau 2004; Bejder et al. 2006). Declines in relative abundance of bottlenose dolphins were reported from Shark Bay, Western Australia, following long-term exposure to boat-based dolphin-watching activity (Bejder et al. 2006). Theoretically, long-term disturbance of groups could lead to increased risk of injury, harassment and diminished reproductive capacity, directly affecting the viability of a population (Janick and Thompson 1996; Stensland and Berggren 2007).

The conservation status of the bottlenose dolphin population off Mauritius is unknown on account of paucity of data. Dolphin-watching activity is now a substantial contributor to the national economy (Daby 2003) and continues to grow. It is therefore increasingly important that basic population, distribution and movement data are available in order to monitor the impact of this human activity and others on the local dolphin population. Photo-identification techniques can be used to monitor the health and status of a population by estimating abundance and other demographic factors and, over time, the rate of population growth or decline (Hammond 2001). In addition, the same data can be used to investigate site fidelity (Connor et al. 2000; Sargeant et al. 2007), social structure (Smolker et al. 1992; Connor et al. 2000) and movement patterns (Stevick et al. 2002). Knowledge of these features is important to plan and manage populations that may be subject to environmental and/or anthropogenic pressures (Wilson et al. 1997; Chilvers and Corkeron 2003).

The current lack of information is hampering the development of urgently needed conservation management plans. This study aimed to determine the size of the bottlenose dolphin population inhabiting the south-west coast of Mauritius, and hence to provide a baseline from which long-term monitoring of this species can begin. In addition, a management plan to ensure the continued viability of this population can be established, while adding to regional cetacean knowledge.

Material and methods

Study area and survey procedure

Volcanic in origin, Mauritius (20°17' S, 57°33' E) is an oceanic island situated approximately 900 km east of Madagascar in the South-West Indian Ocean (Figure 1). The island is surrounded by a barrier reef on a narrow shelf, which then drops steeply into deeper water.

The study area encompassed some 30 km of coastline, extending offshore from the outer edge of the lagoon to the 100 m isobath, along the west coast of Mauritius between Le Morne (20°29'30″ S, 57°20'22″ E) in the south and Point Moyenne (20°14'33″ S, 57°22'49″ E) in the north (Figure 1). This area included bay (sandy-bottomed and sheltered) and reef-fringed, open-coast environments that included a peninsula (Le Morne), which generally had rougher conditions. The peninsula is positioned on the south-western corner of the island and is exposed to southerly and easterly winds.

Boat-based surveys were conducted year-round between April 2008 and June 2010 and 2–3 times a week when conditions were favourable (Beaufort sea state ≤3). There were two survey types, with the following objectives: (i) to monitor the behaviour and interactions of dolphins with dolphin-watching boats (behaviour survey); and (ii) to investigate cetacean diversity and distribution. The same area was covered for both survey types and photo-identification was always carried out. However, due to the amount of time spent with the focal group (defined below), photographic coverage was considered comprehensive only in the case of behavioural surveys, and only those photographs were used for abundance estimates. All surveys were conducted between 06:00 and 14:00, which encompassed the period when dolphin-watching boats operated. Surveys were abandoned if sea conditions and/or visibility deteriorated. Most trips were conducted using a 6.4 m rigid-hull vessel, powered by two 60 hp, four-stroke outboard motors.

Survey routes were not standardised because objectives varied, but were generally conducted from Black River Bay northwards, skirting lagoons and following the coast. If dolphins were not sighted by the time Point Moyenne was reached, the searching direction was reversed and continued southwards to Le Morne. Once dolphins were encountered, they were approached at low speeds to within approximately 50 m and the vessel was then steered parallel to the animals. Dorsal fin images were taken with a Canon EOS 450D digital camera equipped with a Canon 70–300 mm zoom lens and a Hoya Digital 58 mm/0.75 polarising filter. A conscious effort was made to photograph every individual in the group from both sides, independent of the size and distinctiveness of individual marks.

