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Research and Consultation Report

Review of the Code of Practice for the Humane Treatment of Wild and Farmed Australian Crocodiles

April 2024

Department of Climate Change, Energy, the Environment and Water

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Background

The Code of Practice on the Humane Treatment of Wild and Farmed Australian Crocodiles (Code of Practice) (Australian Government 2009) was developed and endorsed by the Natural Resource Management Ministerial Council (NRMMC) on 21 May 2009. The NRMMC consisted of Australian Government and state, territory and New Zealand Government Ministers responsible for primary industries, natural resources, environment and water policy. The Code of Practice was developed to establish an achievable minimum standard of humane conduct for the treatment of wild and farmed crocodiles in Australia. Compliance with the Code of Practice is a requirement of approved Wildlife Trade Management Plans for the commercial use (and export) of crocodiles under the *Environment Protection and Biodiversity Conservation Act 1999* (Cwth) (EPBC Act).

The current Code of Practice is based on the knowledge and technology available at the time of publication. In 2009, it was anticipated that the Code of Practice would be reviewed within 5-10 years of publication. It was also acknowledged that at the time of publication, there were some deficiencies in the experimental study of crocodile sensory perception, physiology, behaviour, discomfort and pain thresholds and that the knowledge at the time was often based on subjective assessment rather than well-founded experimental evidence.

It is important to note that many First Nation Australians have an important relationship with the crocodile. As a sacred totem for many First Nations groups in Northern Australia, many First Nation Australians feel a responsibility for the care and management of the crocodile. As such, their contribution will be important to this review process.

The Department of Climate Change, Energy, the Environment and Water (the Department) have contracted Callida Consulting as an independent delivery partner to lead a review of the Code of Practice.

Overview of the Industry

Commercial crocodile harvesting in Australia is comprised of both wild take and farming activities (Australian Government 2009). As of November 2023, the Australian saltwater crocodile (*Crocodylus porosus*) industry consisted of 21 operators in the Northern Territory, Queensland and Western Australia (Pattison, Isberg and Strappe 2023).

The Australian crocodile industry is reported to play a significant role in the Australian economy, particularly in Northern Australia and is renowned for producing high-quality skins that cater to the luxury fashion market as well as other crocodile products including meat, teeth and taxidermy specimens that are traded both domestically and internationally (Australian Government 2009; Pattison, Isberg and Strappe 2023). The main importing countries of crocodile products are France, Singapore, Italy and Japan. Overall, Australia is a relatively small exporter of crocodilian skins when compared to the United States, Colombia, Bolivia, South Africa, Zimbabwe, Thailand and Vietnam (Pattison, Isberg and Strappe 2023). Australia is, however, the largest exporter of *C. porosus* skins which is considered to produce the highest quality skins (Pattison, Isberg and Strappe 2023).

Noting that data on the market value of crocodile farming is limited, the industry's value-added contribution in the Northern Territory (NT) alone is reported to have been $54.3 million in 2014-15

(Pattison, Isberg and Strappe 2023; Ernst & Young 2017). This industry has grown and expanded since 2014-15 therefore, the value of the industry would now be higher (Pattison, Isberg and Strappe 2013; Ernst & Young 2017). To our knowledge, there has been no further quantification of the value of the industry in recent years.

Purpose of the Review

The purpose of the review is to consider whether the guidance contained in the Code of Practice is clear, well informed and appropriate for its users. The review will test the current content established in 2009 with modern advancements, allowing it to be updated and republished for use by industry, government, the research sector, regulatory bodies, and members of the public.

While the overarching purpose of the review is to consider all relevant advances in knowledge since 2009, the review will specifically consider:

- **Traditional knowledge** of non-commercial methods of hunting, keeping and handling crocodiles by First Nations Peoples, including cultural significance.
- **Advances in scientific research** including but not limited to crocodile sensory perception, discomfort and pain thresholds and veterinary medications.
- **Advances in technology and handling** including but not limited to egg collection, transport and incubation, housing and maintenance and capture and restraint methods.

The review will not consider matters relating to:

- The expansion of the Code of Practice to **Australian zoos and recreational and educational facilities.**
- **Human safety** beyond the context of commercial crocodile industry and related Wildlife Trade Management Plans.
- **Population survey** methodology and modelling.

Purpose of the Report

The purpose of this report is to articulate key review findings obtained through research and consultation activities during the review process. It is important to note that this report does not place a weighting on any submissions or findings, arrive at any conclusions based on these findings, nor does it provide recommendations for the revised Code. This report serves as a summary of key findings to date.

Research Methodology

The approach taken for reviewing and updating the Code of Practice involved combining objective research methods with insights and feedback from scientists, researchers, industry, non-government organisaitons (NGOs), First Nations Peoples, government, veterinarians and the general public. This will facilitate a revised Code that takes into consideration a broad range of perspectives, backgrounds and motivations for stakeholders' engagement with the Code. By doing so, it ensures the Code of Practice review is high-quality and grounded, as much as possible, in evidence-based practices.

Desktop Research

Sources were identified through desktop research to inform consultation with industry experts. Material collected included research published in peer-reviewed scientific journals, best practice updates from the International Union for Conservation of Nature (IUCN) Species Survival Commission Crocodile Specialist Group (an international network of parties actively involved in the conservation of crocodilians) and information from government agencies.

This research served as a sound knowledge base for informed discussions with experts in the field, enabling Callida to frame questions, identify gaps in knowledge, and seek expert insight into potential areas for review and improvement.

Academic research into crocodilians is an emerging area of interest. Crocodilian farming is a novel and small industry compared to other areas of traditional agriculture. This has meant that academic research into crocodilians, their biology and welfare is still in its infancy. Despite this, since the release of the current Code, a number of advancements have been made, with particular regard to crocodile behaviour in the wild, stress levels in reaction to stimuli and the effectiveness and appropriateness of new husbandry techniques.

Acknowledging that understanding of crocodilians is still evolving, this desktop review delved into a range of articles covering different crocodilian species. However, only relevant sources within scope of this review are included within this report. The two primary crocodilians relevant for the Code of Practice are the *Crocodylus porosus* (saltwater/estuarine crocodile) and *Crocodylus johnstoni* (freshwater crocodile). While academic research specifically focused on these species is not exhaustive, the review also considered research into other crocodilians, such as the *Alligator mississippiensis* (American alligator), *Crocodylus niloticus* (Nile crocodile) and *Caiman crocodilus* (spectacled caiman). Although research on these other crocodilians was considered, the literature pertaining to *C. porosus* and *C. johnstoni* was prioritised. Additionally, the review examined several articles related to reptiles more broadly, primarily for contextual purposes.

Expert Advisory Panel (EAP) Consultations

An Expert Advisory Panel (EAP) was established by the Department to guide the review and ensure matters are fully explored throughout the review process. The EAP consisted of subject matter experts from industry, state and territory government, CSIRO, the veterinary science and scientific research sectors and the NGO sector.

Four EAP members have a history of working with crocodilians in a scientific capacity, either through research or veterinary practices. Three of these EAP members hold PhDs in animal and veterinarian science and have had their work cited by the IUCN Species Survival Commission Crocodile Specialist Group (CSG). Two EAP members are state government regulators who interact with the Code of Practice on a day-to-day basis through their regulatory responsibilities. Two EAP members are business owners, active in crocodilian farming and one EAP member is an NGO representative.

All EAP members were required to declare any conflicts of interest before participating in the Review.

