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ORIGINAL RESEARCH

Characterisation of cataracts and other ophthalmic findings in various species of captive penguins

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Abstract

Background: The identification of ophthalmic diseases that affect vision and/or cause discomfort should be a priority in captive penguins to improve their overall health and quality of life.

Methods: A routine ophthalmological examination was performed on 80 clinically normal penguins (160 eyes), and any lesions observed were recorded.

Results: Ocular lesions were frequent (56% of penguins), with cataracts being the most common (48.8% of penguins). Cortical cataracts (63% of eyes) and posterior subcapsular cataracts (27.4%) were the most commonly occurring. All maturation stages were found; incipient cataracts (52.1% of eyes with cataracts) were predominant, while Morgagnian cataracts (8.2%) were the least frequent. A correlation existed between lenticular changes and increasing age. Uveitis was present in 43.8% of eyes with cataracts, and ectropion uveae was the predominant clinical sign. Other ocular findings included blepharitis (3.8% of all eyes), corneal leukoma (5.6%) and posterior lens subluxation (7.5%).

Limitations: The small number of birds of some species prevented the comparison of ophthalmic findings between species.

Conclusion: This study corroborates the high prevalence of ocular lesions in captive penguins. Cataracts were frequent and age related. Most cataracts were cortical, and the predominant maturation stage was incipient. Lens-induced uveitis was a common finding. Lowered intraocular pressure was related to cataract formation.

KEYWORDS
avian, intraocular pressure, lens, ocular, uveitis

INTRODUCTION

Vision is a critical sense for penguins in the wild, who rely on their sight for navigation, foraging and social behaviour.[1,2] Visual impairments also seem to have a negative influence on the ability of captive penguins to navigate their physical and social environments.[3] Thus, identifying ocular lesions that may affect vision and/or cause discomfort should be a priority in zoos and aquariums to ensure the quality of life of penguins under human care.

There are a few references in the literature regarding ophthalmic findings in captive penguins.[4–7] In these studies, cataracts were the most common ocular finding, with an incidence varying from 14% to 68% in different colonies.[4,6,8] Most of these cataracts were age related.[6,8,9] Environmental oxidative stressors have also been postulated as a hypothetical cause of cataracts.[4,8] Cataract location (capsular, subcapsular, cortical and nuclear) has not been specified in previous studies, but they all classify the cataracts based on the maturation stages (incipient, immature,

mature, hypermature and hypermature resorbed).[5–8] Intraocular pressure (IOP) readings have been found to be significantly lower in penguins with cataracts than in penguins without cataracts, hypothetically due to the presence of lens-induced uveitis (LIU) in the former.[6,8]

Other eye problems identified in penguins include eyelid lacerations, corneal trauma, chronic proliferative keratitis, uveitis and subluxated and completely luxated cataractous lenses.[4,6,8]

The purpose of this study was to describe the ophthalmic findings in a population of 80 captive penguins of different species, categorise cataracts by their location and maturation stage, determine the distribution of IOP in eyes with cataracts and compare these tonometric results to the different stages of cataract formation and the presence of LIU.

MATERIALS AND METHODS

This observational study was approved by the Animal Management and Welfare Committee of the Complutense Veterinary Hospital in Madrid. Eighty clinically normal penguins (160 eyes) housed at two different institutions in Madrid (Faunia and Zoo de Madrid), Spain, were evaluated. A routine ophthalmic examination was performed on both eyes of all penguins by the same ophthalmologist. The examination included gross appearance, pupillary light responses, slit lamp biomicroscopy (Kowa SL-14; Kowa Optimed), indirect ophthalmoscopy and IOP measurements with the rebound tonometer (TonoVet; Icare) using the dog calibration setting.

