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General introduction

Skimmers (Order Charadriiformes, Family Laridae) are large tern-like birds closely related to gulls and terns. They are represented by widely distributed three species, the Black Skimmer (*Rynchops niger*), Indian Skimmer (*R. albicollis*) and African Skimmer (*R. flavirostris*). Three races of Black Skimmer inhabit North and South America. The North American race (*Rynchops niger niger*) is almost entirely coastal, while the South American races (*R. n. cinerascens* and *R. n. intercedens*), as well as the Indian Skimmer and the African Skimmer nest mainly on riverine habitat (Gochfeld & Burger (1994). Indian Skimmers range from Pakistan to Southeast Asia and are confined to larger rivers. They are partly migratory and partly nomadic depending on water conditions (Ali & Ripley 1983). African Skimmers range includes Sub-Saharan Africa from Senegal to Sudan, south to Botswana (Urban *et al*. 1986). All three species are migratory within each continent.

All three species are similar in appearance and have two features unique among birds, a laterally compressed and knife-like bill and, vertical pupil. The bill is remarkably flexible and the lower mandible of the bill extends several centimeters beyond the upper mandible. This flexibility and extension allows skimmers to fly low over the water, slicing the surface with the lower mandible, whilst keeping their bill open. When the lower mandible touches a prey item, usually a fish, well-developed neck musculature allows the head to flex downwards, trapping the prey sideways in the bill (Zusi 1962). Skimmers often feed at dusk and throughout the night. The skimmer's eye has a vertical pupil, much like that of a cat, which enhances vision (Brown *et al*. 1982; Roberts 1986; Wetmore 1919; Zusi & Bridge 1981). Skimmers prefer to feed in waters with little surface turbulence, such as lakes and river edges. After "cutting a trail" in the water, birds often double back and retrace their course, snapping up prey in their wake. They usually feed alone or in pairs and, occasionally larger groups.

Skimmers are highly social birds, nesting in colonies and occasionally pairs. Skimmers generally nest on open sand or shell, but Black Skimmers occasionally nest on salt marshes. Black Skimmers also nest in mixed colonies with terns, whilst Indian and African Skimmer breed in non-mixed colonies. Male Black Skimmers are larger than females however, such dimorphism does not occur in either African or Indian Skimmers. Males and females switch incubation duties frequently, especially in the hottest part of the day. Foot and belly-wetting by adults helps to regulate the temperature of incubated eggs (Dowsett 1975; Grant 1978; Roberts 1976; Turner & Gerhart 1971).

African Skimmers (*Rynchops flavirostris*)

African Skimmers are an endemic intra-african migrant. They are frequent to common but locally distributed in the low tropical to subtropical latitudes from, Senegal to Sudan and south to Angola and Northern Botswana (Map 1). As a breeding bird, skimmers are confined to broad rivers and lakes in the dry months when water levels are lowest and, areas of sand bare of vegetation are exposed. The availability of these areas of sand varies with latitude due to the north-south movement of the wet season through the tropics. In the northern tropics skimmers breed earlier in the year compared to those in the southern tropics.

An extensive search of African ornithological literature indicates records on the breeding status and, breeding and non-breeding movements of skimmers are limited. Skimmers breeding on Lake Turkana (*n.* Rudolf) in Northern Kenya (March to September) are thought to disperse southwards and occasionally to the coast in the wet season whilst, those breeding in Zambia and Southern Tanzania (March to November) evidently spend the wet season on lakes in the East African Rift system, regularly as far as and beyond the Equator. No breeding is recorded for skimmers between East or Central Africa between Northern Kenya to Southern Tanzania, apart from a single record in Uganda (Britton & Brown 1972). In Southern Africa skimmers occur on Lake Ngami, Okavango Delta, Chobe and Zambezi Rivers and suitable rivers in Mozambique (Maclean 1985). Breeding has been rarely recorded in South Africa (Chubb 1943; Garland 1944) were skimmers are now recorded extinct as a breeding species (Tree 1989).

The Okavango Delta, situated in Northern Botswana represents the skimmers most south-westerly breeding limit (Map 2). The Delta is part of the large (22,000km^2) internal drainage basin at the southern extension of the East African Rift system although, receives most of its water from summer rainfall in the highlands of Angola. Both the Cubango and Cuito rivers arise in these highlands and unite to form the Okavango River that flows into Botswana from the north-west at the village of Mohembo (Ross 1987). Downriver of Mohembo, the river passes through a region known as the Panhandle where water flow is confined by papyrus (*Cyperus papyrus*) and reeds (*Miscanthus junceum*).

Sand banks in the upper reaches of the Panhandle near the village of Shakawe (Map 3), are exposed each year for a brief period between July to November. These sand banks are important breeding sites for skimmers that have bred north and south of Shakawe between Mohembo (18^{o}17'S, 21^{o}49'E) to Skimmer Island (18^{o}49'S, 21^{o}58'E, Map 4) every year since at least 1975 and, almost certainly prior to 1975. No records exist for the number of skimmers between Mohembo to Skimmer Island during this time however, anecdotal reports suggest skimmer numbers are lower today relative to 1975. In particular, most reports indicate skimmer numbers have declined most rapidly in the last 10-14 years whilst, some reports suggest there has not been a decline as such but instead a shift in their distribution away from tourist lodges and villages (Pryce B & E *per comm.*).

Prior to 1986, the road to Shakawe was a heavy undertaking and few visitors or tourists came to this area of the Okavango River. Subsequent to improved road conditions in the mid-1980's both the number of people living in Shakawe and nearby villages and, number of tourists visiting the area have increased. This increase in population and tourist numbers has also lead to an increase in the number and use of motor-boats by the local village people, the Botswana Defence Force (BDF), new tourist lodges (Drotsky's Cabins and Xaro Lodge), existing tourist lodges (Shakawe Fishing Lodge), residents visiting regionally and new residents. Similarly, there has also been an increase in number and use of mekoro[1] by local village people and, airboats by the BDF. Furthermore, up until 1986 a mine recruiting company based in Shakawe provided many local village people with work however, a substantial amount of remuneration was lost to the area when recruitment was suspended. Thus, there has been more pressure on the river in and around Shakawe since 1986 as both a food resource, whether for subsistence or for sale and, as a tourist resource relative to earlier years.

The consequences of this increase in river use by motor-boats, mekoro and BDF airboats on skimmers between Mohembo to Skimmer Island are not known. Nevertheless, there is cause for concern given evidence from anecdotal reports suggests motor-boats and BDF airboats are capable of flooding nests. Furthermore, there is concern regarding collection of eggs and chicks by local fishermen and children given that collection of chicks has been observed in a previous breeding season.

In 1990, in response to these suggestions, the Kalahari Conservation Society (KCS) placed interpretative signboards on boat launching sites at tourist lodges and villages. These signboards inform boat drivers to motor slowly and not to approach skimmers. Unfortunately, these signboards were only produced in English. In the same year, following the placement of KCS's signboards, the Shakawe Junior Community Secondary School (SJCSS) Wildlife Club visited local villages, tourist lodges and residents to inform people about the decline in skimmer numbers and care required by fishermen, mokoro polers and motor-boat drivers help reduce the disturbance of skimmers.

In 1992/93, Conservation International liaised with tourist lodges to determine the extent motor-boat disturbance on skimmers and provide suggestions to mitigate disturbance. These

[1]local wooden dug-out canoes: mekoro=plural, mokoro=singular.

suggestions included, limiting boat engine size and enforcing speed limits however, they were impractical given they are difficult to enforce and everyone has full access to the river.

To determine the effects of increased river use by motor-boats and mekoro on skimmers breeding between Mohembo to Skimmer Island requires a long-term and controlled study. Thus, the aim of this research is to provide baseline information for the initiation of such a study on skimmers found between Mohembo to Skimmer Island (Map 4).

The specific objectives of this study are presented in separate chapters and are as follows:

- Determine skimmer distribution and abundance (Chapter 1).
- Determine skimmer breeding success (Chapter 2).
- Determine differences in temporal and spatial distribution of boat activity (Chapter 3).
- Determine the short-term effect of and recovery from boat disturbance exhibited by skimmers (Chapter 3).

Map 1 and 2.

Map 3.

Map 4.

Map 4.

General methods

From early July to late November 1994, data on skimmer distribution and abundance (Chapter 1), breeding success (Chapter 2), distribution of motor-boats and mekoro and, effect of and recovery from motor-boat and mokoro disturbance (Chapter 3) were jointly collected on visits to the study area between Mohembo to Skimmer Island. All data were collected with the use a motor-boat, binoculars, telescope, camera and a stop-watch

Due to the size of the study area (~40km) and time required for data collection, coverage of the area was undertaken over two consecutive days at 2 to 5 day intervals. Therefore, the study area was broadly sub-divided into two regions, a northern region between Mohembo to Shakawe Fishing Camp and, a southern region between Shakawe Fishing Camp and Skimmer Island (Map 4).

Most data were collected during the morning (6.30am to 10.30am) and afternoon (2.30pm to 6.30pm) to minimise my exposure to high temperatures and, heat-stress on skimmer eggs and chicks during the hottest hours of the day (10.30am to 2.30pm).

For specific details of methods used to collect and analyse data for please refer to the respective chapters as mentioned above.

1.0 Distribution and abundance of African Skimmers

1.1 Introduction

Knowledge of the distribution and abundance of skimmers in the Panhandle and lower Delta is limited to a few anecdotal reports and computer records held at the Botswana Bird Club. These records include frequent but local reports of between 2 to 6 skimmers along sections of the Okavango River between Nxamaseri to Ikoga and the lower Delta at Txichira Lagoon and, Third bridge, Khwai River and Xakanaxa in the Moremi Game Reserve (Burm J; Ives M; Pryce E; Liversedge T; Motlotle S; Ouzemann L all *pers comm*.). Elsewhere in Botswana, up to 45 skimmers have been sighted on the Chobe River (Randall 1994) whilst, less recent records indicate up to 15 pairs frequent Lake Ngami and, up to 30 pairs occur at Mopipi (Tree 1989)

The objective of the study outlined in this section is to present results of a survey on skimmer distribution and abundance between Mohembo to skimmer Island.

1.2 Methods

Skimmer abundance and distribution surveys were conducted between July to November 1994. On sand banks where all skimmers were not equally visible I took an average of 4 counts over 20 minutes. Details of skimmer colony and pairs locations were then transferred to a survey and lands 1:50,000 scale topographical map.

1.3 Results

The first skimmer sighting for the 1994 breeding season was on 23 June, prior to my arrival. Skimmer numbers reached a peak between 19-20 July with approximately 206 birds counted but, thereafter showed steadily decline with most skimmers departing prior to December (Figure 1.1).

A total of 12 groups of skimmers were found of which there were, 8 (61.5%) pairs, 1 (7.7%) colony of 6 birds and 3 (30.8%) colonies of ≥21 birds (Table 1.1 & 1.). The first three colonies were found during the first survey on 3 July whilst, the fourth colony was found much later in the season on 2 October. All 8 skimmer pairs were found at different stages between 3 July to 20 September.

All colonies and pairs were found on 14 (43.8%) of 32 sand banks uncovered either before my arrival on 1 July or during the study. The difference between the number of skimmer sightings (n=12) and number of sand banks where nests were found (n=14) is due to skimmer pairs that relayed on nearby sand banks after the failure of initial clutches (see section 6.0). Of the 14 sand banks skimmers, 7 (50.0%) sand banks were uncovered prior to 3 July (Map 4, Appendix 1). All four colonies were found on sand banks uncovered prior to 1 July whilst, pairs were found on 3 (21.4%) of sand banks uncovered prior to 1 July (Table 1.1 & 1.2, Appendix 1).

Colonies 1 and 2 were found on sand banks near to Mohembo (Map 4). All skimmers in colony 1 however, disappeared from sometime between 1 to 6 August. On the same day (6 August) I found colony 1 had disappeared, I found a colony of similar size on a sand bank further down river. I am certain skimmers in this second colony are from colony 1 given, similarity in skimmer numbers between the two colonies, the close proximity to original sand bank and, skimmer numbers in colony 2 further down river remained relatively unchanged. Colony 2 however, was found down river of colony 1 and, was the largest of all four colonies found (Table 1.1)

In contrast, colonies 3 and 4 were found up river of Skimmer Island (Map 4). Colony 3 had ~65 skimmers but at some stage between 12 to 16 August disappeared. Unlike, the relocation observed for colony 1, colony 3 disappeared from the study area altogether. However, approximately 3 weeks later (12 to 16 August), 12 skimmers were re-sighted at the original location of colony 3, increasing to a maximum of 26 skimmers between 7 to 19 September. Colony 4 was the smallest (6 skimmers) and last colony found in the study area (Table 1.1).