Each EAP member met individually with Callida consultants for an initial meeting. Four questions were posed to each EAP member:

1. What changes to the current Code of Practice would you recommend and why?
2. What should be included in the revised Code of Practice that does not appear in the current Code of Practice and why?
3. What will be required to support implementation of the revised Code of Practice and why?
4. Is there anything additional you would like to add?

The EAP then met collectively to discuss common topics derived from the initial individual meetings. The insights provided by the EAP during this session allowed Callida to compile a list of topics for discussion at Focus Group consultations. These topics form the basis of the thematic summary of findings below.

Focus Group Consultations

Four Focus Group consultations were conducted to explore important review themes identified by EAP members. Callida generated a series of questions to frame Focus Group discussions based on discussions with EAP members. Focus Group participants were nominated by EAP members and the department and were segmented into the following categories:

- Non-government organisations (NGOs)
- Scientists and researchers
- Government (federal, state and territory)
- Industry members (e.g. farmers).

First Nations groups were engaged through targeted consultation with representative bodies and direct feedback through written submissions.

Call for Public Submissions

Between 20 November 2023 and 2 February 2024, the department published a request for public submissions regarding the Code of Practice review. During this period a total of 303 public submissions were received via webform and direct email.

The most submissions were received from NSW (28.1%), followed by QLD (22.03%), VIC (22.34%), Outside Australia (13.22%), WA (4.75%), SA (3.73%), NT (2.71%), TAS (1.69%), and ACT (1.36%).

Of the total public submissions:

- 1 supported the Code of Practice as currently written
- 117 were campaign style submissions which contained largely identical content
- 67 opposed the existence of the crocodile farming industry, or any use of animal products
- 74 were nil responses.

Of the remaining 44 submissions, 28 submissions were from members of the public, were not campaign style and did not strongly oppose the farming industry. The other 16 were submitted by NGOs and Governments and of these, 3 organisations provided detailed annotations against various sections of the Code of Practice.

Findings

As previously outlined, a comprehensive range of consultation and desktop research activities were conducted to inform the findings presented below. These findings draw from both scientific peer-reviewed literature and insights gathered through consultations with various stakeholders, including the EAP, the general public, Focus Group attendees, First Nations peoples, experts in the crocodile farming industry and professionals in veterinary science and animal welfare.

Research and consultation activities revealed that the existing Code of Practice is largely fit for purpose. However, it was also found that is it essential to incorporate advances in scientific research and contemporary perspectives related to farming practices and animal welfare since the Code's initial publication in 2009. Feedback from consultation activities and findings from desktop research was consistently aligned and can be categorised into six broad areas, which are discussed in greater detail below.

Whole of Code Changes

Consultation highlighted some specific areas and sections of the Code that require attention as part of the review, as well as suggested changes relating to the overall structure, tone and framing of the document.

Prescriptive vs Outcome Focused

Common feedback emphasised the need for the revised Code to strike a balance between being prescriptive and outcomes focused. Members of the EAP as well as Industry and Science Focus Group attendees expressed that while some areas of the revised Code should remain prescriptive (e.g. stunning equipment standards to ensure a high degree of animal health and wellbeing are met) allowances should be made for innovation and incorporation of new research and technologies as advancements in the field are recognised. This position though must be considered against feedback from the NGO Focus Group which highlight that while prescriptiveness may limit innovation, it holds users of the Code to a high standard by providing less room for interpretation.

It was also noted that maintaining high levels of prescription should require the Code of Practice to be reviewed more regularly to ensure the Code remains best practice as new research and innovation in farming practices emerges. Two Public Submissions recommended a mandatory review period to maintain a high standard and to ensure the revised Code is consistently updated with advances in science and humane farming practices.

Sentience and the Five Domains Model for Animal Welfare

Focus Group attendees, public submissions and some of the EAP members noted that reptiles are becoming more commonly recognised as sentient beings, defined as having the 'capacity for sensation or feeling' (Robertson and Goldsworthy 2022; Lambert, Carder and D'Cruze 2019). While research into animal sentience is relatively novel, literature in this area is increasing and the importance of understanding how positive experiences and emotions contribute to animal wellbeing as opposed to just negative experiences is considered to be increasingly important (Proctor, Carder and Cornish 2013; Littlewood, Heslop and Cobb 2023).

Due to this, most public submissions and feedback from the NGO and Science and Research Focus Groups strongly suggested the Five Domains Model be used to underpin the requirements

(standards) and best practice (guidelines) in the revised Code of Practice. Animal welfare is multidimensional and considers factors such as good animal health and freedom of behaviour (Botreau et al. 2007). The Five Domains Model for animal welfare was founded by Mellor and Reid (1994) but has been most recently updated in 2020 and is increasingly used globally when considering the lived experience of animals in human care (Mellor et al. 2020). The domains of the 2020 model are as follows: 1. Nutrition, 2. Physical Environment, 3. Health, 4. Behavioural Interactions and 5. Mental State (Mellor et al. 2020). The first four domains focus on factors that influence negative or positive experiences for the animal, which contribute to the animal's mental state (domain 5) (Mellor et al. 2020).

Public submissions emphasised the integration of the Five Domains Model to ensure crocodiles experience enrichment within a stimulating and psychologically positive environment. Submissions emphasised that an 'enriched environment' should facilitate the expression of natural behaviours by crocodiles. This environment should be free from discomfort, fear and distress. It should allow them to swim over distances, exercise, fully submerge themselves in water and experience both isolation and social interactions with other crocodiles at their discretion. The presence of positive emotion is cautiously inferred from these behaviours, as they reflect the animal's engagement in activities that it genuinely 'wants to do' (Littlewood, Heslop and Cobb 2023). However, while there is existing literature on environmental enrichment for reptiles, specific research related to crocodilians remains limited (Burghardt 2013).

It was agreed by all Focus Group attendees that language throughout the Code of Practice could benefit from a more progressive tone. Specifically, it was agreed that the language should be modified to acknowledge the enhanced understanding that crocodiles are not solely aggressive creatures with 'prehistoric' tendencies. In light of this, EAP members suggested that language and wording in the revised Code should align with guidelines set by World Organisation for Animal Health (World Organisation for Animal Health 2022).

Aligning the Revised Code of Practice with Existing Welfare Standards

Several public submissions and NGO Focus Group attendees requested that the Code of Practice be upgraded to Standards (mandatory requirements) and Guidelines (best practice), to be in line with other contemporary animal welfare standards. These Standards and Guidelines should include a list of general principles of animal welfare, list responsibilities for operators, and provide national best practice standards that are enforceable across all jurisdictions. Feedback and research indicated that due to concerns regarding the limited enforceability of 'codes' that there is a common transition occurring within the farming industry to 'standards', which are designed to be implemented within state and territory legislation (Department of Agriculture, Fisheries and Forestry 2024; White and Dale 2013).

If retained as a Code of Practice, then 'specific requirements' should be highlighted separately or, 'called out' throughout the document. Also, in the Introduction section of the Code, an explanation of the difference between requirements and guidelines should be included.

One submission recommends that the revised Standards and Guidelines should seek to achieve conditions that are considered humane by a broad consensus of animal welfare scientists and by Australian community standards. The submission outlined that this would be consistent with Environment Protection and Biodiversity Conservation Regulations 2000 (EPBC Regulations)

(regulation 9A.05) for animal welfare which require treatment that is generally accepted to minimise pain and suffering. This submission expands to outline that the definition of humane treatment used in the current Code is qualified by 'avoidance of unnecessary pain and suffering'. It argues that the definition should be 'treatment that avoids inflicting pain and suffering and seeks to optimise the physiological and psychological welfare of the animal'. The submission also argues that including the phrase 'unnecessary pain and suffering' adds subjectivity which is inappropriate in a definition and will create difficulties for enforcement.

