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Relationship between skin colour, conjunctivitis, and dermatitis in captive *Caiman latirostris* in Argentina

Samuel Hilevski[1,2,*], Hernan Ciocan[2], Luis Bassetti[3], and Pablo A. Siroski[1,2]

Abstract. The commercial production of crocodilians for skin and meat has been considered an important industry in the world, with skin being the most valuable product, while the meat is considered a by-product. This study was designed to identify some diseases that can affect crocodilians farmed in Argentina, examining the relationships between skin colour and these diseases. Each caiman was classified according to their skin colour and kind of diseases (conjunctivitis or dermatitis). In broad-snouted caimans the prevalence of conjunctivitis was 0.41, and dermatitis was 0.23. Statistical tests indicate that there may be a relationship between the skin colour and health status of the caiman, where the dark–skin animals appear healthier (35.76%) than the light–skin animals (15.89%), where these last are more vulnerable to suffer ocular diseases, and skin diseases at the same time (14.57%). In addition, the body mass and length of healthy animals (dark and light) were higher than caimans with eye disease or with both associated diseases. These results may help crocodilians farms caring by isolation of susceptible animals, establishing stricter criteria for health status. This may imply a decrease in diseases that affect the quality of the skin and the loss of individuals, with a consequent increase in profits obtained by the industry.

Keywords. Caiman; Crocodile; Skin colour; Skin disease; Ophthalmological disease

Introduction

The commercial production of wildlife is described as the rearing of non-domesticated animals for captive breeding. This is an alternative to subsistence hunting which has less negative impact on the environment, as it reduces the pressure and dependence on wild animal populations. Additionally, it can provide food and income in areas where local conditions limit traditional agricultural production (Nogueira and Nogueira, 2011).

In this context, the valuation of a species and the environment is essential for sustainable use to serve as a conservation tool being that the commercial use of crocodilians for production of skin and meat has been considered one of the most successful models, having the skin as its most valuable product.

The skin of crocodiles, as in other amphibians and reptiles acts in the thermoregulation, respiration, and defence (i.e., colouration and production of chemical substances) (Vitt and Caldwell, 2014); and any disease affecting it diminishes the quality of the leather and hence its market value. Skin and ocular diseases such as dermatitis and conjunctivitis have been reported in alligators and crocodiles (Ladds and Donovan, 1989; Bounds and Norman, 1991; Ladds et al., 1995; Clippinger et al., 1996; Buenviaje et al., 1997). The first may cause discolouration or result in a fine white coating over the dorsal area, while in the abdominal area may cause small yellow- brownish lesions. This can be caused by bacteria or fungi (Buenviaje et al., 1997; Huchzermeyer, 2003).

Conjunctivitis is characterised by the inflammation of the eye area, including the internal mucosal surface and external eyelids. It may be caused by viruses, bacteria, or fungi (Ladds et al., 1995; Villafañe et al., 1996). Both diseases are the most common in captive breeding of crocodilians and have been recognised by farmers as an economically important problem in all continents (Buenviaje et al., 1997) because the meat and hides of the affected animals are downgraded (Buenviaje et al.,

[1] Laboratorio de Ecología Molecular Aplicada, Instituto de Ciencias Veterinarias del Litoral, Universidad Nacional del Litoral / Consejo Nacional de Investigaciones Científicas y Técnicas, R.P. Kreder 2805, Esperanza, 3080 Santa Fe, Argentina.
[2] Laboratorio de Zoología Aplicada, Gobierno de Santa Fe, Facultad Humanidades y Ciencias, Universidad Nacional del Litoral, Av. Aristóbulo del Valle 8700, 3000 Santa Fe, Argentina.
[3] Laboratório de Ecologia Isotópica, Centro de Energia Nuclear na Agricultura, Universidade de São Paulo, Av. Centenário 303, Piracicaba, 13416–000 São Paulo, Brazil.
[*] Corresponding author.
E-mail: samuel.hilevski@icivet.unl.edu.ar

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1997; Huchzermeyer, 2003). None of the mentioned diseases had been reported in any crocodile farm in Argentina prior to this study.

The conditions under which crocodilians are kept in captivity are probably the most important factor in the development of these diseases. Temperature, management, diet, and the stocking density can cause an increase in stress and subsequent rise in corticosterone levels, which impairs the animals' immunity (Matsumoto and Huang, 2000; Siroski and Moleón, 2020), and may become infected by bacteria or other pathogens. In this sense, the presence of stressors within the breeding system can trigger catastrophic disease outbreaks and a high mortality rate (Buenviaje et al., 1997; Huchzermeyer, 2002, 2003).

