

## CHAPTER 4

### THE CURRENT NILE CROCODILE POPULATION IN THE LOSKOP DAM

#### A CASE OF "CROCS IN CRISIS"

##### INTRODUCTION

Jacobsen stated in 1984 that the substantial decline of the population of Nile crocodiles in the Loskop Dam was already a cause for concern (Jacobsen, 1984). During a symposium in 1992 on crocodile habitat, he reported that the Loskop Dam Nile crocodile population once numbered over 80 individuals. However, during 1979 a total of 21 Nile crocodiles were known to occur in the Loskop Dam (Jacobsen, 1984) and during the 1981 aerial survey of the Olifants River, only six crocodiles could be found in the dam (Jacobsen 1984).

The declining Loskop Dam crocodile population was also mentioned in the 1982/1983, 1983/1984 and 1984/1985 annual reports of the Transvaal Nature Conservation Division. The following paragraphs from these reports indicate the gravity of the situation and some of the history behind the decline of the crocodile population in the Loskop Dam:

- "The continuing drop in the crocodile population of the dam is causing concern, and a monitor programme to determine the cause has been started." (Transvaal Nature Conservation Division, 1983).

- “Three crocodile censuses were undertaken, a maximum of 16 being counted. Three of the animals were caught below the dam on private property and released in the dam. The crocodile population in the dam causes concern and the monitoring programme to determine the cause of the falling numbers is being continued.” (Transvaal Nature Conservation Division, 1985).
- “In an effort to replenish the waning numbers of crocodiles in the dam and in the upper reaches of the river, a further six crocodiles were released” (Transvaal Nature Conservation Division, 1986).

All of this prompted Jacobsen to suggest that the Nile crocodile population in the Loskop Dam may very well be on the decline and that it would only be a matter of time before this population became extinct (Jacobsen 1984).

The Loskop Dam is situated in a narrow opening or “poort” in the Olifants River approximately 32km south (upstream) of the town of Groblersdal in the Mpumalanga province of South Africa. Construction work on the Loskop Dam commenced in 1934 and was completed during 1938 by the Department of Water Affairs (Loskop Irrigation Board, 2009). A decision was later taken to increase the height of the wall and construction on the increase of the wall height was completed in 1979 raising it to its current height of 54m above the foundation (Loskop Irrigation Board, 2009).

The catchment area of the Loskop Dam is 12 300km<sup>2</sup> and at full supply level the surface area of the dam covers 2 350ha with the net storage capacity of the Loskop Dam currently given as 348 million m<sup>3</sup> of water making it one of the five largest dams in the Olifants River system (Loskop Irrigation Board, 2009). The main propose of the Loskop Dam is to provide water to the Loskop Water Scheme which supplies water for irrigation to over 16 117ha of agricultural land on 702 properties via a canal system with a total length of approximately 495km (Loskop Irrigation Board, 2009). Wheat, vegetables, tobacco, peanuts, cotton, citrus and grapes are cultivated using water from the scheme. Apart from the Loskop Water Scheme, water from the Loskop Dam is also supplied to the Hereford Irrigation Board, Olifants River Irrigation Board and the Groblersdal and Marble Hall Municipalities (Loskop Irrigation Board, 2009).

Two main reasons have been put forward to explain the decline in crocodile numbers in the Loskop Dam. The first being that pollution from higher up in the Olifants River catchment could have a detrimental effect on the reproductive potential of the crocodiles in the dam and secondly that the raising of the Loskop Dam resulted in flooding of basking and nesting areas making these unusable by crocodile (Jacobsen, 1984). The unexplained periodical deaths of large numbers of crocodiles in the Loskop Dam remain very disturbing to this day. Therefore, this study aims to determine the numbers, sizes and distribution of Nile crocodiles in the Loskop Dam due to the apparent decline in crocodile numbers in the dam.

Jacobsen warned in 1984 that should the decline in crocodile numbers in the Loskop Dam be a result of pollution, then recovery is unlikely and re-introduction of crocodiles into the system would be pointless. However, more than 20 years after Jacobsen's warnings, we are unfortunately no nearer to an answer for the question: "What is happening to the Nile crocodiles of the Loskop Dam?"

## **METHODS**

Surveys of the crocodiles in the Loskop Dam were done using two methods, aerial counts from aircraft and spotlight counts from boats.

The 2001 aerial survey was done as an incidental survey to investigate the possibility of gathering baseline data on the numbers and size class distribution of Nile crocodiles in the Loskop Dam while the 2005 and 2009 aerial surveys formed part of the bigger survey of the entire Olifants River (see chapter 3).

Helicopters were used during the 1981, 2005 and 2009 aerial counts but a microlight aircraft was used for the 2001 aerial count (see Table 11). When using a helicopter, the survey team consisted of the pilot and a navigator seated in the front of the helicopter with two observers sitting in the back of the helicopter. Team members in the back of the aircraft are responsible for observing to the left and the right-hand side of the helicopter. During

aerial counts using a microlight aircraft, the pilot acted as second observer looking out to the front, left and right of the aircraft while the passenger (sitting behind the pilot) observed to the left and right of the aircraft and operated the GPS and/or palm computer. All aerial counts were done with the aircraft flying at a constant height of about 100 to 150 feet while maintaining a constant ground speed of about 60 to 65 kph following the shoreline in one direction. The observers counted all crocodiles spotted and also estimated every animal's total length (TL) to the nearest metre. The position of each crocodile counted was marked with a handheld Global Positioning System (GPS) and the TL noted down with the waypoint number on a datasheet or palm computer. Data were later downloaded from the GPS and/or palm computer and datasheets to a notebook computer.

