ASSESSMENT OF SKIN QUALITY TRAITS OF NILE CROCODILES (*CROCODYLUS NILOTICUS*) AT LALELE CROCODILE FARM IN LIMPOPO PROVINCE

BY

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DECLARATION

I declare that the mini dissertation hereby submitted to the University of Limpopo for the degree of Master of Science in Agriculture (Animal Production) is my work. It has not been submitted for any other purposes or to any other University, and all the materials contained in this dissertation have been acknowledged.

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DEDICATIONS

This dissertation is dedicated to my late brother, Nico Thola Mahaole, may his soul continue to rest in peace. It is also dedicated to everyone who contributed to making me the person that I am today, more especially my family, friends, and all the teachers who groomed me from primary school until matric, not forgetting all the lecturers who equipped me with academic information to ensure success in my academic journey.

ABSTRACT

Nile crocodiles (*Crocodylus niloticus*) are widely distributed across Africa, and they sometimes conflict with humans as they prey on people and livestock. Crocodile skins are used to produce expensive luxury products such as belts, shoes, bags and clothes. However, smallholder crocodile farmers sometimes fail to cover their costs because of a high number of crocodile skins being downgraded. Hence, the current study intended to shed information on skin quality traits of Nile crocodiles and their economic values, which might help crocodile farmers and breeders in selecting traits to achieve premium skin grades. This study was conducted at Lalele Crocodile Farm using 177 Nile crocodile skins. The skins were graded on a grading scale of 1 to 4 using quality traits such as double scaling (DS), skin cuts or holes (SC), irregular scales (IS), skin scars or scratches (SS), wrinkles (W), missing legs (ML), skin osteoderms (SO), skin infections (SI), skin blemish (SB) and skin lesions (SL). Frequencies and percentages were used to summarise evaluated skins and Spearman's correlations were used to determine the associations between the skin price and skin quality traits. Stepwise and multiple regression analyses were used to develop a model to estimate skin price. The results showed that only 3% of the skins were of first grade while the remaining were made up of 34%, 32% and 31% of second grades, third grades and rejects, correspondingly. The study revealed that skin price had a positive highly significant correlation with belly weight (BW) and body length (BL) ($p<0.01$), and a negative highly significant correlation with SG, DS, SS and SB ($p<0.01$), but a negative significant correlation with IS ($p<0.05$). The stepwise regression model with IS and skin grade (SG) was the best fitted model to estimate Nile crocodile skin prices. The study concludes that there is relationship between skin price and skin quality traits. Hence, minimizing the occurrence of the traits correlated to the skin price of Nile crocodiles can help farmers to better skin grades for higher financial returns. However, more studies should be conducted to investigate the factors causing occurrence of skin quality traits that cause downgrading and use them to guide farmers. Similar studies should be conducted on skins of different animal species.

Keywords: Nile crocodiles, skin quality traits, skin cuts, skin grade, skin price

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LIST OF ABBREVIATIONS

Abbreviation	Full text
AREC	University of Limpopo Animal Research Ethics Committee
BL	Belly length
BW	Belly width
Cm	Centimetre
CV%	Coefficient of variation percentage
DS	Double scaling
IS	Irregular scales
ML	Missing legs
^{ns}	Not significant
P	Probability
Q1	Quadrant 1
Q2	Quadrant 2
Q3	Quadrant 3
Q4	Quadrant 4
R	Coefficient of determination
SB	Skin blemish
SC	Skin cuts or holes
SE	Standard error
SG	Skin grade
SI	Skin infections

SL	Skin lesions
SO	Skin osteoderms
SP	Skin price
SPSS	Statistical Package for the Social Sciences
SS	Skin scars or scratches
US$	United States Dollar
W	Wrinkles
ZAR	South African Rand

CHAPTER ONE

GENERAL INTRODUCTION

1.1 Background

Nile crocodiles (*Crocodylus niloticus*) are raised for their belly skin and are the most common crocodile species in South Africa (Webb et al., 2021). This species has 26 to 32 transverse scales row number on the belly (between collar and cloaca), which is more compared to many crocodile species such as Philippine crocodile (*Crocodylus mindorensis*) and caimans (*Caimaninae*) (FAO, 2014). In the Crocodilian skin market, Saltwater crocodile (*Crocodylus porosus*) skin value is ranked as the best, followed by Nile crocodile skin (Gray et al., 2007; Mpofu et al*.,* 2015). Crocodile skin business is an exotic and luxury business that is not common (Chala et al., 2020). Its skin marketing generates about 80% of the crocodile value, with the remaining 20% being generated from by-products, including meat, backstrap, and oil (Isberg et al., 2005). Leather making from crocodile skin is a promising business with the potential to grow (Chala et al., 2020). The leather is used to produce luxury products such as shoes, wallets, handbags, furniture, and belts (Chala et al., 2020; Mkhonza et al., 2022).

1.2 Problem statement

Quality is of utmost importance in the crocodile leather industry. Hence, crocodile farmers are mostly subjected to low skin prices because of downgrading due to poor quality (Isberg et al., 2003; Huchzermeyer et al., 2009). Crocodile skins are subjectively judged based on a grading scale of 1 to 4, which takes skin quality traits into consideration (Manolis et al., 2000; Isberg et al., 2003; Webb et al., 2021). According to MacGregor (2002), the lack of a regulated grading system in the skin industry benefits the stakeholders with reputation and power. Manolios et al. (2000) revealed that the stricter grading standards resulted from the elevated global demand for classic skins and the increased number of crocodile farms (Serna-Lagunes et al., 2011). Captive breeding of crocodiles has a higher influence on the distortion of skin scale patterns because of line breeding (Serna-Lagunes et al., 2011). Determining traits with high economic value might be the best approach to help farmers improve their skins and get better prices (Hermesch and Isberg, 2022). Serna-Lagunes et al. (2011) reported that selecting breeding crocodiles with larger body size might help increase skin yield and quality.

1.3 Rationale

The Nile crocodile plays a vital role in the exotic leather industry, where they make up 16% (275k) of the world's crocodilian skin production (Chala et al., 2020; Exotic Leather SA, 2023). The drop in skin prices has led to a worldwide crisis, which caused several Crocodilian ranches in countries such as Botswana, Brazil, Ethiopia, Malawi, Mozambique and Uganda to be closed (Thorbjarnarson, 1999). Additionally, most small crocodile farms are less likely to cover the operating costs due to rejection of skins and cost of keeping the breeding stock (FAOala, 2014). Belly skin width yield of Nile crocodiles starts to diminish significantly at around 2 - 3 years whereas the feeding costs increases due to the rise in feed requirements (Isberg, 2007; FAO, 2014; Price, 2017). Isberg et al. (2004) reported that only 30% of crocodile skins meet the first-grade conditions. However, MacNamara et al. (2003) found that at most 50% of crocodile skins met the conditions for first grade. Animal skins are graded based on the skin quality traits that results in downgrading and significant economic losses (Manolis and Webb, 2011; Tsigab et al., 2020). Therefore, producing skins looking at the traits related to the price can enable farmers to demand higher prices in the international market (Friehiwot, 2020). Veldsman (2019) found abscesses, brownspot, double scaling, freckles, hole, infection, scratch, teeth, wrinkles, and yellowed scars as traits affecting of captively reared Nile crocodiles. Manolis and Webb (2011) also discovered wrinkles, scratches, irregular scales, double scaling, cuts, infections, scale lift, black dots and pits on skins of Saltwater crocodiles reared captively. However, a study by Urge et al. (2020) found cockle, flaying cuts, pox lesions and branding marks as traits of economic importance on livestock skins. Alemnesh et al. (2018) reported cockle, flay cuts, scratches, scars, pox lesions and branding marks on livestock skins to affect quality. Improving the quality of crocodile skins will not only help the farmers to get better revenue for the leather, but it will also help to limit poaching or harvesting of wild crocodiles (Thorbjarnarson, 1999; Manolis et al., 2000; Chala et al., 2020).