All ocular lesions were recorded. Active uveitis was diagnosed if conjunctival hyperaemia, ciliary flush, corneal oedema, flare or iris swelling were present, while inactive or chronic uveitis was diagnosed when rubeosis iridis, ectropion uveae, dyscoria due to posterior synechia and/or anterior capsule pigmentation were observed. Cataracts were categorised according to their location, as anterior or posterior capsular, anterior or posterior subcapsular, cortical or nuclear. Based on maturity, they were categorised as incipient (involving less than 10–15% of the lens volume), immature (any lens involvement with a cataract from the incipient stage to a complete cataract), mature (involving the entire lens structure, inspection of the fundus is not possible and vision no longer exists), hypermature (the lens capsule appears wrinkled) and Morgagnian (total liquefaction of the cortex, allowing the nucleus to sink to the bottom of the capsular bag).[10]

The penguins were manually restrained in the prone position by trained keeper staff during the ophthalmic examination. The handler restrained the midsection of the body, including the wings, with one arm, while using the other hand to steady the beak and prevent biting. The birds' heads were kept in an extended position (avoiding excessive stretching or torquing of the neck) for ease of IOP measurement. Special care was taken to avoid applying too much pressure around the neck and the head, which could influence IOP values.

TABLE 1 Mean age for each penguin species

Penguin species	Mean age ± SD (years)
African	10.5 ± 8.8
Gentoo	9.2 ± 9.1
Chinstrap	27.1 ± 6.5
Humboldt	12.2 ± 5.8
King	16.3 ± 7.4
Rockhopper	15.2 ± 4.2
Magellanic	20
Adélie	20

Statistical analysis

The different categorical variables were described by percentages and frequencies; the median and standard deviation were used for numerical variables. The chi-squared test and the exact Fisher test were used for qualitative variables, and a Pearson and ANOVA correlation was estimated between quantitative variables. Relationships between nominal and numerical or ordinal data were analysed with the Wilcoxon rank sum test. All analyses were performed using SAS (version 9.4) software (SAS Institute), with a p-value of less than 0.05 indicating a significant relationship.

RESULTS

The study population included 80 penguins housed at two institutions, consisting of 23 (28.8%) African penguins (*Spheniscus demersus*), 16 (20%) gentoo penguins (*Pygoscelis papua*), 14 (17.5%) chinstrap penguins (*Pygoscelis antarcticus*), 10 (12.5%) Humboldt penguins (*Spheniscus humboldti*), seven (8.8%) king penguins (*Aptenodytes patagonicus*), six (7.5%) rockhopper penguins (*Eudyptes chrysocome*), two (2.5%) Magellanic penguins (*Spheniscus magellanicus*) and two (2.5%) Adélie penguins (*Pygoscelis adeliae*). The sex distribution was 46 (57.5%) females and 34 (42.5%) males. Ages ranged from 1 to 38 years, with a mean age of 14.7 ± 9.7 years. The mean age for each species is specified in Table 1.

A total of 45 penguins (56.2%) had ocular lesions, with 80 eyes (88.9%) being affected. Lesions were unilateral in 10 birds ($n = 10/80$; 12.5%) and bilateral in 35 birds ($n = 35/80$; 43.6%).

Six penguins (6/80; 7.5%) (6/160 eyes; 3.8%) had lesions in the ocular adnexa: four eyes had blepharitis (Figure 1), one eye had a laceration of the nictitating membrane and another eye had a nictitating membrane haemorrhage (Figure 2).

Corneal lesions were present in 10 penguins (10/80; 12.5%) and 15 eyes (15/160; 9.4%). Eleven eyes (11/160; 6.9%) had corneal leukoma (Figures 3 and 4), two eyes (2/160; 1.3%) had pigmentation, one eye

FIGURE 1 Blepharitis characterised by erythema and feather loss in a chinstrap penguin. Mature cortical cataract and dyscoria due to posterior synechiae are also present

FIGURE 2 Nictitating membrane haemorrhage, probably due to trauma, in a chinstrap penguin. The nictitating membrane is displaced, covering the entire corneal surface. An incipient cortical cataract is also present

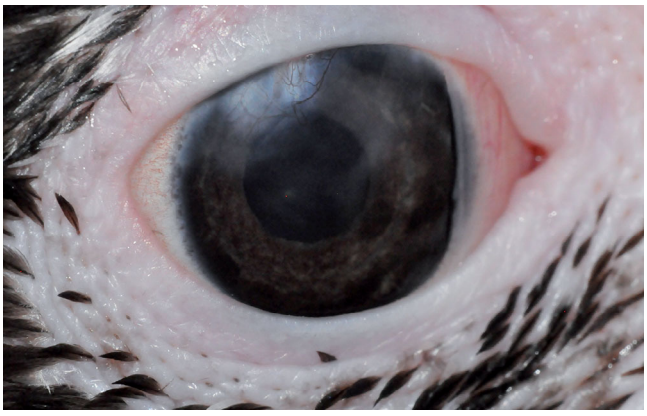

FIGURE 3 Corneal vascularised leukoma in a Humboldt penguin

FIGURE 4 Corneal leukoma and a hypermature posterior subluxated cataract in a king penguin. Note the vitreous bands in the area of the aphakic crescent