The size of completely submerged crocodiles was estimated using certain environmental and behavioural characteristics. These included factors such as habitat type, water depth, water swirl, mud trails and wakes (Jacobsen, 1984; Woodward and Moore, 1993). According to Jacobsen (1984) the tendency to underestimate the size of crocodiles spotted from the air is regarded as a constant factor and can therefore be ignored. While it is difficult to spot hatchlings and smaller sized crocodiles from the air, Woodward and Moore (1993) suggest that despite its weakness, the approach to include "unknown length" animals is still superior to ignoring them in the analysis of different size classes. Economic reasons eventually necessitated the decision to concentrate on spotlight counts rather than aerial counts to monitor population trends in the Loskop Dam Nile crocodile population. However, spotlight

counts are regarded by many authors as a suitable and reliable method for estimating crocodilian population size (Webb and Messel, 1979; Bayliss, Webb, Whitehead, Dempsey and Smith, 1986; Hutton and Woolhouse, 1989; Games, 1990; Woodward and Moore, 1993).

Since 2006 spotlight counts were used to establish the number and size class distribution of Nile crocodiles in the Loskop Dam. An eight metre fibreglass hull boat equipped with a single 80 hp Yamaha outboard motor was used for every count. During these counts, Nile crocodiles were located using an 800 000 candlepower halogen spotlight and identifying the reflective eye-shine that characteristically glows red.

Counts were normally started after sunset as soon as conditions became dark enough to use the spotlight. The boat was always operated at an average speed of about 10 - 15 kph while using the same route. The crew consisted of two researchers (one of whom also piloted the boat) who both spotted and counted crocodiles. The coordinates of all crocodiles found in this manner would be marked by GPS while the observers would also estimate the animal's total length to the nearest metre. Crocodiles that submerged before size estimation could be made were noted as "unknown" length animals. Woodward and Moore (1993) commented on this method of size estimation saying that the ability of observers to detect crocodilians increases quickly with experience. Data were later downloaded from the GPS and/or palm computer and datasheets to a notebook computer.

In both types of survey, the total length of individual crocodiles encountered were estimated to the nearest metre and animals assigned to the following broad size classes:

Class 1: Small sized crocodiles (TL <1.5m)

Class 2: Medium sized crocodiles (TL 1.5 - 2.0m)

Class 3: Large sized crocodiles (TL 2.0 - 4.0m)

Class 4: Very large sized crocodiles (TL >4.0m)

Unless stated otherwise, all statistics were calculated using the data analysis tool of Microsoft Excel 2007 part of Microsoft Office Professional 2007 with Windows 7 Professional as operating system.

## RESULTS

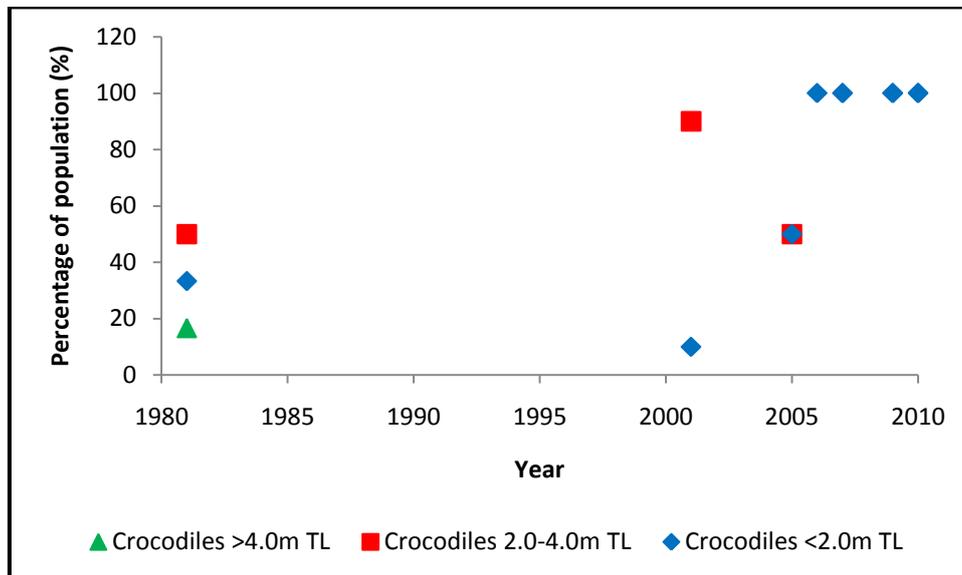
The surveys produced a very low total number of crocodiles and also a very poor distribution of crocodiles over the size classes compared to that expected to be present in healthy populations. A total of only 8 crocodiles were found in the whole of the Loskop Dam during the 2006 spotlight survey (Table 11). This included the Olifants River as far as the boat could navigate upstream. Previous surveys in 2001 and 2005 produced similar low results of 10 and six animals respectively. Also of interest is that no crocodiles in the large (2.0 - 4.0m) size class were found during the July 2006, January 2007, August 2007, August

**Table 11:** Summary of Nile crocodile surveys in the Loskop Dam showing size distribution and density of crocodiles/km of available shoreline.

Survey year	Type of survey	Size class					Total number	Adjusted number	Number re-introduced	Density (crocs/km)
		< 1.5m	1.5-2.0m	2.0-4.0m	>4.0m	Unsure				
1981 <sup>#</sup>	Aerial survey	0	2	3	1	0	6	9	0	0.09
2001	Aerial survey	1	0	9	0	0	10	15	0	0.14
December 2005	Aerial survey	2	1	3	0	0	6	9	0	0.09
July 2006	Spotlight survey	7	1	0	0	0	8	12	0	0.11
January 2007	Spotlight survey	6	4	0	0	2	12	18	0	0.17
August 2007	Spotlight survey	7	7	0	0	2	16	25	13	0.23
August 2009	Spotlight survey	2	7	0	0	1	10	15	0	0.14
November 2009	Aerial survey	2	4	0	0	0	6	9	0	0.09
February 2010	Spotlight survey	1	3	0	0	0	4	6	0	0.06
August 2010	Spotlight survey	0	2	0	0	2	4	6	0	0.06
<b>Total all surveys</b>		<b>28</b>	<b>31</b>	<b>15</b>	<b>1</b>	<b>7</b>	<b>82</b>	<b>126</b>	<b>13</b>	<b>-</b>
<b>Mean all surveys</b>		<b>3</b>	<b>3</b>	<b>2</b>	<b>0</b>	<b>1</b>	<b>8</b>	<b>13</b>	<b>-</b>	<b>0.12</b>
<b>Standard deviation</b>		<b>2.78</b>	<b>2.42</b>	<b>2.92</b>	<b>0.32</b>	<b>0.95</b>	<b>3.82</b>	<b>5.89</b>	<b>-</b>	<b>0.05</b>

