CHAPTER 1

THE IMPORTANCE OF CROCODILIANS IN THE ECOSYSTEM

According to King and Burke (1997) the term crocodilian refers to the 23 living species of crocodile-like animals (e.g. alligators, caimans, crocodiles, gharials and false gharials) comprising the order Crocodylia. The order Crocodylia is currently arranged in three families i.e. Alligatoridae, Crocodylidae and Gavialidae (Appendix II) (King and Burke, 1997; Ross, 1998). Brochu (2003) comments that crocodilian phylogeny reveal a more complex history and that phylogenetic relationships and time of divergence of the two living gharials, the relationship among living true crocodiles and the relationships among caimans must be considered by phylogeneticists in future. The Nile crocodile is among the largest and best known of all crocodilians. It is the most widespread crocodilian of the African continent (Figure 1) and is found throughout tropical and southern Africa and Madagascar (Ross and Magnusson, 1990). African countries within its range include: Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central African Republic, Chad, Congo, Côte d'Ivoire, Democratic Republic of Congo, Egypt, Ethiopia, Equatorial Guinea, Gabon, Gambia, Ghana, Guinea, Guinea Bissau, Kenya, Liberia, Madagascar, Malawi, Mali, Mozambique, Mauritania, Namibia, Niger, Nigeria, Rwanda, Senegal, Sierra Leone, Somalia, South Africa, Sudan, Swaziland, Tanzania, Togo, Uganda, Zambia and Zimbabwe (Ross, 1998). The historical distribution of the Nile crocodile included the Nile River delta and the Mediterranean coast from Tunisia to Syria while isolated populations are known to have existed in lakes and

waterholes in the interior of Mauritania, south-eastern Algeria and north-eastern Chad in the Sahara desert (Ross and Magnusson, 1990). Two other species of crocodilian occur in Africa. They are the slender-snouted crocodile (*Crocodylus cataphractus*) and the dwarf crocodile (*Osteolaemus tetraspis*) but neither of these two species occurs in southern Africa.

