Best Management Practices for Crocodilian Farming

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Contents

Cover Photograph: *Crocodylus siamensis* (Grahame Webb)

Citation

This document can be cited as follows:

Manolis, S.C. and Webb, G.J.W. (compilers) (2016). Best Management Practices for Crocodilian Farming. Version 1. IUCN-SSC Crocodile Specialist Group: Darwin, Australia.

Acknowledgements

The BMP-Manual benefitted greatly from detailed review by various CSG members and industry members/associations (CFAZ, ZaCFA), and subsequent review by the CSG Steering Committee, including: Rambli bin Ahmed, Matthew Brien, John Calderon, Sue Childes, Helen Crowley, Ruth Elsey, John English, Benoit Fayd'herbe, Rich Fergusson, Christopher Foggin, Giam Choo Hoo, Nigel Hough, Sally Isberg, Kevin van Jaarsveldt, Dietrich Jelden, Hank Jenkins, Johann Jordaan, C.H. Koh, Eric Langelet, Alejandro Larriera, Christine Lippai, Paolo Martelli, Samuel Martin, Lonnie McCaskill, Sergio Medrano-Bitar, Jan Myburgh, Carlos Piña, Parntep Ratanakorn, Paul Reilly, J. Perran Ross, Jaelle Rowland, Cathy Shilton, Matt Shirley, Anslem de Silva, Pablo Siroski, Gerry Swan, Marisa Tellez, Bill Thomas, Alvaro Velasco, Nikhil Whitaker and Allan Woodward.

Glossary

ACFS	The National Bureau of Agricultural Commodity and Food Standards, Thailand Ministry of Agriculture and Cooperatives
BLC	British Leather Confederation
CEESP	IUCN Commission on Environmental, Economic and Social Policy
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CFAZ	Crocodile Farmers Association of Zimbabwe
CSG	IUCN-SSC Crocodile Specialist Group
EMP	Environmental Management Policy
Hatchling	crocodilians 0<1 year of age
IUCN	International Union for Conservation of Nature
LDWF	Louisiana Department of Wildlife and Fisheries (Louisiana, USA)
LWC	The Leather Working Group
SVM-LSU	School of Veterinary Medicine - Louisiana State University (Louisiana, USA)
NRMMC	Natural Resources Management Ministerial Council (Australia)
OH&S	Occupational Health and Safety
SABS	South African Bureau of Standards Division
SB-AWR	Science-Based Animal Welfare Research
SSC	Species Survival Commission of IUCN
SULi	IUCN-SSC Sustainable Use and Livelihoods Specialist Group
TL	total length
ZaCFA	Zambia Crocodile Farmers Association

Preface

Crocodilian farming is a relatively new form of animal production. As such, it lacks the 5000+ year history of accumulated knowledge on domestic animal production processes available for most conventional agricultural animals - chickens, ducks, sheep, goats, cattle, etc. Crocodilian farming began seriously in the 1970s, when the demand for skins could no longer be satisfied by unregulated wild harvesting, which had increased significantly from the late 1940s onward. Long considered as pests, especially the larger crocodilian species that prey on people, their depletion in the wild was initially seen as a social benefit. This situation changed in the 1960s, when the plight of endangered wildlife, including predators on people, captured the imagination of the world. The pioneering crocodilian farms were mainly focused on skin production in facilities distant from wild populations, but they also provided a source of stock that could be used for conservation purposes.

When the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES) came into force in 1975, all crocodilian species were listed on either Appendix I or Appendix II. International trade in crocodilian products - raw, processed or manufactured items - was only possible if a strict set of conservation criteria were met. This was new territory for an animal production industry to navigate, and it remains so today. During the 1970s and 1980s the number of crocodilian farms, and species being farmed within them, increased greatly (Luxmoore 1992), and pioneering research fuelled a steep learning curve about all aspects of crocodilian farming (Hutton and Webb 1992).

Captive husbandry practices on farms were originally guided by experiences within zoos, and by knowledge and insights gained by herpetological researchers working within university contexts. But as farm-based research and experience grew exponentially, so zoos and researchers are increasingly learning about captive husbandry from the crocodilian farming industry. Still, the central focus of farms is raising high numbers of crocodilians in an economically viable way, whereas zoos and researchers typically maintain smaller numbers of animals, with exhibition and experimentation being the primary goals respectively. Where farms and researchers typically deal with one species of crocodilian, zoos often deal with multiple species, and as such, have played a critical role in recognising species-specific traits, incorporated into farm pen designs and procedures.

So there is a growing wealth of knowledge and experience being exchanged continually through organisations like the IUCN-SSC Crocodile Specialist Group (CSG). The CSG was established in 1971 within the Species Survival Commission (SSC) of the International Union for Conservation of Nature (IUCN). As trade and conservation of crocodilians are intimately linked, the CSG and its members have been involved with crocodilian farming for the last 45 years. The CSG now consists of 550+ members in 63 countries (in 2016), and includes the world's leading scientists and experts on crocodilian biology, research, conservation, management, animal health, veterinary sciences, zoo-keeping, farming, tanning and manufacture. The CSG is thus uniquely positioned to provide guidance on best management practices, despite new insights being gained continually through research.

It is estimated that some 4000 to 5000 crocodilian farms now exist worldwide (2016), ranging from village level farms, with a few animals, low investment and low technology, to highly sophisticated production farms, with over 100,000 animals, high investment and high technology. Numerically, most farms produce stock through closed-cycle captive breeding (eg >2500 operations with *Crocodylus siamensis* alone), sometimes using a contract-farming structure (satellite farming): smaller farms selling stock to larger farms, and/or larger farms subcontracting the raising of stock to smaller farms (see Section 3.2). The practice of satellite farms is common within conventional livestock sectors. Other farms depend partly or solely on "ranching", in which wild eggs and/or juveniles are legally collected and subsequently raised in controlled conditions in farms.

In 2010-2013 around 40-45% of crocodilian skins in international trade were estimated to have been derived through ranching programs (eg *Crocodylus niloticus*, *C. porosus*, *Caiman latirostris*, *C. yacare*, *Alligator mississippiensis*). The provision of commercial benefits from ranching to local people living with wild crocodilians plays a significant role in the *incentive-driven conservation programs* for crocodilians that now operate in many countries (eg Joanen *et al.* 1997; Hutton *et al.* 2002; Table 1).

Crocodilians are semi-aquatic reptiles that are anatomically and physiologically distinct from mammals and birds, where most animal production experience has been gained. Of particular importance, crocodilians are ectotherms (or "cold-blooded" animals), a trait they share with fish, amphibians and other reptiles. They have a brain heavily developed for olfaction ("smell") rather than higher learning (Richardson *et al.* 2002), although they can be successfully trained for some tasks (See Annex 1 - Section 15). Crocodilian behaviours are mostly subtle and difficult to interpret (Brien *et al.* 2013). They spend a great deal of time in an apparent restive, motionless state - watching but not moving - more alert than they appear (eg Kelly *et al.* 2015). This is perhaps not surprising, because in the wild they are preyed upon by many species (Somaweera *et al.* 2013), including other crocodilians, and they maintain dominance hierarchies, with injury and death resulting from bursts of aggressive social interactions, particularly during breeding seasons (Vliet 2001).

Farm husbandry practices are continually informed by scientific research, and that research is stimulated by an increasing expectation from both manufacturers and consumers that the supply chains leading to retail products will comply with acceptable standards of science-based animal welfare.

To this end, national codes of practice for crocodilian farming have been developed for different species by a number of producer nations [eg Australia – Natural Resource Management Ministerial Council (NRMMC 2009); Louisiana, USA – Louisiana Department of Wildlife and Fisheries and School of Veterinary Medicine-Louisiana State University (LDWF and SVM-LSU 2016); Zimbabwe – Crocodile Farmers Association of Zimbabwe (CFAZ 2012); South Africa – South African Bureau of Standards Division (SABS 2014); Thailand – National Bureau of Agricultural Commodities and Food Standards (ACFS 2016); Zambia – Zambia Crocodile Farmers Association (ZaCFA 2013)].

It is thus timely that a global overview of important issues be undertaken, and that this provides guidance for individual farms to assess their procedures relative to what can be considered best management practice. The CSG has now compiled information on *Best Management Practices for Crocodilian Farming* (CSG-BMP), as we know them today. Given management practices are an evolving science, the CSG-BMP is considered a living document, which will be reviewed, updated and adapted as new insights are provided through research.

Aims

The CSG-BMP provides guidance to crocodilian farming operations about current best management practices. It also provides a checklist that can be used to assess farm husbandry practices and compliance with governance regimes. The capacity to achieve best management practices will probably be greater in high investment industrial-scale farms, than in smaller village-level farms. Similarly, the capacity to engage in research, development and innovation, and to be both aware of and implement new technologies, will not be uniform across all crocodilian farms. The aim of the CSG-BMP is not to be critical of low technology farms - from which much is to be learnt - but rather to provide options through which better management practices can simultaneously improve productivity and animal welfare in all farms.

The case for assisting, rather than excluding, low-technology farms to improve management practices is a compelling one. Improving the livelihoods of rural people has increasingly been recognised as a global obligation. It is incorporated within Corporate Social Responsibility (CSR) obligations adopted by companies (see Section 17), and is now a fundamental principle accepted by the Parties to several multilateral biodiversity-related conventions such as the Convention on Biodiversity (CBD) and CITES [Resolution Conf. 16.6 *CITES and livelihoods* and Resolution Conf. 13.2 (Rev. CoP14) *Sustainable use of biodiversity: Addis Ababa Principles and Guidelines*]. Within the IUCN it is primary objective of the Sustainable Use and Livelihoods Specialist Group (SULi), the Species Survival Commission (SSC) and Commission on Environmental, Economic and Social Policy (CEESP).

The CSG-BMP accepts that scientific research is ongoing around the world, and will continually change our understanding of what constitutes best management practice. This is particularly germane to advances in *science-based animal welfare research* (SB-AWR) generally, and for example, the increasing awareness that species-specific traits in crocodilians impact greatly on the application of management practices to different species. It is for this reason that the CSG-BMP does not aim to be overly prescriptive. It recognises and accepts that farming conditions in different countries, for different species, have evolved separately, using both scientific and traditional knowledge, and that there is no single farming model that fits all circumstances. The CSG-BMP serves as a tool to ensure awareness among farmers of the five fundamental aspects of animal welfare (the “five freedoms” – see below), even though they may be achieved in different ways:

1. Freedom from hunger and thirst
2. Freedom from discomfort
3. Freedom from pain, injury and disease
4. Freedom to express normal behaviour
5. Freedom from fear and distress

The *Code of Practice on the Humane Treatment of Wild and Farmed Australian Crocodiles* (NRMMC 2009) has been a primary model used for developing other State or National codes [eg Zambia, Zimbabwe, South Africa and USA (Louisiana)], each modified to reflect differences in species and national contexts. Queensland (Australia) developed its own code of practice for crocodile farms under its jurisdiction (DEHP 2008, 2010). The Australian code was originally prepared by Wildlife Management International (WMI) on behalf of the Australian Government, and is a fundamental reference point for developing the CSG-BMP. The diversity of topics covered by the CSG-BMP reflects the complexity of issues involved in crocodilian farming.

1. CITES

CITES is a critical element of trade in crocodilians, and it requires cooperation between farms (existing and impending) and national CITES Management and Scientific Authorities. It also requires management authorities to be familiar with CITES and their obligations under the Convention.

CITES is an international convention to which countries can accede. The Convention establishes a legal framework for either preventing or regulating trade in species that are considered endangered or likely to become so without regulation. It gives both producer and consumer countries responsibilities for different aspects of trade, and fosters international co-operation to achieve trade that is legal, sustainable and verifiable.

Preliminary text of the Convention was drafted in 1964 following a resolution adopted by the General Assembly of the IUCN in 1963, which called for "*an international convention on regulation of export, transit and import of rare or threatened wildlife species or their skins and trophies*". The final text was agreed by a Plenipotentiary Conference held in Washington DC (USA) in 1973, and CITES entered into force on 1 July 1975. As of 1 October 2015, 181 countries were Parties to CITES (CITES 2015).

Since 1975 all species of living crocodilians have been listed on either Appendix I or Appendix II of CITES (CSG 2015; CITES 2015), and international trade in them must be regulated accordingly. Article II of the Convention, *inter alia*, states:

> Appendix I: "*shall include all species threatened with extinction which are or may be affected by trade. Trade in specimens of these species must be subject to particularly strict regulation in order not to endanger further their survival and must only be authorized in exceptional circumstances*."
>
> Appendix II: "*shall include all species which although not necessarily now threatened with extinction may become so unless trade in specimens of such species is subject to strict regulation in order to avoid utilization incompatible with their survival*".

Jelden *et al.* (2014) provide a summary of the many CITES decisions and resolutions that are particularly relevant to crocodilians and the regulation of trade in them. For example:

a. Resolution Conf. 8.3 *Recognition of the benefits of trade in wildlife*
b. Resolution Conf. 9.24 (Rev. CoP16) Annex 3: *Criteria for amendment of Appendices I and II*
c. Resolution Conf. 10.16 (Rev.) *Specimens of animal species bred in captivity*
d. Resolution Conf. 11.12 (Rev. CoP15) *Universal tagging system for the identification of crocodilian skins*
e. Resolution Conf. 11.16 (Rev. CoP15) *Ranching and trade in ranched specimens of species transferred from Appendix I to Appendix II*
f. Resolution Conf. 12.10 (Rev. CoP15) *Registration of operations that breed Appendix-I animal species in captivity for commercial purposes*
g. Resolution Conf. 13.7 (Rev. CoP16) *Control of trade in personal and household effects*
h. Resolution Conf. 14.3 *CITES compliance procedures*
i. Resolution Conf. 14.7 (Rev. CoP15) *Management of national established export quotas*
j. Resolution Conf. 16.6 *CITES and livelihoods*
k. Resolution Conf. 16.7 *Non-detriment finding*

2. Harvest Regimes

The types of commercial use implemented for crocodilians vary between species and countries (Table 1), and largely reflect the status of wild populations, their absolute abundance, national policies with regard to the types of use considered acceptable, and well-established concepts about the risks of harvesting different life stages.

Within the context of CITES, commercial exploitation of crocodilians broadly fits into three categories - captive breeding (C), ranching (R) and wild harvest (W):

a. Captive Breeding - the production of eggs from captive adults in a controlled environment with the progeny reared in captivity;
b. Ranching - the collection of eggs, hatchlings or juveniles from the wild, that are then reared in captivity; and,
c. Wild Harvest - the direct harvest of crocodilians from the wild, which does not involve farming and is not addressed further in the CSG-BMP.

Table 1. Current use programs for crocodilians. C= captive breeding; R= ranching; W= wild harvest; *= under development; ** program suspended. Operations in Mali and Senegal are assumed to comprise stocks of *Crocodylus suchus* (previously considered to be *C. niloticus*; Hekkala *et al.* 2011).

Species	Use	Country
Alligator mississippiensis	C, R, W	USA
Alligator sinensis	C	China
Caiman crocodilus	W	Nicaragua, Guyana
Caiman crocodilus	C	Colombia
Caiman crocodilus	C, R*	Brazil
Caiman crocodilus	R, W	Venezuela
Caiman latirostris	R	Argentina
Caiman yacare	R	Argentina
Caiman yacare	C, W, R	Bolivia
Caiman yacare	C, R	Brazil
Caiman yacare	W**	Paraguay
Melanosuchus niger	W	Brazil
Crocodylus acutus	C	Honduras, Colombia
Crocodylus acutus	R, C	Cuba
Crocodylus johnstoni	C, R, W	Australia
Crocodylus moreletii	C, R*	Mexico
Crocodylus niloticus	C, R	Zimbabwe, Kenya, Namibia
Crocodylus niloticus	C, R, W	Madagascar
Crocodylus niloticus	R, W	Tanzania, Mozambique
Crocodylus niloticus	R	Botswana, Malawi, Zambia, Uganda, Ethiopia, Swaziland
Crocodylus niloticus	R*	Egypt
Crocodylus niloticus	C	Mauritius, South Africa, Tunisia
Crocodylus suchus	C	Senegal, Mali
Crocodylus novaeguineae	R, W	Papua New Guinea, Indonesia
Crocodylus porosus	C	China, Singapore, Vietnam, Thailand, Philippines
Crocodylus porosus	C, R, W	Australia, Indonesia, Papua New Guinea
Crocodylus porosus	C, R*, W*	Malaysia
Crocodylus rhombifer	C	Cuba
Crocodylus siamensis	C	Thailand, Cambodia, Vietnam, China

Approaches to utilization and farming can vary across a species' range. For example, captive breeding of *C. porosus* is currently the only acceptable option for commercial production and trade in Bangladesh, the Philippines, Singapore, Thailand, Vietnam and most parts of Indonesia, where wild populations are depleted or extinct. However, where populations are large and secure (Australia, Papua New Guinea, Papua and West Papua Provinces of Indonesia), uses involve wild harvest, ranching (eggs and/or juveniles) and captive breeding. Populations in parts of Malaysia (eg Sarawak, Sabah) appear to have recovered sufficiently to allow use programs to be developed and implemented (R. Bin Ahmad, pers. comm., 2015).

The wild *C. acutus* population in Cuba sustains a ranching program based on eggs harvested from the wild, but in Colombia and Honduras production is limited to captive breeding in closed-cycle farms, considered better suited to the depleted status of the wild populations. Colombia (in 2016) proposed a split listing for its population of *C. acutus,* with a sub-population in Cispata Bay transferred to Appendix II to allow a successful community-based ranching program to continue, while the remainder of the national population is retained on Appendix I. Split listings are not encouraged within CITES [Resolution Conf. 9.24 (Rev. CoP16) Annex 3: *Criteria for amendment of Appendices I and II*], but in certain circumstances, like this, it can assist conservation.

Within the same country, different States and Provinces may adopt different use programs. In Australia, the Northern Territory (NT) and Western Australia (WA) allow captive breeding, ranching and wild harvest, whereas Queensland (QLD) currently only allows production through captive breeding. Crocodile farms in QLD purchase stock from the NT ranching program.

Similarly in the USA, Florida, Louisiana and Texas allow captive breeding, ranching and wild harvest of *A. mississippiensis*, and alligator farmers in Alabama and Georgia routinely purchase stock from Florida and/or Louisiana. Louisiana allows a liberal egg harvest but requires a proportion of the raised juvenile alligators to be released back to the wild within two years of hatching, while Florida has a more limited harvest with no release requirement. Several other US states restrict harvest to nuisance alligator management or recreational sport hunting.

The Indonesian population of *C. porosus* is on CITES Appendix II, but has highly variable status across this vast archipelago nation. Management of the population in Papua and West Papua Provinces (previously Irian Jaya) involves wild harvest, ranching and captive breeding, but elsewhere use is restricted to ranching (egg and juveniles <80 cm TL) and captive breeding.

Some crocodilian species were/are farmed outside their natural range (eg *A. mississippiensis* and *C. niloticus* in Israel; *C. niloticus* in Brazil; *C. siamensis, C. niloticus* and *C. porosus* in China). The CSG does not support the farming of exotic crocodilian species within the natural range of other naturally occurring crocodilians, because of the risks of establishing feral populations and creating hybridization problems.

3. Captive Breeding of CITES Appendix-I Species

3.1. General

International commercial trade in CITES Appendix-I species is subject to strict regulation that does not allow the export of wild-caught individuals. Trade is permitted in the progeny of captive-bred Appendix-I specimens, in accordance with Article VII, para. 4 which, *inter alia*, states: "*Specimens of an animal species included in Appendix I bred in* *captivity for commercial purposes, ... shall be deemed to be specimens of species included in Appendix II*."