One submission suggested that the revised Code of Practice should state that a precautionary approach should be taken to addressing more specific and detailed topics of crocodile care, due to the limited availability of scientific literature addressing detailed care requirements.

Format and Reference Materials

A stand-alone submission suggested several improvements to the format and reference guidance material in the updated Code of Practice including that:

- guiding principles should be included in the 'Introduction' section of the Code
- a glossary of terms should be included for terms such as sentient, slaughter, humane killing, animal welfare, consciousness, environmental enrichment, distress, duty of care, and irreversible stunning
- diagrams and description of the most humane methods for restraining and killing unviable hatchlings should be included as an Appendix in the Code
- diagrams and description of the most humane methods for capturing wild and captive crocodiles should be included as an Appendix in the Code
- diagrams and description of the most humane methods for restraining wild and captive crocodiles should be included as an Appendix in the Code.

NGO Focus Group attendees also considered that the glossary of terms should be updated to reflect the terms mentioned above.

Good Husbandry Practices

Central to successful welfare outcomes for crocodiles are good animal husbandry practices. Husbandry refers to the care, cultivation and breeding of crops and animals and in this case, refers to the practices put in place to care for crocodiles as they grow. Support for strong husbandry practices was universal amongst stakeholders consulted as it links to positive health and welfare outcomes for animals and assists in strong economic outcomes for the farming industry. It is noted that on the whole, husbandry practices under the current Code are supported by industry, stating that most of the practices remain fit for purpose and there are only minor improvements to be made. This is supported through research that has found hatchling crocodiles within their first year, kept under the conditions as set out in the current Code of Practice show baseline stress levels lower than previously reported in saltwater crocodile hatchlings (Finger et al. 2015).

Animal Health

EAP members and Focus Group attendees were asked whether a healthy animal assessment could be included or referenced within the revised Code to provide measures of animal health rather than just the presence of illness. Industry, NGO, Government and Science and Research Focus Group

attendees agreed that this would be useful. NGO attendees specifically outlined the importance of 'positive welfare measures' e.g. normal behaviour patterns and signs of enrichment such as play between individuals rather than only 'negative welfare measures' such as the presence of illness. Industry attendees agreed that a healthy animal assessment should be behaviour-based as well as appearance-based. For example, understanding normal animal behaviour in relation to food consumption, basking patterns and breeding patterns can often provide a better indication of animal health than physical characteristics. Industry attendees mentioned that it is important to distinguish between an animal being unwell and an animal living in sub-optimal conditions which is affecting the individual's growth rate. It was also noted that season and age need to be considered as part of a healthy animal assessment. If an individual is looking underweight during the season optimal for growth this would be a concern however, it is common that animals may lose weight during the dry season.

Academic research has articulated some animal-based measures of welfare for crocodiles. Hewitt and Small (2021) identified 12 welfare criteria across four welfare principles and tested these with an expert panel. This panel included 80 individuals who had a background in veterinary medicine, crocodilian management or animal welfare research. The principles were good feeding, good housing, good health and appropriate behaviour. The measures relating to 'good feeding' and 'good health' received the highest scores for validity and feasibility, while 'appropriate behaviour' scored the lowest. Although some of these indicators may be suitable for inclusion in a health animal assessment, further research and understanding are needed for other indicators. Additional to positive health indicators, administration of vaccines has also been proven to be supported to protect against key diseases such as West Nile Virus (Habarugira et al. 2023).

Public submissions supported that guidance regarding monitoring of crocodile health should be included in the revised Code as well as measures for the management of sick animals. Suggestions for inclusion in the revised Code include:

- advice on appropriate frequency and recording of health monitoring for crocodiles
- details of therapeutics considered best practice
- mandating that a hospital pen be established for treatment of sick individuals
- advice that sick or injured crocodiles must be assessed by an experienced person as soon as possible and appropriate action taken to alleviate suffering by immediately commencing appropriate treatment or euthanasia.

Biosecurity

Discussions with stakeholders also touched on whether the revised Code should include a reference to, or a requirement for, farms to have a biosecurity plan to protect against pathogens and disease. While the overwhelming response was that every farm should have a biosecurity plan it was mostly agreed the revised Code would not be an appropriate place to outline what the contents of a biosecurity plan should be. This is because every farm will have a unique set of environmental variables and risks to consider when developing a biosecurity plan. It was suggested however, that the need for a biosecurity plan and potentially, for a dedicated biosecurity officer could be referenced in the revised Code. Government Focus Group attendees noted that biosecurity

requirements for farms are covered under state legislation and that this could be easily referenced in the revised Code. The requirement for biosecurity plans was supported through the desktop review with publications highlighting the impacts of disease as one of the top 3 causes of death for farmed crocodiles (Isberg 2009) and that new diseases regularly emerge within crocodile farms (Shilton et al. 2016; Finger 2012). Additionally, NGO attendees outlined that high quality housing standards will naturally result in a lower threat to biosecurity on farms. It was mentioned that zoonotic diseases often occur when animals are kept in environments with poor hygiene and in enclosures at high density.

Food Preparation and Storage

In order to maintain a high degree of animal health and to avoid pathogen spread, similar feedback was received around the inclusion of food preparation and storage standards. Stakeholders indicated that the revised code should include requirements for fresh food, a clean preparation environment and appropriate food storage however, the guidance should not be too detailed or prescriptive.

In order to set a consistent food standard similar to other farmed animals, there have been various attempts to pelletise feed within the crocodile industry, but none are yet to establish an effective pelletised diet (Isberg 2007; Peucker and Jack 2006). A study conducted by Peucker and Jack (2006) undertook a series of trials on Australian crocodile farms in which animals were fed pelletised food. The trials found that there was mixed success with both juvenile and adult animals both managing pelletised food and uptake of the new diet. This was mainly attributed to texture of the pellets (Peucker and Jack 2006). None of the participating farms were able to fully convert animals from meat-based diets to pelletised foods however, there were a number of confounding factors at the time of this study that likely contributed to this result such as the presence of disease (Peucker and Jack 2006). In lieu of standardised feed methods, consensus amongst stakeholders is that feeding practice should meet a minimum standard of freshness and cleanliness. For example, some stakeholders suggested that food should be sourced fresh from a reputable abattoir.

However, it was noted that there are some practicality issues with food standards in some farming environments as they can be in very remote areas with limited access to food sources. This may need to be caveated within the revised Code. Consultation with the Industry Focus Group noted that wild buffalo, which are an abundant pest in remote areas of Australia are a suitable and cost-effective source of fresh meat for crocodiles.

Feedback from NGO Focus Group attendees included that food preparation and storage procedures may also be informed by the animal welfare principle of ‘good feeding’ which consists of the absence of prolonged hunger (including appropriate diet) and the absence of prolonged thirst. This is achieved by the animal having appropriate access to nutritionally adequate food and water.

Release, Transportation and Marking

Updating of crocodile release and transportation procedures was also discussed and in particular, was highlighted by Industry as a section that should be improved. Feedback was that the current Code details release procedures mostly relevant to large, adult individuals and that procedures are

less relevant for juvenile or small crocodiles. Frequently, stock on farms are not categorised as 'large' and therefore, more guidance is needed on procedures for release and transportation of smaller stock. Industry attendees also mentioned that transportation procedures are one area that could be more prescriptive. For example, the revised Code should include further clarification and guidance around padding in tubes used for animal transportation, whether restraint is necessary when an animal is being transported in a box or tube, methods for temperature control and how these guidelines apply to crocodile transportation within a farm setting versus off-farm relocation to a new destination.