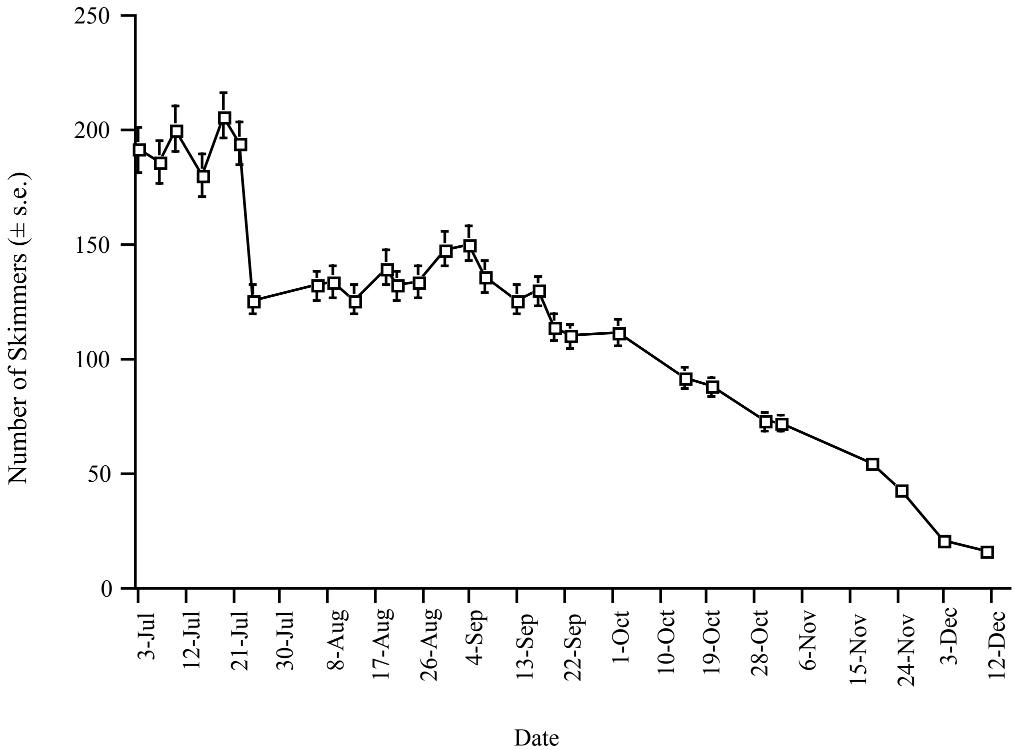


Figure 1.1 - Number of skimmers found during surveys between early July to early December.

	Sand bank	Date found	No. of skimmers
Colony 1 (original)	1	3 July	~24-30
Colony 1 (new)	3	6 August	24
Colony 2	6	3 July	~100-130
Colony 3 (original)	27	3 July	`60-65
Colony 3 (new)	27	16 August	~18-26
Colony 4	26	2 October	6

[a] count range for first month of skimmer surveys.

Table 1.1 - Date, location and number of skimmers found in each of the 4 colonies

Sand bank	Date found
11	20 Sept
14	24 Sept
15[a]	26 Aug
16[a]	4 Oct
18[b]	21 Aug
19[b]	16 Aug
22[c]	19 Aug
22[c]	1 Oct
23	20 Aug
25	26 Aug
28	14 Oct

[a,b,c] represent skimmer pairs with second clutches (nest relays).

Table 1.2 - Date and location of nests for all skimmer pairs .

Study	*n*	River	Group size of skimmers (%)							
			1	2	3-5	6-10	11-15	16-20	21-50	>50
This study	13	Okavango	0	61.5 (8)	0	7.7 (1)	0	0	30.8 (2)	15.4 (2)[a]
Attwell (1959)[b]	21	Luangwa	42.8 (9)	14.3 (3)	23.8 (5)	14.3 (3)	4.8 (1)	0	0	0
Coppinger *et al*. (1988)	133	Zambezi	16.5 (22)	39.8 (53)	18.0 (24)	8.3 (11)	3.8 (5)	6.0 (8)	6.8 (9)	0.8 (1)
Wood & Tree (1991)	16	Zambezi	18.8 (3)	62.5 (10)	18.8 (3)	0	0	0	0	0

[a] includes colony 3 before and after skimmers departed.

[b] sightings for same area between 1952 to 1958.

Table 1.3 - Comparison of group sizes for African Skimmers between different studies. Number of groups are shown in parentheses.

Study	River	Length of river section	Number of skimmers sighted	Estimated density (skimmers/km)
This study	Okavango	40km	~206	3.4[a]
Attwell (1959)[b]	Luangwa	35km	~20	0.6
Coppinger *et al*. (1988)	Zambezi	1550km	~1428	0.9
Wood & Tree (1991)	Zambezi	256km	~36	0.1

[a] skimmer density between August to September.

[b] sightings for the same area between 1952 to 1958.

Table 1.4 - Comparison of the number of African Skimmers found per kilometre of river between the Okavango River in Botswana and, Luangwa and Zambezi Rivers in Zambia.

1.4 Discussion

This skimmer survey indicates skimmers are more abundant between Mohembo to Skimmer Island relative to available counts for the lower Panhandle and Delta There are however, many areas of the Delta where the presence or absence of skimmers remains unknown.

The distribution of skimmers appears to be governed by the availability of sand banks. Most skimmers settle on the first exposed sand banks, indicating a preference for large elevated sand banks. This suggestions of habitat preference is supported by observations in Kenya by Modha & Coe (1969) who found a grass zone at the back of sand banks an important feature for skimmer chicks that seek shelter from extreme temperatures and predators. Furthermore, in Black Skimmers the size, height and vegetation cover of habitat are important determinants of nest site selection (Burger & Gochfeld 1990).

However, not all seemingly skimmers used suitable or first exposed sand banks. This preference among seemingly suitable sand banks suggests other factors besides sand bank characteristics influence nest site selection. These factors most likely include; proximity of sand banks to tourist lodges and villages, use of sand banks by local fishermen, children and cattle (see chapter 3) and, level of boat activity (see chapter 3).

The size and relative proportion of skimmer groups between Mohembo to Skimmer Island are similar to that found for skimmers breeding on the Zambezi and Luangwa Rivers in Zambia (Table 1.3). Groups of two birds were also the most common group size on the Zambezi River (Coppinger *et al*. 1988; Wood & Tree 1991) however, Attwell (1959) found single skimmers were most common on the Luangwa River (Table 1.3). Although most skimmers are found in groups, a relative density estimate of 3 birds per kilometre of river between Mohembo to Skimmer Island is higher than an estimated 0.1 to 1.0 birds per kilometre on the Zambezi River and Luangwa River (Attwell 1959; Coppinger *et al*. 1988; Wood & Tree 1991, Table 1.4). Comparisons of both skimmer density and group size between the Okavango, Zambezi and Luangwa rivers are subject to limited data and do not account for variations in: river topography, characteristics of sand banks, sand bank availability, date or time of count between the rivers.

2.0 Breeding success of African skimmers

2.1 Introduction

The breeding success of African Skimmers is poorly documented. In extensive search of African ornithological literature I found just two records that refer to breeding success (Coppinger *et al*. 1988; Modha & Coe 1969). Otherwise, most records are relatively old but, do provide good descriptions skimmer breeding biology albeit on only a handful of nests (Attwell 1959; Beven 1944; Chubb 1943; Coppinger *et al*. 1988; Garland 1944; Hanmer 1982; Modha & Coe 1969; Pitman 1932; Tree 1989).

Skimmers are monogamous breeders, nesting colonies and occasionally pairs. Nests are a simple unlined deep scrape hollowed in either dry but occasionally damp sand. Clutch size varies between 1 to 4 eggs and second broods are suspected (Pitman 1932). Eggs are generally laid at night, at intervals between 9 hours to 5 days (Urban *et al*. 1986). Incubation starts with the first egg and takes approximately 21 days. Eggs hatch asynchronously and it is stated the first chick wanders off within a day of hatching and the remaining eggs are abandoned (Urban *et al*. 1986). Chicks are well camouflaged and fledge in 5-6 weeks or less (Hanmer 1982).

Records indicate skimmers are vulnerable to predators, flooding and human egg removal. On Lake Turkana (*n*. Rudolf) in Kenya, Modha & Coe (1969) found 35 clutches (62 eggs) of which 20 clutches (28 eggs) were destroyed in 19 days by storms and predators. They also found 21 chicks of which 14 were lost to predators in 5 days and suggest chicks left unattended can also die of heatstress or drown in rain or, when washed from the shoreline (Modha & Coe 1969). In Zambia, Coppinger *et al*. (1988) found children remove eggs from clutches whilst, traps are used to catch chicks.

The objective of the study outlined in this chapter is to describe breeding success of skimmers between Mohembo to Skimmer Island.

2.2 Methods

2.2.1 Observations

A motor-boat, binoculars and telescope were used to locate skimmer nests from a distance. Each nest was photographed and marked using a numbered wooden tag, placed approximately one metre to the right of each nest .

The following was recorded on a standard score sheet for each nest found:

- Date when a nest is first and last sighted,
- Number of eggs and chicks per nest,
- Cause of egg and/or chick disappearance, described as either:
  - Hatched,
  - Lost through predation - observations or evidence of shell and/or chick remains,
  - Unknown cause of nest or egg disappearance - described as disappearing;
    - <17 days incubation, or
    - ≥17 day's incubation
  - Trampled - clutches destroyed by cattle,
  - Abandoned - clutches present after 25 days or eggs are partially buried, and
  - Flooded - signs of water washing a nest.
- Number of fledglings.

2.2.2 Data analysis

Nest success is estimated by the Mayfield method (1975). This analysis considers the number of days nests, eggs and chicks were under observation and is therefore a more accurate estimate for nests that are not followed from first egg to departure of chicks or failure along the way. It uses all available partial information expressed relative to the time nests have been under observation ("exposure time").

Exposure time in 'nests days' is the number of days that an active nest has been under observation. Exposure time was measured from the first day a nest is found to mid-way between the nest check when an egg(s) were no longer present and the last nest check when an egg(s) were present. Individual nest day exposures are averaged to obtained the mean number of days a nest survival per colony and single nests. Similarly, exposure time in 'egg days' is calculated as the number of days that eggs in each nest were under observation. The exposure time for chicks could not be determined as individual chicks could not be identified and due to their semi-precocial most had left their nests within 3-4 days of hatching.

The following calculations are used to determine the survival of eggs and chicks between skimmer colonies and pairs.

- Total egg mortality is calculated as:

$$\text{Daily egg mortality} * \text{incubation period}$$

  where daily egg mortality is:

$$\frac{\text{Total no. of eggs disappearing}}{\text{Total egg day exposure}}$$

- The hatching success (of eggs surviving incubation) is calculated as:

$$\frac{(\text{Total no. chicks})}{(\text{Total no. eggs}) - (\text{Total no. eggs disappearing})}$$

- Chick mortality (the proportion of chicks successfully hatching, but which disappear before fledging) is calculated as:

$$\frac{(\text{Total no. fledglings})}{(\text{Total no. chicks})}$$

- Fledging success (proportion of eggs producing fledglings) is calculated as:

$$= (1 - \text{total egg mortality}) * (1 - \text{chick mortality}) * (\text{hatching success})$$

- Breeding success (the mean number of chicks fledging per nest started) is calculated as:

$$= \text{Mean clutch size} * \text{number of nests}$$

2.3 Results

A total of 67 nests (171 eggs) including nests relays were found. The success or loss of all or some eggs in 29 nests (47 eggs) between the four skimmer colonies and eight skimmer pairs is not known.

Of these 29 nests, the success or loss of all 25 eggs in 10 nests between 17 to 21 days of incubation is not known (Table 2.1). It is not known if these eggs failed in either late incubation or in fact, successfully hatched. Nevertheless, if these eggs successfully hatched, it is still not known whether or not the chicks survived. As the fate of these 10 nests is unknown, they are only included in calculation of the laying period (section 2.3.1), clutch size (section 2.3.2) and, the description of nest and egg disappearance (section 2.3.4 and 2.3.5). Otherwise, all 10 nests are excluded from data analysis.