This study is the product of several observations and represents an initial attempt to describe the prevalence and probability of skin and ocular diseases among farmed *Caiman latirostris* (Daudin, 1802) in Argentina, based on their skin colour. It establishes a relationship between skin colour and disease, while also providing new information on certain pathologies of this species.

Materials and Methods

Animals and Housing. Broad-snouted caimans used in this study were hatched from wild, artificially incubated eggs, and captive-reared at "Yacarés Santafesinos" facilities (Gobierno de Santa Fe/MUPCN). All caimans in this study were housed in concrete pens, each of 1 m high with a total area of ~10 m² [divided into land (33%) and water (67%; 25 cm deep) areas]. They are maintained with stocking densities of 0.27 m²/Ind and natural light. Air and water temperatures were maintained at 29 ± 2 °C, and tanks were cleaned and refilled with warm water (27–30 °C) daily before animals were fed (with balanced feed-supplemented minced chicken head *ad libittum*). Caimans between 6 and 10 months old (n = 151) had a body mass (BM) of 1056.23 g ± 589.65 SE and a total length (TL) of 60.67 cm ± 10.65 SE.

Measurements and Physical Examination. Measures of TL (from snout tip to tail end) and BM were taken from all animals. After the measurements, a physical examination was performed on each animal, classifying them according to the skin tone (light or dark; Fig. 1) and their health status (healthy or diseased). During the physical examination of the caimans, the eyes, the dorsal and abdominal skin were carefully examined looking for visible signs to diagnose them with conjunctivitis (Fig. 2) and dermatitis (Fig. 3). The origin and cause of these pathologies were not determined, because is not the aim of this work.

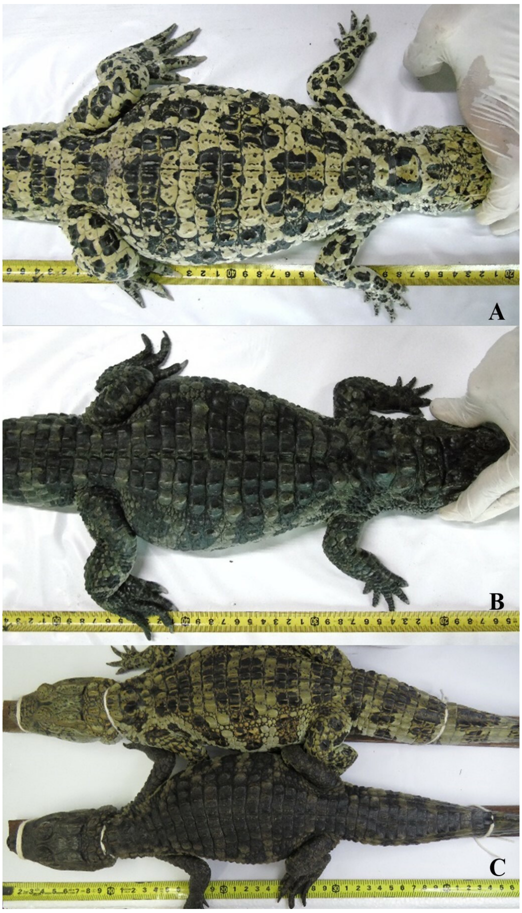

Figure 1. *Caiman latirostris* presents an evident variable skin colouration between individuals of the same species. The figure shows two animals (classified as light and dark skin caimans) to emphasise the differences between the tones of colour of skin. At left side, an individual is classified like dark skin, this present tones from greasy green to dark green. At right side, an individual is defined like light skin, which has tones ranging from light yellow and yellow to light green. Photos by Samuel Hilevski.