Public submissions were received relating to the marking of crocodiles, especially the use of scute clipping as a marking technique. Scute clipping involves removing some vertical scales from a crocodile's tail to assist with identification. It is a requirement in some countries to meet obligations under the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), to show that a harvested crocodilian comes from a farmed environment (Webb and Manolis 2016). Public submissions suggested that scute clipping with a knife or scalpel as a marking procedure be banned, and other more humane marking methods be introduced into the revised Code. Only one submission suggested it be practiced with appropriate pain relief. Alternative methods currently used in farms are insertion of radio frequency identification (RFID) tags under a crocodile's skin or attaching tags to webs or tails (Webb and Manolis 2016).

Housing

All public submissions and NGO Focus Group attendees raised concerns about appropriate housing conditions for crocodiles, both in communal and individual pens. Most public submissions raised specific concerns about the maximum density for housing of crocodiles and the Code's minimum water depth requirement of 0.8m. Research has been undertaken to inform appropriate stocking conditions in reptiles including crocodilians. Much of this research relies on the use of corticosterone (CORT) as an indicator of stress levels and overcrowding (Elsey 1990a; Elsey 1990b; Isberg and Shilton 2013). CORT is a steroid hormone produced in the cortex of adrenal glands in animals and CORT concentration in blood can provide an indication of stress (Turton et al. 1997). Previously, research on alligators has demonstrated that stress levels exhibit a relationship with stocking density. Specifically, at lower densities, alligators experience reduced stress levels (Elsey 1990a and Elsey 1990b). It has also been established that CORT is impacted by water temperature (Turton et al. 1997), implying that all pens containing sufficient water for submergence must be an appropriate temperature to avoid unnecessary stress. Additionally, research undertaken by Isberg and Shilton (2013) indicates that there is limited difference in CORT levels of crocodiles between individual and communally housed animals.

Industry Focus Group attendees acknowledged the importance of utilising individual housing for animals in the period before slaughter, as it enables crocodiles to heal any damage to skins which can impact harvest value (Hermesch and Isberg 2022). However, many submissions outlined that the use of solitary cages or concrete pens that are only 0.25m² for animals over 1 year old and 0.1m² for hatchlings were deemed to be unacceptable. Allowing crocodiles to be kept in pens shorter than their body length or in overcrowded communal pens was also considered to be unacceptable. NGO Focus Group attendees also felt that individual 'finishing pens' were not a satisfactory form of

housing for crocodiles as these pens do not allow for 'enrichment' and natural behaviour. Many public submissions called for the prohibition of individual pens that are currently used in the months prior to slaughter, as they place severe restrictions on physical behaviours and fail to provide opportunity for mental stimulation. Many submissions observed that while saltwater crocodiles are 'highly mobile' the minimum standards support captivity for a long time in closely confined conditions involving high densities of animals. Most agreed that nationally consistent minimum standards that are more reflective of the crocodile's natural environment should be required. Additionally, observations indicate that crocodiles can interact and display 'play behaviour' with other crocodiles (Dinets 2015) highlighting the potential benefits of communal housing.

While many people assume crocodiles are highly mobile the crocodile's nomadic nature has recently been questioned with research indicating that in Queensland, crocodiles are more philopatric (tend to return or remain near a particular area) and that 90% of crocodiles remain within 50km of their birth area (Lloyd-Jones et al. 2023). This has been supported by other research that indicates the largest driving factor for crocodile's habitat is environmental resistance and competition for habitat rather than a natural tendency for mobility (Fukuda 2022).

Many public submissions referred to other guidance for housing reptiles, such as the draft Australian Standards and Guidelines for the Welfare of Livestock at Processing Establishments, the NT Government guidance around keeping crocodiles as pets (NT Gov 2024), the Code of Practice for the Private Keeping of Reptiles (NSW Gov 2013), and the Australian Animal Welfare Standards and Guidelines for Exhibited Animals - Crocodilian (NSW Gov 2019), or other farmed animals such as the Australian Animal Welfare Standards and Guidelines for Poultry (Department of Agriculture, Forestry and Fisheries, 2022), as documents containing example of improvements to housing standards that could be referred to in the Revised Code.

Changes to Egg Management

Egg management is one of the key steps in the crocodile management cycle. The majority of captive crocodiles are ranched, meaning they are hatched from eggs collected in the wild. The mortality rate of eggs in the wild is relatively high but has improved following egg collection and artificial incubation (Isberg and Thompson 2021). Crocodiles lay eggs in nests which are subject to natural variables such as flood, predation and unseasonably cold weather (Isberg and Thompson 2021). All of these variables have a significant impact on egg survival.

The current Code stipulates that the incubation environment must maintain an incubation temperature between 31 and 33°C. Literature has indicated that incubation temperatures above 30°C improves egg survivability (Isberg and Thompson 2021) and that temperature around 32°C increases embryo growth rate and reduces the period of time before hatching. Additionally, post-hatching survival of *C. porosus* has been observed as highest for individuals that underwent incubation at 32°C (87%) as compared to those incubated at 29°C (44%) (Webb and Cooper-Preston 1989). It has also been observed that crocodile gender is influenced by incubation temperature and at higher temperatures, males make up 86% of all crocodiles. The ideal ranges for incubation range from a low of 24°C to a high of 33°C (Webb and Manolis 2016).

Several submissions raised concerns about the current Code supporting wild egg collection. Feedback included that the revised Code should better respect the maternal instincts of crocodiles, by not disturbing females during egg collection. The revised Code should also include a separate

section about the care and welfare of breeding crocodiles and restricting the wild capture of females to ensure nests are not forcibly abandoned and eggs lost.

Most submissions strongly opposed the wild collection off late-stage embryos and one stand-alone submission requested more guidance on the management of hatchling welfare when hatching and washing.

Immobilisation and Restraint

The topic of immobilisation and restraint emerged prominently in discussions with members of the EAP and participants in Focus Groups. This theme was also raised commonly in public submissions. The prevailing view among public submissions was that every method of capture and restraint must undergo comprehensive evaluation concerning animal welfare, with sufficient evidence presented to validate acceptable practices.

Chemical Immobilisation

EAP members along with Science and Research, Government and Industry Focus Group attendees broadly agreed that currently, drugs listed for immobilisation and restraint are not reflective of advances in scientific literature (Olsson and Phalen 2012a; Olsson and Phalen 2012b; Olsson and Phalen 2013a; Olsson and Phalen 2013b) since 2009 and in some cases, what is used in practice.

Trials conducted showed medetomidine, when administered to a crocodile at an appropriately tailored dosage, reliably achieves immobilisation that is reversible with the administration of atipamezole (Olsson and Phalen 2012a). Crocodiles chemically immobilised using medetomidine were observed to return to their normal behaviours (basking, feeding) following release into their enclosure faster than individuals who were physically restrained (Olsson and Phalen 2013a). These crocodiles also had their CORT levels reviewed to infer stress levels. It was found that chemically immobilised animals displayed lower CORT levels, suggesting a lower stress level than those that were physically restrained. When administering chemical restraint, it has been found that a number of factors influence effective immobilisation, predominantly animal size and air temperature (Olsson and Phalen, 2012b). It is essential that these variants are considered in future iterations of the Code of Practice.