A record was made of the location (obtained using a hand-held Garmin eTrex Global Positioning System [GPS]), group size, composition (adult, juvenile and calf) based on size (Sargeant et al. 2007), and predominant behaviour of the focal group. This group was defined as consisting of those dolphins within a 100 m radius of each other that

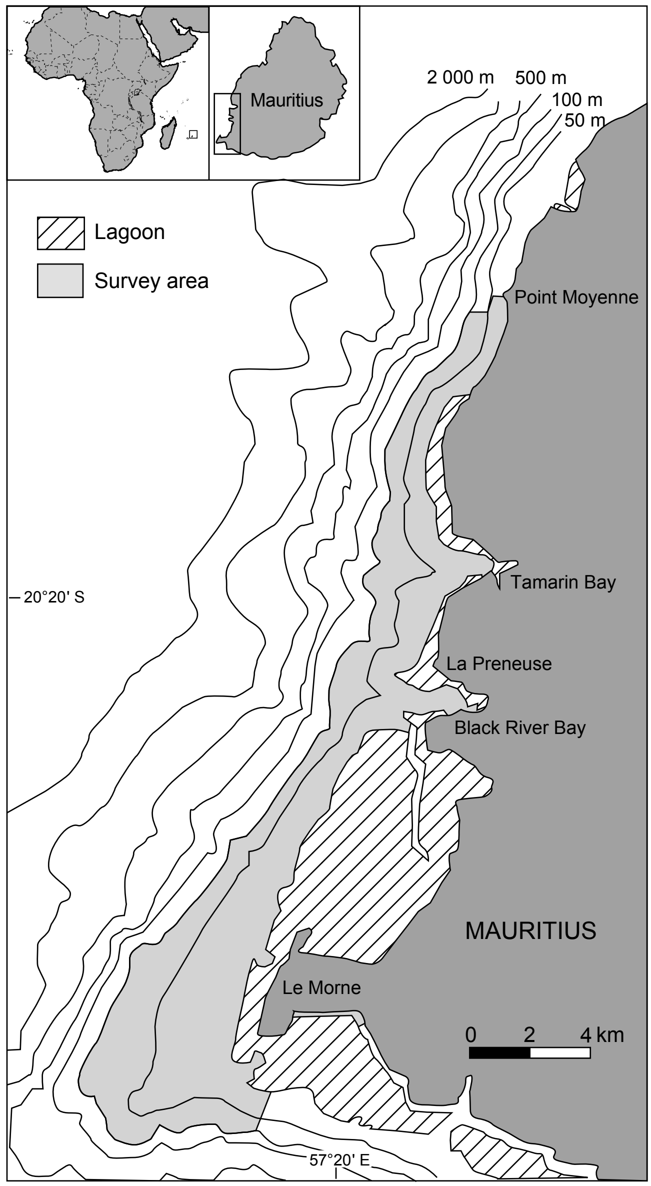

Figure 1: Map of Mauritius showing the position of the study area extending to the 100 m isobath on the south-west coast of the island, as well as locations mentioned in the text. The extent of the lagoon system is indicated

were involved in the same or similar activities and/or were interacting over time-scales sufficiently short that there were few changes in membership (Shane 1990).

Photo-identification

Capture-recapture studies, based on photo-identification, have proven to be a reliable method for estimating population parameters. The dorsal fins of small cetaceans acquire unique nicks and marks that allow researchers to differentiate between individuals (Würsig and Würsig 1977; Würsig and Jefferson 1990). Dorsal fin images were classified as poor, good or excellent depending on photographic quality (angle, clarity, contrast and proximity). Subsequently, all good- and excellent-quality photographs were examined manually for distinctiveness and scored (1–5) to identify individuals and develop an identification catalogue (Würsig and Jefferson 1990). Predetermined guidelines (Table 1) were used to score the individuals, with 1 being indistinct and 5 very distinct (adapted from Urian et al. 1999). Those with a distinctiveness score of 3–5 were included in mark-recapture analysis and are referred to hereafter as the 'distinctively marked individuals' (DMIs). Newly photographed fins were compared to those already in the catalogue to identify resightings or new animals.

The proportion of marked animals in the population (θ) was calculated by expressing the number of dorsal fins that could be reliably identified (DMIs) as a proportion of the total number of photographed fins with good or excellent photo quality.

Mark-recapture analysis

Mark-recapture analysis of monthly encounter histories of DMIs was performed using the software MARK (White and Burnham 1999). Given that the study area was a small part of the coast it was expected that animals would be moving in and out of it, and hence the population could not be assumed to be closed. Population parameters were estimated using the open-population POPAN parameterisation (Schwarz and Arnason 1996). POPAN assumes the animals identified during surveys are a component of a larger superpopulation. POPAN output includes the parameter N, representing the size of a superpopulation, defined here as the total number of marked animals available for capture at any time during the study (Nichols 2005). N_{Total} is the population including both marked and unmarked individuals.