Few studies have been published on the assessment of different skin quality traits of Nile crocodiles and their economic value in South Africa. Thus, this study intended to assess skin quality traits and their economic values on Nile crocodile skins. This

information might help crocodile farmers and breeders in selecting traits to improve skin grades and economic returns. It might also help in implementation of improved management practices.

1.4 Aim

The aim of the study was to assess the quality traits of the Nile crocodile skins and their economic values at Lalele Crocodile Farm, Limpopo province of South Africa.

1.5 Objectives

The objectives of the current study were to:

i. To evaluate skin quality traits in Nile crocodiles.
ii. To determine the association between skin quality traits and the skin price of Nile crocodiles.
iii. To determine the economic values of different skin quality traits in Nile crocodiles.

1.6 Research questions

i. What are the skin quality traits in Nile crocodiles?
ii. What is the association between skin quality traits and the skin price of Nile crocodiles?
iii. What are the economic values of different skin quality traits in Nile crocodiles?

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

There are about 23 crocodilian species worldwide distributed across rivers, lakes, marshes, mangrove swamps, and estuaries (Manalo and Alcala, 2013; Maisuthisakul, 2015; Chala et al., 2020). These crocodiles were described as one of the ecologically important animals in aquatic habitats as they produce nutrients that serve as feed sources for aquatic organisms such as fish (Somaweera et al., 2020). Nile crocodiles are native to the African continent, and they are the most reared species in most African countries including South Africa, Zimbabwe, Tanzania and Kenya, and Euro-Asian countries (Maisuthisakul, 2015). They are among the most internationally traded crocodilian species such as *Crocodylus siamensis*, *Crocodylus porosus*, *Crocodylus novaeguineae*, *Crocodylus acutus*, *Crocodylus moreletii*, *Crocodylus crocodilus*, *Crocodylus yacare*, *Crocodylus latirostris* and *Alligator mississippiensis*. South Africa produces skins and hides from a wide group of animals including reptiles (crocodiles and snakes), livestock (sheep, pigs, goats and cattle), and wild animals (ostriches, buffalos and elephants) (Department for Agriculture, Forestry and Fisheries, 2017). Crocodile farm is descried as any facility that is utilized to breed and/or grow crocodiles for commercial use (Maisuthisakul, 2015). It was estimated that over 40% of crocodilian skins traded internationally were produced from on-farm or ranching programmes (Manolis and Webb, 2016). A total of 1 377 809 Nile crocodile skins were traded globally from 1999 to 2008 (Caldwell, 2010), whereas 1 600 640 were traded from 2002 to 2011 (Caldwell, 2013). Crocodile farming and ranching have economic and financial viability in African countries through meat and skin production; however, they remain small due to bureaucratic restrictions and capital shortages (Barnes, 2008).

The major goal of this chapter is to provide a detailed review of the following subtopics: Exotic leather, Production of crocodile leather in South Africa, and Grading of crocodile skins.

2.2 Exotic leather

In African countries, crocodiles and snakes are the most common animal species used to produce exotic leathers which are perceived to have unique beauty, durability, texture and astonishing properties (Chala et al., 2020). The use of crocodilian skins for commercial purposes was first recorded in North America in the 1800s (Maisuthisakul, 2015). An average of 1.55 million Nile crocodile skins were traded annually worldwide from 2001 to 2008 (Maisuthisakul, 2015). Leather is the primary product of crocodile farming whereas meat, blood, organs, bones and oil are the by products in the crocodile industry (Maisuthisakul, 2015; Veldsman, 2019). Besides viability in food and luxury industry, crocodiles are also used for cultural, religious, decorative, and medical purposes (Maisuthisakul, 2015). Crocodile skins make up about 20% of crocodile live weight, whereas lean meat, bones, and fat respectively make up 60.8%, 26.6% and 12.2% of the carcass weight of crocodiles (Maisuthisakul, 2015).

2.2.1 Other exotic animals used for leather

The leather industry is estimated to be worth around $3 billion, with exotic leather being one of its essential components (Belleau et al., 2004). Leather or skin production is not limited to only crocodiles; several studies reported that other animal species such as alligators, caimans, cattle, goats, sheep, ostriches, lizards and snakes are used for this purpose (Engelbrecht et al., 2009; Ebrahiem et al., 2015; Amde, 2017; Steyn, 2018; Nemutandani et al., 2024). Around 500 000 skins from pythons, which are one of the largest snakes in the world, are exported annually from Asian countries, mainly to produce luxury leather products and musical instruments (Natusch et al., 2014). One of the African countries, such as Ethiopia was reported to be capable of producing 3.78 million skins from cattle, 8.41 million skins from sheep and 8.42 million skins from goats between 2012 and 2013 (Amde, 2017; Kenea, 2019). This high production of skins from livestock species as compared to other animal species is a result of livestock skins being by-products of the well-established livestock industry playing an important role as primary source of animal protein globally. Local and international trade of sheep, goats and cattle leather products was able to generate

as much as $139 million in Ethiopia in the early 2010s (Kenea, 2019). Leather production from alligators was also discovered to be a multimillion-dollar industry in the southern United States of America, with reports from well-established individual farms being able to generate over $77 million (Nikum et al., 2018). Ostrich leather has a significant presence in this competitive strict leather industry (Schalkwyk et al., 2005). This is because ostrich leather has high demand, and its quality is considered to be premium like leather from crocodile species.

Several animal species such as emus, rheas, kangaroos, fishes and chicken are also used for leather production (Leather Dictionary, 2024). According to Patel et al. (2015), emu leather is used to produce fashionable products such as clothing, boots, bags and wallets, and it is highly demanded in the international leather industry. Rheas are also used to primarily produce commercialized leather of excellent quality along other main products such as meat, feathers and oils (Souza et al., 2008; Picasso et al., 2016). The presence of ostrich, emu and rhea skins in the skin industry is likely due to their evolutionary relationship as they are of the same infraclass. On the other hand, 2 to 3 million kangaroos are harvested annually and processed into leather, meat and furs, however, this volume is low compared to number processed bovine and ovine skins (Looney et al., 2002). Kangaroo leather is very strong, lightweight and flexible; and for these characteristics it is commonly used to produce high quality performance sport gear such as football shoes and cycling cloves (Mouwen, 2018). Approximately $20 million worth of finished kangaroo leather is exported from Australia (Looney et al., 2002). Leather is the most common and important by product in the meat production from fish species (Zengin et al., 2015), and both bovine and poultry species (Karthikeyan and Babu, 2017). This is because the leather market is well established and there is demand for skins locally and internationally. Several fish species including sharks, eels, salmons, carp and sea basses are used for leather production (Grey et al., 2006). According to Zengin et al. (2015), multiple fashion quality products such as hats, shoes, clothing and handbags can be derived from several species of fishes. Fish leather is found appealing due to its durability and waterproof qualities (Grey et al., 2006). Chicken leather is produced primarily from the paw or leg skin which is

known to have good tear strength, elongation and tensile strength characteristics similar to exotic animals used to yield small to medium leather products (Teshome et al., 2022).