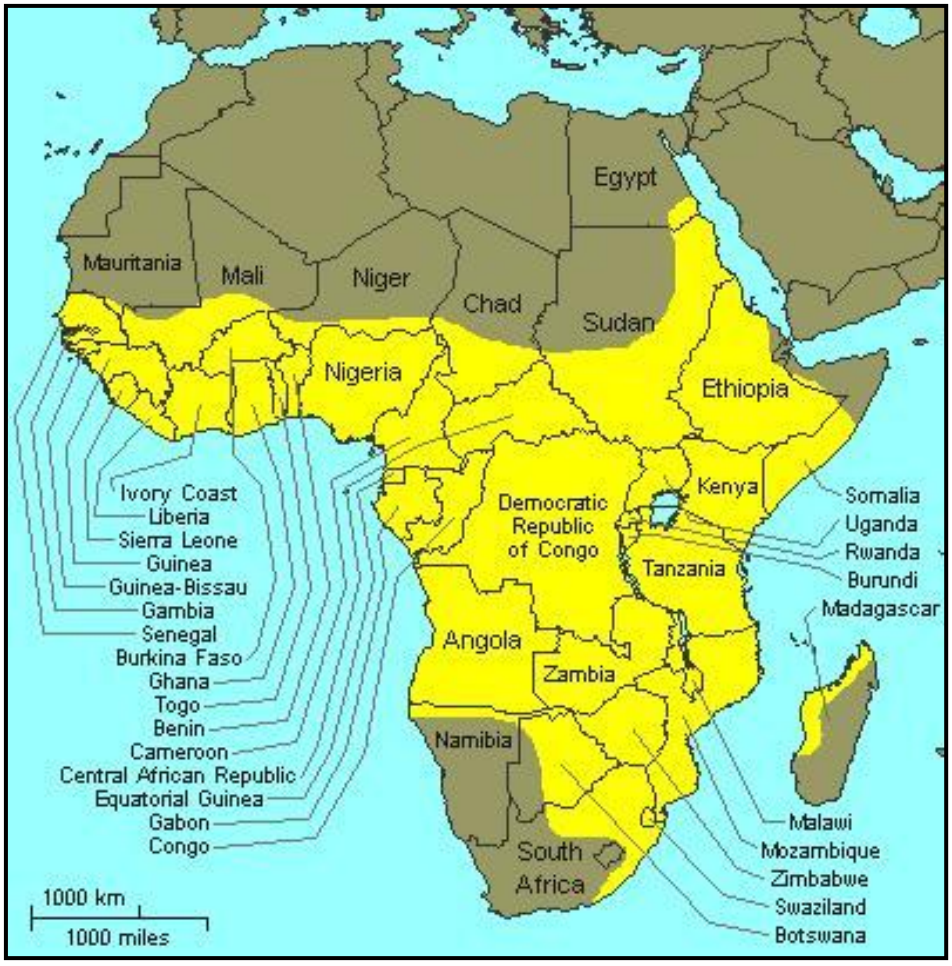

Figure 1: Distribution (in yellow) of *Crocodylus niloticus* in Africa (Britton, 2007).

The distribution of Nile crocodiles in South Africa is limited to the north-eastern parts of the country. Here they occur in the area of the former Transvaal province (now North West province, Limpopo province and Mpumalanga province) from the towns of Brits and Rust de

Winter northwards and eastwards extending into Natal (now KwaZulu-Natal province) as far as the Tugela River (Jacobsen, 1988) (Figure 2). However, the historical distribution of Nile crocodiles in South Africa occurred over a much larger area which extended as far southwards as the Transkei and the Great Fish River in the Eastern Cape (now Eastern Cape province) (Jacobsen, 1988).