There were varying views within public submissions regarding chemical immobilisation. Several submissions recommended that chemical restraint should only be used as a last resort and administered by veterinarians. Whereas a submission from a licensed veterinarian suggested that the use of sophisticated agents (such as Alpha-2 adrenergic agonist medications) should be prioritised over physical restraint techniques, especially harpooning, wherever possible, given their welfare outcomes. This submission also mentioned that the Code needs to incorporate improvements in veterinary practice to decrease reliance on chemical immobilisation agents which offer no form of anxiolysis (sedation) or analgesia (pain relief).

Science and Research Focus Group attendees also discussed whether the Code should mandate that only veterinarians administer immobilisation drugs or if individuals with substantial expertise in administering such drugs to crocodiles should also be permitted to do so. It was the consensus of the Science and Research Focus Group that it would not be appropriate or possible to limit the administration of immobilising drugs to veterinarians only. Some public submissions called for certified vets to be the only people allowed to administer immobilising drugs however, it was also

acknowledged that while veterinarians will have more in depth knowledge of individual drugs and the protocol surrounding their use, farmers will often have more experience with handling of crocodiles. Due to this, Focus Group attendees suggested that while training and certifying of individuals to administer immobilising drugs should fall to the veterinarian, experienced professionals within the crocodile farming sector should be allowed to administer immobilising drugs with appropriate training.

Electrical Stunning

Advances in electrical stunning as an immobilisation technique was discussed with Focus Group attendees and it was agreed that as this is still an emerging field of research, the revised Code will need to provide the ability to incorporate advances in knowledge as new peer-reviewed research is published. Some Focus Group attendees commented that while it seems to be an effective immobilisation method there is still a lack of understanding as to the impacts that stunning has on the animal long term and a caveat to this effect should be included in the revised Code. One study has been conducted into the welfare outcomes and effectiveness of electrical stunning as a means of restraint (Small et al. 2023). This study measured brain activity of crocodiles through an Electroencephalogram (EEG) before and after electrical stunning. The study identified the optimal power levels and application position to achieve a consistent stun and ultimately, unconsciousness. It is noted that scientific understanding of crocodile's brain activity is still in its infancy and will require further research to best understand impacts of stunning. One public submission suggested that more evidence is required to understand the stress response associated with electrical stunning compared to traditional restraint methods such as noosing and roping.

Most submissions called for the revised Code to include techniques or technologies to restrain crocodiles that reduce pain and distress. One submission requested that a summary of key animal welfare risks and list of appropriate equipment for restraint be provided in detail within the Code to inform responsible consideration.

Many submissions indicated that the use of rubber bands, tape, cord and cable ties to tether a crocodile's jaw causes unnecessary distress due to the highly sensitive sensory receptors on their heads, snout and skin, and increases the likelihood of inducing metabolic acidosis. These sensory receptors are known as integumentary sensory organs, and are primarily used for detecting water movements, indicating when to bite based on direct contact of pursued prey (Leitch and Catania 2012). However, there have not been many studies on the sensory organs role in perception or if tethering a crocodile's jaw would result in increased levels of pain (Reber 2020). One submission recommended that the duration of restraint must be kept to a minimum (perhaps provide guidance e.g. 10 minutes maximum) and in quiet, clean surroundings and that operators must be competent in handling methods and being able to recognise signs of injury or stress.

Some submissions requested that restraint procedures that have the potential to cause pain should only be undertaken with pain relief provided by qualified veterinarians.

Physical Capture and Restraint

In terms of physical capture methods, most submissions suggested a total ban on harpooning as it causes 'unnecessary pain' for the animal. Similarly, indirect methods of capture such as baited fishhooks and unattended snares should be removed due to the risk of 'causing prolonged suffering'.

One submission suggested harpooning should only be reserved for cases in which urgent capture due to safety concerns is necessitated. This submission also mentioned that the use of indirect capture methods is more humane than harpooning but could be improved through advancements such as drones, sensors, and remote video monitoring. When asked about capture methods Government Focus Group attendees outlined that baited hook methods, to their knowledge, have not been used for years and agreed with the view expressed in public submissions that these methods should be used only as a last resort.

Killing

Crocodilians are required to be killed for various reasons including human safety, stock harvest, population control and euthanasia of sick individuals. It is essential for a modern Code of Practice to have the most up to date and humane killing practices as possible. Best practice with regard to killing is achieved via rapid death without stress or pain (Martelli et al. 2020). It is understood that painful stimuli will take 0.2 seconds to reach the brain and be perceived as pain. Therefore, trauma leading to death must achieve destruction of the brain in less than 0.2 seconds (Martelli et al. 2020).

Academic research into the killing of American alligators has focussed on ensuring that slaughter methods achieve a quick death without any unnecessary suffering (Flint et al. 2023). Three forms of slaughter were applied, and the subject was monitored for clinical signs of life (such as loss of blink reflex, pupillary light response, jaw tone and respiration) and brains were reviewed afterwards for signs of stress. The three forms of slaughter considered were use of captive bolts followed by spinal cord severance, electro-stunning following by spinal cord severing and pithing (insertion of a rod or probe to ensure thorough brain destruction), and lastly just spinal cord severance following by pithing. It was found that captive bolt and electro-stunning methods were the most effective methods in facilitating humane deaths (Flint et al. 2023).

The World Organisation for Animal Health (WOAH) has developed specific guidance for '*Killing reptiles for their skins, meat and other products'.* This guidance includes recommendations that address the need to ensure the welfare of crocodilians (amongst other reptiles) during the process of killing. In identifying these preferred methods, the following factors were considered:

- minimising agitation, fear, stress and pain to the reptiles
- appropriate consideration for the species, size, age and health of reptiles
- reliability and reproducibility of the killing method
- use of a stunning method ahead of killing
- ensuring death occurs during unconsciousness.

Keeping in mind the above, the following method is recommended within the WOAH guidance; electrical stunning (to cause stunning) followed by either penetrative or non-penetrative captive bolt, percussive blow to the head, gunshot, pithing or decapitation/spinal cord severance. Some methods were also noted that are not acceptable for stunning and killing such as exsanguination, freezing, boiling, suffocation or drowning amongst others (WOAH 2022).

Many public submissions opposed the killing of crocodiles for any reason other than self-defence. Several submissions observed that the Code allows for methods of killing crocodiles that have the potential to inflict pain and suffering on the animal and are therefore, neither humane nor in line with contemporary community expectations.

A submission from a qualified veterinarian recommended that the Code should be updated to align more closely with contemporary understanding and to mitigate the risk of adverse welfare consequences. The submission proposed a two-step euthanasia process, involving initial heavy sedation or rapid stunning of the animal followed by irreversible destruction. The submission cautioned against the use of barbiturate euthanasia intraperitoneally (into the lower abdomen) without prior heavy sedation or loss of consciousness, citing its potential to induce pain. Additionally, it emphasized the need for improvement in the dilution procedure outlined in the Code to minimize injection volumes and reduce subsequent restraint duration.

Further submissions suggest redefining terms used in the Code regarding the killing of crocodiles. Specifically, submissions called for the redefinition of 'euthanasia' as being undertaken to relieve suffering i.e. when an animal is sick or injured and is not able to be treated and 'humane killing' to relate to the killing of a healthy animal for population control or other reasons and, the inclusion of 'slaughter' where crocodiles are processed for human consumption and/or sale of skins. These definitions were also suggested by members of the NGO Focus Group.