2.3 Production of crocodiles in South Africa

2.3.1 Structure of crocodile production in South Africa

Farming of crocodiles for commercial purposes started in the 1970s in South Africa and it became an international enterprise (Webb et al., 2021). South Africa is one of the major producers of crocodiles worldwide alongside Thailand, Vietnam, Cambodia, China, Australia, and the United States, together they contribute towards the production of 2 million crocodiles annually worldwide (Maisuthisakul, 2015). Moreover, South Africa and Zimbabwe are the leading producers of Nile crocodiles among other southern Africa countries (Webb et al., 2021). Similarly, Caldwell (2013) indicated that South Africa, Zimbabwe and Zambia have been the major producers of Nile crocodiles amongst the SADC countries such as Angola, Botswana, Comoros, Democratic Republic of Congo, Eswatini, Lesotho, Madagascar, Malawi, Mauritius, Mozambique, Namibia, Seychelles and United Republic of Tanzania since 2002. According to Manolis and Webb (2016), there are between 4000 to 5000 crocodile farms globally ranging from communal level with less crocodiles to well established commercial farms carrying over 100 000 crocodiles. The most common crocodile production system in South Africa is the intensive communal pens which is notable for limiting some behaviours and activities such as territory formation and roaming (Webb et al., 2021). Crocodile breeding started to shift from wild to on-farm or captivity breeding from at least the early 2000s (Maisuthisakul, 2015). Nile crocodile is the commonly farmed crocodile species in South Africa among the 15 crocodile species farmed specifically for their skins (Webb et al., 2021).

It is estimated that there is a minimum of 80 crocodile farms in South Africa, with some farm holding over 20 000 crocodiles in captivity (Louw, 2019). This concurs with the information from, National Council of Societies for the Prevention of Cruelty to Animals (2022). The 40% of South African crocodile farms are in Limpopo province, whereas

20% and 15% are located in North West and KwaZulu-Natal respectively (Louw, 2019).

2.3.2 Trading of crocodile products

Over 1 million crocodile skins are legally traded worldwide from around 30 countries (Maisuthisakul, 2015). Almost all the South African Nile crocodile skins were reported to be from captively bred crocodiles (Caldwell, 2007). It is estimated that South Africa harvests/slaughters around 54 563 crocodiles on yearly basis, this estimation was based on 2016 to 2018 production data (Louw, 2019). Further estimations indicated that around 362 874 kilograms of meat were produced yearly from Nile crocodiles, Siamese crocodiles and American alligators combined from 1990 to 2005 (Veldsman, 2019). Caldwell (2007) reported a fluctuating export of Nile crocodile skins in South Africa from 1997 to 1999 where 13 573 skins were exported in 1997, which decrease to 8 863 in 1998 and later rose to 27 641 in 1999. Furthermore, from 2000 to 2004, reports of South African world trade of crocodile skins showed that 29 698, 33 335 and 45 755 Nile crocodile skins were traded annually at an increasing rate in years 2000, 2001 and 2002 respectively (Caldwell, 2006; Caldwell, 2008; Caldwell, 2009). However, an annual decline in exports was observed from 2002 to 2003 when the exports declined from 45 755 to 31 321 even though it eventually inclined to 35 760 in the year 2004 (Caldwell, 2007; Caldwell, 2011; Caldwell, 2013). In the preceding years, 35 486, 34 203 and 36 014 Nile crocodile skins were reported to be traded in the years 2005, 2006 and 2007 respectively (Caldwell, 2009). Further fluctuation in skin exports was observed in the year period of 2008 to 2011 where 44 697, 25 050, 53 329 and 30 685 Nile crocodile skins were exported in the years 2008, 2009, 2010 and 2011 correspondingly (Caldwell, 2013).

According to Louw (2019), South Africa exported 519 900 Nile crocodile skins and 782 900 kilograms of Nile crocodile meat from 2005 to 2014. However, on average, 51 900 skins were exported annually in the year period from 2005 to 2014. On the other hand, Caldwell (2020) reported that South Africa managed to export 623 389 Nile crocodile skins from 2009 to 2018, and this translated to an average of 62 339 Nile crocodile skins exportations per year. Furthermore, 770 177 Nile crocodile skins were also

exported from South Africa during 2014 to 2023 and this averaged on 77 018 Nile crocodile skin exportations per year (Caldwell, 2025). There was a notable increase in the exportation number Nile crocodile skins exported from 2005 to 2023 and this suggest that there might be an increase in the crocodile farms and/or breeding stocks enabling rearing of more crocodiles in South Africa.

A total of 485 420 Nile crocodile skins were officially traded in the year period of 1999 to 2011 (Caldwell, 2007; Caldwell, 2008; Caldwell, 2011; Caldwell, 2013). These large export numbers can be traced back to the nature of South Africa being the largest re-exporter of the skins produced in the neighbouring countries such as Zimbabwe and Zambia (Caldwell, 2006). Figure 2.1 presents a Trend of South African trade of Nile crocodile skins from 1997 to 2011.

Figure 2.1: Trend of South African trade of Nile crocodile skins from 1997 to 2011 (Caldwell, 2006; Caldwell, 2008; Caldwell, 2011; Caldwell, 2013).

2.3.3 Pricing of crocodile skins

Crocodile leather has good market value (Chala et al., 2020). However, there is limited information on the pricing of crocodile skins as opposed to skins from other animal groups such as livestock, ostriches, impala and springboks, which are priced per skin or weight (DAFF, 2017). Bags made from crocodile skins can cost as much as $20 000 to $40 000 per unit since it may take as much as four individual crocodiles to make one bag (Maisuthisakul, 2015). Several studies indicated that crocodile skins are priced based on their grade and price per centimetre assigned to each grade, with first grade skins having the highest price per centimetre and fourth-grade skins having the lowest (Gray et al., 2007; Mpofu et al., 2015).

2.4 Grading of crocodile skins

2.4.1 Grading of skins

The crocodile skin industry has expanded in recent years leading to stricter grading standards making it hard for skin producers particularly in the developing countries to yield excellent grade skins (Veldsman, 2019). Skins are graded based on the presence of skin defects or quality traits such as scratches, scars, blemishes, cuts, holes, osteoderms, double scaling, missing legs, irregular scale patterns and lesions which cause downgrade of skins (Barnett and Cardeilhac, 1998; Urge et al., 2020; Roje Exotic Leather, 2023). The locations (like belly quadrants) and severity of the defects on the skins are taken into consideration when grading the skins (Veldsman, 2019). Crocodile skins are graded on a 1 to 4 grading scale where grade 1 skins are of high quality with minimum to zero defects, and grade 4 skins, usually called rejects or culls, are of the lowest quality with high significant defects (Manolis and Webb, 2011; Roje Exotic Leather, 2023). Veldsman (2019) revealed that at most 30% of graded crocodile skins meet the expectations of first grade. Based on the summary of Manolis and Webb (2011); Veldsman (2019) on the skin grades: first grade skins are allowed to have small defects on the tail and throat area coupled with defect-less belly, or defect-less throat and tail coupled with one belly quadrant having small defects, whereas a second grade skins have severely damaged throat and tail areas with the minimum defects on either the bottom or top or right or left belly quadrants. However, third-grade

skins are those that have defects on the diagonal belly quadrants or those that have significant damages on the belly quadrants, and fourth grade or reject skins are those not meeting the requirements of first or second or third grade. Some skins are also rejected due to small size (Roje Exotic Leather, 2013). Manolis and Webb (2011) revealed that crocodile skins are reassessed when they enter the tannery using different grading standards from the ones used on-farm.

