SEASONAL TRENDS AND TOTAL ABUNDANCE OF THE WALVIS BAY BOTTLENOSE DOLPHINS (*TURSIOPS TRUNCANTUS*)

By:

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Declaration

"I hereby declare that this work is the product of my own research efforts, undertaken under the supervision of Professor Edosa Omoregie and Dr. Simon Elwen and has not been presented elsewhere for the award of a degree or certificate. All sources have been duly and appropriately acknowledged".

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Justina Ndawapeka Shihepo

200304208

Certification

"This is to certify that this report has been examined and approved for the award of the degree of the Bachelor of Science in Fisheries and Aquatic Sciences of the University of Namibia".

Approved

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Internal Supervisor

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Head of Department

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ABSTRACT

The highly productive waters of the Southern Africa coast have an estimated amount of 37 species of cetaceans. Along the Namibian coast, the status of the bottlenose dolphins (Tursiops truncatus) is rarely documented. A survey was carried out in 2010 winter and summer seasons and the data obtained were combined with data obtained in the survey carried out in 2008 and 2009. The study was to undertaken to estimates the total population of bottlenose dolphins in the Walvis Bay area and establishes their seasonal trends. A total of 78 and 82 of quality (Q456) marked dolphins were recorded on both left and right fin side respectively of which 56 dolphins were of usable Distinctiveness (D345). Mark-recapture methods were applied to photo identification to estimate the population of the Walvis Bay bottlenose dolphins. The Closed Models of Huggins in Program Mark were used in population estimates. One way Analysis of Variance was used to test difference between fin sides and seasonal variations. The Mth (time varying with recapture heterogeneity) model of Huggins (1989) was found to be the best for the data. The estimated population was 59 (95% CI 56-62) for right fin side and 57 (95% CI 55-59) for left fin side. In order to include the number of dolphins of D12 in the population, the proportion of marked dolphins to unmarked was estimated to be 0.68 on right and 0.72 on left sides. This has resulted in the total population to range from 82-91 dolphins. The Analysis of variance showed no statistical difference in the number of dolphins sighted during summer and winter ($P>0.05$, F-value =0.091).

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CHAPTER ONE

INTRODUCTION AND LITERATURE REVIEW

1.1. BACKGROUND

The southern African sub-region is particularly rich in cetacean species. Although there is an uncertainty on the exact number of cetacean species in the world due to taxonomic uncertainties, at least 51 species of whale, dolphin or porpoise of the just over 80 known worldwide, occur in the Southern African sub-region (Best 2007). However, there is relatively limited knowledge on cetaceans locally, compared to other marine life due to a general lack of research.

1.2. BOTTLENOSE DOLPHINS (*Tursiops truncatus*)

Globally, there are two species of bottlenose dolphin recognized, the common bottlenose dolphin (*Tursiops truncatus*) and the Indo-Pacific bottlenose dolphins (*T.anducus*), (Best 2007). The common bottlenose dolphins are found in temperate and subtropical waters worldwide including the offshore and inshore waters of the Namibian coast. Two other species of dolphin which are commonly found in the coastal waters of Namibia are the Heaviside's dolphin (*Cephalorhynchus heavisidii*) and the Dusky dolphin (*Lagenorhynchus obscurus*), (Wells and Scott, 2002).

On the Namibian coast, small populations of common bottlenose dolphins are found in the near shore waters. This population is unique within the Benguela ecosystem and range between Walvis Bay and Cape Cross, (Findlay *et al*.1992). The distribution of this population overlaps the area where majority of human activities take place, hence there is the need for proper conservational and monitoring management practice to ensure their survival.

1.2.1. Seasonal distribution and migration patterns

The movement of bottlenose dolphin varies from seasonal migrations, year-around home ranges, periodic residency and a combination of occasional long-range movements of repeated local residency. Due to the high variability of the Benguela ecosystem such as water temperatures and fish spawning, seasonal fluctuations in the number of dolphins in the bay is possible.

The Namibian bottlenose population is encountered in water generally less than 15 m deep (Elwen & Leeney, 2008). Within the Namibian coastal waters, they are sighted most frequently within the Walvis Bay and close to shore along the coast to the north and south of the bay. The bottlenose dolphins are seen in small groups in summer than in winter (Best 2007).

1.2.2. Biology and behavior

Common bottlenose dolphins are a wide ranging species with a broad range of social and ecological habits. They can be found in groups of 2-15 individuals but large group of more than 1000 have been reported by Wells and Scott, (2002), especially in offshore populations. In bays and estuaries, they tend to form smaller groups than those in offshore groups and the groups tend to be dynamic with sex, age, reproductive condition and familiar relationship as noted by Wells and Scott, (2002) .On the inshore of the Namibian coast, dolphins occurs in groups of 1-39 with the average size being seven, (Best 2007). Bottlenose dolphins have long life span and low reproductive rates (Wells, 1991). Both sexes could live for up to 45 years and a female born in captivity at Marineland of Florida in February 1953, has so far lived for 54 years (Best 2007).

1.3. ANTHROPOGENIC IMPACTS ON DOLPHINS

The extent of human threats to the dolphin population is unknown due to difficulties in assessing the severity and the current estimate to mortality are rough estimates. In the eastern tropical Pacific tuna purse seine fishery, dolphin mortalities has been well studied and results indicated that their population has been greatly reduced, (LeDuc, 2002). LeDuc (2002) further stated that, pollution also affects dolphin directly by poisoning or by making the animals more susceptible to pathogens and parasites, decreasing their productive capacity and shortening their life span It was found that, first-born calves of South African bottlenose dolphins (*T. truncatus*) received a substantial amount of their mother's body burden of contaminants residues, perhaps leading to increased neonatal mortality (Cockroft *et a.l* 1989, de Kock *et al*. 1993).

In Walvis Bay, up to 25 tour boats operate with this ~10x10km bay. There is a serious concern about these impacts of this on the local populations as studies in other areas have shown negative effects of the boats on the dolphin. The presence of boats was observed to disrupt and shorten the resting behavior of the dolphins; the socializing behavior is highly impacted by interaction and this was indicated by a horizontal avoidance of boats i.e. an increase in travelling behavior in most interaction (Lusseau, 2004). Increased dive intervals, increased speed and variations in vocalization have also been reported (Kruse 1991, Corkeron 1995, Janik and Thompson 1996, Bejder *et al*. 1999, Nowacek *et al*. 2001, Van Parijs and Corkeron 2001, Williams *et al*. 2002). Dolphins also have avoided the area when boat traffic is high (Lusseau *et al*.2002, Lusseau

2003). Dolphins reduced foraging opportunity and increased travelling time, which can lead to greater energetic cost by decreased energy intake (Lusseau and Bejder 2007). Dolphins were also found to switch from a short-term behavior avoidance strategy to long-term avoidance strategy or habitat displacement (Lusseau 2004).

Other anthropogenic activity negatively affecting dolphin population is marine aquaculture, for instance the oysters farms have take up a considerable part of Walvis Bay, including areas used by bottlenose dolphins. Further, water enrichment from the feeds and feacal may also have negative effects on the dolphins (Elwen and Leeney, 2008).

As mentioned earlier, the bottlenose dolphins are sighted most frequently within the bay, the expansion of the Walvis Bay port might have a considerable effects on the dolphins such as habitat displacement. Coastal development has increased the rate of siltation of the lagoon which is part of the Walvis Bay wetland, making it difficult for the bottlenose dolphins to enter. This wetland suffers from serious sedimentation and deterioration, with tidal flow diminishing over a 30-year period from 3.46 meters per second to the present 0.32 meters per second (Pavlic 1998).

In order to protect marine mammals from anthropogenic mortality and disturbance, the United States enacted the Marine Mammal Protection Act in 1972 (MMPA, amended 1994), (Gosliner, 1999) and various mitigations such as acoustic deterrent devices and turtle-exclusion devices are being put in places. The effectiveness of these methods however depends on the enforcement of both regional and international regulations, such as enforcement of Marine Mammal Protection Act and ***Convention on International Trade in Endangered Species*** **(**CITES).

1.4. POPULATION ESTIMATION

An integral part of any management strategy is the assessment of the number of individuals in a population and any trends in abundance (Taylor and Gerrodette, 1993). Marine mammals spend most of their time under water; hence estimation of population size presents difficulties (Wilson *et al.*, 1999). The main techniques used are the line transects and the mark recaptures photo identification.

Mark-recapture method uses photo-identification and boat survey is one of the methods currently used. This method has the advantage over line transect methodology in that it calculates the number of animals using a particular area over a period of time and not just during a specific survey. This method uses natural marks of animals which has more advantage over using method whereby the animals are captured as this does influence their behaviour and the capture probability of the animal.

Mark-recapture model uses the following assumptions: 1) dolphins do not lose their marks (notches) during the sturdy period, 2) No new individuals were born or immigrated into the population and none died or emigrated during the study periof, 3). All animals in the population have equal probability of being captured, 4) The probability of recapture is not affected by the animal's response or behaviour to capture and 5) Marks are properly identified on first sighting.

It can be assumed that both marked and unmarked animals has the same capture probability at any sampling occasion and same survival probability between sampling occasions (Hammond, 1986). Mark recapture is applicable to either open or closed population whereby the open population animals enter and leave the population through migration, births and deaths, whereas closed population assumed to be constant during the study period of which should be of a short duration.

Long period studies are based on both closed and open populations models such that over the short time intervals (primary period) the population of interest is closed, but it is closed when the study run for long-term perspective over multiple primary periods. To analyze such data, Pollock (1982) has introduced the “robust design” which combines the sampling design of both closed and open population’s models.

1.5. PROBLEM STATEMENT

There is very little information available on the distribution, abundance and the behavior of delphinids in Namibia. Due to historic and commercial interests, the majority of marine research in Namibia has focused on the commercial fisheries and on species thought to directly influence them, such as Cape fur seals (Elwen and Leeney, 2008). Little is known about the delphinids populations and there is a concern over the human impacts such as by-catch, pollution, high levels of tourism and depletion of their prey. The bottlenose dolphins are sighted throughout the bay and they show high site preference to small ranges, (Elwen and Leeney, 2008), this makes them more vulnerable to threats due to the uses of the bay and potential environmental change.