Several submissions outlined the need for the revised Code of Practice to include greater detail around regulated and mandated training for all workers involved in the sector, with a specific focus on anatomy and physiology of reptiles. This training should be targeted to those tasked with slaughter to ensure a greater understanding of administering a humane and rapid death. These submissions requested that the Code enforce training alongside Standard Operating Procedures (SOPs) that can be checked by the relevant regulator. Some submissions suggested mandating third party training for all workers currently in the sector, given the rapidly advancing fields of welfare science, new technologies and chemical agents available. This training would prevent the 'handing down' of incorrect practices.

Focus Group attendees were asked whether there are newer, more innovative and humane killing techniques that should be included in the Revised Code. The Science and Research Group outlined that the World Organisation for Animal Health (WOAH) guidelines are the industry standard for killing of reptiles. These guidelines are heavily based on the Australian experience and many other countries rely on these guidelines to inform best practice.

There was some suggestion by Science and Research Focus Group attendees that killing methods such as decapitation and blunt trauma are no longer appropriate for the killing of hatchlings and that the current Code does not do enough to differentiate between appropriate methods of killing for juvenile and adult crocodiles. Much of the current content is based on larger, wild animals while 90% of the industry consists of smaller animals. Additionally, Industry Focus Group attendees mentioned that in around 99.5% of cases captive bolt is a successful killing method however, in 0.5% of cases it is not, which is why spinal cord severance and brain pithing is required (Flint et al. 2023). Feedback from the Government Focus Group outlined that killing method should also be situational e.g. engaging in a lethal kill shot should be employed in public safety situations to avoid disaster.

Emerging Wild Management Techniques

In the time since the previous Code was published, some new wild management tools have been trialled with success. This includes the use of drones as a technique for wild capture (QLD Gov, 2020). This technique trialled by the Queensland government involves hanging bait off of a drone directly above the water. When a crocodile attacks, a noose is released locking the animal's jaw. A

float attached to the bait indicates the crocodile's location, assisting in quick capture of the crocodile. Inspections indicated that the technique caused no abrasion or bruising to the crocodile.

Similar trials were conducted to test the effectiveness of 'aversive conditioning'. Aversive conditioning has been previously used with dangerous creatures to avoid interactions with humans by changing predator behaviour or moving them away (Booth et al. 2023). In these trials, crocodiles over two metres in length within a study area were subject to two non-lethal beanbags fired from a 12-gauge shotgun. This appeared to have an impact on crocodile behaviour increasing wariness, however, it is suggested that more sustained conditioning may be required to fully realise the impacts (Booth et al. 2023).

First Nations Considerations

As part of this review, specific consideration was given to First Nation Australians and their relationship with crocodiles. Feedback received through consultation provided invaluable insights into the cultural landscape that surrounds the Code of Practice. While some of the feedback received may extend beyond the immediate scope of this review, all contributions provided significant context for the review and enhanced the understanding of the important cultural and spiritual environment within which the Code exists and operates.

Crocodiles are sacred totems for many First Nations groups in Northern Australia. First Nation groups remember and represent the travels of the ancestral crocodile through their art, song and dance. These stories represent songlines connecting the many 'crocodile people' together along the tropical coastline of Australia (Ligtermoet et al. 2023). As a sacred totem, First Nations people respect the crocodile and acknowledge the clans or groups responsible for its care and management. These 'custodian' clans or groups are responsible for both the physical and spiritual wellbeing of the crocodile and the country (both the land and water) it naturally occupies. It is also typical that these custodians are Traditional Owners or native title holders that control access to natural crocodile breeding areas (Wright et al. 2012).

Consultation was held directly with a senior First Nations elder from Blue Mud Bay, East Arnhem who reinforced this perspective of the crocodile's significance to Indigenous ceremony, custom and culture. He shared the story of bäru, a human who transformed into a crocodile at Yathikpa and travelled through the country strengthening many clans with his fire and spirit. As a result, crocodiles are seen as ancestors, who when realised through ceremony give strength to clans and individuals. The First Nations elder described how bäru is represented in his ceremony and tradition, with dances embodying a crocodile's spirit and movement, including creation and demolition of a nest and use of fire.

In its submission, a First Nations representative body shared that is evident that relationships with animals is a vital element of the world view of many First Nations groups and any changes or barriers to the enjoyment of the spiritual relationship between human and animals (including crocodiles) has the potential to be detrimental to the spiritual life of many. The revised Code of Practice must recognise this world view as the crocodile industry, in an unregulated form, has the potential to be damaging to the physical and spiritual well-being of First Nations people.

Each crocodile is intrinsically linked to a number of First Nations clans and the harvest for commercial purposes has spiritual impacts. As such, the Code should recognise and respect the impacts of humane treatment on both the physical animal and its spiritual significance.

Many public submissions also broadly recognised the importance of including First Nations knowledge, spiritual connection and participation in the management of the farming industry in the Code, particularly in regard to the wild collection of crocodiles and crocodile eggs.

Themes drawn from discussions and submissions from Land Councils, Ranger groups and senior elders for consideration in updating the Code are as follows:

Spiritual and Wellbeing Concerns

A prevalent sentiment in public submissions highlighted a sense of disconnect with the spirit of wild crocodiles when they are captured and relocated without their new location being communicated to local custodians. An example given was that people grow up with crocodiles in their area and become accustomed to them and their families on country. A First Nations body representing the views of traditional owners and several Ranger groups, indicated that custodian clans should be involved in the process of relocation. The intent of this would be to:

- ensure the country is aware of the loss of a significant inhabitant
- ensure a connection is maintained where possible with the crocodile in its new location
- to ensure that any revenue being made from those crocodiles is being shared with the right mob back on country.

Another concern raised was the safety of the crocodile. This related to all aspects of farming and wild crocodile management. First Nations groups consulted in this process expect that the right custodians are informed and involved in decisions to capture, methods to capture, processes to house and methods to kill their crocodiles. This included a preference for reduction of suffering through using appropriate equipment and techniques. An example given was that previously, the design for harpoons was improved to reduce suffering following advice from elders.

First Nations feedback also covered safety of people. This noted that the regrowth of the wild population had seen crocodiles appear at sites upstream and inland where they posed a potential danger to humans and other freshwater crocodile species. A First Nations representative body also provided feedback that the Code needs to recognise that these people/human interactions are likely to occur in remote regions and wild crocodile management needs to be responsive to people's need for community safety.

First Nations perspectives emphasized the need for enhancements in wild management practices, such as relocation, egg collection to prevent overbreeding, and population control through shooting. They proposed the enhancement of safety education and training initiatives, suggesting that the Indigenous Ranger network would serve as a suitable platform for disseminating this information. While not in scope, this feedback was captured as it provides important context for wild crocodile management arrangements.

Access Management

A First Nations representative body outlined that the Code would be improved by including references to the various agreements and management arrangements on Aboriginal Land that have been endorsed by landowners.

These include *Aboriginal Land Rights Act 1976* section 19 agreement processes (specifically for the Northern Territory), Indigenous Protected Area Management Plans, Healthy Country Plans and joint management arrangements over National Parks where crocodile harvesting exists.

Industry Management

First Nations groups indicated frustration due to a lack of engagement from the crocodile farming industry to date. Three main concerns were raised with regards to a First Nations perspective. These include:

- A general lack of transparency and accountability from farms regarding processes, earnings, and engagement with First Nations groups both at the farm location and in areas of wild harvest.
- Biosecurity risks associated with farms, specifically when flooding inundates a farm. In this scenario, farmed crocodiles may escape into local rivers increasing the natural wild population and potentially transmitting disease.
- Collection and use of wild eggs including limited transparency over harvest location and use of non-viable eggs. In relation to wild egg harvesting, a representative body called for greater transparency in the industry and greater reporting (including keeping GPS records) about where crocodile nests are harvested and how many. They stated that Traditional Owners want clear communication about this as part of their responsibilities to ensure country is kept strong and healthy and that practices are sustainable.