Operations breeding Appendix-I crocodilians for commercial purposes are required to be registered with the CITES Secretariat in order to export, following procedures outlined in Resolution Conf. 12.10 (Rev. CoP15) *Registration of operations that breed Appendix-I animal species in captivity for commercial purposes*. Specimens produced by the operation must qualify as "bred in captivity" according to the provisions of Resolution Conf. 10.16 (Rev.) *Specimens of animal species bred in captivity*:

a. Specimens must be born or otherwise produced in a controlled environment, with breeding stock obtained in accordance with national laws and in a manner not detrimental to the survival of the species.

b. Breeding stock should be maintained without the introduction of specimens from the wild, except: i) to prevent inbreeding; dispose of confiscated specimens [in accordance with Resolution Conf. 10.7 (Rev. CoP15) *Disposal of confiscated live specimens of species included in the Appendices*]; or, iii) in exceptional circumstances, for use as breeding stock.

c. A further requirement, that has often been misinterpreted, is that breeding stock must have produced F2 (second generation) or subsequent generation offspring (eg F3, F4); or, *is managed in a manner that has demonstrated to be capable of reliably producing F2 offspring in a controlled environment*. With crocodilians, the latter condition is usually applied, as all crocodilian species have demonstrated the ability to produce F2 offspring in controlled environments.

d. Registration procedures [Annex 1 of Resolution Conf. 12.10 (Rev. CoP15)] require demonstration that *the operation has bred at least two generations of the species* or *if the operation has only bred one generation of the species, that the husbandry methods used are the same as, or similar to, those that have resulted in second-generation offspring in other operations*.

All operations that breed CITES Appendix-I animal species in captivity, including crocodilians, for commercial purposes, and which seek to be registered with the CITES Secretariat in accordance with the procedure specified in Resolution Conf. 12.10 (Rev. CoP15), *inter alia*, must provide; "*Assurance that the operation shall be carried out at all stages in a humane (non-cruel) manner*."

In some countries, for example Colombia, the national enabling legislation to implement CITES currently restricts the export of Appendix-I captive-bred specimens to F2 generation stock. This stricter domestic measure (Article XIV, para. 1) has serious ramifications for investment in commercial farming of *C. acutus* through captive breeding, as 10-20 years are required until F2 stock can be produced and traded internationally.

As a result of recommendations by the CSG and other organizations, from 2016 onwards it is likely that production of *Caiman crocodilus* in Colombia will shift from captive breeding only to mixed production involving both captive breeding and ranching. Production will be distributed between captive breeding farms, supervised by Government, and a ranching quota to be developed by the Colombian CITES Management and Scientific Authorities.

CITES-registered captive breeding operations currently exist for *C. acutus* (Colombia, Honduras), *C. niloticus* (Tunisia), *C. suchus* (= *C. niloticus*; Mali, Senegal), *C. porosus* (Bangladesh, Malaysia, Philippines, Singapore, Thailand), *C. siamensis* (Cambodia, Thailand, Vietnam), *C. rhombifer* (Cuba) and *A. sinensis* (China). CITES maintains a register of captive breeding operations on its website (see http://cites.org/eng/common/reg/e_cb.html).

It is important to note that the Parties to CITES are not obliged to follow protocols outlined in a Resolution, if they believe they go beyond the requirements and intent of the Convention itself. Some Parties do not implement Resolution Conf. 12.10 (Rev. CoP15) and do not register farms formally with the CITES Secretariat, electing to regulate trade in captive-bred specimens of Appendix-I species in accordance with the provisions of Article III of the Convention (*Regulation of Trade in Specimens of Species included in Appendix I*).

The widespread commercial captive breeding of *C. siamensis* in Southeast Asia, with networks of village-level satellite/contract farms, does not fit easily with the CITES resolutions concerning Appendix-I captive breeding, and it has been suggested that a program tailored to this specific local situation, may be more effective than trying to comply with Resolution Conf. 12.10 (Rev. CoP15) (Jelden *et al*. 2005; see Section 6.7).

3.2. Satellite Farms (Contract Farms)

Registered captive breeding operations for Appendix-I species are expected to be closed-cycle operations, with the captive population largely contained within the confines of the operation. Satellite or Contract farming, widely adopted with *C. siamensis* in Thailand, Vietnam and Cambodia, was not taken into consideration when Resolution Conf. 12.10 (Rev. CoP15) was adopted by the Parties to CITES in 2002. Satellite/contract farming can be regulated in accordance with the Convention text, but not easily under Resolution Conf. 12.10 (Rev. CoP15) (Jelden *et al*. 2005).

Large *C. siamensis* farms are mostly registered as CITES captive breeding operations, but they enter into contractual arrangements with small- to medium-sized farms. They either: i) buy hatchlings that small farms produce from a few captive adults; or, ii) sell their own hatchlings to smaller farms for raising to culling size, when they are purchased back by the registered farm. Problems sometimes develop when price structures change over time, and when market requirements for skin quality change, but the system generally operates well, and greatly increases the livelihood benefits from crocodilian farming to rural communities. Within satellite/contract farming systems, the obligation is on the registered farms to ensure compliance with national legislation.

Satellite/contract farming allows village-level farms to operate without high investment, which is well-suited to many national contexts. However, it increases the number of establishments that ideally need to be regulated. For example, in Vietnam it appears that mixing of legally-produced crocodiles derived from farms in the country and illegally acquired crocodiles from neighbouring countries is commonplace (Jelden *et al.* 2008). The potential for wild-caught crocodiles to enter farms illegally is also presumably higher as the number and geographic distribution of farms increase, which is a concern within Cambodia, where the farm population of *C. siamensis* is large but the wild population is very small (Simpson and Bezuijen 2010; Sam *et al.* 2015).

4. <u>Skin Tagging</u>

The marking of skins in trade produced from legal and sustainable sources is a fundamental and powerful tool for the regulation of trade and realization of conservation benefits of commercial production. CITES Resolution Conf. 11.12 (Rev. CoP15) *Universal tagging system for the identification of crocodilian skins* outlines an agreed tagging system for the identification of raw, tanned and/or finished crocodilian skins in international trade.

Skin tags must be: self-locking, resistant to tampering, heat and chemical and mechanical processing, and contain alphanumeric information, which may include bar-coding applied by permanent stamping (Figs. 1 and 2). A variety of tags have been developed that meet these criteria and are used by various countries. They all share the characteristic that production and distribution of tags is regulated by the national authority and CITES to ensure tags are not duplicated or misused.

Figure 1. Skins tags used for *Caiman crocodilus fuscus* in Colombia (left), *Melanosuchus niger* in Brazil (centre) and *Alligator mississippiensis* in the USA (right). Photographs: Charlie Manolis.

Figure 2. Skins tags must have the minimum information as prescribed in Resolution Conf. 11.12 (Rev. CoP15), but can also include bar-coding to assist record keeping. Photographs: Charlie Manolis.

The CITES Secretariat maintains a list of approved manufacturers of skin tags that meet the requirements of Resolution Conf. 11.12 (Rev. CoP15). This list is periodically amended and distributed to the Parties to CITES through Notifications (most recently Notification No. 2013/029 of 5 July 2013; CITES 2015). Approved manufacturers must only sell skin tags to CITES Management Authorities, or in the case of non-Parties, to designated Government agencies recognized by the CITES Secretariat in accordance with Resolution Conf. 9.5 (Rev. CoP15) *Trade with States not party to the Convention.* It is recommended that CITES

Management Authorities (or in some cases farms) approach the CITES Secretariat [see CITES (2016) for the most up-to-date list of tag manufacturers.

In some countries, the CITES Management Authorities may authorise skin tags to be purchased directly by farms or farm associations, as the management authorities are often distant from the farming operations, and it is the most efficient means of getting tags to farms.

5. Marking of Animals

Various marking systems are used to identify individual crocodilians in farms. Requirements for marking farm stock may be established through national or local legislation or adopted voluntarily by farms as part of their stock management (eg tracking stock within and between farms). CITES-registered captive-breeding operations are required under Resolution Conf. 12.10 (Rev. CoP15) to ensure that an appropriate and secure marking system is used to identify breeding stock of species on Appendix I. Article VI (7) of CITES provides a general legal basis for marking CITES-protected specimens.

The marking protocol should be matched to the actual need. In some cases there may be a need for marking each individual with a distinctive, recognizable mark, while for others it may sufficient to mark all of a particular set of individuals in the same manner [eg source (captive-bred, ranched or wild), year of production, clutch, etc.].

Commonly used marking systems include:

5.1. Scute-clipping involves a unique combination of vertical tail scutes being removed (see Richardson *et al.* 2002). If the scutes are cut properly, even from the time of hatching, the healed scars, and the number they represent, will be retained indefinitely (Fig. 3). If scutes are not cut properly, they may re-grow (Fig. 4). It is advisable to avoid cutting the last few single vertical scutes, as this section of the tail may be lost through amputation caused through social interactions.

Figure 3. Double (left) and single (right) vertical tail scutes that were cut at the time of hatching. These markings will be identifiable on the animal even after it reaches adulthood (or on the skin that is produced from this animal). Photographs: Charlie Manolis.

Figure 4. Single (left) and double (right) vertical tail scutes showing re-growth as a result of not being cut properly 1-2 years earlier. Red lines indicate the point along which scutes should have been cut in the first instance. Photographs: Charlie Manolis.

In Colombia, exports of *Caiman c. fuscus* are currently limited by national legislation to captive-bred specimens from nationally registered farms. Concerns by Colombia about the laundering of wild skins through farms led to national regulations in 2007 requiring all captive-bred hatchlings to be scute-clipped at hatching. At the time of culling, the skins of these animals bear a scar (Fig. 5), indicating their origin as captive-bred (see CITES Notification No. 2014/033 of 24 July 2014; CITES 2015). Skins where scutes have been cut post-mortem are readily identifiable (A. Larierra, pers. comm., 2015).

Figure 5. Crust-tanned *Caiman c. fuscus* skin showing a "scar" caused by the removal of a single vertical tail scute at the time of hatching. Photographs: Charlie Manolis.

5.2. Radio Frequency Identification (RFID) or Passive Integrated Transponder (PIT) tags, inserted under the skin or into the muscle, are also used to identify stock, particularly adult breeders. Reading RFID/PIT tags (and identifying the animal) requires a scanner (Fig. 6) that must be held close to the skin, while the animal is out of the water. Getting close enough to scan a RFID/PIT tag can pose difficulties in situations where crocodilians are not restrained.

Figure 6. Two types of scanners used to read PIT tags. Photographs: John Calderon (left), Samuel Martin (right).

The site of injection of a RFID/PIT tag affects the probability that it will move as the animal grows, and the neck and tail (Fig. 7) are considered the best sites. The last third of the tail allows the PIT tag to be scanned at a safer distance from the mouth for unrestrained animals. In Colombia, all captive adult *Caiman crocodilus* (>80,000) must have a PIT tag inserted under the neck scutes. Others recommend the tag be placed in the foreleg (Fig. 7), as the crocodilian foreleg has two natural constrictions (ankle and knee) that limit tag migration.

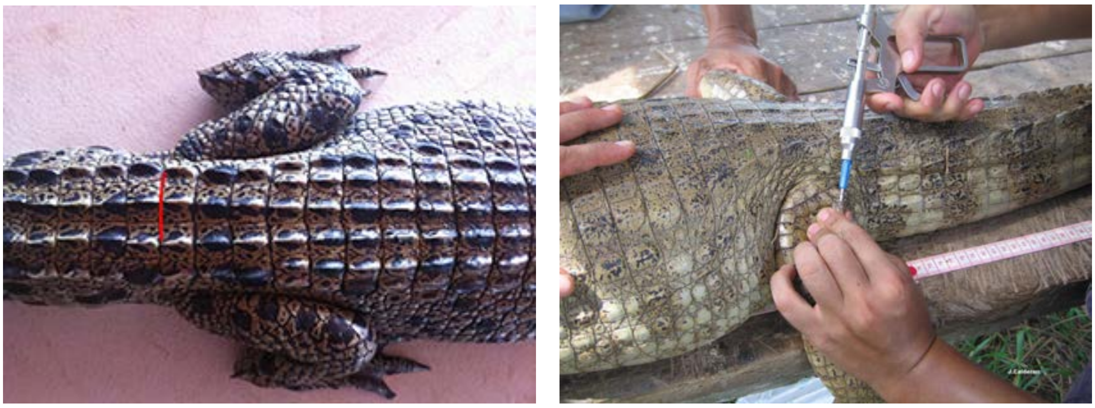

Figure 7. Left - Site of injection (interscalar area lining up with back of legs) of PIT tags for juvenile and adult *C. porosus* at one farm in Australia; Right - PIT tag being injected under the skin of the hindlimb of a caiman. Photographs: Charlie Manolis (left), John Calderon (right).

Reagan *et al.* (2002) evaluated the effectiveness of PIT tags for marking and identifying wild American alligators. PIT tags have limited utility for regular identification of individuals in large enclosures, where it may not be possible to approach individual animals. Yet they may be adequate for identifying individuals during inventories, or when adults are culled and their skins enter trade. PIT tags can sometimes be pushed back out of the insertion hole and lost soon after insertion, although this can be avoided by using dental cement or other adhesives (eg Superglue) to seal the “entry hole”. Care must be taken to locate and remove the PIT tag if the meat is to be used for human consumption. The use of anti-migration additives may assist in preventing/reducing migration of PIT tags as animals grow (eg Kaimmer *et al.* 2012).

5.3. Numbered livestock tags (usually cattle ear tags) attached to the vertical tail scutes provide a visible, practical and cost-effective form of identification (Fig. 8). These can be easier to read, but have a higher probability of being lost during social interactions, and are thus more suited to short-term rather than long-term identification. Their use on Colombian caiman farms was discontinued, as most tags were lost within 5 years (S. Medrano-Bitar, pers. comm. 2015). Application of this type of tag requires a hole to be made in the scute (eg with an electric drill).

Figure 8. Numbered plastic tags applied to the single (left) and double (right) vertical tail scutes of adult *C. siamensis* in Vietnam. Photographs: Charlie Manolis.

5.4. Webbing tags are a highly effective method for marking crocodilians (Fig. 9). They are relatively easy to apply and are available in different sizes for different sized individuals. However, as tag loss does occur, duplicate webbing tags, with the same number, are often placed on both rear feet. The smallest webbing tags may become difficult to read over time or be lost as the animal grows. A small tag that is applied to a hatchling is unlikely to be suitable for a large juvenile or adult, although this has been reported to occur from time to time. Although materials from which webbing tags are manufactured (eg monel, titanium) are supposedly resistant to rusting, some agencies have noted rusting as a problem.

Figure 9. Webbing tags used to identify *Alligator mississippiensis* (left) and *Crocodylus porosus* (right). Photographs: Ruth Elsey (left), Charlie Manolis (right).

6. Eggs

6.1. Collection

Most crocodilian species have the capacity to guard their nest aggressively (eg *C. acutus*, *C. niloticus*, *C. porosus*, *C. rhombifer*, *C. siamensis, A. mississippiensis*), but do not always do so. There is thus a potential risk of injury to egg collectors (eg see http://www.youtube.com/watch?v=hcmdbyhybRU). Collectors in farms (as in the wild) should ensure no crocodilians are in the vicinity of the nest, and if possible be accompanied by a separate person responsible for guarding and fending off attacks by nesting females (or males).

In the case of *C. porosus* in Australia, attacks by nesting females can be blocked using a stout pole (around 5 cm diameter, 2.0-2.5 m in length), and often a boat oar is used. Females can usually be encouraged to leave the nest area by delivering a sharp tap to the head, which is thick-boned and not injury prone (NRMMC 2009).

In small enclosures, the female (and male) may need to be tethered, using a snout rope, while eggs are collected. The use of sliding doors on "breeding stalls" allows *C. siamensis* and *C. porosus* eggs to be collected in safety on farms in Cambodia, Thailand, Malaysia and Vietnam.

When it is safe to remove eggs from a nest, the following general procedures should be considered:

a. Recording of temperature around the eggs can provide valuable information of the conditions experienced by the eggs prior to collection (Webb and Cooper-Preston 1989; Webb and Manolis 1991), which can sometimes help explain embryo morality and abnormalities due to high temperatures. Temperature can be measured using a mercury/alcohol thermometer or electronic sensor – ideally, thermometers and temperature probes should be calibrated against a standard thermometer, so that temperature readings can be adjusted to "real" temperatures.

b. Eggs should ideally be marked on the uppermost surface (where the embryo will be positioned inside the egg) using a pencil or non-toxic marker as the eggs sit in the nest before being removed.

c. Eggs should not be rotated as they are removed, but rather maintained with the marked surface uppermost. They should be laid in a horizontal position in the collection crate/box (see c. below), with the marked surface uppermost.

d. Damp nest vegetation, hay, vermiculite, sand or other materials can be used to pack eggs in the transport container, to restrict rolling or rotation, prevent dehydration and increase thermal stability en route to the incubator.

e. Where several nests are being transported in one container, clutches should be separated in some way (eg a layer of vegetation), or marked so they can be identified before processing (eg "x" on the egg instead of a "-").

f. Eggs should not be exposed to conditions that will lead to egg temperatures higher than 33°C. Lower temperatures for short periods are not as critical, but temperatures should ideally be kept above 24°C.

g. Rotation of young eggs containing small embryos (<2 weeks old) is more likely to lead to embryo mortality than rotation of older eggs (>2 weeks old) (Webb *et al.* 1987).

h. Late-term embryos (last 50% of incubation) have greatly increased metabolic needs and if eggs need to be held in containers for long periods (eg >5 hours), adequate ventilation is needed to allow gas exchange between the embryos and the environment (through pores in the eggshell).

i. Typically, all eggs within a nest, or all eggs that appear "live" within a nest, are collected (ie dead and/or infertile eggs may be left in the nest). In some cases, wild nests may be partially harvested, in the belief that the impact of the harvest on the population will be less if nesting females are left with some eggs. However, there is no evidence that this is the case (Jenkins *et al.* 2006), and partial clutch harvesting may result in increased predation, through females abandoning a nest and/or exposing scents from the eggs that predators detect.

6.2. Transport

a. Eggs can generally be transported at any stage of development. However, mechanical injury through rough-handling or jolting should be avoided, particularly if eggs are between 8 and 16 days of age (when embryos are delicately attached to the eggshell and can be easily dislodged; Fig. 10) (Bock *et al.* 2004) or close to hatching (as mechanical stimulation may cause premature hatching).

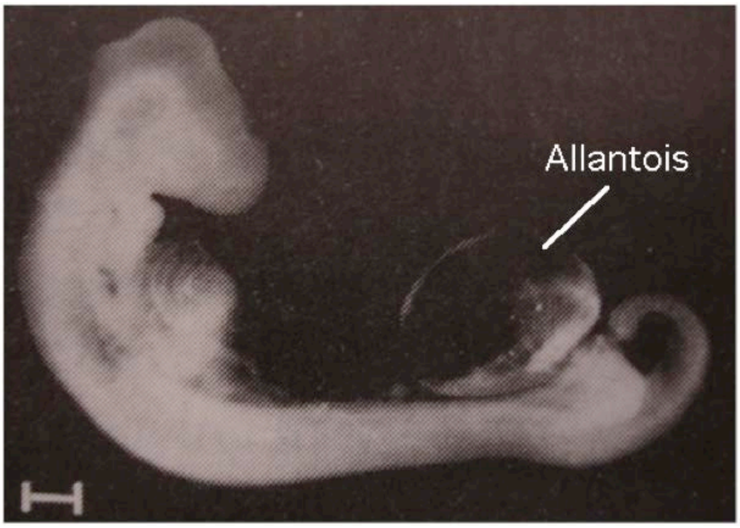

Figure 10. Crocodilian embryo at around 10 days of age (at 30^{o}C incubation), showing the newly-formed allantois. This membrane will eventually cover the inside of the egg, and serve as the "lung" for the developing embryo. From Ferguson (1987).

b. As stated above, eggs should not be exposed to hot (>33^{o}C) or cold (<24^{o}C) temperatures for extended periods during transport.

c. Ranched eggs may be held in transport containers for long periods of time (eg Piña *et al.* 2007), as long as they are not subjected to sub-optimal conditions that may result in dehydration, overheating or inadequate gas exchange.