In order to have a sound management strategy for these dolphin population, data on their abundance, distribution and habitat are needed. Population structure, abundance and mortality level information is required in order to be able to assess the potential impact of by-catches and human disturbance. Currently, the global population of bottlenose dolphins has been classified as Least concern in the IUCN Red List (IUCN, 2010), but several regional populations (IUCN,

2003) are threatened due to human impacts (Reeves *et al.*, 2003). The current study is investigating seasonal patterns in abundance, or the number of animals using the bay during the study periods.

1.6. OBJECTIVES OF THE STUDY

The current study forms part of a large Namibian Dolphin Project which is collecting data on the distribution, habitat use, and abundance of bottlenose and Heaviside's dolphins in Walvis Bay to assess the conservational status of the local populations. These results are a precursor to the development of longer term management strategies and an assessment of the potential impact of human activities on cetaceans in the area.

Specific objectives

The research seek to estimate the abundance of bottlenose dolphins in Walvis Bay area over five sampling periods across two years, using photographic mark-recapture method from empirical data. To establish the winter and summer trends of the bottlenose dolphins in the Walvis Bay Area

1.7. HYPOTHESIS

H_{01}: There is no significant difference in the number of sighted bottlenose dolphins in the Walvis Bay area between the months of summer and winter.

H_{11}: there is a significant difference in the number of sighted bottlenose dolphins in the Walvis Bay area between the months of summer and winter.

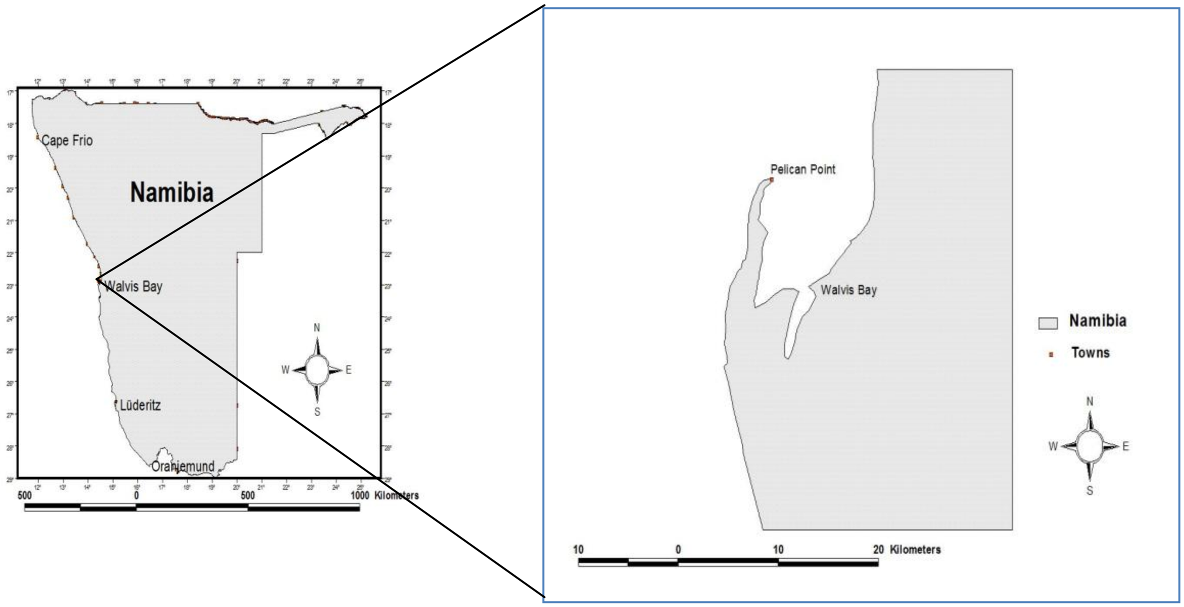
CHAPTER TWO

MATERIALS AND METHODS

2.1. STUDY AREA

The coastline of Namibia is relatively straight with few embayments. All data were collected between Walvis Bay (22°57') and Swakopmund (22°40'S). The area is very productive due to the wind driven upwelling of the Benguela current ecosystem which extends from south-western margin of Africa at Cape Agulhas into Angola, 10^{o}C south.

The Walvis Bay area is situated midway between the southern and northern Namibia borders. The bay is bounded by a peninsula which ends at Pelican Point and this protects the bay from strong south-westerly winds. Walvis Bay town is the largest along the Namibian coast with an estimated population of about 60 000 and it has the largest commercial harbor in Namibia. The Walvis Bay wetland (Ramsar site) is considered to be amongst the top three wetlands of Africa in terms of the total number of birds it supports (Pavlic, 1998). The bottlenose dolphins enter the lagoon considerably less frequently that they used to according to local operators and conservationists, (Elwen and Leeney, 2008). This may be due to siltation which increases the shallowness of the lagoon.



Cape Frio
Namibia
Walvis Bay
Lüderitz
Oranjemund
N
W
E
S
500
0
500
1000 Kilometers
Pelican Point
Walvis Bay
Namibia
Towns
N
W
E
S
10
0
10
20 Kilometers

Figure 1. Study area showing the bay, Pelican Point and the lagoon.

2.2.DATA COLLECTION

In this investigation, the 2008 and 2009 data were already collected. The same procedures for 2008 and 2009 where followed to collect data for 2010. The 2010 data collected from trips with commercial tour operators and from dedicated scientific surveys. Scientific surveys were run from two vessels, an 8m catamaran ski-boat (*Pedro*) with twin 80HP 4-stroke Honda engines and a 6m inflatable with twin 50HP 2-stroke engines (*Nanuuq*). The boat was launched daily from the Walvis Bay Yacht Club, weather permitting (visibility good, low wind and swell) and a search for dolphins was made throughout the bay in a random direction (no set survey route). Generally, surveys were either headed north along the coast towards Swakopmund or on random routes across the bay towards Pelican Point. Once a group of bottlenose dolphins was encountered, group size and behavior was recorded as well as water temperature, depth and the number of tour boats present. Both sides of the animals dorsal fins were photographed until all animals have been successfully captured or the group lost. Communication with skippers of commercial tour boats was maintained to provide direct information on the whereabouts of groups of dolphins through VHF radio, and this improved the encounter rate with groups considerably. However, it was attempted not to work with groups of dolphins in the immediate vicinity of tour boats to minimize boat traffic around the dolphins and for requirement of the research vessel for closer approaches for proper photographing.

2.3.PHOTO IDENTIFICATION OF BOTTLENOSE DOLPHINS IN WALVIS BAY

Many bottlenose dolphins' fins have nicks, notches, and deformations which results from intra- and inter-specific interactions. These marks persist and can be used to identify captured individuals, enabling researchers to track individuals.

All the pictures of the photographed bottlenose dorsal fins were graded for quality (Q) based on size, focus, and angle of fin and given a rating of 1-6, (Table 1), with 1 being very poor or barely identifiable and 6 being of an excellent quality (big, focused, well lit and perpendicular to camera). Once graded and matched, individual animals were also rated for distinctiveness (D) on a scale of 1-5 (Plate 1), with 1 being with no mark and 5 five being extremely obvious mutilations/markings. All the dolphins with Q≥3 are given a temporary daily ID. The best images on both right and left side are matched to the existing catalogue from the 2008 pilot study, if they were not matched then they were added to the catalogue ad given a new permanent ID. Separating left and right side identifications has several benefits: it results in two catalogues and 2 estimates from the same data set, animals that are only identifiable from scarring on one side or the other can be included in the catalogue (Elwen and Leeney, 2008). Only images with of Q≥4 and animals D≥3 were used for analysis.

Table 1: Image quality and distinctiveness grading parameters used in estimating Bottlenose dolphins population in Walvis Bay

Breakdown of ratings Quality and Distinctiveness used to grade fin images and individual dolphins prior mark-recapture analysis, (Elwen & Reeney, 2008).

Image Quality (Q)	Distinctiveness (D)

1) Barely identifiable	1) No marks
2) Very poor. Tip only/ very out of focus	2) small single notch/marking or scarring only
3) Any of: too small or far away. Soft focus, angle Poor, partial fin visible	3) 1 bigger or 2 small marks of reasonable size or fairly unique marking/ scarring + TE marks or odd fin shape
4) Good, can make out small marks but not excellent (slightly soft or small)	4) > 2or obvious edge markings, scarring
5) Good and focused but backlit/ silhouette (i.e. Scaring not visible)	5) extremely obvious mutilations/markings
6) Excellent: big, focused, well lit, and perpendicular to Camera	

Q2: very poor. tip only/ very out of focus

Q3: any of: too small or far away, soft focus, angle poor, partial fin visible

Q4: good, can make out small marks but not excellent (slightly small)

Q5: good and focused but backlit/ silhouette (i.e. scarring not visible)

Q6: excellent: big, focused, well lit and perpendicular to camera.

Plate 1:Examples of image quality 2-6

2.4.NUMERICAL AND STATISTICAL ANALYSIS OF POPULATION ESTIMATE OF BOTTLENOSE DOLPHIN

In this investigation, bottlenose dolphin population was estimated using the maximum likelihood models of Huggins (1998) by fitting various Huggins closed capture-recapture models to the data using a day as sampling events. The analysis was done using the programme MARK (developed by the Department of Fisheries and Wildlife, Colorado State University, 2004). Mark-recapture methods use data on the number of animals marked and their proportion on the subsequent samples to estimates population parameters including abundance (Seber, 1982). Mark-recapture method assumes identical mortality of marked and unmarked individuals and that no loss of marks through regeneration or deterioration. The proportion of marked dolphins in the sample reflects the proportion of marked dolphins in the population. The capture recapture model:

$$\frac{n1}{N} = \frac{m2}{n2}$$

Where:

N: population size

n1: marked individuals in the population caught on the first occasion

n2: animals caught on the second capture occasion

m2 : animals in the second capture occasion which are marked

The abundance estimate was done using daily encounter as the smallest sampling unit and the proportion of marked dolphins will be calculated from the final catalogue as the average of the daily proportion of animals D3-5 of the total number identified for each side. The mark-recapture estimates were than extrapolated to total population size (multiplying by 1/mark rate) to account for those unmarked dolphins not included in the estimate (D1-2) and the proportion of marked dolphins was calculated as D345/allD.