The success or loss of 22 eggs in a further 19 nests occurred where both eggs and chicks were present at the last nest check is also not known. I assume that all 22 eggs hatched successfully given that the observed hatching period for a clutch is approximately 1 to 3 days and nest checks were every 2 to 4 days. Thus, all 19 nests have been included in the data analysis.

2.3.1 Laying period

All 67 nests were found during nest checks between 8 July to 30 October. The first two nests were found on 23 July in colony 2 however, they were later found abandoned. No further nests were not located until almost one month later on 18-19 August with nests found in colonies 1, 2 and 3 and between several pairs.

Of the 67 nests, approximately 25 (37%) nests were found between 18-31 August; with more than half (64%) of all nests found within the first month between 18 August to 18 September. The laying period was longest in colony 2 with most nests (excluding the first two nests) found between 19 August to 15 October, whilst in colony 3 the laying period was restricted to between 18 August to 2 October and in colony 1 it was restricted to between 18 August to 20 September. All nests in colony 4, however, were found between 2-14 October whilst single nests of skimmer pairs were found between 18-26 August and 20 September to 4 October (Figure 2.1).

Second nests were found between skimmers in both colonies and pairs. Second clutches were most common in colony 1 when all eggs in 7 nests found between 18 August to 3 September disappeared. Approximately two weeks later (20 to 24 September), 7 new nests were found however, all eggs in these second nests also disappeared. No further nests were found in colony 1 after 24 September (Figure 2.1). Second nests were also found between 3 skimmer pairs. In two pairs however, these second nests were on second sand banks that were within ~500m of original sand bank (see Chapter 1, Table 1.2 & Map 4).

2.3.2 Clutch Size

From a total of 67 nests examined on more than one occasion, 6 had one-egg, 20 had two-egg, 39 had three-egg and 2 had four-egg clutches (Figure 2.2). No significant difference however, is detected the mean number of eggs per clutch between colonies or pairs (One-way ANOVA, $F=1.50$ $P=0.217$, $df=4,52$, Table 2.1). The mean clutch size between colonies and pairs is 2.55 (s.e.=0.09) eggs per nest.

	Colony 1	Colony 2	Colony 3	Colony 4	Pairs	Total
Number of nests[a]	14	17	16	3	7	57
Average clutch size (eggs ± s.e.)	2.79 ± 0.11	2.52 ± 0.15	2.63± 0.18	2.33 ± 0.33	2.14 ± 0.34	2.58 ± 0.09
Average incubation period (days ± s.e.	0	21.38 ± 0.98	22.09 ± 0.99	20.33 ± 2.33	20.25 ± 2.14	21.38 ± 0.64
Average nest survival (days ± s.e.)	12.86 ± 2.23	18.00 ± 2.53	18.13 ± 1.96	20.33 ± 2.33	16.29 ± 3.32	16.68 ± 1.17

[a] excludes 10 nests that disappeared ≥17 days incubation

Table 2.1 - Comparison of the number of nests found clutch size, incubation period and nest survival between colonies and pairs.

Figure 2.1

Figure 2.2

2.3.3 Incubation

Incubation was calculated using 26 (38.8%) nests where either some or all eggs successfully. Of these 26 nests, 8 (n=20) nests were in colony 2, 11 (n=18) nests were in colony 3, 3 (n=3) nests were in colony 4 and, 4 (n=11) nests between pairs. These nests do not include nests disappearing at ≥17 days incubation.

No significant difference is detected in the length of incubation between colonies and pairs (One-way ANOVA, F=0.41, P=0.746, df=3,22). Most eggs hatch between 20.3 days (s.e.=2.1) days to 22.1 days (s.e.=1.0) incubation with an overall mean incubation of 21.4 days (s.e.=0.6, Table 2.1).

2.3.4 Nest survival

Nest survival was calculated for nests (n=67) found between colonies and pairs. No significant difference was detected in the mean nest survival between colonies and pairs (One-way ANOVA F=0.98, P=0.424, df=4,52) although, nest survival is lowest in colony 1 where all first and second nests disappeared. Nests in colony 1 survived on average 12.9 (s.e.=2.2) days relative to 16.3 (s.e.=3.3) days for nests between skimmer pairs and, 18.0 (s.e.=2.5) days to 20.3 (s.e.=2.3) days in colonies 2, 3 and 4 (Table 2.1). The mean nest survival for all nests is 16.7 days (s.e.=1.2) days, approximately 5 days shorter than mean incubation.

Of the 67 nests found, the cause of disappearance for 19 (28.4%) nests is not known. These 19 nests include, 10 nests that disappeared at ≥17 days incubation and 9 nests that disappeared at <17 days incubation. Of the remaining 48 nests, 26 (38.8%) of nests had either some or all eggs successfully hatch, 14 (20.9%) nests had eggs removed almost certainly by local village people and 8 (11.9%) nests were either trampled by cattle, destroyed by predators, abandoned or found flooded (Table 2.2, Figure 2.3).

	n	Unknown disappearance (%)		Hatched	Known disappearance (%)				Human
		<17 days	≥17 days		Abandoned	Predated	Trampled	Flooded	
Colony 1	14	0	0	0	0	0	0	0	100.0 (14)
Colony 2	20	30.0 (6)	15.0 (3)	40.0 (8)	10.0 (2)	0	5.0 (1)	0	0
Colony 3	18	16.7 (3)	11.0 (2)	61.1 (11)	5.6 (1)	5.6 (1)	0	0	0
Colony 4	4	0	25.0 (1)	75.0 (3)	0	0	0	0	0
Pairs	11	0	36.4 (4)	36.4 (4)	0	0	9.0 (1)	18.2 (2)	0
Total	**67**	**13.4 (9)**	**14.9 (10)**	**38.8 (26)**	**4.5 (3)**	**1.5 (1)**	**3.0 (2)**	**3.0 (2)**	**20.9 (14)**

Table 2.2 - Comparison of nest fate between colonies and pairs. Number of nests are shown in parentheses.

Figure 2.3

2.3.5 Hatching success

A total of 171 eggs were found between 67 nests of which 70 (40.9%) eggs survived to hatching. These 70 eggs do not include the 25 eggs from 10 nests that disappeared at ≥17 days incubation. Of these 70 eggs, only 47 (67.1%) eggs are known to have hatched, of which 0 (n=40) eggs were in colony 1, 16 (n=43) eggs were in colony 2, 22 (n=41) eggs in colony 3 and, 3 (n=7) eggs in colony 4 and, 6 (n=15) between pairs (Table 2.3).

Of the remaining 101 eggs, the cause of egg loss for 41 (40.6%) eggs is not known although, egg shell remains were found next to a nest in colony 2 and, the spoor of either Water Monitor's (*Varanus niloticus*) were also found amongst nests in colony 2 and 3.

Human egg removal is strongly suspected as the cause of egg loss for at least 40 (39.6%) eggs, all of which were in colony 1. This egg loss is based on the fact that most nest tags had been removed, human foot-prints were present around nests, local village people were seen on the sand bank and, no egg shell remains were found.

Predation of eggs was seen on only one occasion when a Yellow-billed Stork (*Ibis ibis*) destroyed a nest of 3 eggs. Otherwise, skimmers were often seen mobbing and chasing African Fish Eagles (*Haliaetus vocifer*), Yellow-billed Kites (*Milvus migrans*), Hammerkops (*Scopus umbretta*) and Coppery-tailed Coucals (*Centropus cupreicandus)*. and occasionally Water Monitors.

The remaining 17 eggs were lost to nest abandonment (8 eggs), trampling by cattle (5 eggs) and flooding (4 eggs). Cattle are extensively farmed along the river north of Shakawe and they often use sand banks as drinking points. Colonies 1 and 2 were both surrounded by cattle-churned sand. The nesting areas was also criss-crossed by cattle hoof prints but was relatively less disturbed. No evidence of cattle was seen in colonies 3 and 4. The two flooded nests were single nests found on two very shallow sand banks relative to all other nests in colonies and pairs.

2.3.6 Chick survival and fledging success

A total of 47 chicks were found between 9 September to 30 October of which, 16 (34.0%) chicks were in colony 2, 22 (46.8%) chicks in colony 3, 3 (6.4%) chicks in colony 4 and 6 (12.8%) chicks between pairs (Table 2.4).

Only 11 (23.4%) of chicks survived. The cause or mortality for 4 (11.1%) chicks is known whilst, the mortality of the remaining 32 (88.9%) chicks is not known. Of the 4 chicks, 2 (4.3%) chicks were found dead and 2 (4.3%) chicks were taken by an African Fish Eagle and Coppery-tailed Coucal. The two chicks found dead were between 1 to 10 days old and had sustained puncture wounds to the abdomen.

No chicks survived to fledging in either colony 4 or between pairs whilst, only 5 (9.9%) chicks in colony 2 and 6 (14.0%) chicks in colony 3 successfully fledged (Table 2.4).

2.3.7 Breeding success

A total of 171 eggs were laid in a total of 67 clutches of which 47 eggs successfully hatched and 11 chicks successfully fledged. Colony 3 had the highest breeding success with approximately 0.37 chicks per nest relative to 0.25 chicks per nest in colony 2 and 0 chicks per nest in either colony 4 or pairs (Table 2.4). Overall breeding success is lower relative to colony 2 or colony 3 because of the poor breeding success between colonies 1 and 4 and, pairs. True breeding success, i.e. the number of chicks raised per pair is probably higher due to a number of re-nests found between colonies and pairs.

	Colony 1	Colony 2	Colony 3	Colony 4	Pairs	Total
Number of nests[a]	14	17	16	3	7	57
Total number of eggs	40	43	41	7	15	146
Number of eggs disappearing	40	21	9	0	6	76
Total egg mortality (%)	100	54.3	25.3	0.0	56.3	66.1
Hatching success (%)	0	69.6	68.8	42.9	66.7	66.2

[a] excludes 10 nests disappearing at ≥17 days incubation

Table 2.3 - Comparison of the number of eggs, egg disappearance, egg mortality and hatching success between colonies and pairs.

	Colony 1	Colony 2	Colony 3	Colony 4	Pairs	Total
Number of chicks observed	0	16	22	3	6	47
Number of fledged chicks	0	5	6	0	0	11
Chick mortality (%)	0	68.8	72.7	100	100	76.6
Fledging success (%, per egg)	0	9.9	14.0	0	0	5.3
Breeding success (%, per nest)	0	25.0	36.8	0	0	13.6

Table 2.4 - Comparison of the number young chicks, fledged chicks and chick mortality in each between colonies and pairs.

Study	*n*	Number of eggs per clutch				Mean (± s.e.)
		1	2	3	4	
This study	67	2	20	39	2	2.55 ± 0.09
Coppinger *et al.* (1988)	101	13	23	57	8	2.58 ± 0.08
Hanmer (1982)	4	0	3	1	0	2.25 ± 0.50
Modha & Coe (1969)	36	15	13	7	0	1.78 ± 0.13
Attwell (1959)[a]	13	2	5	5	1	2.38 ± 0.66

[a] mean for same area between 1952-1955

Table 2.5 - Comparison clutch size distribution and mean clutch size for African Skimmers in Botswana, Zambia (Attwell 1959; Coppinger *et al.* 1988; Modha & Coe 1969) and Malawi (Hanmer 1982).

Species	Source	Common clutch size	Mean No. of eggs per nest	Mean No. of chicks fledged per nest
African Skimmer	This study	3	2.6	0.14
	Coppinger et. al. (1989)	3	2.6	*
	Hanmer (1992)	2	2.3	1.25[a]
	Modha & Coe (1969)	1	1.8	*
	Attwell (1959)[b]	2-3	2.4	*
Black Skimmer	Burger & Gochfeld (1990)	*	3.6	0.25-0.91[c]
	Erwin (1977)	4	3.6	0.4[c]
	Krannitz (1989)	3	2.8	1.66

* no available data.

[a] assuming sighted chicks are from same nests seen earlier in the season.

[b] mean for same area between 1952-1955.

[c] mean number of chicks fledged per pair.