<sup>#</sup> = Jacobsen (1984)

2009, November 2009, February 2010 and August 2010 surveys whereas no crocodiles in the very large (>4.0m) size class were found during the 2001, 2005, 2006, 2007, 2009 and 2010 surveys (Table 11). Although these surveys failed to locate any crocodiles in the over 4.0m TL category, they did at least confirm the presence of at least three crocodiles in the 2.0 - 4.0m size class during 2005 but by 2006 these crocodiles also disappeared from the dam (Table 11). The current crocodile population density in the Loskop Dam is very low at 0.06 crocodiles/km of shoreline (Table 11). This figure has remained very low over the years since 1981. The standard deviation of the population density figures is 0.05 (Table 11) which indicates that the figures do not deviate from the mean density very much and remain fairly stable at a low level. However a scatter plot graph shows that crocodiles in the 2.0 - 4.0m TL and > 4.0m TL size classes have been clearly declining in numbers over the last 27 years (Figure 21).



**Figure 21:** An illustration of the changes in the age structure of the Loskop Dam population of Nile crocodiles since 1981 (Data from Table 11).

During the 2001, 2005, 2006, 2007, 2009 and 2010 spotlight surveys crocodiles were found in the Olifants River around the western inlets of the dam and also in the area of the eastern inlets of the dam at the Kranspoortspruit and Scheepersloop areas (Figure 22). The distribution pattern of crocodiles in the Loskop Dam does not vary in any meaningful way between winter and summer periods (Figure 22) over a total of six spotlight surveys since 2001.

The line graph of the total population numbers (Figure 23) indicate that the population is declining. During 1979 a total of 21 crocodiles were counted in the Loskop Dam (Jacobsen, 1984) which translates to an estimated 32 animals which could have been present in the dam at that time. However, the February and August 2010 spotlight survey results (Table 11, Figure 23) confirm that the population is currently at an extremely low level with an only an estimated 6 animals in the total population. The brief increase registered during the July 2006 and January 2007 spotlight surveys is likely to be a function of the observers gaining experience rather than of a successful population increase.

However, an important factor is that a total of 13 animals were re-introduced during March 2007 causing an artificial increase in the number of crocodiles present in the dam during the August 2007 spotlight survey but the August 2009 spotlight survey results clearly show that these animals did not survive over the long term (Table 11, Figure 23).

