TANZANIAN CROCODILE SURVEY, OCTOBER, 1999

A REPORT TO THE DIRECTOR OF WILDLIFE

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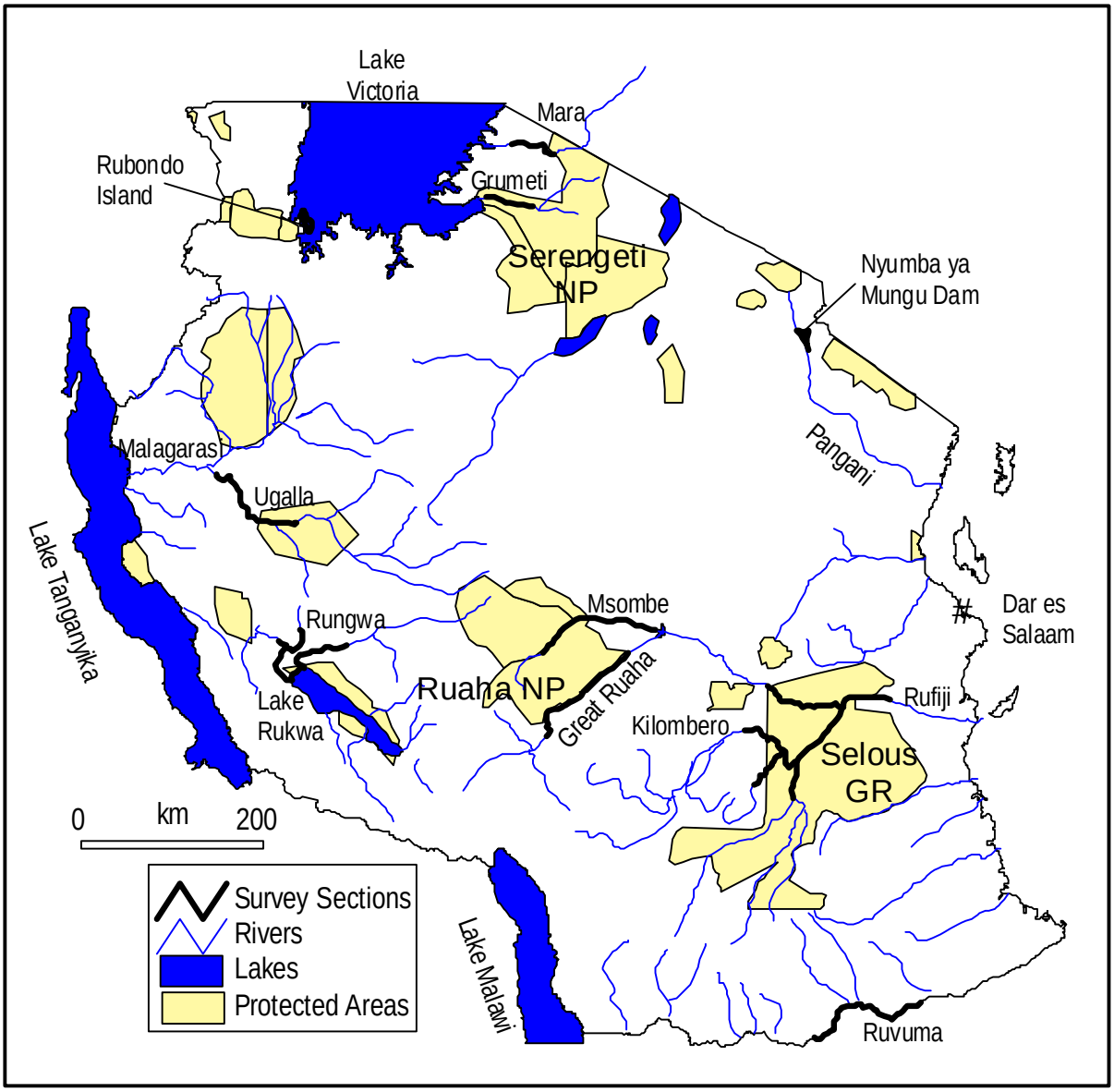

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EXECUTIVE SUMMARY

An aerial survey was carried out on selected rivers and lakes in Tanzania in October, 1999. The survey was initiated to continue a series of surveys started in 1988 and to collect further data for presentation at the 11 CITES Conference of the Parties in April, 2000 in Nairobi.

As in the previous years the survey concentrated on the Selous Game Reserve as this area must have one of the most impressive Nile crocodile populations in Africa. The survey also added several new rivers to the series (Table A) which included sections outside protected areas.

Table A: Summary of crocodile densities (crocodiles/km) in some Tanzanian rivers and lakes as estimated by aerial survey in 1999.

RIVER	DENSITY	RIVER/LAKE	DENSITY
Selous Game Reserve		**Other Rivers and Lakes**	
Ulanga	3.55	Mara	0.33
Rufiji	16.90	Grumeti	1.24
Ruaha	2.27	Ruaha (in Ruaha N.P.)	2.42
Kilombero	6.08	Rubondo Island	0.60
Luwego	0.46	Ugalla	1.50
Luhombero	0.35	Msombe	0.15
		Rungwa	0.31
		Ruvuma	0.05

It appears that crocodile densities have increased in the rivers and lakes surveyed in the Selous Game Reserve with that of the Rufiji river having the highest rate of increase (Figure A). This is also apparent from spotlight counts for crocodiles in the Rufiji river (Figure B).

Figure A: Density trends for crocodiles in the major rivers in the Selous Game Reserve as estimated from aerial surveys.

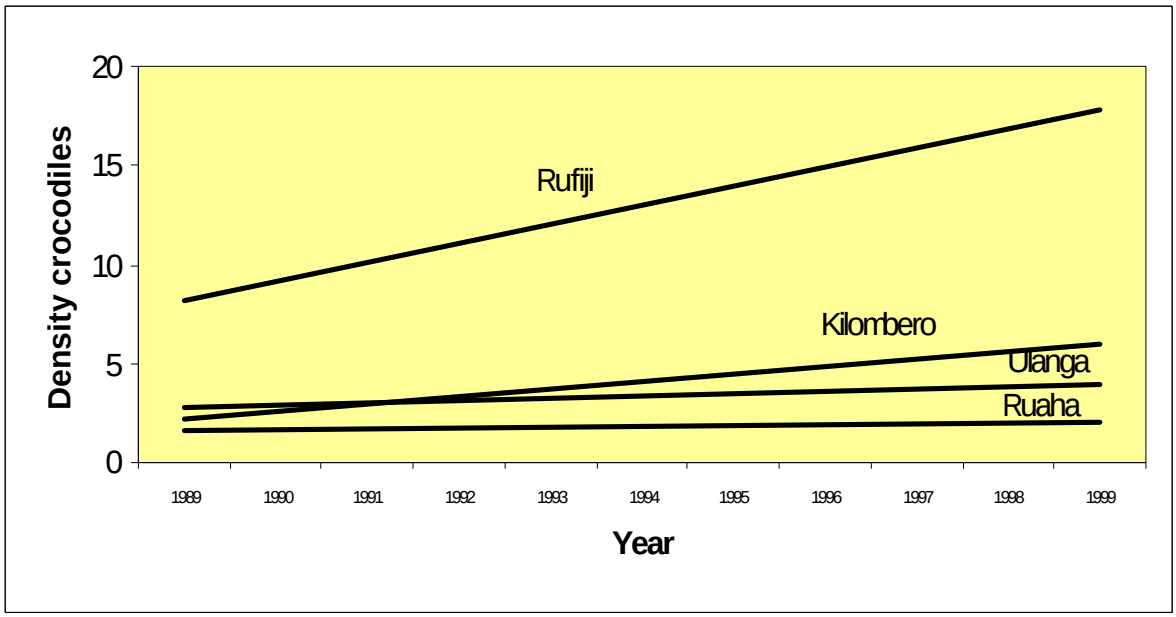
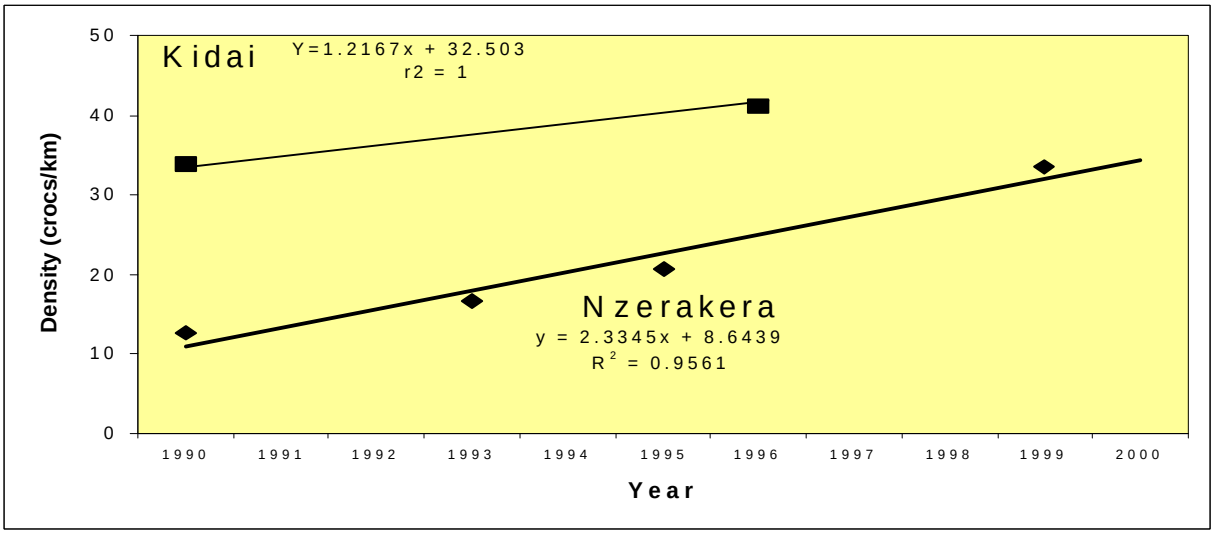


Figure B: Density trends for crocodiles in Rufiji river as estimated from by spotlight counts at night.



Data from other rivers and lakes is more difficult to interpret but and some rivers show increases while other areas indicate a decrease. Problems with equipment also meant that some of the results were not directly comparable with previous years.

Density increases were recorded from the Ruaha and Ugalla rivers – quite substantial in the case of the Ugalla. Decreases were noted in the Mara, Grumeti and the Rubondo island shoreline. In the latter case all of these are in, or adjacent to protected areas.

Several new sections of river were added to the survey this year which included the Msombe, Upper Ruvuma and the Lukima rivers. Densities were low in all.

INTRODUCTION

Tanzania has carried out aerial surveys for crocodiles since 1988 (see references) as part of its data collection activities for proposals to CITES. Much of this work has been concentrated in the Selous Game Reserve which has the largest crocodile population in the country. However, surveys have also been carried out in many other rivers and lakes (Table 1).

Table 1: Summary of aerial surveys for crocodiles in Tanzania 1989 to1999.