2.5 Conclusion

In conclusion, Nile crocodiles were revealed to be important to South African economy and food security as they produce valuable skins and meat. South Africa is the largest producer and exporter of Nile crocodile skins. This highlights the need for South African crocodile farms to thrive and continue to operate due to their significant contribution towards South African economy and production of luxury products. This literature review managed to expose fluctuations in the marketing of Nile crocodile skins throughout the years. These fluctuations maybe have been caused by the increased demand for skins of premium quality and high number of skins of poor-quality, and variations in the grading standards between the farms and tanneries. The consulted literature showed that the crocodile leather industry has a potential to expand even more due to the level of diversification (skin, meat and tourism) and constantly increasing demand for leather products. However, none of the literature indicated the contribution of each skin defect or quality trait towards the skin value of Nile crocodiles. As a result, it is recommended that more studies be conducted to determine the economic contribution of the skin quality traits towards the skin value. This will help crocodile farmers to know which traits they should put more emphasis on to get more value out of their skins. There is also a need to implement a universal grading method for Nile crocodile skins, which will yield the same results when the skin is graded by the seller or the buyer.

CHAPTER THREE

METHODOLOGY AND ANALYTICAL PROCEDURES

3.1 Study area

This study was conducted at Lalele Crocodile Farm, situated near Mookgopong town in the Waterberg District Municipality of Limpopo Province, South Africa. This farm has an estimated elevation of 1310m with latitude and longitude of 24°27'33.38''S and 28°34'25.55''E respectively (Google Maps, 2023). Figure 3.1 shows the map location of the farm.

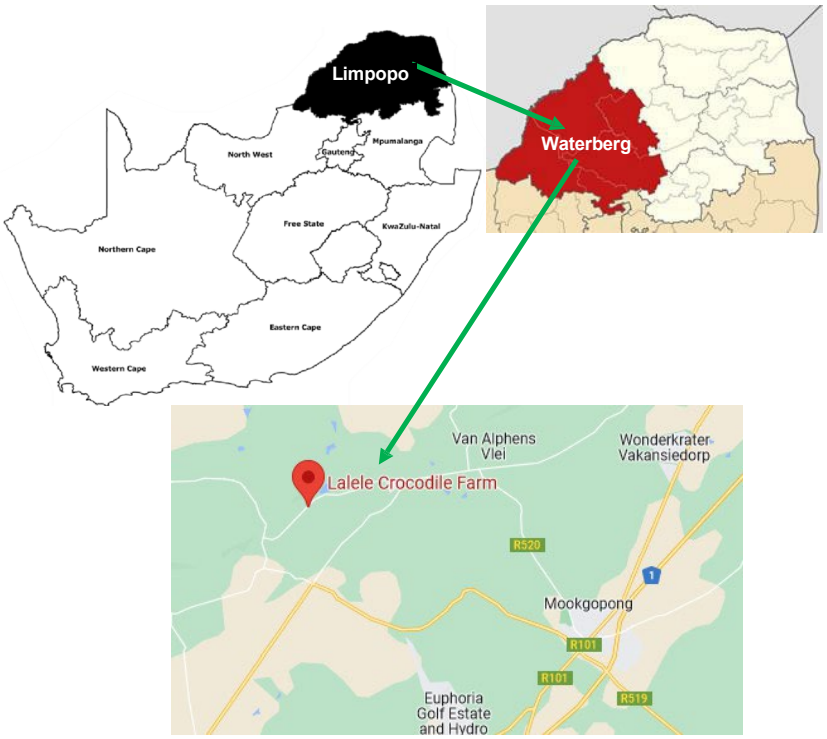

Figure 3.1: Map showing the Lalele Crocodile Farm (with red pin) within the Waterberg District Municipality in Limpopo Province of South Africa (Google Maps, 2023).

3.2 Ethical approval

This study received ethical clearance from the University of Limpopo Animal Research Ethics Committee (AREC) with Project Number AREC/09/2024: PG.

3.3 Study design

A cross-sectional study design was used as the research design of the study. It is a type of observational study. The characteristics of the crocodile skins were only

observed and measured without assigning any treatments during the study period. A cross-sectional study design only allows researcher to collect data from a population once-off without following it over time (Hemed, 2015).

3.4 Sampling technique

Lalele crocodile farm was purposively selected as a study area due to its possession of experimental units necessary for the current study and the consistent farming practices (such as feeding, housing and handling conditions) and controlled captive environment. A prior visit to the farm was made, and the researcher was given consent (Annexure A) by the farm owner to conduct the study on the farm. Convenience sampling was used to determine the sample size during data collection. This is a type of non-probability sampling method that involves taking the sample that is accessible to the researcher at the time of study (McCombes, 2022).

3.5 Animal management

The crocodiles in Lalele Crocodile Farm were raised in a captive breeding environment. Captive breeding is characterised by controlled mating and favourable environmental conditions (Farquharson et al., 2021). The crocodiles were kept in specially designed enclosures, which are ideal for growing the crocodiles and ensuring the safety of the handlers (Manolis and Webb, 2016). All the enclosures had ponds. The farm is complying with the requirements of South African National Standard (SANS) of Crocodiles in captivity. The crocodiles were slaughtered for skin harvesting when they reach of three years of age at Thaba Kwena Abattoir (Physiscal address: Buisfontein 24, Bela-Bela, 0480, Limpopo, South Africa). Thaba Kwena Abattoir is a Veterinary Approved Establishment, certified by the South African Department of Agriculture, Forestry & Fisheries (DAFF) since 2010 for export to the European Union (EU) and other compliant markets. This abattoir is among the three Limpopo-based crocodile abattoirs (CDT crocodiles, Mfuleni Crocodile Abattoir and Thaba Kwena Abattoir) recognized by the South African Department of Agriculture, Land Reform and Rural Development (DALRRD). The crocodiles were slaughtered by trained personnel following humane methods recommended by the South African Meat Safety Act, 2000

(Act 40 of 2000) regulating South African crocodile meat production. Electrical stunning was used to render the crocodiles unconscious before they can be slaughtered to minimize pain. Spinal Cord Severance slaughtering method is the standard crocodile slaughtering method capable of killing/paralysing the crocodiles instantly.

3.6 Data collection

The raw skins were laid flat on a flat light table to measure the skin quality traits (defects) as indicated in Figure 3.2. The belly skin pattern area was divided into four quadrants as indicated in Figure 3.3. Skin quality traits such as double scaling, skin cuts or holes, irregular scales, skin scars or scratches, wrinkles, missing legs, skin osteoderms, skin infections, skin blemish and skin lesions were subjectively assessed by physical inspection and used to grade the skins by the researcher (Mpofu *et al*., 2015; Roje Exotic Leather, 2023). The location for each defect was recorded for skin grading purposes (Roje Exotic Leather, 2023). The belly width was also measured and used for determining price of each skin (FAO, 2014). A ruler and tape were used to measure the belly width as the space between the inner edges of the horny cutes which are indicated as white asterisks in Figure 3.3. The skins were measured and graded by one person to eliminate bias.