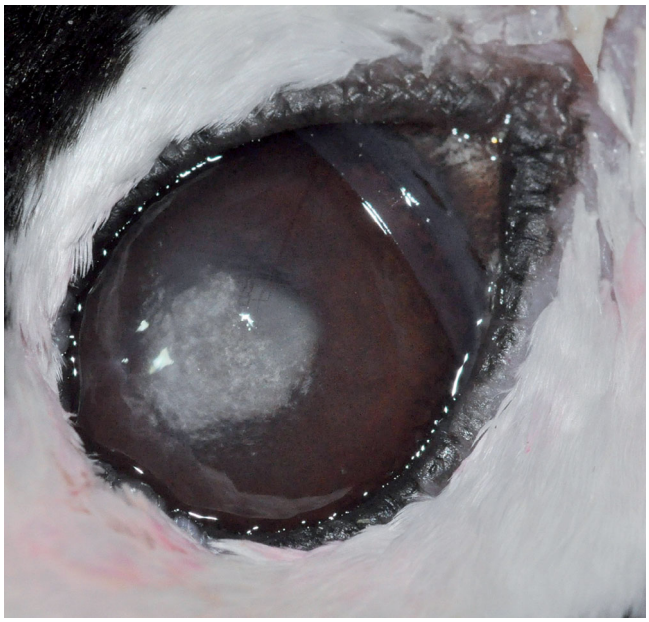

FIGURE 5 Anterior stromal corneal degeneration in a chinstrap penguin. Note the corneal neovascularisation and the mature cataract

(1/160; 0.6%) had corneal anterior stromal degeneration (Figure 5) and diffuse chronic oedema with superficial vascularisation was identified in another eye (1/160; 0.6%).

Thirty-nine penguins (39/80; 48.8%) (73/160 eyes; 45.6%) had cataracts. They were bilateral in 34 birds (34/80; 42.5%) and unilateral in five birds (5/80; 0.6%). The mean age of penguins with cataracts was 32.5 ± 8.6 years, while penguins without cataracts had a mean age of 11.8 ± 8.3 years. Statistical analysis determined that age was a significant risk factor for cataracts in penguins ($p < 0.001$), while sex was not. Chinstrap penguins showed a significantly higher cataract prevalence ($p = 0.0003$) than other species.

FIGURE 6 Immature posterior subcapsular cataract in a gentoo penguin

FIGURE 7 Immature anterior subcapsular cataract in a king penguin

Cortical cataracts (46/73 eyes; 63%) were the most frequent, followed by posterior subcapsular cataracts (20/73 eyes; 27.4%) (Figure 6). Anterior subcapsular cataracts (4/73 eyes; 5.5%) (Figure 7) and anterior capsular cataracts (3/73 eyes; 4.1%) were the least common. Cataracts were classified as incipient in 38 eyes (52.1%) (Figure 8), immature in nine eyes (15.1%), mature in 11 eyes (12.3%) (Figure 9), hypermature in nine eyes (12.3%) (Figure 10) and Morgagnian in six eyes (8.2%).

Signs of chronic uveitis were present in 32 eyes that had cataracts (32/73; 43.8%). Ectropion uveae was the clinical sign most frequently observed (28/32 eyes; 87.5%) (Figure 10), followed by dyscoria due to posterior synechia (9/32 eyes; 28.1%) (Figures 1 and 10) and anterior capsule pigment (5/32; 5.6%) (Figure 11), while rubeosis iridis was found in one eye (1/32; 3.23%) (Figure 11). A significant ($p < 0.01$) and moderate to high correlation (0.62) was noted between cataract maturation and the presence of uveitis.