6.3. Processing

The degree of egg processing varies from establishment to establishment. In some cases eggs are incubated in the same containers in which they are collected, without inspection. In other cases, eggs are individually inspected before incubation, to remove dead and infertile eggs, and/or other contaminants. Where close inspection of eggs takes place the following procedures are recommended:

a. Eggs are removed from the collection crates and washed (keeping the "marked" surface uppermost) in clean water (26-32^{o}C), to remove contaminants (eg nest material, mucous, mud), before laying them horizontally for inspection (with the marked upper surface maintained upward). Eggs may be dipped or sprayed with disinfectant (eg F10SC Veterinary Disinfectant, 1:500 dilution) prior to placement in the incubator.

b. If egg size is to be measured (length, width and/or weight), then it should be done with eggs maintained in the horizontal plane, taking care not to rotate the egg.

c. Infertile eggs can be identified with 100% accuracy by candling (bright light source shone from behind the egg to show detail through the shell), which allows the absence of subembryonic fluid to be ascertained (Webb *et al.* 1987), and they can be removed. If staff are unsure about detecting infertile eggs by this method, the eggs can be left in the incubator for around 2 days, by which time live fertile eggs can be identified by the formation of the opaque band by that time. In mound-nesting species the eggshell may sometimes be stained by the nest vegetation, making the opaque band a little more difficult to see.

d. Individual eggs that have died before collection can sometimes be identified by comparing the stage of development of the opaque band with eggs from the same clutch (Webb *et al.* 1987). If the majority of eggs has reached a certain stage of opaque band development, those that have not reached that stage are usually dead and can be removed (as they are a source of bacterial contamination). Opaque band development, together with visual assessment by candling of the colour of the albumen in the unbanded translucent poles of the egg can be used to discern dead from live eggs within a clutch. The colour reflects the extent of vascularization of the allantoic membrane.

e. Removal of dead eggs at the time of processing, and before eggs are placed in the incubator, helps prevent flies or other insects being attracted to the incubator. These can be detrimental to developing eggs and hatchlings (Manolis and Webb 1991).

f. Rough handling or jolting of eggs during processing needs to be avoided (see 6.2.a above).

g. Eggs should not be exposed to hot (>33^{o}C) or cold (<24^{o}C) temperatures for long periods during processing.

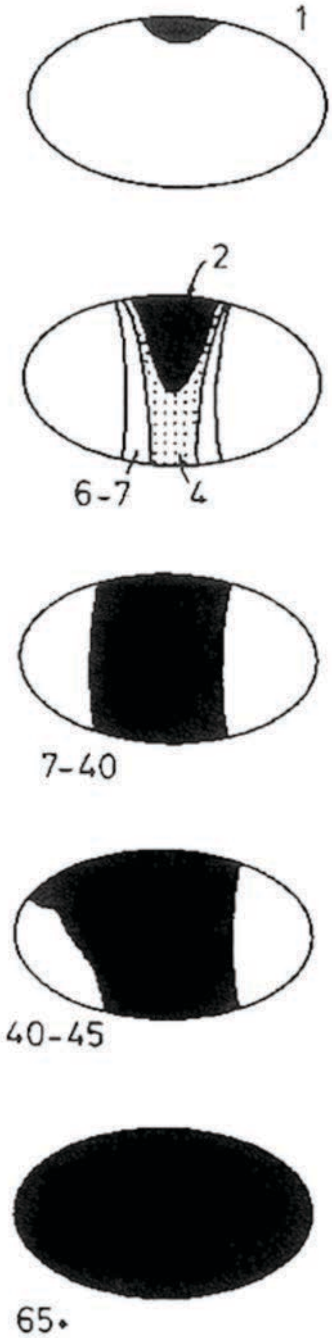

Figure 11. Opaque banding of crocodilian eggs. Numbers indicate approximate days of incubation at 30^{o}C for *C. porosus* (hatching at 90 days); 1 d = spot; 2 d = incomplete band (5/10 in this case); 4 d = just complete; 6-7 d = complete and expanding band; 7-40 d = even band; 40-45 d = band spreading to one end; 65+ d = band completely opaque.

6.4. Incubation

Crocodilian egg incubators vary in design and operation, and issues such as stability of electricity supply, numbers of eggs being incubated, and the ability to control temperature, moisture and gas exchange, all need to be considered when choosing the most appropriate incubation method in any given context. The incubation environment in terms of temperature, humidity, oxygen supply and removal of carbon dioxide remain critical to incubation success.

a. Egg temperature, rather than the temperature at some place in the incubator, dictates embryonic development rate and should ideally be in the 31-33^{o}C range – but should not exceed 33^{o}C.

b. The effects of variable temperatures in incubators that are more exposed to ambient conditions (ie say 28-33^{o}C versus 31-33^{o}C) are not well understood with any crocodilian species and some evidence indicates they may be advantageous to hatchling fitness in some species, for example *C. johnstoni* (Webb *et al*. 1992).

c. Where temperature, moisture and gas exchange can be controlled precisely, eggs can be incubated on open racks, without nesting media. Where precise temperature control is not possible, eggs should be packed in a moist medium [eg nest vegetation, sand, vermiculite (Medrano-Bitar and Calderon-Mateus 2008)] to buffer them against temperature and moisture extremes.

d. Where eggs are incubated on open racks (ie without any moist media), humidity at the level of the eggs needs to be 99+%, with no free water on the eggs.

e. Oxygen levels can be maintained, and carbon dioxide removed, by either pumping moist air into the incubator, or by ensuring the packing medium in which eggs are packed is sufficiently porous to allow gas exchange. Gas exchange requirements are determined by embryo size. During the early stages of incubation embryos are small and require relatively little oxygen, but oxygen demand increases exponentially as the embryo grows (Whitehead 1987).

f. Swelling of eggs, often in the last trimester of incubation, indicates the incubation environment is too wet. Changing the nesting medium or decreasing humidity and/or reducing free water in the incubator is the appropriate action.

g. The appearance of air spaces under the eggshell indicates the incubation environment is too dry, and so wetting of the nesting medium or increasing humidity in the incubator is required.

h. Regular inspection of eggs throughout the incubation period is recommended, because it allows identification and removal of dead eggs, and can assist in maintaining a more hygienic incubation environment (eg control of flies; Manolis and Webb 1991). However, in some types of incubators the eggs are buried in different types of media, which compromises regular inspection.

i. Hatching success (defined as the proportion of live eggs incubated that produce healthy, viable hatchlings) should exceed 80%. In cases where wild-collected eggs are incubated without inspection, hatchling success is usually reduced due to infertile eggs, or eggs containing dead or compromised embryos being included (Webb and Cooper-Preston 1989).

j. Low hatching success (of all eggs incubated) can reflect poor quality eggs (a captive-breeding problem), or poor quality incubation (an incubation problem) (eg Webb and Manolis 1991; Webb and Cooper-Preston 1989). A reasonable degree of egg inspection is required to discern between these two issues and ultimately solve problems.

6.5. Hatching

a. The first hatchlings from a clutch should be checked to determine whether the residual yolk has been withdrawn completely into the body cavity. If not, the remaining eggs should be left undisturbed until yolk internalization is complete. In some cases the first hatchlings to emerge may cause the hatching of others where the yolk is not fully internalized – the latter may be left in the incubation container to allow complete internalization.

b. If the yolk is internalized normally, and incubation conditions have been identical for all eggs, the remainder of the clutch should be at the same stage of development and can be opened by hand. Some hatchlings have difficulty pipping and/or emerging from the egg, which in the wild, is often aided by the adult female mouthing the eggs.

c. If the incubation temperatures are more variable, and there are temperature gradients across a clutch, then some individuals may indeed be a few days more advanced than others. If so, more caution is required when attempting to assist the hatching process. Unhatched eggs in a clutch that has begun hatching are best left in the incubator for a few more days.

d. Immediately after hatching, hatchlings can be washed with clean water (28-32^{o}C) and/or a mild (diluted) disinfectant (eg F10SC; Huchzermeyer 2003).

e. With normal development, the umbilical scar should be reasonably narrow and if still raw looking, can be disinfected with chlorine or iodine solution. Wide umbilical scars, invariably in hatchlings with abundant internalised yolk, with a bump on the cranial platform, are not "premature". They are individuals whose incubation environment has been compromised during the last half of incubation (when embryo growth rates are high), and the embryo has responded by hastening development to try hatch as soon as possible rather than die in the egg.

f. Weak or deformed hatchlings generally have a low chance of survival and are usually euthanized (see Section 12). If large numbers of deformed hatchlings are produced, incubation conditions are usually inadequate. As embryos are reasonably well advanced at the time of laying, spinal and tail injuries can sometimes reflect the conditions females were exposed to just before laying, or the temperatures in the nest at the time of laying: nests made from high energy grasses in captivity can be very hot, either killing embryos or creating deformities within the first few hours after laying.

g. With some species, clutches of eggs/hatchlings that are "chirping" are removed from the incubator, because it is claimed that they cause premature hatching of other clutches of eggs in the incubator, with younger embryos. It does not appear to be a problem with most species.

7. Husbandry

7.1. Science-based Animal Welfare

In their natural state in the wild, crocodilians inflict serious injuries on each other, and although they have remarkable healing abilities, perhaps linked to antibiotics in their blood (eg Merchant *et al.* 2003), most wild adults are battle-scarred, often with amputations of the limbs, snout or tail (Webb and Messel 1977; Webb and Manolis 1983). The thick skin and heavy armour, with cutaneous osteoderms, have probably evolved to counter these conspecific battles.

In captive farm environments, husbandry practices are highly effective at reducing conspecific conflict. They have to be, to produce skins that are not damaged by bites and scars. Husbandry techniques are continually evolving to ensure animals are maintained in good health. There are clearly advantages in paying attention to animal welfare – the prevention of undue pain or suffering within a particular husbandry context. The context is clearly important, because the housing of small numbers of individuals, as pets or exclusively for public exhibition purposes, is quite different to the housing of large numbers of individuals, in higher densities, within a commercial farm environment.

There are four major approaches to assessing science-based animal welfare and for detecting potential problems in a farm environment. All rely on inference and assumptions that are difficult to test objectively:

a. *Anatomical and Physiological Assumptions*. With issues such as culling and euthanasia (see Section 12), accepted ways of reducing pain and suffering are based on widely accepted scientific assumptions. If the brain is shocked and destroyed rapidly, the animal dies instantly and cannot "feel" any pain, even though various body movements may continue after death, due to spontaneous muscle spasms within tissues.

b. *Health Correlations.* It is normally assumed that animal welfare is not being compromised if the health of farm animals is being maintained at high levels, as indicated by:

    i. <u>Body condition</u> can be assessed visually by inspecting the neck, abdomen and base of the tail. A crocodilian in good condition will have sufficient fat stores that these three sites are rounded and not sunken. The ratio of body weight to length is an index of body condition that can be used to quantify the relative condition of individuals of different lengths.

    ii. <u>Growth rates and size,</u> after a period of raising, approximating a normal distribution and not being strongly bimodal. When one group of individuals in a pen are growing very rapidly, it may be at the expense of others in the same pen that are growing very slowly or losing weight, due to social problems.

    iii. <u>Survival rates</u> are at acceptable levels for a particular species. This can be assessed by comparing survival rates for the same species on other farms. If unavailable, information on closely related species may be a guide. Poor survival rates can be linked to various known factors, such as incubation conditions, disease, injury, inappropriate husbandry, or genetics (Isberg *et al.* 2009).

    iv. <u>Frequency of injuries</u> inflicted on each other by conspecifics is low. A high incidence can indicate inadequate stocking rates and food access is low, which has direct implications on skin quality.

    v. <u>Disease incidence</u> is low, and its impact on health, growth and survival rates. Disease can represent the effect of pathogens unrelated to husbandry and management, or it can be exacerbated by compromised husbandry and management procedures.

vi. Parasite incidence is low. Like diseases, parasites can impact on health, growth and survival rates (eg pentastomids, ticks), and even if benign to health, can adversely affect skin quality (eg *Paratrichosoma* sp., leeches).

vii. Reproductive performance in terms of the rate of reproduction amongst adult females and the quality of live fertilised eggs produced are important indices of good health, husbandry and the species-specific adequacy of different housing strategies.

c. *Biochemical Indicators* such as comparative corticosterone levels are an indicator of stress (Elsey *et al.* 1990a,b; Turton *et al.* 1997; Franklin *et al*. 2003; Isberg *et al*. 2009, 2013; Finger *et al.* 2015).

d. *Behavioural Observation and Stimulus Response* are the two most common mechanisms used to indicate whether animals are healthy and behaving normally. Piling, 'stargazing', distress calls, anorexia, hydrophobia, dehydration, excessive lithophagy and dilated pupils are behavioural indicators that health may be compromised, and management interventions may be necessary. Providing adequate thermoregulatory resources (exposed and covered areas, cool versus warm areas), management practices (stocking density, size-grading, cleaning and feeding techniques, excessive handling), and reducing shock factors (unpredictable noises and/or visual stimuli) appear to reduce "stress" and favour good health.

Over and above genuine concerns about animal welfare, the media is often used to promote information that is a deliberate manipulation of factual evidence. There are organisations and individuals totally opposed to animal farming, and they use *emotion-based animal welfare* concerns to win support for their positions from the public. Filming post-mortem movements of crocodilians, and falsely implying that they are being skinned alive, is a reasonably common occurrence. There is thus a class of contrived *emotion-based animal welfare* concerns, best countered by *science-based animal welfare* evidence.

7.2. General Considerations

Husbandry strategies for different aged and sized crocodilians have evolved separately in different farms and for different species, and there is no single raising strategy that can be considered ideal for all species in all contexts. Innovation, research and experimentation are major drivers of adaptation of farm technology, and the changing demand for high quality skins in recent years is stimulating new research on husbandry practices around the world. Nevertheless, there are some fundamental principles that can be applied to most, if not all, species.

a. Good incubation and hatchling treatment (see Section 6): Incubation conditions influence post-hatching growth and survival, and impact on raising success (eg Hutton, 1987; Joanen and McNease 1987a; Webb and Cooper-Preston 1989).

b. Initiation of hatchling feeding: After hatching, some farms initiate feeding immediately whereas others maintain hatchlings in the incubator for 2 to 7 days before feeding starts - it is thought to stimulate yolk utilization, but allows seriously compromised hatchlings to be detected. It remains unclear whether real advantages are accrued from either strategy, although neither strategy appears harmful. Some farms place individuals that have not started feeding readily, with individuals that have started, to stimulate them.

c. Treatment of hatchlings in the first few weeks of life, after feeding is initiated, is critical to their performance. Failure to Thrive (FTT), leading to 'runtism', is a common problem with some species in some raising contexts. It can be detected within a few weeks, by declining body condition (Brien *et al*. 2014), giving the option of applying different management interventions.

d. Foods and Feeding

   i. Hatchling diets vary greatly across different farms and different species, and the hatchlings of some species appear more diverse in their food preferences than others. Minced or finely diced red meat, abattoir offal, discarded carcases from intensive animal farming (eg pigs, chickens) or fish with vitamin and mineral (including calcium and phosphorus) supplements, are commonly used. Small vertebrates (eg fish, frogs) and invertebrates (eg crickets) are used in some countries, often to initiate feeding (see later).

   The hatchlings of some species demonstrate preferences for different types of meat, and there appear to be clutch-specific elements of those preferences (Webb *et al*. 1990). Growth rates may vary depending on the type of diet: eg fish versus red meat (Joanen and McNease 1987b).

   Alligator farms in the USA typically feed hatchlings dry, pelletized feed made from fish and poultry by-products, as well as extruded corn and soybeans (Staton *et al.* 1990). The advantages of dry feed are that it can be stored for longer periods without refrigeration, comes with the proper nutrient supplement, and weighs about 20% of that of wet meat, thus saving on electricity for storage and fuel and labor for transportation and handling. Pelletized food has been used in *C. niloticus* farms in South Africa (Shipton and Hecht 2005) and Zimbabwe. However, pelletized feeds are not available in many parts of the world and some species of crocodilians (eg *C. porosus*) do not readily eat it (Isberg 2007).

   ii. Hatchlings are usually fed daily in the immediate post-hatching period, and for some species this rate of feeding may be maintained for much of the first year (C. Foggin, pers. comm., 2015), or reduced to 4-5 days per week depending on size. Older stock are typically fed less frequently (eg 2-4 times per week).

   iii. As crocodilians increase in size, the size of food particles can be increased (eg minced or finely diced feed for hatchlings versus larger chunks for juveniles), although the ability to eat smaller particles may not be lost in some species. Dry pelletized feed can be fed to juveniles as well, if available and the species accepts it. An additional consideration is the loss/wastage of finely diced food and fouling of pens and water by uneaten food.

   iv. Adults may only require feeding every 1 to 2 weeks, and frequency of feeding is best determined by assessment of body condition. Females that are overweight may have reduced clutches, which is thought to be linked to the available abdominal space becoming partly filled with fat, but lower reproductive success may also be linked to the effects of obesity on the female's reproductive physiology.

v. Nutritional deficiencies and imbalances can occur if the diet does not provide the basic nutrients required, and will be reflected in reduced growth and survival rates. Crocodilians have the ability to convert a high proportion of their food (animal protein) into body weight (Joanen and McNease 1987b; Staton *et al.* 1990; Webb *et al*. 1991, 2013). Sources of high protein food are sometimes difficult to access in developing countries, due to competition with the needs of the human population. There are significant differences between species with regard to food preferences, including the acceptance of formulated rations (Manolis 1994) and the ability to assimilate vegetable proteins (Staton *et al.* 1990; Reigh and Williams 2013; Webb *et al*. 2013; Tracy *et al*. 2015).

vi. Calcium supplementation is mandatory if bone is not included in the diet. Red meat in particular is high in phosphorus and unless calcium is provided, spongy bone syndrome (rickets) will occur. Where crocodilians are kept out of direct sunlight, a supplementary source of vitamin D_3 (cholecalciferol) is needed to assist with calcium homeostasis.

vii. Storage, wholesomeness and hygiene of preparation of non-formulated diets is an important element to consider. Source of feed is an important consideration, particularly where there is the potential for biological and/or chemical contamination (eg chicken carcases).

e. Metabolic Rate and Temperature. Under optimum raising conditions, with adequate temperatures, hatchlings have high metabolic rates, high food requirements, and they grow rapidly (eg Lang 1987a; Piña and Larriera 2002). However, maintaining high metabolic rate in hatchlings of some species, through constant high temperatures (32°C), may lead to rapid weight loss if feeding ceases (catabolism). A very high proportion of food eaten by hatchlings is probably allocated to maintenance rather than growth (Webb *et al*. 2013). In countries with "cold" winters (eg USA), crocodilians are grown very successfully in heated sheds, but not all species appear to require or can tolerate high and constant temperatures. Some require a mosaic of temperatures, where they can spend part of, rather than the whole day with body temperatures in the 30-33°C range.

f. Sub-optimal Temperatures (eg <25°C), particularly with young (small) animals, can lead to physiological problems (eg uric acid in the kidneys), disease (through decreased immunity), reduced growth rates and increased mortality. Within this context the effect of air temperature and humidity, relative to substrate and water temperatures, remains unclear.

g. Effects of Hatchling Size on Growth. Egg size can vary considerably (by 100%) between clutches, and it determines hatchling size. In some species initial hatchling size is a poor predictor of growth rates to one year of age (Isberg *et al.* 2005), because smaller hatchlings grow faster relative to larger ones (Brien *et al*. 2014).

h. Effects of Sex on Growth. Males grow faster than females but sex-specific growth rates under optimum conditions in captivity are often not apparent until after one year (Joanen and McNease 1987a; Webb and Cooper-Preston 1989). In a production setting, and depending on the size of skin being produced, sex-specific difference in growth rate may or may not be a significant factor (Isberg *et al.* 2005).

i. Growth, Survival and Age to Slaughter. The economic success of a farm depends to a large degree on the interplay between growth rates, survival rates and time to slaughter, which is itself dictated by market demand for skins of different sizes, for the manufacture of specific products. If well-fed, stress-free and raised under optimal temperature conditions, crocodilians achieve higher grow rates in controlled farming environments than when living in the wild, and sometimes spectacularly so (Joanen and McNease 1987b).

j. Species Effects on Growth Rates. The size of skin that different crocodilian species can produce in a commercially viable way is dictated to a large degree by species specific variation in the average size of full-grown adults. For example, adult male *C. porosus* are mostly within the range 4.5 to 5.2 m, and a 2 m long animal can be achieved in 3-4 years in Australia. By way of contrast, adult male *C. johnstoni* are mostly in the range 2.0 to 2.4 m, and a length of only 1.2 m can be achieved in 3-4 years.

k. Disease. Outbreaks of disease are problematic on most farms from time to time, and can cause high mortality rates (eg Foggin 1987; Ladds and Donovan 1989; Buenviaje *et al.* 1994; Huchzermeyer 2003; Jerrett *et al.* 2008; C. Shilton, pers. comm., 2015). Access to veterinary assistance and information specific to crocodilian diseases is clearly important. Disease outbreaks are sometimes indicative of poor husbandry practices (eg high density, inadequate mineral/vitamins, social factors, sub-optimal temperatures, inadequate hygiene), in which treatment of disease symptoms does not necessarily address the primary problem. Use of antibiotics should be prescribed by qualified people (eg veterinarians) to reduce antimicrobial resistance (AMR), which may cause problems for crocodilians, humans and the environment.