Table 2.6 - Comparison of common clutch size, mean clutch size and breeding success between African Skimmers and Black Skimmers.

2.4 Discussion

Skimmer breeding phenology (date of arrival, date of initial egg-laying and duration of egg-laying) varies between colonies and pairs. The cause of this variation is unknown but, variation can most strongly argued as being the cause of natural variation and human related disturbance. Broadly, skimmers in colonies 1, 2 and 3 initiated egg-laying earlier than colony 4 or pairs. Thus, these skimmer pairs could have been first time breeders or pairs that relocated and re-nested after the failure of first clutches. On the other hand, evidence for one colony strongly suggests human egg removal is as the cause of two distinct periods of egg-laying.

There is no significant variation in mean clutch size between skimmers nesting in colonies or pairs. Nevertheless, skimmers in either colonies or pairs initiating egg-laying later in the season do have marginally smaller clutch sizes. Furthermore, mean clutch size is also similar to that recorded for skimmers breeding on the Shire River, Malawi (Hanmer 1982) and, the Zambezi and Luangwa Rivers in Zambia (Attwell 1959; Coppinger *et al*. 1988). In Kenya however, skimmers have the smallest recorded mean clutch size (Modha & Coe 1969, Table 2.5).

Breeding success is also variable between colonies and pairs and, is closely associated with the variability observed in clutch size. Thus, breeding success also appears lower for both colonies and pairs that initiate egg-laying relatively late in the season. Overall, breeding success very low but, there are no other records for comparison that detail breeding success. A very approximate comparison can be made with skimmers on the Shire River in Malawi. Hanmer (1982) sighted five fledged chicks in the same area where several weeks early four nests were found. Thus, assuming chicks are from the same nests skimmer breeding success could be as high as 1.25 chicks fledging per nest compared to an average of only 0.14 chicks fledging per nest in this study. Clearly, additional studies need to be completed to determine the relative breeding success of skimmers in this study to other areas of the Delta and Africa in general.

Comparisons between African and Black Skimmer clutch size shows clutch size of African Skimmers is markedly smaller relative to Black Skimmer colonies breeding in coastal areas (Erwin 1977) but, are similar for colonies breeding on inland river systems (Krannitz 1989). Breeding success is also markedly lower relative to Black Skimmers breeding on inland river systems (Krannitz 1989).

Studies on coastally breeding Black Skimmers are not comparable because of different measures used to quantify breeding success, Nevertheless, these studies shows Black Skimmer breeding success in also highly variable (Table 2.6). The cause of this variability is mostly attributed to flooding and predation.

In this study, the cause for a large proportion of egg disappearance (~41%) and even larger proportion of chick disappearance (~68%) is not known because nests were under observation for only part of the time. The unknown egg and chick disappearance however, is similar to the known egg and chick mortality found for skimmers breeding in Kenya (Modha & Coe 1969). Modha & Coe (1969) found ~45% of eggs and ~66% of chicks were destroyed by either storms or predators. Interestingly, Modha & Coe (1969) observed most egg and chick mortality over 19 days and 5 days respectively whilst, in this study figures are for observations for ~10 weeks.

Evidence from this study suggests aerial predators and, to a lesser degree, mammalian predators are the major natural hazard and likely cause of egg and chick disappearance. Furthermore, other studies also suggest aerial and mammalian predators are an important natural hazard and likely cause of egg and chick mortality. For example, avian predators cited in other studies that are also common to this study area include African Marsh Harriers (*Circus ranivotus*), African Fish Eagles and Yellow-billed Kites whilst, potential mammalian predators include Crocodiles (*Crocodylus niloticus*) and Water Monitors. In Kenya however, Scared Ibis's (*Threskiornis aethipicus*) were identified as the cause for most egg mortality (Modha & Coe 1969).

Evidence in this study strongly suggests the collection of eggs by local fishermen or children is the cause of the largest proportion of known egg disappearance. Human interference of skimmer nests is also cited as a cause of egg mortality on the Zambezi River, where children were found to collect eggs and traps specific for chicks were found (Coppinger *et al*. 1988). In this breeding season the collection of chicks were not seen however, has been observed in this study area in at least one previous breeding season.

These are the first data on the breeding success in African Skimmers. The generality of this data can only be ascertained when additional studies of this species are completed in other parts of Africa.

3.0 Distribution of boat activity and, effect of and recovery from boat disturbance

3.1 Introduction

Many colonial breeding waterbirds that nest on the ground are susceptible to short-term intrusions and interactions from predators, chance weather events and, human related disturbance. Such short-term interactions between humans and waterbirds can be placed into two categories, for example, those causing direct mortality e.g. egg collection, boats flooding nests (see Chapter 2) and, those causing general disturbance e.g. boating.

Motor-boats (tourist, local fishing, private and BDF), mekoro and BDF airboats are suspected to be important sources of disturbance and/or direct mortality to breeding skimmers. Skimmers breed during the tourist high season when motor-boat traffic and to a lesser extent, mokoro and BDF airboat traffic, are highest.

Studies on other waterbird populations have shown motor-driven boats cause a higher level of disturbance relative to non-motor driven boats. In Scotland for example, motor-boats cause more disturbance in Eider ducks (*Somateria mollissima*) relative to windsurfers (Keller 1991) whilst, in Thailand, motor-driven boats also cause more disturbance in several waterbird species relative to poled boats.

Furthermore, boat disturbance is an important cause of low breeding success and subsequent declines in some waterbird populations due either egg or chick loss as a result of increased predation during absences from nests (Åhlund & Götmark 1989; Keller 1989; Kury & Gochfeld 1975; Mikola *et al*. 1994) or, abandonment of nests after disturbance (Trembley & Ellison 1979; Safina & Burger 1983).

The first objective of the study outlined in this chapter is to provide an estimate of both the temporal and spatial distribution and, abundance of each boat-type between Mohembo to Skimmer Island. The second objective is to assess the effect of and recovery from disturbance exhibited by skimmers towards each boat-type.

3.2 Methods

3.2.1 Temporal and spatial distribution of mekoro and motor-boats

The distribution and frequency of different boat-types was evaluated by dividing the study area into 9 sections of approximately equal size (Map 4). Consequently, on the first (or second) day of the two-day survey period required to cover the study area, either river sections 1 to 6 (between Mohembo to Shakawe Fishing Camp) or, river sections 7 to 9 (between Shakawe Fishing Camp to Skimmer Island) were visited and surveyed for the presence and absence of each boat-type.

For each river section, the date, time on entering and leaving and, number of mekoro, BDF airboats, local fishing, private, BDF and tourist motor-boats were recorded on a standard score sheet.

3.2.2 Observations on disturbance

Data on motor-boat (tourist, local fishing, private and BDF), mokoro and airboat disturbance were collected from observations made of skimmers in colony 3 between 1 July to 30 September. Observations were made from either a motor-boat or riverbank opposite (~30m from) the colony. Although most observations were made either mid-morning or late afternoon, effort was made to balance the number of observations all times of the day and stages of nesting. For each boat-type the following was recorded on a standard score sheet:

- Date of observation (grouped for analysis into stage of nesting; 1-15 July, 15-31 July, 1-15 August, 15-31 August, 1-15 September, 15-30 September).
- Time of the day for each boat disturbance the colony (grouped for analysis into; 6.30am-10.30am, 10.30am-2.30pm, 2.30pm-6.30pm).
- Speed of boat (slow, moderate or fast).
- Passing distance between each boat and sand bank (near, middle and far).
- Proportion of skimmers disturbed into flight (as a percentage of the colony) and,
- Time taken by at least 70% of skimmers in flight to return to the colony (return flight time).

The mean proportion of skimmers disturbed into flight is the measure of the effect of boat disturbance, whilst mean return flight time is the measure of the recovery from boat disturbance.

3.3 Data analysis

3.3.1 Temporal and spatial distribution of mekoro and motor-boats

All motor-boat (tourist, local fishing, private and BDF) and airboat observations were combined and analysed together due to small sample sizes and missing data. This combined data will be referred to as motor-boats. To analyse the number of mekoro and motor-boats encountered between boat surveys, two General linear model (GLM) ANOVA's were used with fixed factors; river section, month and time of day. I used the time (in minutes) spent in each river section as the covariate, to adjust for unequal observation times. Both GLM ANOVA's are reduced models due to missing cells as motor-boats and mekoro were not seen for all combinations of the above factors.

Results of these analyses are presented and discussed in terms of motor-boat and mokoro activity. Activity is defined as the number of motor-boats and mekoro passing through each river section per hour. Activity is calculated using the following formula:

$$\frac{\text{No. of mekoro or motor-boats per river section * 60 minutes}}{\text{Net time in minutes per river section}}$$

3.3.2 Observations on disturbance

The effect of and recovery from motor-boat disturbance at different times of day, stage of nesting, passing distance and speed are analysed using data available for tourist motor-boats only, due to small sample sizes for mekoro, BDF airboats, local fishing, private and BDF motor-boats.

The effect of and recovery from boat disturbance were analysed separately using Two-way ANOVA's with fixed factors; time of day and stage of nesting and, speed and passing distance. Data for the proportion of skimmers disturbed into flight were transformed into arcsin values and return flight times were transformed into $\log_{10}$ values due to a large range of recorded values. To analyse the effect of and recovery from disturbance between boat-types a One-way ANOVA was used. Tukey's *a posteriori* tests are used to determine differences within significant main factor effects.

All analyses of variance were performed using the Minitab statistical package.

3.4 Results

Results of the analyses are presented as follows: Section 3.4.1 - temporal and spatial distribution of motor-boats and mekoro encountered during boat surveys; Section 3.4.2 - observations on the effect of and recovery from motor-boat (section 3.4.1.1), and mekoro, BDF, local fishing, private and BDF airboats (section 3.4.1.2). Section 3.4.3 - Other sources of disturbance.

3.4.1 Temporal and spatial distribution of motor-boats and mekoro

An average of 36 (s.e.=4) days were spent surveying mokoro and motor-boat distribution and abundance in each river section between 3 July to 25 November. The mean duration of time spent in each river section was 20.6 (s.e.=4.9) minutes per day. Due to a small number of BDF airboats, local fishing, private and BDF motor-boats seen in only a few river sections, these boats have all been combined for analysis with tourist motor-boats.

3.4.1.2 Motor-boats

Interactions between month and both, river section and time of day were not significant (Table 3.1). In contrast, the interaction between river section and time of day was significant (Table 3.1). Inspection of Figure 3.1 shows that motor-boats were more frequent in the afternoon in river sections 6, 8 and 9, whereas in most other river sections they were seen most often in the middle of the day. Nevertheless, for particular river sections many of these apparent differences would not be statistically significant.

The number of motor-boats encountered between boat survey's however, does vary significantly between river sections, but not between month or time of the day (Table 3.1). Tukey's pairwise comparisons indicate significant differences in the number of motor-boats encountered between river section 7 and the river sections 1, 2, and 3 (Figure 3.2).

Inspection of Figure 3.2 shows the highest level of motor-boat activity is in river section 7 where 3.7 (s.e.=0.9) motor-boats pass per hour. River section 7 is mid-way between Xaro Lodge and Drotsky's Cabins (Map 4) and as expected, the two adjacent river sections (river sections 6 and 8) also have high motor-boat activity. In contrast, the lowest levels of motor-boat activity are between river sections 1 to 3 where 0.2 (s.e.=0.3) to 0.5 (s.e.=0.2) motor-boats pass per hour.

3.4.1.3 Mekoro

No significant interactions were detected between any of the factors: river section, month and time of day (Table 3.2). One main effect is significant however; the number of mekoro encountered did vary significantly between river sections but, not between different month or time of day (Table 3.2). Tukey's pairwise comparisons indicate the main significant difference in the number of mekoro encountered is between river section 4 and all other river sections (Figure 3.2).