FIGURE 8 Incipient anterior cortical cataract in an Adélie penguin

FIGURE 9 Mature cortical cataract and dyscoria in a chinstrap penguin

FIGURE 10 Hypermature cortical cataract, dyscoria and ectropion uveae in a chinstrap penguin

FIGURE 11 Rubeosis iridis, dyscoria and posterior synechiae due to uveitis in a king penguin. A hypermature cataract and anterior capsule pigment are also present

Posterior lens subluxation was observed in six penguins (6/80; 7.5%), affecting seven eyes (7/160; 4.4%) (Figure 4). All of these lenses were cataractous; four eyes had Morgagnian cataracts and three eyes had hypermature cataracts. In two of these eyes, vitreous strands were noted in the anterior chamber.

Measurements of IOP could not be taken in six penguins (12/160 eyes) due to their behaviour. The mean IOP for all normal eyes was 31.6. ± 6.1 mmHg. There were no significant differences in IOP between the right and left eyes regardless of the order in which eyes were examined. Sex and age had no effect on these recorded measurements. In eyes with cataracts, the mean IOP was 31.63 mm Hg. These eyes were subdivided into eyes with cataracts with no signs of uveitis, which had a mean IOP of 32.7 ± 6.2 mmHg, and eyes with cataracts and uveitis, with a mean IOP of 30.9 ± 11.6 mmHg. There were no significant differences in IOP between eyes without cataracts and eyes with cataracts ($p = 0.8725$). Comparisons of the tonometric measurements of the five groups of cataract maturity indicated a significant difference between the incipient group and the hypermature ($p = 0.0043$) and Morgagnian ($p = 0.0341$) groups, and the IOP decreased with cataract progression. Significant differences were also found between immature and hypermature ($p = 0.0273$) cataracts.

DISCUSSION

The results of this study show a high incidence of ocular lesions in penguins kept under human care (56% of penguins). Cataracts were the most frequent anomaly, affecting 48.8% of penguins (73/160 eyes; 45.6%). Previous studies have found that the incidence of cataracts varies from 14% to 68% in different colonies.[4,6,8]

Potential causes of cataracts in the rockhopper and macaroni penguins have been discussed. Husbandry factors such as fluorescent exhibit lighting, high population density, hand-feeding, increasing minimum photoperiod length, dietary smelt and dietary capelin have been associated with increased odds of cataracts, while hereditary cataracts seem to be uncommon.[8] Age has been established as an important risk factor for cataracts.[6,8] This has also been corroborated in the present study, where a correlation existed between lenticular changes and increasing age. The chinstrap penguins had a greater incidence of cataracts than the other species in this study. This was probably due to the higher average age of this group (27.1 ± 6.5 years) (average age of the other species combined: 10.9 ± 8), which corroborates the importance of age-related cataracts in these birds. The correlation between the presence of cataracts and age could explain why cataracts are frequent in these captive penguins, as they have a longer life expectancy than wild penguins.[11] However, further studies would be needed to determine the real influence of husbandry factors in the development of cataracts in captive penguins.[8] Cataracts were not sex related, as established by previous authors.[7]

Consistent with previous reports, all stages of cataracts were observed.[6–9,12] Incipient cataracts were the most frequent (38/73 eyes; 52.1%). This finding varies from a previous study, where incipient cataracts represented 24% of all eyes in a colony of macaroni penguins, while they were not observed at all in a population of rockhopper penguins.[6] Hypermature cataracts have been described as being the most common, at 61.1% and 55.2% in two colonies of macaroni and rockhopper colonies, respectively, while in our study, they were only present in 12.3% of all eyes.[6] This difference could partly be explained by the differentiation in our study of hypermature cataracts from Morgagnian (a type of hypermature cataract) cataracts, while Bliss did not distinguish between the two.[6] On the other hand, the mean age of penguins with cataracts in our study was lower than that described in previous studies. This could also explain both the higher incidence of incipient cataracts and the lower incidence of hypermature cataracts.[6,10]

Penguins with incipient cataracts had a mean age of 15.2 ± 5.1 years, while penguins with mature, hypermature or Morgagnian cataracts had a mean age of 24.0 ± 9.4 years. These findings are consistent with age-related cataracts in penguins, as previously reported.[6,8]