Models fitted were the null model (equivalent to M_0 of Otis *et al*.1978), time varying capture probability (equivalent to Mt), individual heterogeneity in capture probability (Mh) and a model with both parameters (equivalent to Mth). Program capture tests were used to analyze the data and model Mth had a bigger p-value was considered the most fit.

The data for each year and seasons were analyzed separately on the right and left side fins. For 2008, only winter data were analyzed as there was no survey conducted in summer. For the year 2009 and 2010, the results of both seasons (winter and summer) were analyzed separately. The estimated population for all the years (2008-2010) were analyzed by combining the data obtained from all the years i.e. data obtained over the five primary sampling occasions.

<u>Assessment of mark-recapture assumptions</u>

When the assumptions of mark-recapture are fulfilled, the photographic techniques can provide unbiased estimates of the population size than with line transect (Fairfield 1990 and Calambokidis *et al*.1990).

1. Animals do not lose their marks during the sturdy period

If animals lose their marks after the first capture, they are likely to be misidentified as new animals in the subsequent recapture occasions, which will lead to over estimation. Bottlenose dolphins has marks and notches that persist for a longer period if not permanent, hence they are unlikely to be lost during the study period. Only animals with big notches or marks (D345) were used for analysis and not the one with scars that are likely to be lost, hence the assumption is likely met.

2. No new individuals were born or migrated into the population and none died or emigrated

The sampling were done on short durations, i.e. two months of each season, hence it is likely that the population remains constant with negligible changes.

3. All animals in the population have equal probability of being captured.

Some animals preferred certain area over the others, which may affect individual capture probability. Attempt where made to cover the whole study area and photograph all the individuals in each encounter group. Analyses allowing for heterogeneity in recapture probability were used to further reduce violation.

4. The probability of recapture is not affected by the animal's response or behaviour to capture.

In capture - recapture used in this study, actual recapture is not necessary; records of re-sighting provided the needed information. Since animals were not captured physically, there was no need to model any behaviour response to the analysis.

5. Marks are properly identified on capture.

This assumption is likely to be violated if poor quality and less distinctive photographs are used to identify individual animals. To avoid the violations, only good quality photographs (Q456) and highly distinctive (D345) were used.

2.5.STATISTICAL ANALYSIS

The Genstat statistical package using the Analysis of Variance (one way ANOVA with no blocking) was used to test for significance between the left side fin results and right fin side for each season. The fin sides were treated as individual factors. The same was applied to test for difference in seasonal trends whereby the data from all winter seasons were compared to the summer seasons. The One way ANOVA works on assumptions that, the population from which the samples were obtained is normally distributed, the samples are independent and the variances of the populations must be equal. The data were analyzed at 95% confidence intervals.

CHAPTER THREE

RESULTS

During the study period, many tour boats up to 10 were found within the bay at the same time. It was discovered that more than two boats were found to follow a group of dolphins which could be stressful to the dolphins especially the mother and calves. Plate 3 shows three boats at the same area and the fourth boat (Plate2) was the research boat were the photo was taken from. Some dolphins were found to follow the boats, bow-riding.

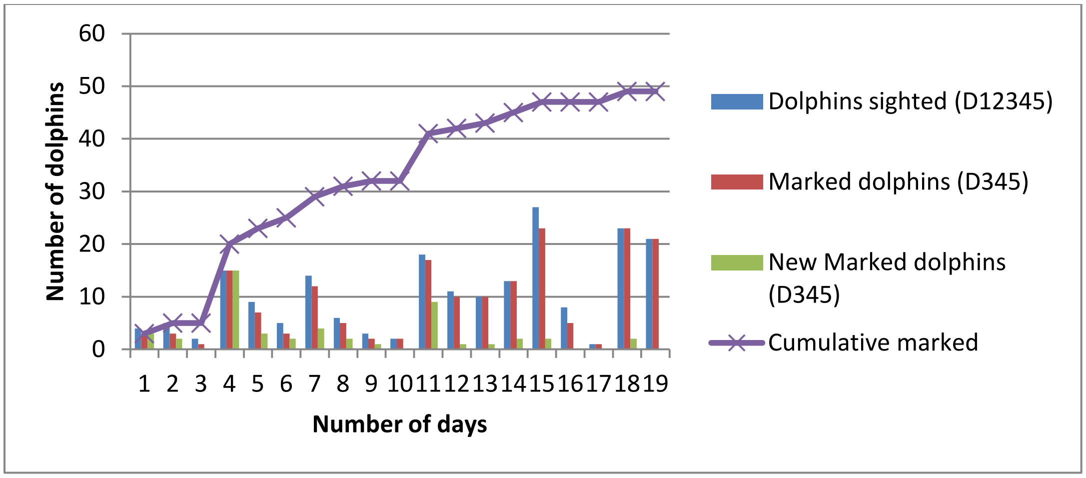
Plate 2: The research boat used during the study (Photo: JShihepo, 2010)

Plate 3: Tour boats in the bay, (Photo: MWcisel, 2010)

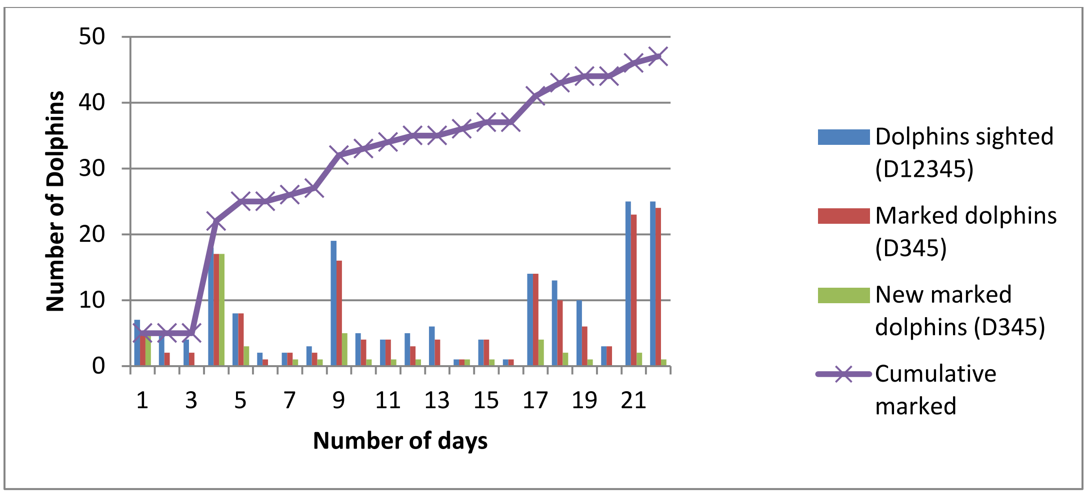
3.1. DISCOVERY CURVES AND GRAPHS OF ALL SAMPLING SEASONS

The number of dolphins photographed indicating marked and newly marked dolphins in each sighting during the period of survey are presented in Appendix 1 and the Analysis of variance tables are in Appendix 2. The discovery curves for each year of the survey per season are presented in Figures 2,3,4,5 and 6 respectively.

From Figure 2, it can be seen that the discovery curves of both the left side and right side fins does not level out (cumulative marked did not reach a constant value). About 49 (left fin side) and 47 (right fin side) marked dolphins of distinctiveness (D345) and quality (Q456) were captured during the winter season of 2008, within 21 days of survey. On day 4, most new marked dolphins (15 left sides and 17 right sides) were captured, while no new marked dolphins were captured on certain days of surveys. The number of marked on both right and left side fin indicated no significant difference (P>0.05, F-Value=0.701).



2a

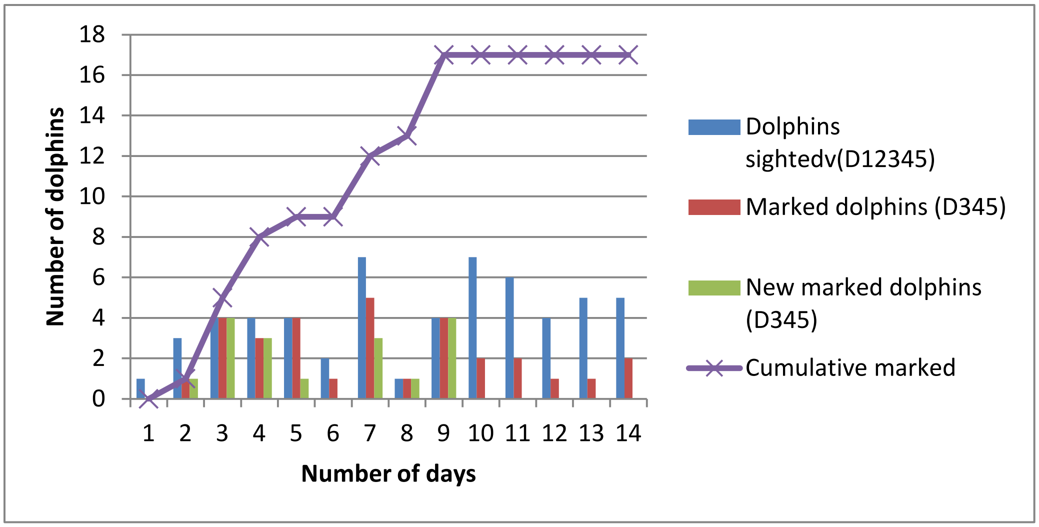


2b.