   Implementation of biosecurity practices is increasingly being recognised as an important safeguard in the prevention and spread of diseases on crocodilian farms. However, there are clearly problems implementing high biosecurity practices in low-technology farms producing crocodilians with relatively low value skins.

   Some bacteria and parasites are ubiquitous in wild crocodilian populations (Webb and Manolis 1983), and do not appear to affect the health of the animals, but can impact seriously on skin quality (eg *Paratrichosoma* sp., *Dermotophilus* sp.). Like many other animals, especially poultry, some pathogens carried by crocodilians present zoonotic disease potential for humans (eg *Salmonella*, *Trichinella*).

l. Teeth clipping. The teeth of juvenile crocodiles are deeply embedded in the jawbone, with only the exterior third, enamelled and protruding. Despite a large number of teeth of different sizes and shapes (Iordansky 1973), the longest teeth, with the sharpest tips, are at the front, on both sides of the upper and lower jaws. In addition to playing a key role in capturing and pinning live prey in the wild, they are the teeth that inflict most injuries on other crocodiles during agnostic encounters with each other. In commercial farming, where the need to catch live prey no longer exists, and where these teeth are responsible for most bite and rake marks on other crocodiles, various experiments have been undertaken on capping or clipping the sharp tips of these front teeth. In the few countries where clipping does take place, it is recommended (CFAZ 2012), that it be done when the animals are immobilized, and that it not be extended into the pulp cavity without analgesia and veterinary supervision.

7.3. Housing and Management

The types of housing employed in crocodilian farms, for different species, in different national and climatic contexts, are immensely variable. However, within all individual farms, housing and management varies with purpose (eg hatchling raising, juvenile raising, captive breeding) and the primary market product (eg meat, large or small skins). All facilities to house crocodilians represent a compromise between what may be considered optimal conditions for the animals versus the safety and time required by workers to manage the animals. This in turn is affected by the costs of labour, which vary considerably across the spectrum of countries involved in crocodilian farming. There is no single approach that constitutes best management practice for housing in all contexts, and it is not possible here to be highly prescriptive regarding structures and processes. However, all crocodilian enclosure designs should aim to provide the five "freedoms" (see Preface).

For the purposes of hatchling production, the aims and goals globally are similar: to maximise survival and growth rates. But for the purposes of growing juveniles, there are significant differences between whether skin or meat production is the main goal. For meat production, minor abrasions, bite marks or minor cuts in the skin may be inconsequential - indeed, the skin is often considered worthless and may be cooked with the meat. However, where skin production is the main goal, any blemish on the skin is a problem, reducing skin value and increasing the probability of skins being downgraded or rejected in the marketplace. Hence a great deal more effort, expense and research goes into pen design when skin production is the main goal, especially where larger skins are needed and growing time is extended accordingly.

Housing requirements within farming operations may be subject to State/Provincial and/or national legislation, regardless of whether they are up-to-date and consistent with the latest insights into optimal housing conditions or not.

In any overview, the maintenance of "good health", as determined by the procedures outlined for assessing science-based animal welfare (Section 7), provides the best index for assessing the merits of specific housing strategies.

Blemishes on the skin have commercial consequences, but do not in themselves indicate a welfare or animal production problem. For example, 80+% of wild *C. johnstoni* over 1.3 m TL have scars and parasite trails on the skin (Webb and Manolis 1983), as do 80+% of wild *C. porosus* over 3.0 m TL (Webb and Messel 1987).

Despite verification of best management practice only being achievable through objective testing, the checklist of factors below, drawn largely from NRMMC (2009), provides some guidance:

a. <u>Water sources</u> should ideally be fresh rather than saline, although opportunistic exposure to salt water may be used to control some pathogens. Some species are more tolerant to saline conditions than others, but a freshwater supply is needed for drinking if high salinities (>17 parts per thousand of salt) occur. Very high salinities will occur if evaporative losses from saline water are replaced with more saline water. The use of untreated water taken from a source in which wild free-ranging crocodilians occur may present a problem for farm stocks, through the transmission of parasites or other pathogens.

b. Water depth should be sufficient to allow animals to submerge completely and deep enough to allow thermal stratification if high surface temperatures (>34^{o}C) occur and animals cannot leave the water for cooler places.

c. Water area substrates should ideally be sealed (impervious to water), and where appropriate, resistant to burrowing activities likely to damage skins, cause mortality through entrapment, lead to escapes or become a breeding ground for pathogens. For skin production, surfaces should ideally be smooth and non-abrasive.

d. Emergent areas (land or floating platforms) should be provided unless circumstances confirm they are not needed in a particular context. It may be beneficial for crocodilians, or at least some species, to have the option to periodically "dry out", in order to reduce fungal and bacterial diseases, potentially associated with a constantly wet environment. Land areas need to be sufficient for feeding and basking, and for skin production, they should have non-abrasive surfaces and be sufficiently large to avoid crowding.

e. Entry/exit steps or slopes into and out of the water should facilitate easy transition. For skin production they should be free of rough surfaces likely to erode the belly scales and be of sufficient size that every individual can thermoregulate without crowding and associated social interactions that may damage the skin. Shallow water areas adjacent to exit areas make it easier to exit and give another option for crocodilians to use in thermoregulation.

f. Water area should be sufficient to allow normal behaviour and promote good health, and for skin production, to avoid excessive crowding that may lead to agonistic social interactions.

g. Water temperature should be sufficient to promote good health, and may include artificial heating during cooler periods in different climates.

h. Water clarity, despite its aesthetic desirability, may not contribute as significantly to good health as turbid waters. This may be particularly true for species that seek refuge in water to hide, or which utilize thermal stratification. Conversely, clear water assists management (being able to see crocodilians underwater) and may be a consequence of water treatment aimed at minimizing disease.

i. Water quality in terms of pollutants should be monitored and controlled so that it does not compromise the promotion of good health. For skin production, good water quality (including water treatment) is considered beneficial to combat some pathogens that can damage the skin. Generally, the build-up of biological wastes promotes pathogens that can lead to mortalities, particularly in younger stock.

j. 'Ecosystem-type' ponds for crocodilians are aesthetically pleasing, but the fish and shrimps within them are intermediate hosts for a range of parasites, some of which (eg pentastomids, flukes) can cause significant health problems and mortality of crocodilians. Landscaping with rocks and logs can also damage skins.

k. Land temperature can be controlled by adjusting the proportion of land area that is exposed versus shaded, or through artificial heating. The type and extent of land temperature control will vary between facilities, and depend on prevailing climatic conditions. Best practice is the approach that sustains good health and promotes or sustains feeding and growth.

l. Optimal densities vary for different sized crocodilians, of different species, being raised for different purposes, in different types of raising pen. Managers should review available research literature for guidelines to establish initial densities, and modify them following experimentation, and depending on the resulting health, growth rates and skin quality of stock.

m. Density guidelines available in various documents for communal pens are at best broad indicators, and do not necessarily represent best management practice across all species. Nevertheless, they provide starting points for assessment.

   For *C. porosus*, considered to be one of the most aggressive species of crocodilian with the least tolerance of conspecifics (Lang 1987b), NRMMC (2009) recommends minimum densities of:

Hatchlings	10-15 ind./m^2	0.10 to 0.07 m^2 per individual
Raising stock at 1 m	2 to 4 ind./m^2	0.5 to 0.25 m^2 per individual
Raising stock at 2 m	0.5 to 1 ind./m^2	2 to 1 m^2 per individual

   For *C. niloticus* in Zimbabwe, CFAZ (2012) recommends densities of:

Hatchlings (first few months)	<15 ind./m^2	>0.07 m^2 per individual
Raising stock at 1-1.5 m	2 to 4 ind./m^2	0.5 to 0.25 m^2 per individual
Raising stock at 1.5-2 m	1 to 2 ind./m^2	1 to 0.5 m^2 per individual

   For *A. mississippiensis* in Louisiana, USA, LDWF and SVM-LSU 2016 (2016) recommend minimum densities of:

Raising stock (<0.6 m long)	<11.1 ind./m^2	>0.09 m^2 per individual
Raising stock at 0.6-1.2 m	3.7 ind./m^2	0.27 m^2 per individual
Raising stock at >1.2-1.35 m	2.8 ind./m^2	0.36 m^2 per individual
Raising stock at >1.35-1.5 m	2.2 ind./m^2	0.45 m^2 per individual

   Raising stock >1.5 m – add 0.09 m^2 per individual for every 0.15 m above 1.5 m TL

   Huchzermeyer (2003) provides detailed guidelines about *C. niloticus* as well as general guidelines for all crocodilians.

n. Density assessments need to account for the uneven utilization of different spaces within an enclosure, which can change throughout the day and night (eg when animals congregate while feeding or basking on land, in water, or when seeking security under hide structures). The way in which crocodilians use pen space often results in a mosaic of densities within an enclosure. Although conventionally measured in terms of surface area, it is likely that deep (2-3 m) versus shallow (<1 m) water within an enclosure should also be considered in density calculations.

o. Density and social behaviour are intimately linked, more so in some species than others. Agonistic interactions between individuals damage skins (bites and cuts), and thus reducing densities in communal pens may improve skin quality. Against this, agonistic behaviours are not linearly related to density, and may increase in frequency as density is reduced or increased (Brien 2015), again pointing to health assessments as an important tool in defining best practice.

p. Noise is a variable that can adversely affect health, particularly low frequency sounds and vibrations caused by excavation or blasting. Crocodilians respond socially to such stimuli with an upsurge of agonistic behaviours, which can lead to injury or skin damage. Against this, crocodilians may become acclimated to noise through the deliberate provision of background "noise" such as music or radio.

q. Visual stimulation can also adversely affect health, particularly amongst hatchlings adapted to predator avoidance (eg birds flying overhead). However, explosive upsurges of activity in communal raising pens, in response to visual stimulation (eg people, vehicles) increases the risk of animals biting each other. Solid or mesh fences around enclosures, that either shield or expose crocodilians to visual stimuli at ground level, may reduce the probability of crocodilians exhibiting panic responses to visual stimuli.

r. Communal versus individual pens. Tolerance of conspecifics is a species-specific trait in crocodilians (Lang 1987b) that may be apparent from the time of hatching (Brien *et al*. 2013), but which decreases with increasing size and age. Some species avoid conspecifics and rarely congregate in the wild, whereas others congregate in large numbers. Agonistic behaviours, even in hatchlings, reflect these differences (Brien *et al*. 2013). Raising crocodilians singularly, in individual pens of different forms, overcomes agonistic social stresses (Isberg *et al*. 2013) and allows treatment, care and feeding to be monitored and tailored to individuals - which cannot be achieved in communal pens. Avoidance of conspecifics, dominance within a space, no competition for food, and reduced movement, all act synergistically in individual pens to promote good health and growth.

s. Individual pen juvenile designs, structures and concepts vary between locations around the world. All contain water areas of different shapes and sizes, which allow full submergence. They may have an emergent land area for basking and feeding, are enclosed in various ways, and are heated or shaded as appropriate within different climatic regions or seasons. Both fixed solid structures (Isberg *et al*. 2013) and portable mesh enclosures (Webb *et al*. 2013) are used. They all appear to reduce stress and promote good health and healing of injuries if required. Experimental use of individual pens with areas of 1.5 m^2 demonstrably promoted good health in 1.6 m long *C. porosus* (Webb *et al.* 2013); doubling the size of the pen (3.0 m^2) did not improve crocodile health. "Good health" is the primary factor driving adaptation and assessment of pen design and structure.

t. Breeding pens and species-specific traits are intimately linked in captive breeding. In the case of artificial pens, available land area for a farm dictates options for the size of breeding pens. Species-specific traits dictate the number and ratio of adult males and females that can be penned together without compromising survivorship, or promoting social exclusion of individuals from reproduction. It does not automatically follow that larger natural ponds reflect better management practice than smaller ones. With *C. porosus* and *A. mississippiensis* breeding aggregations in larger ponds often have high mortalities, low reproductive success (low numbers of nests and eggs per adult female housed), and low egg fertility rates. Improvements can be obtained in very large ponds (>1 ha), or in smaller pens (10 m x 5 m) containing single pairs, but physical and visual barriers in ponds and on land are important for reducing agonistic behaviour in some species.

u. Breeding pen assessments, aimed at identifying best management practices for a given species, are ideally based on the number of viable hatchlings produced per adult female maintained. Various forms of social stress can reduce successful nesting and egg quality (Elsey *et al.* 1990a), so it is probably reasonable to assume that successful reproductive performance is correlated with reduced social stress. However, other factors such as nutrition and age (maturity) of breeding stock may impact on reproductive performance. An adaptation period may be required for 'new' breeding stock being moved into new facilities.

v. Breeding pen environments need to provide options for the animals to thermoregulate within preferred limits. Caution needs to be exercised that water temperatures do not exceed levels required for healthy development of embryos in the eggs, while they are within the female's body for 3-4 weeks prior to egg-laying. Similarly, sufficient heating must be available to ensure that females can elevate body temperatures above levels that may compromise normal egg/embryo development (>29^{o}C). For mound-nesting species, caution must also be exercised that vegetation available for building nests, whether growing in the pen or provided, is not rich in composting energy, and likely to elevate nest temperatures to lethal limits (>34^{o}C) through the heat of decomposition, at the time of egg-laying. Mound nests made from some energy-rich vegetation can exceed 40^{o}C and kill all embryos within hours of egg-laying. Moving gravid females, with hard-shelled eggs, should only be done in emergencies, and then in ways that do not involve any struggling. The hard-shelled eggs in the oviducts are brittle, easily broken, and the shells can cut the thin-walled oviducts in which they are being held releasing them into the body cavity - which is fatal for the female.

w. Protection from physical abuse by unsupervised visitors, or by inexperienced staff, such as trying to promote movement by poking or hitting with sticks, or throwing rocks, is completely unacceptable.

x. Training and induction of staff engaged in crocodilian farm activities should include the transfer of basic knowledge about reptile husbandry, particularly thermoregulation and the way they regulate body temperature by behavioural means, and the importance of stress-related issues even though they may not be obvious when inspecting animals (see Section 21).

y. Objective, sometimes scientific assessment, of the results of particular housing conditions or management practices is critical to defining and achieving best management practice.

z. Security. Both enclosures and perimeter fencing need to be adequate to prevent escape from, or uncontrolled mixing within a farm. Fencing generally needs to be adequately strong, buried a short distance into the ground (or based on a firm foundation (eg poured concrete) and regularly inspected and maintained. Fencing must be adequately high to prevent crocodilians climbing out, or have an inward projection at the top. Suitable fencing includes chain link, 'diamond' mesh fencing, steel mesh, concrete slabs, bricks or concrete block construction. Fencing of timber, brush, poles or similar native materials is generally inadequate. Despite the best security and fencing, all farms experience occasional escapes and the prudent farmer will develop a response plan to manage escapes, both to recapture valuable stock and maintain good relations with neighbours. Adequate fencing is also an important component of demonstrating stable inventory and legal sources of stock for local regulatory and CITES purposes.

8. Capture and Restraint

The methods of capture used for farmed crocodilians vary with the size of the animal, the capture context and the available expertise (Table 2). Some methods are more effective for some species of crocodilian than others. The safety of handlers must be taken into consideration, and induction and training of staff are essential.

Table 2. Capture methods for different sized crocodilians (Cherkiss *et al.* 2009; CFAZ 2012; NRMMC 2009).

Method	Size (m)	Situation/Notes
Direct		
Tongs	<0.9 m	Around neck
Hand capture	<1.5 m	Around neck; easier and safer if crocodilian is submerged in shallow water
Hand capture (hessian bag)	<1.2 m	Around neck; easier and safer if crocodilian is submerged in shallow and/or clear water
Noose	1.0-1.5 m	Around neck or upper jaw
Rope	>1.5 m	Around upper jaw
Electro-stunning	1.0-2.4 m	Applied to neck
Skin harpoon	1.0-5 m	Tail for <1.2 m long animals; neck for >1.2 m
Nets	>0.5 m	
Treble hook/noose	>1.0 m	Usually around tail or back
Indirect		
Cage trap	>1.5 m	
Snare/baited noose	>2 m	around neck or upper jaw
Baited digestible hook	>1.5 m	ingested

During most captures, crocodilians will struggle, and in doing so may injure themselves, other crocodilians or handlers. Consideration should be given to methods that minimize struggling, and the animal should be restrained or killed (if harvested) as soon as is practical after the initial capture effort.

As a general rule, noise and idle talk by staff during capture and restraint exercises should be minimized. This may reduce the sensory inputs to the crocodilian, possibly reducing stress, but it is important for the welfare of the staff as well - distractions can be dangerous. A single staff member should be put in charge of capture exercises, particularly with large crocodilians, and should be the only individual who talks.

In large individuals (>4.5 m), the build up of lactic acid through excessive struggling can lead to death unless countered with assisted respiration, to clear the lungs of carbon dioxide and to provide oxygen (Seymour *et al.* 1987).

