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Abundance and Distribution of Indo-Pacific Humpback Dolphins (*Sousa Chinensis*) in the Shimoni Archipelago, Kenya

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Abstract—This paper provides the first record of the distribution of Indo-Pacific humpback dolphins (*Sousa chinensis*) and an estimate of their abundance within the Shimoni Archipelogo, Kenya. Boat-based surveys (n=167) were conducted during 2006, using photographic identification (photo-id) techniques and mark-recapture methods for open populations (Jolly-Seber model) to estimate the abundance of humpback dolphins inhabiting the Wasini Channel (104: 95% CI 67-160). Their distribution was mapped within a 50% isopleth of encounter locations in the Wasini Channel, identified as the core habitat area. Most (97%) sightings were recorded outside the Kisite-Mpunguti Marine Protected Area (KMMPA). Further research is required but it is likely that the protection afforded by the Kenyan Wildlife Service (KWS) in their management of the KMMPA needs to be expanded to the Wasini Channel to ensure protection of the habitat of this small group of humpback dolphins.

INTRODUCTION

Indo-Pacific humpback dolphins (*Sousa chinensis*) inhabit coastal waters of the Indian and Western Pacific Oceans (Ross *et al.* 1994). The abundance of inshore cetaceans along most of the world's coastline is unknown (Leung & Leung 2003) and information on African humpback dolphin populations is mostly limited to South African waters (Barros *et al* 1991; Cockcroft 1990; Karczmarski *et al.* 1998, 1999, 2000), coastal waters around Zanzibar (Stensland *et al* 2006; Amir *et al.* 2002) and Mozambique (Guissamulo *et al.* 2004). Due to

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their proximity to the coast, humpback dolphins are more at risk from human interference and, consquently, are among the most threatened species of cetaceans in need of management intervention to reduce anthropogenic threats (Thompson *et al.* 2000; Parra *et al.* 2006). However, effective management of Marine Protected Areas (MPA) requires information on the population abundance and distribution of key species (Hooker *et al.* 1999; Wilson *et al* 1999; Ingram & Rogan 2002; Parra *et al.* 2006). Increasingly, population size estimates based on mark-recapture analysis (White *et al* 1982; Hammond 1990) are being applied to cetaceans using photographic identification of animals' natural markings (Wursig & Wursig 1977; Wells & Scott 1990; Williams *et al.* 1993; Wilson *et al.* 1999; Karczmarski *et al.* 1999; Ingram 2000 etc). Dorsal fin nicks persist for many years without change (Wells & Scott 1990; Parsons 2001) and photo-identification of these nicks have repeatedly proven to be a powerful and effective tool in estimating population abundance (Ingram 2000).

Animal sightings can be plotted and investigated using analytical tools such as Geographical Information Systems (GIS) and distribution, habitat heterogeniety and critical areas have been successfully identified in a wide range of papers using GIS (see e.g. Wilson *et al.* 1999, Parra *et al.* 2006, Stensland *et al.* 2006). Other analytical tools, such as the home-range software Calhome (Kie *et al.* 1994) or the animal movement analysis extension for GIS (Hooge & Eichenluab 2000), can be used to highlight preferred habitat by dolphins using harmonic mean transformation of sightings, which creates a non-parametric gridding system that plots isopleths of dolphin distribution (Ingram 2000, Ingram *et al.* 2002).

The Kisite-Mpunguti Marine Protected Area (KMMPA) and the marine wildlife it contains constitute an important tourist attraction and, as a result, an important resource for Shimoni and the surrounding communites. It remains one of the highest ranking Marine Parks within Kenya, both in terms of tourist numbers and revenue generated (Emerton & Tessema 2001). This paper presents the first known estimates of abundance and residence patterns of humpback dolphins in the Shimoni Archipelago of East Africa. This information will contribute towards the long-term management strategies for the KMMPA, as well as ensuring sustainable tourism and conservation within the region.