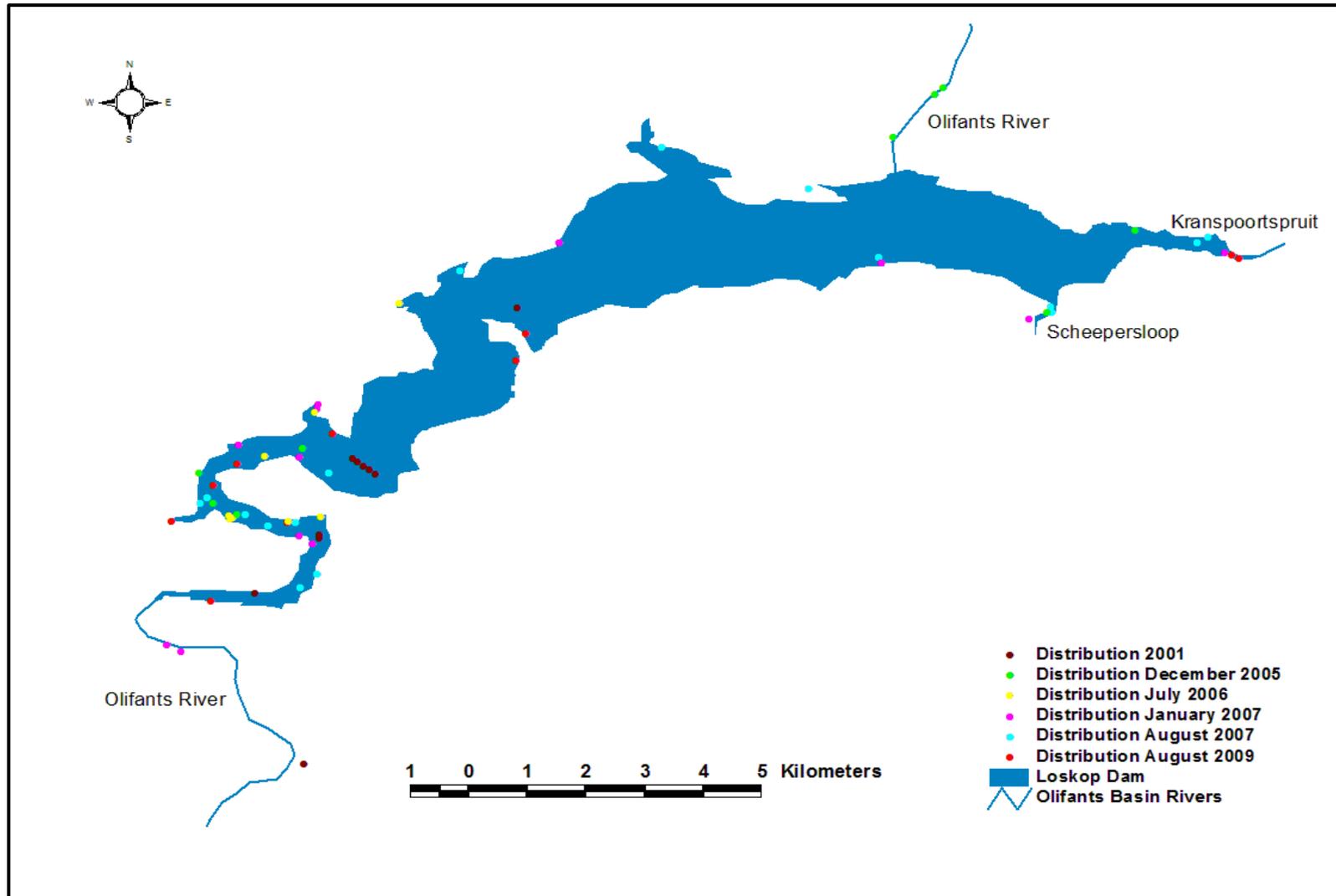
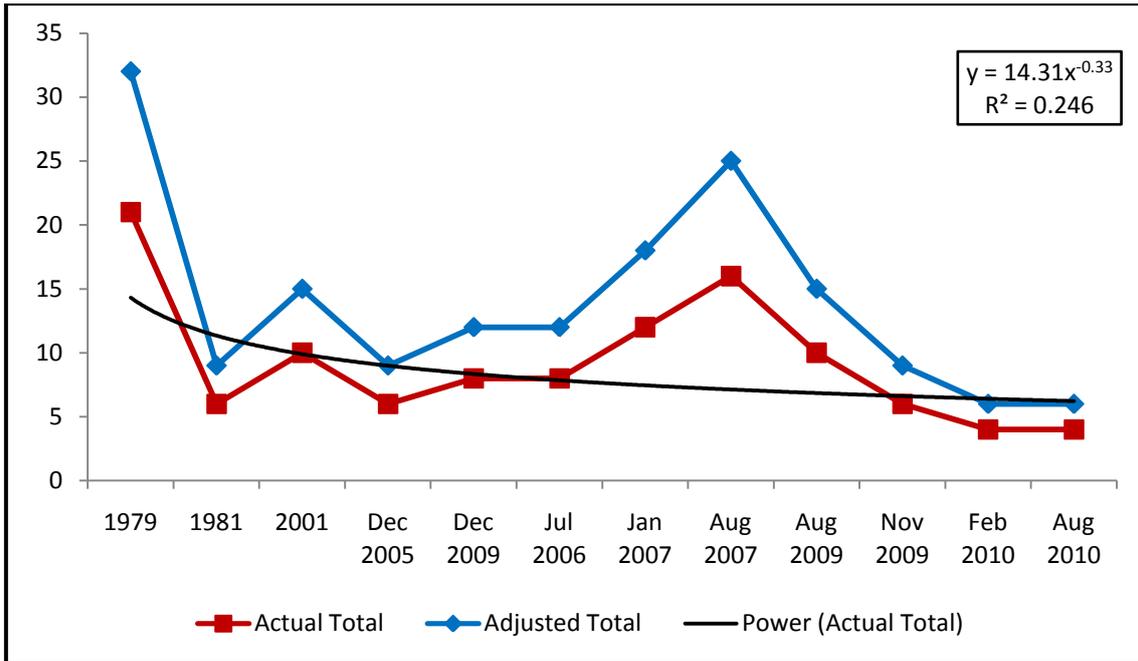
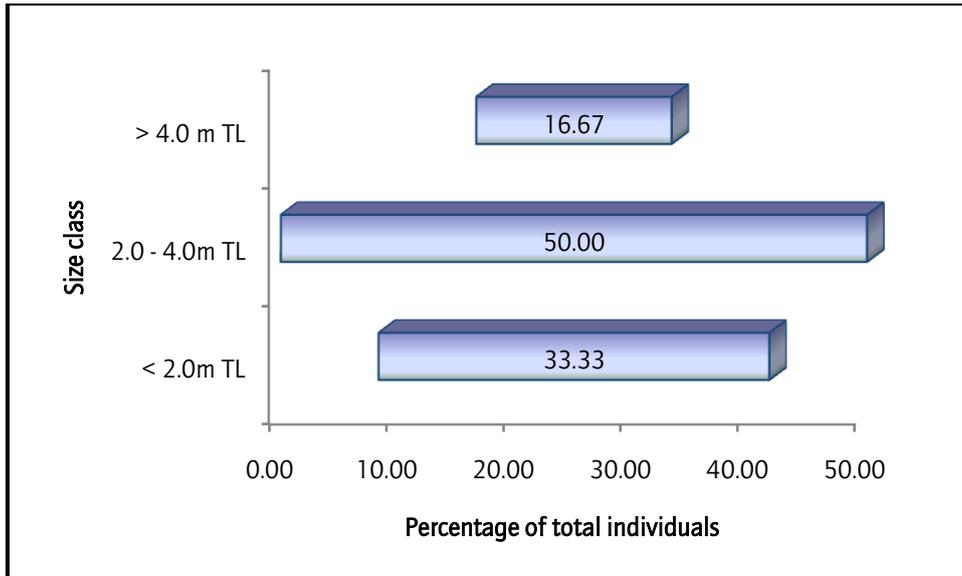


Figure 22: Distribution of Nile crocodiles in the Loskop Dam during surveys done in 2001, 05, 06, 07 and 09 (one dot represents one animal).