Area	1989	1990	1993	1995	1996	1999
Selous	Rufiji Ulanga Luwego Ruaha Kilombero	Rufiji Lakes Luwego Ulanga Ruaha Kilombero	Rufiji Lakes Ulanga Ruaha Kilombero	Rufiji Lakes Ulanga Ruaha Kilombero	Rufiji Lakes Ulanga Ruaha Kilombero	Rufiji Lakes Luwego Ulanga Ruaha Kilombero Luhombero
West		Ruaha Rungwa Lake Rukwa Kavuu Lake Chada Ugalla Malagarasi	Ruaha Rungwa Lake Rukwa Kavuu Lake Chada Ugalla Malagarasi	Ruaha Rungwa Lake Rukwa Ugalla Malagarasi	Ruaha	Ruaha Msombe Rungwa Lake Rukwa Kavuu Ugalla
East		Pangai Nyumba		Wami Nyumba	Nyumba	Nyumba
North		Rubondo Mara Grumeti	Rubondo Grumeti	Rubondo	Rubondo Mara Grumeti	Rubondo Mara Grumeti
South			Ruvuma			Ruvuma

This survey was initiated by the Wildlife Division to continue the monitoring effort and to gather information for a downlisting of its Nile crocodile population to Appendix II at the 2000 COP in Nairobi.

The current survey was country-wide on selected rivers and lakes but, as in previous years, it concentrated on the Selous Game Reserve.

While reading this report it should be appreciated that it is just that – a report. Time and deadline constraints meant that the analysis of some of the results was not as exhaustive as if it was being written up for publication.

METHODS

DATA COLLECTION

Aerial Surveys

Two aircraft were used on this survey; a 206 (5H-SGR) with a six hour endurance and a 182 (5H-MPZ) with a four hour endurance. The majority of the crews had been on crocodile surveys in previous years as had both the pilots. Both aircraft started the survey in the Selous Game Reserve but then split to allow greater ground coverage in the time available. The 206 remained in the south to cover the Ruaha, Rukwa and Ruvuma rivers while the 182 continued to cover the northern lakes and rivers (Nyumba ya Mungu, Victoria, Mara, Grumeti and Ugalla).

As on previous surveys the rivers were divided into arbitrary sections based on time or character of the river. Sections were called out by an observer/recorder and these were marked on all recorder sheets.

In both aircraft two observers sat on the right hand side of the aircraft and one on the left hand side. The pilot was left to concentrate on flying and was not used as an observer. On occasions the rear right hand seat observer acted as a recorder and did not actively search for crocodiles. The highest count of the right observers was used for the calculations.

The pilot positioned the aircraft for maximum visibility of the river. Height and speed were dictated to by safety considerations and pilot experience. On most rivers counting was carried out from both sides of the aircraft. There was no cross counting (i.e. those on the "far side" did not count or point out crocodiles to the "near side" observers).

The advent and development of GPS technology and its related software has made studies such as this easier and less prone to error. On this survey tracks were recorded at 15 second intervals on short flights and 30 second intervals on longer flights. Waypoints were recorded to mark the start and finish of each survey as well as section breaks during the survey. After each survey both the track and waypoints were downloaded to a computer using Fugawi navigational software and converted for use with mapping software (Arcview). However, having been on the receiving end of technology lapses in the bush on several occasions all waypoints were also transcribed on paper prior to being deleted from the GPS.

Night Counts

A single count for crocodiles was done at night on a section of the Rufiji river inside the Selous Game Reserve (Lake Nzerakera to Rufiji River Camp). Standard spotlighting techniques were used (Games, 1990).

DATA ANALYSIS

"Traditional" sample counts require that the river is stratified prior to survey and that selected representative samples are surveyed from each of the strata (Graham, 1988). In this way an overall estimate of the river is obtained and the coefficient of variation calculated. However, the lengths of river involved in the Selous and other areas meant that, in many cases, the entire river was surveyed. This led to the possibility of stratification "after the event", as some sections of the rivers showed higher concentrations of crocodiles than others. It was hoped to relate the higher (or lower) concentrations to some biological (*e.g.* many fishing villages) or physical feature (*e.g.* rocky areas) of the river.

Analysis of the sample counts followed the method outlined by Graham (1988) which was based on that of Jolly (1969). The coefficient of variance or CV (the standard error as a percentage of the estimate) is a measure of the precision of a count. It was estimated by first calculating S_d^2 with:

$$S_d^2 = \frac{(\Sigma d^2 - (\Sigma d)^2) / (n)}{(n-1)}$$

where:
d = density of the samples
n = number of samples

The variance of the count (V) was then calculated by:

$$Var\ \boldsymbol{N} = (Z^2 / n) S_d^2$$

where:
Z = total length surveyed
n = number of samples

and the CV calculated by

$$CV = (\sqrt{V} / N) 100$$

where:
V = variance of the count
N = number of crocodiles

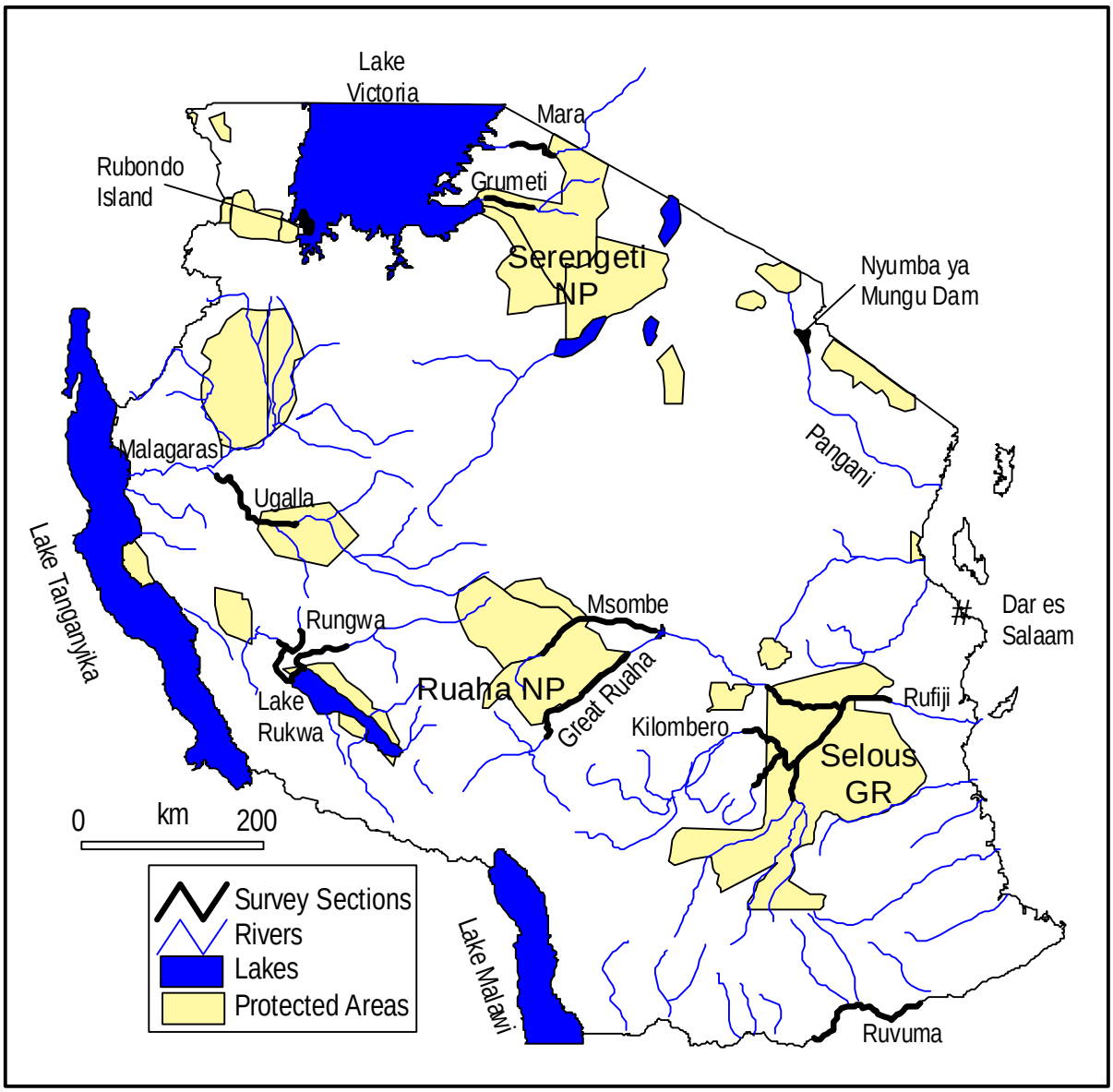
As these were not sample counts in the true sense (*i.e.* the whole length of the river was counted) a population estimate was not directly derived from them. Densities, and fluctuation thereof over the years was considered more important.

RESULTS

AERIAL SURVEYS

The surveys concentrated on the Selous Game Reserve as this has the largest population of crocodiles in Tanzania. Sections of the Ruaha, Msombe, Rungwa, Kavuu, Lukima, Ugalla, Mara and Grumeti rivers were surveyed. In addition parts of Lakes Nyumba ya Mungu, Mtera, Rukwa and Victoria (Rubondo Island) were also surveyed (Figure 1).

Figure 1: Surveys for crocodiles in Tanzania in October, 1999



Selous Game Reserve

Surveys were carried out between the 2nd and 5th October, 1999 in the Selous Game Reserve (Table 2). Both aircraft were used.

Table 2: Aerial surveys for crocodiles in the Selous Game Reserve, October, 1999

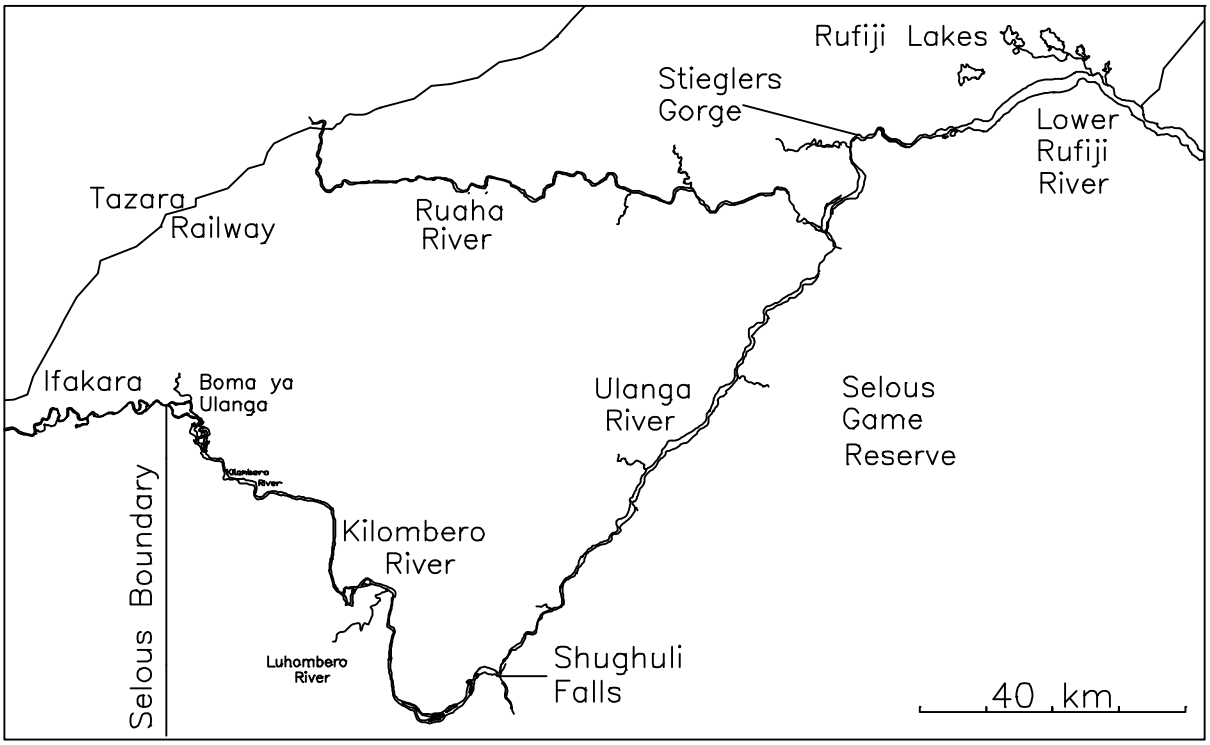
Date	Sections Surveyed	Comments
02	Rufiji, Ulanga, Kilombero, Ruaha	
03	Rufiji, Ulanga, Ruaha, Luwego, Luhombero	
04	Rufiji, Kilombero	Rain
05	Rufiji,	Incl. outside Reserve

In summary the Rofiji (downstream of Stiegler's Gorge) was surveyed five times, the Ulanga (Stiegler's Gorge to Shughuli Falls) three times, the Kilombero and the Ruaha two times and the Luwego and Luhombero once each (Table 3; Figure 2).