Figure 2 a&b: Discovery curves showing number of dolphins seen (D12345), marked dolphins (D345), number of new marked dolphins (345) and cumulative marked of photographic fins in winter of 2008 plotted against number of days[1] at sea, a) Left side fin and b) Right side fin.

[1] Number of days are specific dates when surveys were carried out

During the summer season of 2009 (Figure 3), sampling was carried out within 15 days and 17 dolphins with Distinctiveness (D345) and Quality (Q456) were photographed on the left fin side and 15 on the right side fin. The cumulative curve is constant from day 9 (17 animals left side) and day 10 (15 animals right side), as no new marked dolphins were observed after those days. The highest number of newly marked dolphins recorded is 4. The results showed no significant difference in the number of dolphins sighted on right side fin and left side fin ($p>0.05$, F-Value= 0.707).



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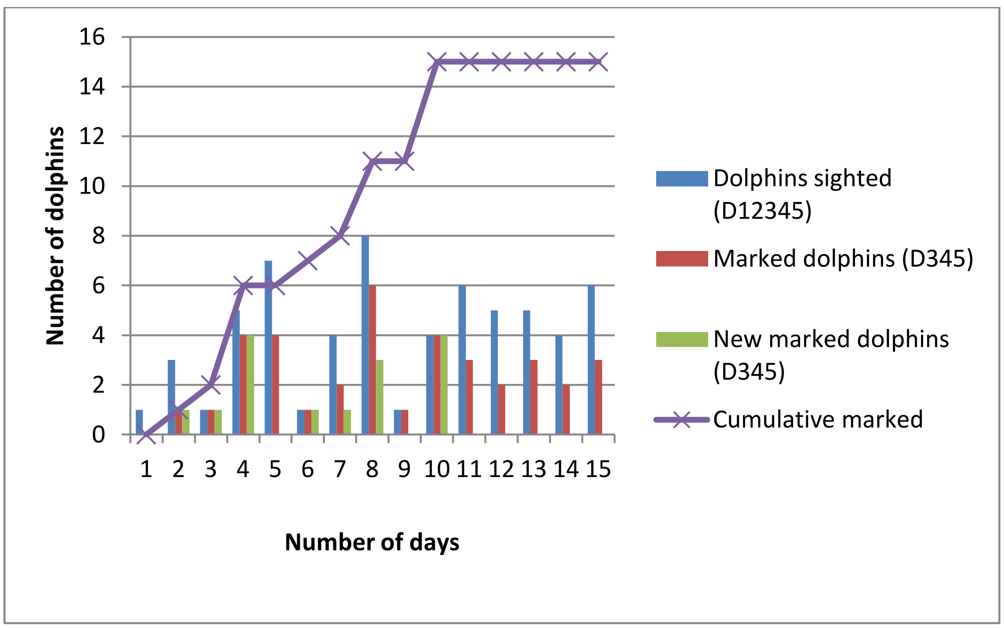
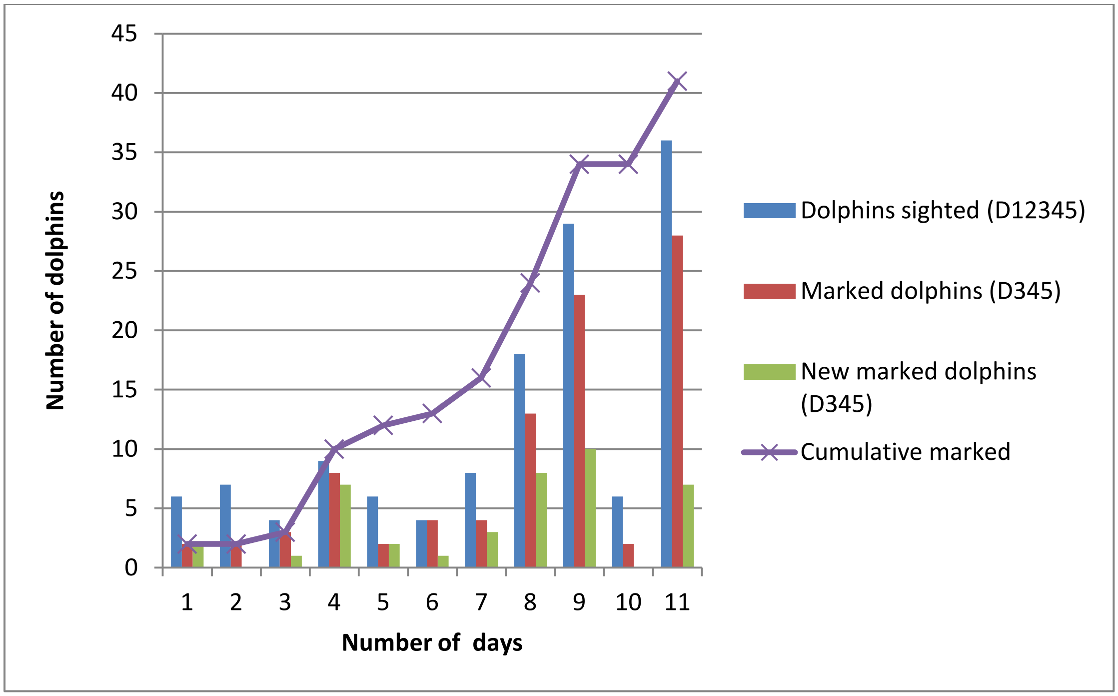


3b.

Figure 3a&b: Discovery curves showing all dolphins sighted (D12345), marked dolphins (D345), number of new marked dolphins (D345) and cumulative marked of photographic fins in summer of 2009 plotted against number of days at sea a) left side fins and b) right side fins.

In winter of 2009, eleven days were spent in surveying, 41 and 37 dolphins with D345 and Q456 were recorded on left and right side fin respectively (Figure 4). However, the cumulative curve shows that not all animals were captured during the sampling period as the curve did not reach asymptote. The most newly marked dolphins (10) were recorded on day 9 on left side fin and on day 3 and 11 (8 dolphins) on right side fin. The results showed no significant difference in the number of dolphins sighted on left and right side fins ($p>0.05$, F-value = 0.806).



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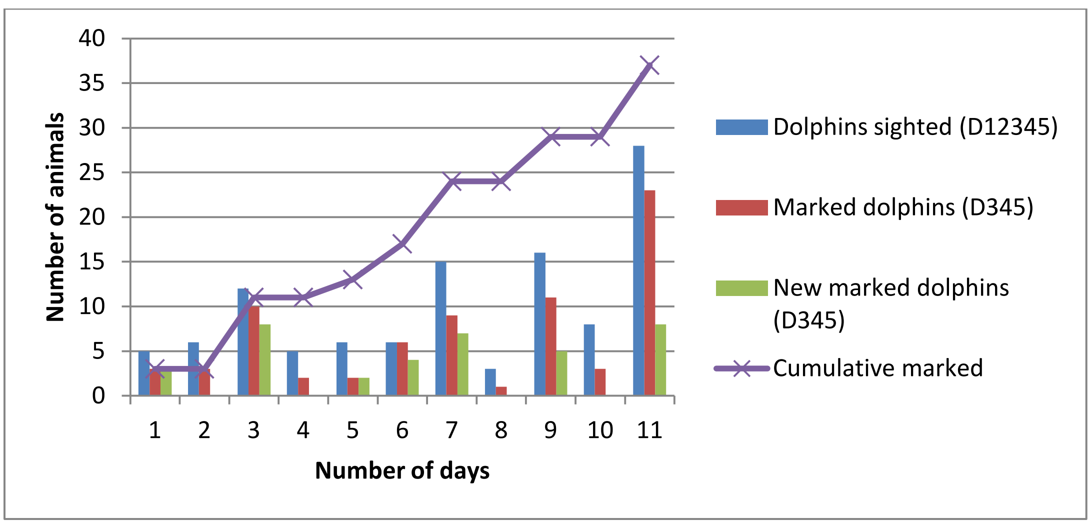
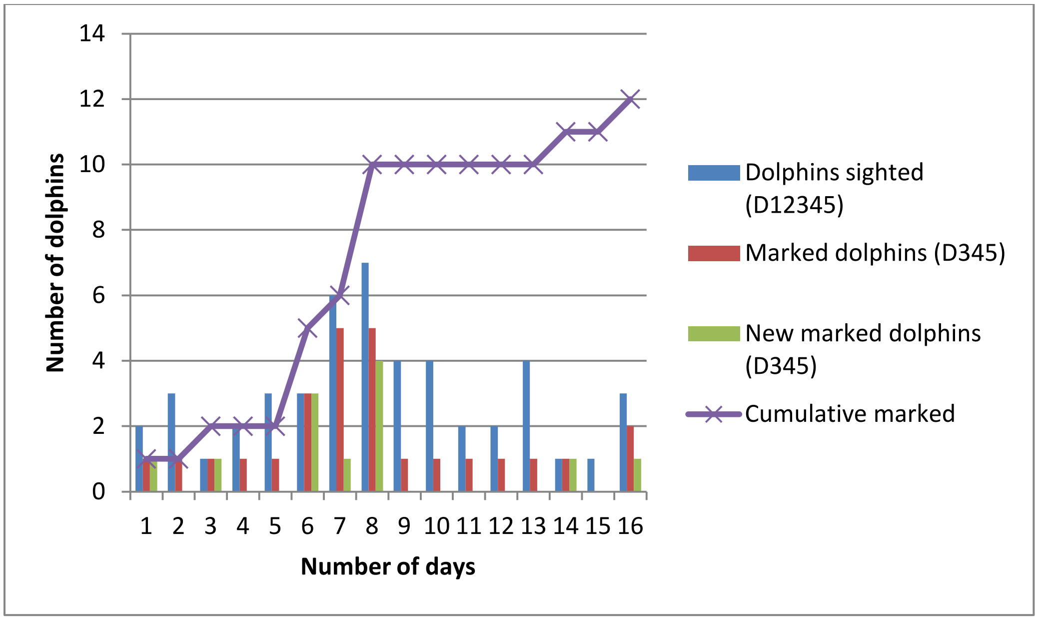


4b.