MATERIAL and METHODS

Study area and field methods

The KMMPA (Kisite Marine Park: 39.362° E; 4.714° S) within the Shimoni Archipelago covers an area of 39 km². Dolphin watching companies from Shimoni almost daily travel the 1.5 km wide Wasini Channel to the KMMPA (Emerton & Tessema 2001).

Dolphins were surveyed along the shore by boat in a ca 80 km² area south of the Shimoni Achipelago, encompassing the Wasini Island and parts of the marine park and the marine reserve (Fig. 1). Since sea conditions south of the Wasini channel often deteriorated quickly (beaufort state ≥ 3), the weather-protected Wasini channel (Study Area A, Fig. 1) was surveyed more intensely than the rest of the study area (Study Area B). Surveys within Study Area B were opportunistic and weather-dependent. Interestingly, local fishermen also reported more humpback dolphin sightings in the channel. Hence, increased sampling effort in this area was also assumed to increase our chances to sight the dolphins.

The survey was conducted throughout 2006 during four ten-week periods separated by three-week breaks to analyse data. We used a 5.8 m catamaran powered by two 85 hp Yamaha two-stroke engines. In addition, a 6.2 m vessel powered by a 40 hp Yamaha two-stroke engine was used as back-up. All surveys were conducted in calm sea conditions (i.e. Beaufort sea state ≤ 3) between 07:00 and 12:30 to optimise the humpback dolphin identifications.

Once a dolphin school was sighted, it was approached slowly to within ten metres to record its location, identify the species, estimate the group size and take photographs. The latitude and longitude of dolphin encounters were recorded using a

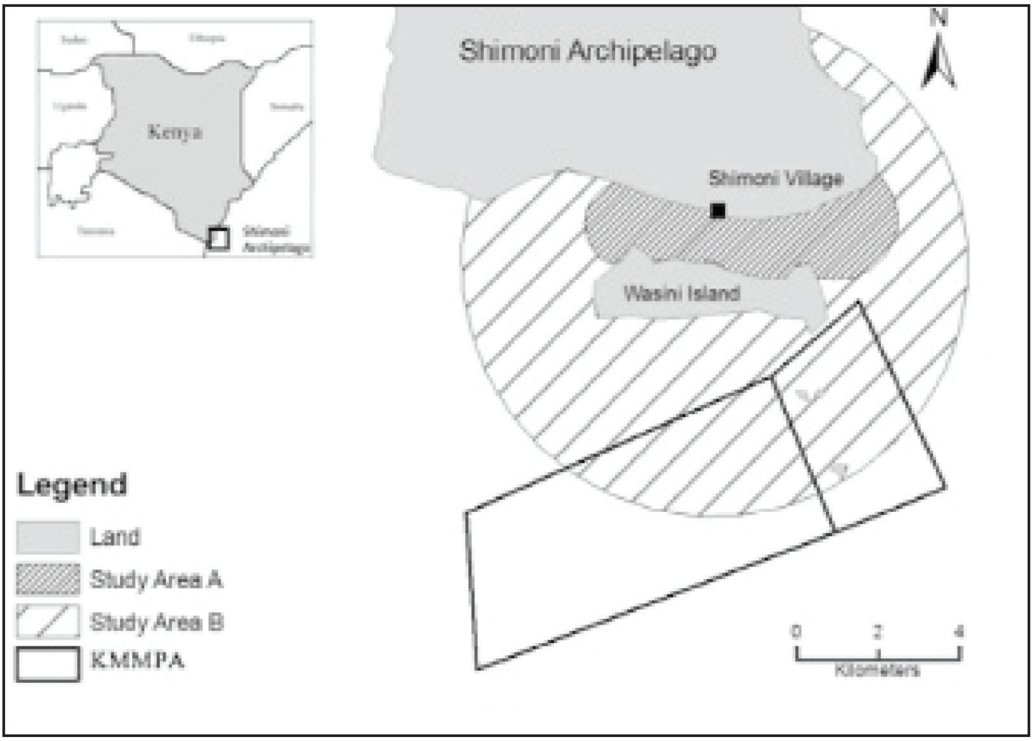

Figure 1. Humpback dolphin study area in the Shimoni Archipelago, showing Study Area A (11 km^2) in the Wasini Channel and Study Area B (80 km²).