3.6.1 Skin grading

Each skin was classified into one of the four skin grade classes: either first, second, third or fourth grade (reject) based on the defects present, and their severity and location (Webb et al., 2021). The skin quality ranges from first to fourth grade and first grade skins are of premium quality, whereas fourth grade skins are of poorest quality. Table 1 presents the crocodile skin grading system method. Figure 3.3 shows the locations or sections of crocodile skin for grading purpose.

Table 3.1: Crocodile skin grading method

Skin grade	Conditions
First grade	A skin was considered as first grade if:

	• It had no defects in none of the areas; however, it was allowed to have minor defects in the tail and head area (Veldsman, 2019). • It had minor defects in one belly quadrant and no defects at all in the tail and head area (Manolis and Webb, 2011). • At most 5 irregular scales within the pattern area (Roja Exotics, 2023). All first-grade skins should lack double scaling, irregular scale pattern, and osteoderms in the pattern area and they will have a tail and all the legs present [L1 (Leg 1) – L4 (Leg 4)] (Roje Exotic Leather, 2023).
Second grade	A skin was downgraded to second grade if: • It had minor defects in one of the non-diagonal quadrants (Q1 and Q4 or Q2 and Q3) and severe defects in the head and tail area (Veldsman, 2019). • It had 1 missing leg and at most two osteoderms in the pattern area. • If it had severe defects in one of the quadrants. • If there were minor defects in one of the diagonal quadrants. • If it had irregular scales in one 20% of the skin area (Roje Exotic Leather, 2023).
Third grade	A skin was be downgraded to third grade if: • It had severe defects in one of the non-diagonal belly quadrants (Manolis and Webb, 2011). • It had at most 5 irregular scales within the pattern area, and minor defects in one of the non-diagonal quadrants and severe defects in the head and tail area. • It had at least 2 legs missing. • It had less than 75% of the tail area present. • It had severe defects in the other areas except the three of the belly quadrants. • It had not more than 10 osteoderms in the pattern area. • It had irregular scale pattern in less than 20% of the skin area (Roje Exotic Leather, 2023).

Fourth grade (Reject)	A skin was downgraded and rejected if its defects are worse than a third-grade skin (Manolis and Webb, 2011; Veldsman, 2019; Roje Exotic Leather, 2023).

Figure 3.2: Crocodile skin on light table (Own picture).

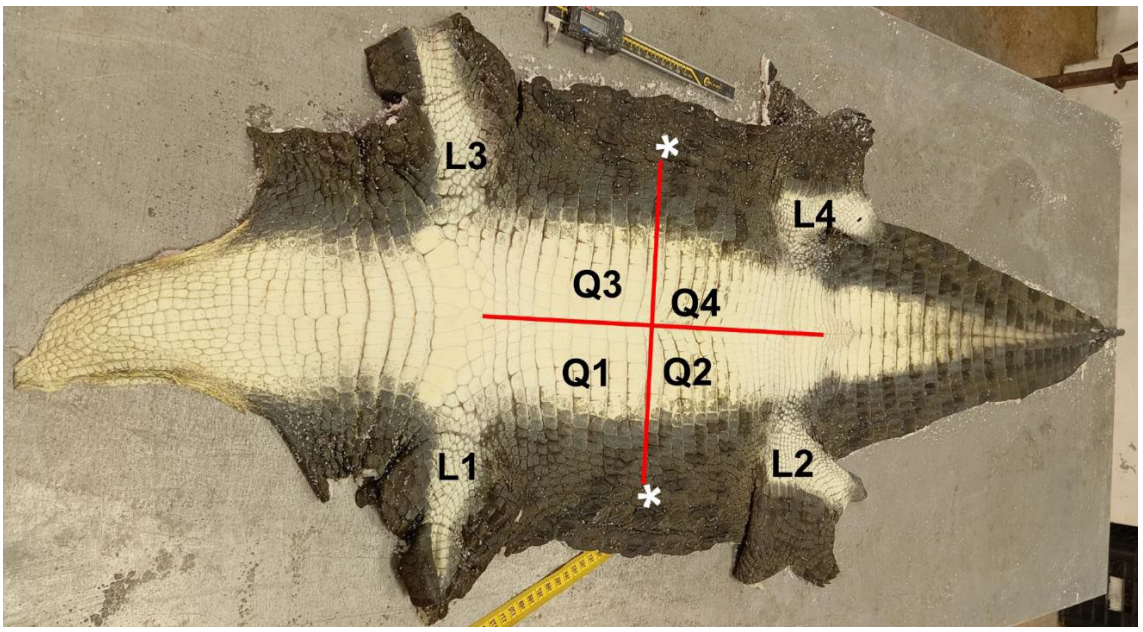

Figure 3.3: Sections of crocodile skin for skin-grading purposes (Own picture).

4.7 Price determination

The data collected from Lalele Crocodile Farm on skin grade and skin quality traits was used to calculate the value of each skin in South African Rand (ZAR). Second, third and fourth grade skin prices of crocodiles translates to 75%, 50% and 0% of the first-grade skin price, respectively (Manolis and Webb, 2011; FAO, 2014). The pricing of the crocodile skins was based on the prices that were revealed by Gray et al. (2007); Mpofu et al. (2015) as presented in Table 3.2.

Table 3.2: Prices per cm in US$ and ZAR of different Nile crocodile skin grades obtained from Gray et al. (2007); Mpofu et al. (2015)

Grade	Price per cm of skin in US$	Corresponding price per cm of skin in ZAR
1	3.70	69.27
2	2.50 – 3.00	46.8 – 56.16
3	1.85	34.64
4	0	0

4.8 Statistical analysis

The data was analysed using Statistical Package for the Social Sciences (IBM Corp, 2022) software version 29.0. Frequencies and percentages were used to summarise the evaluated skins to achieve the first objective of this study. The second objective was achieved using Spearman's correlations. Stepwise and multiple regression analyses were used to achieve the third objective of this study. The independent variables that were included in the stepwise regression were the skin grade (SG), double scaling (DS), skin scars or scratches (SS), irregular scales (IS), skin blemish (SB).

The following stepwise regression model was used:

$Y = a + b_1X_1 + \ldots + b_nX_n$

Where:

Y = Dependent variable (skin price in ZAR),

a = Intercept,

b = Regression coefficients for skin value on the respective independent variables ranging from 1 to 5, and

X's = Modelled independent variables (SG, DS, IS, SS, and SB).

The following multiple regression models were fitted to estimate skin price from various skin quality traits:

Model 1 included all the independent variables that were observed in the skins:

Price = SG + DS + SC + SS + SS + SI + W + IS + SB + SL

Model 2 included all the independent variables that were observed in the skins except for SG:

Price = DS + SC + SS + SI + W + IS + SB + SL

Model 3 included all the independent variables that were observed in the skins except for SG and DS:

Price = SC + SS + SI + W + IS + SB + SL

CHAPTER FOUR

RESULTS

4.1 Descriptive statistics of skin quality traits and price

Descriptive statistics of the skin quality traits and price of Nile crocodile skins is displayed in Table 4.1 below. A total number of 177 crocodile skins were assessed for skin quality traits. However, SA, ML and SO were absent from all the skins. The coefficient of variation ranged from 9.31% for BL to 989.38% for SI.