The First Nations representative body indicated several ways the Code could be improved in this regard:

- The Code could be strengthened by tightening regulations about recording who is collecting eggs and going on Aboriginal Land.
- That the industry would be improved and be more transparent through stronger partnerships with Indigenous Ranger groups throughout the Top End Region.
    - This could include involvement of Indigenous Rangers in cultural observer activities whilst harvesting is occurring, Ranger Groups becoming a conduit for communicating with landowners around activities, links to Healthy Country Plans and caring for country activities.
- The Code should also reference Aboriginal Land properly, in its various forms under the *Aboriginal Land Rights Act 1976*, as Traditional Owners have shared that some industry operators do not follow the rules causing significant complaints and distress.
- The Code should also reference the use of drones and the use of artificial intelligence that are currently being trialled in checking crocodile nests and potentially harvesting for crocodile eggs. This is new technology that has implications for First Nations representative bodies and sacred site custodians. The Code should acknowledge that technology is rapidly

changing in this area and Traditional Owners need to be consulted on these significant changes when they are implemented.

The narrow scope of the Code was noted, but First Nations groups believed more direct involvement of Indigenous Organisations in the cultural guidance of the industry is an important element that is missing.

Benefit Sharing

Of significant issue to First Nations groups was concern that benefits from the crocodile farming industry was not being shared with the local communities and workforce. While this feedback is outside of the scope of the Code review it has been captured as it provides important context within which the Code operates.

A First Nations representative body shared that Traditional Owners have for some time been interested in being directly engaged in the industry with interest in crocodile farms and other forms of direct involvement in the industry. While the code does not directly speak to this the representative body believes the Code does not adequately recognise Aboriginal peoples interests and connection to this species either through caring for country responsibility and economic development opportunities from their land and sea rights.

Additionally, First Nations stakeholders provided feedback that they had experienced a reduction in fees paid for collection of viable and non-viable eggs due to less eggs being harvested. A lack of transparency over the numbers being collected in licenced areas was also reported, with some stakeholders reporting eggs being harvested outside of licenced areas.

These benefits include opportunities for employment, access to training and industry knowledge such as tanning and skin production, leasing and licencing payments and building more partnerships between industry and Aboriginal Corporations.

Closing Remarks

Through undertaking extensive desktop research and engaging in consultation activities, it is evident that the commercial crocodile industry in Australia and the associated Code of Practice is of significant interest to a diverse array of stakeholder groups, each contributing unique insights and perspectives.

The Department extends its sincere gratitude to all stakeholders that have submitted feedback or have participated in consultation activities to date. Your valuable insights, feedback and contributions have played a pivotal role in shaping this report and will remain essential as we advance through the review process.

We are committed to carefully considering this diverse range of perspectives and the information gathered throughout the development of the Revised Code of Practice.

Callida Consulting

References

Aboriginal Land Rights Act 1976 (Northern Territory)

Australian Government (2009) *Code of Practice for the Humane Treatment of Wild and Farmed Australian Crocodiles, 1st Edition,* accessed 23 April 2024. Code of practice for the humane treatment of wild and farmed Australian crocodiles (dcceew.gov.au)

Burghardt GM (2013) 'Environmental enrichment and cognitive complexity in reptiles and amphibians: Concepts, review and implications for captive populations', *Applied Animal Behaviour Sciences*, 147(3-4): 286-298.

Booth S, Taplin L, Brien M, Campbell H, Christian K (2023) 'Aversive Conditioning of Larger Estuarine Crocodiles (Crocodylus porosus) and the Remote Deployment of Transmitters', *Herpetological Conservation and Biology,* 18(1):168–181.

Botreau R, Veissier I, Butterwork A, Bracke MB and Keeling LJ (2007) 'Definition of criteria for overall assessment of animal welfare', *Animal Welfare,* 16(2): 225-228.

Dale A and White S (2013) 'Codifying Animal Welfare Standards – Foundations for better animal protection or merely a façade?', *Animal Law in Australasia*, 2nd edn, Federation Press.

Department of Agriculture Forestry and Fisheries (2024) '*Australian Animal Welfare Standards and Guidelines'*, accessed 20 March 2024. Australian Animal Welfare Standards and Guidelines - DAFF (agriculture.gov.au)

Department of Agriculture, Fisheries and Forestry (2022), '*Australian Animal Welfare Standards and Guidelines for Poultry'*, accessed 26 March 2024. Australian Animal Welfare Standards and Guidelines for Poultry - DAFF (agriculture.gov.au)

Dinets V (2015) 'Play behaviour in crocodilians', *Animal Behaviour and Cognition*, 2(1): 49-55.

Elsey RM, Joanen T, McNease L and Lance V (1990a) 'Growth rate and plasma corticosterone levels in juvenile alligators maintained at different stocking densities', *The Journal of Experimental Zoology,* 255(1): 30-36.

Elsey RM, Joanen T, McNease L and Lance V (1990b) 'Stress and plasma corticosterone levels in the American alligator – relationships with stocking density and nesting success', *Comparative Biochemistry and Physiology Part A: Physiology*, 95(1): 55-63.

Environmental Protection and Biodiversity Conservation Act 1999 (Cwth).

Ernst & Young (2017) *Economic Value of the Crocodile Farming Industry to the Northern Territory,* accessed 22 April 2024. Final report: Economic value of the crocodile farming industry to the Northern Territory

Finger Jr JW and Isberg SR (2012) 'A review of innate immune functions in crocodilians', *CAB Reviews,* 7(67): 1-11.

Finger Jr JW, Thomson PC, Adams AL, Benedict S, Moran C and Isberg SR (2015) 'Reference levels for corticosterone and immune function in farmed saltwater crocodiles (Crocodylus porosus)

hatchlings using current Code of Practice guidelines', *General and Comparative Endocrinology,* 212: 63-72.

Flint M, Sagrera K, Wainwright K and Flint JB (2023) 'Field based assessment of clinical signs of irreversible loss of consciousness and death confirmed by brain destruction in juvenile American alligators (Alligator mississippiensis) after penetrating, captive bolt stunning or electrostunning with probe pithing', *Journal of Applied Animal Welfare Science. 2023*: 1-12.

Fukuda Y, Moritz C, Jang N, Webb G, Campbell H, Christian K, Lindner G and Banks S (2022) 'Environmental resistance and habitat quality influence dispersal of the saltwater crocodile', *Molecular Ecology*, 31(4): 1076-1092.

Habarugira G, Harrison JJ, Moran J, Suen WW, Colmant AM, Hobson-Peters J, Isberg SR, Bielefeldt-Ohmann H and Hall RA (2023) 'A chimeric vaccine protects farmed saltwater crocodiles from West Nile virus-induces skin lesions', *npj Vaccines,* 8(1):93.

Hermesch S and Isberg SR (2022) Economic values for skin grade, days to market and number of hatchlings in the Australian saltwater crocodile industry. Proceedings of the 12th World Congress on Genetics Applied to Livestock Production (WCGALP) Technical and species orientated innovations in animal breeding and contribution of genetics to solving societal challenges, 1749-1752, Wageningen Academic Publishers.

