MARK-RECAPTURE ABUNDANCE ESTIMATE OF BOTTLENOSE DOLPHINS

(*Tursiops truncatus*) AROUND MAUI AND LANA'I, HAWAI'I,

DURING THE WINTER OF 2000/2001

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Abstract

Bottlenose dolphins were photo-identified in the area between the islands of Maui, Lana'i, Moloka'i and Kaho'olawe, Hawai'i (an area of approximately 3,000 km^2) between November 2000 and March 2001. A total of 328 hours were spent on the water during 49 days, and bottlenose dolphins were encountered on 32 occasions on 22 days. Fifty-nine individual dolphins had long-term recognizable markings (dorsal fin or back notches), and an additional 12 individuals (including 4 calves) were also documented based on body scars, dorsal fin shape or pigmentation patterns; thus, approximately 82% of individuals are thought to be recognizable in the long-term. Identification data were combined with a catalog of 63 individuals that had been documented in the same study area in 1999 and during the spring of 2000. During this entire period each "marked" individual was documented an average of 3.6 times (range 1-16), though individuals were not re-sighted randomly; some were seen more often and some less often than expected by chance. A mark-recapture analysis of the population using identifications from 1999 and from November 2000-March 2001, taking into account the proportion of marked individuals, produced an estimate of 134 dolphins (95% CI = 107-179). Using modeled rates of discovery the population was estimated at 122 individuals. Given the size of the study area and the presumed transitory nature of bottlenose dolphins around oceanic islands, the population in this area is surprisingly small.

Introduction

In the "main" Hawaiian Islands, a group of eight islands in the southeastern part of the Hawai'i archipelago, three species of odontocetes are relatively common in nearshore waters: the spinner dolphin (*Stenella longirostris*), pantropical spotted dolphin (*Stenella attenuata*), and bottlenose dolphin (*Tursiops truncatus*). Considerable research has been undertaken on spinner dolphins in Hawai'i (Norris et al. 1994), but little is known about the population size or status of the other two species. Bottlenose dolphins are found throughout the island chain, in both nearshore and offshore waters (Rice 1960; Shallenberger 1981; Mobley et al. 2000). Scott and Chivers (1990) noted that there is a large area with relatively few sightings of bottlenose dolphins in the western part of the eastern tropical Pacific (ETP), possibly indicating that the Hawaiian population is spatially isolated from populations in the remainder of the ETP. Based on aerial surveys Mobley et al. (2000) produced an estimate of 743 bottlenose dolphins in the main Hawaiian Islands, however the confidence intervals associated with this estimate were quite large (95% CI from 265-2,088 individuals).

During the winter of 2000/2001, we undertook an assessment of the population of bottlenose dolphins in the area between the islands of Maui, Lana'i and Kaho'olawe, Hawai'i. Photographic re-sighting data obtained during the winter of 2000/2001 are compared with data obtained during 1999 and the spring of 2000 (Baird unpublished). We estimate population size by using conventional mark-recapture techniques and by examining the rates of discovery ("discovery curves") of new individuals (Darling and Morowitz 1986). We compare theoretical rates of discovery with actual data (a similar approach to that taken by Calambokidis et al. 1990), taking into account the observed frequencies of sightings of individuals.

Methods

A 7-m rigid-hulled inflatable was used as a survey platform between November 22, 2000 and March 24, 2001, based out of Lahaina, Maui. A total of 328 hours were spent on the water during daylight hours on 49 field days. The study area was approximately 3,000 km^2 (Figure 1). Distribution of effort was not equal throughout the area due to weather conditions. The survey speed ranged between 15 and 25 kph and 3-5 observers scanned in 360 degrees, with occasional stops (typically every 10-15 minutes) for 360 degree scans with 7-9 power binoculars. When bottlenose dolphins were encountered, in most cases efforts were made to obtain good quality photographs of the left and right sides of all individuals in each group, using a 35 mm camera with a 100-300 mm zoom lens (f4.5-5.6) and 100 ISO color slide film (occasionally pushed to 200 ISO). However, there were some days when we were working with other species of cetaceans (e.g., false killer whales, *Pseudorca crassidens*) when bottlenose dolphins were sighted. Weather, fuel or light conditions also occasionally prevented us from obtaining good quality photos of all individuals. Infrequently, the presence of dolphin-watching boats or the behavior of the dolphins themselves (e.g., when high speed traveling) prevented us from following the group long or closely enough to obtain good photos of all individuals.