Indirect capture methods such as traps, snares and baited hooks (Table 2) are generally unattended, and should, wherever possible, be established such that captured crocodilians have access to shade or permanent water until they can be recovered.

As soon as possible after capture, the crocodilian's eyes should be covered with suitable material (eg hessian bag, tape) to reduce visual cues. The jaws should be tied together (eg cord, tape, zip ties), taking care not to cover or close the nostrils. When restraining crocodilians, and preparing them for transport, care should be taken to avoid restraining them with unnatural spinal flexion: where possible the head and trunk should be restrained in a linear position.

With larger crocodilians (>3 m TL) that may have a stomach full of fluid or water (possibly caused during capture), regurgitation may occur if they are transported on a flat surface, with the weight of the body pressing on the stomach. If the head can be elevated slightly, such fluids may drain back down the oesophagus, rather than accumulate around the glottis where the risk of asphyxiation increases. Inserting a mechanical obstruction (wood, plastic, rope, rubber) in the jaws, so that they remain slightly ajar when tied (rather than being tightly closed), will help dispel regurgitated fluids and facilitate respiration.

Struggling can be reduced further by lifting the front and hind feet off the substrate, usually by tying them together over the back. Knots should be firm, but locked, so that they cannot tighten and restrict blood flow into the limbs.

9. Transport of Live Crocodilians

The method of transport of live crocodilians will generally be determined by the size and number of animals being moved, and distance involved. Care is needed to avoid dehydration, overheating (>34°C), excessive cooling (<20°C) and struggling. Transport time should be minimized. In cool conditions, insulated and/or heated containers with holes for ventilation may need to be considered. Refrigerated trucks may be used to transport crocodilians if conditions are considered too hot. The possible impact of heat coming up from the road, or from exhaust systems to the bottom of a truck, needs to be considered.

Smooth interiors of containers, with padding around the snout of the crocodilian, can minimize damage, particularly of the snout. Plastic pipe of different diameters, cut to appropriate lengths (depending on the size of animal) is amenable to various rack systems, and are increasingly being used to transport crocodilians up to 2.5 m TL.

The type of crate used for transport of live crocodilians by air may under the provisions of CITES need to comply with established airline regulations. CITES Resolution Conf. 10.21 (Rev. CoP16) *Transport of live specimens* recommends the full and effective use of the International Air Transport Association (IATA) "Live Animals Regulations" (https://www.iata.org/publications/Pages/live-animals.aspx) for animals and the "CITES Guidelines for the Non-air Transport of Live Wild Animals and Plants" (https://www.cites.org/eng/resources/transport/index.php#4_1_5). Plastic pipes within boxes or other forms of packaging are acceptable and have proved very successful.

Immobilizing agents can be used to calm crocodilians during transport (see Section 10). Not feeding animals a few days prior to transport, and using capture techniques that do not cause the animal to swallow excess amounts of water, will reduce the probability of animals regurgitating and possibly suffocating if immobilized with their mouths tied shut.

10. Chemical Immobilization

Immobilizing agents (in conjunction with reversing agents) are commonly used when capturing crocodilians and/or transporting them, and they reduce the risk of injury to both animals and handlers. Key factors are:

a. Immobilizing drugs do not have the same effect as anaesthetics - immobilized animals can still feel pain! Procedures with the potential to cause pain must not be undertaken whilst crocodilians are only immobilized.

b. Simple surgical procedures may be done on immobilized crocodilians, but require the use of local anaesthetics. Major surgery needs the use of general anaesthetics, the effects of which vary greatly between species (eg Loveridge and Blake 1972, 1987; Bates 2001; Huchzermeyer 2003).

c. Immobilizing drugs may be administered using a pole-syringe or dart-gun in the case of unrestrained crocodilians, or by syringe if the animal is safely restrained.

d. The use of certain drugs may be subject to local regulations and/or legislation. Drugs should be administered by trained personnel, as accidental injection of handlers may be harmful or fatal.

e. Intramuscular injections can be made in the tail or into the front leg, targeting the soft, non-keratinous skin between the scales. The tail is the preferred site of injection, as it appears to result in the least discomfort for the animal. Injections with a dart gun into the top or side of the neck have proven effective in situations where the tail cannot be reached.

f. If possible, and for more rapid effect, the drug should be injected at a number of sites rather than the full dose at one site. Injection into a fat layer, which slows diffusion of the drug, can be difficult to avoid and may result in the drug taking longer than predicted to take effect. Potentially drugged crocodilians should be approached with the same caution after injection, as before, until the effects can be confirmed.

g. The palatal valve will become relaxed due to the effect of immobilizing agents, and can lead to drowning if the animal is in water. Care should be taken to ensure that the head is held out of water (eg with a snout rope) during immobilization.

h. As crocodilians regulate their body temperature by behavioural means they should be kept in their optimum thermal range (usually 24-32^{o}C) whilst immobilized and during the recovery period.

i. Immobilizing agents or other drugs should not be used on crocodilians being culled if their flesh is to be used for human consumption.

j. The effect of any drug may vary between species and between individual animals, and can be influenced by other factors (eg extent of struggling and temperature conditions), which may need to be considered when applying dosage rates. Body weight may vary greatly among similar-sized animals, and may need to be considered when calculating dosage rate (see Tables 3-6).

k. Care should be taken to ensure that animals have recovered sufficiently from the effects of immobilizing drugs before they are released back into water.

l. Immobilizing drugs, and associated reversing agents, that have been used with crocodilians include:

- Flaxedil (gallamine triethiodide), the effects of which are reversed by Neostgmine (neostigmine methylsulphate) (Table 3), has been successfully used with *C. niloticus* (Loveridge and Blake 1972, 1987), *C. rhombifer* (Lloyd 1999), *C. palustris* (Whitaker and Andrews 1989), *C. porosus* and *C. johnstoni* (NRMMC 2009). The response in *A. mississippiensis* is variable (Jacobson 1984), and deaths in *T. schlegelii* have been attributed to this drug (Frye 1991). Flaxedil is the recommended immobilizing agent for *C. niloticus* on South African crocodile farms (SABS 2014).

Table 3. Injection rates for Flaxedil (gallamine triethiodide; 40 mg/ml) and Neostigmine (neostigmine methylsulphate; 2.5 mg/ml) for different sized *C. niloticus* (adapted from Loveridge and Blake 1972).

Total Length (m)	Flaxedil (mg)	Flaxedil (40 mg/ml) (ml)	Neostigmine (ml)
0.9	4.0	0.10	-
1.1	6.0	0.15	-
1.2	10.0	0.25	0.1
1.4	16.0	0.40	0.2
1.5	23.8	0.60	0.3
1.7	31.0	0.80	0.4
1.8	29.5	1.00	0.5
2.0	47.8	1.20	0.6
2.1	61.6	1.50	0.8
2.3	71.8	1.80	1.0
2.4	95.8	2.40	1.4
2.6	114.0	2.80	1.8
2.7	124.1	3.10	2.1
2.9	134.6	3.40	2.4
3.1	142.6	3.60	2.6
3.2	163.4	4.00	3.2
3.4	175.2	4.40	3.7
3.5	188.0	4.70	4.3
3.7	201.0	5.00	4.9
3.8	212.7	5.30	5.7
4.0	225.7	5.60	7.1
4.1	229.8	5.80	8.1
4.3	233.1	5.80	9.0
4.4	240.7	6.00	10.0
4.6	239.0	6.00	10.8
4.7	246.0	6.20	11.8
4.9	266.0	6.70	12.8

- Pavulon (pancuronium bromide) was identified as a suitable replacement for Flaxedil, when the latter was no longer readily available in Australia (Bates 2001; Bates *et al.* 2004). Like Flaxedil, the effects of Pavulon are reversed by Neostigmine. Due to the time required for Pavulon to take effect (10-30 minutes), 2 ml of Valium (5 mg/ml diazepam) is routinely mixed with Pavulon (Parks and Wildlife Commission NT, unpublished data), particularly for crocodiles that might struggle. Dosage rates for Pavulon (2 mg/ml) are in Table 4.

Table 4. Injection rates for Pavulon (pancuronium bromide; 2 mg/ml) and Neostigmine (neostigmine methylsulphate; 2.5 mg/ml) for different sized captive [adapted from Bates (2001) and Bates *et al*. (2004)] and wild (Parks and Wildlife Commission NT, unpublished data) *C. porosus*. Rates for prolonged immobilization of large crocodiles (>4 m TL) are extrapolated and should be used with caution. Dotted line indicates change of dosage rate in larger crocodiles. Doses may be reduced if animals are considered thin relative to their length, and increased if they are considered obese. Adapted from NRMMC (2009).

Total Length	------------- Captive -------------		--- Wild ---	
(m)	Pavulon (ml) <2 hours	Pavulon (ml) 2-6 hours	Pavulon (ml)	Neostigmine (ml)
1.5-1.9	0.05-0.10	0.15	-	0.1
2.0-2.1	0.15	0.3	0.3	0.2
2.2-2.3	0.25	0.4	0.4	0.3
2.4-2.5	0.3	0.55	0.5	0.35
2.6-2.7	0.4	0.7	0.7	0.4
2.8-2.9	0.5	0.85	0.8	0.5
3.0-3.2	0.3-0.5	0.5-0.8	0.8	0.75
3.3-3.4	0.4-0.6	0.7-1.0	0.8	0.75
3.5-3.6	0.5-0.7	0.8-1.2	1.0	1.0
3.7-3.8	0.6-0.8	0.9-1.4	2.0	1.0
3.9-4.0	0.7-1.0	1.1-1.7	2.0	1.0
4.1-4.3	0.8-1.2	1.3-2.1	2.0	1.0
4.4-4.6	1.0-1.5	1.6-2.7	2.0	1.0

- Scoline (suxamethonium chloride) produces muscle relaxation without anaesthesia, but is not widely used. Period of action is short (30-60 mins), there is no specific antidote, and dosage rates for different species may vary greatly. Loveridge and Blake (1972) and Spiegal *et al.* (1984) used Valium with Scoline in *A. mississippiensis* and *C. niloticus.* Johnson (1991) immobilized juvenile *Caiman crocodilus* with Scoline at dosages of 0.33-2.2 mg/kg. Dosage rates for *C. porosus*, *C. johnstoni* and *A. mississippiensis* are in Table 5.

Table 5. Intramuscular dosage rate of Scoline; (suxamethonium chloride 50 mg/ml) for different-sized (TL= total length) *C. porosus, C. johnstoni* and *A. mississippiensis*. Adapted from Messel and Stephens (1980) and Jacobson (1984).

C. porosus		*C. johnstoni*		*A. mississippiensis*	
TL (m)	Dosage (ml)	TL (m)	Dosage (ml)	TL (m)	Dosage (mg/kg)
1.2	2.0	1.1	0.16	<1.5	1.0
1.5	2.4	1.2	0.21	>1.5	0.4
1.8	3.6	1.5	0.28		
2.0	4.8	1.6	0.38		
2.5	5.2	1.8	0.42		
3.0	6.0	2.1	0.54		
3.5	10.4				
4.0	16.2				
4.5	21.5				

- Domitor (medetomidine) has been used successfully for immobilization of *A. mississippiensis*, *C. porosus* and *C. johnstoni*, with Antisedan (atipamezole) as a reversing agent (Smith *et al.* 1998; Olsson and Phalen 2012a,b) (Table 6). Interestingly, Olsson and Phalen (2012a) concluded that intramuscular injection of Domitor in the base of the tail (20% immobilized) or forelimbs (0% immobilized) was not as effective as injection into the hindlimbs (100% immobilized). They also reported that intramuscular and intravenous administration of Domitor at dosage rates of 0.5, 0.75 and 1.0 mg/kg were not effective on 1-2 kg *C. porosus* (Olsson and Phalen 2012a,b). Domitor (0.08-0.35 mg/kg), together with ketamine (5-20 mg/kg) and butorphanol (012-0.25 mg/kg) has been used successfully for *C. niloticus* (S. Martin, pers. comm.).

Table 6. Intramuscular dosage rates for Domitor (medetomidine) and Antisedan (atipamezole).

Species	Domitor	Antisedan	Source
A. mississippiensis (juv.)	0.15 mg/kg	0.75 mg/kg	Smith *et al.* (1998)
C. johnstoni (4-12 kg)	0.75 mg/kg	-	Olsson and Phalen (2012a)
C. porosus (1-2 kg)	not effective	not effective	Olsson and Phalen (2012a)
C. porosus (3-11 kg)	0.50 mg/kg	2.5 mg/kg	Olsson and Phalen (2012a)
C. porosus (150-370 kg)	0.13-0.17 mg/kg	0.09-0.12 mg/kg	Olsson and Phalen (2012b)

- Alfaxan: Olsson and Phalen (2013) tested Alfaxan (alfaxalone; injected intravenously at 3 mg/kg) with captive juvenile *C. porosus* (0.6-2.5 kg) and *C. johnstoni* (0.2-0.6 kg) at different temperatures. Although the drug resulted in immobilization, its unpredictable results following induction suggest that it may <u>not</u> be suitable for field situations.

- Atracurium: Clyde *et al.* (1990) immobilized *A. mississippiensis* using Atracurium (atracurium besylate) intramuscularly at 15 mg/kg, 15 minutes after administering

Valium (diazepam, 0.4 mg/kg). However, most animals had to be manually ventilated after becoming apneic (less than 1 breath/minute).

11. Electro-stunning

Electro-stunning was investigated on *A. mississippiensis* in the early 1970s (Joanen and Perry 1971), and the technique was refined and tested with juvenile *C. porosus* in Australia in the early 2000s (Peucker *et al.* 2004, 2005). The physiological stress response in electrically-stunned *C. porosus* was found to be significantly less than that in animals manually captured by noosing and roping (Franklin *et al.* 2002, 2003; Pfitzer *et al.* 2014). The method is now used extensively to immobilize crocodilians in Australia, Papua New Guinea, Philippines, South Africa, Spain, Thailand, Zambia and Zimbabwe (eg Peucker *et al.* 2005; Mercado 2007; CFAZ 2012; Ganswindt 2012; Pfitzer *et al.* 2014; SABS 2014).

Immobilization is achieved by the delivery of a suitable charge (eg 110-volt in Australia; Peuker *et al.* 2005) for 4-6 seconds (depending on the size of crocodile) through a pole with a set of metal prongs on the end, which is placed on the neck of the animal. Immobilization is rapid, following 3-10 seconds of rigor and tail twitching. Stunned animals may be immobilized for up to 10 minutes, but most individuals regain movement after about 3 minutes. The technique requires the crocodilian's skin at the contact site to be wet, and is effective on crocodilians housed in both fresh and saline water. Some farms avoid electro-stunning animals whilst their heads are under water, to reduce the risk of water being inhaled as they are being immobilized. Other farms do electro-stun when the animal is under water, but note that the effectiveness of the equipment is reduced (J. English, pers. comm., 2015).

CFAZ (2012) recommend that electro-stunning equipment "*must be capable of creating unconsciousness within 6 seconds without any negative impact to the health of the animal*" and that there should be a maximum of two electro-stunning applications on the day before slaughter. SABS (2014) approves "*electrical immobilization*" on juvenile and adult crocodiles, but notes that the method's applicability to adult crocodiles is still being investigated with respect to duration and level of voltage required. In Zimbabwe, adult *C. niloticus* in excess of 2 m TL are successfully immobilized in less than 6 seconds using a 220-volt stunner (J. English, pers. comm., 2015).

Although various aspects of electro-stunning remain under investigation, there is simply no doubt that electro-stunners have contributed enormously to the improved health, safety and welfare of farmed crocodilians. The serious challenges of having to catch and move large numbers of large crocodilians (>1.8 m TL) in communal pens, without them struggling to exhaustion or inflicting injuries on themselves, have been largely overcome. It has also greatly improved the safety of staff involved in capturing and handling of crocodilians. By reducing the labour costs and staff risks, it has also allowed management interventions (such as grading for size and health assessments) to be undertaken more regularly, which improves welfare and economic management. The safety of staff using electro-stunners relies in part on the use of appropriate protective clothing (eg gloves, boots), particularly in 'wet' environments (see Fig. 12).

Figure 12. Electro-stunning equipment used in Zimbabwe (left) and Australia (right). Photographs: John English (left), Matthew Brien (right).

12. Culling and Euthanasia

Crocodilians and other reptiles differ from mammals with respect to basic anatomy, physiology, behaviour, discomfort and pain awareness (LDWF and SVM-LSU 2016). Notwithstanding these differences, there is an international expectation that the slaughter of farmed crocodilians will be undertaken in a humane manner, generally interpreted as meaning rapid unconsciousness and death with minimal pain (Expert Panel 2013).

An international panel, including 6 CSG members, was recently established by the Swiss Federal Veterinary Office to analyze humane killing methods for all reptiles in the international skin trade (Expert Panel 2013), and it specifically examined humane methods of slaughter for crocodilians. Guidelines proposed long ago by the CSG (Hutton 1992), and integrated into existing Codes of Practice in Australia (NRMMC 2009), Louisiana (LDWF and SVM-LSU 2016), Zambia (ZaCFA 2013), Zimbabwe (CFAZ 2012) and South Africa (SABS 2014), were upheld.

Due to the anaerobic physiology and neural organization of crocodilians, some local reflex activity (twitching) is evident after killing and destruction of the brain. Opponents to crocodilian farming have long used film of these movements to erroneously imply a slow painful death from inhumane methods of slaughter - that animals were being skinned alive and experiencing great pain. In reality, with the brain destroyed, no pain can be perceived, and the twitching is largely a local response of muscles that continue to operate independently after death.

Where crocodilians are being culled for the production of meat for human consumption, tools that come into contact with the skin (eg pithing rod, chisel, knife, hook) should be sterilized between use on different animals (NRMMC 2009; CFAZ 2012).

Recommended methods of slaughter include:

12.1. Captive-Bolt Pistol

This method has been used for the slaughter of caimans, alligators (Campos 2000; Aleixo 2008) and crocodiles (M. Burns, pers. comm., 2015). Specifically:

a. The method can be used for all sizes of crocodilians.

b. The pistol must provide sufficient power (charge) to penetrate the skull and brain (penetrating captive bolt) or cause fatal stunning (non-penetrating captive bolt). Charges suitable for mammals may not be sufficient for crocodilians, due to the more heavily ossified skull.

c. The animal must be properly restrained.

d. The captive-bolt pistol should be placed directly on the skull over the brain case. Appropriate charge (air or gunpowder) should be selected to match the size of the animal.

e. Personnel should be given induction and training in safe and effective use of the device. The exact positioning of the pistol to ensure a direct hit on the brain, the maximum size of animal on which a pistol with a specific charge can be used effectively, and standard procedures about avoiding operator contact, are important.

12.2. Cervical Dislocation

The method can be performed where the animal can be firmly secured, or immediately after it has been stunned electrically or by using a captive-bolt pistol (non-penetrating bolt) or an appropriate tool.

a. Spinal cord severance must be achieved instantly, with one blow of a heavy hammer on a sharp metal chisel positioned between the skull and the first cervical vertebra, just behind the cranial platform (Hutton 1992), or by using a sharp knife (SABS 2014).

b. Immediately following severance of the spine the brain can be destroyed by pithing [insertion of a stainless steel (or metal) rod into the brain]. Spinal pithing (ie backwards down the spinal column) is also required for Zimbabwean (CFAZ 2012) and Zambian (ZaCFA 2013) farms, although this was not identified as necessary by the Expert Panel (2013). Spinal pithing facilitates skinning, as it reduces post-mortem movements. Spinal severance alone, without pithing (destruction) of the brain, is an unacceptable method of slaughter (Nevarez *et al.* 2014).