Table 4.1: Descriptive statistics of skin quality traits and price of Nile crocodile skins

Trait (Unit of measurement)	N	Mean ± SD	CV%	Range	Skewness	Kurtosis
SG score (1-4)	177	2.90 ± 0.87	29.98	1.00 – 4.00	-0.07	-1.16
BW (cm)	177	26.89 ± 3.04	11.31	20.20 – 36.00	0.26	-0.06
BL (cm)	177	38.29 ± 3.57	9.31	28.50 – 48.50	-0.07	0.04
DS score (0-4)	177	0.28 ± 0.60	213.26	0.00 – 3.00	2.31	5.29
SC score (0-4)	177	0.37 ± 0.77	207.53	0.00 – 4.00	2.52	6.79
SS score (0-4)	177	2.63 ± 1.11	42.11	0.00 – 4.00	-0.31	-0.86
SA score (0-4)	177	0.00 ± 0.00	-	0.00 – 0.00	-	-
ML score (0-4)	177	0.00 ± 0.00	-	0.00 – 0.00	-	-
SI score (0-4)	177	0.02 ± 0.17	989.38	0.00 – 2.00	10.66	118.86
W score (0-4)	177	0.03 ± 0.20	698.82	0.00 – 2.00	7.78	65.82
IS score (0-4)	177	1.26 ± 1.09	86.71	0.00 – 4.00	0.31	-0.81
SO score (0-4)	177	0.00 ± 0.00	-	0.00 – 0.00	-	-
SB score (0-4)	177	0.57 ± 0.77	134.30	0.00 – 3.00	0.99	-0.32
SL score (0-4)	177	0.42 ± 0.84	200.01	0.00 – 4.00	1.97	3.10
Price (R)	177	787.32 ± 570.86	72.51	0.00 – 1788.92	-0.33	-1.28

Skin grade (SG); belly width (BW); belly length (BL); double scaling (DS); skin cuts or holes (SC); skin scars or scratches (SS); skin abscess (SA); missing legs (ML); skin infection (SI); wrinkle (W); irregular scales (IS); skin osteoderms (SO); skin blemish (SB); skin lesions (SL); total number (N); standard deviation (SD); coefficient of variation percentage (CV%)

4.2 Assessment of the Nile crocodile skins

Table 4.2 displays a summary of the 177 assessed Nile crocodile skins. The skins ranged from first to fourth grade, with the least percentage of the skins falling under first grade (2.82%), whereas the majority of the skins fell under second grade (34.46%)

followed by third grade (32.2%) and fourth grade (30.51%). None of the skins had SA, ML, or SO. However, over 50% of the assessed skins had SS, IS and SB, while 20 to 25% were affected by DS, SC, and SL. It was further noted that SI and W were each present in 1.13% and 2.26% of the assessed skins, respectively.

Table 4.2: Summary of the assessed Nile crocodile skins

Skin quality trait	Number of skins	Percentage of skins (%)
First grade	5	2.82
Second grade	61	34.46
Third grade	57	32.20
Fourth grade	54	30.51
DS	38	21.47
SC	44	24.86
SS	173	97.74
SA	0	0.00
ML	0	0.00
SI	2	1.13
W	4	2.26
IS	117	66.10
SO	0	0.00
SB	100	56.50
SL	42	23.73

Double scaling (DS); skin cuts or holes (SC); skin scars or scratches (SS); skin abscess (SA); missing legs (ML); skin infection (SI); wrinkle (W); irregular scales (IS); skin osteoderms (SO); skin blemish (SB); skin lesions (SL).

4.3 Correlation between skin price and skin quality traits

Table 4.3 presents Spearmen's correlation coefficient between skin price and skin quality traits of Nile crocodiles. The results of the current study showed that skin price had a highly significant correlation ($p<0.01$) with SG, BW, BL, SS, DS and SB.

Moreover, it had a significant correlation ($p<0.05$) with IS, and a non-significant correlation ($p>0.05$) with SC, SI, W and SL.

Table 4.3: Correlation between skin price and skin quality traits of Nile crocodiles

Traits	SG	BW	BL	DS	SC	SS	SI	W	IS	SB	SL	Price (R)
SG												
BW	-0.28**											
BL	-0.27**	0.86**										
DS	0.21**	-0.20**	-0.14^{ns}									
SC	0.09^{ns}	-0.05^{ns}	-0.10^{ns}	0.01^{ns}								
SS	0.71**	-0.19*	-0.22**	0.09^{ns}	-0.00^{ns}							
SI	0.01^{ns}	-0.04^{ns}	-0.02^{ns}	-0.06^{ns}	0.05^{ns}	-0.02^{ns}						
W	0.06^{ns}	0.11^{ns}	0.10^{ns}	0.01^{ns}	0.10^{ns}	0.05^{ns}	-0.02^{ns}					
IS	0.26**	0.17*	0.12^{ns}	0.09^{ns}	0.10^{ns}	0.19*	-0.08^{ns}	0.04^{ns}				
SB	0.21**	-0.03^{ns}	-0.05^{ns}	0.19*	0.02^{ns}	0.03^{ns}	0.04^{ns}	0.01^{ns}	-0.02^{ns}			
SL	0.01^{ns}	0.33**	0.25**	-0.29**	0.15*	0.11^{ns}	0.09^{ns}	0.12^{ns}	0.18*	-0.20**		
Price (R)	-0.96**	0.50**	0.46**	-0.24**	-0.11^{ns}	-0.65**	-0.03^{ns}	-0.02^{ns}	-0.19*	-0.20**	0.07^{ns}	

skin grade (SG); belly width (BW); belly length (BL); double scaling (DS); skin cuts or holes (SC); skin scars or scratches (SS); skin infection (SI); wrinkle (W); irregular scales (IS); skin blemish (SB); skin lesions (SL); **: correlation significant at $p<0.01$, *: correlation significant at $p<0.05$, ^{ns}: not significant.

4.4 Stepwise regression model for estimating skin price

Table 4.4 shows the stepwise regression models for estimating the skin price of Nile crocodiles. The results indicated that only two significant ($P<0.05$) stepwise regression models were produced, incorporating a maximum of two traits, namely SG and IS. The results indicated that SG was the first trait to be included in the model, and it explained higher variation in the skin price of Nile crocodiles with R^2 value of 92% and SE value of 158.90. Furthermore, these results indicated that addition of IS into SG led to higher variation, increased R^2 from 92 to 93% and reduced SE value from 158.90 to 155.01.

Table 4.4: Stepwise regression model for estimating skin price from skin quality traits

Model	**Regression equation**	**SE**	**R^2**	**p-value**
1	P = 2616.88 - 630.03SG	158.90	0.92	<0.001

2	P = 2606.66 - 641.64SG + 34.88IS	155.01	0.93	<0.001

Skin grade (SG); irregular scales (IS); price (P); standard error (SE); coefficient of determination (R^2).

4.5 Multiple regression models for estimating skin price

4.5.1 Multiple regression model 1

Table 4.5 shows the summary of multiple regression model 1, incorporating all the skin quality traits observed in assessed skins. The model was designed with skin price as a dependent variable and skin quality traits (SG, DS, SC, SS, SI, W, IS, SB and SL) as independent variables. The regression coefficients of only DS, SC, SS, SI and W variables were found to be non-significant ($p>0.05$) among all the independent variables. The results showed that SG (-647.94) had the highest significant ($p<0.05$) contribution to the skin price followed by SL (45.45), SB (33.85) and IS (33.28). Coefficient of determination (R^2) value of 0.94 was observed, indicating that the model explained 94% of the variations in skin prices.