Only good quality photographs (in focus, un-obscured, with the dorsal fin relatively perpendicular to the plane of the photograph, and with the dorsal fin large enough to identify small notches, if present) were used in the analyses. Individual dolphins were identified from photographs based primarily on the size, location and pattern of notches on the trailing edge of the dorsal fin and on the back directly behind the dorsal fin (cf. Wells and Scott 1990; Wursig and Jefferson 1990). Those individuals with dorsal fin or back notches are hereafter referred to as "marked" animals. Individuals without dorsal fin or back notches could often be identified within and between encounters based on other features (e.g., pigmentation patterns, dorsal fin shape, skin scrapes or scars). However, because the longevity of many of these features is known to be shorter than dorsal fin notches (Wilson 1995), those dolphins identified only from such characters were not used for mark-recapture or rate of re-sighting analyses. The proportion of individuals in the population with dorsal fin or back notches was estimated using a simple ratio of these individuals to the total number of individuals identified during the study period. The total number of individuals also included unmarked calves (individuals approximately half the size of adult dolphins with no marks on the dorsal fin) and unmarked adults.

The frequency of re-sightings of all marked individuals (including those documented in 1999 and spring 2000) was compared to that expected if individuals were re-sighted randomly. The random frequency distribution of re-sightings was constructed by repeatedly sampling at random from the total number of marked individuals identified in the study. Four individuals (the average number of marked animals identified in each encounter) were sampled at random (with replacement), and this process was repeated for the number of encounters recorded in the study. One hundred iterations of this procedure were averaged to generate the frequency distribution of re-sightings if the population were sampled at random.

The observed rate of discovery of new individuals was visually compared to modeled populations (of different sizes) using a similar procedure. Since the observed frequency of re-sightings did not match that expected from random sampling, the observed non-random frequency was used to model the expected discovery curves. Four individuals were sampled in each step (with replacement) from each population. The frequency at which individuals were sampled in these simulated populations used the same frequency distribution as found for individuals in the wild. For each step, two outputs were recorded, the cumulative number of individuals sampled (which takes into account individuals which had been sampled in previous steps by omitting them from the count), and the cumulative total number of animals sampled (i.e., for each step, an additional four individuals were added to the total). One hundred iterations of this process were averaged to construct discovery curves for each simulated population size.

Population size was also estimated using mark-recapture techniques. Estimation was carried out for all marked individuals using the POPAN module of SOCPROG 1.2 (Whitehead 1999) with two periods (June-October 1999 and November 2000-March 2001) as units. The June-October 1999 period was chosen since this period had the highest number of individuals identified prior to the November 2000-March 2001 study. A closed (Schnabel) model was fitted to the population estimates using log-likelihood methods. Due to the short duration of the study, we have assumed that mortality or births are unlikely to be important. Maximum likelihood methods were used to estimate the population size of animals in the study area based on this model.

Results and Discussion

Between November 2000 and March 2001 there were 32 encounters with bottlenose dolphins on 22 days. Bottlenose dolphins were found throughout the study area (Figure 2) in deep and shallow waters, as was reported by Baird et al. (2001). The geographic limits of the study area during this period were greater than during the previous bottlenose dolphin photo-identification efforts (1999 and spring of 2000), including some coverage around the island of Kaho'olawe (a restricted area), and further offshore off the southwest coast of the island of Lana'i (Figure 1).

Approximately 1,250 photographic frames were taken during the study. Marked individuals were photo-identified in 27 of the encounters on 19 different days. Group sizes estimated in the field ranged from 1 to 16 individuals (median = 6, mean = 6.3, SD = 4.5). Number of marked individuals identified in each encounter ranged from 1-14 (median = 2, mean = 3.89, SD = 3.38 total = 105 identifications). Fifty-nine individuals were identifiable based on notches on the trailing edge of the dorsal fin or back, eight individuals were identified based on body or dorsal fin scars, and an additional four calves were present, totaling 72 individuals. Based on the ratio of marked to total animals documented approximately 82% of the population were marked.

Data from this study were combined with photographic data obtained in 1999 and the spring of 2000 (Baird unpublished). During this earlier period marked bottlenose dolphins were photo-identified in 45 encounters on 43 days in the same study area (the study area in this earlier period was actually only about half the size of the study area in November 2000-March 2001). Out of 210 identifications 63 marked individuals were documented. Of the 59 marked individuals documented between November 2000 and March 2001, 34 had been recorded during the previous study, resulting in 88 marked individuals recorded from this area between January 1999 and March 2001.