Data Analysis. Shapiro-Wilk's and Levene's tests were used to determine normality and homogeneity of variance of the variables. After that, a chi-square test was used to detect the relationship between variables skin colour–health condition, skin colour–number of lesions, and skin colour–kind of lesion were analysed using. A two-way ANOVA was used to detect variations in body mass and total length of caimans by skin colour and health status. These analyses were performed

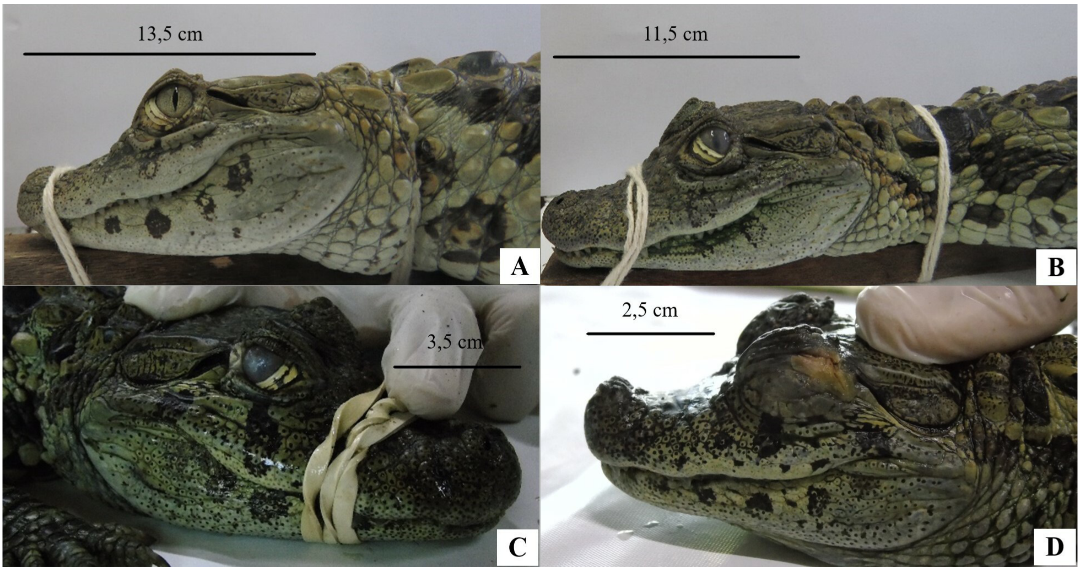

Figure 2. The different stage of eyes lesion looked during eyes examination of *C. latirostris*. (A) Healthy eyes. (B) Eyes with an initial stage of conjunctivitis. (C) Middle stage of the disease. (D) The advanced stage of conjunctivitis. Photos by Samuel Hilevski.

Figure 3. The signs of dermatitis looked during belly skin examination of *C. latirostris*. (A) shows healthy belly skin. (B) Close-up of the healthy belly skin. (C) The belly skin with dermatophilosis. (D) Close-up of the disease. Photos by Samuel Hilevski.

with commercial software (SPSS version 25, IBM Corporation, Armonk, New York 10504, USA), and statistical significance was set at alpha 0.05.

Results

Animals classified as "healthy" by the total absence of clinical signs of any disease, whereas the animals diseased were diagnosed under the following criteria:

a. Conjunctivitis: Inflammation of the conjunctivae and the lining of the mucosa of the inner surface of the two outer eyelids and the third eyelid, as well as the conjunctival sac. Increased lacrimation or exudate, and blindness due to the accumulation of fibrinous material behind the eyelids (Villafañe et al., 1996) (Fig. 2).
b. Dermatitis: Lesions in the form of a small yellow-brownish colour between the abdominal scales accompanied by keratin lifting. Depression and erosion of the epidermis by hyperplasia and ulceration of the tissue (Buenviaje et al., 1997, 1998a, b) (Fig. 3).

Figure 4 shows the percentages of individuals classified according to their skin colour (light or dark), health status (healthy or diseased), number of diseases (one or two), and kind of disease (dermatitis, conjunctivitis, or both diseases).

Figure 5 shows the number of healthy and diseased caimans for every skin colour category. It is shown that the dark-healthy caimans (35.76%) are more abundant than light-healthy (15.89 %), dark-diseased (15.89 %), and light-diseased caimans (32.46 %). Furthermore, light-diseased caimans are more abundant than light-healthy, and dark-diseased caiman. The chi-square test indicated that there may be a relationship between the skin colour and health status of the caimans, where the dark–skin animals are healthier than the light–skin animals (X^2 = 19.956, *df* = 1, *n* = 151, α = 0.001).