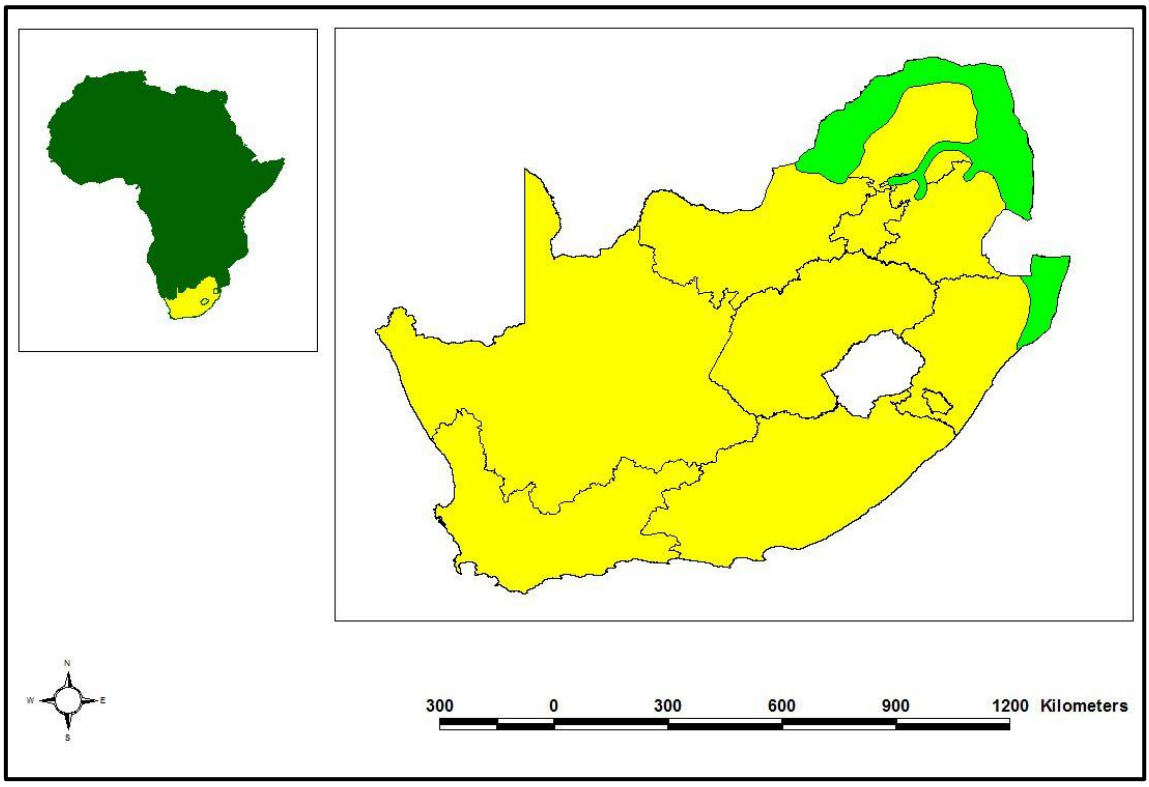

Figure 2: The distribution (in green) of *Crocodylus niloticus* in South Africa based on a map published by Jacobsen in 1988.

Crocodilians are of great antiquity with hundreds of fossil forms and three major radiations (Ross, 1998). Despite their antiquity, it is quite inappropriate to treat crocodilians as "living fossils" whose "inferiority" forced them into a marginal ecological role as amphibious

predators in a world now dominated by mammals (Sues, 1990; Brochu 2003). In fact, they are highly specialized for their particular mode of life and during their long evolutionary history that spans more than 200 million years, they have undergone considerable changes (Sues, 1990).

Crocodiles have always represented the power and virility of nature to many ancient cultures from the Egyptians and Mayans to the aboriginals of Australia and New Guinea. There were, however, others to whom crocodilians were all that were terrible about nature and nothing more than a dangerous nuisance to be eliminated. Over many centuries, crocodile skin have been used by the Egyptians, the Romans, native people from Africa, America and Asia but in the late 19th and early 20th centuries crocodile skin became not only functional but also fashionable. After World War II the demand for crocodile skin sky-rocketed and several species of crocodilian almost became extinct because to most people the only good crocodile was a dead one. Many crocodilians experienced uncontrolled exploitation where sub-adult and adult crocodiles were hooked, speared, shot or otherwise killed for their skins for international trade. Many crocodile species around the world suffered serious declines in their numbers with only those species with difficult to tan skins, escaping relatively unmolested. During the 1970's once the harm caused by uncontrolled exploitation had been realised, scientists and even former hunters began to advocate harvest restrictions as a protective measure before it was too late. Improved protection and tightly controlled exploitation rescued many crocodilian populations from continued decline. Saltwater

crocodiles in the Northern Territory of Australia recovered from an estimated 3000 animals in 1971 to an estimated 80 000 animals thirty years after their initial protection began (Britton, 2008). Scientists and conservationists realised that something had to be done to prevent the problem of declining crocodile populations due to harvesting pressure, repeating itself. The challenge was to change people's attitudes towards crocodiles; simply telling people that crocodiles are great for the environment was not going to be enough. Despite efforts to educate people that crocodiles are dangerous and should be treated with caution and respect, conservation efforts suffer a severe setback every time another crocodile attack on a person is reported. The removal of problem crocodiles from public and other areas where there is conflict with humans becomes the best option for conservation authorities. The reasoning behind this being that it is worth the effort to relocate ten or twenty crocodiles in order to avoid one human death, which in turn could lead to public pressure demanding the culling of a hundred (or a thousand) crocodiles.

The establishment of hundreds of crocodilian farms worldwide during the last quarter of the 20th century was responsible for a fundamental change in the production of crocodilian skin (Luxmoore, 1992). Crocodile farming is defined as the rearing of crocodilians in captivity for commercial production of skins and other products or live animal sales (Luxmoore, 1992). The term "crocodile farming" encapsulates two fundamentally different activities namely "captive breeding" and "ranching". The term "captive breeding" refers to the raising in captivity of crocodilians, which originate from eggs produced by captive adults while

"ranching" refers to the raising in captivity of crocodilians, which originate from wild-harvested eggs or hatchlings (MacGregor, 2006).