Including all 88 marked individuals, on average each was documented on 3.64 occasions (SD = 3.68, range = 1-16). The frequency at which individuals were sighted was not random (Figure 3); some individuals were seen more often and some less often than would be expected by chance. The non-random re-sighting rates could potentially be due to a number of factors. These factors include: 1) individuals having preferred home ranges such that the study area only covered the core range of a sub-set of individuals (cf. Wilson et al. 1997); 2) potential sex differences in use of the study area (cf. Wells and Scott 1990); or 3) more than one "community" of dolphins using the area (cf, Rossbach and Herzing 1999; Gubbins 2000). There is some support for the first of these possibilities. During the winter of 2000/2001 efforts were made to survey the area around the island of Kaho'olawe, on the southwest corner of the study area. This region was not surveyed during 1999/spring 2000 due to vessel restrictions in the area. During the only three encounters near this island 22 marked individuals were documented, 15 of which were new to the catalog (an average of 5 new individuals per encounter); the largest per encounter increases of new individuals in the study. Over all encounters between 1999 and 2001, on average only 1.2 new individuals were documented per encounter (SD = 1.7, median = 1). Overall during the winter 2000/2001 study, six groups were encountered where 50% or more of the individuals identified were new to the photo-identification catalog, and five of these were at the periphery of the study area (Figure 2), suggesting that the wider geographic sampling may be resulting in encounters of new individuals whose core ranges are elsewhere.

The discovery curve (Figure 4) continued to rise throughout the study, with new marked individuals being regularly documented. However, the rate at which new dolphins were discovered generally decreased over time, at least up until the end of the 1999 sampling (Figure 4). Sampling during 1999 ended in mid-October, and during 2000 did not begin until late February. After this greater than four-month lapse in sampling, the rate of discovery of new individuals was relatively steady, which could reflect the wider geographic distribution of effort in 2000/2001. Modeled discovery curves of 90 and 100 individuals, based on the observed re-sighting frequency, generally bracket the observed discovery curve (Figure 4). Using a value of 100 individuals, with 82% of the population being identifiable, produces a population estimate of 122 individuals.

The estimated number of marked animals from a Schnabel mark-recapture analysis comparing the November 2000-March 2001 data set to a five-month period during 1999 was 109 (95% CI = 87.8-147.2). Correcting this estimate to account for the proportion of animals that are identifiable results in a population estimate of 134 individuals (95% CI = 107.1-179.5).

The estimates produced by modeling non-random discovery curves and by mark-recapture techniques only vary by 9%, and both suggest a relatively small population of bottlenose dolphins using this area, particularly given the size of the area (about 3,000 km^2). If we take into account relatively low levels of effort in some parts of the study area and assume the population inhabits only the areas more consistently sampled (approximately 1,300 km^2), the density of individuals, assuming all are present at one time, is only about 0.1 individuals/km^2. This value is at the low range of the densities for bottlenose dolphins reported by Wells and Scott (1999). Unfortunately, few data on bottlenose dolphins around other oceanic islands are available for comparison. Scott and Chivers (1990) examined group sizes in the eastern tropical Pacific, including those found in association with oceanic islands (including Hawai'i), and found group sizes substantially larger than in our study (median and mean group sizes of 20 and 93 around oceanic islands). Their definition of island areas includes waters potentially as much as 110 km offshore however, so such data are not strictly comparable. Around Cocos Island, off the coast of Costa Rica, Acevedo-Gutierrez (1999) found groups slightly larger than those that occur around Maui and Lana'i (median and mean of 8 and about 10 individuals in the Acevedo-Gutierrez study). The most striking difference between our results and the Acevedo-Gutierrez (1999) study are in the estimated relative population sizes. Acevedo-Gutierrez (1999) documented 765 distinctive individuals, with most individuals sighted only once, in an area of approximately 250 km^2. Thus, while populations around some oceanic islands may be large and transitory, our results suggest that in part of the Hawaiian Island chain the population is relatively small, and some individuals show considerable fidelity to the area.