Figure 4 a&b: Discovery curves showing all dolphins sighted (D12345), marked dolphins (D345), number of new marked dolphins (D345) and cumulative marked of photographic fins in of winter 2009 plotted against number of days at sea, a) left side fin and b) right side fin.

For the 17 days of sampling during the summer of 2010, 12 and 14 marked dolphins (D345&Q456) were observed on left and right side fin respectively (Figure 5). Most marked dolphins were recorded on day 8 (4 animals on left side fin) and day 15 (4 animals on right side). There is no significant difference on the number of dolphins recorded on the left and right side fin ($p>0.05$, F-value =0.868).



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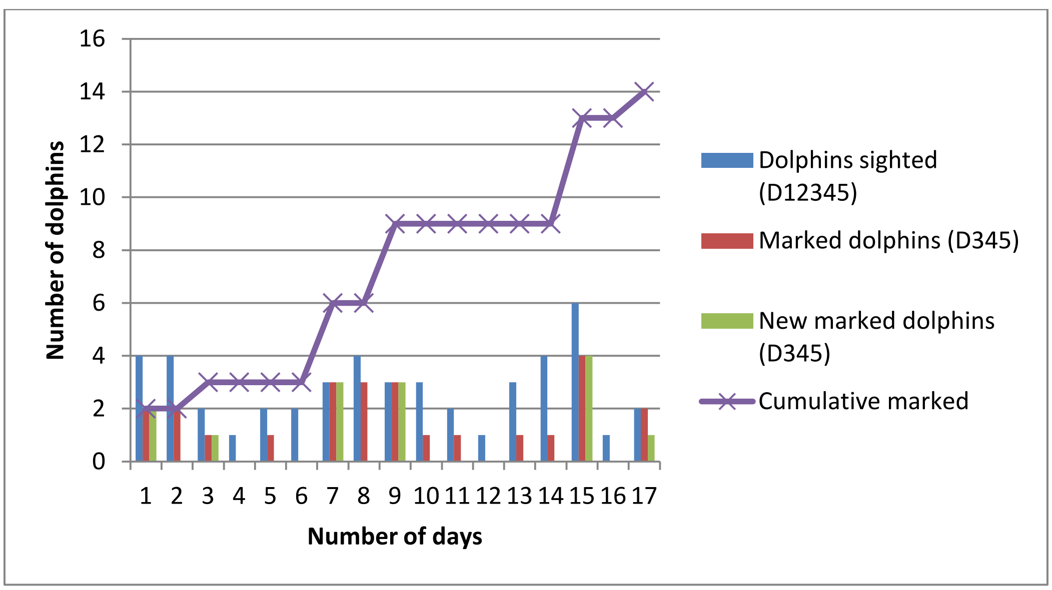
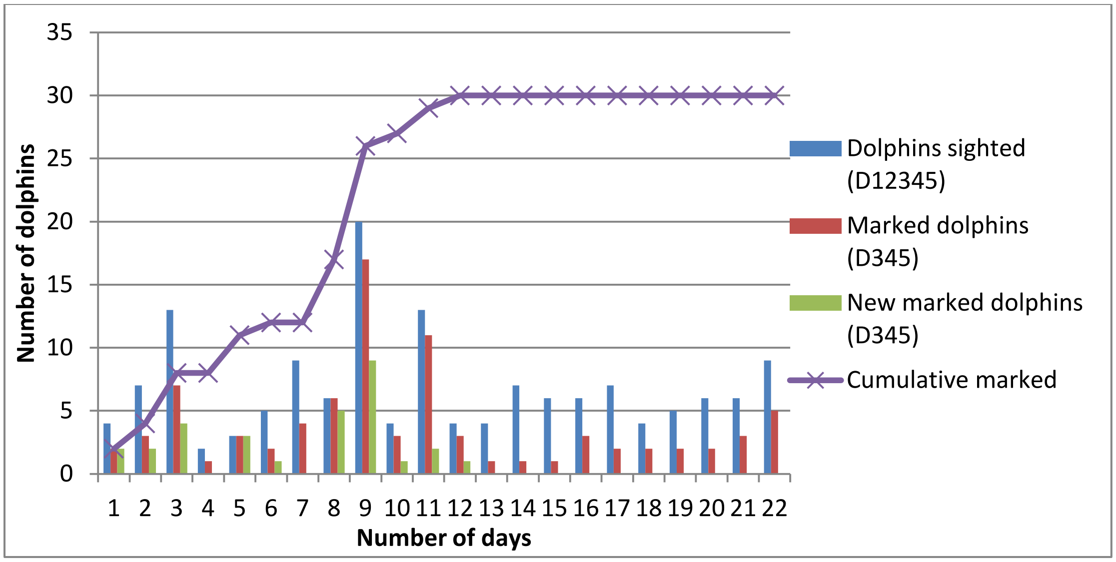


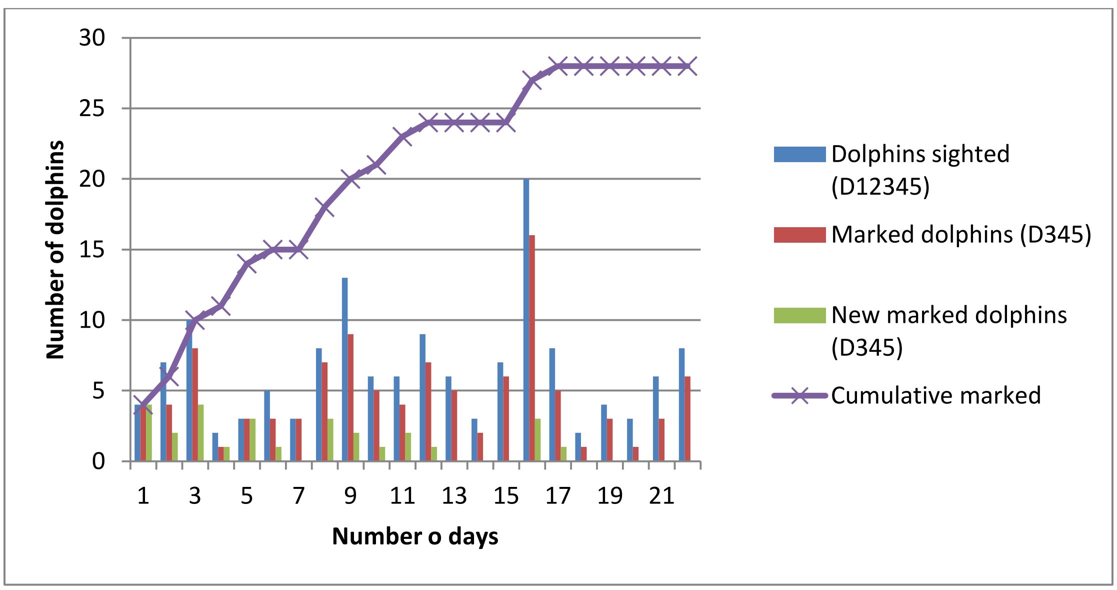
5b

Figure 5a&b: Discovery curves showing all dolphins sighted (D12345), marked dolphins (D345), number of new marked dolphins (D345) and cumulative marked of photographic fins in summer of 2010 plotted against number of days at sea, a) left side fin and b) right side fin.

During the winter of 2010, 22 days were spent on surveying of which 30 and 27 marked dolphins (D345) were recorded on left and right fin side respectively. Very few new marked dolphins were recorded after day 13 (4 on right side fin) and none on left side fin. Both discovery curves (Figure 6 a & b) reached constant. Day 9 of the sampling recorded most newly marked dolphins (9) on left side fin. The results show no significant difference on the number of marked dolphins on left and right fin side ($p>0.05$, F-value =0.231).



6a



6b.

Figure 6: Discovery curves showing total number of dolphins sighted (D12345), marked dolphins (D345), number of new marked dolphins (D345) and cumulative marked of photographic fins in winter of 2010 plotted against number of days at sea, a) left side fin and b) right side fin.

3.2. ABUNDANCE ESTIMATION RESULTS AS TESTED IN PROGRAM CAPTURE

Various models in programme capture were used to estimate the abundance of bottlenose dolphins for each seasons, each fin sides were analyzed separately. Model M_{th} was found to be the appropriate model for the data, (large p-value than the other three models).

During the winter of 2008, the estimated population size ($\hat{N}$, Table 7) of bottlenose dolphins was calculated to be 50 and 51 (model $_{Mth}$) with the estimated proportion of marked animals of 0.83 and 0.81 on the left and right side fin respectively.

Table 2: Population estimates of 2008 winter results showing both left and right fin sides analyzed separately.

Fin side	Model	$\hat{N}$ [1]	SE	CI 95%	θ^2	N^3	SE/Var	CI low 95%	CI high 95%
Left side	M_o	49	1.03	47-51	0.83	59	1.49	56	61
	M_h	53	3.50	49-58	0.83	64	5.07	60	68
	M_t	51	2.51	48-54	0.83	61	3.64	58	65
	M_{th}	51	2.12	48-53	0.83	61	3.07	58	65
Right side	M_o	48	1.28	48-54	0.81	59	1.95	57	62
	M_h	49	1.92	46-59	0.81	61	2.93	57	64
	M_t	48	1.62	46-51	0.81	59	2.47	56	62
	M_{th}	50	2.64	47-53	0.81	62	4.02	58	66

[1]Estimated population
[2]Proportion of marked individuals (D345) to total observed dolphin (D12345)
[3]Total population

During the winter of 2009, the estimated population ($\hat{N}$, Table 3) was observed to be 50 and 66 (model M_{th}) on left and right side fin respectively. The marked proportion (θ) is 0.80 for both sides.

Table 3: Population estimates of 2009 winter results showing both left and right fin sides.