The shift from hunting crocodiles for their skins to captive breeding has some important impacts on the conservation of crocodilians. The first impact on the conservation of crocodilians is that captive breeding operations are likely to have limited interest in wild crocodilians because they operate as closed systems and can therefore have a particularly erosive effect on *in-situ* conservation plans (Ross, 2001). The re-investment in wild crocodilians is particularly unsupported in practise by captive breeding operations because in commercially successful operations, re-investment in wild crocodilian populations is simply not undertaken (Hutton *et al*., 2001; MacGregor, 2001, 2002; Moyle, 2003). Sustainable use of wild crocodilians is likely to be of reduced interest to successful captive breeding operations as the relative returns from crocodile habitat are much lower than those from alternative forms of land use (e.g. forestry, livestock) (Woodward, 1998; Thorbjarnarson and Velasco, 1998; Thorbjarnarson, 1999). Therefore, local farmers and landholders are much less likely to tolerate the proximity of wild crocodilians and the risks they pose to humans and livestock without some form of compensation. As a result, they are therefore much more likely to respond to incentives to transform crocodilian habitat (MacGregor, 2006) and less likely to be concerned with the conservation of crocodile habitat and restocking of dwindling wild populations. It makes sense then that without the conservation of nesting habitat, crocodile conservation will have severe difficulty in succeeding.

The second more important impact is that that countries relying primarily on captive breeding of crocodilians for production, as opposed to ranching or wild harvest, are more often than not associated with poorly known, depleted wild crocodilian populations (Luxmoore *et al.*, 1985; Ross 2001). Both the studies of Luxmoore *et al.* (1985) and Ross (2001), done more than 15 years apart, confirmed that this state of affair follows because of the poor ties these countries (e.g. Columbia, South Africa, Thailand and Mexico) often maintain with the wild resource. It is my opinion that South Africa and more specifically the northern provinces fall into exactly this category because none of the official conservation departments or parks boards in the North West province, Limpopo province or Mpumalanga province currently employ a crocodile expert specifically to monitor wild crocodile populations.

Poaching for hides is no longer regarded as a threat (Blake and Jacobsen, 1992) and the status of the Nile crocodile is relatively secure and abundant in southern and eastern Africa, where it is regarded as a species with a moderate need for the recovery of the wild population (Ross, 1998). However, Pooley warned as long ago as 1969 that crocodilians are not only threatened by over exploitation but also significantly by other human activities such as destruction or alteration of their wild habitat. Since then, Nile crocodile populations have been severely depleted especially in recent years primarily due to the reduction of riverine habitat caused by the construction of dams, weirs and irrigation schemes (Jacobsen, 1988). This, along with the flooding of nesting banks, pollution of rivers and persecution by

man due to incompatibility with livestock farming has led to the fragmentation of breeding populations and a subsequent decrease in hatchling numbers (Jacobsen, 1988). It is estimated that less than 150 Chinese alligators (*Alligator sinensis*) currently exists in a tiny fraction of their former range (Britton, 2008). This drastic reduction in numbers is the direct result of thousands of hectares of former alligator habitat being converted into agricultural land needed to feed and house thousands of people (Britton, 2008). South Africa currently finds itself in a similar situation where large tracts of land are needed to feed and house thousands of people. In their efforts to survive, crocodilians destroy irrigation canals and kill valuable livestock leading to their own indiscriminate destruction.