The high proportion of individuals in this population that are recognizable suggest that photo-identification efforts from other island areas in Hawai'i (e.g., off the islands of Oahu or Hawai'i) would be quite informative, in terms of determining whether some individuals have ranges spanning large areas or whether the core ranges of some of our infrequently seen animals are elsewhere. The long-range movements documented for both coastal and offshore forms of bottlenose dolphins elsewhere (Wells et al. 1990, 1999) suggest that movements between islands in the Hawaiian chain could occur. We recognize that our sample size is small, and further research on bottlenose dolphins around the Hawaiian Islands, and other oceanic islands, is necessary to better understand the variability in this species. In general, however, our results appear to indicate that the population of bottlenose dolphins around this isolated oceanic island chain shows surprising similarities to coastal populations, in terms of small population size and evidence of site fidelity by some individuals.

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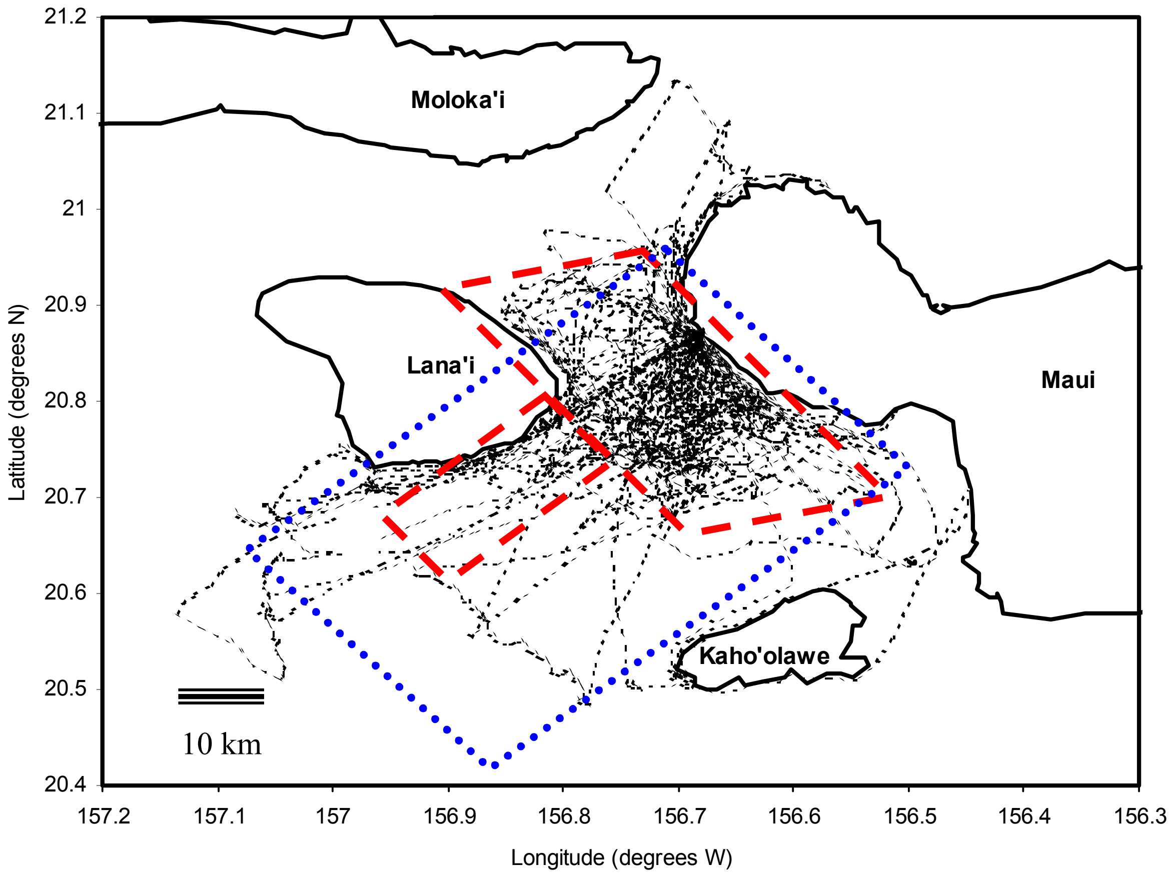

Figure 1. Distribution of search effort during the winter of 2000/2001. Effort was constrained largely by sea conditions and thus was non-random. Combined, the two heavy dashed boxes indicate a 1,300 km^2 portion of the total study area with relatively high levels of effort, while the larger dotted box indicates a 3,000 km^2 area.