Cataract location has not been previously described in penguins. Cortical cataracts (36% of eyes with cataracts) were the most common in this study, at any stage of maturation. Posterior subcapsular cataracts were the second most common (27.4% of eyes with cataracts), and all of them were in incipient cataracts. Anterior subcapsular cataracts were present in 5.5% of eyes with cataracts, again all incipient cataracts. In dogs, common sites for initial opacity development are at the equator, Y-suture regions or anterior and posterior subcapsular, and depending on aetiology, they may or may not progress.[12] Thus, periodic evaluation of these eyes would be very interesting to determine the progression of the cataract. Anterior capsular cataracts represented only 4.1% of eyes with

cataracts and were identified in eyes that also showed clinical signs of uveitis, which may suggest a possible origin of these lenticular opacities.

Dislocation of the lens was found in 4.4% of the eyes (7/160). The lens was posteriorly subluxated in all the cases with hypermature or Morgagnian cataracts. In two of these eyes, degenerative vitreal strands were observed prolapsed into the anterior chamber. This is a frequent clinical finding associated with lens luxation or subluxation. Lens subluxation is a common finding associated with hypermature cataracts in dogs and has also been described in penguins.[7] Subluxation presumably results in a reduction in overall lens size with resorption, causing zonular rupture through direct physical stretching.[13] It is likely that the same is also true in penguins. Associated chronic lens-induced inflammation can cause a zonulytic effect due to the enzymatic degradation of fibrillin proteins, thus contributing to lens instability.[7] In this study, five of the seven eyes with lens subluxation also had clinical signs of uveitis, so intraocular inflammation probably also contributed to lens luxation.

Chronic uveitis was diagnosed in 19 penguins (19/80; 18.8%) and 32 eyes (32/180; 16.8%). Ectropion uveae was the most common clinical sign associated with uveitis (87.5% of eyes with uveitis), followed by dyscoria due to posterior synequia (28.1%). Ectropion uveae can be found in dogs with cataracts and uveitis; Kern and Colitz[5] had previously noted the presence of ectropion uveae in at least one penguin with hypermature cataracts, but it has not been described in other studies in penguins with cataracts and uveitis.[7,8] Rubeosis iridis was found in only one eye, which differs from previously published data where this clinical sign was more frequent (7–18%).[6,12] Consistent with previous reports, no overt signs of active disease, such as blepharospasm, discharge or hyperemia, were noted in the penguins of the current study.[12]

Chronic uveitis was found in eyes concurrently affected by cataracts, which is consistent with LIU due to the leakage of soluble lens protein through an intact lens capsule.[14,15] The diagnosis of this type of uveitis is presumptive and is made on the observation of cataracts and the absence of other ocular or systemic disease.[16] A positive correlation was found between the degree of cataract maturation and the presence of uveitis. This is consistent with findings in different species, where phacolytic uveitis occurs in eyes with cataracts of different degrees of maturation, although more clinically relevant inflammation may develop with hypermature cataracts.[16] Also, in a previous study, anterior segment anomalies, including rubeosis iridis, irregular pupillary margins and corneal oedema, were found only in the penguins with cataracts. However, a statistical correlation between anterior segment anomalies and the stage of cataracts could not be calculated because the majority of cataracts (55-60%) were hypermature.[6]

In three eyes, uveitis was consistent with focal anterior capsule cataracts, thus making it plausible that the lenticular opacity could have been caused by intraocular inflammation following the same mechanisms as in dogs, such as capsular deposition of inflammatory cells.[13]

Normal values of IOP, measured by rebound tonometry, as in the present study, have been reported in different penguin species; mean IOP values in these studies ranged between 28.1 and 42.0 mmHg.[6,9,17,18] The results of this study are consistent with previous results and indicate a mean IOP of 31.6. ± 6.1 mmHg. However, a limitation of this study is that IOP values for each different species were not considered due to the low number of birds in most of them. There was no significant correlation between age and lowered IOP. This result agrees with a study in rockhopper penguins but differs from the rest of the previous reports.[6,8,12]