Gardenfors *et al.* (2001) states that when the population as a whole is considered, a taxon may not have a high risk of extinction but that the probability of local extinction is generally higher in smaller populations. Similarly I believe that while Nile crocodiles are currently regarded as "vulnerable" in South Africa, local populations, such as the Olifants River population, on their own may very well be worse off especially when one takes into account that the Olifants River is one of the most polluted and threatened rivers in South Africa (Myburgh, 1999; Water Research Commission 2001; Driver *et al.*, 2004). A recent survey by Driver *et al*. (2004) has shown that 82% of all rivers in South Africa are threatened while 44% of all South African rivers are critically endangered compared to 5% critically endangered terrestrial ecosystems. Jacobsen warned in 1988 that unless the utilisation of water from rivers is rationalised the situation would become detrimental to the survival of

crocodiles. Britton (2008) expresses the opinion that people who live around crocodilians need to see advantages in conserving these reptiles. He suggested that it would be difficult for these people to support conservation efforts if crocodilians have no intrinsic, aesthetic, environmental, economic, social or cultural value to them. Therefore the important question becomes what exactly is the worth of crocodiles? Leading crocodile and alligator experts feel that crocodiles express their worth to their environment in the following important ways.

1. Crocodiles maintain biodiversity of wetlands by opening up trails and maintaining deeper pools of open water which is also used by fish, other reptiles, amphibians, birds and even some mammals (Alcala and Dy-Liacco, 1990). They deepen waterholes during drought and provide microhabitats for smaller aquatic organisms (Alcala and Dy-Liacco, 1990).

2. Crocodiles encourage biodiversity by preying on the most abundant species thereby increasing resources for less abundant species. For example, crocodiles keep the Sharptooth catfish (*Clarias gariepinus*) populations under control allowing smaller fish species such as tilapia and yellow fish populations to survive (Alcala and Dy-Liacco, 1990). By preying on what is considered to be a commercially worthless fish species, crocodilians eliminate the predator of an important human economic resource (Alcala and Dy-Liacco, 1990). It is conceivable that this balance could be essential for the health of both the environment and the human population living near wetlands, rivers

and streams. A number of water borne diseases are vectored by mosquitoes and healthy fish populations that include small fish preying on mosquito larvae could have a profound influence on the spread of these diseases. Over population of an aquatic system with predatory fish like Sharptooth catfish (*C. gariepinus*) could alter the balance in the system, potentially leading to greater numbers of disease bearing mosquitoes. In terms of maintaining high species diversity and healthy ecosystems essential to human health, crocodilians are a powerful and keystone species in tropical ecosystems (Craighead, 1968; King, 1988, Alcala and Dy-Liacco, 1990; Mazotti *et al.,* 2008).

3. Crocodiles are an environmental indicator species and monitoring contaminant levels in crocodiles can provide a good indication of the level of contaminants in the aquatic ecosystem (Crain and Guillette, 1998; Guillette and Iguchi, 2003; Milnes and Guillette, 2008).

4. Crocodiles have aesthetic value and people are fascinated with these huge and powerful predators. They form part of the traditional "wildlife of Africa" which people travel around the world to see, photograph or hunt. Newsome *et al.* (2005) came to the conclusion that the crocodile has become an iconic image of visitor experience. According to the South African Tourism website, between 20 and 27% of international tourists who visited South Africa during the first three quarters of 2008 undertook natural or wildlife related activities (South African Tourism, 2008a; South African

Tourism, 2008b; South African Tourism, 2008c).

5. Crocodiles are economically important, with assets on a single well managed crocodile farm such as the Renishaw Farm on the KwaZulu-Natal south coast being worth as much as R 5 724 000 (Crookes Brothers Limited, 2008). Products such as skins and meat can generate a profit of around R 1 575 000 per year on a single well managed crocodile farm per year (Crookes Brothers Limited, 2008). Studies in Botswana have shown that the financial return on investment in crocodile farming is in fact higher than the mean economic rates of return (Barnes, 2001)

6. Crocodilians are apex predators in their habitats where they have virtually no predators of their own and reside at the top of their food chain. Food chains transfer energy, in the form of food from its source in plants to herbivores and on to carnivores and omnivores. In tropical areas, nutrients are recycled rapidly following decomposition, leaving streams and lakes nutrient poor. Research proved that crocodilians feeding on adult fish nearly doubled the amounts of calcium, magnesium phosphorus, potassium and sodium in these nutrient poor streams and lakes making it a much more productive system for hatching fish and other aquatic organisms (Alcala and Dy-Liacco, 1990; Vitt and Caldwell, 2009).