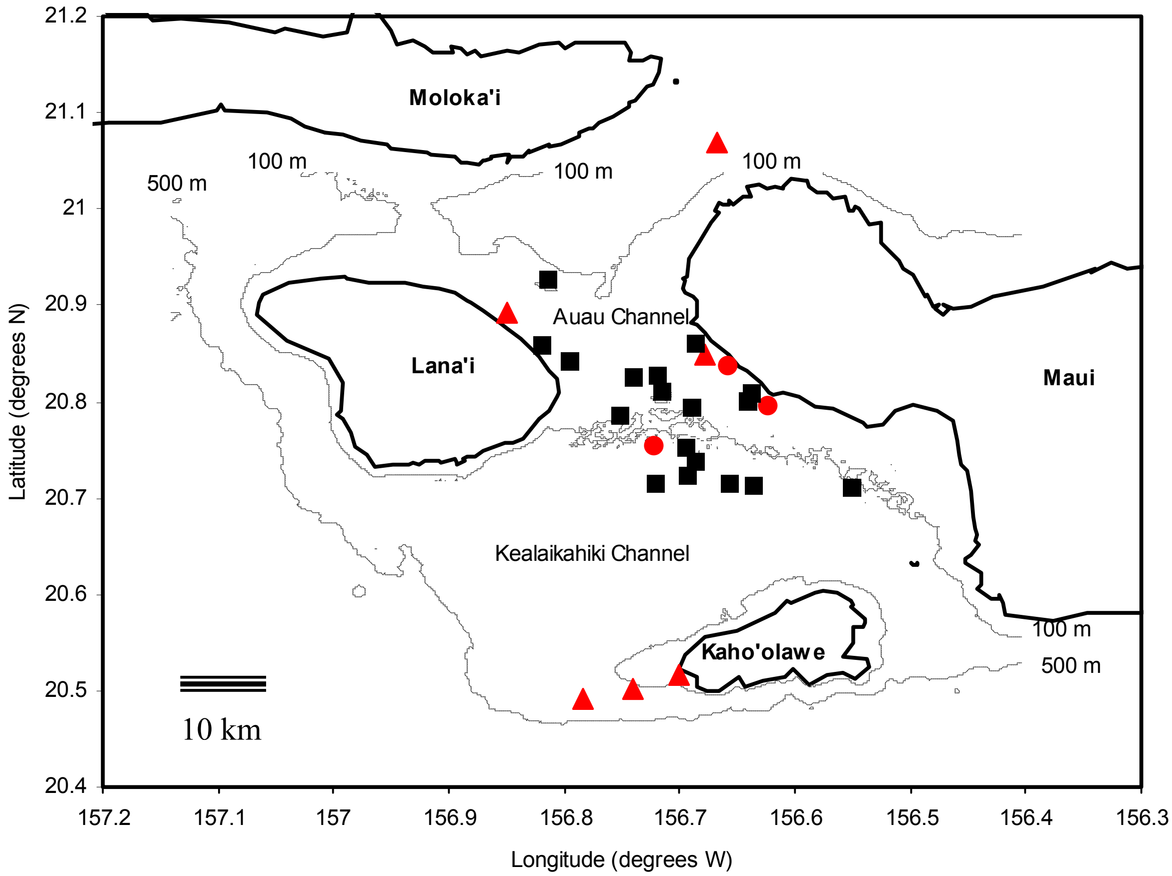

Figure 2. Distribution of sightings of bottlenose dolphins during the winter of 2000/2001. Filled triangles represent sightings where 50% or more of the individuals identified were new to the catalog. Filled circles represent sightings where one or more new individuals were identified, though the number of new identifications was less than 50% of the total identifications. Filled squares represent sightings where all individuals identified had been previously documented. The 100 and 500 m depth contours are shown.