Inspection of Figure 3.2 shows river section 4 is near to Shakawe, where 9.3 (s.e.=1.2) mekoro pass per hour. There is also a high level of mokoro activity, although not significant, in river sections 6 and 7 between Xaro Lodge and Drotsky's Cabins where between 3.0 (s.e.=0.7) to 4.0 (s.e.=0.8) mekoro pass per hour. In contrast, mokoro activity is lowest in river sections away from tourist lodges and villages - for example, between river sections 8 to 9 where 0.3 (s.e.=0.2) to 1.0 (s.e.=0.3) mekoro pass per hour.

	df	MS	F	*p*
River section	8	4.459	6.16	0.000
Month	4	0.412	0.57	0.685
Time of day	2	1.117	1.54	0.214
River section * time of day	32	1.396	1.93	0.016
River section * month	16	0.409	0.57	0.975
Month * time of day	8	0.597	0.83	0.580
Minutes	1	124.99	172.76	0.000
Error	543	0.724		

Table 3.1 - Three-way analysis of variance for the factors; river sections, month and time of day on the number of motor-boats encountered during boat surveys.

	df	MS	F	*p*
River section	8	13.992	12.51	0.000
Month	4	2.318	2.07	0.083
Time of day	2	2.828	2.53	0.081
River section * time of day	16	0.754	0.67	0.821
River section * month	32	1.404	1.25	0.162
Month * time of day	8	0.978	0.87	0.538
Minutes	1	9.721	8.69	0.003
Error	543	1.119		

Table 3.2 - Three-way analysis of variance for the factors river section, month and time of day on the number of mekoro encountered during boat surveys.

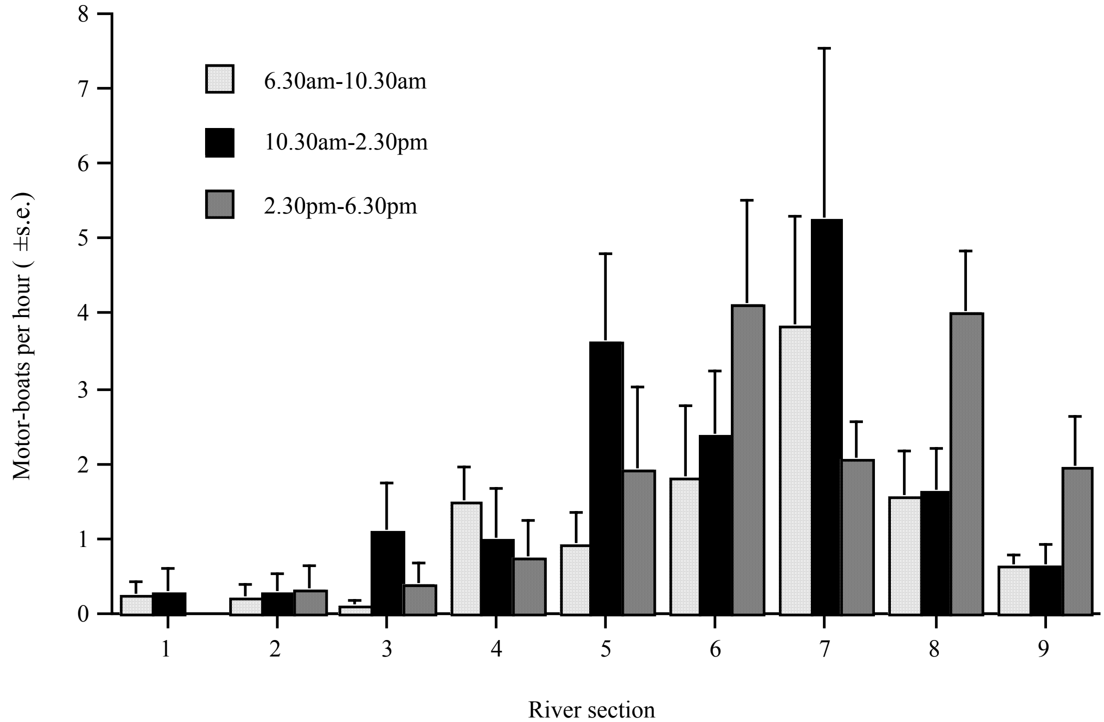


Figure 3.1 - Mean number of motor-boats encountered per hour for each river section at different times of day.

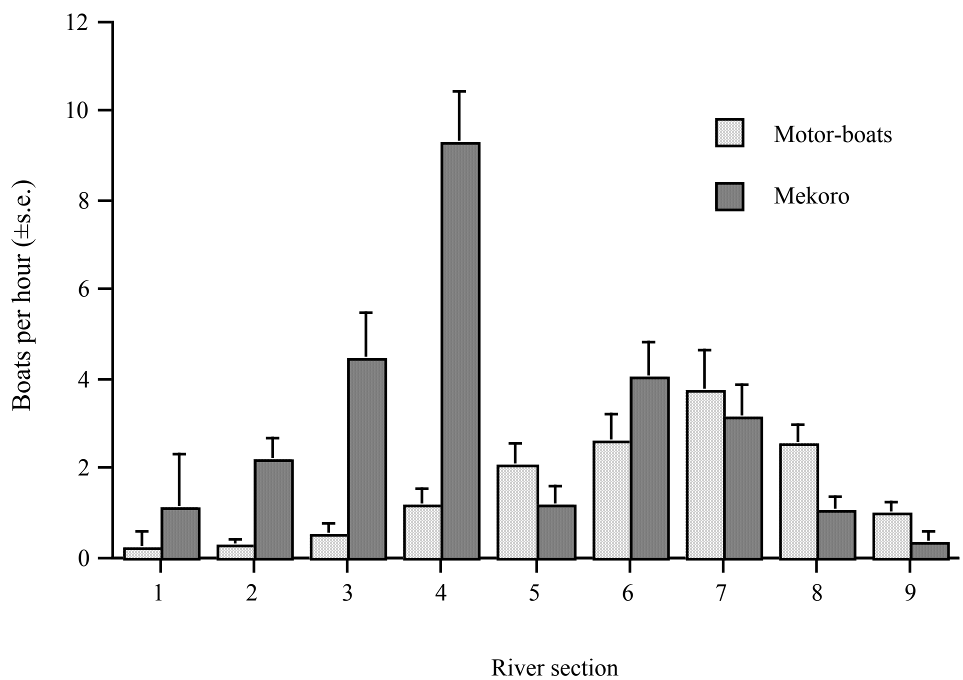


Figure 3.2 - Mean number of motor-boats and mekoro encountered per hour for each river section.

3.4.2 Observations of motor-boat and mokoro disturbance

A total of 14 mekoro, 74 motor-boats (62 tourist, 6 local fishing, 2 private and 2 BDF motor-boats) and 2 BDF airboats were seen in 88.3 hours of observations over 27 days. An average of 3.2 (s.e.=0.2) hours per were spent per observation period. Tourist motor-boats were seen during 24 (88.9%) observation periods whilst, mekoro, local fishing, private and BDF motor-boats and, BDF airboats were seen between 10 (26%) observation periods.

3.4.1.1 Tourist motor-boats

The effect of and recovery from tourist motor-boat disturbance is extremely variable even when a similar time of day, stage of nesting, speed and passing distance prevailed. Nevertheless, interactions between either time of day and stage of nesting or, passing distance and speed were not significant (Tables 3.3 & 3.4).

Comparison between nesting stages

No significant difference was detected in the proportion of skimmers disturbed into flight and stage of nesting (Table 3.3). Nevertheless, the effect of disturbance appears greatest between 1-15 July when approximately 64.7% (s.e.=11.6) of skimmers are disturbed into flight. The two weeks between 1-15 July are however, only a short time after the arrival of skimmers (in late June) and it assumed that the birds are still reasonably restless. In contrast, 41% (s.e.=7.0) of skimmers are disturbed into flight prior to egg laying (1-15 August) and 27.9% (s.e.=6.1) of skimmers disturbed into flight in the first weeks of egg-laying (15-31 August).

A significant difference is however, detected between stage of nesting and the recovery of skimmers from disturbance (Table 3.3). Tukey's pairwise comparisons show there are significant differences between 1-15 September and, the two weeks between both 1-15 August and 16-31 August. Mean return flight times are shortest at the beginning of egg-laying (16-31 August) when skimmers in flight take on average 34.1 (s.e.=10.2) seconds to return to the colony. Interestingly however, skimmers take approximately three times longer to return to the colony in the following two-week period (1-15 September) when the first clutches have hatched. In this two-week period skimmers take on average 93.9 (s.e.=20.1) seconds to return to the colony (Figure 3.3).

Comparison between time of day

No significant differences were detected in either the effect of or recovery from motor-boat disturbance and time of day (Table 3.3). Nevertheless, inspection of Figure 3.4 shows skimmers appear to be more sensitive to disturbance between 2.30pm to 6.30pm relative to hours between 10.30am to 2.30pm.

Comparison between passing distances

The effect of and recovery from disturbance is extremely sensitive to motor-boats passing at near distances (Table 3.4). The mean proportion of skimmers disturbed into flight more than halves from 87.8% (s.e.=9.2) at far passing distances to 37.8% (s.e.=5.7) at near distances. Mean return flight times also decrease from 89.5 (s.e.=32.4) seconds at near distances to 52.9 (s.e.=9.9) seconds at far passing distances (Figure 3.5).

Comparisons between speeds

No significant difference is detected between effect of disturbance and motor-boat speed (Table 3.4). On average, the proportion of a colony disturbed into flight at slow, medium or fast speeds is 44.5% (s.e.=4.1, range=43.3-45.5). In contrast, a significant difference was detected in the recovery of skimmers (Table 3.4). Mean return flight times more than double from 36.3 (s.e.=6.5) seconds at fast motor-boat speeds to 96.4 (s.e.=22.5) seconds at a slow motor-boat speeds (Figure 3.6).

Interactions between either no decrease, gradual or sudden decrease in speed and original speed on the effect of and recovery from disturbance were not significant (Table 3.4). One main effect is significant however, the effect of and recovery from disturbance does vary between no decrease, gradual and sudden decrease in speed. (Table 3.4). On average, the proportion of the colony disturbed into flight more than doubles from 26.5% (s.e.=7.1) with no decrease in speed to 75.9% (s.e.=6.3) with a sudden decrease in speed. Mean return flight times also increase from 49.7 (s.e.=15.8) seconds at a sudden decrease in speed to 65.3 (s.e.=10.3) seconds at a more gradual decrease in speed (Figure 3.7).

	% skimmers in flight				Return flight time (seconds)			
	df	MS	F	*p*	df	MS	F	*p*
Time of day	2	0.354	2.43	0.099	2	0.050	0.38	0.686
Stage of nesting	4	0.218	1.50	0.218	4	0.362	2.74	0.039
Time of day * nesting	8	0.141	0.97	0.472	8	0.052	0.39	0.919
Error	47	0.146			47	0.132		

Table 3.3 - Two-way analyses of variance for the effect of and recovery from passing motor-boats at different times of the day and stages of nesting.

	% skimmers in flight				Return flight time (seconds)			
	df	MS	F	*p*	df	MS	F	*p*
Motor-boat speed	2	0.009	0.056	0.946	2	0.728	6.312	0.003
Passing distance	2	0.577	3.580	0.035	2	0.604	5.250	0.008
Speed * passing distance	3	0.089	0.549	0.651	3	0.029	0.258	0.857
Error	54	0.161			54	0.115		

Table 3.4 - Two-way analyses of variance for the effect of and recovery from passing motor-boats at different speeds and passing distances.

	% skimmers in flight				Return flight time (seconds)			
	df	MS	F	*p*	df	MS	F	*p*
Speed	2	0.097	0.28	0.692	2	1.272	6.08	0.004
Decrease in speed	2	2.697	7.81	0.000	2	0.786	3.75	0.030
Speed * Decrease	4	0.057	0.17	0.880	4	0.527	2.52	0.052
Error	53	0.345			53	0.209		

Table 3.5 - Two-way analysis of variance for the effect of and recovery from passing motor-boats decreasing speed.