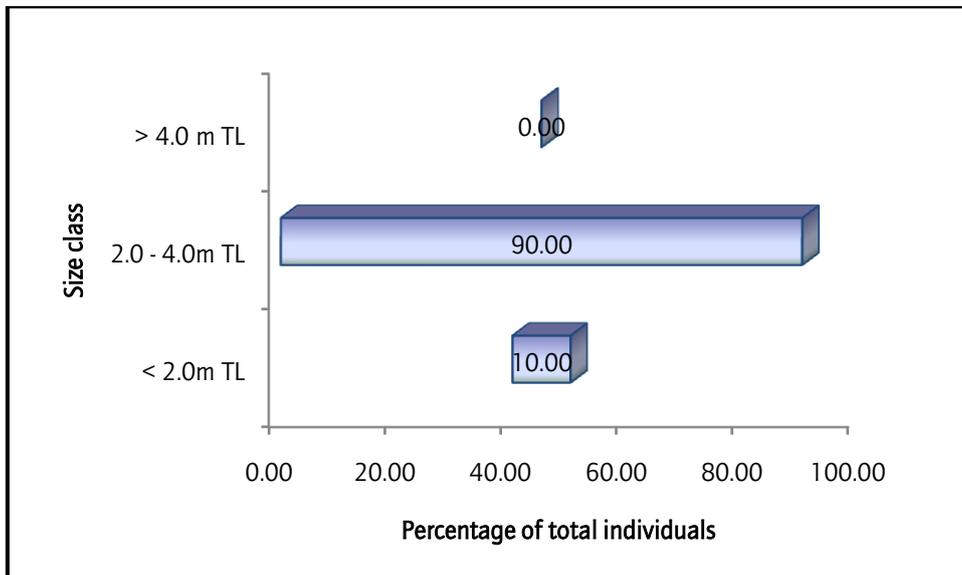


**Figure 23:** Actual number of Nile crocodiles counted in the Loskop Dam and the adjusted number of Nile crocodiles present in the Loskop Dam during survey years (The spike in August 2007 represent the experimental release of 13 Nile crocodiles into the system).

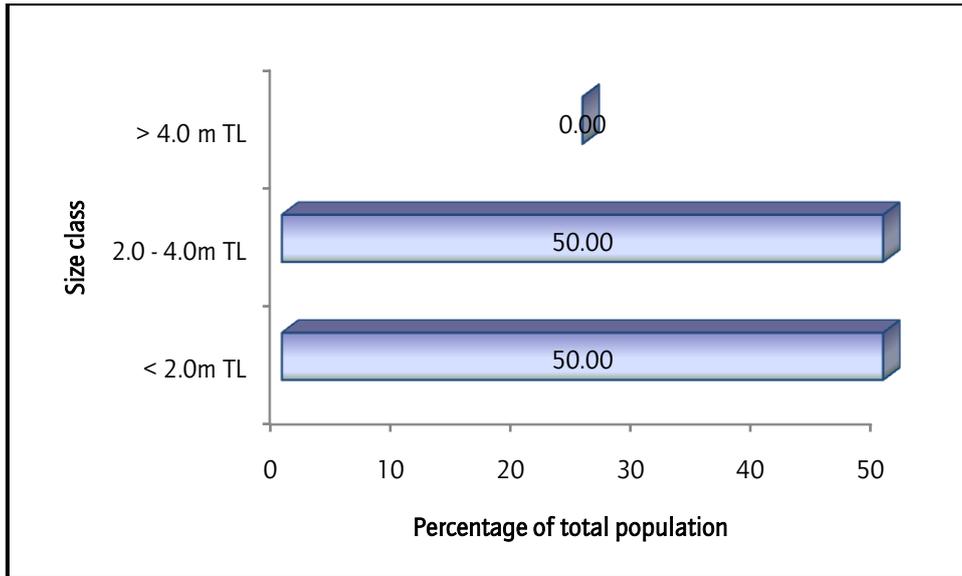
The 1981 population structure reported by Jacobsen (1984) indicates that the segment of the population consisting of small and medium sized crocodiles (all crocodiles less than 2.0m TL) are smaller in number than the large size class which consist of crocodiles between 2.0 and 4.0m TL (Figure 24). By 2001 and 2005 the crocodiles in the over 4.0m TL size class have disappeared from the population (Figures 25 and 26) and are still absent during 2006, 2007, 2009 and 2010 (Figures 27, 28, 29 and 30). However, by 2006, 2007, 2009 and 2010 all crocodiles in the 2.0 - 4.0m TL size class have also disappeared from the population (Figure 27, 28, 29 and 30).



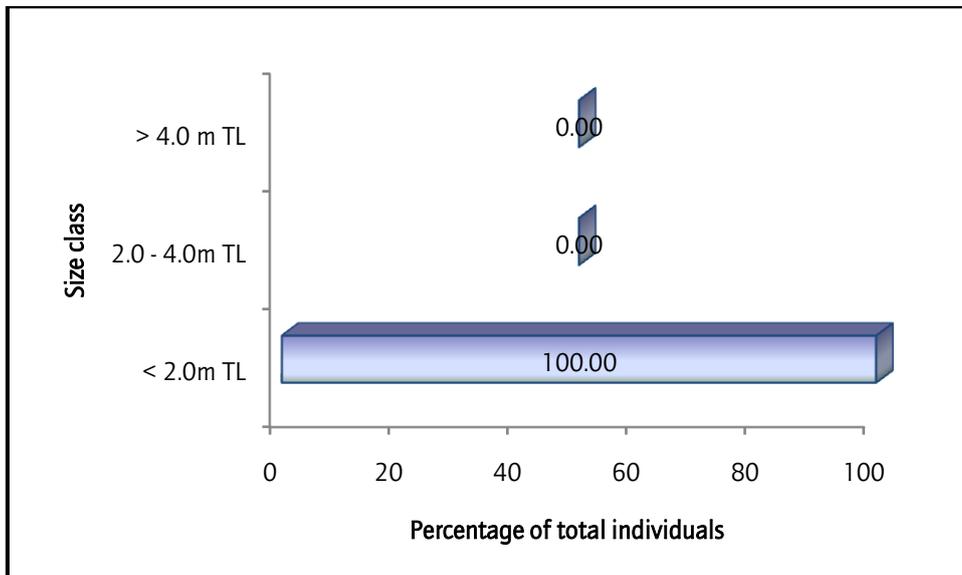
**Figure 24:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during 1981 based on aerial survey results reported by Jacobsen (1984).