12.3. Shooting

a. Farms should comply with relevant national and local legislation with regard to the use of firearms (eg licensing, storage, training).

b. The point of aim should be the brain, and thus crocodilians of all sizes may be shot through the back or side of the cranial platform or between the eyes (Fig. 13).

c. With increasing size, more powerful centre-fire calibres are required. For captive and/or restrained individuals, the following projectile sizes are suitable: crocodilians up to 2 m long - .22 shorts (low velocity); 2-3 m long crocodilians - rim fire .22 long rifle or .22 magnum; and, >3 m long crocodilians, higher velocity centre-fire calibres (NRMMC 2009).

d. For free-ranging crocodilians between 1.5 and 3.0 m in length, centre-fire, high velocity calibres should be used (eg .222, .243, .270 or any 7 mm calibre). For free-ranging crocodilians greater than 3 m in length, a 7 mm weapon is the minimum calibre that should be used.

e. Care should be taken to ensure that bullet trajectory is away from personnel in the vicinity. High-powered calibres should never be used in confined spaces because of the risk of ricocheting projectiles.

f. Regardless of the situation, as soon as possible after shooting the brain should be pithed (insertion of a steel rod; see 12.2) to ensure it has been destroyed.

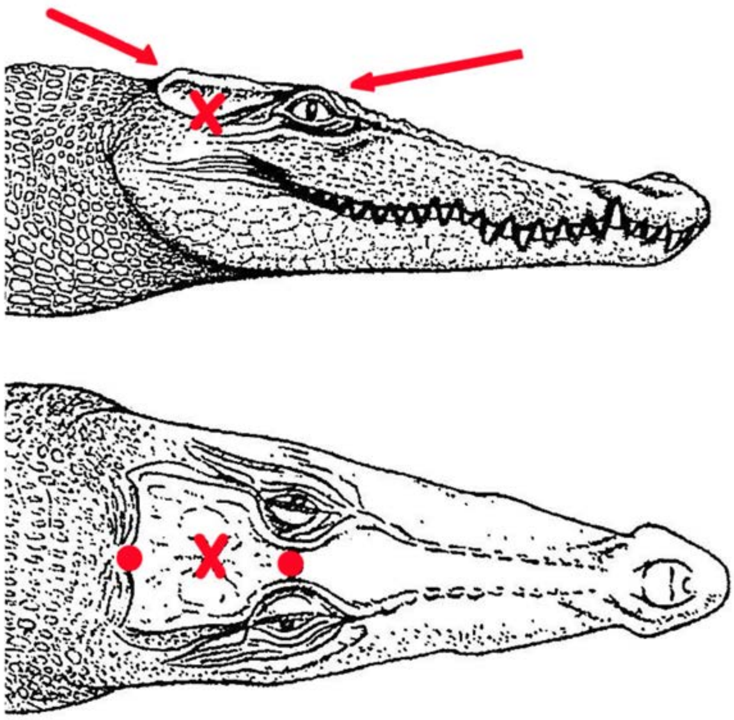

Figure 13. (Top) Side view of head showing point of aim (x) for shot to side of head. Arrows indicate preferred trajectory for shot to the back or front of head. (Bottom) Dorsal view of head showing location of brain (x) and points of aim for shots to back or front of head. From NRMMC (2009).

12.4. Decapitation

Although not a method for commercial culling of crocodilians, decapitation is sometimes used for hatchlings or small juveniles that need to be euthanized (eg sick or deformed animals). Decapitation should be instant (eg with sharp knife or hammer and chisel), and followed by destruction of the brain by pithing or other methods (eg blunt trauma).

12.5. Chemical Methods

There may be occasions where the foregoing forms of immobilization or euthanasia are considered inappropriate (eg for surgical procedures, research), and where chemical euthanasia is required. The application of inhalants and/or agents by intravenous delivery may require trained or licensed personnel.

Sodium pentobarbitone is considered an effective and humane form of euthanasia that can be delivered intravenously into the cephalic sinus immediately behind the cranium (intravenous), or into the body cavity (intracoelomic) (NRMMC 2009; Expert Panel 2013).

12.6. Freezing

In its analysis of humane killing methods for reptiles in the skin trade, the Expert Panel (2013) considered the immobilization of reptiles by cooling (eg in deep freezers) to be inappropriate, but rapid freezing of deeply anaesthetized animals and eggs/embryos (<50% incubation), leading to immediate death, was considered acceptable (eg see AVMA 2013). Recent findings by Shine *et al.* (2015) with amphibians suggests that cooling, followed by freezing, may be widely applicable to other ectotherms.

13. Abattoirs/Processing Facilities

Crocodilian meat is a valuable by-product of some commercial farming operations. The production of meat for human consumption typically involves compliance with relevant national public health regulations covering the design, construction and operation of abattoirs, food standards, and procedures established specifically for the processing of crocodilians for meat recovery.

In the Northern Territory of Australia, crocodile abattoirs operate on Hazard Analysis Critical Control Point (HACCP) based quality assurance plans, where bacterial testing occurs at critical control points, including walls, work surfaces, equipment, clothing, etc. Bacterial counts (total viable count) are used as a metric to ensure that the process is delivering good results on a continuous basis, rather than judging the wholesomeness of individual pieces of product (ARMCANZ 1997). South African regulations stipulate that meat be processed in the same manner as red meat, in a HACCP-certified processing facility (SABS 2014).

In the USA, state health regulations regarding animal slaughter are applied to facilities processing alligator meat. In Florida and Louisiana slaughter and processing of *A. mississippiensis* is the same as with fish. This is primarily because alligators are ectothermic, which reduces the risk of bacterial contamination during the slaughter process. Processing facilities in the USA are required to meet normal health code requirements for human consumption, although meat is not inspected by government authorities prior to packaging.

Importing countries may require more stringent procedures than may otherwise be required for domestic trade (eg pathogens that pose a risk for human consumption). For example, the bacterial count on Zimbabwean *C. niloticus* meat for export must fall within prescribed limits in order to be acceptable for human consumption (total bacterial count <1 x 105 cfu/g; total coliform count <1 x 103 cfu/g; *E. coli* count <10 cfu/g; *Salmonella* zero). All crocodile farms in Zimbabwe are also required to undergo *Trichinella* testing (CFAZ 2012), and non-hatchling crocodiles proposed for importation into South Africa must be screened for *Trichinella*. Australian crocodile abattoirs exporting meat must comply with stricter guidelines than are imposed for domestic trade, and be regulated through the Australian Quarantine Inspection Service - only crocodile meat produced through AQIS-approved abattoirs can be exported. National legislation in different countries will dictate the regulations governing the production of meat for export.

14. Skinning and Skin Preservation

The majority of "classic" crocodilian skins in international trade are "belly skins" (high dorsal cut lines) (Fig. 14), with relatively few "hornbacks" (skin opened along the mid-line of the belly) in trade. In contrast, most farmed caiman skins are currently traded as hornbacks.

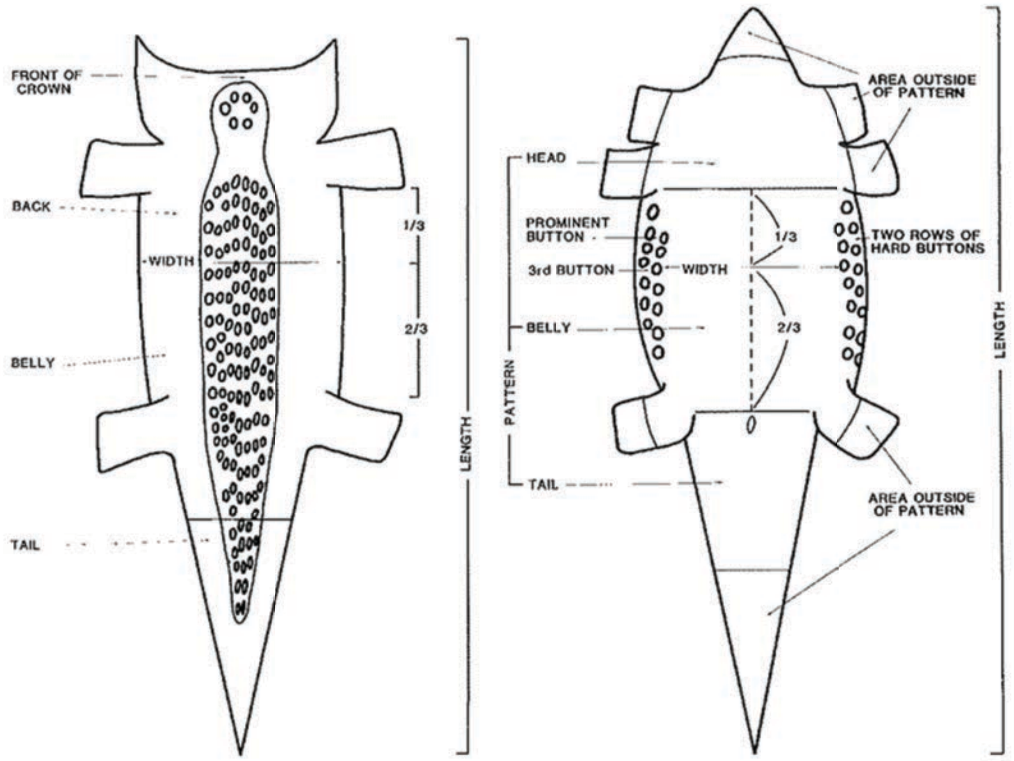

Figure 14. Diagram of "hornback" (left) and "belly" (right) skins (from Van Jaarsveldt 1987).

The factors that affect the efficiency of curing (preservation) start well before the application of curing chemicals. The manner and conditions under which the skin is removed from the animal post-mortem, and the way it is handled immediately, before curing, are important.

a. Skinning (flaying)

- Skinning should be carried out as soon as possible after the animal has been killed, in a shaded, cool area (see King and Wilson 1989; Van Jaarsveldt 1987; Marais and Smith 1992). Where the meat is to be used for human consumption, skinning is typically carried out in facilities and under conditions specified by State/National regulations.
- Care should be taken to avoid mechanical damage to the skin (eg cuts, scratches), restrict contamination (eg blood, dirt), and avoid exposure to heat (sunlight or just warm ambient conditions).
- The correct opening lines should be made on the animal, so that the final shape of the skin complies with accepted market standards (Fig. 15), which may vary from buyer to buyer.
- Numbers (and sizes) of animals to be slaughtered each day needs to be matched to the processing capacity.
- Crocodilians killed for processing may be hung in the shade or in a cool-room to facilitate exsanguination and the cessation of post-mortem movements.

- Crocodilian skins do not easily separate from the underlying flesh and tissue and therefore need to be carefully cut from the underlying fascia by smooth strokes of a small blade, knife or air-knife.

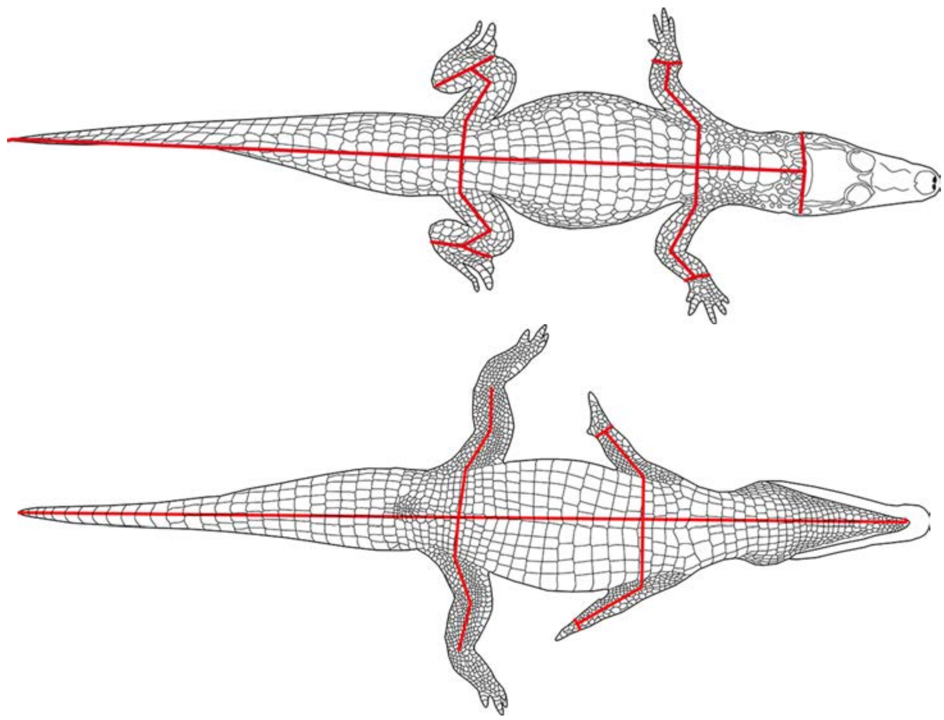

Figure 15. Opening lines for the standard skinning of crocodilians; belly skin (top), hornback skin (bottom). Courtesy of Alvaro Velasco.

b. Flensing (fleshing)
   - All flesh, fat and blood on the underside of the skin should be removed by scraping (using a blunt knife, scrapers with rounded corners, air knife or high pressure water jets).
   - Air knives are particularly effective for removing much of the tissue at the time of skinning.
   - If not removed properly, these layers of tissue may interfere with the penetration of salt during the curing process.
   - If the skin is allowed to heat (eg in the sun or in warm ambient conditions), the release of fat from these layers can penetrate the skin itself and result in "grease stains" on the finished leather.

c. Curing
   - Raw skins are subject to microbial deterioration (decomposition), which must be controlled by curing and preservation techniques until the skins are converted into leather. This is best achieved by dehydration of the skin by saturation with raw salt, or by preservation in a brine solution (David 1987).
   - No amount of curing can rectify damage caused by decomposition.
   - In most farming situations, fine-medium grained salt equivalent to around 50% of the weight of the skin (or 1-2.5 cm deep) is applied initially, by rubbing into the underside of the skin. It absorbs water, which is withdrawn from the skin (Fig. 16).
   - After 24-48 hours the first layer of salt is removed and discarded, and the skin is re-salted with a thin layer of fresh salt.
   - Skins that are dried out completely become brittle and may crack, resulting in downgrading of skin quality.

- Hawkins and Huynh (2004) confirmed the efficacy of using 60% and 100% brine solutions for the preservation and storage (David 1987), and subsequent transport of crocodile skins in vacuum sealed bags.

Figure 16. (Left) Crocodile skins laid underside-up on a sloped table, with the first layer of salt applied. (Right) skins with second (lighter) layer of salt: note the water in the tray at bottom right-hand corner that has been extracted from the skins after the first salting and drained along the sloped table. Photographs: Charlie Manolis.

d. Storage

- Skins need to be stored in a way that does not compromise quality.
- Skins can be rolled without folding, like a bedroll, starting from the tip of the head skin and finishing with the tail tip. If rolled like this and maintained in a cool, climate-controlled facility, the possibility of fold marks damaging the skin, and reducing its value, can be avoided.
- Folding the sides inward, and then rolling the skin so that the keratin on the outside but no part of the underside of the skin is exposed, is the preferred method for storage and transport of both American alligator (Fig. 17) and Siamese crocodile skins. The risk of folds is considered less important than the risk of exposed parts of the skin being dehydrated and damaged in other ways.
- On farms, salted skins are typically stored in a refrigerated room (5-10^{o}C). This is not possible for wild-harvested skins in remote areas, in which case the salted skins should be at least stored in a cool, shaded place, perhaps in hessian bags, to prevent heating and drying out.
- Salted skins should not be stored for long periods of time without inspection. Although salt retards bacterial growth, some bacteria are tolerant to salt, and may damage the skin (eg *Halobacterium* sp. causing “red heat”). The addition of chemicals to the salt may counter the effects of salt-resistant bacteria.
- David (1987) investigated the effect of storage techniques (salt box, refrigeration, brine) on the development of “red heat” in salted alligator skins. However, few alligator trappers (in Florida) now use brine to cure their skins, because problems arise if minimal salt saturation levels are not maintained, or if the solution becomes too heavily saturated with salt (P. Ashley, pers. comm., 2015). LAAC (2015) recommend that alligator skins affected by “red heat” or scale-slip (where the keratin layer starts to peel off), be treated for 15 minutes in a mixture of water (97.6%), bleach (2.0%) and “Tide and Borax” laundry detergent (0.4%).
- Brine solutions (eg 60%) are used for initial preservation of skins by some farms in Australia (see Hawkins and Huynh 2004; J. Lever, pers. comm., 2015). LAAC (2015)

suggest brine solutions comprise water (82.5%), salt (16.7%), boric acid (0.4%) and bleach (0.4%) as an effective curing medium.

Figure 17. American alligator skins being inspected by LDWF staff prior to shipment in wooden crates. Photographs: Ruth Elsey.

15. <u>Tanneries</u>

In many countries, tanneries are built on farms as an integral investment in value-adding (eg Colombia, Madagascar, Mexico, South Africa, Thailand, USA, Vietnam, Zimbabwe). In some cases local tanning is mandatory and prescribed in national legislation. For example, Indonesia and Colombia do not allow the export of raw crocodilian skins (Manolis 2007; Manolis and McInnes 2007; S. Medrano, pers. comm. 2015) - they must be processed to at least a "wet blue" stage (Fuchs 2006).

The operation of tanneries is usually regulated through mechanisms focused on controlling the adverse effects of chemical pollution on the environment and people. The global leather industry is well aware of the pollution potential of tanneries (Bosnic *et al.* 2000), and national regulatory mechanisms, although varying from country to country, are ever improving.

Some 80-90% of leather in the world is "chrome tanned", a process that uses trivalent chromium sulphate. Chromium occurs naturally in the environment as "Cr III" (trivalent chromium), but "Cr VI" (hexavalent chromium) is produced through industrial processes, and is more toxic than the Cr III. Given the carcinogenic nature of Cr VI (Thanh 2011) and other chemicals used in the tanning process, authorities and consumers are now looking more closely at whether hazardous substances are present in leather and leather products. Consequently, the importation of leather products into some major markets is becoming subject to stricter regulation by importing countries. For example, importation into the European Union (EU) of crocodilian leather or other products that will come in direct contact with the skin of people, and may do so repeatedly, must now comply with European Commission Regulation (EU) No. 301/2014 with respect to levels of Cr VI ($\leq$3 mg/kg of dry weight; http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=OJ:JOL_2014_090_R_0001_01&from=EN).

Tanneries are increasingly being required to decontaminate wastewater if it is to be discharged into the environment (see Bosnic and Buljan 2000), due mainly to concerns about chromium. Many crocodilian tanneries in Europe are now considering ways to reduce their reliance on chrome tanning. Chrome-free tanning is the subject of a number of research and development projects. The BLC Leather Technology Centre commissioned a study on tanning chemicals, and found no significant difference between chrome, vegetable and aldehyde tanning – though each has environmental impacts, *albeit* different ones. Impediments to the wider use of vegetable tanning as a replacement for chrome tanning include additional expense, more difficulty in attaining consistency across batches of tanned skins, and the final tanned skins are generally less flexible.

The Leather Working Group (LWG; http://www.leatherworkinggroup.com) is a multi-stakeholder group formed in 2005 that aims to "*develop and maintain a protocol that assesses the compliance and environmental performance of tanners and promotes sustainable and appropriate environmental business practices within the leather industry ... The group seeks to improve the tanning industry by creating alignment on environmental priorities, bringing visibility to best practices and providing suggested guidelines for continual improvement*."