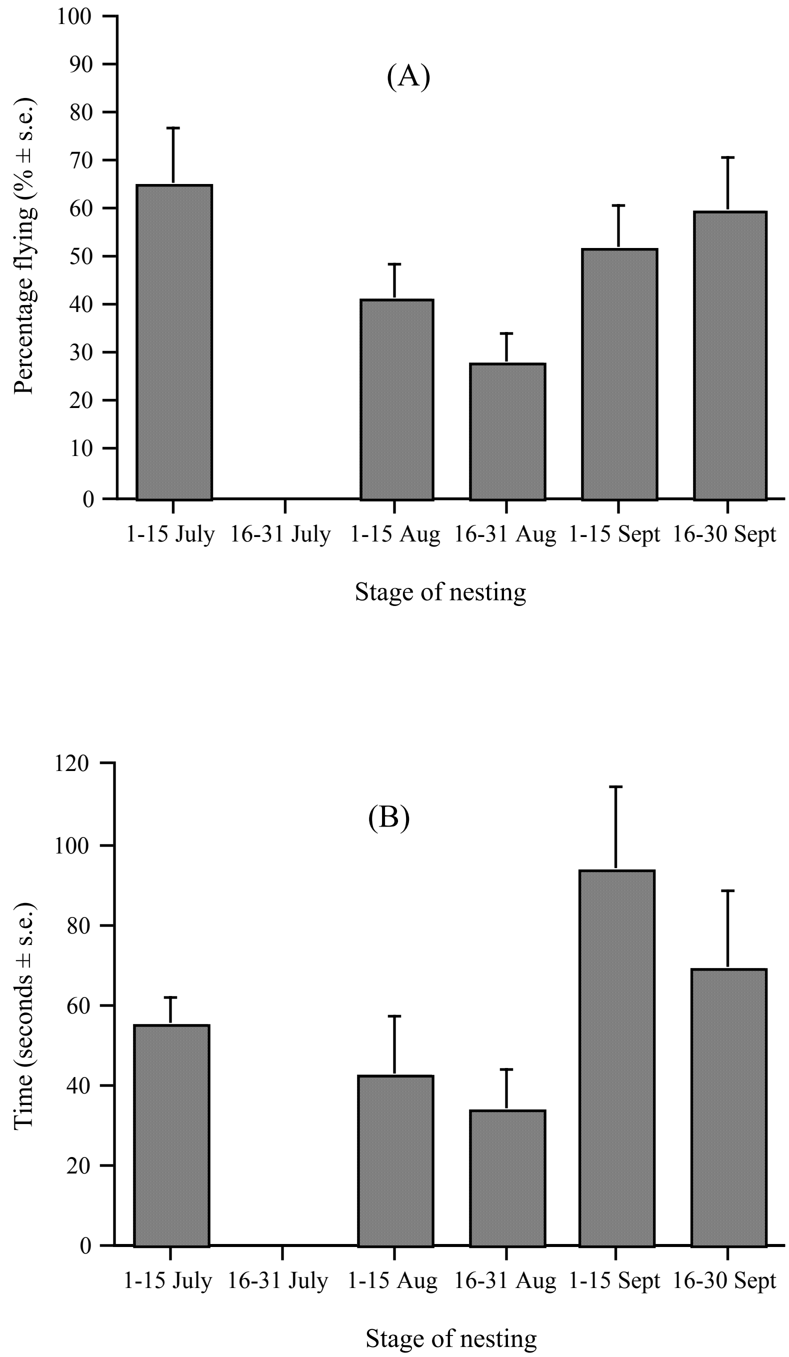
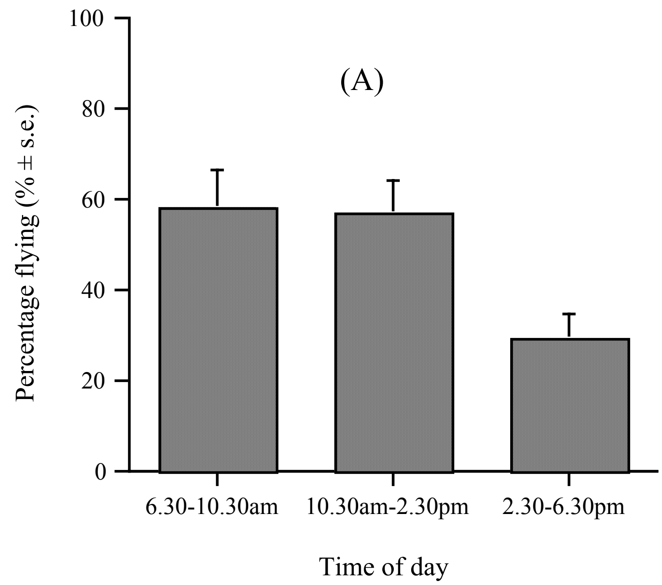


Figure 3.3 - Variation in the effect of and recovery from passing motor-boats at different stages of nesting: (A) Mean proportion of colony disturbed into flight; (B) Mean return flight time.



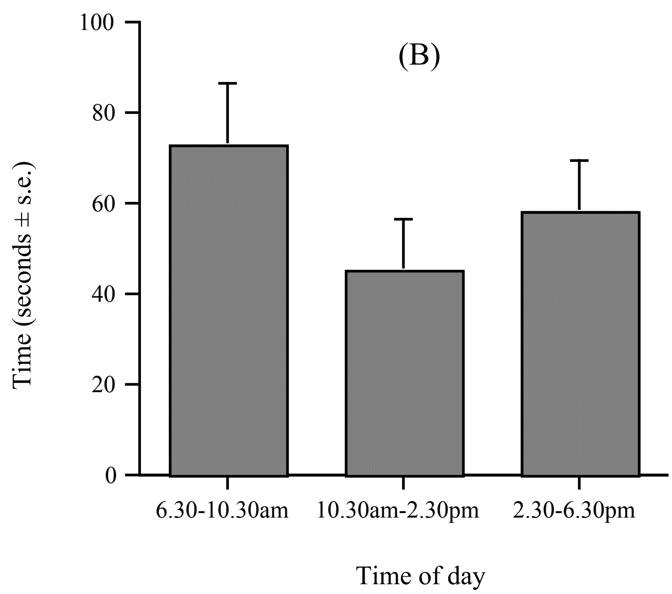
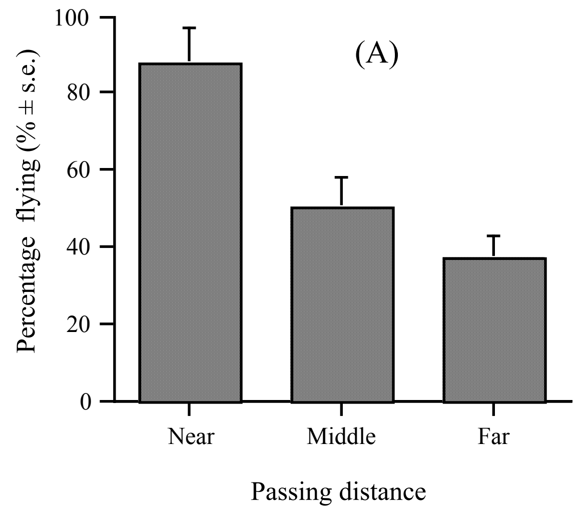


Figure 3.4 - Variation in the effect of and recovery from passing motor-boats at different times of the day: (A) Mean proportion of a colony disturbed into flight; (B) Mean return flight time.



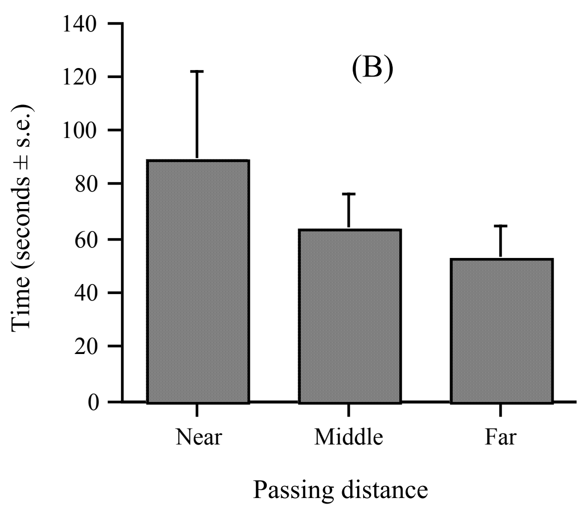


Figure 3.5 - Variation in the effect and recovery from passing motor-boats at different passing distances: (A) Proportion of a colony disturbed into flight; (B) Mean return flight time.

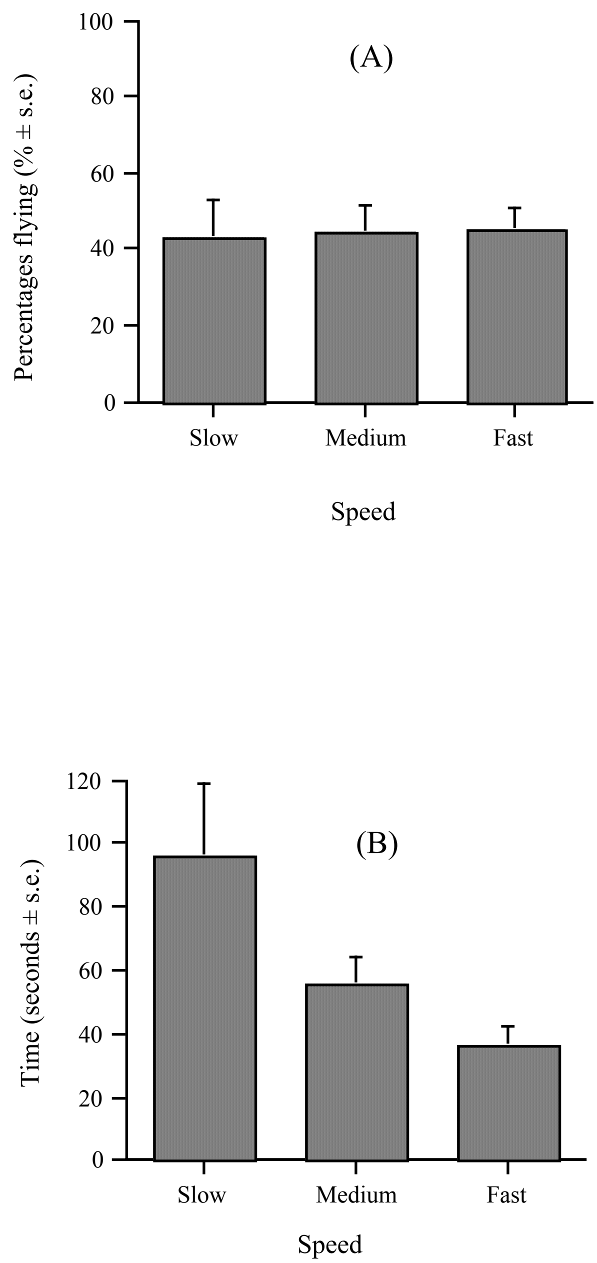


Figure 3.6 - Variation in the effect of and recovery from passing motor-boats at different speeds: (A) Mean proportion of colony disturbed into flight; (B) Mean return flight time.

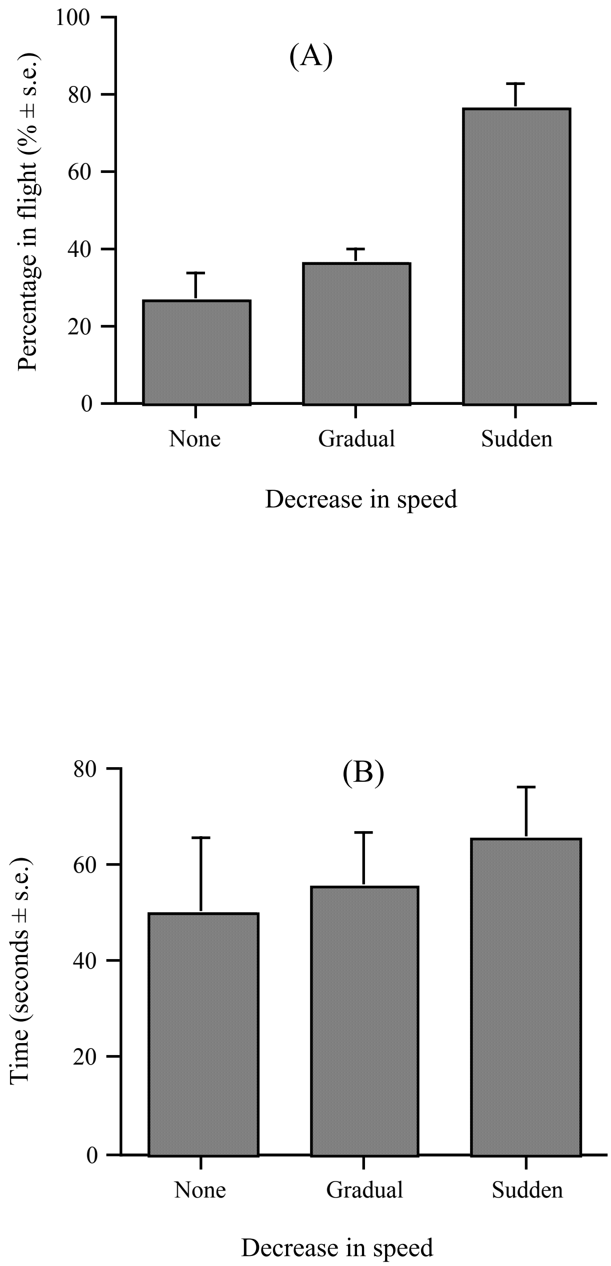


Figure 3.7 - Variation in the effect of and recovery from passing motor-boats decreasing speed (A) Mean proportion of a colony disturbed into flight; (B) Mean return flight time.