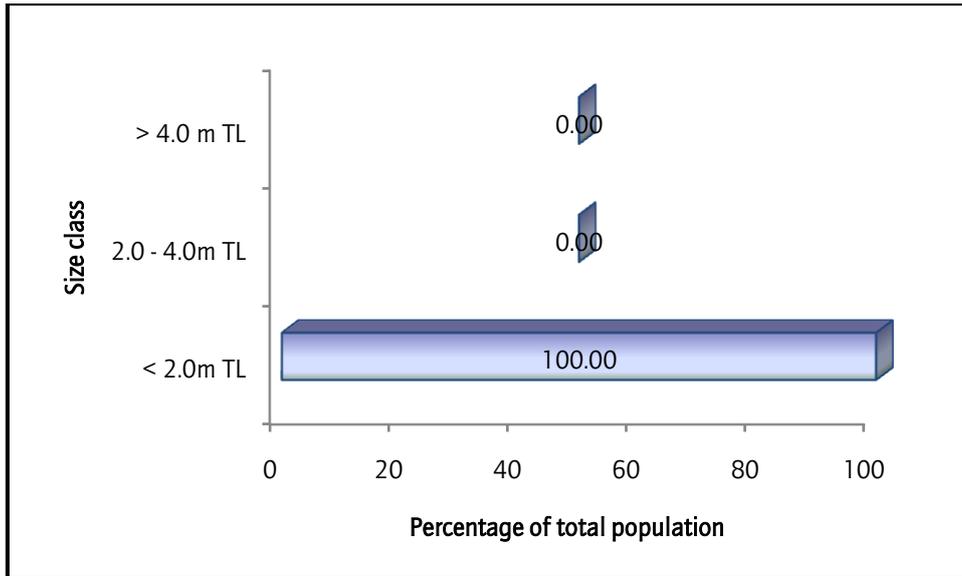
**Figure 25:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during 2001 based on aerial survey results.



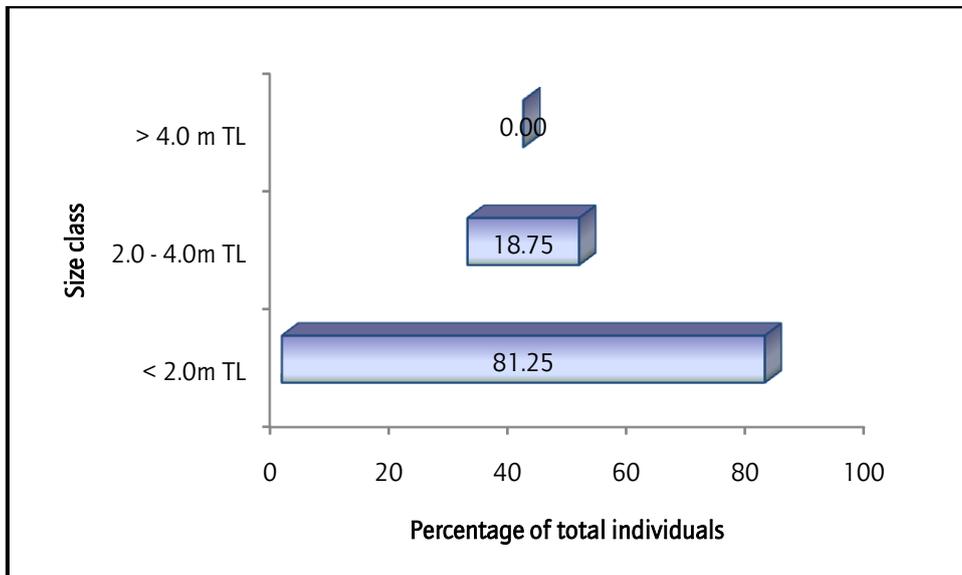
**Figure 26:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during 2005 based on aerial survey results.



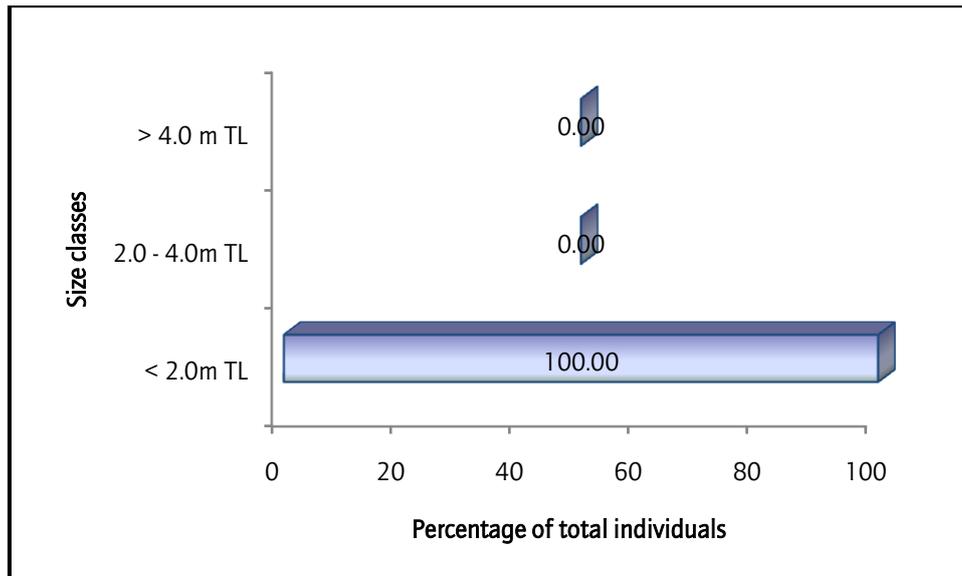
**Figure 27:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during June 2006 based on spotlight survey results.



**Figure 28:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during January 2007 based on spotlight survey results.



**Figure 29:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during August 2007 based on spotlight survey done after the experimental release of juvenile crocodiles in the dam.



**Figure 30:** Population structure of Nile crocodiles (both sexes combined) in the Loskop Dam during August 2009 based on spotlight survey results.

## DISCUSSION

The results of the different surveys indicate several interesting possibilities with regards to the Nile crocodile population in the Loskop Dam. The low total number of individuals encountered in the Loskop Dam during the 2006 and 2009 surveys corresponds closely with that of the 2001 and 2005 surveys. More importantly, the low number of animals in 2006 is virtually the same as the result of the 1981 survey and the very low numbers from the 2010 surveys indicate that recruitment via reproduction or immigration from the Olifants River system into the dam has been almost nonexistent for decades. This indicates that the observed decline in population size did not change over the long term is not a function of a naturally fluctuating population or poor censusing techniques.

