Substrate influence on the prevalence of bumblefoot in captive Chilean flamingos: Assessing the use of infrared thermography as a diagnostic screening tool

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Abstract

Flamingos are a commonly kept species in zoological collections due to their charismatic appearance and popularity with visitors. One of the comments of concerns for those keeping captive flamingos is their susceptibility to "bumblefoot" (ulcerative pododermatitis). Previous studies have found nutrition, abnormal weight bearing, poor sanitation and suboptimal substrates to be the major influencing factors in disease progression. Early diagnosis of bumblefoot is essential for improvement of welfare in affected flamingos. The main objective of this study was to determine whether substrate type influences the prevalence of bumblefoot. This study also tested the effectiveness of thermal imaging as a diagnostic tool for sub-clinical identification of bumblefoot and assessed its use as a potential long-term diagnostic method. Fourteen captive Chilean flamingos (*Phoenicopterus chilensis*), housed at Harewood Bird Garden were used for this study. Rubber matting was used as a trial substrate based on recommendations from published literature, and for ease of cleaning and sanitation. Bumblefoot severity was measured prior to and after substrate change in accordance to Nielsen's severity scores. Thermal images and photographs were also taken prior and post substrate change. Average temperatures of each digit per foot (three per foot) were measured using FLIR software. Results of the study showed a 12.6% increase in bumblefoot severity with the implementation of rubber matting. No significant correlation was found between bumblefoot severity level and thermographic screening. The results identify that substrate may influence susceptibility to bumblefoot development. However, the effectiveness of infra-red thermography in the sub-clinical identification of bumblefoot needs to be further investigated, as data variation and subsequent limitations did not allow for solid conclusions to be formed.

Resumen

Los flamencos son una especie comúnmente mantenida en colecciones zoológicas debido a su apariencia carismática y popularidad entre los visitantes. Una de las condiciones que preocupan a quienes mantienen a los flamencos en cautiverio es su susceptibilidad a la dermatitis plantar (pododermatitis ulcerosa). Estudios anteriores han encontrado que la nutrición, el soporte de peso anormal, el saneamiento deficiente y los sustratos subóptimos son los principales factores que influyen en la progresión de la enfermedad. El diagnóstico temprano de dermatitis plantar es esencial para mejorar el bienestar de los flamencos afectados. El principal objetivo de este estudio fue determinar si el tipo de sustrato influye en la prevalencia de la patología dermatitis planter. Este estudio también probó la efectividad de la imagen térmica como una herramienta de diagnóstico para la identificación subclínica de dermatitis planar y evaluó su uso como un posible método de diagnóstico a largo plazo. Para este estudio se utilizaron catorce flamencos australes (*Phoenicopterus chilensis*) en cautiverio, alojados en Harewood Bird Garden. La alfombra de goma se utilizó como sustrato de prueba según las recomendaciones de la literatura publicada y para facilitar la limpieza y el saneamiento. Se midió la gravedad la

pododermatitis antes y después del cambio de sustrato de acuerdo con las puntuaciones de Nielsen. También se tomaron imágenes térmicas y fotografías antes y después del cambio de sustrato. Las temperaturas promedio de cada dígito por pie (tres por pie) se midieron utilizando el software FLIR. Los resultados del estudio mostraron un aumento del 12,6% en la gravedad de la pata con la implementación de alfombras de goma. No se encontró una correlación significativa entre el nivel de gravedad de la pata y la evaluación termográfica. Los resultados identifican que el sustrato puede influir en la susceptibilidad al desarrollo de pododermatitis en la pata. Sin embargo, la efectividad de la termografía infrarroja en la identificación subclínica de la pododermatitis debe investigarse más a fondo, ya que la variación en los datos y las limitaciones posteriores no permitieron establecer conclusiones sólidas.