Sustainable use strategies work in some areas but the question is whether they will continue to work in the long term, especially in the unstable political climates of African states. One undeniable factor is that conservation is expensive and effective action without sufficient resources is impossible. Management programs need further development if they are to help the remaining endangered and vulnerable crocodilian populations.

The primary objective of this study is to determine the distribution, status (numbers and population structure), vulnerability (conservation status) and the extent of any population changes in wild populations of Nile crocodiles occurring in the Olifants River its tributaries and impoundments. This should give an indication of the stability of the crocodile population in the Olifants River system.

The second objective of the study is to determine whether there is any change in the general health of crocodiles, based on the levels of certain parameters in their blood biochemistry, over the gradient of the Olifants River and particularly those crocodile populations occurring in the Loskop Dam, Flag Boshielo Dam, Olifants River Gorge and the Blyderivierspoort Dam. These four populations have been chosen as research sites because they represent populations in the upper, middle and lower Olifants River with the Blyderivierspoort Dam used as control population since it is situated in a tributary of which the catchment is situated in a protected area and is therefore not subjected to the same levels of abuse as the rest of the Olifants River is.

It is known that external factors such as environmental conditions influence the normal physiology and health of ectothermic vertebrates (Campbell, 2006). Blood biochemistry profiles therefore are often used to assess the physiologic status of reptilians (Campbell, 2006). However, reptilian clinical chemistry has not achieved the same degree of critical evaluation as seen in mammals and because of the difficulty in obtaining meaningful reference intervals for each species of reptile decision levels are often used when assessing reptilians (Campbell, 2006). Due to this lack of meaningful blood biochemistry reference intervals for reptiles and Nile crocodiles in particular, studies contributing to this knowledge is of great value.

Blood samples has been analysed for: Total Serum Protein (TSP), Albumin, Globulin, Albumin/Globulin Ratio, Alanine transaminase (ALT), Alkaline phosphatise (ALP), Aspartate aminotransferase (AST), Glucose, Sodium (Na), Potassium (K), Calcium (Ca^{2+}), Total Calcium (Ca^{Total}), Magnesium (Mg), Cholesterol, Creatinine, Chloride (Cl), Uric Acid, Serum Inorganic Phosphate (SIP), Triglycyrides, Vitamin A and Vitamin E since these are the blood biochemical tests that appear to be the most useful in reptilian diagnostics (Campbell, 2006).

Results from tests of these parameters should indicate the general health of crocodiles in these populations and thus allow speculation regarding the overall health of crocodile populations in the Olifants River.

The third objective of the study is to suggest a management program/plan to guide future development of the Olifants River, utilisation of the aquatic resource, crocodile nesting and basking habitat, identify possible sustainable use programs and suggest measures to protect the wild crocodile population in the Olifants River system of South Africa.

REFERENCES

ALCALA, A.C. and DY-LIACCO, M.T.S. 1990. Habitats. In: *Crocodiles and Alligators*. Edited by C.A. Ross. Merehurst Press, London.

BARNES, J.I. 2001. Economic returns and allocation of resources in the wildlife sector of Botswana. *South African Journal of Wildlife Research.* 31(3-4): 141-153.

BLAKE, D.K. and JACOBSEN, N.H.G. 1992. The conservation status of the Nile crocodile (*Crocodylus niloticus*) in South Africa. In: *Conservation and utilisation of the Nile crocodile in South Africa – Handbook on crocodile farming*. Edited by G.A. Smith and J. Marais. The Crocodilian Study Group of Southern Africa.