In recent years the consumer market for wildlife products has started to move towards retailers having a higher level of responsibility for their products. The BLC Leather Technology Centre has developed a family "Sure" certification trademark to satisfy this growing demand for product assurance (BLC Leather Technology Centre 2008):

- Only leathers tested at BLC for critical restricted substances (eg azo-dyes, formaldehyde, pentachlorophenol, chrome VI) and which comply with specific requirements are eligible for the "ConsumerSure" mark.
- The "MetalSure" mark involves compliance with heavy metal and chrome VI content in leather.
- The "EcoSure" mark is designed as a credible tool to aid the sourcing of leather (skins) and to demonstrate environmental compliance at point of sale. Retailers, manufacturers and tanners who are able to meet the requirements of this standard are eligible to use the EcoSure mark. It is operated in conjunction with the Leather Working Group (LWG).

Many large-scale crocodilian tanneries (eg in France, Singapore) utilize barcoded house skin tags to aid recordkeeping and to track skins. Some exporting countries have also integrated barcodes on the CITES skin tag itself to facilitate improved record keeping. There is no international legal requirement to tag crocodilian skins used for domestic use, or skins used in the manufacture of products for export, but national and local requirements vary among producer countries. Tanneries, like crocodilian farms, represent potential sites through which "illegal" raw skins can and do get laundered for the legal international market, and so inspection and monitoring of tanneries can and should be an integral part of the checks and balances needed to ensure production and trade are legal, sustainable and verifiable.

16. Reintroduction/Release to the Wild

The reintroduction or release of crocodilians into the wild is carried out for different reasons, but is often integrated with crocodilian farming. The IUCN-SSC Reintroduction Specialist Group (RSG) and Invasive Species Specialist Group (ISSG) have developed "Guidelines for Reintroductions and Other Conservation Translocations" (IUCN/SSC 2013) that provides important insights into best management practice.

In Louisiana (USA), a proportion of the wild *A. mississippiensis* eggs harvested are released as 'head-started' juveniles within two years of egg collection. This is largely to compensate for an extensive annual harvest, involving some 400,000+ eggs and 30,000-35,000 wild alligators. Return rates are based on expected survival rates of different sized animals, with some 35,000-40,000 juvenile alligators released annually (Elsey and Kinler 2012). In years of high nest production, and with higher numbers of eggs being collected, higher numbers of alligators are released accordingly.

Many countries with crocodilian ranching programs, but no significant wild harvest at the adult stage, retain the option to release a proportion of harvested eggs back to the wild as juveniles as a precautionary measure. However, it has rarely been required, because no detrimental impacts of harvesting eggs alone have been demonstrated scientifically, even at high egg harvest rates (Jenkins *et al.* 2006), and hence releases may be cosmetic rather than beneficial. For *C. porosus* and *C. niloticus* density-dependent factors, namely increases in hatchling survival rates when hatchling recruitment decreases due to egg harvest, may compensate for the egg harvest (Fergusson 1992; Webb and Manolis 1992).

Reintroductions may also be carried out for solely conservation purposes, namely to re-establish or restock depleted wild crocodilian populations. To date, conservation reintroduction programs have been implemented for: *Alligator sinensis* (China), *Crocodylus mindorensis* (Philippines), *C. porosus* (India, Malaysia), *C. acutus* (Colombia), *Caiman c. fuscus* (Colombia), *C. intermedius* (Venezuela, Colombia), *C. rhombifer* (Cuba), *C. siamensis* (Thailand, Vietnam, Cambodia, Lao PDR) and *Gavialis gangeticus* (India, Nepal). A reintroduction project with *Mecistops cataphractus* is in the starting phase in Côte d'Ivoire.

In theory, reintroductions and releases (deliberate and otherwise) can create new problems that need to be considered, including:

1. Establishment of feral populations;
2. Genetic dilution and introgression by release of hybrids;
3. Mixing of genetically distinct sub-populations within/between countries;
4. Introduction of parasites or diseases with potentially negative impacts on wild (and captive) populations; and,
5. Increased human-crocodilian conflict.

With the exception of feral populations (eg *Caiman crocodilus* in USA, Cuba and Puerto Rico) and in some cases hybridization with naturally occurring populations (eg *C. rhombifer, C. porosus* and *C. siamensis* in Southeast Asia), few of these problems have been demonstrated as being significant with crocodilians.

The CSG does not support the establishment of crocodilian farming operations using species outside of their natural range.

17. Corporate Social Responsibility

Fashion houses and farms are increasingly adopting policies on Corporate Social Responsibility (CSR) – a term used to describe the way in which a business takes into account the financial, environmental and social impacts of their decisions and actions. This 'Triple Bottom Line Approach' responds to increased awareness by civil society of issues such as sustainability (or 'responsible sourcing'), pollution, conservation, livelihoods and animal welfare, and is applied to the management of complete supply chains. Companies involved with wildlife products may express CSR in different ways, including through waste and pollution reduction (eg tanneries), by contributing to educational, social and environmental programs (eg reducing carbon footprints), and by ensuring products are derived from responsibly managed resources (eg sustainable crocodilian management programs, benefits to livelihoods, humane treatment of animals). By adopting CSR issues into their business approach, companies can witness a variety of competitive advantages, particularly with regard to improved brand image and reputation.

18. Traceability

Intimately linked to CSR is an increasing interest in traceability within supply chains. For many agricultural animal and plant products, supply chains can be clearly defined, and by restricting sources to a small number of large producers, capable of meeting an expected standard, traceability is simplified. This of course sometimes comes at the expense of smaller producers and the livelihoods of people they support, despite by definition, CSR usually includes commitments to supporting livelihoods.

Wild plants and animals support the livelihoods of billions of people, who are often living in remote areas in relative poverty. Nevertheless, some products, or parts of them, find their way into high-end international markets (eg crocodilian skins, snake and lizard skins, dried shark fins, rubber, vicuña wool), often through complex and opportunistic chains of local traders. For example, in Papua New Guinea crocodiles may supply the only source of income for many remote communities – all at risk if precise and accurate traceability schemes reaching down to the level of one hunter taking one crocodile were required. Village-level farms for crocodilians and snakes in South-East Asia are often low-technology family enterprises, in remote areas, in which the skins produced eventually find their way through intermediaries to high-end markets. There is no accurate nor secure mechanism that would be cost-effective to operate, for tracing intricate in-country trade routes that are unstable and opportunistic. There are clearly risks associated with high-end companies claiming otherwise, regardless of what certification systems they may adopt, and organisations opposed to animal use will have little difficulty demonstrating how most proposed traceability systems can be thwarted!

The obvious dilemma for crocodilian farming is that if companies interpret their CSR obligations as requiring perfect traceability, it will favour large commercial producers, with limited livelihood benefits, versus village-level producers, with high livelihood benefits.

19. Environmental Management Policies (EMP)

Over and above the issues associated with environmental control of tanneries (see Section 15), there are increasing obligations on crocodilian farmers to consider what adverse impacts their farming activities may have on the environment, inside and outside the farm, and to take such actions as may be needed to counter them. Environmental assessments are sometimes (but not always) an integral part of the permitting process to develop, construct and operate crocodilian farms, and may be subject to a range of different national legislation. However, it is increasingly expected that farmers will examine their own "footprint" carefully, and incorporate the results in a farm-based Environmental Management Policy (EMP).

Issues that need to be addressed in EMPs for a crocodilian farm include, but are not limited to:

a. Compliance with existing legislation.

b. Adverse impacts outside of the farm associated directly (or indirectly) with obtaining stock, over and above the process being legal, sustainable and verifiable.

c. Amounts, treatment, containment and/or disposal of:

i. Food sources and waste food
ii. Solid animal waste
iii. Dissolved nutrients
iv. Abattoir waste
v. Skin treatment waste

d. Water extraction and waste-water treatment, containment and disposal generally.

e. Off-site versus on-site treatment, containment and/or disposal of all waste.

f. Responsible use of antibiotics for treatment and prevention of disease.

20. Security

Regardless of species, crocodilians are generally considered by the public to be “dangerous” (Rinat 2015). As a result, farm designs should ensure that stock are held within secure facilities that prevent crocodilians escaping (Anonymous 2015), even in the face of natural events such as extreme flooding occur (Anonymous 2011, 2012; Starkey 2013). Indeed, Resolution Conf. 12.10 (Rev. CoP15), which prescribes the minimum standards for registering commercial breeding operations for Appendix-I listed species, requires each operation to describe what security measures are in place to prevent escapes and/or thefts.

In many farms, stock theft remains a serious security issue highlighting the need for security staff and/or surveillance (CCTV) cameras. In addition, uncontrolled access to crocodilians on farms may result in injury (or worse) for farm visitors or trespassers. Farms are encouraged to restrict visitors on a “needs only” basis.

21. Staff Training

At a global level, crocodilian farming is undertaken in a variety of different economic, social and cultural contexts, involving staff with varying levels of education and literacy. Crocodilians are dangerous animals, and training in capture, handling and culling techniques is an important element of responsible farm management, and mandatory in countries where Occupational Health and Safety legislation is applied. In some countries formal qualifications and training in crocodilian capture, handling and husbandry are available (see NRMMC 2009), but most staff training is informal, on-site, and depends on new employees acquiring experience by learning from experienced employees. There may or may not be a solid foundation of knowledge underpinning the information exchanges involved in this process. There are many advantages in ensuring staff are formally trained, during induction courses or through attending formal crocodilian management courses.

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Annex 1

Best Management Practices for Skin Production - A Checklist of Things to Consider

1. CITES

Because all crocodilian species are listed on the CITES Appendices, any farm that aims to produce skins for export must comply with CITES requirements. Key issues to consider are:

1.1. Countries that are Parties to CITES (181 countries in 2015) appoint national CITES Management and Scientific Authorities, and must enact national legislation to implement their new international obligations under CITES. They can apply stricter domestic measures than are required by CITES if required. Crocodilian farms must comply with their national legislation and interact with their national CITES Management Authority, rather than with the CITES Secretariat itself.

1.2. All crocodilian skins in international trade must be tagged with an approved CITES skin tag, usually purchased by a country's CITES Management Authority from an approved manufacturer.

1.3. CITES is concerned with international trade, not domestic trade. However, it is a breach of CITES to attempt to export skins that have not been obtained in accordance with national legislation (Webb and Jenkins 2016).

1.4. If a farming operation involves the production of an Appendix-I species through closed-cycle captive breeding, then the CITES Management Authority may need to register the farm with the CITES Secretariat before it can trade internationally – if the Party accepts the Resolutions concerning captive breeding.

2. Marking and Identifying Stock

It is not a requirement of CITES to use a marking system to individually identify all stock on a crocodilian farm, except for adults in CITES-registered captive breeding operations of Appendix-I species. But marking systems may sometimes be required under national and/or state laws, and marking systems are often used (eg scute-clipping, RFID/PIT tags, webbing tags, livestock tags) to track individuals for on-farm for various management purposes.

3. Origin of Stock

National laws normally dictate where stock can be obtained. The most common options are:

a. Wild-caught animals to use as breeding stock;
b. Wild-caught "problem/nuisance animals" to use as breeding or raising stock;
c. Wild-collected eggs and juveniles to rear ("ranching");
d. Captive-bred stock; and/or,
e. Stock purchased or otherwise obtained from other farms or even other countries.

4. Availability of Stock

It is clearly important to ensure that the stock required to operate a farm, in accordance with a specific business plan, will be available in sufficient numbers, at an acceptable price, for the life of the business plan.

5. Species to be Farmed

Choice of species to be farmed is limited by various factors, and the viability of farming will ultimately be determined by the commercial demand for the skin produced. The following need to be considered:

5.1. The species to be farmed should be restricted to a species residing in the country where the farm occurs, even if stock of that species may be acquired from neighbouring countries. The CSG does not support the establishment of crocodilian farming operations with species outside of their natural range.

5.2. Ten crocodilian species are currently farmed in significant numbers, primarily for their skins:
- American alligator (*Alligator mississippiensis*)
- Broad-snouted caiman (*Caiman latirostris*)
- Yacare caiman (*Caiman yacare*)
- Brown caiman (*Caiman crocodilus fuscus*)
- American crocodile (*Crocodylus acutus*)
- Morelet’s crocodile (*Crocodylus moreletii*)
- Nile crocodile (*Crocodylus niloticus*)
- New Guinea freshwater crocodile (*Crocodylus novaeguineae*)
- Saltwater crocodile (*Crocodylus porosus*)
- Siamese crocodile (*Crocodylus siamensis*)

5.3. Amongst these 10 species there is extreme variation in the value and sizes of skins required by the market for different products, and in the performance of different species subjected to the same housing and management regimes.

5.4. The crocodilian species not farmed for their skins mostly have excessive ossification in their scales or have relatively large belly scales in few rows, both of which result in decreased workability for the skin and reduced market value. Others are small species that cannot be grown to large sizes in a reasonable time period or are restricted from use by national legislation for various reasons.

6. Choice of Site

Although choice of site is invariably a compromise, and depends on whether the farm is going to be located indoors in a constant environment facility, or outdoors with exposure to the elements, the following need to be considered:

a. Water supply and costs
b. Electricity supply and costs
c. Communication access and costs
d. Road access

e. Location relative to the availability (and cost) of food, materials and staff
f. Climate (temperature and rainfall)
g. Land slope
h. Soil type
i. Probability of flooding
j. Planning requirements
k. Government permits/regulations
l. Community opinion and support

7. Grading and Final Product

The viability of crocodilian farming will ultimately depend on the number and quality of skins produced. The market is increasingly demanding higher and higher quality skins. This is partly because more crocodilian skin products are being made in light colours (reflecting fashion trends), which show imperfections more than the black and dark-brown colours used historically. Notwithstanding specific grading standards that different skin buyers may have:

7.1. The system of discerning skin quality involves assigning grades at the raw salted skin stage: Grade 1 (highest quality), Grade 2, Grade 3 and Grade 4 or rejects.

7.2. The criteria used to grade raw skins involve detecting imperfections, and determining whether their location on the skin is likely to impact on the ability to use the core area of the skin for a particular product.

7.3. However, there is a degree of precaution in the selection process for raw skins. This is because during tanning, the majority of imperfections will remain, some will disappear, and new ones may appear, sometimes due to an undetected problem but at other times due to damage caused in the tanning process.

7.4. Imperfections at the crust stage of tanning determine the real value of a skin, to the manufacturer, for making a particular product.

7.5. The most common imperfections in wild and farmed skins are: scars or bite marks (caused by agonistic behaviour between animals); erosion of scale edges and cuts (caused by rough surfaces in enclosures), double-scaling (most likely caused by growth stopping and starting, but could involve other factors), localised pitting and/or infections in or between scales (caused by pathogens; water quality possibly involved), parasite trails (caused by a nematode worm with an intermediate host of small fish or shrimps), and severe pattern abnormalities (caused during incubation within the egg).

7.6. The probability of most of these problems occurring can be reduced through good management practices.

8. Eggs and Hatchlings

In general, most crocodilian farms will need to have a functional incubator capable of successfully incubating the eggs taken from the wild (ranching) or laid on the farm (captive breeding). Once successfully incubated, hatchling care and rearing requires size-specific management to ensure that the farm stock has the optimal start to rearing to culling size.

Farms will need to consider:

8 .1. The type of incubator that is going to be used, and the level of egg inspection that is going to be involved during incubation.

8.2. Hatchling rearing facilities and a species-specific management approach optimized to promote high survival and high growth rates, that are normally distributed (rather than bimodal), with low frequencies of injury due to agonistic behaviour.

8.3. The temperature environment needed to ensure hatchlings can maintain body temperatures of around 32^{o}C when they elect to do so, and avoid high and low temperatures likely to be lethal for a particular species.

9. Juvenile Rearing Facilities

In addition to sustaining high survival rates and high, normally distributed growth rates, a central aim needs to be the maintenance of high quality skins. Bites, cuts and a host of other problems (see 7.5 above) can affect the skin quality, sometimes in ways that cannot be healed. Prevention needs to be a stronger commitment than repair. Issues that need to be considered in the raising stage are:

9.1. The optimum density for a particular species in a particular type of housing, needs to be determined by experimentation, with animal welfare, health and skin quality as key variables.

9.2. Density is linked to the probability of social interactions likely to damage the skin. Disturbance should be avoided if it is likely to cause flurries of activity that could result in individuals biting each other.

9.3. Water quality is generally considered important to preventing the growth and spread of pathogens, with regular cleaning or flushing to remove waste generally, and in particular, to remove floating oils and fats that are likely to build up on the head and eyes.

9.4. Consistent and reliable food sources needs to be identified. Food needs to provide basic nutritional needs and a diversity of vitamins and minerals to promote growth while sustaining good muscle, bone and gut health. Sudden changes in food, or the use of spoiled (eg decomposing meat, particularly fish) or contaminated foods (sometimes in formulated feeds) can impact seriously on health and well-being.

9.5. Grading and sorting according to size is generally considered a sound mechanism for preventing the establishment of social hierarchies that lead to subordinate animals being bitten and restricted from feeding.

9.6. All enclosure surfaces ideally need to be smooth and unable to damage the skin.

9.7. De-watering pens completely with some species is discouraged as it causes stress, and multiple ponds or deep-water ponds that are changed less frequently may be needed, especially in hot weather.

9.8. At all stages in juvenile raising, attention needs to be paid to the ability of animals to regulate their body temperature at or around 32^{o}C. Exposure to cool environments, where body temperatures fall below 25°C for prolonged periods will constrain growth. Body temperatures above 36-37°C are likely to be lethal.

10. Finishing

Regardless of the strategy used for raising juveniles, the skins of some individuals will have blemishes, and will not attract Grade-1 prices. Some of these can be healed if the animal is maintained in a unitized (individual) pen, protected from interactions of dominant animals, and provided individually with high quality food and water. Maintaining the highest number of Grade-1 skins is critically important to the commercial viability of crocodilian farming.

11. Captive Breeding

It is important to use captive breeding enclosures and management techniques that have been demonstrated as being efficient, in terms of hatchlings produced per breeding female maintained (or per breeding male and female maintained) for that particular species.

12. Security and Boundary Fencing

For a variety of reasons, some individual crocodilians may escape from their enclosures, due to human error on-farm, or outside interference. Having boundary fences to prevent the wider dispersal of escapees is usually mandatory, but inspection is required to ensure fences are not cut. Burying the bottom of fences in the ground prevents animals escaping by burrowing. Security from theft and vandalism is a serious consideration in some countries.

13. Veterinary Assistance

Access to veterinary and animal health expertise is important to detecting and treating diseases, and ensuring good health is maintained, especially in hatchlings and juveniles. Overuse of antibiotics and other medications should be avoided.

14. Animal Welfare

There is an increasing expectation that crocodilians will be farmed and treated in a humane way with no unnecessary pain or suffering.

15. Behavioural Conditioning

Many of the advances in crocodilian behaviour have historically been made in zoos or by amateur keepers, where the ratio of staff to crocodilians is very high, where attention to individual crocodilians is a daily occurrence, and where over and above the academic interest, the animals and their behaviour are often on public exhibit. Behavioural conditioning of captive crocodilians in these contexts is commonplace. For example, different coloured buckets can be used to signal to crocodilians whether they are about to be fed, or their pens drained and cleaned, and the crocodilians behave accordingly: remaining motionless during the cleaning. Adult crocodilians have often been taught to come when called, remain passive for inspection and move to specified areas in response to commands. Behavioural conditioning does occur in some commercial farm contexts, but is an area likely to increase in importance in the future.