handheld Garmin Etrex Global Positioning System (GPS). Photographs were taken using a Canon EOS 350D digital camera and a 75-300 mm lens and subjected to the photo-ID methodology of Parsons (2001). Both the left and right flanks of every individual within the group were photographed, where possible.

Definitions

A dolphin group was defined as any aggregation of more than one dolphin of any age class, within visual range of the survey group (Karczmarski *et al.* 2000). The term "sighting" was applied to both groups and solitary animals. Two age classes were distinguished: adult and calf. Adults were described as robust in form, approximately 2.5 m in length with a pronounced dorsal hump. Calves had foetal folds, a pale skin, and stayed close to a larger animal, presumably the mother (Ingram 2000). For the purpose of this study, individuals that could be classified as juveniles (approximately 2 m, visibly less robust than adults) but often swam independently were considered adults for mark-recapture analysis.

Photographic identification and mark-recapture analysis

All photographs were graded into categories which ranged from 0 (poor quality, distant, out of focus) to 3 (perfect photo-ID shots). A photo-ID catalogue was then created in which individuals were given a unique identification number. This is an important procedure, allowing for future re-sighting of individuals on a long-term basis (Parsons 2001). In order to reduce the problem of making false positive matches, poorly marked grade 1 animals were excluded from the mark-recapture anaylsis, with only identified adults of both grade 2 and 3 being used. Since the acquisition of dorsal fin nicks and other long-lasting marks in cetaceans is cumulative (Wursig & Wursig 1977), identified calves were not used in the mark-recapture analysis to avoid bias in re-idenitification.

To ensure that the surveyed area was representatively covered, mark-recapture analysis was only undertaken on photographs taken in the Wasini channel (Area A, Fig. 1). This 11 km² area is comparatively sheltered (as explained above) and the size of the area allowed each boat survey to cover the entire study area within the channel. This ensured that the search effort of each boat survey was nearly uniform throughout study area A, a requirement for mark-recapture anaylsis (White *et al.* 1982).

A matrix of mark-recaptured individuals was then created. The computer program MARK (White & Burnham 1999) was used to estimate the number of the humpback dolphins in study area A. This software has previously been used to estimate the size of several dolphin populations around the world (Williams *et al.* 1993; Wilson *et al.* 1999; Ingram 2000). Open population models permit birth, death and migration proccesses to operate (White *et al* 1982). The Shimoni dolphin population appeared to be demographically open throughout the sampling period as new individuals were identified throughout the study, and the distribution of sightings (Fig. 2) suggested that dolphins spent time outside the study area. Therefore open population analysis (Jolly 1965, Seber 1965) was used in the MARK program to estimate their abundance. The Akaike Information Criterion (AIC) was used to select the appropriate model as recommended by Burnham *et al* (1995) (AIC results not shown).

A subset of data was selected for the mark-recapture analysis using an eight month sampling period between February and September 2006, which was the period of maximum encounters of humpback dolphin.

Abundance estimates derived from MARK were based on the sighting data of identified adult dolphins only. This was then corrected following Karczmarski *et al.* (1999) to include calves. The final estimate took into account the ratio of identified adults and the mean proportion of adults in a sighting of humpback dolphins, calculated according to the formula:

Abundance estimate = (X/Y)/Z

Where X = estimate of the number of adults calculated using MARK, Y = ratio of identified adults and Z = mean proportion of adults in a group of humpback dolphins. This is an estimate of total abundance, including calves.

Figure 2. Humpback dolphin sightings (•) in the Shimoni Archipelago with 50% and 90% isopleths.