Figure 5 also shows the number of caimans with dermatitis, conjunctivitis, or both diseases in each skin colour category. Results shown that the light–skin caimans with dermatitis, conjunctivitis (17.88%) or both diseases (14.57%) are equal or more abundant than dark–skin caimans with dermatitis, conjunctivitis (13.91%), or both diseases (1.99%). The frequency of conjunctivitis was higher in light–skin caimans (prevalence = 0.30) than in dark–skin caimans (prevalence = 0.19). The frequency of dermatitis in dark–skin caimans was slightly higher than in light–skin caimans (prevalence = 0.07 and 0.06 respectively). Finally, the frequency of both diseases in light–skin caimans (prevalence = 0.30) is more abundant than in dark–skin caiman (prevalence = 0.03).

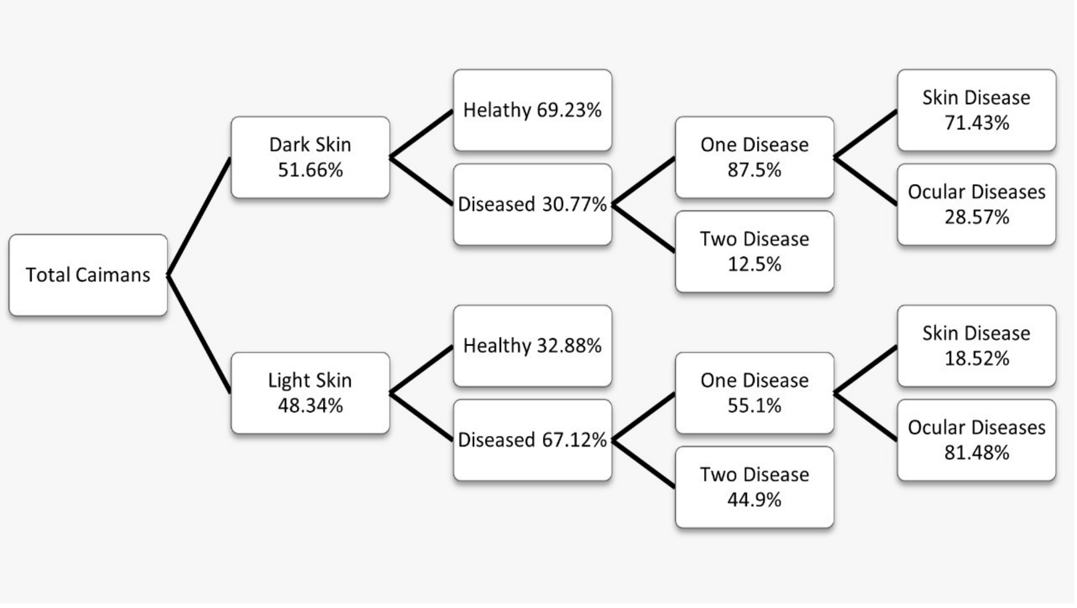

Figure 4. Total caimans in each category.

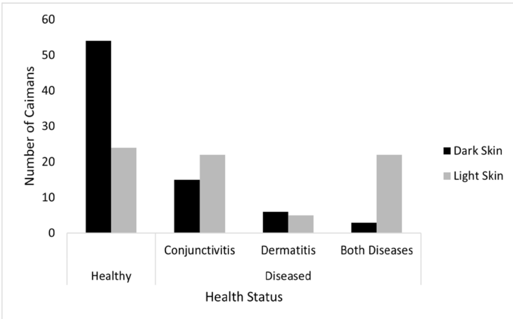

Figure 5. Number of caimans for each category of health condition, and skin colour.

The chi-square test indicated a relationship between the skin colour of the caimans and the susceptibility of these animals to exhibit lesions such as conjunctivitis or dermatitis, where the light caimans are more vulnerable to suffer these two kinds of diseases simultaneously ($X^2 = 26.592$, $df = 2$, $n = 151$, $p \leq 0.001$). Furthermore, the results are indicating a correlation between the skin colour of the caimans and the kind of disease that they may suffer, the conjunctivitis being more frequent ($X^2 = 27.258$, $df = 3$, $n = 151$, $p \leq 0.001$).

Figure 6 shows the body mass of light–skin caimans and dark–skin caimans in each category of health status. The results of two-way ANOVA for body mass of caimans were different by health status ($F = 17.233$, $df = 3$, $p < 0.0001$), but not for skin colour or the interaction between these variables. Bonferroni test revealed that the body mass of healthy light or healthy dark caimans was higher than caimans with dermatitis, conjunctivitis, and both diseases ($p < 0.0001$).

Figure 7 shows the total length of light skin caimans and dark–skin caimans in each category of health condition. Regarding body mass, the results of two-way ANOVA indicate that the length of caimans was different by health status ($F = 16.934$, $df = 3$, $p < 0.0001$) but not for skin colour or the interaction between these variables.