Table 3: Summary of Selous aerial surveys, 1999

Summary	
Lower Rufiji = 5 surveys	Kilombero = 2 surveys
Ulanga = 3 surveys	Ruaha = 2 surveys

Figure 2: The " Selous Triangle"



Crocodiles were concentrated in the Rufiji river and its associated lakes (Tagalala, Manze, Nzerakera, Siwandu and Mzizimia) but only inside the Selous Game Reserve. Once outside the Reserve crocodile densities dropped dramatically (Table 4).

Other rivers had moderate to high densities of crocodiles with some clumping of the population evident, especially in the Kilombero river. Again crocodile densities dropped outside the reserve on the Kilombero.

Table 4: Summary of crocodile surveys in the Selous Game Reserve – October, 1999

River	Density	Comments
Lower Rufiji	11.77	02; Start 09:00
	14.78	02; Start 15:30
	14.75	03: Start 09:00
	16.90	04: Start 09:15
	13.74	05: Start 09:30; Only inside Selous used for density
	0.078	Outside Selous only
Ulanga (Upper Rufiji)	2.49	02: Start 09:20
	3.55	02: Start 16:30
	3.34	03: Start 10:55
Kilombero	3.67	02: Start 09:45
	6.08	04: Start 10:15
	0.38	02: Outside Selous
	0.14	04: Outside Selous
Ruaha	2.27	02: Start 16:15
	1.57	03: Start 09:15
Luwego	0.46	03: Start 16:30
Luhombero	0.35	03: Some outside Selous
Lakes are total counts and not densities		
Tagalala	339	Poor surveys
Manze	87	
Nzerakera	145	
Siwandu	93	
Mzizima	25	

The densities of the rivers surveyed and also in the individual sections for all the surveys are shown in Figures 3 to 9.

Summary of Figures on following pages

Figure 3 Lower Rufiji – 2nd October
Figure 4 Lower Rufiji – 3rd and 4th October
Figure 5 Lower Rufiji 5th October
Figure 6 Ulanga and Luwego rivers – 3rd October
Figure 7 Ulanga River – 2nd and 3rd October
Figure 8 Ruaha River – 2nd and 3rd October
Figure 9 Kilombero River – 2nd and 4th October