Résumé

Les flamants sont une espèce couramment conservée dans les collections zoologiques en raison de leur apparence charismatique et de leur popularité auprès des visiteurs. L'un des commentaires préoccupants pour ceux qui gardent des flamants en captivité est leur susceptibilité aux pododermatites ulcéreuses. Des études antérieures ont montré que la nutrition, une mise en charge anormale, un mauvais assainissement et des substrats sous-optimaux étaient les principaux facteurs influençant la progression de la maladie. Un diagnostic précoce est essentiel pour améliorer le bien-être des flamants affectés. Le principal objectif de cette étude était de déterminer si le type de substrat influence la prévalence de cette pathologie. Cette étude a également testé l'efficacité de l'imagerie thermique en tant qu'outil de diagnostic pour l'identification subclinique de la pododermatite et évalué son utilisation en tant que méthode de diagnostic potentielle à long terme. Quatorze flamants du Chili captifs, logés au Harewood Bird Garden, ont été utilisés pour cette étude. Des tapis en caoutchouc ont été utilisés comme substrat d'essai sur la base des recommandations de la littérature publiée et pour faciliter le nettoyage et l'assainissement. La sévérité de la pododermatite a été mesurée avant et après le changement de substrat conformément aux scores de sévérité de Neilson. Des images thermiques et des photographies ont également été prises avant et après le changement de substrat. Les températures moyennes de chaque doigt (trois par pied) ont été mesurées à l'aide du logiciel FLIR. Les résultats de l'étude ont montré une augmentation de 12,6% de la gravité des pododermatites avec les tapis en caoutchouc. Aucune corrélation significative n'a été trouvée entre le niveau de gravité de la pathologie et le dépistage thermographique. Les résultats indiquent que le substrat peut influencer la sensibilité au développement des pododermatites. Cependant, l'efficacité de la thermographie infrarouge dans l'identification subclinique de cette pathologie doit être étudiée plus avant, car la variation des données et les limitations ultérieures n'ont pas permis de tirer des conclusions solides.

Introduction

Flamingos (Phoenicopteridae) are commonly kept avian species in zoos, arguably one of the most ubiquitous (Rose et al., 2014). In 2010, it was reported that a total of 8837 flamingos were held in captivity; three of the most common species being the Chilean flamingo (*Phoenicopterus chilensis*), the greater flamingo (*P. roseus*) and the Caribbean flamingo (*P. ruber*) (King and Bračko, 2013).

Animal welfare is delineated as the physical and physiological state of an animal, influencing measurable aspects such as quality of life, reproductive success and health status (Rose *et al*., 2016). The main causes for poor welfare in captivity arises through discrepancies between a species'

requirements, the knowledge of care givers on the species' ecology and the husbandry regime of the zoo (Rose *et al*., 2016). With such specific requirements, many species are susceptible to poor welfare due to lack of knowledge on their needs and gaps in the research present on what their requirements are (Fidgett and Gardner, 2014).

A common disease of captive birds, predominantly found in wading, domestic and raptor species, is bumblefoot (ulcerative pododermitis) (Stransky *et al.,* 2016). The cause of the disease can be bacterial, with infection found to occur through breakages in the plantar surface of the metatarsal pad (Tolpinrud *et al*., 2017). Nielsen *et al.* (2010) established that 100% of sampled flamingos within a captive population showed varied levels of foot change in comparison to wild counterparts. Wyss *et al.* (2015) further found that bumblefoot was the primary cause or secondary cause for 95% of euthanasia cases of captive flamingos. Despite the high prevalence of bumblefoot in captivity, there is limited literature present whether this is a disease occurring in wild populations (Tolpinrud et al., 2017). Consequently, complete disease aetiology is still unknown, although the requirement for preventative measures to be undertaken for zoo-housed birds are increasing (Tolpinrud et al., 2017).

Methods

To understand potential causative factors of bumblefoot and to determine a non-invasive way of detecting pathological changes to flamingo foot health, a 10-month study was undertaken on 14 captive Chilean flamingos held at Harewood Bird Garden, Leeds. The flock was comprised of eight males and six females, with a median age of 37.8 years old.

The aim of the investigation was to determine whether substrate type influences the prevalence of bumble foot in flamingo's to aid in the discovery of preventative measures for the future, and to investigate the effectiveness of thermal imaging as a diagnostic tool for the sub-clinical identification of bumble foot and to assess its use as a potential long-term diagnostic method.

Tolpinrud et al. (2017) tested the use of thermal imaging as a diagnostic tool for birds and found a statistically significant difference between regions of the plantar surface that contained nodules, and those that did not. Despite the difference, the success of the tool as a non-invasive diagnostic screening method was still limited due to variations in flamingo foot temperature between each foot and overlapping temperature between sound and abnormal feet (Tolpinrud et al., 2017).

A baseline assessment of bumblefoot severity was first recorded. Photographs of each foot of each flamingo were taken using a smartphone camera and a handheld FLIR (Forward Looking InfraRed) E60BX thermography camera (Figure 1). The duration of the investigation (10 months) allowed for sufficient time for changes in foot health to occur. Foot assessments occurred three times over the duration of the study period (November 2016, February 2017 and November 2017) to reduce stress and prevent disturbance during any potential breeding event. Due to high variation and inconsistency in temperature readings however, the findings of the second foot assessment were discounted from the analysis. A comparison of data was drawn between the original substrate (concrete) and the implemented substrate (rubber matting). Analyses of thermal images occurred using FLIR software, provided with the camera (Figure 2).