The Bonferroni test indicated that the total length of healthy light or healthy dark caimans was comparable to that of light or dark caimans with dermatitis. However, it was found to be longer than the total length of caimans with conjunctivitis, regardless of their colour. Additionally, both dermatitis and conjunctivitis were observed in these caimans ($p < 0.0001$).

Discussion

The diseases in crocodilians like in other animal taxon can have different origins, such as bacterial, viral, fungal, nutritional, even neoplastic (Millichamp et al., 1983; Foggin, 1987; Conley et al., 2018). The conjunctivitis and dermatitis reported in this study for individuals of *C. latirostris* (Fig. 4) could be caused by non-specific viral, bacterial, or fungal infections. Any cause of eyes and skin infection may be predisposed by temperatures (cooler), or other environmental stressor factor (Millichamp et al., 1983; Buenviaje et al., 1998a, b; Huchzermeyer, 2003; Meyers et al., 2009; Rainwater et al., 2011). In the captive breeding of crocodilians, the environmental conditions can affect the stress levels of individuals. High stress levels can compromise the immune system and, in some cases, causing immunosuppression (Keller et al., 2006; Nevarez, 2019).

Regardless of the origin of the infections, the results also show a correlation between the skin colour and the susceptibility of *C. latirostris* to suffer conjunctivitis and/or dermatitis, making the light skin caimans

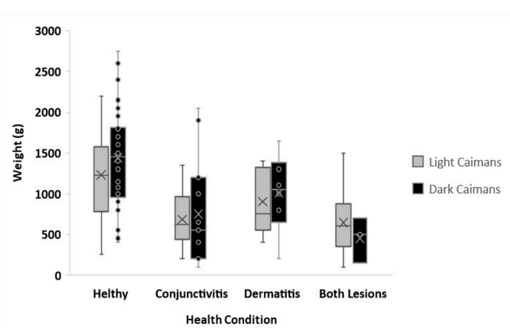

Figure 6. Body mass of healthy caimans, with skin, ocular, or both diseases in each category of skin colour.

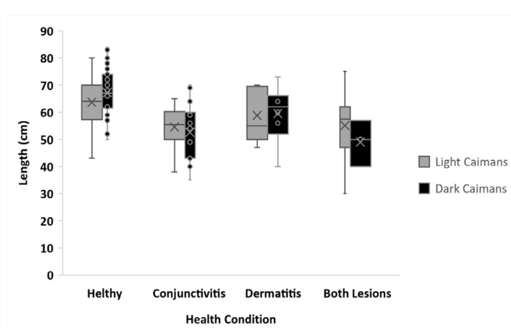

Figure 7. Total length of healthy caimans, with skin, ocular, or both diseases in each category of skin colour.

more vulnerable to suffer these diseases (Fig. 5). In crocodilians, as in other reptiles, skin colour is a genetic trait that is expressed in the phenotype of the animals as different skin tones (Bagatto et al., 2012; Senczuk et al., 2021). The superficial dermis of crocodilians, similar to other reptiles and mammals, consists of sparsely distributed elastin fibres, fibroblasts, and chromatophores (Alibardi, 2011; Lott et al., 2018). The chromatophores contain a specific type of pigment that gives the tone or skin colour, which varies depending on the density of the chromatophores and their shape (Alibardi, 2011; Lott et al., 2018; Goda and Kuriyama, 2021).

In this way, the differences of skin colouration of *C. latirostris* (Fig. 1) may be due to the fact that dark–skin caimans have a higher density of chromatophores than light–skin caimans (Alibardi, 2011). The reported susceptibility of the light skin colour caimans to suffer conjunctivitis and dermatitis (Fig. 5) could be attributed to a lower density of chromatophores present in their skin, which may result in less retention of provitamin A (pigment carotenoids obtained from diet; Elkan and Cooper, 1980; Conley et al., 2018), making them vulnerable to suffering hypovitaminosis A and subsequently, may cause alterations in the mucosal surfaces associated with decreased cellular and humoral immunity to potential pathogens present in the animal's environment opening the door to further invasion by other opportunistic microorganisms that may cause the lacrimal duct obstruction, hyperkeratosis of the lacrimal gland, metaplasia, ataxia, stomatitis, lethargy, or anorexia, among others (Ariel et al., 1997; Buenviaje et al. 1998a, b; Alibardi, 2011; Conley et al., 2018; Lott et al., 2018; Nevarez, 2019).