Figure 3: Lower Rufiji – Crocodile densities October 2nd 1999

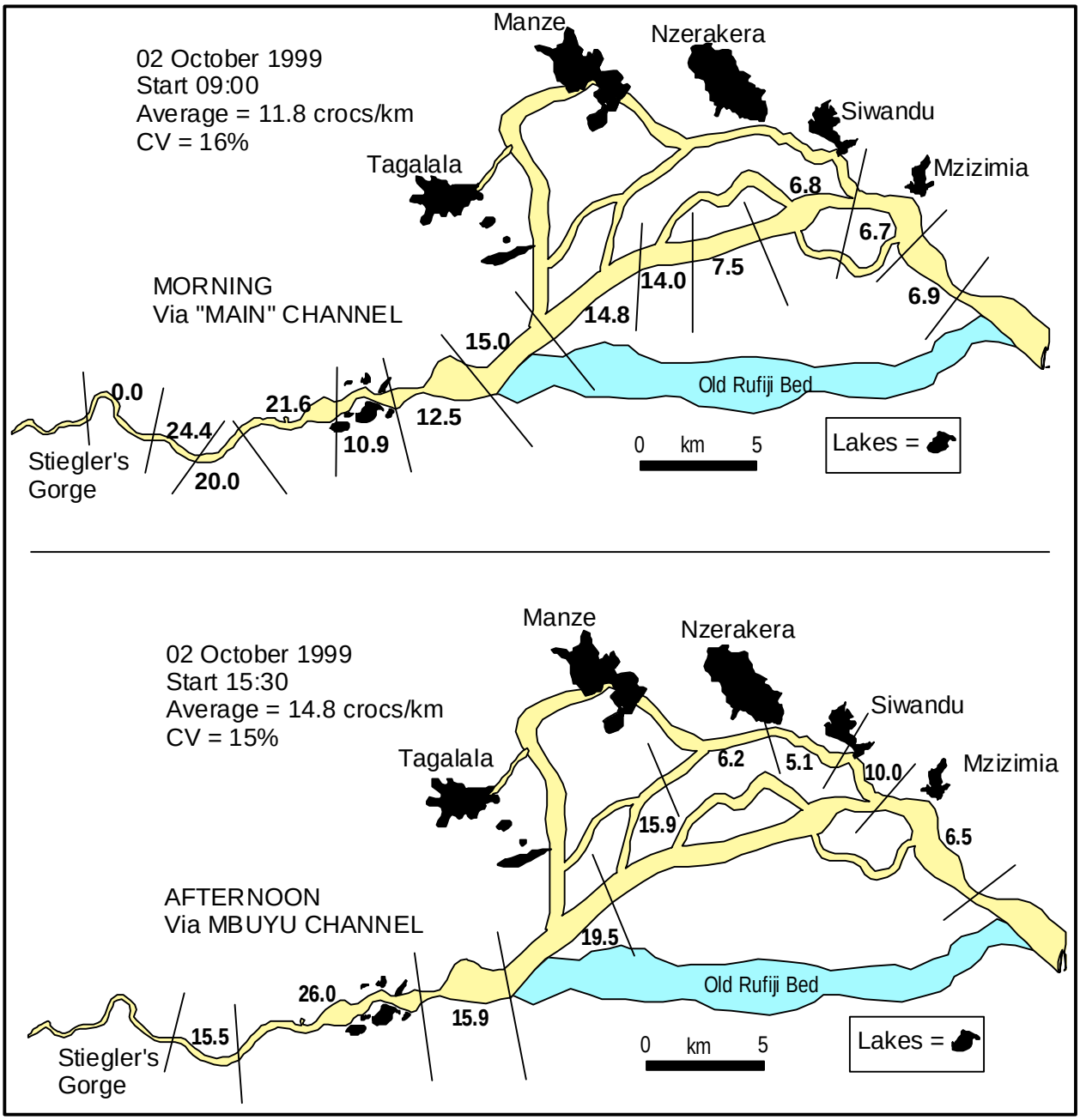


Figure 4: Lower Rufiji – Crocodile densities October 3rd and 4th 1999

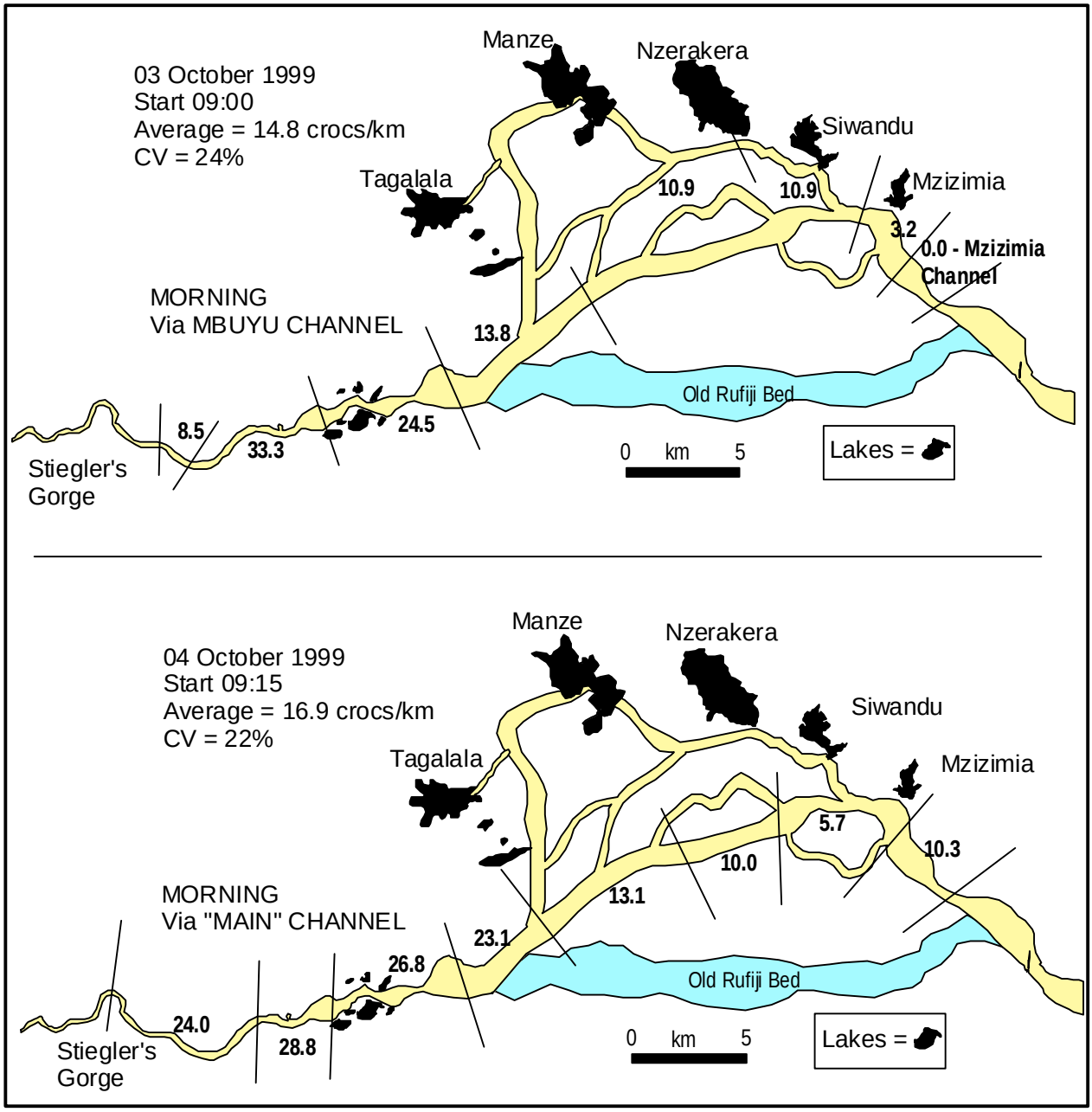


Figure 5: Lower Rufiji – Crocodile densities October 5th 1999

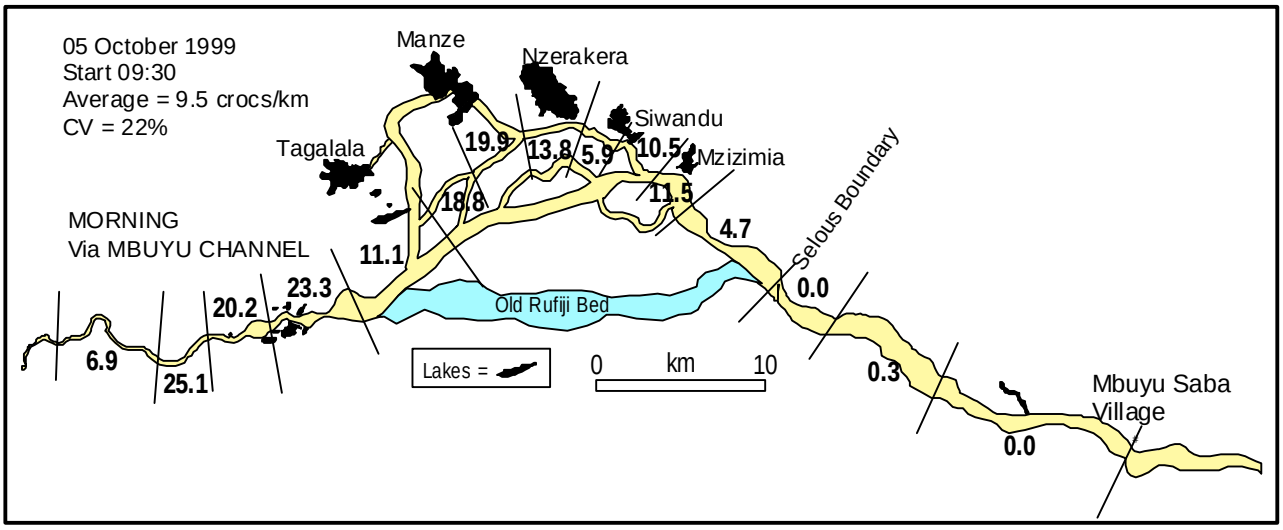


Figure 6: Ulanga and Luwego – Crocodile densities on 3rd October, 1999

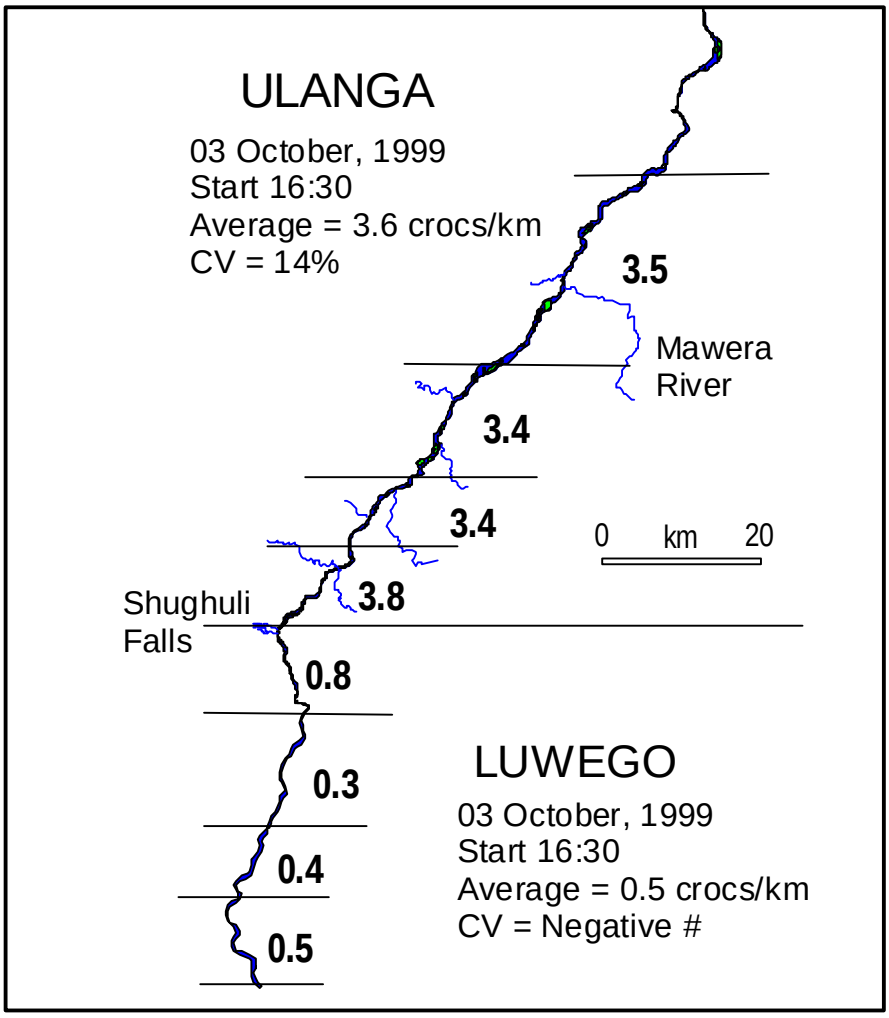


Figure 7: Ulanga – Crocodile densities 2nd and 3rd October, 1999

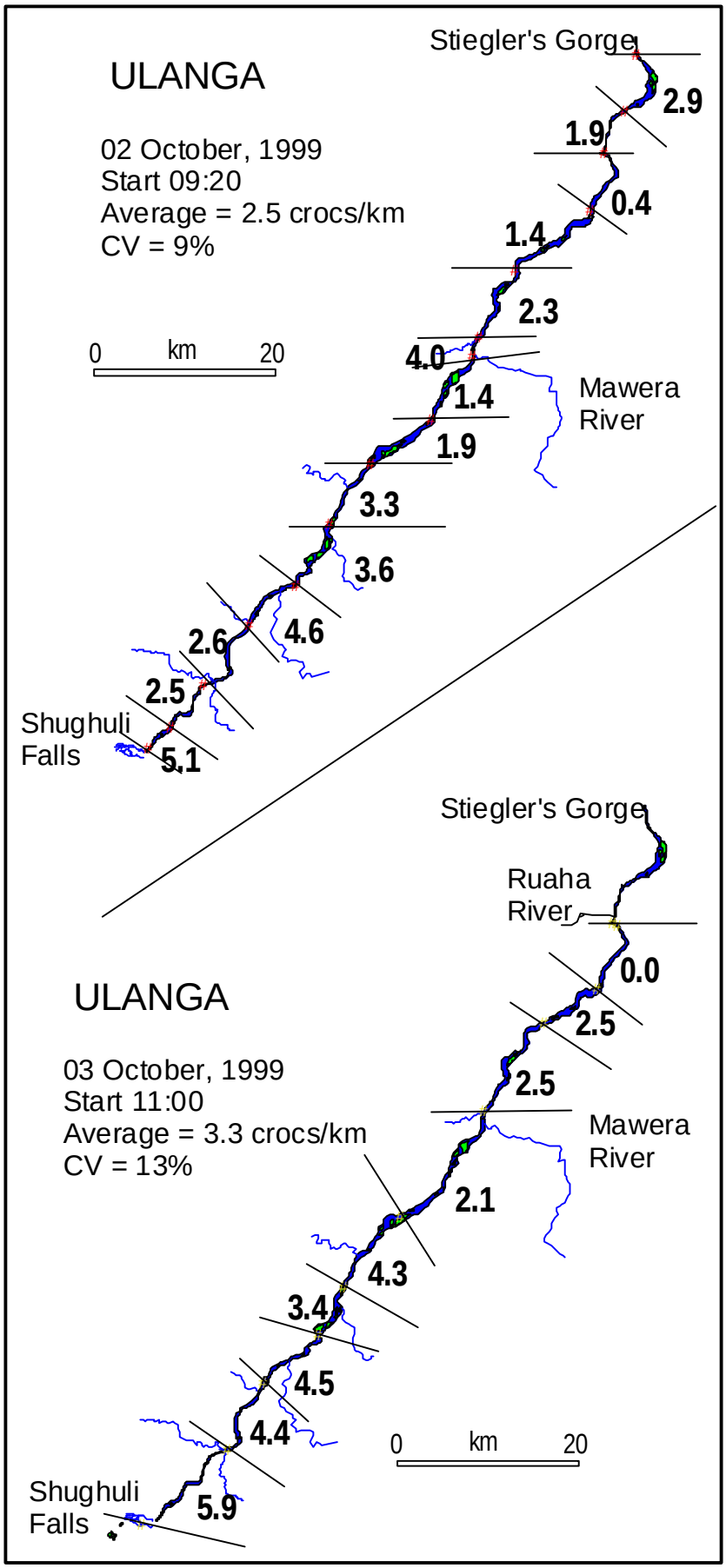


Figure 8: Ruaha – Crocodile densities 2nd and 3rd October, 1999

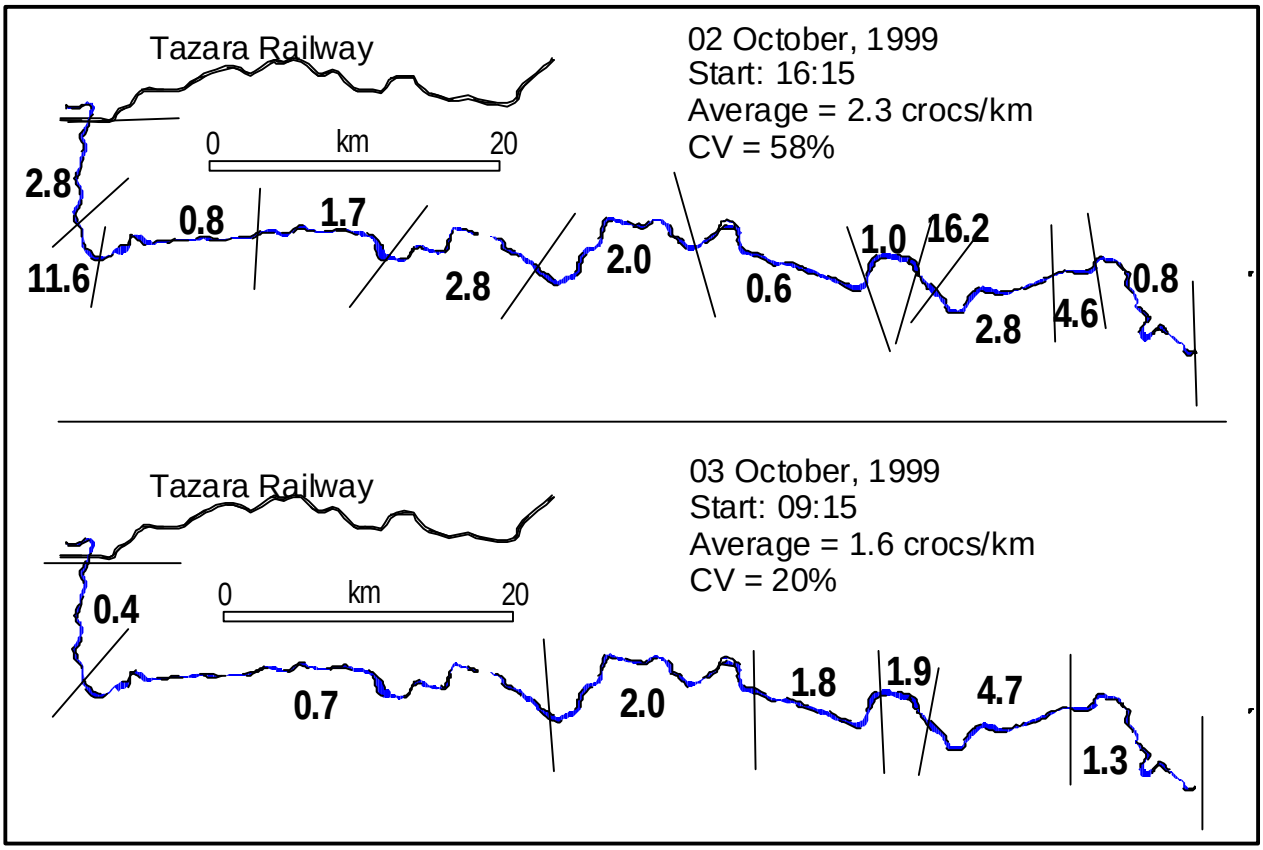
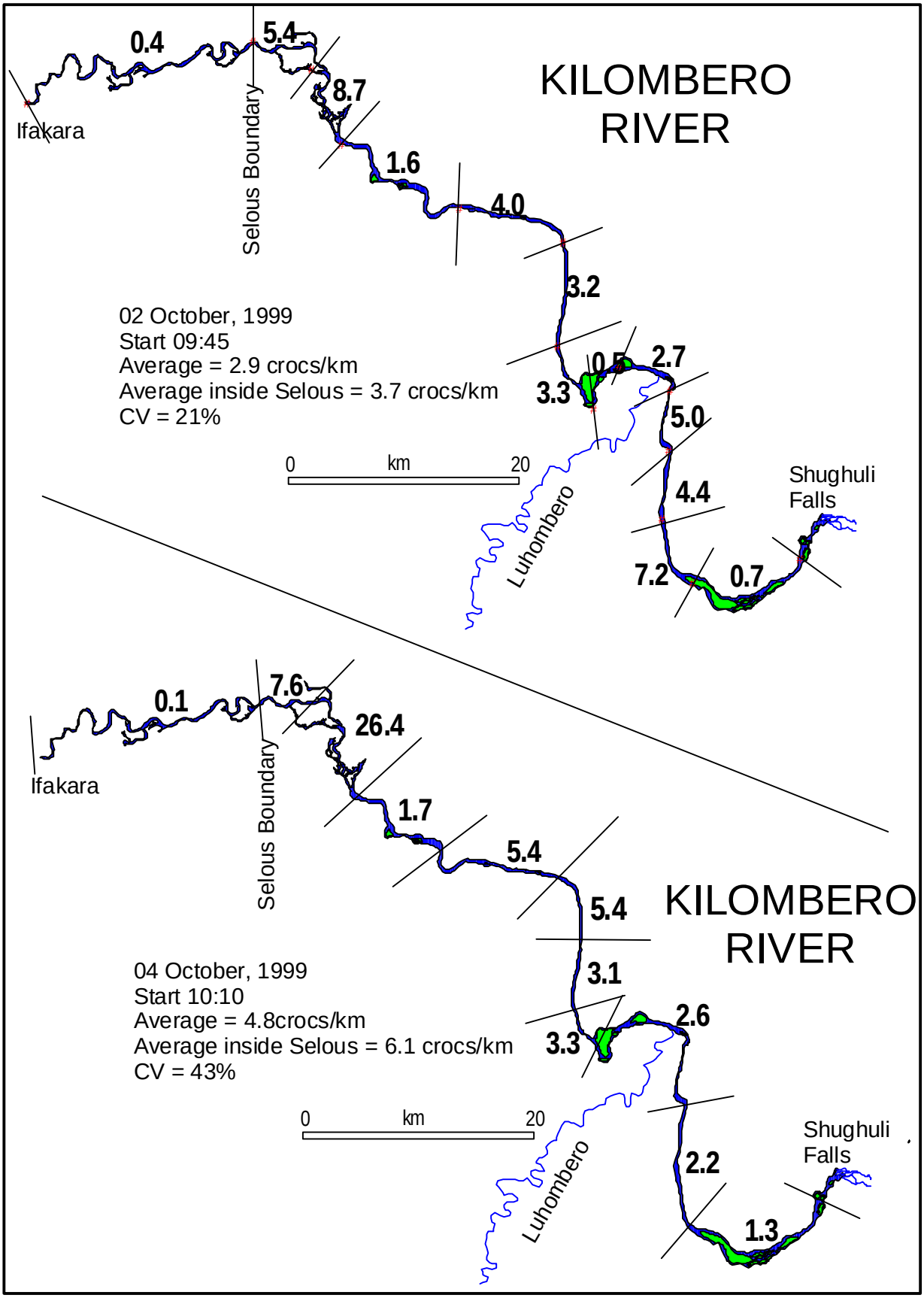


Figure 9: Kilombero – Crocodile densities October 2nd and 4th , 1999



OTHER RIVERS AND LAKES

A number of other rivers and lakes were surveyed between the 5th and 10th of October using two aircraft (Table 5). These were Lakes Nyumba ya Mungu, Mtera, Rukwa and Victoria and the Great (or upper) Ruaha, Msombe, Mara, Grumeti, Rungwa, Kavuu, Lukima, Ugall and Ruvuma rivers.

Table 5: Aerial Surveys for Crocodiles Outside the Selous Game Reserve