Crocodiles do not show fluctuations in population size quickly because they are long lived animals with long generation times. Further, given the reintroductions that occurred during 1983/1984 (three crocodiles), 1984/1985 (six crocodiles) and 2007 (13 crocodiles), the population should surely have shown at least some change over 25 years but it did not.

Taking the number of animals not seen into consideration (Botha, 2005; Swanepoel, 2001; Bayliss 1987) the estimated total number of crocodiles in the Loskop Dam is possibly between four (4) and six (6) animals. This underlines the lack of population growth over a period of 28 to 30 years.

The influence that a population of animals exerts on the ecosystem depends largely on the number of animals in that population, in other words it depends on the density of the population (Odum, 1971). Population density is expressed as the number of crocodiles per kilometre of shoreline in a particular area. The population density of the current crocodile population in the Loskop Dam converts to 0.06 crocodiles/km of shoreline (Table 11). It is conceded that all of the shoreline is not good habitat but it once was good habitat. Historical records show that human settlement of the area where the dam is today started as long ago as 1886 (Loskop Irrigation Board, 2009) and that crocodiles were abundant along the Olifants River then. Therefore, it is intended to show the loss of habitat that occurred over time by taking all of the shoreline into account when determining the density of crocodiles in the area. The densities indicate a gradual increase which can be explained by the experimental re-introduction of 13 animals into the population but overall the

density trend seems to indicate that the population has been at a very low level since 1981. The standard deviation for the population density from all surveys is 0.05 indicating that the figures do not deviate much from the mean. Therefore, although the total counts fluctuate, the population density remains stable at a very low level proving that the population is already severely depleted. This supports the hypotheses that the observed decline in the population numbers has continued over the long term and is not a function of a naturally fluctuating population. When compared to other crocodile populations in similar habitats (i.e. living in dams or lakes) the low population density of the Loskop Dam becomes abundantly clear (Table 12). The Flag Boshielo Dam situated downstream from the Loskop Dam in the Olifants River has a density of 3.25 crocodiles/km of shoreline. The Olifants River in the Kruger National Park has a density of 3.98 crocodiles/km of shoreline while the Olifants River Gorge in the Kruger National Park has an astounding density of 30.00 crocodiles/km of shoreline (Botha, 2005). All of this underlines the fact that the current crocodile population in the Loskop Dam is severely depleted at a density of only 0.06 crocodiles/km of shoreline.

**Table 12:** Comparison of Nile crocodile population densities from the Olifants River in South Africa.

Crocodile population	Reference	Length of shoreline (km)	Number of crocodiles	Density (crocodiles/km)
Flag Boshielo Dam (Olifants River, South Africa)	Botha, 2005	65	211	3.25
Kruger National Park (Olifants River, South Africa)	Current study	95	379	3.98
Olifants River Gorge (Olifants River, South Africa)	Current study	10	300	30.00
Olifants River between Loskop Dam and Flag Boshielo Dam	Current study	80	24	0.30
Loskop Dam (Olifants River, South Africa)	Current study	70	4	0.06

The stationary nature in the size of the crocodile population suggests that a situation have been reached where the mortality of the population is at least equal to but possibly even higher than recruitment into the population. Such a situation certainly indicates that the population is fast nearing the point where it won't be able to sustain itself and start to decline until none are left. In addition to the stationary nature of the population, no hatchling crocodiles (animals less than one year old) have been found during either the 2006, 2007, 2009 or 2010 spotlight surveys. The dynamics of the population is seriously challenged with only one animal in the >4.0m size class being reported during the 1981 survey and none during any of the subsequent surveys. These very large animals are considered to be the dominant animals necessary for normal competition, behaviour and successful nesting in any population. It is my contention that complete absence of this size class in a wild population will hamper that population's chances of expanding normally since large crocodile must have an ecological purpose in the population. Their disappearance from the population is unlikely to be linked to the lack of nesting areas because one would then expect the small crocodiles to disappear first due to no recruitment taking place and this did not happen. Age pyramids constructed from the various sets of aerial survey data reported by Jacobsen (1984) show that in 1981 the Loskop Dam population had an age distribution characteristic of a declining population (Figure 23) with the number of small and medium sized crocodiles (all crocodiles less than 2.0m TL) being less than the large size class which consist of crocodiles between 2.0 and 4.0m TL (Figure 24). This is a highly skewed population and could indicate a shrinking population due to

poor recruitment or possibly a problem with the survey technique. However, the population changed to a top heavy structure in 2001 with few juvenile animals and a large proportion of adult animals (Figure 24) which is normally indicative of a population associated with deteriorating habitat (Odum, 1971; Ryke, 1978). By 2005 the population structure seems to have become stationary with an equal distribution of young and adult animals (Figure 25). The final age pyramids from 2006, 2007 and 2009 clearly show that all animals over 2.0m TL have disappeared out of the population (Figure 26, 27, 28 and 29). Age pyramids confirm the complete absence of any dominant animals in the population since at least 2001 while the large scale die-off of crocodiles during the period 2005 to 2007 are also reflected in the age pyramids.

A primary concern remains to be the lack of animals observed in the 2.0 - 4.0m TL size class during the latest surveys of 2006, 2007 and 2009. If one accept that animals in the >4.0m TL size class is absent from the population then one would expect the next size class (2.0 - 4.0m TL) to "stand in" so to speak for the dominant animals. However, if they too are now absent from the population then Jacobsen's remark of the population becoming extinct is probably about to be realised in our lifetime (Jacobsen, 1984).

Die-off events in the Nile crocodile population at Loskop Dam at intervals over the last 28 years have been well documented in nature conservation files at the Loskop Dam Nature Reserve. Anecdotal evidence describe die-off events where only large (2.0 - 4.0m TL) animals were reported to have died. This could very well be the reason for their total absence from

the population during the latest survey. It is important that this factor be confirmed by further surveys especially during the next couple of breeding and nesting seasons.