16. Skinning

When crocodilians are killed for skinning, the methods used should ensure an instantaneous death with destruction of the brain. The animals may be skinned immediately after killing, or are sometimes hung in a cool room before skinning (where meat is to be used for human consumption, times between culling and skinning may be defined). Skinning, flensing, salting and storage should all be done in a way that does not damage the skin, nor contaminate it with blood or other materials. Skins should be kept refrigerated at around $5^{o}C$ until shipment.

Annex 2

Best Management Practices for Crocodilian Farming - Assessing Individual Farms

1. Name of farm: ______________________________

2. Farm owners: ______________________________

3. Location (town/district/province/country): ______________________________

4. In what year was the farm established? ______________

5. Is the farm legally established?

   5.1. Is it compliant with national/state laws? ……………………………..…………………… Yes / No

   5.2. Have documents of compliance been sighted? ……………………………………………. Yes / No

6. Which species are being farmed commercially for skin and/or meat production? (tick box/s)

   American alligator (*Alligator mississippiensis*) (Appendix II) ……… ☐
   American crocodile (*Crocodylus acutus*) (Appendix I & II) ………… ☐
   Broad-snouted caiman (*Caiman latirostris*) (Appendix I & II) ……….. ☐
   Yacare caiman (*Caiman yacare*) (Appendix II) ……………………… ☐
   Brown caiman (*Caiman crocodilus fuscus*) (Appendix II) ………….. ☐
   Chinese alligator (*Alligator sinensis*) (Appendix I) ………………….. ☐
   Morelet's crocodile (*Crocodylus moreletii*) (Appendix I & II) ……… ☐
   Nile crocodile (*Crocodylus niloticus*) (Appendix I & II) ……………. ☐
   New Guinea crocodile (*Crocodylus novaeguineae*) (Appendix II) ….. ☐
   Saltwater crocodile (*Crocodylus porosus*) (Appendix I & II) ………… ☐
   Siamese crocodile (*Crocodylus siamensis*) (Appendix I) ……………. ☐

   Other (specify) ______________________________ ☐

7. If exported from the country of origin with appropriate CITES Export Permits, can skins or other products be imported legally into all countries (with appropriate CITES Import Permits if required), or are imports into some countries still banned under "stricter domestic measures" such as national Endangered Species Acts that are not completely synchronised with CITES ? If "yes" please specify ………………….….. Yes / No

   ____

   ____

8. Is the farm required by national law to follow any code or regulations concerning:

   8.1. Farm construction (pen design, security fencing, etc.) …………….………………………. Yes / No

   8.2. If so, what code or regulations? ______________________________

   8.3. Farm management ………………………………………………………………………. Yes / No

   8.4. If so, what code or regulations? ______________________________

9. With regard to science-based animal welfare and/or the humane treatment of crocodilians:

9.1. Is the farm required by national/state law to abide by any code of practice? ……………. Yes / No

9.2. If so, what is the code? ____

9.3. If not required by national law to abide by any code, has the farm adopted a code or guidelines to guide its activities? …………………………………………………….. Yes / No

9.4. If so, what is the code? ____

9.5. Is compliance with a code audited by an official agency? ……………………………….. Yes/No

10. With regard to the knowledge-base supporting farm activities:

10.1. Does the farm operate with a high degree of traditional knowledge? ………………….. Yes / No

10.2. Does the farm have staff that can effectively translate and apply scientific knowledge? .. Yes / No

10.3 Does the farm engage seriously in its own research and development? ……..……..… Yes / No

10.4. Does the farm have ready access to general veterinary knowledge? ………..………… Yes / No

10.5. Does the farm have ready access to skilled veterinary knowledge about crocodilians? ... Yes / No

10.6. Are veterinary diagnostic laboratories available to the farm? ………………………….. Yes / No

11. If the species is on Appendix I of CITES, is the farm:

11.1. Registered with CITES as a captive-breeding operation? ……………………………… Yes / No

11.2. If not registered, is their an intention to register the farm? ……………………………… Yes / No

11.3. If there are no plans for registration:
a. Is it a satellite/contract farm? …………………….……………………………………… Yes / No
b. Is it linked to a single registered captive-breeding operation? ………………………. Yes / No
c. If yes, what is the name of the registered farm? ______________________
d. If not a satellite/contract farm and not linked to a registered farm, explain how trade occurs:
……….………..……………………………………………………………………………
……….………..……………………………………………………………………………

12. What are the average annual total stocks of crocodilians on the farm over the last three years? (tick box)

<10 ……………………… ☐
11-50 …………………….. ☐
51-100 …………………… ☐
101-250 ………………… ☐
251-500 ……..………… ☐
501-1000 ……..………… ☐
1001-2500 ……..……….. ☐
2501-5000 ……..……….. ☐
5001-10,000 …….……… ☐
10,001-25,000 …..……… ☐
25,001-50,000 …..……… ☐
50,001-100,000 …..……... ☐
100,0001-150,000 …..…… ☐
>150,000 ………………… ☐

13. From a commercial return viewpoint, concentrating only on crocodilian production, does the farm produce and sell? (tick box)

a. Mainly live hatchlings to other farms (<1 yr) ………… ☐
b. Some live hatchlings ……………………………………. ☐
c. Mainly live juveniles to farms or for eating (1<3 yr) …… ☐
d. Some live juveniles ……………………………………. ☐
e. Mainly skins for leather production ……………………. ☐
f. Some skins ……………………………………………… ☐
g. Mainly meat for human consumption ………………….. ☐
h Some meat ………………………………………………. ☐
i. Mainly finished products ……………………………… ☐
j. Some finished products ………………………………… ☐
k. Mainly other by-products ……………………………… ☐
l. Some other by-products ………………………………… ☐

14. What is the mean level of annual recruitment of new stock (hatchlings + other purchased stock) onto the farm over the last three years?

<10 …………………….. ☐
11-50 ………………….. ☐
51-100 ………………… ☐
101-250 ………………. ☐
251-500 ………………. ☐
501-1000 ……………… ☐
1001-2500 ……………. ☐
2501-5000 ……………. ☐
5001-10,000 …………… ☐
10,001-25,000 ………….. ☐
25,000-50,000 ………….. ☐
>50,000 ………………. ☐

15. What is the most common sources of stock recruitment (estimate in percentages) over the last 3 years (should add to 100%)?

a. Captive-bred hatchlings produced: _______ %

b. Captive-bred juveniles from other farms: _______ %

c. Ranched hatchlings produced: _______ %

d. Ranched juveniles from other farms: _______ %

16. For captive breeding last year (Year = ______):

a. Number of adult-sized females on farm _______

b. Number of adult-sized males on farm _______

c. Number of nests produced _______

d. Number of eggs produced _______

e. Number of hatchlings produced _______

17. If the farm is an Appendix-I captive-breeding operation:

17.1. In what years was the majority of founder stock obtained? ________

17.2. Were the adult founder stock obtained in accordance with national legislation? ………. Yes / No

17.3. Is documentation verifying the legal origin of founder stock available and sighted? …… Yes / No

17.4. Did the founder stock come direct from the wild?
a. All founder stock ……………………………………………………………….. ______ %
b. Some founder stock …………………………………………………………….. ______ %

17.5. If founder stock were obtained from other farms, how did they obtain stocks?:
a. From the wild ………………………………………………………………………. Yes / No
b. From captive breeding ……………………………………………………………… Yes / No
c. Unknown ……………………………………………………………………….. Yes/ No

17.6. Other (explain how founder stock were obtained)

____
____
____

18. Do the adults used for captive breeding appear to be in good health? …………………………. Yes / No

19. If not in good health, what are the problems and likely causes?

____
____

20. What percentage of annual farm stock recruitment of hatchlings is derived through ranching? ______ %

21. Where ranching is involved:

21.1. What percentage involves:
a. Wild-collected eggs _________ %
b. Wild-collected hatchlings _________ %
c. Wild-collected juveniles _________ %

21.2. Are the ranched eggs/animals:
a. purchased; or,
b. provided gratis

21.3. If purchased, who are the main beneficiaries (use percentages):
a. Government _________ %
b. Individual landowners _________ %
c. Local communities _________ %
d. Random hunters _________ %

21.4. Does the ranching program benefit the livelihoods of people? (Explain)

____
____
____

25. Does the farm have a policy on Corporate Social Responsibility? …………………………… Yes / No

INCUBATION

26. Are eggs incubated on the farm? ………………………………………………………….. Yes / No

27. Does incubation involve:

27.1. A controlled environment chamber (<1°C fluctuation) with eggs exposed on racks or exposed in crates, that are inspected throughout incubation? ……………………….. Yes / No

27.2. A controlled environment chamber (<1°C fluctuation) with eggs in media (nest vegetation, vermiculite, etc,), that are inspected throughout incubation? …………..…………… Yes / No

27.3. A controlled environment chamber (<1°C fluctuation) with eggs in media (nest, vermiculite, etc,), that are not inspected throughout incubation? …………..…………… Yes / No

27.4. Incubation in sand or nest material with some control over nest temperature extremes? .. Yes / No

27.5. Incubation in sand or nest material with no control over nest temperature extremes? ..… Yes / No

28. Is the incubation technique suited to the farm given factors such as reliability of electricity supply? ……………………………………………………………………….. Yes / No
(Explain) ____
____
____

29. Are improved incubation techniques likely to be practical or cost-effective options for farm? … Yes / No
(Explain) ____
____
____

30. Are staff responsible for incubation trained with regard to current information about eggs and embryos? ………………………………………………………………………. Yes / No

31. Are eggs inspected before or during incubation with a view to establishing whether incubation losses are due to the quality of eggs or the adequacy of incubation conditions? ..…. Yes / No

32. Do more than 5% of eggs:
a. Develop air spaces between the eggshell and eggshell membrane? …..………. Yes / No / Unknown
b. Develop swelling, with the eggshell cracking longitudinally? ..………………. Yes / No / Unknown

33. Do more than 5% of hatchlings produced:
a. Have obvious problems (eg fully developed but dead in egg)? …..…………. Yes / No / Unknown
b. Hatch with external yolk or with large yolks and small bodies? ……..…..…. Yes / No / Unknown
c. Show twisted tails or spines? ………………………………..………………. Yes / No / Unknown

HATCHLING REARING

34. Are hatchlings produced on the farm? ……………………………………………………….. Yes / No

35. If hatchlings are produced, what percentage are:
a. On-sold immediately? ……………………………………………………………… _______ %
b. Retained and grown to older hatchlings/juveniles for sale? …………………………… _______ %
c. Retained and grown to older hatchlings/juveniles to shift to satellite/contract farms …. _______ %
c. Retained and grown on the farm for eventual culling/sale? …………………………… _______ %

36. Over the last 3 years, what is the average proportion of apparently normal hatchlings that end up as healthy, surviving 1-year-olds (including healthy but undersized hatchlings that may be culled)?

95.1-100% ………. ☐
90.1-95.0% ………. ☐
80.1-90.0% ……… ☐
70.1-80.0% ………. ☐
50.1-70.0% ……… ☐
<50% ……………. ☐
Unknown ………… ☐

37. What are the major problems with hatchlings?
a. Failure to thrive (runtism) ………….. ☐
b. Disease (explain) …………………. ☐
c. Other (explain) ……………………… ☐
(Explain) ____

____

____

38. If problems are being encountered with hatchling rearing, do the facilities and management techniques appear adequate for this species in terms of:

38.1. Water quality
a. quality of water supply …………..……………………………………. Yes / No / Possibly
b. contamination ……………………………………………………….. Yes / No / Possibly

38.2. Temperature environment ……………..……………………………………. Yes / No / Possibly

38.3. Food
a. source…..…………………………..………………………………….. Yes / No / Possibly
b. storage ..…………………………..………………………………….. Yes / No / Possibly
a. preparation …..……………………..………………………………….. Yes / No / Possibly

38.4. Vitamin and mineral supplements ………..………………………………… Yes / No / Possibly

38.5. Protection from disturbance
a. Visual ………………………………………………………………… Yes / No / Possibly
b. Sound or vibration ………………………………………………… Yes / No / Possibly
c. From management practices …………………………………………. Yes / No / Possibly
d. Sudden changes in management practices ………………………….. Yes / No / Possibly

38.6. Biosecurity controls generally ……………………………………………. Yes / No / Possibly

38.7. Densities ………………………………………………………………… Yes / No / Possibly

38.8. Size grading ………………………………………………………………. Yes / No / Possibly

38.9. Pen design generally …………………………………………………….. Yes / No / Possibly

38.10. Pen surfaces ………………………………………………………………. Yes / No / Possibly

38.11. Inadequate antibiotic use ………………………………………………… Yes / No / Possibly

38.12. Staff training/experience ……..…………………………………………. Yes / No / Possibly

38.13. Other ……………………………………………………………………. Yes / No / Possibly
(Explain as required) ____

____

____

____

____

____

JUVENILE REARING

39. What is the average age of farm crocodilians at time of culling? (tick box)

<1 year …………… ☐
1-2 years ………… ☐
2-3 years ………… ☐
3-4 years ………… ☐
>4 years ………….. ☐

40. Do the juvenile crocodilians appear to be in good health with good body condition? ………… Yes / No

41. If the juvenile crocodilians do not appear to be in good condition, what percentage of sick, thin or injured animals are amongst the healthy ones?
a. No ……………........…….. ☐
b. Yes, <1% ……………… ☐
c. Yes, 1-5% …….……… ☐
d. Yes, 5-10% ……..……….. ☐
e. Yes, >10% ……..……….. ☐

42. If juvenile crocodilians do not appear to be in good condition, which of the following reasons do you consider may be implicated:

42.1. Water quality:
a. quality of water supply (explain) ______________________ ☐
b. contamination (explain) ______________________ ☐

42.2. Temperature environment (explain) ______________________ ☐

42.3. Food (explain) ______________________ ☐

42.4. Vitamin and mineral supplements (explain) ______________________ ☐

42.5. Protection from:
a. Visual disturbance (explain) ______________________ ☐
b. Sound or vibration disturbance (explain) ______________________ ☐
c. Management procedures (explain) ______________________ ☐
d. Sudden changes in management practices (explain) ______________________ ☐

42.6. Biosecurity controls generally (explain) ______________________ ☐

42.7. Densities (explain) ______________________ ☐

42.8. Size grading (explain) ______________________ ☐

42.9. Pen design generally (explain) ______________________ ☐

42.10. Pen surfaces (explain) ______________________ ☐

42.11. Best practice handling, management procedures not being used? ______________________ ☐

42.12. Inadequate antibiotic use ______________________ ☐

42.13. Staff training/experience ______________________ ☐

42.14. Other (explain) ______________________ ☐

43. If the juvenile crocodilians appear to be in good health, with good body condition, what is the quality of the skins before shifting to individual pens or being culled?

- a Very bad (<20% 1st grade) ………………. ☐
- b. Bad (20-40% 1st grade) …………………. ☐
- c. Reasonable (40-60% 1st grade) ………….. ☐
- d. Good (60-80% 1st grade) ………………… ☐
- e. Excellent (>80% 1st grade) ……………… ☐

44. How would you rank (0 to 10; with 0 = no concern) the following problems and potential causes:

44.1. *Problem*: Bites, cuts or scars resulting from interactions between individuals, potentially caused by:
- a. Densities too high ………………….… ☐
- b. Interactions during feeding ………….. ☐
- c. Not enough grading …………………... ☐
- d. Insufficient land area in pens …………. ☐
- e. Insufficient water area in pens ……….. ☐
- f. Mistreatment by staff ………………..… ☐

44.2. *Problem*: Infections on the skin (brown spot, pitting), potentially caused by:
- a. Quality of the basic water supply …….. ☐
- b. Water pollution after feeding ……..…. ☐
- c. Insufficient cleaning after feeding ……. ☐

44.3. *Problem*: Erosion on the edges of belly scales, potentially caused by:
- a. Rough surfaces on the land …………………………………. ☐
- b. Rough surfaces in the water ………………………………… ☐
- c. Rough surfaces on the land-water interface ………………… ☐

44.4. *Problem*: Double scaling, caused by seasonal growth arrest periods, due to:
- a. Low winter temperatures …………… ☐
- b. Lack of food for prolonged periods … ☐

44.5. *Problem*: Parasite trails caused by nematode worm infestation due to:
- a. Live fish and shrimps (intermediate hosts) living in the same pens as the crocodilians ………………………………………………………….. ☐
- b. Infected juveniles from freshwater areas relocated onto a farm …………... ☐

44.6. *Problem:* Other (explain) ____
____
____

45. Do the juvenile crocodilians housed in individual pens appear to be in good health, with good body condition? ………………………………………………………………….. Yes / No

46. If the juvenile crocodilians housed in individual pens do not appear to be in good health, with good body condition, what is considered the likely cause?

- a. Inadequate temperature regime (explain) ________________________________ ☐
- b. Inadequate water quality (explain) ________________________________ ☐
- c. Inadequate water quantity (explain) ________________________________ ☐
- d. Inadequate feeding regime (explain) ________________________________ ☐
- e. Inadequate size of water area (explain) ________________________________ ☐
- f. Inadequate size of land area (explain) ________________________________ ☐

KILLING AND SKINNING

47. Is the farm required by national law to follow any code/regulations concerning the killing and/or skinning of crocodilians, and/or preparation of crocodilian meat for human consumption? ….. Yes / No

48. If yes, what codes and/or regulations apply? ____
____
____

49. Has the abattoir/processing facility been certified according to standards required by some importing countries? ……………………………………………………………………………… Yes / No
(Explain) ____
____

50. If no, has the farm formulated its own code or adopted a code from another country? (Explain)
____
____
____

51. Does method of killing crocodilians result in instantaneous death without pain and suffering? ….. Yes / No

52. If yes, what method/s are used to kill crocodilians? ____
____

53. If not, why are recognised methods for killing crocodilians without pain not being used? (Explain)
____
____
____

54. Rank different aspects of the skinning process and curing of skins (ranks 0 to 10, with 10 being the highest standards):

a. A CITES tag or equivalent is attached as soon as possible after killing ……………..…… ☐
b. Skinning carried out in a cool environment …………………………………………… ☐
c. Skins kept free of blood and detritus ………………………………………………….. ☐
d. Excess meat removed from the skin (flensing) …………………………………….. ☐
e. Skin salting and storage in a cool, clean area ………………………………………… ☐
f. Skins salted with clean, fine salt …………………………………………….………… ☐
g. Skins soaked in brine ……………………………………………………….………….. ☐
h. Skins given a second salting with clean, fine salt ……………………………………... ☐
i. Skins rolled to avoid creases (or to customer specifications) ………………………… ☐

55. Do the skins that are exported have the correct permits and procedures as may be required by the CITES Management Authority and other local and national agencies …………………. Yes / No

56. Does the farm have tanning facilities? ………………………………………………………… Yes / No

a. If so, to what stage of tanning are skins processed? (tick box/s)

Wet blue ……………… ☐
Crust …………………… ☐
Finished leather ……..… ☐
Finished products ……… ☐

b. Does the tannery comply with national/state regulations with respect to waste water and solid waste treatment? ……………………………………………………………..… Yes / No

c. Does the tannery use an internal tagging system to allow source of skins to be identified? . Yes / No

d. If so, what is the percentage of skins sighted in the tannery with appropriate tags ……… ______ %

57. Does the farm have an environmental policy? ……………………………………..……..….. Yes / No

STAFF OH&S

58. Are staff adequately trained and familiar with the farm's standard operating procedures, particularly with respect to animal welfare and work health and safety: ………………..….. Yes / No

59. Are corrective actions applied in the case of non-compliance with standard operating procedures? …………………………………………………………………………….. Yes / No

60. Are appropriate OH&S procedures in place? ……………..…………………………….. Yes / No