DATE	SECTIONS SURVEYED	COMMENTS
05th	Lake Nyumba ya Mungu	Afternoon
06th	Upper Ruaha, Mtera Dam, Msombe	Morning, Afternoon
06th	Mara, Grumeti	Afternoon
07th	Rungwa, Lake Rukwa, Kavuu, Lukima	Morning
08th	Ruvuma	Morning
09th	Rubondo	Afternoon
10th	Ugalla	Morning

The results of these surveys are summarised below (Table 6). Figures 10 to 14 show the sections of river/shoreline surveyed and their relevant densities.

Table 6: Surveys for crocodiles in Tanzania, October 1999

RIVER	DENSITY	COMMENTS
Msombe	0.15	Morning
Ruaha	2.42	Late afternoon
Rungwa	0.31	Morning
Mtera Dam	0.03	35 kilometres shoreline surveyed
Kavuu	0,04	Few pools left
Lake Rukwa	0.61	Only northern shore surveyed
Lukima	0.00	No crocodiles seen
Ruvuma	0.05	Shallow river upstream of Lugenda junction
Lake Nyumba ya Mungu	0.10	Entire shoreline covered
Mara	0.33	Outside Serengeti National Park
Grumeti	1.24	Most in Kirawira section
Rubondo	0.60	No GPS readings
Ugalla	1.50	No GPS readings

Figure 10: Great Ruaha and Msombe rivers – Crocodile densities 6th October, 1999

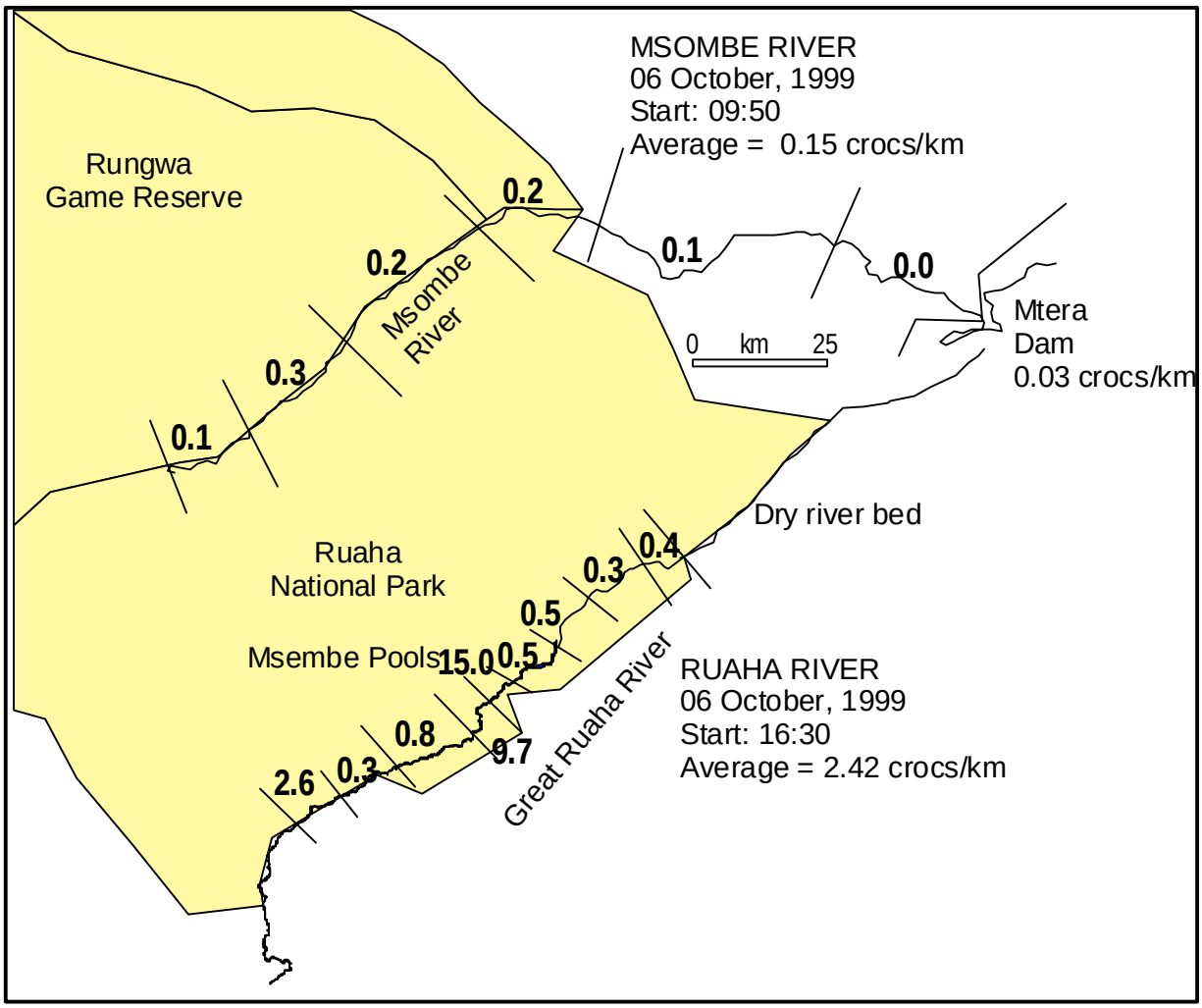


Figure 11: Rungwa, Kavuu and Lukima and Lake Rukwa – Crocodile densities 7th October