BRITTON, A. 2007. *Crocodilians natural history and conservation*, viewed 09 July 2007, http:// www.crocodilian.com/

BRITTON, A. 2008. *A brief history of crocodilian conservation*, viewed 29 April 2008, http://www.flmnh.ufl.edu/cnhc/cbd-con-1.htm/

BROCHU, C.A. 2003. Phylogenetic approaches toward crocodilian history. *Annual Review of Earth and Planetary Sciences.* 31:357-397.

CAMPBELL, T.W. 2006. Clinical pathology of reptiles. In: *Reptile medicine and surgery,* 2nd Edn. Edited by D.R. Mader. Saunders Elsevier, St Louis.

CRAIGHEAD, F.C. 1968. The role of the Alligator in shaping plant communities and maintaining wildlife in the southern Everglades. *Florida Naturalist.* 21: 2-7, 68-74, 94.

CRAIN, D.A. and GUILLETTE JR, L.J. 1998. Reptiles as models of contaminant-induced endocrine disruption. *Animal Reproduction Science*. 53: 77-86.

CROOKES BROTHERS LIMITED. 2008. *Annual Report.* Reinshaw, KwaZulu-Natal.

DRIVER, A., MAZE, K., ROUGET, M., LOMBARD, A.T., NEL, J., TURPIE, J.K., COWLING, R.M., DESMET, P., GOODMAN, P., HARRIS, J., JONAS, Z., REYERS, B., SINK. K and STRAUSS, T. 2004. National spatial biodiversity assessment 2004: priorities for biodiversity conservation in South Africa. *Strelizia*. 17: 1-45.

GARDENFORS, U., HILTON-TAYLOR, C., MACE, G.M and RODRIGUEZ, J.P. 2001. The application of IUCN red list criteria at regional levels. *Conservation Biology*, 15(5): 1206-1212.

GUILLETTE JR, L.J. and IGUCHI, T. 2003. Contaminant-induced endocrine and reproductive alterations in reptiles. *Pure and Applied Chemistry*. 75(11-12): 2275-2286.

HUTTON, J., ROSS, J.P. and WEBB, G. 2001. *Using the market to create incentives for the conservation of crocodilians: A Review.* IUCN/SSC Crocodile Specialist Group. IUCN, Gland, Switzerland.

JACOBSEN, N.H.G. 1988. The Nile crocodile. In: *South African red data book – reptiles and amphibians. South African National Scientific Report No 151*. Edited by W.R. Branch. CSIR, Pretoria.

KING, F.W. and BURKE, R.L. (eds.) 1997. *Crocodilian, Tuatara and Turtle species of the world. A taxonomic and geographic reference.* Association of Systematics Collections, Washington. D.C., viewed 21 March 2009, http://www.flmnh.ufl.edu/natsci.herpetology/turtcroclist/

KING, F.W. 1988. Crocodiles: Keystone wetland species. In: *Wildlife in the Everglades and Latin American wetlands: Proceedings of the First Everglades National Park Symposium*. Edited by G.H. Dalrymple, W.F. Loftus and F.S, Bernadino. Miami.

LUXMOORE, R.A., BARZDO, J.G., BROAD, S.R. and JONES, D.A. 1985. *Directory of crocodilian farming operations*. IUCN, Gland, Switzerland.

LUXMOORE, R.A (ed.) 1992. *Directory of crocodilian farming operations.* 2nd edition. IUCN, Gland, Switzerland.

MACGREGOR, J. 2001. The potential threats to long-term conservation of wild populations in situ from captive breeding for trade. *IUCN/SSC Workshop on commercial captive propagation and wild species conservation.* White Oak Florida, USA.