Figure 1: Example of data collection using the FLIR camera (photo credit: C. Iling)

Evaluation

Despite Hall (2008), Muir and King (2013) and Fiorello (2017) recommending the use of rubber matting as a substrate in both seabirds and wading birds, the results of this study were inconsistent, with a 12.6% increase in bumblefoot severity post implementation of the rubber matting. Various causative factors eliciting the negative result could have included where the matting was placed, with matting only distributed around the indoor pool due to keeper recommendations. Natural rubber has increased thermal conductivity in comparison to concrete and this may increase the potential for disease organisms to survive (Hernández et al., 2012; Aguilar-Bolados et al., 2016). Enclosure usage may also influence these results, with the flock being provided with access to natural environments (access to lake and pasture) during the warmer months.

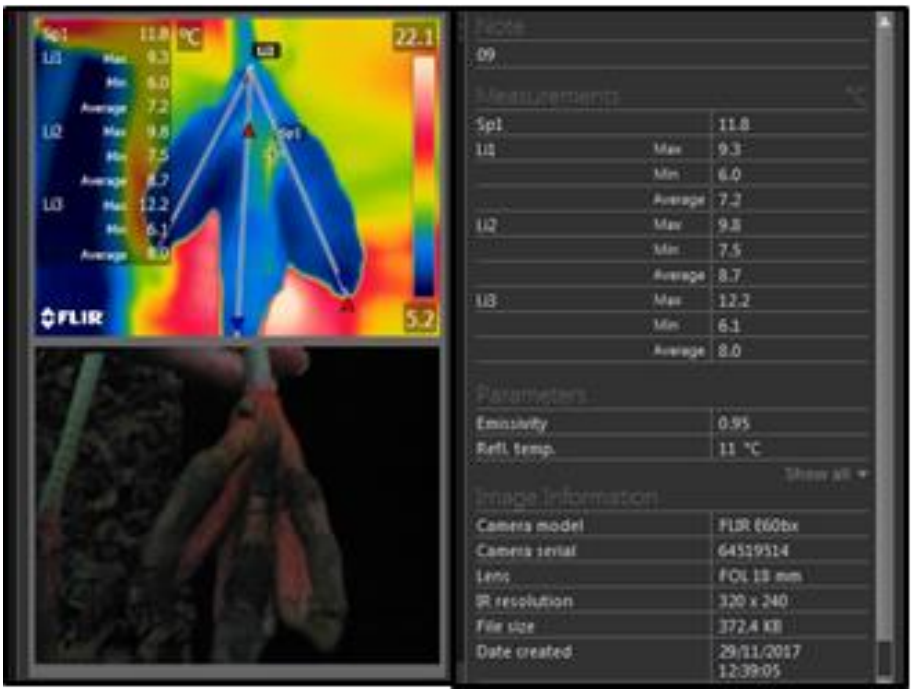

Figure 2: Example of the results from the FLIR camera software, showing the measures taken for the heat gradients per digit (Photo credit: C. Iling).

Thermal readings were inhibited due to atmospheric temperatures; something that potentially combined with the flamingo's behavioural adaption to thermal regulation (the raising of one leg close to the body) (Anderson and Williams, 2009), causing fluctuations in heat signatures detected by the FLIR camera. Variation in temperature could have also occurred between hyperkeratosis and papillomatous growths due to proliferation of the epithelial tissue and the increased distance between the epithelial surface and deeper vasculature tissue (Tolpinrud et al., 2017). The state of the bumblefoot lesion (active or dormant) and subsequent inflammation would also have influenced the readings taken by the FLIR camera (Marques *et al*., 2009).

An area not investigated for this study was the effect of nutrition. Flamingos in captivity are generally provided with formulated pellets, of breeding or maintained types. Influences of diet on bird health, body mass and exercise could be considered alongside of environmental factors that affect foot condition. Furthermore, although thermal images throughout the study showed highlighted heat signatures where bumblefoot susceptibility is high, due to data variation and subsequent study limitations, a definitive conclusion could not be drawn on the efficacy of this recording method.

Conclusion

The results of this study, although formally uncertain, highlights the importance of substrate type and where the substrate is located to flamingo management and health. Currently, although diagnostic methods for bumblefoot, both traditional scoring and infrared thermography are invasive, a combination of both methods could be more accurate in confirming disease presence and monitoring progression, if other environmental influences and individual bird health status is considered and measured too.

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