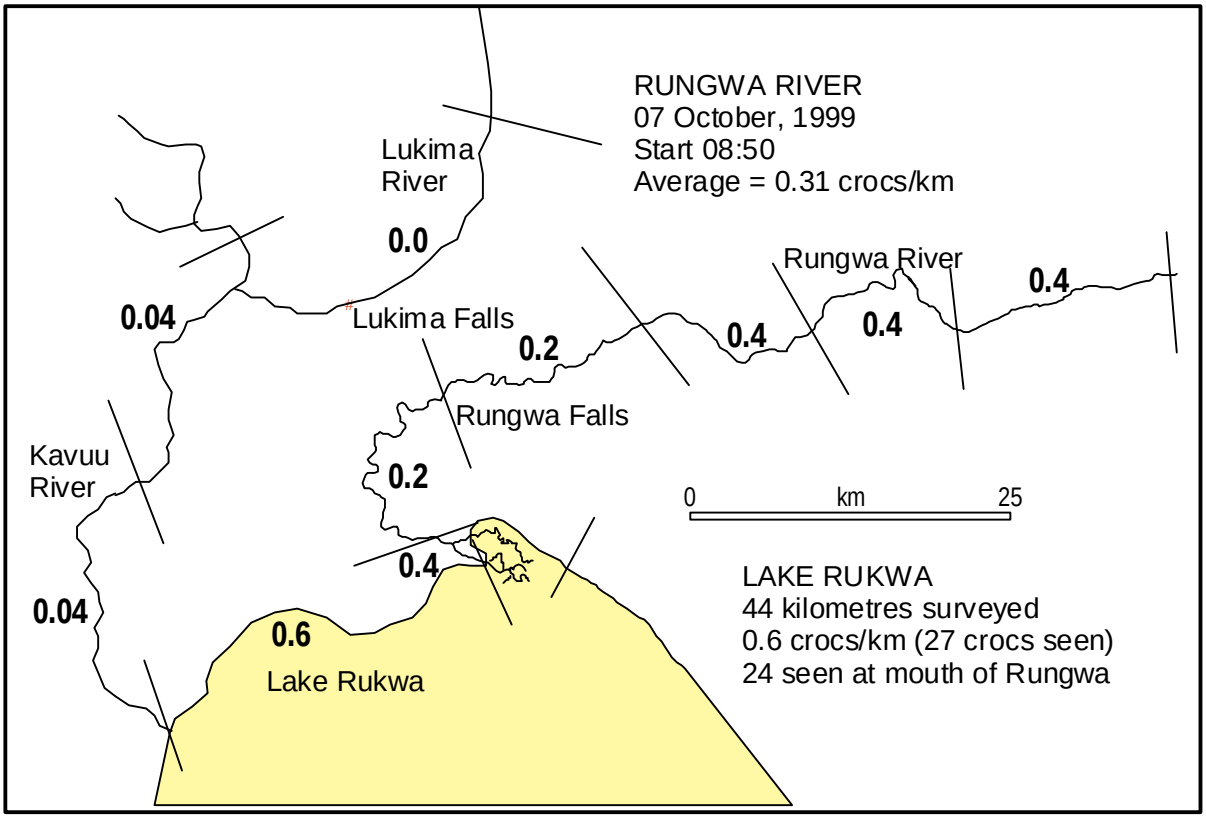


Figure 12: Ugalla – Crocodile densities 10th October, 1999

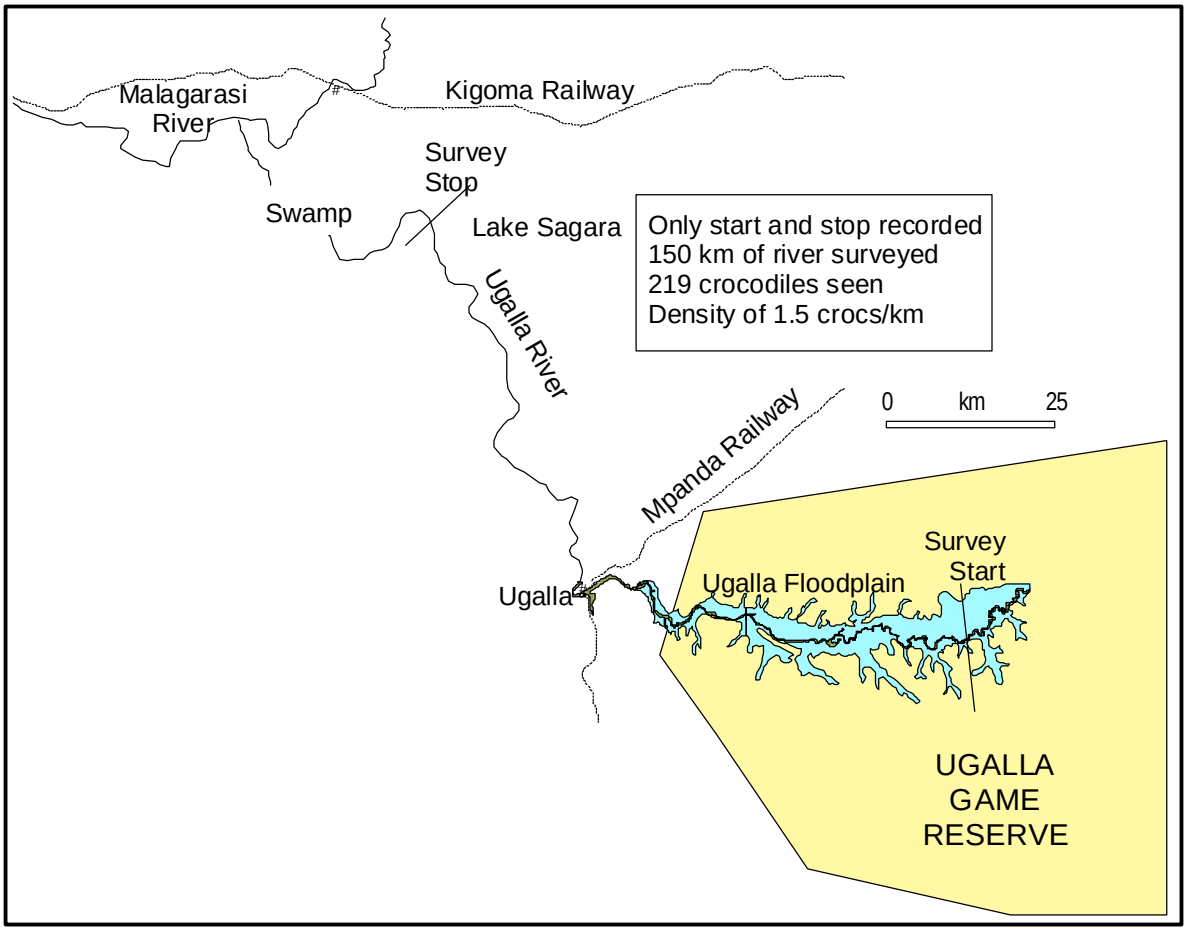
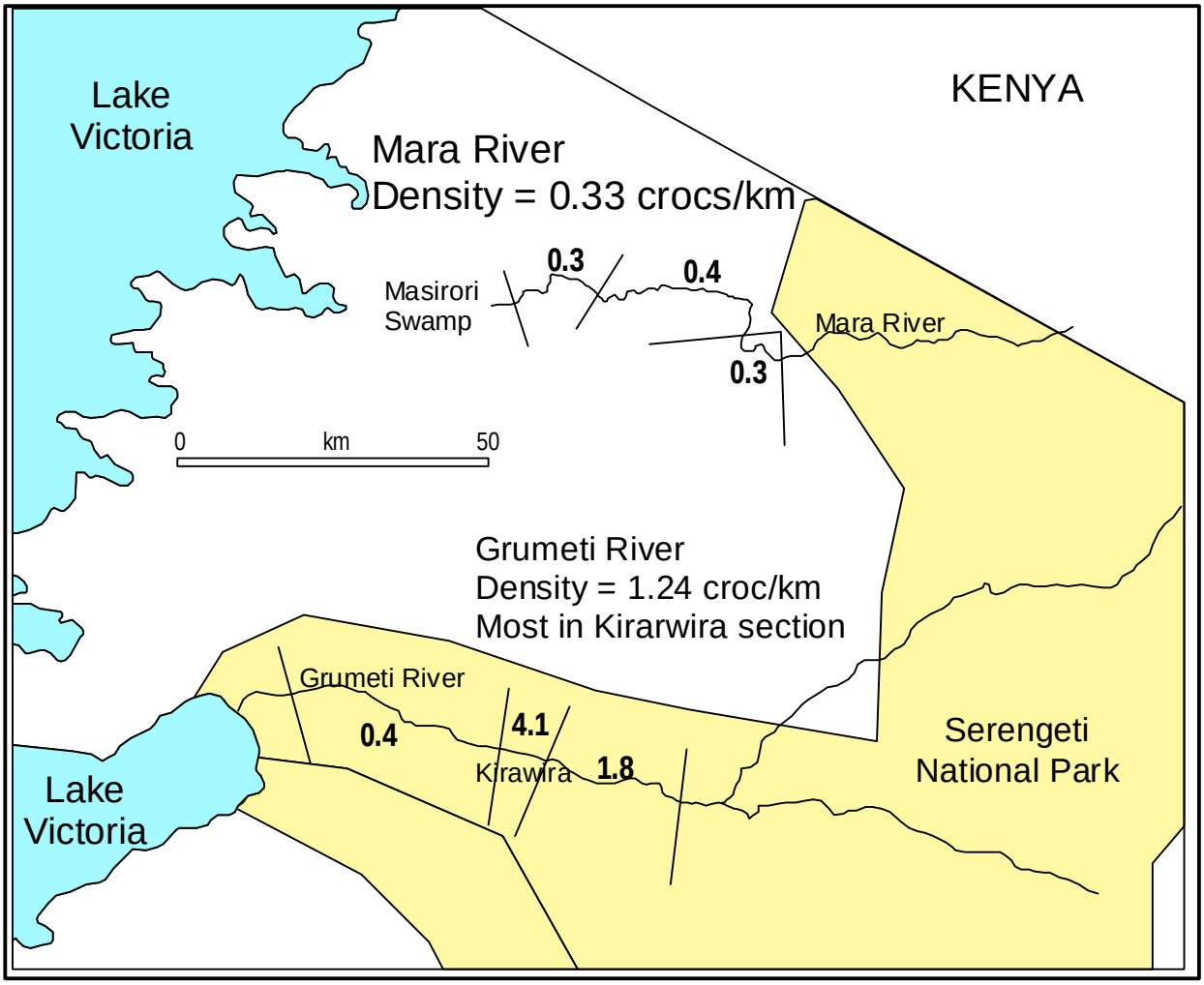