Table 4.5: Summary of multiple regression model 1 for estimating skin price from skin quality traits

Skin quality traits	b	SE	p-value
SG	- 647.94	20.58	<0.01
DS	- 23.74	20.25	0.24
SC	- 13.00	15.13	0.39
SS	14.30	15.29	0.35
SI	62.54	68.11	0.36
W	14.49	57.81	0.80
IS	33.28	11.04	<0.01
SB	33.85	15.80	0.03
SL	45.45	14.70	<0.01
Intercept (a) = 2590.22, coefficient of determination (R^2) = 0.94			

Skin grade (SG); double scaling (DS); skin cuts or holes (SC); skin scars or scratches (SS); skin infection (SI); wrinkle (W); irregular scales (IS); skin blemish (SB); skin lesions (SL); b (Regression coefficient); standard error (SE).

4.5.2 Multiple regression model 2

Table 4.6 shows the summary of multiple regression model 3 incorporating all the observed skin quality traits except for SG. The model was designed with skin price as a dependent variable and skin quality traits (DS, SC, SS, SI, W, IS, SB and SL) as independent variables. The regression coefficients of SI, W, IS and SL variables were found to be non-significant ($p>0.05$). The results showed that when SG was removed from model 1, the regression coefficients of DS, SC and SS variables became statistically significant ($p<0.05$), whereas those of IS and SL became statistically insignificant. However, the significance of the regression coefficients of SI and W variables were not affected by the removal of SG from model 1. Based on these results, SS (-339.86) had the highest significant ($p<0.05$) contribution towards the skin prices, followed by DS (-138.56), SC (101.80) and SB (93.05). In the absence of SG, model 2 explained 54% of the variation ($R^2=0.54$) in skin prices.

Table 4.6: Summary of multiple regression model 2 for estimating skin price from skin quality traits

Skin quality traits	B	SE	p-value
DS	- 138.56	53.94	0.01
SC	- 101.80	39.57	0.01
SS	- 339.86	28.02	<0.01
SI	- 92.83	180.72	0.61
W	- 99.12	153.50	0.52
IS	- 22.76	29.00	0.43
SB	- 93.05	40.67	0.02
SL	62.93	39.06	0.11
Intercept (a) = 1817.18, coefficient of determination (R^2) = 0.54			

Double scaling (DS); skin cuts or holes (SC); skin scars or scratches (SS); skin infection (SI); wrinkle (W); irregular scales (IS); skin blemish (SB); skin lesions (SL); b (Regression coefficient); standard error (SE)

4.5.3 Multiple regression model 3

Table 4.7 shows the summary of multiple regression model 3 incorporating all the observed skin quality traits except for SG and DS. The model was designed with skin

price as a dependent variable and skin quality traits (SC, SS, SI, W, IS, SB and SL) as independent variables. The regression coefficients of SI, W and IS variables were found to be statistically insignificant ($p>0.05$). The results showed that when DS was removed from model 2, the regression coefficient of SL variable became statistically significant. However, the significance of the regression coefficients of SI, W, IS, SC, SS and SB variables were not affected by the removal of DS from model 2. Based on these results, SS (-343.88) had the highest significant ($p<0.05$) contribution towards the skin prices followed by SB (-111.90), SC (106.88) and SL (86.79). In the absence of SG, model 3 explained 52% of the variation ($R^2=0.52$) in skin prices.

Table 4.7: Summary of multiple regression model 3 for estimating skin price from skin quality traits

Skin quality traits	**b**	**SE**	**p-value**
SC	-106.88	40.20	0.01
SS	-343.88	28.46	<0.01
SI	-83.22	183.77	0.65
W	-95.06	156.12	0.54
IS	-33.51	29.20	0.25
SB	-111.90	40.71	0.01
SL	86.79	38.62	0.03
Intercept (a) = 1804.46, coefficient of determination (R^2) = 0.52			

Skin cuts or holes (SC); skin scars or scratches (SS); skin infection (SI); wrinkle (W); irregular scales (IS); skin blemish (SB); skin lesions (SL); b (Regression coefficient); standard error (SE)

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

Crocodile industry plays an important role in the economic status and livelihood of rural communities through the production of high-value crocodile skins (Hermesch and Isberg, 2022). Nile crocodile skins are the second most valuable skins in the whole crocodile skin industry (Mpofu et al., 2015). Crocodile skin grading is based on the skin quality traits such as holes, scratches and infections that cause declines in the economic values of crocodile skins through downgrading (Manolis and Webb, 2011). Hence, the first objective of this study used frequencies and percentages to evaluate the skin quality traits in Nile crocodiles kept at Lalele Crocodile Farm. The current study showed that over 90% of the evaluated skins failed to meet the requirements of first grade. However, most of the skins met the requirements of the second grade, followed by the third grade. The skins of Nile crocodiles at Lalele Crocodile Farm did not possess any osteoderms, abscesses or missing legs. This study found SS, IS, SB, DS, W, SI, SC and SL to be present in some skins, with more than half of the skins being affected by SS, IS and SB. The prevalence of SS, IS and SB on the Nile crocodile skins is the most common factor limiting over 90% of the skins from meeting the conditions for first grade.

A study by Veldsman (2019) identified skin quality traits similar to the current study on skins of Nile crocodiles raised in captivity. Another study by Manolis and Webb (2011) using skins of Saltwater crocodiles found skin quality traits comparable to the current study such as wrinkles, scratches, irregular scales, double scaling, cuts, infections and other traits (scale lift, black dots and pits) which were not covered in the current study. Supporting results were also found by Urge et al. (2020) on a study focusing on livestock skins which confirmed scars and cuts on skins. Veldsman (2019) further found scratches and teeth marks to be one of the most common traits in Nile crocodile skins, this was consistent with findings of the current study. However, contradicting results were found by Wangui (2016) in a study focusing on livestock skins which found brand marks, dirtiness, bruises, poor pattern or shape and cuts as the most common skin quality traits. The variations in the results may be due to the physical differences

of the skins from different species and significantly different management systems practiced on conventional and unconventional animal species.

The low number first grade skins and high frequency of skins with scratches and scars justifies the challenge of skin downgrading being faced by farmers. This relatively high number of damaged skins imply that there might be a management-related problem such as high stocking density and housing crocodiles of relatively different sizes together. A stocking density of approximately 1000 Nile crocodiles per pen was employed at the study area of this research. High stocking density was reported to be synonymous with increased aggressive behaviour (biting) in both Saltwater (Brien et al., 2016) and Nile crocodiles (Webb et al., 2021). Aggression behaviours in Nile crocodiles are also prevalent when crocodiles of relatively larger sizes are present in the pens (Morpurgo et al., 1993). The evaluation of the belly sizes of the skins at the research farm gave some indication on the variability of crocodile sizes/lengths before slaughter. Their belly lengths ranged from 36cm to 49cm and averaged at 38cm, which could mean relatively larger crocodiles were present in the pens to increase agonistic behaviours.