3.4.1.2 Mekoro, BDF airboats, local fishing, private and BDF motor-boats

There is insufficient data to compare the response exhibited by skimmers towards different boat-types because of small sample sizes and difference in speed and passing distances between boat-types; for example, all mokoro pass both nearer and slower to sand banks relative to all other boat-types. Thus, a simple comparison is made for the effect of and recovery from disturbance for each boat-type.

A significant difference is detected in effect of disturbance between boat-types (Table 3.6). Tukey's pairwise comparisons indicate significant differences in the proportion of skimmers disturbed into flight is between both BDF airboats and mekoro and, tourist, private, local fishing and BDF motor-boats. On average, mekoro disturb 93.7% (s.e.=3.1) of skimmers whilst, BDF airboats disturb 100% of skimmers. In contrast, tourist, local fishing and private motor-boats disturb on average between 30.4% (s.e.=2.6) to 44.5% (s.e.=4.6) of skimmers into flight (Figure 3.8).

A significant difference is also detected in recovery from disturbance between boat-types (Table 3.6). Tukey's pairwise comparisons indicate significant differences in mean return flight times between both local fishing and tourist motor-boats and, mekoro. Skimmers take on average 162.4 (s.e.=24) seconds to recover after mokoro disturbance relative to only 33.4 (s.e.=3.3) seconds for local fishing motor-boats and 27.8 (s.e.=4.2) for private motor-boats. Otherwise, the mean return flight time for mekoro is two to four times longer relative to tourist and BDF motor-boats and, BDF airboats (Figure 3.8).

	% colony in flight				Return flight time (seconds)			
	df	MS	F	*p*	df	MS	F	*p*
Boat-type	5	2.440	12.31	0.000	5	0.851	7.54	0.000
Error	82	0.198			82	0.113		

Table 3.6 - One-way analysis of variance for the effect of and recovery from disturbance between boat-types.

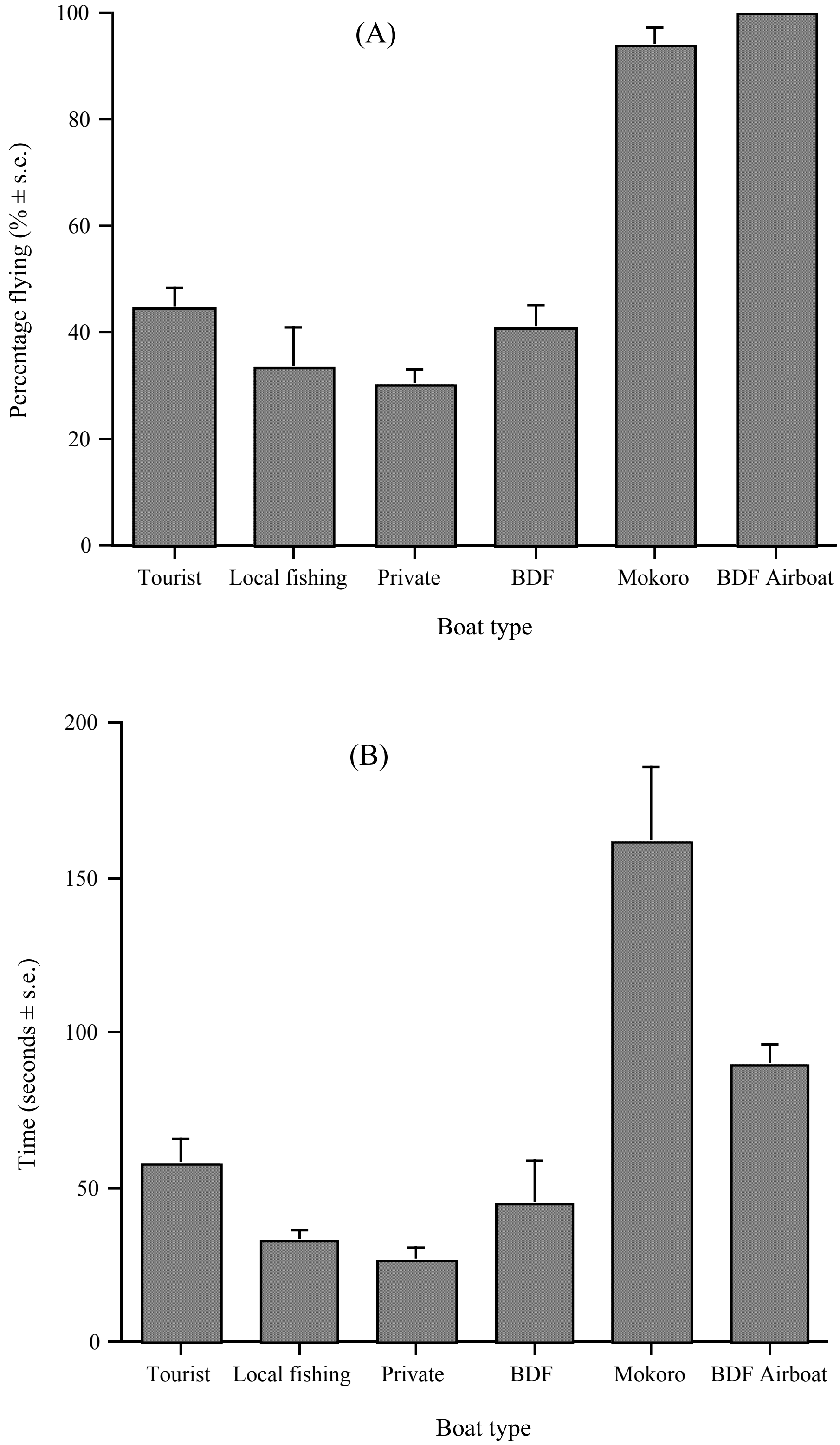


Figure 3.8 - Variation in the effect of and recovery from mekoro (n=14), BDF airboats (n=2), tourist motor-boats (n=62), local fishing motor-boats (n=2), private motor-boats (n=2) and BDF motor-boats (n=2): (A) Mean proportion of a colony disturbed into flight; (B) Mean return flight time.

3.4.3 Other sources of disturbance

Local fishermen and children were seen more often on sand banks between Shakawe to Mohembo relative to sand banks between Shakawe to Skimmer Island (Figure 3.9). Local fishermen and children were seen on sand banks in 25% of visits in river sections 3 and 4 near Shakawe compared to between 2% to 9% of visits in river sections 7, 8 and 9.

Cattle were also more common on sand banks between Shakawe to Mohembo relative to sand banks between Shakawe to Skimmer Island. Cattle were seen on average between 5% to 33% of visits between river sections 1 to 4.

Local fishermen and children were seen on sand banks for periods up to 25 minutes however, on most occasions they were present prior to my arrival and, on my departure. Most activities involved the preparation of fish (scaling and smoking) and, the repair of fishing nest. Although I did not record return flight times, it is evident skimmers are disturbed into flight for longer periods of time relative to boat disturbance. Disturbed skimmers were seen to either remain in flight, settle on opposite end of sand bank, if sand bank was relatively large or, occasionally settle on a nearby sand bank. On the other hand, skimmers were reasonably tolerant of cattle on sand banks however, when cattle come within several metres of a nest skimmers are highly distressed.

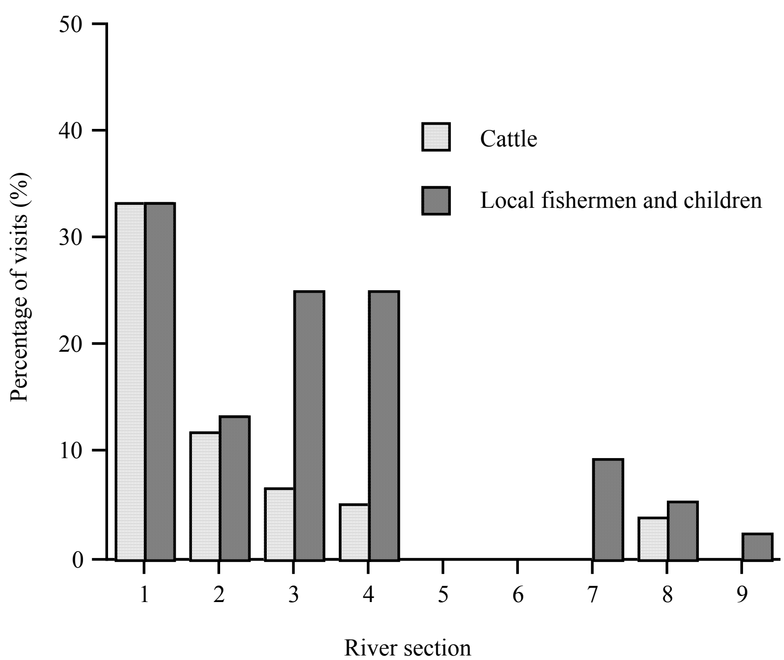


Figure 3.9 - Proportion of visits to each river section where local fishermen and children or, cattle were seen on sand banks.

3.5 Discussion

There is no doubt disturbance from motor-boats (tourist, local fishing, private and BDF), mekoro and BDF airboats are a reality for skimmers nesting on sand banks between Mohembo to Skimmer Island. In particular, motor-boat activity is highest in the peak tourist months between August to November relative to the low tourist months between December to July, overlapping with the breeding season (August to October) of skimmers.

Motor-boat and mokoro activity are spread evenly between August to November but, not between river sections. As expected, motor-boat activity is highest near the tourist lodges; Xaro Lodge, Shakawe Fishing Camp and Drotsky's Cabins whilst, mokoro activity is highest near Shakawe although there is also a high level of mokoro activity near tourist lodges. Thus, river sections near tourist lodges and villages with sand banks are potentially areas of greatest motor-boat and mokoro disturbance for skimmers and other avian species.

Motor-boats, particularly those operated by tourist lodges, were the most frequent boat-type in disturbance observations relative to mekoro and BDF airboats. Mekoro however, cause the greatest disturbance whilst, motor-boats that decrease speed suddenly or pass near to the sand bank also cause a high level of disturbance. In contrast, other studies that have found motor-boats are a cause of considerable disturbance (Åhlund & Götmark 1989; Mikola *et al*. 1994) and, non-motor-driven boats cause less disturbance relative to motor-driven boats (Pierce *et al*. 1993; Tuite *et al*. 1984).

There are two plausible reasons why skimmers exhibit a greater level of response towards non-motor driven (mekoro) than motor-driven boats (motor-boats).

Firstly, it is possible skimmers can habituate to a boat-type that most frequently passes the sand bank, in this case motor-boats. If true, it could in part explain why skimmers in the observed colony are least sensitive to motor-boats relative to mekoro. Unfortunately, this cannot be confirmed because I was not able to observe skimmers in a river section of equivalent mokoro to motor-boat activity. Thus, further research is necessary to determine if skimmers exhibit greater tolerance to particular boat-type that most frequent pass the colony.

Secondly, the location of a sand bank might also be an important factor that affects the response exhibited by skimmers. For example, the colony used to record disturbance observations was situated on a river corner where the field of view is smaller relative to a straighter section of the river. It is probable skimmers in this colony use boat noise as important cue for boat disturbance. Mekoro are silent and skimmers are less likely to be alert to the approach of a mokoro relative to the approach of a motor-boat. Thus, it is probable skimmers use different cues when responding to the presence of different boat-types; for example the sound of a motor-boat relative to the sight of a mokoro. Furthermore, because mekoro pass close to sand banks the response to mekoro is further intensified.

Skimmers exhibit a greater level of response to BDF airboats relative to motor-boats despite both being motor-driven. This difference is most likely due to a higher level of boat noise and larger wake of BDF airboats compared to most motor-boats.