Figure 13: Mara and Serengeti – Crocodile densities 6th October, 1999



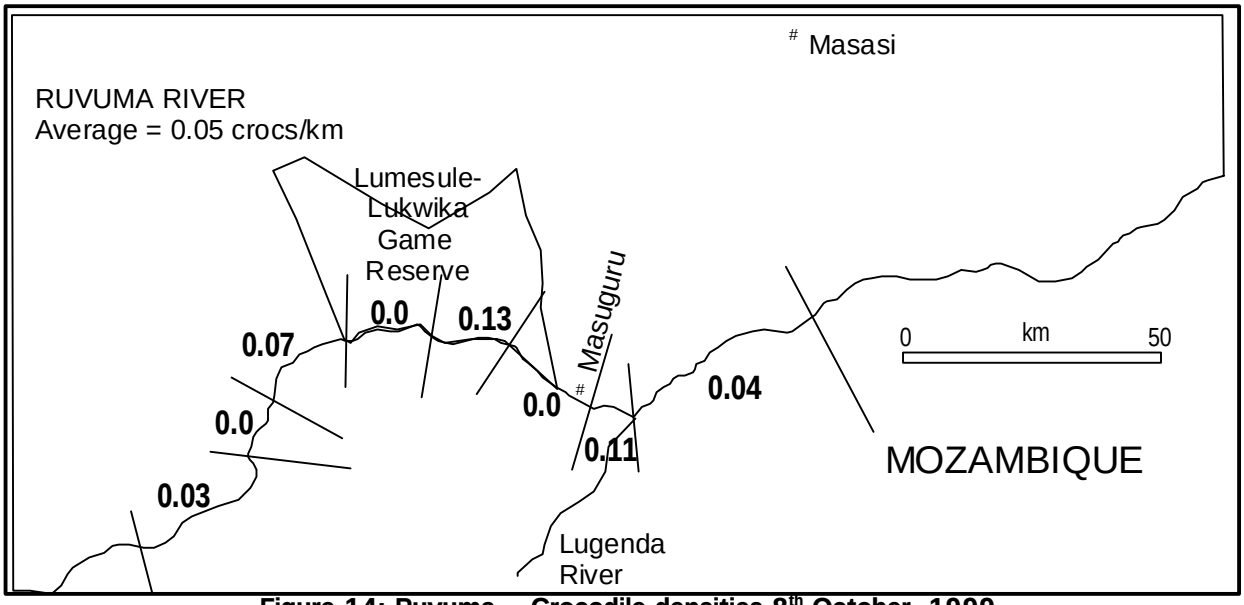


Figure 14: Ruvuma - Crocodile densities 8th October, 1999

Night Counts

The night count revealed 442 crocodiles in 13.2 kilometres of river giving a density of 33.5 crocodiles per river kilometre (Table 7).

Table 7: Night count – L. Nzerakera to Rufiji River Camp

Section	Distance (km)	Crocodiles	Density
1	2.15	63	29.3
2	0.30	10	33.3
3	0.38	13	34.1
4	0.60	16	26.7
5	0.48	17	35.4
6	1.04	54	51.9
7	1.43	78	54.5
8	0.68	30	44.1
9	0.66	20	30.3
10	0.92	35	38.0
11	1.32	48	36.4
12	1.20	27	22.5
13	0.96	18	18.8
14	1.09	13	11.9
TOTALS	**13.21**	**442**	**33.5**

A correction factor the aerial surveys was also calculated from the night counts in the lower Rufiji. The night count revealed 442 crocodiles between Lake Nzerakera while two separate aerial counts along the same stretch of river counted 89 and 114 crocodiles. This gives a "correction factor" of 4.9 and 3.9 respectively (Table 8).

Table 8: Night count correction – Lower Rufiji River - Selous Game Reserve, 1999

	NUMBERS	DENSITY	CORRECTION FACTOR
15:30	89	6.7	4.9
09:15	114	8.6	3.9
Night – Boat	442	33.5	

DISCUSSION

Selous Game Reserve

Densities of crocodiles as recorded by aerial survey appear to be increasing or remaining stable in the major rivers in the Selous Game Reserve. Densities for these rivers are summarised below (Table 9). Some fluctuations are evident but these are believed to be due to observer bias and pilot experience. The Rufiji, Ulanga and Kilombero populations show an overall increase since 1989 while the Ruaha seems to be stable.

Table 9: Summary of crocodile densities in the Selous Game Reserve as estimated by aerial survey

	Parker/ Graham	Hutton/ Katalihwa	Games and Severre					
	1963	**1988**	**1989**	**1990**	**1993**	**1995**	**1996**	**1999**
Ulanga	1.95 - 3.51	0.98	3.15	2.89	2.26	2.6	5.55	3.55
Lower Rufiji			6.75	11.83	10.49	10.1	19.98	16.90
Lake Tagallala				18.07	23.38	28.2	46.07	26.08
Ruaha		1.56	1.77	1.57	1.68	1.6	1.67	2.27
Kilombero		0.28	(7.74)	2.86	3.54	3.2	5.6	6.08
Upper Luwego			2.74					
Lower Luwego		0.33	1.64					0.46
Luhombero								0.35

Notes:
- Kilombero and Lower Rufiji estimates for inside the Selous Game reserve.
- 1988 survey carried out during high flood conditions so not really comparable except for the Ruaha. This is because Ruaha is controlled by a dam so levels do not vary much.
- Lower Rufiji estimates are the best count of the day. i.e. 16:30 in 1990; 18:00 in 1993, 17:30 in 1995, 16:30 in 1996 and 09:15 in 1999.
- The 1989 estimate for the Kilombero is so far in excess of the others that the original data was accessed and reworked and the implications of this discussed below.

Figure 15: Densities of crocodiles recorded by aerial survey in the RUFIJI river since 1989

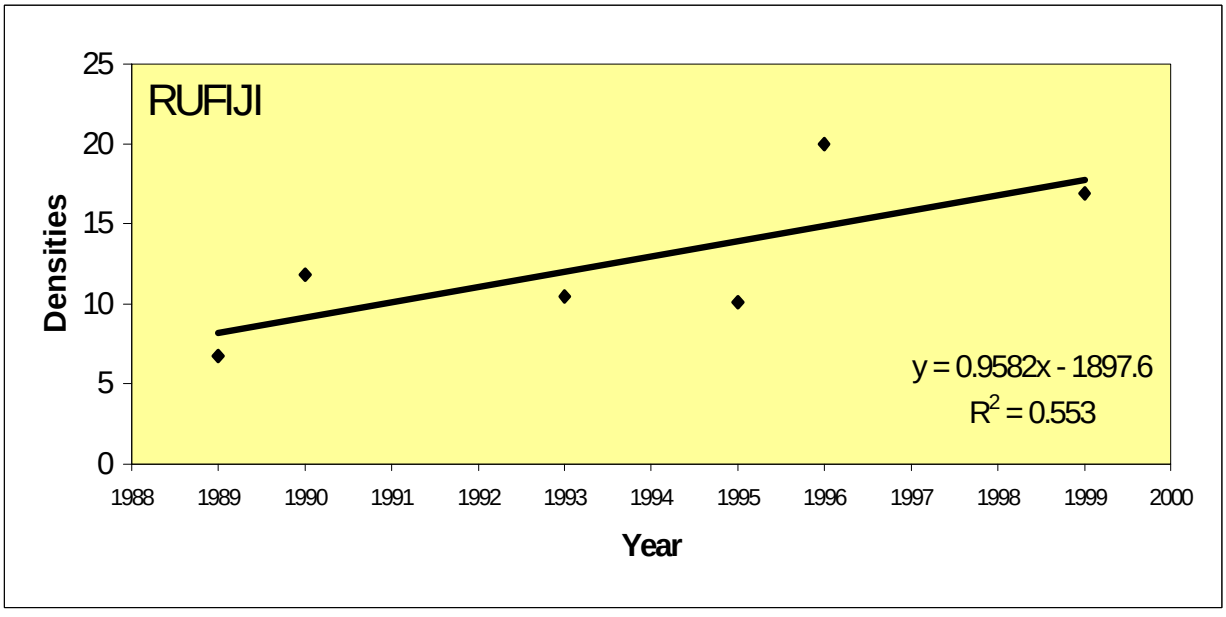


Figure 16: Densities of crocodiles recorded by aerial survey in ULANGA the river since 1989

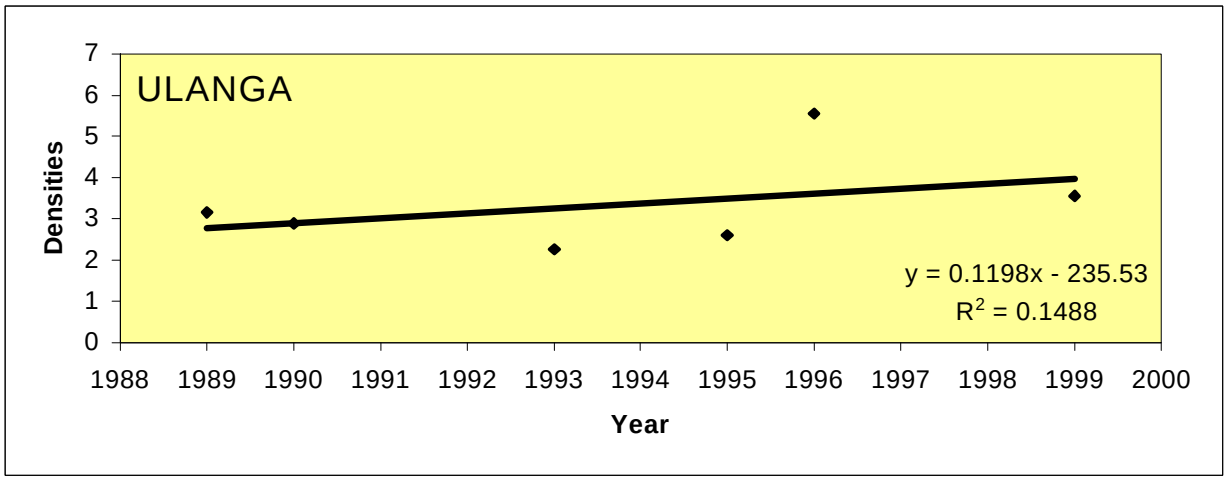


Figure 17: Densities of crocodiles recorded by aerial survey in KILOMBERO the river since 1989