Knowledge on the economic values of skin traits is the probable solution to help farmers improve quality of their skins for higher market value (Hermesch and Isberg, 2022). As a result, the second objective of this study used Spearman's correlation to explore the associations between skin quality traits and skin price of Nile crocodiles. The study found that skin price has a positive highly significant correlation with BW and BL, and a negative highly significant correlation with SG, DS, SS and SB. Moreover, skin price had a negative significant correlation with IS and a non-significant correlation with SC, SI, W and SL.

The results of the current study were similar to those of Friehiwot (2020), who indicated that price of animal skin is associated with its general quality and grading. Similarly, Manolis and Webb (2011) indicated that skin quality and grade have a connection with the price commanded for Saltwater crocodile skins in markets. Hermesch and Isberg (2022) revealed that Saltwater crocodile skin price is related to size of the belly width,

this was consistent with the findings of the current study. Several studies on other species used for skin production rather than crocodiles gave indications on the associations between skin prices and quality traits. Results corresponding to those of the current study were reported by Arkebe (2009) in a study focusing on skins of several livestock species which revealed that poor skin quality traits such as cuts, scratches, scars and infections were related to skin price derived by farmers. Isberg et al. (2004) reported opposing results in study focusing on Saltwater crocodile skins suggesting that belly length and scale patterns had no influence on skin price.

Due to the highest correlation coefficient values skin price had with SG and SS, they can both be used to select skins that will attain higher prices markets. The correlation results imply that Nile crocodile farmers can significantly improve their skin prices by aiming at increasing skin grade value, belly width and belly length, and reducing the occurrence of DS, SS, SB and IS.

However, correlation technique has a limitation of providing information on only the relationship between two variables, but not the contribution of the independent variable(s) towards variation of the dependent variable (Mathapo et al., 2022; Tyasi et al., 2024). To bridge this gap, the current study further used stepwise and multiple regression techniques to develop models for predicting skin price from different skin quality traits of Nile crocodiles such as SG, DS, SC, SS, SS, SI, W, IS, SB and SL. The best fitted models for estimating skin price were determined using the coefficient of determination (R^2). The results showed that stepwise regression model 2 using SG and IS as predictors was the best fitted stepwise regression model for predicting skin prices of Nile crocodiles since it featured the highest coefficient of determination compared to model 1 which used only SG. The best fitted multiple regression model for estimating skin price of Nile crocodiles was model 1 which had high coefficient of determination value of 0.94. This model featured SG, DS, SC, SS, SI, W, IS, SB and SL as predictors for skin price. However, among all the featured independent variables, only SG, IS and SL had significant contribution towards the variation in Nile crocodile skin prices.

The results of this study are conflicting with the reports of Manolis et al. (2000) and Isberg et al. (2004) who indicated that scale patterns have no contribution towards the premium prices of Saltwater water crocodile skins. These differences may be due to the lack of standard grading systems for crocodile skins. Engelbrencht (2014) indicated that skin grade is one of the factors that are used for price determination of ostrich skins. Furthermore, a study by Nemutandani et al. (2024) similarly discovered that skin grade can be used to determine price of ostrich skins. These results were in line with findings of the current study regardless of major skin physical variations between crocodile and ostrich skins. This may be due to the importance premium quality skins in both crocodile and ostrich leather industry.

The findings of this study imply that when multiple skin quality traits are included in the prediction model, skin price can be estimated more accurately. The current study suggests that a stepwise regression model employing SG and IS can be used to estimate skin prices of Nile crocodiles accurately. All the skin quality traits in this stepwise regression model significantly contributed towards the variations in the skin prices unlike the multiple regression models. The model implies that a unit change in SG and IS corresponds to R641.64 and R34.88 change in skin price, respectively.

5.2 Conclusion

The current study used descriptive statistics to evaluate the Nile crocodile skins at Lalele Crocodile Farm. As a result, it identified several skin quality traits (SS, IS, SB, DS, W, SI, SC and SL) and found scratches and scars to be the most apparent skin traits at the farm. This study also used Spearman's correlation to determine the association between skin price and skin quality traits of Nile crocodiles. SG, DS, SB, SS, BW and BL were highly correlated to skin price of Nile crocodile, they may therefore be used as selection criteria for high skin price. The exploration of stepwise and multiple regression models suggested that SG and IS can be used to precisely predict skin prices of Nile crocodiles. The limitation of this study was a lack of enough related literature. Hence, more similar studies should be done using larger sample sizes and on other species used for skin production.

5.3 Recommendations

With respect to the findings of the current study, the following is recommended:

- Due to the discovered significant correlations, skin quality traits including SS, IS, SB, DS, W, SI, SC and SL can be used as selection criteria to derive high prices out of Nile crocodile skins.
- More studies should be done to investigate the causal factors of the most common crocodile skin quality traits that cause downgrading and use them as guide to develop improved management systems aimed at maximising skin value.
- Studies should be done to compare the skin quality traits of captive and wild raised crocodiles to try to determine the direct and indirect effects of environment and management systems on the skin quality traits of crocodiles.
- Similar studies should be conducted on skins of different animal species.

CHAPTER SIX

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ANNEXURE A: Gate Keeper's Consent Form

Gate Keeper's Consent Form

LALELE CROCODILE FARM

Section 55, Welgevonden Farm (R520), Box 1549, Naboomspruit 0560, South Africa

Cell: 082 600 2114

Email: info@lalele.co.za

INFORMED CONSENT FORM FOR CONDUCTING A RESEARCH STUDY

I, H.J. Pienaar....., the owner of Lalele crocodile farm give consent to Mr Mahaole ASW – [redacted] to conduct a study in our farm under the topic "ASSESSMENT OF SKIN QUALITY TRAITS OF NILE CROCODILES (*CROCODYLUS NILOTICUS*) AT LALELE CROCODILE FARM IN LIMPOPO PROVINCE" for the degree of Master of Science in Agricultural Science in Animal Production in the Department of Economics and Animal Production, University of Limpopo.

Henning Johannes		14/6/23
Farm owner	Signature	Date

(Full name)

ANNEXURE B: Ethical Approval Certificate

University of Limpopo
Department of Research Administration and Development
Private Bag X1106, Sovenga, 0727, South Africa
Tel: (015) 268 3935/2401 Fax: (015) 268 2306, Email: Tukiso.Sewapa@ul.ac.za

ANIMAL RESEARCH ETHICS COMMITTEE CLEARANCE CERTIFICATE

MEETING: 22 May 2024
PROJECT NUMBER: AREC/09/2024: PG

PROJECT:

Title:	Assessment of skin quality traits of Nile crocodiles (*Crocodylus niloticus)* at Lalele Crocodile Farm in Limpopo Province
Researcher:	ASR Mahaole
Supervisor:	Dr TJ Mugwabana
Co-Supervisor/s:	Dr KR Nemutandani Prof TL Tyasi
School:	Agricultural and Environmental Sciences
Degree:	Master of Science (Animal Production)

PROF LJC ERASMUS

CHAIRPERSON: ANIMAL RESEARCH ETHICS COMMITTEE

The Animal Research Ethics Committee (AREC) is registered with the National Health Research Ethics Council, Registration Number: **AREC-290914-017**

Note:
i) **Should any departure be contemplated from the research procedure as approved, the researcher(s) must re-submit the protocol to the committee.**
ii) **The budget for the research will be considered separately from the protocol.**
iii) **Please note that this clearance certificate is valid for a period of 12 months from date of issue.**
iv) **PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES.**

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