Fin side	**Model**	$\hat{N}$ [1]	**SE**	**CI 95%**	**θ**[2]	**N**[3]	**SE/Var**	**CI low 95%**	**CI high 95%**
Left side	M_o	46	2.85	43-49	0.80	58	4.45	54	62
	M_h	46	3.95	42-50	0.80	57	6.17	53	63
	M_t	44	2.63	41-47	0.80	55	4.11	51	59
	M_{th}	50	5.84	45-55	0.80	63	9.13	57	68
Right side	M_o	44	3.73	40-48	0.80	55	5.83	50	60
	M_h	53	9.88	47-60	0.80	66	15.44	60	74
	M_t	48	6.94	43-53	0.80	66	10.84	58	67
	M_{th}	66	14.95	59-74	0.80	82	23.36	74	93

[1]Estimated population
[2]Proportion of marked individuals (D345) to total observed dolphin (D12345)
[3]Total population

The estimated population of bottlenose dolphins recorded during the summer months of 2009 ($\hat{N}$, Table 4) was 40 and 19 on left and right side respectively. The proportion of marked animals shows a big difference (0.71 left side) and (0.65 right sides).

Table 4: Population estimates of 2009 summer results showing both left and right fin sides.

Fin side	**Model**	$\hat{N}$ [1]	**SE**	**CI 95%**	**θ**[2]	**N**[3]	**SE/Var**	**CI low 95%**	**CI high 95%**
Left side	M_o	21	3.16	18-25	0.71	30	6.27	25	35
	M_h	37	17.4	30-46	0.71	52	34.52	42	65
	M_t	28	9.47	23-35	0.71	40	18.79	32	49
	M_{th}	40	16.48	32-48	0.71	57	32.69	46	67
Right side	M_o	16	1.31	14-18	0.65	25	3.10	21	28
	M_h	17	2.51	14-20	0.65	26	5.94	22	31
	M_t	16	1.01	14-18	0.65	25	2.39	22	28
	M_{th}	19	3.89	16-23	0.65	29	9.21	24	36

[1]Estimated population
[2]Proportion of marked individuals (D345) to total observed dolphin (D12345)
[3]Total population

The estimated population ($\hat{N}$, Table 5) in 2010 winter was calculated to be 41 and 36 bottlenose dolphins on left and right side respectively. The proportion of marked dolphins (θ) is 0.77 on left side and 0.7 on right side fin.

Table 5: Population estimates of 2010 winter results showing both left and right fin sides separately.

Fin side	**Model**	**$\hat{N}$ [1]**	**SE**	**CI 95%**	**θ[2]**	**N[3]**	**SE/Var**	**CI low 95%**	**CI high 95%**
Left side	M_o	31	1.53	29-34	0.77	40	2.58	37	44
	M_h	33	3.06	30-37	0.77	43	5.16	39	48
	M_t	32	2.00	29-35	0.77	42	3.37	38	45
	M_{th}	41	7.15	36-47	0.77	53	12.06	47	61
Right side	M_o	28	0.69	26-30	0.7	40	1.41	38	42
	M_h	30	2.54	27-33	0.7	43	5.18	37	48
	M_t	30	1.86	27-33	0.7	43	3.80	39	47
	M_{th}	36	5.16	32-41	0.7	51	10.53	45	58

[1]Estimated population
[2]Proportion of marked individuals (D345) to total observed dolphin (D12345)
[3]Total population

The estimated population ($\hat{N}$, Table 6) in 2010 of summer was calculated to be 26 and 25 bottlenose dolphins on left and right side respectively. The proportion of marked dolphins (θ) is 0.75 on left side and 0.7 on right side fin.

Table 6: Population estimates of 2010 summer, showing both left and right fin sides results.

Fin side	**Model**	$\hat{N}$ **[1]**	**SE**	**CI 95%**	**θ[2]**	**N[3]**	**SE/Var**	**CI low 95%**	**CI high 95%**
Left side	M_o	13	1.61	11-16	0.75	17	2.86	14	21
	M_h	16	3.85	13-20	0.75	21	6.84	17	27
	M_t	14	1.93	12-17	0.75	19	3.43	15	23
	M_{th}	26	11.63	20-34	0.75	35	20.68	27	45
Right side	M_o	16	2.66	13-20	0.7	23	5.43	19	28
	M_h	18	4.84	14-23	0.7	26	9.88	20	33
	M_t	16	2.98	13-20	0.7	23	6.08	19	28
	M_{th}	25	9.95	20-32	0.7	36	20.31	28	46

[1]Estimated population
[2]Proportion of marked individuals (D345) to total observed dolphin (D12345)
[3]Total population

The estimated number of dolphins for the whole study period ranges between 57 and 59 with a proportion of marked dolphins (θ) of 0.72 on left side and 0.68 on the right side fin respectively. The highest estimated population was in winter of 2009 with 66 dolphins and the lowest in summer of 2009 with 19 dolphins. Total number of bottlenose dolphins in the Walvis Bay area is recorded at 79-87 (CI 95% 76-91) on left and right side according to this study.

The investigation showed that in 2009, there was a significant difference in population estimated during winter and during summer ($p < 0.05$, F-value < 0.001) with summer recorded low number of dolphins (19-40) while winter recorded high number (50-66). The estimated population of 2010 showed no significant difference between the number of dolphins sighted in summer and winter ($p < 0.05$, F-value $=0.388$). This comparison could not be done for 2008 since the survey was not carried out in summer.

When the analysis was carried out for combined data (winter data of all the years compared to summer data of all the years), the result showed no significant difference between the number of bottlenose dolphins recorded during the winter seasons of all the years ($p>0.05$, F-value $=$ 0.170). The same was obtained for summer ($p>0.05$, F-value $= 0.552$). Also this results showed no significant difference between the number of dolphins sighted in winter to those sighted in summer ($p>0.05$, F-value $=0.091$), which support the hypothesis. The population estimates ($\hat{N}$) for all the year are shown in Table 7 and Figure 7 respectively.

Table 7: Population estimates of bottlenose dolphins of the three years of study, with both left and right fin side analyzed separately.

Fin side	**Model**	**$\hat{N}$ [1]**	**SE**	**CI 95%**	**θ [2]**	**N [3]**	**SE/Var**	**CI low 95%**	**CI high 95%**
Left side	M_o	56	0.19	55-57	0.72	78	0.37	77	79
	M_h	57	1.77	54-60	0.72	79	3.41	77	83
	M_t	57	1.07	55-59	0.72	79	2.06	76	82
	M_{th}	57	1.39	55-59	0.72	79	2.68	76	82
Right side	M_o	56	0.35	55-57	0.68	82	0.76	81	84
	M_h	57	1.62	55-60	0.68	84	3.50	80	86
	M_t	57	1.18	55-60	0.68	84	2.55	81	87
	M_{th}	59	2.50	56-62	0.68	87	5.41	82	91

[1] Estimated population
[2] Proportion of marked individuals (D345) to total observed dolphin (D12345)
[3] Total population

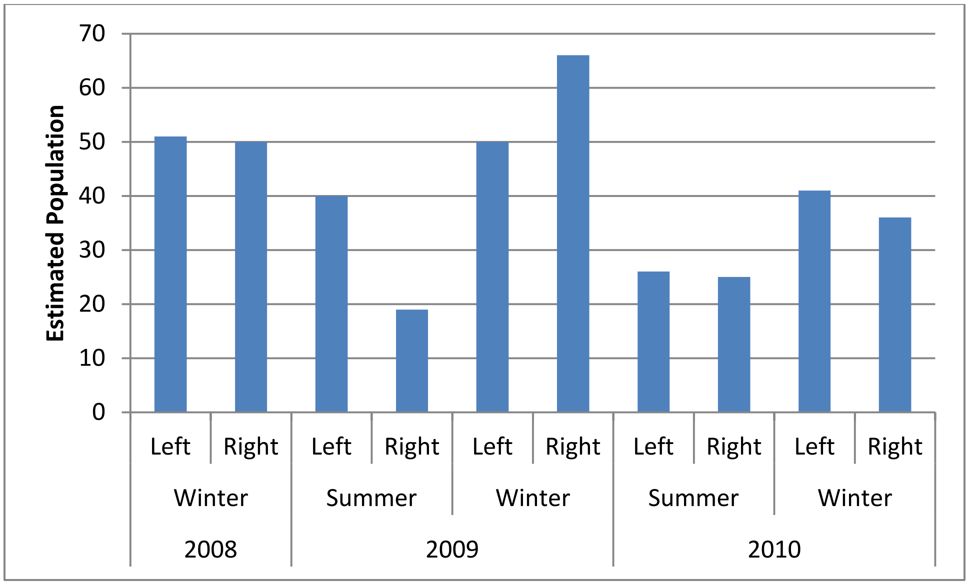


Figure 7: The estimated population ($\hat{N}$) of bottle nose dolphins for all the years of survey.

CHAPTER FOUR

DISCUSSION

The specific objective of this study was to estimate the total population of bottlenose dolphins in the Walvis Bay as well as establishing the seasonal trends (winter and summer) of the dolphins. This information is required to establish the long term management conservation strategies of the dolphins in the area. There has been less study done on the area on the population and seasonal trend. An unpublished data of the 1990 indicated that the population of dolphins in the Walvis Bay area ranges between 100-150 animals (Best, 2007). In this investigation, the total population was estimated to be between 79-87 (95% CI 76-91) bottlenose dolphins. This shows a considerable low figure compared to 100-150 population (estimated over two years) which is a matter of concern as this study was carried out for 3 years. Although the discovery curves shows that most new animals were captured within the first survey, new marked dolphins were observed each season i.e. dolphin with ID T-089 and T-090 were observed in 2010. However since only two new dolphins were discovered in 2010, this in an indication that most dolphins in the area are captured.

The Walvis Bay area has become a center of tourism attraction and there is an influx of job seeking people, putting more pressure on the resources. In our study area, the majority of encounters with dolphins overlap with the area of high tourism activities. It is well documented that, increased boat activities might lead to avoidance of boat traffic by dolphins (Lusseau *et al*.2002, Lusseau 2003) and they were also found to switch from a short-term behaviour avoidance strategy to long-term avoidance strategy (habitat displacement) (Lusseau 2004).