Table 1: Guidelines for the scoring of individual mark distinctiveness of bottlenose dolphins photographed off the south-west coast of Mauritius, 2008–2010

Score	Description
1	No distinctive features
2	Small notch/es – too small and indistinct to be reliable or too similar to others
3	One small–medium-sized notch on dorsal fin
4	More than one small–medium-sized notch on dorsal fin
5	Very distinct – includes fins that can be immediately recognised by large notches, very unusual shape or half/no dorsal fin

Encounter histories were run through a number of models in POPAN, accounting for variation in capture probability (P), probability of an animal entering the study area population from the superpopulation (b) and apparent survival (φ). Each parameter can be set as time dependent (t) or constant (.). The sum of the probability of entry was set to 1 using the 'mlogit' function. Initial analysis involved testing the fully time-dependent model for goodness-of-fit (GOF) using the program U-CARE (Choquet et al. 2005) to validate model assumptions. Because no overdispersion of data was indicated, no adjustments were made (see Results). Additional tests for trap dependence (Test 2CT) and transience (Test 3SR) were also run. Sampling occasions were defined as months, and gaps in the sampling were accounted for by adjusting the time intervals in the program settings, resulting in 21 sampling occasions.

A total of eight models were constructed and compared. Model selection was based on the corrected Akaike's information criterion (AIC_c), in which models are ranked on both the quality of fit (deviance) and the precision (number of parameters) (Lebreton et al. 1992). The difference between the best model and subsequent models is represented by ΔAIC. A model with a ΔAIC value of <2 is considered to have substantial empirical support (Burnham and Anderson 2002). The estimate of N from mark-recapture analyses represents the marked population. To determine the total population (N_{Total}), estimates were adjusted to account for the unmarked animals by dividing N by the proportion of marked animals.

The variance for the estimated total population size was derived using the formula of Williams et al. (1993):

$$\text{var}(N_{\text{Total}}) = N_{\text{Total}}^2 \left(\frac{\text{var}N}{N^2} + \frac{1-\theta}{n\theta} \right)$$

where n is the total number of dorsal fins from which θ was calculated. Log-normal 95% confidence intervals were calculated with a lower limit of $N_{\text{Total}}^{L} = N_{\text{Total}} / C$ and an upper limit of $N_{\text{Total}}^{U} = N_{\text{Total}} \times C$, where:

$$C = \exp\left(1.96 \sqrt{\ln\left(1 + \left(\frac{\text{SE}N_{\text{Total}}}{N_{\text{Total}}}\right)^2\right)}\right)$$

(Burnham et al. 1987).

Resighting patterns

Residency was estimated using the temporal distribution of the resightings of individuals (sighting frequency). Resightings of individuals had to be a minimum of 24 h apart to be used in residency analysis.

Results

Between April 2008 and June 2010, 137 groups of bottlenose dolphins were recorded during 229 days of surveys of either dolphin behaviour or cetacean diversity and distribution (Table 2). Groups were encountered in every month of the study and ranged in size from 1 to 18 individuals, with a mean group size of 5.5 individuals (SE 0.3). Of these, 70 groups were encountered on 59 behaviour survey