Skimmers are generally less sensitive to the speed than the passing distance of a motor-boat. Skimmers exhibit no change in their level of response to motor-boats at different speeds but, are highly sensitive to sudden decreases in speed. Evidence from boat behaviour shows most motor-boats change speed and/or passing distance in view of a sand bank; for example, many tourist motor-boats slow down whilst, some may even approach the sand bank at the same time.

Skimmers least sensitive to disturbance earlier in the breeding season, particularly during incubation, relative to later in the season when eggs begin to hatch. This response is expected given eggs are more likely to be vulnerable to heatstress and predation relative chicks which leave their nests soon after hatching and are highly mobile.

In contrast however, time of day has no affect the level of response exhibited by skimmers. This is not expected given eggs and chicks are most vulnerable to heatstress during the hottest hours of the day (10.30am to 2.30pm). Nevertheless, this response can in part be explained by the behaviour of disturbed breeding pairs; for example, during many disturbances the proportion of skimmers in flight usually comprises of only one partner from each skimmer pair whilst, the second partner remains with the eggs or chicks. Thus, eggs or chicks are not left completely unattended.

The relatively important finding in this study however, is the potential impact from the presence of local fishermen, children and cattle on sand banks. Although detailed data was no recorded, simple observations show skimmers exhibit a higher level of disturbance to the presence of people and cattle on sand banks. Potentially, disturbance from people and cattle can be many orders of magnitude higher than any boat disturbance as people and cattle are inevitably on sand banks for a longer period of time than it takes for either a mekoro, motor-boat or BDF airboat to pass the sand bank.

Thus, to investigate fully the importance and full implications in the effect of and recovery from boat, human and cattle disturbance will require a long-term and controlled study.

4.0 Conclusions

Most skimmers in the 1994 breeding season arrived at sand banks in late June and departed prior to December. There are no other counts for skimmers in this area to indicate this skimmer population has decreased however, given the few available records and anecdotal evidence skimmer numbers in this area appear higher relative to other areas of the Delta. Nevertheless, there is are many areas of the Delta where the presence or absence of skimmers is unknown.

Motor-boat activity is highest in the peak tourist season between August to November and overlaps with the main breeding period of skimmers between August to October. Motor-boat and mekoro activity however, are evenly spread between these months but are unevenly spread between different areas of the river. Broadly, motor-boat activity is highest near Xaro Lodge, Shakawe Fishing Camp and Drotsky's Cabins whilst mekoro activity is highest near Shakawe and Mohembo.

Most skimmers were found in four colonies of which, two colonies were in river sections of higher motor-boat to mokoro activity and, two were in river sections of lower motor-boat to mokoro activity. Overall, the largest proportion of skimmers were in the two colonies found associated with higher mokoro to motor-boat activity. This pattern of distribution suggests skimmers avoid river sections with higher levels of motor-boat to mokoro activity. Distribution however, can also in part be explained by sand bank availability, proximity to tourist lodges and villages and, use by local fishermen and children.

Skimmers are most sensitive to passing mekoro than motor-boats and, to a lesser degree BDF airboats. In contrast, other waterbird disturbance studies have found motor-boats the cause of considerable disturbance (Åhlund & Götmark 1989; Mikola *et al.* 1994) and, non-motor driven boats the cause of less disturbance relative to motor-driven boats (Keller 1991; Pierce *et al.* 1994). The main difference between these findings is habitat type. These other studies were performed on waterbird species found in more open habitat like lakes (Pierce *et al.* 1993, Tuite *et al.* 1984) and estuaries (Keller 1991). In contrast, this study was performed on a river where habitat is generally narrower and, the field of view smaller relative to lakes and estuaries.

The higher level of response exhibited by skimmers towards mekoro pass is because they pass both nearer and slower to sand banks than all motor-boats and most BDF airboats. Mekoro use these shallow areas of water for safety because they are non-motor-driven.

In the presence of motor-boats and to a larger degree BDF airboats, skimmers are most sensitive to sudden decreases in speed and near passing distances. Skimmers are more sensitive to BDF airboats than motor-boats almost certainly because of their loud noise and wake.

Breeding success of skimmers varies between both colonies and pairs and consequently varies between river sections. There is however, no trend in this variation to suggest breeding success is associated with either higher or lower levels of motor-boat to mokoro activity. In general, the range of values for breeding success are similar between all river sections of higher and lower motor-boat to mokoro activity.

A relatively higher proportion of eggs disappeared from nests found in river sections with lower levels of motor-boat to mokoro activity. This relationship could be associated with the higher levels of disturbance caused by mekoro, but in this case, the collection of eggs by local fishermen or children, is strongly suspected. Therefore, the major problem in this study was not being able determine the cause of most egg and chick disappearance. Nevertheless, eggs and chicks potentially are more susceptible to mortality during mokoro disturbance because more skimmers are disturbed into flight for longer periods relative to motor-boat and BDF airboat disturbance.

On the other hand, although motor-boats and BDF airboats cause less disturbance relative to mekoro, eggs and chicks are potentially susceptible to being flooded by the wake of motor-boats and BDF airboats passing near to sand banks. No nests however, were seen flooded by either motor-boat or BDF airboat wakes during observations but, 3% of all nests found were flooded. Evidence suggests these nests were not flooded by a rise in river level or rainfall although, both these factors can cause of flooding (Modha & Coe 1969). Thus, it is strongly suspected either passing motor-boats or BDF airboats passing near to sand banks flooded these nests.

Another potential impact of boat disturbance during breeding is the interruption of incubation and brooding. When eggs and chicks are left unattended due to boat disturbance they potentially are exposed to thermal stress. Teal (1965) for example, found long exposures (30 minutes) in the sun are lethal for White Ibis (*Eudocimus albus*) eggs. Furthermore, Safina & Burger (1983) found thermal stress is a cause of egg mortality in Black Skimmers colonies that were experimentally disturbed by people (Safina & Burger 1983). The important differences between these are however, differences between waterbird species and temperature and, experimental human disturbance is able to control for factors like frequency of disturbance unlike the collection of observational data.

Thermal stress is most likely the cause of egg failure in nests found abandoned but, the actual cause of nest abandonment is not known. Furthermore, abandoned nests comprise of the first two nests initiated prior to peak egg-laying and, several of the last initiated nests. Thus, nest abandonment appears to not be related with boat disturbance. Nevertheless, mekoro disturbance could potentially be a cause of nest abandonment because skimmers exhibit a higher level of response. Furthermore, there is evidence of nest abandonment in Black Skimmers frequently disturbed during incubation (Safina & Burger 1983).

Most importantly, evidence from this study suggests, the presence of local fishermen, children and cattle on sand banks is potentially a greater source of disturbance, egg mortality and chick mortality than either mokoro, motor-boat or BDF airboat disturbance.

Synopsis

There is insufficient evidence to indicate a definite relationship between skimmer distribution and either motor-boat or mokoro activity because of other confounding factors likely to be affecting skimmer distribution. Nevertheless, skimmers exhibit higher levels of response towards mekoro because they pass slower and nearer to sand banks whilst, motor-boats and BDF airboats that decrease speed suddenly or pass near to the sand bank also cause high levels of disturbance.

Breeding success is both low and highly variable between river sections of higher and lower motor-boat to mokoro activity. There is however, no trend in this data to associate breeding success with varying levels of boat activity. Furthermore, the cause of a large proportion of the variation in breeding success is largely unknown. Nevertheless, there is some evidence to suggest motor-boats and BDF airboats can flood nests but, flooding accounts for a very small proportion of known egg disappearance. Furthermore, it is strongly suspected local fishermen or children were the cause of a large proportion of egg disappearance. Thus, the presence of people on sand banks and, interference with nests is potentially the greatest cause of disturbance and egg mortality in the 1994 breeding season.

There is no direct evidence to indicate the present level of boat activity and distribution and, boat disturbance affect skimmer breeding success and distribution. An increase in boat activity may however, enhance effects. Thus, further ongoing research is needed to determine whether boat activity is having an impact on skimmer distribution and breeding success.

5.0 Management recommendations

The results of this study are useful as guidelines in the management of boat activity during the skimmer breeding season. Recommendations resulting from this study regarding management and suggestions for further research are listed in the executive summary and discussed below.

I have subdivided the following recommendations to bring attention to firstly, the results of this study and secondly, further research recommendations.

- Mokoro are the greatest source of boat disturbance but, as mokoro pass near to sand banks for safety it is impractical to suggest they increase this distance. Instead, it is essential mokoro polers are educated on skimmers and their vulnerability to disturbance.

- Motor-boats and BDF airboats that suddenly decrease speed suddenly or pass near to sand banks with skimmers are also a source of great disturbance. It is essential motor-boat drivers are informed to pass sand banks with skimmers at the greatest distance possible. All motor-boat and BDF airboat drivers should not make sudden changes in speed or approach sand banks. Furthermore, all motor-boat and BDF airboat drivers should keep boat speed to a level that will minimise the impact of boat wakes.

- It is essential all motor-boat and BDF airboat drivers and, mokoro polers keep disturbance to a minimum in the hottest hours of the day between 10.30am to 2.30pm. This precaution will reduce any chances of eggs or chicks being lost to thermal stress.

- It is also essential all motor-boat and BDF airboat drivers and, mokoro polers are informed of the dates between which skimmers are at breeding activity and to keep disturbance to a minimum during this period.

- An enforced total ban should be in place for all people, tourist, fishermen and children alike from landing sand banks with skimmers.

- Cattle should be encouraged to use other areas of the river bank away from sand banks as drinking points.

- The KCS interpretative signboards should be revised and made bilingual.

Further Research Recommendations

- Effort should be made to continue research and/or monitoring on skimmer abundance, distribution and breeding success in following seasons. This can be achieved by:

    a) Banding skimmers between late June to early July prior to breeding and data collection.

    b) Monitoring skimmers numbers and breeding locations between successive breeding seasons.

- Effort should be made to further investigate whether local fishermen and children are collecting skimmer eggs and chicks.

- Effort should be made to further expand on and investigate the effects of and, impacts from human disturbance and interference, and predation on skimmer distribution and breeding success relative to boat disturbance. Furthermore, this research should also include a more in-depth evaluation of addition factors affecting skimmer distribution.

- Effort should also be made in future skimmer research to incorporate other areas of the Okavango River and/or Delta to ascertain the regional distribution, abundance and breeding success of skimmers.

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8.0 Appendix 1

Sand bank	Approximate date uncovered	South Co-ordinate	East Co-ordinate
1	before 1 July	*	*
2	before 1 July	*	*
3#	before 1 July	18o17.17'	21o48.36'
4	before 1 July	18o17.17'	21o48.40'
5	~29 Sept	18o17.29'	21o49.42'
6#	before 1 July	18o17.38'	21o49.07'
7	~15 Oct	*	*
8	~29 Sept	18^{o}18.57'	21^{o}49.49'
9	~24 Sept	18o19.26'	21o49.57'
10	before 1 July	18^{o}20.28'	21^{o}50.08'
11#	~26 Aug	18^{o}20.36'	21^{o}50.21'
12	before 1 July	18^{o}21.44'	21^{o}51.11'
13	before 1 July	*	*
14#	~6 Aug	18^{o}24.10'	21^{o}52.57'
15#	~6 Aug	18^{o}24.02'	21^{o}52.57'
16#	~6 Aug	18^{o}25.11'	21^{o}53.42'
17	~8 Oct	*	*
18#	~10 July	18^{o}25.46'	21^{o}55.11'
19#	before 1 July	18^{o}25.40'	21^{o}55.15'
20	~15 Aug	18^{o}25.40'	21^{o}55.26'
21	*	*	*
22#	before 1 July	18^{o}25.14'	21^{o}56.23'
23#	before 1 July	18^{o}25.01'	21^{o}57.20'
24	~10 July	18^{o}25.02'	21^{o}57.19'
25#	~10 July	18^{o}25.22'	21^{o}58.07'
26#	before 1 July	18^{o}25.43'	21^{o}58.06'
27#	before 1 July	18^{o}25.42'	21^{o}58.25'
28#	~8 Oct	*	*
29	~22 Oct	*	*
30	~3 Sept	*	*
31	before 1 July	*	*
32	~2 Oct	*	*

indicate sand banks with skimmer nests