The distribution pattern of the crocodiles in the Loskop Dam indicates that crocodiles only really occur in numbers in the river-like area at the inlet of the Olifants River to the dam (Figure 21). This is possibly due to the raising of the dam wall which has rendered all other areas in the dam unsuitable for crocodiles. The impact of this is that the population now concentrates in areas of the river where the effects of pollution is probably worse than anywhere else in the dam due to there being less water in the river to dilute pollution agents compared to the rest of the dam. Therefore the distribution of crocodiles, because of the raising of the dam is placing them in an area where they experience pollution at higher levels than elsewhere in the dam. This could very well be a critical element in the episodes of periodic die-off witnessed in the Loskop Dam.

During the 2001, 2005, 2006, 2007, 2009 and 2010 surveys crocodiles were found to occur mostly in the Olifants River and around the inlets of the dam including the inlets of the Kranspoortspuit and Scheepersloop areas (Figure 21). The results of nine surveys since 2001 show that the distribution pattern of crocodiles in the Loskop Dam does not vary in any meaningful way between winter and summer periods (Figure 21). Distribution patterns and movements in crocodilian populations are usually associated with important population milestones such as the onset mating and nesting during summer. Definite seasonal distribution patterns are known to occur in the larger Nile crocodile population of the Flag

Boshielo Dam downstream from the Loskop Dam (Botha, 2005). The total absence of any seasonal variation in distribution support the hypothesis that no crocodiles in the large and very large size class currently occur in the Loskop Dam. It also indicates that important behaviour and population milestones do not occur in the Loskop Dam population any longer indicating that this is an unstable population. Crocodiles are regularly spotted directly below the dam wall in the Olifants River (Figure 21) indicating that the river downstream of the dam is still suitable habitat for crocodiles. In fact, 3.5 times more crocodiles were counted downstream of the Loskop Dam than in the dam itself during the 2005 aerial survey of the entire Olifants River.

## CONCLUSION

The total number of Nile crocodiles in the Loskop Dam has been declining over the last 25 to 30 years. In addition there are no surviving large animals over 2.0m TL in the entire Loskop Dam leaving it in crisis for future breeding seasons. Age pyramids also confirm the complete absence of any dominant animals in the population since at least 2001. Die-off events over the period 2005 to 2007 had devastating effects on the Nile crocodile population of the Loskop Dam. It is likely that the historical distribution pattern of crocodiles in the Loskop Dam are exposing them to concentrated pollutants in the inlets of the dam as opposed to the main water body of the dam where the volume of water probably have a diluting effect on pollutants in the aquatic system. It is clear that the

experimental re-introduction of crocodiles to the population failed to stabilise or contribute to its growth.

## REFERENCES

BAYLISS, P., WEBB, G.J.W., WHITEHEAD, P.J., DEMPSEY, K. and SMITH, A. 1986. Estimating the abundance of saltwater crocodiles, *Crocodylus porosus* Schneider, in tidal wetlands of the Northern Territory: a mark-recapture experiment to correct spotlight counts to absolute numbers and the calibration of helicopter and spotlight counts. *Australian Wildlife Research*. 13: 309-320.

BAYLISS, P. 1987. Survey methods and monitoring within crocodile management programmes. In: *Wildlife management: crocodiles and alligators*. Edited by G.J.W. Webb, S.C. Manolis and P.J. Whitehead. Surrey Beatty and Sons, Chipping Norton.

BOTHA, P.J. 2005. *The ecology and population dynamics of the Nile crocodile Crocodylus niloticus in the Flag Boshielo Dam, Mpumalanga province, South Africa*. M.Sc. Thesis. University of Pretoria.

GAMES, I. 1990. Growth curves for the Nile crocodile as estimated by skeleton-chronology. *Proceedings of the 10<sup>th</sup> working group meeting of the Crocodile Specialist Group of the Species Survival Commission of IUCN*. IUCN. Gland, Switzerland.

HUTTON, J.M. and WOOLHOUSE, M.E.J. 1989. Mark-recapture to assess factors affecting the proportion of a Nile crocodile population seen during spotlight counts at Ngezi, Zimbabwe and the use of spotlight counts to monitor crocodile abundance. *Journal of Applied Ecology*. 26: 381-395.

JACOBSEN, N.H.G. 1984. The distribution and status of crocodile populations in the Transvaal outside the Kruger National Park. *Biological Conservation*, 29: 191-200.

LOSKOP IRRIGATION BOARD, 2009. *Loskop water scheme*. Loskop Irrigation Board, Groblersdal, viewed on 02 April 2009, <http://www.loskopbesproeingsraad.co.za>.

ODUM, E.P. 1971. *Fundamentals of ecology*. Saunders College Publishing, Philadelphia.

RYKE. P.A.J. 1978. *Ekologie, beginsels en toepassings*. Butterworth. Durban.

SWANEPOEL, D.G.J. 2001. The raising of the Arabie Dam wall and the impacts on the Nile crocodile population. Unpubl. Report, Department of Water Affairs and Forestry, Pretoria.

TRANSVAAL NATURE CONSERVATION DIVISION, 1983. *Eighteenth annual report: 1982/83*. Transvaal Provincial Administration, Pretoria.

TRANSVAAL NATURE CONSERVATION DIVISION, 1985. *Nineteenth annual report: 1983/84*. Transvaal Provincial Administration, Pretoria.

TRANSVAAL NATURE CONSERVATION DIVISION, 1986. *Twentieth annual report: 1984/85*. Transvaal Provincial Administration, Pretoria.

WEBB, G.J.W. and MESSEL, H. 1979. Wariness in *Crocodylus porosus*. *Australian Wildlife Research*. 6: 227-234.

WOODWARD, A.R. and MOORE, C.T. 1993. Use of crocodylian night count data for population trend estimation. Paper presented at: Second Regional Conference of the Crocodile Specialist Group, Species Survival Commission, IUCN held in Darwin, NT, Australia 12-13 March 1993.