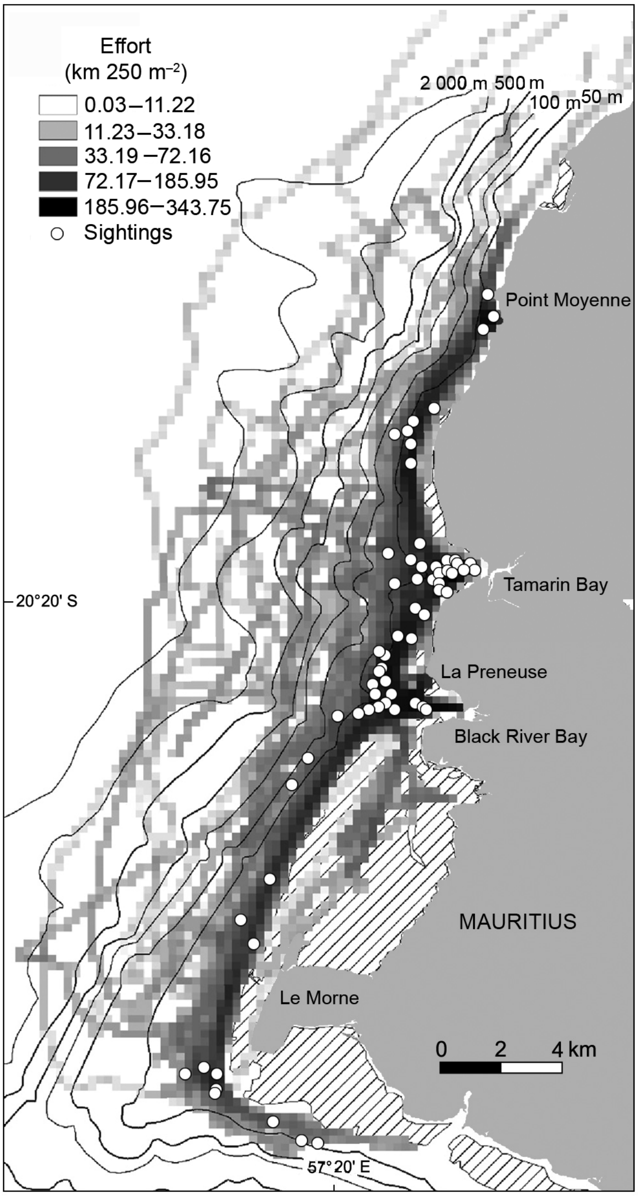

Figure 2: Distribution of effort and sightings of bottlenose dolphins during behaviour surveys conducted between April 2008 and June 2010. Effort is expressed as kilometres of search effort in each 250 m² grid square shown

days (Figure 2). Photo-identification data only from these behaviour surveys were used for abundance analyses.

Photo-identification and proportion of animals identifiable

Over 3 000 dorsal fin images were extracted for grading and analysis. Analysis of all excellent and good quality photographs (n = 1 213) indicated that the proportion of animals that could be reliably identified over time was 0.61.

In total, 54 adult and juvenile animals were identified throughout the study period and catalogued. Of these, 35 adults were DMIs and hence were considered useful for population analysis. The cumulative number of identified individuals (rate of discovery) slowed after the first year of the study. The rate of discovery of new individuals from April 2008 to March 2009 was 2.75 (SE 0.73) animals per month, with 94% of recognisable bottlenose dolphins identified by the end of this period. The discovery rate then decreased to 0.13 (SE 0.09) per month for the following 15 months (Figure 3).

Resighting patterns

Of the 35 DMI bottlenose dolphins, most (n = 30, 85.7%) were sighted more than once. Five individuals were sighted only once, whereas one individual was sighted 17 times (Figure 4). The mean number of sightings per individual

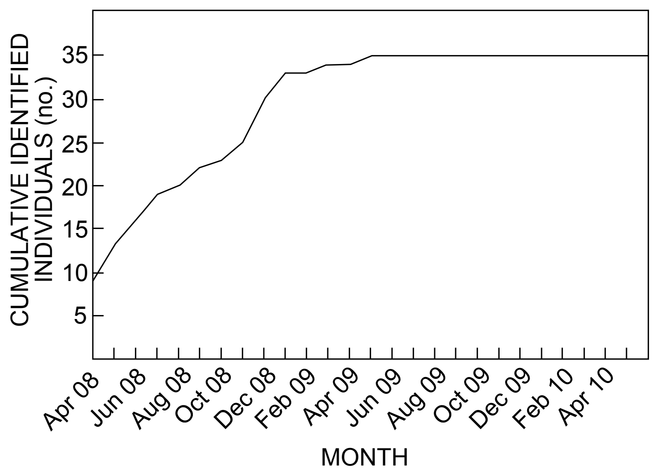

Figure 3: Rate of discovery for newly identified bottlenose dolphins off south-west Mauritius for the period April 2008–June 2010

Table 2: A summary of survey effort between April 2008 and June 2010, off the south-west coast of Mauritius. Summary includes: (A) total number of surveys conducted including both cetacean diversity surveys and bottlenose dolphin behaviour surveys; (B) total number of bottlenose dolphin groups seen during all surveys; (C) number of bottlenose dolphin behaviour surveys conducted; and (D) number of bottlenose dolphin groups seen during behaviour surveys

Survey period	Number of months	(A) Total survey days	(B) Total bottlenose dolphin groups	(C) Behaviour survey days only	(D) Bottlenose dolphin groups on behaviour survey days
April 2008–March 2009	12	90	68	35	42
April 2009–March 2010	12	115	52	22	25
April 2010–June 2010	3	24	17	2	3
Total		229	137	59	70

was 5.2 (SE 0.6), almost half (n = 17, 48.6%) were seen on five or more occasions and six individuals (17.1%) were seen 10 or more times.