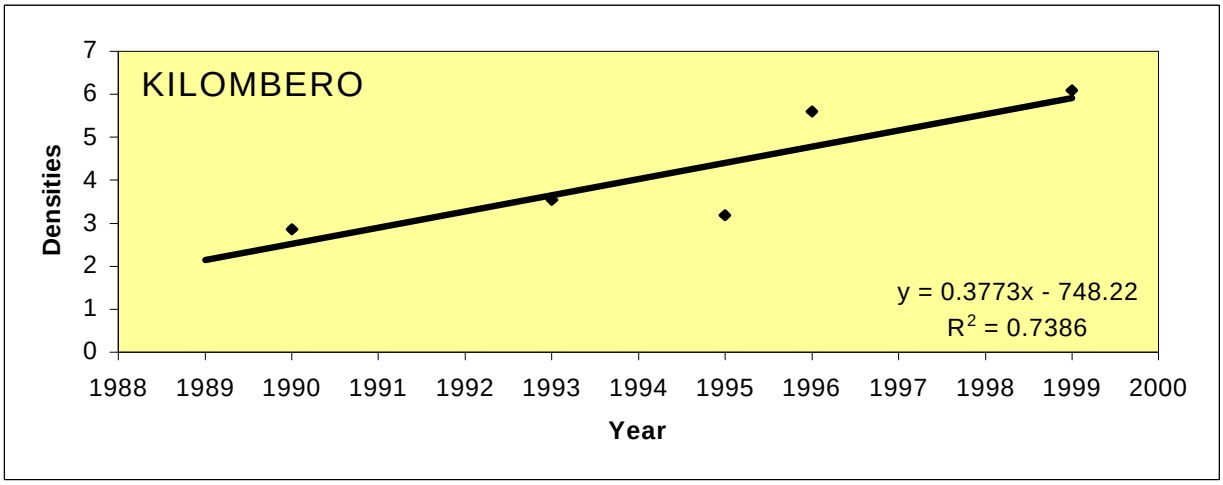
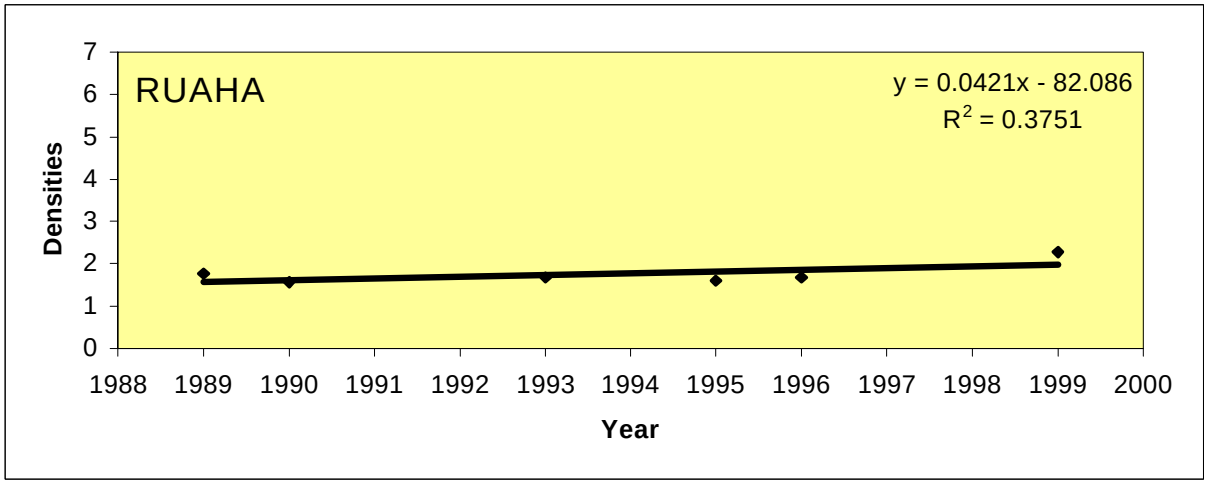


Figure 18: Densities of crocodiles recorded by aerial survey in RUAHA the river since 1989



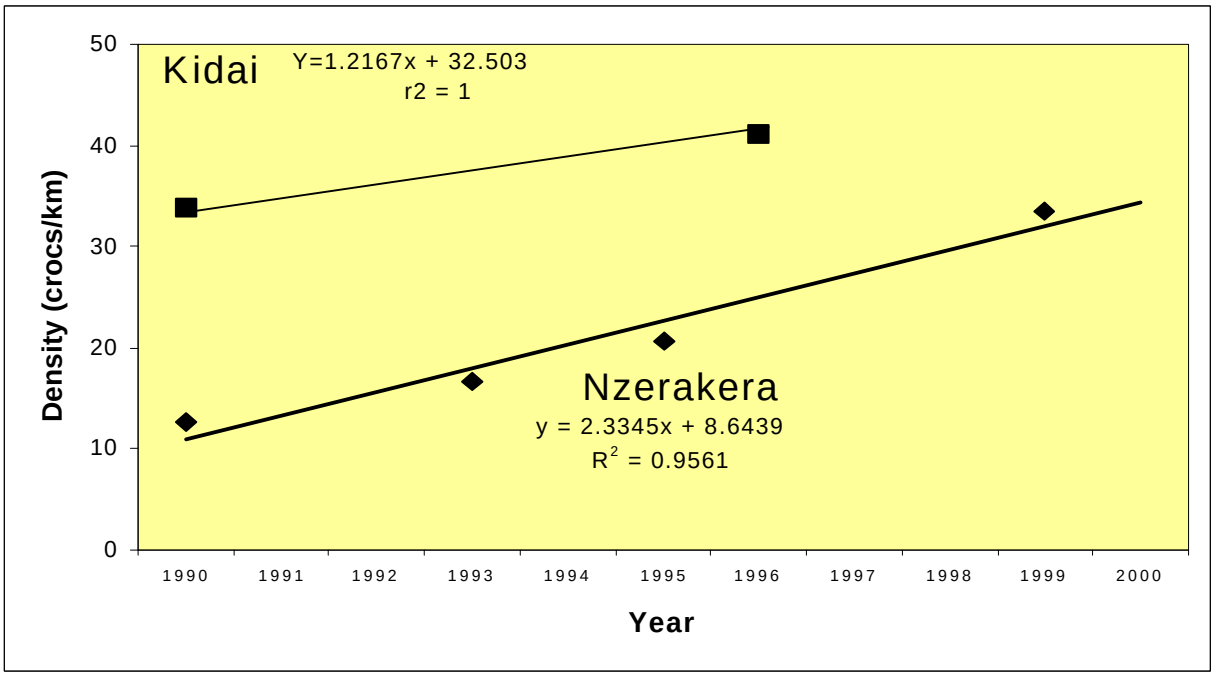
These results were comparable to surveys in 1990, 1993 and 1995 (Table 10). Results were also available for the Kidai area (just south of Lake Tagalala) for 1990 and 1995.

Table 10: Comparison of night counts in the Selous Game Reserve since 1990

	1990	1993	1995	1996	1999
Lower Rufiji	12.7	16.7	20.7		33.5
Kidai area	33.8			41.1	

These surveys show a definite increase in crocodile densities in both areas, with that for the lower Rufiji being almost three times what it was in 1990 (Figure 15)

Figure 19: Density of crocodiles as estimated from spotlight counts at night in the RUFIJI river



Data from the Rufiji lakes was disappointing in 1999 (Table 11). However, as stated in previous years, these are very difficult to survey accurately. The aircraft used was fully loaded with 400 litres of fuel and hence flying was more "sedate" than in 1996. We believe that this is one of the reasons for the poor counts. The ability of the pilot is also crucial.

Table 11: Aerial surveys of the Rufiji lakes

Lake	**1991**	**1993**	**1995**	**1996**	1999
Tagallala	181	304	319	599	339
Manze	71		366	120	87
Nzerakera	79		139	187	145
Siwando	43		250	127	93
Mzizima	14		113	59	25
Conditions	Poor		Good	Variable[1]	Poor

[1] = The ability of the pilot is crucial on the lake surveys. Tight turns close to the ground are the order of the day and the counts increase the better the pilot is.

Other Rivers and Lakes

Trends from other rivers and lakes are more difficult to assess (Table 12). There appears to be in increase since the 1990 surveys in the Ruaha river adjacent to the Ruaha National Park. The Rungwa river appears to have been fairly constant over the years. Both rivers are seasonal and shrink up to large pools during the dry season. Crocodiles are found in some of these pools.

There also appears to be a substantial increase in the numbers of crocodiles seen in 1999 in the Ugalla river. Unfortunately the data has only a start and end point so it is difficult to draw conclusions from this. However, we believe that some of the increase can be explained by and actual increase in crocodile numbers while some of it could be explained by pilot expertise or the flight path, time of day or other variables (water level etc.).

Similarly there is an apparent decrease along the Rubondo island shoreline. Rubondo is an isolated island in Lake Victoria and is a National Park. We believe that a major decline would have been noted by the Parks staff. Again without GPS data it is difficult to draw any precise conclusions about this survey.

Several new river sections were covered on this survey. These include the Ruvuma (a different section to the 1993 survey), the Lukima and the Msombe rivers. The Ruvuma and Lukima both flow (albiet slowly) throughout the year. Both were chosen as they featured in the problem animal reports. The Ruvuma had a low density of visible crocodiles in the main river. Again, it seems likely that the crocodiles would lie up in the deeper pools rather than in the main river – which is only a few centimetres deep over much of its length.

The Msombe river is a seasonal river and again crocodiles are found in pools along its length. It is an unusual river in Tanzania in that almost its entire catchment falls into protected areas (Ruaha National Park and Rungwa Game Reserve).

Table 12: Summary and comparison of crocodile densities in some Tanzanian rivers and lakes as estimated by aerial survey.

RIVER	**1990**	**1993**	**1995**	**1996**	**1999**
Mara	0.88			0.62	0.33
Grumeti	0.83			2.04	1.24

Ruaha (in Ruaha N.P.)	0.86	1.78		2.66	2.42
Rubondo Island	0.62	0.82	0.70	2.66	0.60
Ugalla	0.67	0.61	0.21		1.50
Malagarasi	0.5		0.19		
Msombe					0.15
Rungwa	0.46	0.20	0.40		0.31
Ruvuma Upper					0.05
Ruvuma Lower		0.32			

Correction Factors

Although not the primary purpose of these surveys correction factors were calculated for a short section of the Rufiji river in 1993, 1995, 1996 and 1999 (Table 13).

Table 13: Night count correction – Lower Rufiji River - Selous Game Reserve

	NUMBERS	DENSITY	CORRECTION FACTOR
1993			
09:30	137	7.2	2.3
12:30	52	2.7	6.1
Night – Boat	317	16.7	
1995			
16:30	50	7.1	2.9
Night – Boat	145	20.7	
1996			
09:00	183	19.6	2.1
Night – Boat	382	41.1	
1999			
15:30	89	6.7	4.9
09:15	114	8.6	3.9
Night – Boat	442	33.5	

The results varied considerably with the time of the aerial count. For example, a midday count in 1993 saw only 38% of the crocodiles that were seen at 9:30 am in the same year (1993). An average of these “correction factors” is 3.7 indicating that (on average) aerial survey estimates should be multiplied by this factor to give a more precise estimate of the total numbers of crocodiles in the river.

However, other factors must also be taken into account. If the 1999 estimates are excluded a brief glance at the figures shows that (apart from the 12:30 count in 1993) the “correction factor” is approximately 2.5. The 1999 figures are considerably higher and this is probably related to an increase of crocodiles in the river rather than to other variables such as observer ability etc. Also these correction factors are for the lower Rufiji. Other rivers in the area have different characteristics and the Rufiji correction factors may not be applicable.

Therefore, if one was attempting an estimate of the total population, it would be better to use an average of the 1999 figures (i.e. 4.4) and all sections should have the density multiplied by 4.4 to allow a more precise population estimate.

Recent work by the GTZ Selous Conservation Project has resulted in a detailed map of the Rufiji area based on satellite imagery. It is now possible to estimate channel lengths in the area with some degree of accuracy. BUT it should also be noted that the area was subject to severe flooding AFTER the date of the satellite image and the main channel has changed. The main water now flows a previously small shallow channel. These calculations will be carried out at a later stage.

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