Distribution of encounters

Humpback dolphin sightings were mapped using GIS Arcview 9.3 (ESRI Inc). The Kernel method (Worton 1989) was used to transform encounter locations into activity densities with varying probabilities (e.g. 50% and 90% isopleths), providing kernel contours of habitat selection (Larkin *et al.* 1994, Ingram 2000, Ingram *et al.* 2002). In this case, the package adehabitat (Calenge 2006) was used to estimate the 50% and 90% isopleths of humpback dolphin sightings in study areas A and B.

RESULTS

Dolphin abundance

In total, 167 boat-based surveys were carried out in 2006, humpback dolphins being encountered on 33 occasions. All the boat surveys covered study Area A and 55 included opportunistic searches in study area B. An average of 14 boat surveys were carried out per month throughout the year, with relatively few surveys being conducted in the months of January, April and October. The sighting rate (individuals per hour of effort) for humpback dolphins in 2006 was 1 encounter per 19.3 hours of search effort, with a median number of 5 individuals sighted per group. The eight-month subset of data that yielded the bulk of sightings comprised a total of 144 boat surveys of study area A and was used to calculate the abundance of humpback dolphins (Fig. 2). Of these, 23 individual humpback dolphins were identified, the majority (84%) being adults (n=19). The sighting frequency of individual adult humpback dolphins per encounter ranged from 1 to 13. A relatively small number of these individuals (10.5%) were seen only once, while the majority of individuals (68.4%) were re-sighted frequently (more than five times during different periods of the year). The discovery curve (Fig. 3) began to level off within the first month of surveys and, once this had been achieved, the increase of animals identified over time was at the rate of 0.5 individuals per month.

The ratio of identified adults (0.91) and the mean proportion of adults per group (0.81) were used to derive the final population estimate (Table 1).

Table 1. Population estimate of humpback dolphins inhabiting the Shimoni Archipelago obtained from Mark-Recapture analyses for open populations (Jolly-Seber model).

Estimated number of adults	Estimated population size	95% Confidence Interval	Error
77	104	67-160	±23

Distribution

Humpback dolphins were predominantly encountered on the North side of Wasini Channel (Fig. 2), with the 50% isopleth identified as a core habitat area within the channel. 55 surveys incorporated the KMMPA; however only one sighting was recorded within its boundaries. In total, opportunistic searches in study area B resulted in an extra nine encounters compared to the 24 in study area A. However, over 90% of identified individuals in study area B were also sighted in study area A.

DISCUSSION

This study has provided the first estimates of abundance and distribution of Indo-Pacific humpback dolphins in the Shimoni Archipelago, Kenya. The high numbers of individuals re-sighted throughout the year suggests this is an important location for humpback dolphins in the region. Our population size estimate of 104 and the low sighting rate yielded results remarkably similar to a humpback dolphin abundance study conducted in Maputo Bay, Mozambique, in which the Jolly-Seber model provided a population estimate of 105 dolphins (Guissamulo *et al.* 2004). Stensland *et al.* (2006) found 63 humpback dolphins in a closed mark-recapture study in Zanzibar, Tanzania, encompassing a 26 km² study area. Our results are therefore comparable with other studies undertaken on the east coast of Africa, but note the high 95% confidence interval (67-160) and the fact that open population mark-recapture models

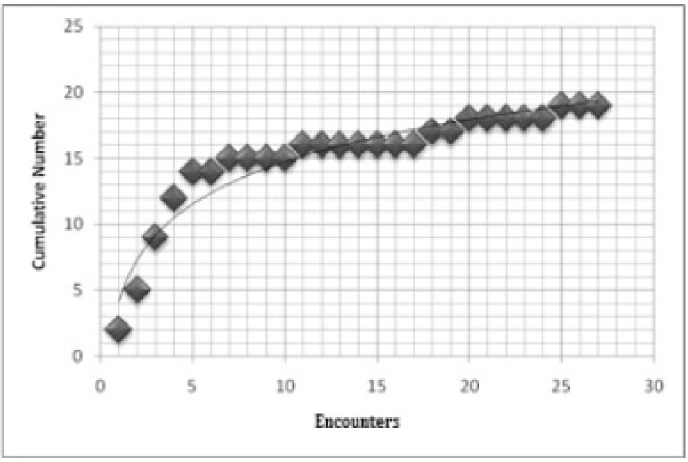

Figure 3. Rate of discovery of newly-identified adult humpback dolphins in the Shimoni Archipelago during 2006.