Model selection and abundance estimates

The GOF test was not significant (χ^2 = 46.50, df = 46, p = 0.45) indicating good fit of the data ($\hat{c}$ = 1.01), so no adjustments were made. However, Test 3SR was significant, indicating some transience (χ^2 = 4.78, df = 5, p = 0.44; statistic for transience: z = 2.16, p = 0.03), whereas Test 2CT did not show trap dependence (χ^2 = 11.79, df = 17, p = 0.81; statistic for trap-dependence: z = –1.36, p = 0.17). The model that best explained the data included constant survival and probability of capture whereas the probability of entry varied with time ($\varphi.P.b_t$) (Table 3). All other models had ΔAIC_c values >2. One of the models did not reach numerical convergence ($\varphi.P_t\,b.$)

The total population estimate (N_{Total}) based on the population estimate from model ($\varphi.P.b_t$) and the proportion of unmarked individuals (0.61), was 58.67 individuals (95% CI 54.31–63.38) (Table 3). This model gave an apparent monthly survival of 0.99 (SE 0.01) and capture probability of 0.23 (SE 0.02).

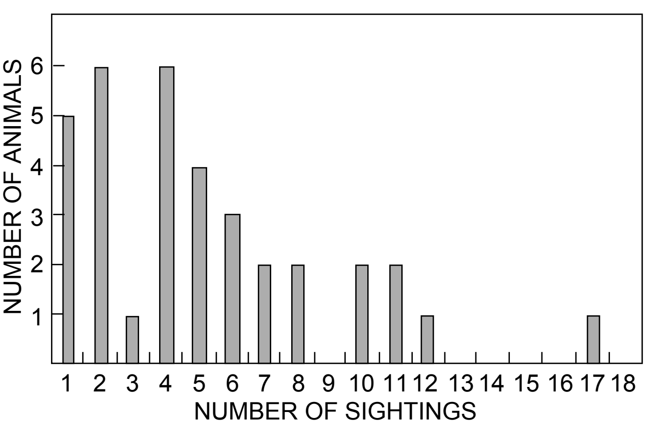

Figure 4: Sighting frequencies for distinctively marked individual bottlenose dolphins (n = 35) during the period April 2008–June 2010

Discussion

The first abundance estimates of bottlenose dolphins in Mauritian waters are presented in this study. The asymptotic discovery curve indicates that the sampling effort was sufficient to identify most of the identifiable individuals that use the region of the coast under study. The low number of identified animals, high resighting rate and low proportion of animals seen only once suggests that the population is small and is using a restricted area of coast, albeit larger than the current study area.

For most populations of coastal delphinids/bottlenose dolphins, an abundance estimate of <100 individuals is usually considered small, although several other populations of a similar size have been reported (e.g. Möller et al. 2002; Fury and Harrison 2008; Pusineri et al. 2014). These estimates are, however, generally relevant to populations in more restricted environments such as lagoons, bays or estuarine systems, although they cover a similar-sized area to that in our study. Given that there are no previous data on the bottlenose dolphin community in south-western Mauritian waters, our results can be used as a baseline from which to monitor future population trends, in the light of possible vulnerability of the population to anthropogenic disturbances.

Of the few studies of bottlenose dolphin abundance around the islands of the Western Indian Ocean, all have reported small resident populations. In Zanzibar, Stensland et al. (2006) estimated a resident population of 136–179 individuals inhabiting their 26 km^2 study area. This estimate is considerably larger than that reported here (59 individuals), yet the area is less than half the size. In contrast, in the large lagoon of Mayotte (1 500 km^2), abundance was estimated at <100 animals (Pusineri et al. 2014). In more open environments, such as the south-east coast of South Africa, populations are substantially larger, with estimates numbering in the thousands (28 482 [95% CI 16 220–40 744]) (Phillips 2006; Reisinger and Karczmarski 2010). These studies illustrate the variety of habitats used by this species of dolphin but also the influence of habitat on population size. In our study, the small population probably reflects both the size and the isolation of the