Many species alter skin colour to varying degrees and by different mechanisms (Kirshner, 1985; Hoglund and Winberg, 2000; Stuart-Fox and Moussalli, 2008; Mack and Beaty, 2022). Merchant et al. (2018) and Staniewicz et al. (2018) affirm that members of the Family Crocodylidae and Gavialidae can modify their skin colouration in response to environmental conditions such as light, background, temperature or even by the social interaction. However, this fact can be excluded because all animals used in this study were raised under the same ambient conditions (stoking density, colour of background, temperature, diet, and light; see above). In addition, Merchant et al. (2018) also said that members of the Family Alligatoridae as *Caiman latirostris* does not possess the ability of alter their skin colour, letting us affirm that the skin colour in these animals is a genetic characteristic.

The body condition of *C. latirostris* is a phenotypic attribute that may be influenced by genetic characteristics from parental and/or the breeding environment (Bagatto et al., 2012) and not health status. This can be observed in the body mass and length of diseases in caimans (light skin and dark skin), which were shorter and less heavy than the healthy caimans (Figs. 6, 7). This is a consequence of infections and diseases in crocodilians causing loss of appetite, lethargy, and anorexia, slowing the growth of animals and increasing the negative impact of diseases (Webb and Manolis, 1983; Buenviaje et al., 1994).

The reported observations here suggest that light skin caimans, due to their lower density of chromatophores in the skin, may accumulate a reduced amount of provitamin A. This could potentially result in hypovitaminosis A, making them more susceptible and prone to skin and eye diseases. Light skin colour has been observed to serve as a beneficial mechanism for preventing certain nutritional deficiencies, conjunctivitis, and dermatitis in crocodilians. These diseases have been documented in other farmed crocodilian species and have been identified as significant causes of economic losses. In some instances, these losses can reach up to 50%, resulting in animal mortality, deterioration of meat quality, damage to hides making them unsellable, or a reduction in selling price. Consequently, the presence of light skin colouration can help mitigate these issues and contribute to overall healthier and more valuable crocodilian populations (Cott, 1961; Millichamp et al., 1983; Jacobson et al., 1989; Newton, 1992; Stuart, 1993; Buenviaje et al., 1998a; Boede, 2000; Huchzermeyer, 2003; Burgstahler et al., 2008).

Early detection of diseases in crocodile farms is crucial as it enables the identification of animals that, despite appearing healthy, may be more susceptible to disease due to specific phenotypical characteristics, such as skin colour. These individuals should be placed in quarantine and closely observed. This proactive measure helps prevent the spread of diseases, allows for timely intervention and treatment, and facilitates adjustments to the diet provided to the animals if necessary.

Through the separation of animals prone to disease, special treatments can be employed to facilitate their recovery, without the need to subject healthy individuals to the same process. This approach helps avoid stress to the animals and reduces production costs. To facilitate the recovery of affected animals, it is possible that the quality of skins produced for the fur industry may be lower, and the meat may become unsuitable for consumption due to disease-related damage (Buenviaje et al., 1997; Huchzermeyer, 2003). This contributes to an economic loss to crocodile farms, while also directly impacting the local communities who benefit economically from the management and conservation programs, because decrease in conservation incentives is a significant factor to consider. This study can provide valuable insights for broad-snouted caiman farmers. However, it would be interesting to expand the research to other commercially bred crocodilian species. Additionally, histological, and molecular techniques can be utilised to identify the pathogens affecting the animals. Analysing the vitamin content of the diets is crucial to fully understand the relationship between vitamins, skin pigments, and diseases. This comprehensive approach will contribute to a better understanding of the complex interactions between these factors.

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References

Alibardi, L. (2011): Histology, ultrastructure, and pigmentation in the horny scales of growing crocodilians. Acta Zoologica (Stockholm) **92**: 187–200.

Ariel, E., Ladds, P., Buenviaje, G. (1997): Concurrent gout and suspected hypovitaminosis A in crocodile hatchlings. Australian Veterinary Journal **75**(4): 247–249.

Bagatto, B., Crossley II, D., Altimiras, J., Elsey, R., Hicks, J. (2012): Physiological variability in yearling alligators: Clutch differences at rest and during activity. Comparative Biochemistry and Physiology Part A: Molecular and Integrative Physiology **162**(1): 44–50.