are generally less precise then closed models (White *et al.* 1982, Sutherland 2006).

In terms of distribution, further research is required along the Shimoni coast to elaborate the complete home range of the humpback dolphins in the Shimoni Archipelago. The 50% isopleth is representative of dolphin activity in Study area A. Since sightings from both study areas were used to derive this, this can arguably create a bias as we spent more time surveying study area A than study area B. Nonetheless, the extremely low sightings in study area B (especially within the KMMPA) suggest that the 50% isopleth is a key habitat for humpback dolphins in the Shimoni Archipelago. Further surveys which encompass the full 39 km² of the KMMPA need to be undertaken to confirm our findings, but informal interviews with dolphin tour operators and fishermen in the area confirm that humpback dolphins are rarely sighted within the protected area.

In terms of conservation, both the small population size and inshore distribution of humpback dolphins render them particularly susceptible to the effects of human activities along the Shimoni coast. Humpback dolphins have been found to inhabit a similar shallow inshore habitat off the south coast of Zanzibar, Tanzania, and in Algoa Bay, South Africa (Karczmarski *et al.* 2000, Stensland *et al.* 2006). These inshore areas have been identified as a "key habitat" in Eastern Cape waters for humpback dolphins (Karczmarski *et al.* 2000) and there is widespread concern in South Africa regarding their continued survival (Cockcroft 1990, Karczmarski *et al.* 1999, 2000).

The by-catch of fishing gear has been recognised worldwide as the most serious threat to small cetaceans, including east African regions (Berggren *et al.* 2007, Read *et al.* 2006). The humpback dolphin by-catch in Kenya is unknown, although it is suspected in many areas where gill nets are used (Kiszka *et al.* 2006; unpublished). Further investigation is required to understand if this constitutes a threat in the Shimoni Archipelago, and to what extent gill nets are used both legally and illegally. The Kenyan Wildlife Service patrols this region frequently and dolphin tourism is respected as an important source of economic wealth in the area. However, given that the Scientific Committee of the International Whaling Commission considers a 2% anthropogenic reduction of small cetacean populations unsustainable (IWC Report 1996, Annex H), research into the dolphin by-catch and harvesting practices in this region is recommended.

While the KMMPA offers direct conservation and habitat protection to cetaceans, only one humpback dolphin sighting was recorded within its protected waters, despite the fact that its high productivity and marine diversity (Emerton & Tessema 2001, Erftemeijer & Mwakoyo 1995) must benefit the Shimoni humpback dolphins in terms of food resources. Furthermore, at the time of this study, private home and hotel developments were planned with the allocation of plots along the Wasini Channel of the Shimoni Coast. Anthropogenic disturbance resulting from sustained, ongoing clearance of forest for development and agriculture in the Shimoni East forest is resulting in an increased risk of sedimentation in the near-shore reef habitats (G. Corti pers. comm., 10 October 2008). Increased boat traffic, water pollution and damage to the shallow inshore reefs of Wasini Channel from unregulated development could displace the resident humpback dolphin population, affecting tourism within the region and impairing the protection required by these animals. The 50% isopleth derived from this study indicates that humpback dolphins inhabit a core habitat in this area. Therefore, given the relatively small size of this population, its limited distribution range and the level of anthropogenic threats facing Indo-Pacific humpback dolphins, improved legislation within this area is recommended until further research can be conducted.

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