Table 3: Open-population model selection for marked population estimates (N) of bottlenose dolphins. The three parameters estimated in the models are apparent survival (φ), capture probabilities (P) and recruitment (b). Models were adjusted to allow each parameter to remain constant (.) or vary with time (t). The lowest AIC_c value indicates which model best explains the data. The difference in AIC_c scores from the best model (ΔAIC_c) and the total number of parameters (NP) are shown, as are standard error (SE) and 95% confidence intervals (CI) on population estimates. The precision of the estimates for identifiable individuals is measured by the coefficient of variation (CV). The total population estimate (N_{Total}), that accounts for unmarked animals, is given

Model choice				Identifiable individuals				Total population		
Model	AIC_c	ΔAIC_c	NP	N	SE	CV	95% CI	N_{Total}	SE	95% CI
$\varphi.P.b_t$	638.98	0.00	23	35.79	1.41	0.04	35.08–43.25	58.67	8.26	54.31–63.38
$\varphi.P_t b_t$	646.64	7.65	43	35.31	1.07	0.03	35.01–42.14	57.89	8.02	54.55–61.43
$\varphi_t P.b_t$	695.06	56.08	42	36.93	2.99	0.08	35.22–51.84	60.54	9.54	51.67–70.93
$\varphi_t P_t b_t$	741.39	102.41	62	35.00	0.00	0.00	35.00–35.00	57.38	7.75	57.38–57.38
$\varphi_t P_t b.$	13 250.29	12 611.31	43	35.00	0.00	0.00	35.00–35.00	57.38	7.75	57.38–57.38
$\varphi_t P.b.$	20 324.37	19 685.39	23	35.00	0.00	0.00	35.00–35.00	57.38	7.75	57.38–57.38
$\varphi.P.b.$	20 668.29	20 029.31	4	80.17	12.30	0.15	61.74–111.29	131.43	26.87	97.46–177.23
$\varphi.P_t b.$	No numerical convergence									

island of Mauritius. Habitat availability, prey availability and distribution, and the presence of predators, both as a direct threat but also as competition for prey, are all factors that influence the size of a population (Heithaus and Dill 2002).

Open-population models, such as that used here, yield estimates of the total number of animals available at any time during the study (Nichols 2005). The study area encompassed approximately 20% of the coastline of the island. A number of bottlenose dolphins were opportunistically photographed outside the study area. This included at least two identified animals that were using almost the entire length of the west coast, an estimated 70 km of coastline (Webster 2012). It is plausible that these particular animals were not the only ones moving similar distances. Identified individuals from Algoa Bay, South Africa, have been photographed as far away as Plettenberg Bay, a distance of some 300 km, demonstrating their dispersal capability (Reisinger and Karczmarski 2010). It is possible that individual bottlenose dolphins in Mauritian waters move right around the island. Given their average travel speed of 5 km h^{-1} (Fish and Hui 1991), it would be possible for the dolphins to circle the island in 2–3 d, which would influence resighting frequencies and would suggest that the population estimate may apply to between half and the entire island.

Mark-recapture assumptions

Mark-recapture estimates have an inherent imprecision as it is difficult to fulfil all the required assumptions for accuracy (Pollock et al. 1990). The estimation of population abundance requires several assumptions, which, if violated, may result in bias (Parra et al. 2006). Assumptions include: (i) mark recognition and no mark loss; (ii) equal probability of capture and survival; (iii) no behavioural response to ‘capture’; (iv) no permanent emigration; and (v) instantaneous sampling. Goodness-of-fit tests, along with a number of set methods, were used to validate the assumptions and obviate as many biases as possible. Notches on dorsal fins are considered to be long-lasting (Wilson et al. 1999) and hence mark loss was assumed to be negligible. Surveys were defined as ‘days’ and were then pooled into monthly sampling occasions for analyses. This ensured that the entire study area was covered during each sampling period. Although attempts were made to photograph every animal regardless of markings, heterogeneity of capture probability was unavoidable because of differences in individual behaviour (Hammond 1986). Additional violations of equal capture probability were minimised by: (i) using photographs from behaviour surveys only; (ii) careful examination of techniques for image quality and distinctiveness; and (iii) ensuring that only one person was responsible for grading and matching images. The test for a behavioural response to ‘capture’ was insignificant, as expected, because photo-identification does not involve handling of the animal (Parra et al. 2006). However, some transience was detected, indicating heterogeneity of capture probability that could have resulted in a downward bias of population estimates.