Boede, E. (2000): Sanitary considerations and diseases in Orinoco crocodile breeders (*Crocodylus intermedius*) from the Venezuelan captive breeding program. Proceedings of 15th working meeting of the IUCN/SSC Crocodile Specialist Group. Varadero, Cuba. IUCN Publications Gland.

Bounds, H., Normand, A. (1991): A brown spot disease of commercially-raised alligators; a preliminary report. Baton Rouge, Louisiana, USA, Louisiana Academy of Sciens.

Buenviaje, G., Ladds, P., Melvillet, L., Manolis, C. (1994): Disease-husbandry associations in farmed crocodiles in Queensland and the northern territory. Australian Veterinary Journal **71**(6): 165–173.

Buenviaje, G., Ladds, P., Martin, Y. (1998b): Pathology of skin diseases in crocodiles. Australian Veterinary Journal **76** :357–363.

Buenviaje, G., Ladds, P., Hirst, R., Summers, P., Millan, J. (1998a): Attempted transmition of dermatophilosis in saltwater crocodiles (*Crocodilus porosus*). Australian Veterinary Journal **76**: 495–496.

Buenviaje, G., Hirst, R., Ladds, P., Millan, J. (1997): Isolation of *Dermatophilus* sp. from skin lesions in farmed saltwater crocodiles (*Crocodilus porosus*). Australian Veterinary Journal **75**: 365–367.

Burgstahler, A., Freeman, R., Jacobs, P. (2008): Toxic effects of silicofluoridated water in chinchillas, caimans, alligators, and rats held in captivity. Fluoride **41**: 83–88.

Clippinger, T., Bennett, R., Johnson, C., Vliet, K., Jacobson, E., Brown, D., Brown, M. (1996): Mycoplama epizootic in a herd of bull alligator (*Alligator mississippiensis*). Proceedings of the American Association of Zoo Veterinarians. Puerto Vallarta, Mexico.

Conley, K., Shilton, C. (2018): Crocodilia. Pathology of wildlife and zoo animals. In: Pathology of wildlife and zoo animals, p. 855–870. Terio, K. A., McAloose, D., Leger, J. S. Eds., Cambridge, USA, Academic Press.

Cott, H. (1961): Scientific results of an inquiry into the ecology and economic status of the Nile crocodile (*Crocodilus niloticus*) in Uganda and northern Rhodesia. Transactions of the Zoological Society of London **29**: 211–359.

Elkan, E., Cooper, J. (1980): Skin biology of reptiles and amphibians. Proceedings of the Royal Society of Edinburgh **79**(B): 115–125.

Foggin, C. (1987): Diseases and disease control on crocodile farms in Zimbabwe. In: Wildlife management: Crocodiles and alligators, p. 351–362. Webb, G., Manolis, C., Whitehead, P., Eds., Sydney, Australia, Surrey Beatty and Sons Pty. Ltd.

Goda, M., Kuriyama, T. (2021): Physiological and morphological color changes in teleosts and in reptiles. In: Pigments, Pigment Cells and Pigment Patterns, p. 387–423. Hashimoto, H., Goda, M., Futahashi, R., Kelsh, R., Akiyama, T., Eds. Berlin, Germany, Springer

Hoglund, E., Winberg, S. (2000): Skin darkening, a potential social signal in subordinate arctic charr (*Salvelinus alpinus*): The regulatory role of brain monoamines and pro-opiomelanocortin-derived peptides. Journal of Experimental Biology **203**: 1711–1721.

Huchzermeyer, F. (2002): Diseases of farmed crocodiles and ostriches. Revue Scientifique et Technique-Office International des Epizooties **21**(2): 265–276.

Huchzermeyer, F. (2003): Crocodiles: Biology, husbandry and diseases. Wallingford, USA, CABI Publishing.

Jacobson, E., Popp, J., Shields, R., Gaskin, J. (1979): Poxlike skin lesions in captive caimans. Journal of the American Veterinary Medical Association **175**: 937–940.

Keller, J., Peden-Adams, M., Aguirre, A. (2006): Immunotoxicology and implications for reptilian health. Toxicology of Reptiles 199–240.

Kirshner, D. (1985): Environmental effects on dorsal coloration in the saltwater crocodile, *Crocodylus porosus*. In: Biology of Australasian frogs and Reptiles, p. 397–402. Grigg, R., Shine, H., Ehmann, G., Eds., Chipping Norton, England, Surrey Beatty and Sons Pty. Ltd.