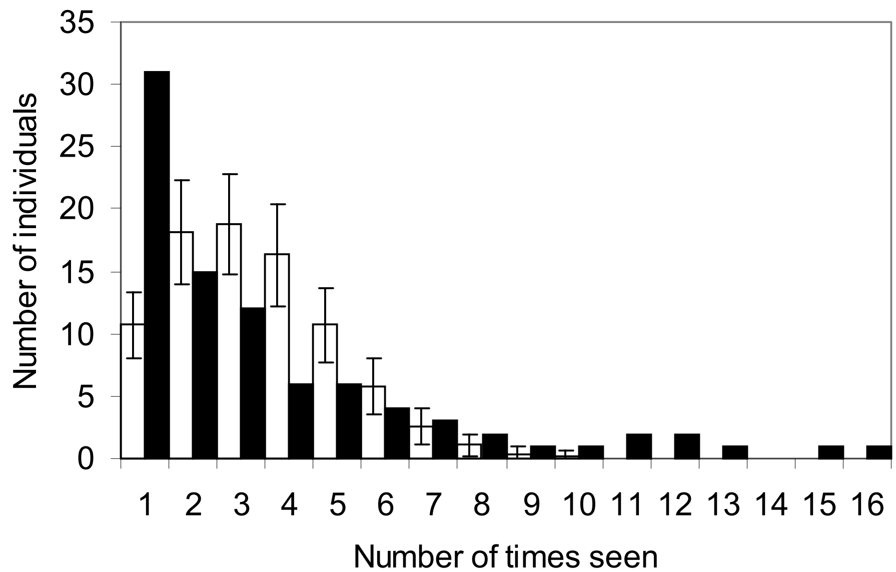

Figure 3. Frequency of re-sightings of bottlenose dolphins photo-identified between January 1999 and March 2001 (solid bars), together with the expected frequency of re-sightings assuming random sampling (open bars- mean values and SD of 100 permutations shown).

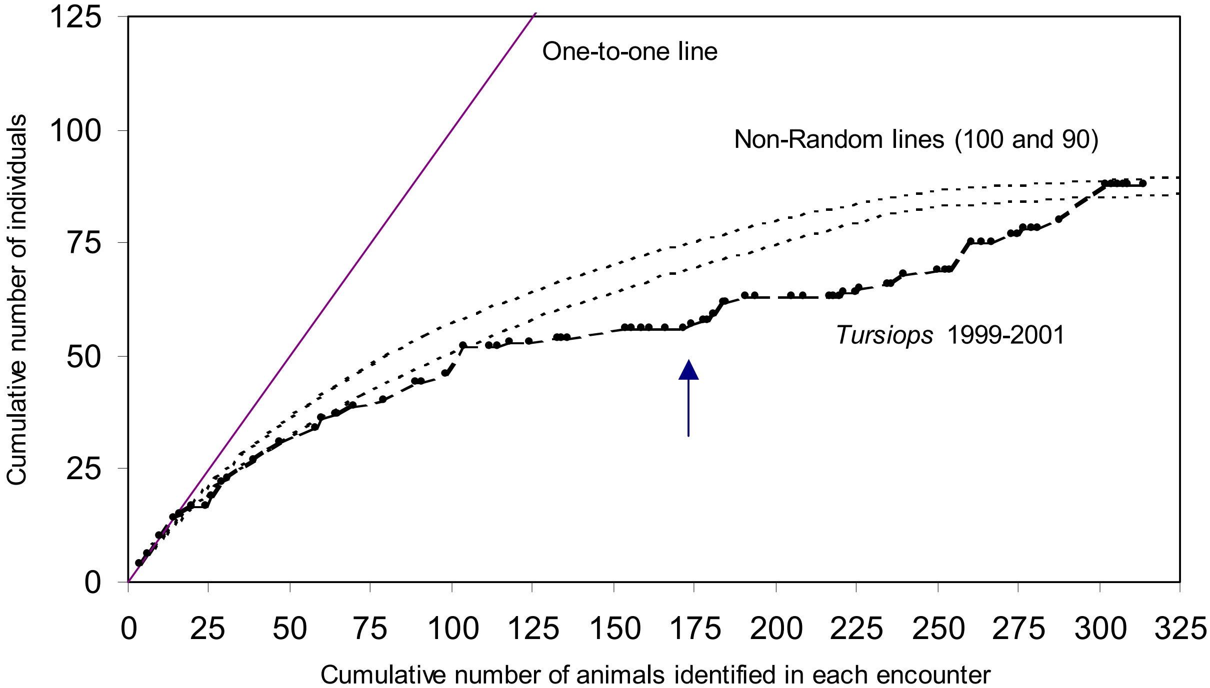

Figure 4. Rate of discovery of new individual bottlenose dolphins between January 1999 and March 2001 (solid line with filled circles). Two non-random model populations (100 and 90 individuals) produced by using the same sighting frequency as in Figure 3 are also shown, as is the one-to-one line (if all individuals documented were new individuals). The arrow indicates the beginning of sampling during February 2000, after a greater than four month period since sampling ended in 1999.