Management and conservation

The small population estimate for bottlenose dolphins off south-west Mauritius has substantial management implications because of the intense anthropogenic activity on this part of the coast. Since 1998, the whale- and dolphin-watching industry in Mauritius has grown, in terms of tourists participating, by an average of 56% annually (O’Connor et al. 2009). In 2009, the Mauritius Marine Conservation Society (MMCS) recorded 64 operators offering dolphin-watching and swim-with-dolphins activities. Most companies use more than one boat and trips are offered every day of the year with, on average, 39 boats operating each day (MMCS unpublished data).

Studies of small, coastal cetacean species have indicated that a population size of <100 individuals carries increased probability of extirpation from natural and anthropogenic effects (Thompson et al. 2000; McCarthy and Thompson 2001; Traill et al. 2007). This applies especially to species that have a naturally low reproductive output, such as bottlenose dolphins (Wells 1991). Natural (disease outbreaks, extreme weather events) and human-induced habitat degradation and environmental changes (e.g. overfishing or global climate change) can cause changes in demography and hence reduce the dolphin population further (Caughley and Gunn 1996; Frankham et al. 2002; Lowe et al. 2004). These risks are increased further when the population is subjected to intense human activity (see below). The low abundance estimates for the bottlenose dolphins under study, together with their dependence on the coastal habitat, raise concerns for their long-term survival in Mauritian waters.

Human activities make the coastal environment one of the most at risk of degradation (McIntyre 1999). Dolphins that rely on such habitats are among the most threatened cetaceans and most in need of conservation management (Thompson et al. 2000; DeMaster et al. 2001). Over the past 25 years there has been considerable growth in the human population and the tourism industry in Mauritius, particularly along the coast (Daby 2003, 2006a). This development has proceeded with little environmental awareness and a lack of environmental impact assessments (Ramjeawon and Beedassy 2004). Subsequently, the productivity of the reef habitats has been negatively affected (Daby 2006a, 2006b; Sobhee 2006). In addition, activities such as fishing and snorkelling and an increase in boating have resulted in the degradation or destruction of large areas of reef and lagoon. These areas are important breeding and feeding grounds for numerous marine species (Sobhee 2006; Sato et al. 2008), many of which are likely to be prey of bottlenose dolphins. Overfishing has been shown to impact on dolphin populations (e.g. Bearzi et al. 2006). In Mauritius, degradation of the lagoon and nearshore habitats, together with overfishing, could have serious impacts on the local dolphin population. Further, the types of marks on the dorsal fin and body of individuals under study indicated likely interactions with local fisheries (Kiszka et al. 2008; Mansur et al. 2012).

The continued growth of human populations in coastal areas has led to a need for improved management to decrease anthropogenic pressures on the associated ecosystems. This includes an urgent need for the introduction and enforcement of appropriate management of dolphin- (and whale-) watching activities. Whereas legislation controlling dolphin watching was introduced in March

2013, there is limited enforcement and further measures are needed. One potential mechanism could be to designate coastal areas with varying levels of protection and controlled use. Marine protected area networks have been used successfully in many parts of the world for the conservation of cetaceans (UNEP-MAP RAC/SPA 2011). As cetaceans are highly mobile, a network of protected areas that covers critical habitats and has different degrees of controlled activity is thought to be more effective than individual sites (Hoyt 2005; Clark et al. 2010). Mauritius relies heavily on the marine environment for its revenue (Daby 2003), and hence the protection of bottlenose dolphins would not be the only motivation for designating protected areas. The south-west coast is very popular for tourism activities such as diving, snorkelling and fishing. The introduction of marine protected areas/no-take zones needs to be considered seriously to ensure the continued viability of these activities.

With the results of our study, it is now possible to begin monitoring the population for fluctuations. Mark-recapture studies should be continued and the surveyed area expanded to include additional sites around the island. Further work regarding movement patterns, habitat preferences and the elucidation of population structure is required. The resulting data will help determine spatial distribution of the bottlenose dolphins, the range over which identified individuals move, critical habitats and accurate total abundance estimates for the island. While such work is ongoing, the implementation of management plans should not be delayed, particularly because the population is small and changes in population size and structure can take years to become evident.

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