Hewitt L and Small A (2021) 'Welfare of Farmed Crocodilians: Identification of Potential Animal-Based Measures Using Elicitation of Expert Opinion', *Animals,* 11(12): 3450.

Isberg SR (2007) 'Nutrition of juvenile saltwater crocodiles (Crocodylus porosus) in commercial production systems', *CAB Reviews,* 2(91): 1-11.

Isberg SR and Shilton CM (2013) 'Stress in farmed saltwater crocodiles (Crocodylus porosus): no difference between individually and communally housed animals', *SpringerPlus,* 2:1-6.

Isberg SR, Shilton CM and Thomson P (2009) Improving Australia's crocodile industry productivity: understanding runtism and survival, Agrifutures Australia, accessed 11 April 2024. Improving Australia's Crocodile Industry Productivity Understanding runtism and survival | AgriFutures Australia

Isberg SR and Thomson PC (2021) 'Saltwater crocodile (Crocodylus porosus) embryo survival: risk factors, 49-58.

Lambert H, Carder G and D'Cruze N (2019) 'Given the cold shoulder: A review of the scientific literature for evidence of reptile sentience', *Animals*, 9(10): 821.

Leitch DB and Catania KC (2012) 'Structure innervation and response properties of integumentary sensory organs in crocodilians', *Journal of Experimental Biology*, 215(23): 4217-4230.

Ligtermoet E, Gumurdul J, Nayinggul C, Baker R (2023) 'The return of the kinga (saltwater crocodile): Population 'bust then boom' shapes shifting baselines in Indigenous biocultural knowledge in northern Australia', *Biological Conservation*, 277.

Littlewood KE, Heslop MV and Cobb ML (2023) 'The agency domain and behavioural interactions: assessing positive animal welfare using the Five Domains Model', *Frontiers in Veterinary Science,* 10.

Lloyd-Jones LR, Brein ML, Feutry P, Lawrence E, Beri P, Booth S, Coulson S, Baylis SM, Villiers K, Taplin LE and Westcott DA (2023) 'Implications of past and present genetic connectivity for management of the saltwater crocodile (Crocodylus porosus)', *Evolutionary Applications*, 16(4): 911-935.

Martelli P, Shilton C and Manolis C (2020)'Humane Euthanasia/Killing Methods for Crocodilians - An Update', *Crocodile Specialist Group Newsletter,* 39(1): 6-8.

Mellor DJ, Reid CS (1994) 'Concepts of animal well-being and predicting the impact of procedures on experimental animals' Improving the well-being of animals in the research environment. Department of Physiology and Anatomy, Massey University, New Zealand.

Mellor DJ, Beausoleil NJ, Littlewood KE, McLean AN, McGreevy PD, Jones B and Wilkins C (2020) 'The 2020 Five Domains Model: Including Human-Animal Interactions in Assessments of Animal Welfare', *Animals,* 10: 1870.

New South Wales Government (2013) *Code of practice for the private keeping of reptiles*, Environment and Heritage, accessed 26 March 2024. Code of Practice for the Private Keeping of Reptiles | NSW Environment and Heritage

New South Wales Government (2019) *Australian Animal Welfare Standards and Guidelines. Exhibited Animals – Crocodilian*, Department of Primary Industries, Edition 1, accessed 26 March 2024. Australian Animal Welfare Standards and Guidelines. Exhibited Animal - Crocodilian

Northern Territory Government (2024) *Keeping crocodiles as pets*, accessed 26 March 2024. Keeping crocodiles as pets | NT.GOV.AU

Olsson A and Phalen D (2012a) 'Preliminary studies of chemical immobilization of captive juvenile estuarine (*Crocodylus porosus*) and Australian freshwater (C. johnstoni) crocodiles with medetomidine and reversal with atipamezole', *Veterinary Anaesthesia and Analgesia, 39: 345-356.*

Olsson A and Phalen D (2012b) 'Medetomidine immobilisation and atipamezole reversal in large estuarine crocodiles (Crocodylus porosus) using metabolically scaled dosages', *Journal of Australian Veterinary Association,* 90: 240-244.

Olsson A and Phalen D (2013a) 'Comparison of biochemical stress indicators in juvenile captive estuarine crocodiles (Crocodylus porosus) following physical restraint or chemical restraint by midazolam injection', *Journal of Wildlife Diseases*, 49(3): 560-567.

Olsson A and Phalen D (2013b) 'The effects of decreased body temperature on the onset, duration and action of medetomidine and its antagonist atipamezole in juvenile farmed estuarine crocodiles (Crocodylus porosus)', *Veterinary Anaesthesia and Analgesia*, 40: 272-279.

Pattison R, Isberg S, Strappe P (2023) Australian Crocodile Industry RD&E Plan 2024-2029, Agrifutures Australia, accessed 23 April 2024, 23-201-Crocodile-Industry-RDE-Plan.pdf (agrifutures.com.au)

Peucker, SKJ and Jack RH (2006) Crocodile Farming Research: On-farm research of pelleted feed for crocodiles, Agrifutures Australia, accessed 26 March 2024, Crocodile Farming Research: On-farm research of pelleted feed for crocodiles | AgriFutures Australia

Proctor HS, Cardner G and Cornish AR (2013) 'Searching for animal sentience: A systematic review of the scientific literature', *Animals,* 3(3): 882-906.

Queensland Government (2010) *Drones are a game-changer in crocodile management*, Department of Environment and Science, accessed September 9, 2024. https://www.des.qld.gov.au

Reber SA (2020) 'Crocodilians are promising intermediate model organisms for comparative perception research', *Comparative Cognition & Behaviour Reviews,* (15): 111-129.

Robertson I and Goldsworthy D (2022) 'Recognising and defining animal sentience in legislation: A framework for importing positive animal welfare through the five domains model', *Monash University Law Review,* 48: 244-271.

Shilton CM, Jerrett IV, Davis S, Walsh S, Benedict S, Isberg SR, Webb GJW, Manolis C, Hyndman TH, Phalen D, Brown GP and Mellville L (2016) 'Diagnostic investigation of new disease syndromes in farmed Australian saltwater crocodiles (Crocodylus porosus) reveals associations with herpesviral infection', *Journal of Veterinary Diagnostic Investigation*, 28(3): 279-290.

Small A, Niemeyer D and Hewitt L (2023) 'Evaluation of a commercial electrical stunning method for farmed grower saltwater crocodiles (Crocodylus porosus) using non-invasive EEG measurements', *Animal Welfare*, 32:1-12.

Turton JA, Ladds PW, Manolis SC and Webb GJW (1997) 'Relationship of blood corticosterone, immunoglobulin and haematological values in young crocodiles (Crocodylus porosus) to water temperature, clutch origin and body weight', *Australian veterinary Journal*, 75: 114-119.

Webb GJW and Cooper-Preston H (1989) 'Effects of incubation temperature on crocodiles and the evolution of reptilian oviparity', *American Zoologist*, 29(3): 953-971.

Webb GJW and Manolis SC (2016) 'Best management practices for crocodilian farming. Version 1. IUCN-SCC Crocodile Specialist Group: Darwin, Australia.

World Organisation for Animal Health (2022) *Killing of reptiles for their skins, meat and other products,* accessed 18 March 2024. chapitre_aw_reptiles.pdf (woah.org)

Wright S, Lloyd K, Suchet-Pearson S; Burarrwanga L, Matalena T (2012) 'Bawaka Country, Telling stories in, through and with Country: engaging with Indigenous and more-than-human methodologies at Bawaka, NE Australia', *Journal of Cultural Geography,* 29(1):39-60.