Ladds, P., Donovan, J. (1989): Diseases of farmed crocodiles. Proceedings of Intensive Tropical Animal Production Seminar. Townsville, Australia.

Ladds, P., Mangunwirjo, H., Sebayang, D., Daniels, P. (1995): Diseases in young farmed crocodiles in Irian Jaya. Veterinary

Record **136**: 121124.

Lott, M., Moore, R., Milic, N., Power, M., Shilton, C., Isberg, S. (2018): Dermatological conditions of farmed Crocodilians: A review of pathogenic agents and their proposed impact on skin quality. Veterinary Microbiology **225**: 89–100

Mack, M., Beaty, L. (2021): The influence of environmental and physiological factors on variation in American toad (*Anaxyrus americanus*) dorsal coloration. Journal of Herpetology **55**(2): 119–126.

Matsumoto, M., Huang, H. (2000): Induction of short-term, nonspecific immunity against *Escherichia coli* infection in chickens is suppressed by cold stressor corticosterone treatment. Avian Pathology **29**: 227–232.

Merchant, M., Hale, A., Brueggen, J., Harbsmeier, C., Adams, C. (2018): Crocodiles alter skin color in response to environmental color conditions. Scientific Reports **8**(1): 1–10.

Meyers, D., Isaza, R., Ben-Shlomo, G., Abbott, J., Plummer, C. (2009): Fungal keratitis in a gopher tortoise (*Gopherus polyphemus*). Journal of Zoo and Wildlife Medicine **40**: 579–582.

Millichamp, N., Jacobson, E., Wolf, E. (1983): Diseases of the eye and ocular adnexae in reptiles. Journal of the American Veterinary Medical Association **183**: 12051212.

Nevarez, J. (2019): Differential Diagnoses by Clinical Signs-Crocodilians. In: Mader's Reptile and Amphibian Medicine and Surgery, p. 1276–1282.e2. Divers, S. J., Stahl, S. J., Eds., Philadelphia, USA, W. B. Saunders.

Newton, J. (1992): Brown spot disease in the Louisiana alligator industry: what we know about the disease and possible control protocols. Proceedings Louisiana Aquaculture Conference. Baton Rouge, USA.

Nogueira, S., Nogueira-Filho, S. (2011): Wildlife farming: an alternative to unsustainable hunting and deforestation in Neotropical forests? Biodiversity and Conservation **20**: 1385–1397.

Rainwater, T., Millichamp, N., Barrantes, L., Barr, B., Bolaños, J., Platt, S., et al. (2011): Ocular disease in American crocodiles (*Crocodylus acutus*) in Costa Rica. Journal of Wildlife Diseases **47**(2): 415–426.

Senczuk, G., Gramolini, L., Avella, I., Mori, E., Menchetti, M., Aloise, G., Castiglia, R. (2021): No association between candidate genes for color determination and color phenotype in *Hierophis viridiflavus*, and characterization of a contact zone. Journal of Zoological Systematics and Evolutionary Research **59**(3): 748–759

Siroski, P., Moleón, S. (2020): Review of the recent knowledge on the crocodilian immune system. South American Journal of Herpetology **18**(1): 68–77

Staniewicz, A., Youngprapakorn, U., Jones, G. (2018): First report of physiological color change in a crocodilian. Copeia **106**(2): 264–267.

Stuart-Fox, D., Moussalli, A. (2008): Selection for social signalling drives the evolution of chameleon colour change. PLoS Biology **6**(1): e25.

Stuart, F. (1993): An investigation into skin lesions in farmed Nile crocodiles: a report and recommedations. Journal of the Zimbabwe Society for Animal Production **5**: 83–85.

Villafañe, F., Rodríguez, G., Martinelli, G., Mantilla, O. (1996): Principales enfermedades que afectan a algunas explotaciones comerciales de *Caiman crocodilus fuscus* en la costa norte colombiana. Proceedings of 13th working meeting of the IUCN/SSC Crocodile Specialist Group. Santa Fe, Argentiba. IUCN Publications Gland.

Vitt, L., Caldwell, J. (2014): Herpetology, an Introductory Biology of Amphibians and Reptiles. New Yor, USA, Academic Press.

Webb, G., Manolis, C. (1983): *Crocodylus johnstoni* in the McKinlay River Area, N.T. V. abnormalities and injuries. Australian Wildlife Research **10**: 407–420.

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