During this study, many dolphins interact closely with tour boats, including bow riding. The excessive number of tour boats around a group of animals (up to 5 tour boat around one group was observed during the study) might play a role in the reduction on the number of dolphin in the Walvis Bay area and impact of this activity therefore on the dolphins should not be ignored. However an investigation on the effect and activities of tour boats needs to be carried out specifically in Walvis Bay area to asses if this is the case. Boat-related effects on bottlenose dolphin behaviour are considered "harassment" under the USA Marine Mammal Protection Act (1972) and should be scrutinized (Mattson et al. 2005).

The impact of the oyster cultivation is not know, since they are cultivated in the bay, taking up much of the dolphin's habitat, which might lead to habitat displacement or reduction in number (habitat competition). Hence thorough investigation on the effect of these mariculture activities needs to be carried out for proper conservation management of dolphins. Overfishing of prey is also one of the major activities that would lead to decrease in the number of dolphins. It has been documented that, one of the inshore species considered to be vulnerable due to overfishing is the bottlenose dolphin in KwaZulu-Natal and Namibia (**Culik, 2010).**

The siltation and increasing shallowness of the lagoon might also be another cause of habitat displacement of dolphins as the water is becoming shallower for them to swim. According to tour operators, bottlenose dolphins used to enter the lagoon more frequently then they presently do (Elwen and Leeney, 2008).

Seasonal trends in numbers are apparent in this study, with numbers lower in summer than winter. However; this figure shows no significant difference statistically on the number of bottlenose dolphins between summer and winter as stated in results. Best (2007) established that the bottlenose dolphins are seen in small group in summer than in winter. The dolphins are known to give births during late summer, but this does not appear to be specifically seasonal.

The seasonal variability in bottlenose dolphins as observed during this investigation might be influenced by the variability of the Benguela current. The Benguella system major future is the strong upwelling, which brings nutrient-rich water to the surface, increasing phytoplankton productivity which in turn leads to high productivity of fish, which forms part of the dolphin’s diet. The upwelling is influenced by prevailing wind. The rate and intensity of upwelling fluctuates with seasonal variations in wind patterns along the Namibian coast with the overall dynamics of the Benguela ecosystem being controlled by seasonal changes in the south Atlantic high-pressure system (O’Toole, 2007).

Bottlenose dolphins show a full range of movements, including seasonal migrations, year-round home ranges, periodic residency, and a combination thereof (Wells and Scott, 1999; 2009). The abundance of the Indo-Pacific humpback dolphins (*Sousa plumbea)* in Algoa Bay varies seasonally, apparently related to the abundance and distribution of inshore prey resources (Karczmarski 1999; Karczmarski *et al.*1999). A similar seasonal pattern has been observed for bottlenose dolphins in the same geographic region (L. Karczmarski, unpublished data), and is likely due to similar ecological causes. Hence this might be the similar pattern of the Walvis Bay bottlenose dolphins. The upwelling at Luderitz to Walvis Bay (24-22^{o}S) occurs throughout the year; nevertheless, there is a seasonal cycle with minimal upwelling during summer (December to January) and maximal in winter (July- September) Longhurst (2007). In this case it is assumed that, during low upwelling, the production becomes low which causes the fish and dolphins population thereof to be low compared to when there is high upwelling during winter season.

Due to the low population of bottlenose dolphins in the Walvis Bay area, they are likely to be more vulnerable to anthropogenic effects and changes in climate.

CONCLUSION AND RECOMMENDATIONS

This investigation has provided valuable information on the population of bottlenose dolphins in the Walvis Bay area, as very little information was found on the literature and built on the 2008 pilot study. It has also given an insight into the seasonal variation of the population in this area. The co-operation of tour boat operators with the study team has made it possible for more information to be obtained, although the bad weather conditions has made it impossible for the sampling to be carried out all days as planned.

These results may be useful in prompting the management planning of the conservation of cetaceans along the coast of Namibia, as they showed that the population is considerable low compared to what it was in the late 1990's, given that the population estimated here was taken over a period of three years study, proper and management plans need to be put on place if sustainable conservation if this population is to be achieved. Coastal development policy and tourism regulations should be enforced at every step of new development or improvements to be undertaken along this area.

Although valuable information has been obtained, seasonal migration pattern could however not be established in this investigation due to the localized nature of the data collection. Further investigation using satellite-linked transmitters on certain individuals would help to answer questions of broader scale movement. Although the anthropogenic effects on dolphins where not the main focus of this study, it can be recommended that further investigation on the effects of tour boats and the oyster cultivation is of considerable importance if proper management is to be put on place. It is of importance that, certain area where dolphins carry out certain activities such as resting and feeding area should be established so that exclusion of tour boats in such area is implemented especially during summer to avoid disturbance of calves.

REFERENCE LIST

Best, P.B. (2007). Whales and Dolphins of the Southern African Sub region. Cambridge University Press. : 337 p.

Bejder, L., S. M. Dawson, and Harrawa, J.A.. **(**1999). Responses by Hector's dolphins to boats and swimmers in Porpoise Bay, New Zealand. *Marine Mammal Science 15*(3):738-750.

Calambokidis, J., Cubbage, G. H., Steiger, K.C., Balcomb and P.Bloedel. (1990). Population estimates of humpback whale in the gulf of the Farallones, California. Reports of the International Whaling Commision. Special Issue 12:325-334

Corkeron, P. J. (1995). Humpback whales (*Megaptera novaeangliae*) in Hervey Bay, behavior and responses to whale-watching vessels. *Canadian Journal of Zoology 73*:1290-1299.

Culik, B. (2010). Odontocetes. The toothed Whale "*Tursiops truncatus*" UNEP/CMS Secretariat, Bonn: Germany.

Elwen, S. and Leeney, R. (2008). Ecology and Conservation of Coastal Dolphins in Namibia, The Namibian Dolphin Project: 33p

Fairfiel, C.P. (1990).Comparison of abundance estimation techniques for the western north

Atlantic whale (*Eubalaena glacialis*) . Reports of the International Whaling Commision. Special Issue 12:119-126.

Findlay, K. P.,BEST, P.B., Ross, G.J.B and Cockroft, V.G. (1992). The distribution of small odontocete cetaceans off the coast of South Africa and Namibia. *South African Journal of Marine Science* 12:237–270.

Gosliner, M.N., (1999). The tuna-dolphin controversy. Pp 120-155 in J.R. Twiss Jr and R.R. Reesves, eds. Conservation and management of Marine Mammals. Smithsonian Institution Press. Washinton, DC (USA).

Hammond, P.S.(1989). Estimating the size of naturally marked whale populations using capture-Recapture techniques. Reports of the International Whaling Commission, Special Issue *8*:253-282.

Huggins,R.M. (1989). On the statistical analysis of capture experiments. Biometrika *76*: 133-140.

IUCN. (2010). IUCN Red List of Threatened Species. Version 2010.1. <www.iucnredlist.org>. Downloaded on 04 May 2010.

IUCN. (2003). Guidelines for applications of IUCN Red List criteria at regional levels, version

3.0 IUCN Species Survival Commision. IUCN gland.Switzerland & Canbrige.UK. II+26p.

Janik, V. M., and Thompon, P.M.. (1996). Changes in surfacing patterns of bottlenose dolphins in response to boat traffic. *Marine Mammal Science 12*:597-602.

Karczmarski, L. (1999). Group dynamics of humpback dolphins (*Sousa chinensis*) in the Algoa Bay region, South Africa. *Journal of the Zoological Society of London 249*:283–293.

Karczmarski, L., V. G. Cockcroft and A. McLachlan. (1999). Group size and seasonal patterns of occurrence of humpback dolphins *Sousa chinensis* in Algoa Bay, South Africa. *South African Journal of Marine Science 21*:89–97.

Kruse, S. (1991). The interactions between killer whales and boats in Johnstone Strait, B.C. Pages 149-159 *in* K. S. Norris and K. Pryor, editors. *Dolphin societies: discoveries and puzzles.* University of California Press, Berkeley, California, USA.

LeDuc, R. (2002). Delphinids, Overview. *In*: Perrin,F, W, Würsig, B. and Thewissen, J.G.M. (ed.), Encyclopedia of Marine Mammals, Academic Press, U.S.A. 310-314 pp.

Longhurst, A. R. (2007). Ecological Geography of the Sea. 2nd edition. Elservier Inc:

United States. 244 pp.

Lusseau, D. (2003*)*. The effects of tourism activities on bottlenose dolphins in Fiordland. Dissertation. University of Otago, Dunedin, New Zealand.

Lusseau, D. (2004). The hidden cost of tourism: detecting long-term effects of tourism using behavioral information. Ecology and Society *9*(1): 2.

Lusseau, D. and Bejder, L.(2007). The Long-term Consequences of Short-term Responses to Disturbance Experiences from Whalewatching Impact Assessment. *International Journal of Comparative Psychology*, *20*: 228-236.

Lusseau, D., Slooten, E.. Dawson,S.m. and Higham.J (2002). The effects of tourism activities on bottlenose dolphins (Tursiops spp.) in Fiordland: working towards a sustainable solution; final report to the New Zealand Department of Conservation. New Zealand

Manly, B.F.J., Amstrup, S.C., and McDonald, T.L. (2005). Capture-Recapture Methods in Practice. *In* Handbook of Capture Recapture Anlaysis. *Edited by* Amstrup,A.S., McDonald,T.L. and Manly,B,F,J. Princeton University Press. pp. 266-274.

Mattson, M. C., Thomas, J. A., Aubin, D.S. (2005). Effects of boat activity on the behavior of bottlenose dolphins (*Tursiops truncatus*) in waters Surrounding Hilton Head Island, South Carolina. *Aquat Mamm 31*: 133-140.