MACGREGOR, J. 2002. *International trade in crocodilian skins: Review and analysis of the trade and industry dynamics for market-based conservation.* IUCN/SSC Crocodile Specialist Group, viewed 09 July 2007, http://www.flmnh.ufl.edu/herpetology/CROCS/MacGregorFinalDec2002.doc.

MACGREGOR, J. 2006. *The call of the wild: Captive crocodilian production and the shaping of conservation incentives.* TRAFFIC International, Cambridge.

MAZZOTTI, F.J., BEST, G.R., BRANDT, L.A., CHERKISS, M.S., JEFFERY, B.M. and RICE, K.G. 2008. Alligators and crocodiles as indicators for restoration of Everglades ecosystems. *Ecological Indicators.* In Press.

MILNES, M.R. and GUILLETTE JR, L.J. 2008. Alligator tales: New lessons about environmental contaminants from sentinel species. *Bioscience.* In Press.

MOYLE, B. 2003. Regulation, conservation and incentives. In: *The trade in wildlife.* Edited by S. Oldfield. Earthscan Publications, London.

MYBURGH, W.J. 1999. Oewerplantegroei van die Olifantsriviersisteem – n ekologiese perspektief. Report No 663/1/99. Water Research Commission. Pretoria.

NEWSOME, D., DOWLING, R.K. and MOORE, S.A. 2005. *Wildlife tourism*. Channel View Publications, Bristol.

POOLEY, A.C. 1969. Preliminary studies on the breeding of the Nile crocodile *Crocodylus niloticus* in Zululand. *Lammergeyer*, 10: 22-44.

ROSS, C.A. and MAGNUSSON, W.E. 1990. Living crocodilians. In: *Crocodiles and Alligators*. Edited by C.A. Ross. Merehurst Press, London.

ROSS, J.P. (ed.) 1998. *Crocodiles. Status survey and conservation action plan.* 2nd edition. IUCN/SSC Crocodile Specialist Group. IUCN, Gland, Switzerland.

ROSS, J.P. 2001. Commercial captive breeding of crocodilians. In: *Using the market to create incentives for the conservation of crocodilians: A Review.* Edited by Hutton, J., Ross, J.P. and Webb, G. IUCN/SSC Crocodile Specialist Group. IUCN, Gland, Switzerland.

SOUTH AFRICAN TOURISM, 2008a. *South African Tourism Index: January to March 2008.* South African Tourism, Pretoria. (Viewed at: www2.southafrica.net/satourism/research).

SOUTH AFRICAN TOURISM, 2008b. *South African Tourism Index: April to June 2008.* South African Tourism, Pretoria. (Viewed at: www2.southafrica.net/satourism/research).

SOUTH AFRICAN TOURISM, 2008c. *South African Tourism Index: July to September 2008.* South African Tourism, Pretoria. (Viewed at: www2.southafrica.net/satourism/research).

SUES, H.D. 1990. The place of crocodilians in the living world. In: *Crocodiles and Alligators.* Edited by C. A. Ross. Merehurst Press, London.

THORBJARNARSON, J. 1999. Crocodile tears and skins: international trade, economic restraints and limits to the sustainable use of crocodiles. *Conservation Biology.* 13(3): 465-470.

THORBJARNARSON, J. and VELASCO, A. 1998. Venezuela's caiman harvest programme, an historical perspective and analysis of its conservation benefits. *Wildlife Conservation Society. Working paper no. 11.* Cited in Ross (2001).

VITT, L.J. and CALDWELL, J.P. 2009. *Herpetology, an introductory biology of amphibians and reptiles.* Third Edition, Academic Press, San Diego.

WATER RESEARCH COMMISION, 2001. State of the rivers report: Crocodile, Sabie-Sand and Olifants River systems. Report No. TT 147/01. Water Research Commission. Pretoria.

WOODWARD, A.R. 1998. Assessment of the economic viability of the Florida Alligator industry. Final Report, Bureau of Wildlife Research. Cited in Ross (2001).