Nowacek, S. M., Wells,R.S. and Solow, A.R.(2001). Short-term effects of boat traffic on bottlenose dolphins, *Tursiops truncatus,* in Sarasota Bay, Florida. *Marine Mammal Science* 17(4):673-688.

Otis, D.L., Burham, K.P., White, G.C. and Anderson, D.R. (1978). Statistical inference for Capture data from closed populations. *Wildlife Monographs No 62*: 135pp.

O'Toole, M and BCLME website "Namibia's Marine Environment" *Namibia Environment Volume 1:* 51-55, available from http://www.bclme.org.na.

Pavlic, A.K. (1998). The Ramsar Convention's Small Grants Fund 1998 allocation report from www.ramsar.org. Retrieved on 10 November 2010.

Pollock, K.H. (1982). A capture-recapture design robust to unequal probability of capture. *Journal of Wildlife Management 46*: 725-757.

Reeves, R. R., Smith, B. D., Crespo, E. A. and Notarbartolo , G. (2003). *Dolphins,* *Whales and Porpoises 2002–2010 Conservation Action Plan for the World's Cetaceans.* IUCN/SSC Cetacean Specialist Group. IUCN, Gland, Switzerland and Cambridge, UK. 139pp.

Seber, G. A. F. (1982). The estimation of animal abundance and related parameters. 2nd edition. Griffin, London, U.K.

Taylor, B.L., and Gerrodette. T.(1993). The uses of statistical power in conservation Biology: the vaquita and northern spotted owl. *Conservation Biology 7*: 489-500

Van Parijs, S. M., and P. J. Corkeron. (2001). Boat traffic affects the acoustic behavior of Pacific humpback dolphins, *Sousa chinensis. Journal of the Marine Association U.K. 81*:533-538.

Wells, R.S. (1991). The role of long-term study in understanding the social structure of a bottlenose dolphin community. Pages 199-225 in K.Pryor and K.S.Norris. Dolphin societies: discoveries and puzzles. University of California Press:USA

Wells, R. S., Scott, M.D. (1999). Bottlenose dolphin - *Tursiops truncatus* (Montagu, 1821) In:

Handbook of marine mammals (Ridgway, S.H., Harrison, S.R, eds.) Vol. 6: The second book of dolphins and porpoises. pp. 137-182.

Wells, R.S. and Scott, M.D. (2002). Bottlenose Dolphins, *Tursiops truncatus* and *T.aduncus. In:* Perrin,F, W, Würsig, B. and Thewissen, J.G.M. (ed.), *Encyclopedia of Marine Mammals*, Academic Press, U.S.A. 122-127 pp.

Wells, R.S.,Scott, M.D.(2009) . Common bottlenose dolphin - *Tursiops truncatus*. In: Encyclopedia of marine mammals . 2nd Ed.(Perrin WF, Würsig B, Thewissen JGM, eds.) Academic Press, Amsterdam, pp. 249-255.

Williams, R., Trites,A.W and D. Bain. (2002). Behavioral responses of killer whales (*Orcinus orca*) to whale-watching boats: opportunistic observations and experimental approaches. *Journal of Zoology 256*:255-270.

Wilson, B.,Hammond, P.S. and Thompson, P.M. (1999). Estimating size and assessing trends in a coastal bottlenose dolphin population. *Ecological Applications 9*:288–300.

APPENDICES

Appendix I: Number of dolphins photographed during the study period

a). Results of 2008 winter survey showing left side fin and right side fin below.

Number of days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**
Dolphins sighted	4	5	2	15	9	5	14	6	3	2	18	11	10	13	27	8	1	23	21
Marked dolphins (D345)	3	3	1	15	7	3	12	5	2	2	17	10	10	13	23	5	1	23	21
New Marked dolphins(D345)	3	2	0	15	3	2	4	2	1	0	9	1	1	2	2	0	0	2	0
Cumulative marked	3	5	5	20	23	25	29	31	32	32	41	42	43	45	47	47	47	49	49

Number of days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Dolphins sighted	7	5	4	18	8	2	2	3	19	5	4	5	6	1	4	1	14	13	10	3	25	25
Marked dolphins(D345)	5	2	2	17	8	1	2	2	16	4	4	3	4	1	4	1	14	10	6	3	23	24
New marked dolphins (D345)	5	0	0	17	3	0	1	1	5	1	1	1	0	1	1	0	4	2	1	0	2	1
Cumulative marked	5	5	5	22	25	25	26	27	32	33	34	35	35	36	37	37	41	43	44	44	46	47

b).Results of 2009 summer survey showing left side fins (top) and right side fins (below).

Number of days	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Dolphins sighted	1	3	4	4	4	2	7	1	4	7	6	4	5	5
Marked dolphins (D345)	0	1	4	3	4	1	5	1	4	2	2	1	1	2
New marked dolphins (D345)	0	1	4	3	1	0	3	1	4	0	0	0	0	0
Cumulative marked	0	1	5	8	9	9	12	13	17	17	17	17	17	17

Number of days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Dolphins sighted	1	3	1	5	7	1	4	8	1	4	6	5	5	4	6
Marked dolphins (D345)	0	1	1	4	4	1	2	6	1	4	3	2	3	2	3
New marked dolphins (D345)	0	1	1	4	0	1	1	3	0	4	0	0	0	0	0
Cumulative marked	0	1	2	6	6	7	8	11	11	15	15	15	15	15	15

c). Results of 2009 winter survey showing left side fins and right side fins (below).

Number of days	1	2	3	4	5	6	7	8	9	10	11
Dolphins sighted	6	7	4	9	6	4	8	18	29	6	36
Marked dolphins (D345)	2	2	3	8	2	4	4	13	23	2	28
New marked dolphins (D345)	2	0	1	7	2	1	3	8	10	0	7
Cumulative marked	2	2	3	10	12	13	16	24	34	34	41

Number of days	1	2	3	4	5	6	7	8	9	10	11
Dolphin sighted	5	6	12	5	6	6	15	3	16	8	28
Marked dolphins (D345)	3	3	10	2	2	6	9	1	11	3	23
New marked dolphins (D345)	3	0	8	0	2	4	7	0	5	0	8
Cumulative marked	3	3	11	11	13	17	24	24	29	29	37

d). Results of 2010 summer survey showing left side fins and right side fins respectively.

Number of days	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Dolphins sighted	2	3	1	2	3	3	6	7	4	4	2	2	4	1	1	3

Marked dolphins (D345)	1	1	1	1	1	3	5	5	1	1	1	1	1	1	0	2
New marked dolphins (D345)	1	0	1	0	0	3	1	4	0	0	0	0	0	1	0	1
Cumulative marked	1	1	2	2	2	5	6	10	10	10	10	10	10	11	11	12

Days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**
Dolphins sighted	4	4	2	1	2	2	3	4	3	3	2	1	3	4	6	1	2
Marked dolphins (D345)	2	2	1	0	1	0	3	3	3	1	1	0	1	1	4	0	2
New marked dolphins (D345)	2	0	1	0	0	0	3	0	3	0	0	0	0	0	4	0	1
Cumulative marked	2	2	3	3	3	3	6	6	9	9	9	9	9	9	13	13	14

e). Results of 2010 winter survey showing left side fins and right side fins respectively .

Days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Dolphins sighted	4	7	13	2	3	5	9	6	20	4	13	4	4	7	6	6	7	4	5	6	6	9
Marked dolphins (D345)	2	3	7	1	3	2	4	6	17	3	11	3	1	1	1	3	2	2	2	2	3	5
New marked dolphins (D345)	2	2	4	0	3	1	0	5	9	1	2	1	0	0	0	0	0	0	0	0	0	0
Cumulative marked	2	4	8	8	11	12	12	17	26	27	29	30	30	30	30	30	30	30	30	30	30	30

Days	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**	**21**	**22**
Dolphins sighted	4	7	10	2	3	5	3	8	13	6	6	9	6	3	7	20	8	2	4	3	6	8
Marked dolphins (D345)	4	4	8	1	3	3	3	7	9	5	4	7	5	2	6	16	5	1	3	1	3	6
New marked dplphins (D345)	4	2	4	1	3	1	0	3	2	1	2	1	0	0	0	3	1	0	0	0	0	0
Cumulative marked	4	6	10	11	14	15	15	18	20	21	23	24	24	24	24	27	28	28	28	28	28	28

Appendix II: Analysis of Variance Results

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a).Variate: New_Marked_animals_D345, Winter 2008

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Fin_side	1	2.00	2.00	0.15	0.701
Residual	39	521.22	13.36		
Total	40	523.22			

b).Variate: New_Marked_animals_D345, Summer 2009

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Fin_side	1	0.333	0.333	0.14	0.707
Residual	27	62.357	2.310		
Total	28	62.690			

c). Variate: New_marked_animals_D345, Summer 2009

Source of variation	**d.f.**	**s.s.**	**m.s.**	**v.r.**	**F pr.**
Fin_side	1	0.73	0.73	0.06	0.806
Residual	20	234.73	11.74		
Total	21	235.45			

d). Variate: New_marked_animals_D345, Winter 2010

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Fin_side	1	0.045	0.045	0.03	0.868
Residual	31	49.471	1.596		
Total	32	49.515			

e). Variate: New_marked_animals_D345, Winter 2010

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Fin_side	1	2.531	2.531	1.48	0.231
Residual	36	61.364	1.705		
Total	37	63.895			

f). Variate: New_Marked_animals_D345, Winter and Summer 2009

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Season	1	74.601	74.601	12.26	<.001
Residual	49	298.144	6.085		
Total	50	372.745			

g). Variate: New_marked_animals_D345, 2010 summer and winter

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Season	1	1.238	1.238	0.75	0.388
Residual	69	113.410	1.644		
Total	70	114.648			

h). Variate: Number_of_New_Marked_Animals_D34 Winter and Summer significance test for all years

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Season	1	26.390	26.390	2.93	0.091
Residual	86	774.701	9.008		
Total	87	801.091			