IOP seems to be associated with the release of prostaglandins and the increase in uveoscleral aqueous outflow through the ciliary body stroma and musculature.[19] Low IOP is an important indicator in the diagnosis of LIU and decreases with the increasing maturity of the cataract.[14,20,21] These relationships are likely to also occur in penguins.[6,8] In the current study, no significant differences were found between the mean IOP in penguins with and without cataracts, in contrast with previous findings in a macaroni population, where the IOP was significantly lower in eyes with cataracts.[6,8] This difference could be attributed to the higher proportion of incipient and immature cataracts in the current study (67.2%) compared to the previous reports (34.5%), as low IOP due to LIU is not so common in early stages of cataract.[21] In a rockhopper population, IOP was not significantly different between normal eyes and eyes with cataracts.[12] This difference, compared to the macaroni population of the same study, was attributed to the fact that macaroni penguins tended to begin cataract development at younger ages and progressed more rapidly compared with rockhoppers, which could lead to the development of more severe LIU in the macaroni. This relationship between cataract age of onset, progression and uveitis severity between different species could not be made in the present study, as all birds, regardless of the species, were considered one population.

IOP readings were not significantly different between eyes with cataracts (32.7 ± 6.2) and eyes with cataracts and signs of uveitis (30.9 ± 11.6 mm Hg), although values were lower in this last group. This could also be attributed to the high proportion of early cataracts in the present study, were low IOP due to LIO is not so common.[21]

Comparisons of the tonometric measurements of the five groups of cataract maturity indicate that the stage of cataract formation had some effect on the IOP, which was reduced with progressive maturation. Significant differences were only apparent between incipient cataracts and hypermature and Morgagnian cataracts and between immature and hypermature cataracts. However, significant differences were not present when comparing the rest of the maturity

stages. A study in dogs concluded that the relationship between IOP and cataract maturity is not clear, as differences in IOP among eyes with cataracts of different maturation stages are too ambiguous to be clinically useful.[21] This seems to be also plausible in penguins.

Adnexal diseases are uncommon in penguins (3.8% of the eyes in this study). Blepharitis is thought to be due to environmental concerns (e.g., high ammonia levels, filtration system contamination and the use of chemical cleaning agents with insufficient ventilation) and stress.[7] Nictitating membrane lesions (a laceration and a haemorrhage) were probably due to trauma.

Corneal lesions were also infrequent (9.4% of eyes in this study). Leukomas, fibrosis and pigmentation were consequent to corneal ulcers, which were probably traumatic. Unilateral anterior stromal degeneration was identified in one geriatric penguin with no history of trauma and with normal fasted bloodwork. This finding was also previously described in three penguins, and as in our case, the affected penguins showed no ocular pain associated with chronic corneal mineralisation.[7] One eye showed chronic oedema and neovascularisation with normal IOP. The origin of this oedema could not be established.

A limitation of this study was that all birds, regardless of their species, were considered a single study population due to the small number of animals in some species. Therefore, comparison of the ophthalmic findings between the different species could not be made.

This study confirmed the high prevalence of ocular lesions in penguins kept under human care. Cataracts were frequent and age related. Most cataracts were located cortically, while the predominant maturation stage was incipient. LIU was a common finding in eyes with cataracts where ectropion uveae was the most frequent clinical sign. Lowered IOP was related to cataract formation.

Periodic ophthalmic examinations of captive penguins should be undertaken in zoological facilities as undiagnosed ocular diseases have the potential to negatively impact quality of life.

AUTHOR CONTRIBUTIONS

Elisa M. González-Alonso-Alegre contributed to the design of the study, performed the ophthalmic examination of the penguins, analysed the results and wrote and revised the manuscript. Eva Martínez-Nevado performed the clinical evaluation of the animals housed at the zoo, helped manage the animals during the ophthalmic examination, contributed to the analysis of the results and revised the manuscript. Lino Pérez de Quadros and Manuel de la Riva-Fragua performed the clinical evaluation of the animals housed at Faunia, helped manage the animals during the ophthalmic examination and revised the manuscript. Alfonso Rodríguez-Alvaro contributed to the design of the study, performed the ophthalmic examination of the penguins, analysed the results and revised the manuscript.

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CONFLICT OF INTEREST STATEMENT

The authors declare they have no conflicts of interest.

FUNDING INFORMATION

The authors received no specific funding for this work.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available from the corresponding author upon reasonable request.

ETHICS STATEMENT

This study was approved by the Animal Management and Welfare Committee of the Complutense Veterinary Hospital in Madrid.

REFERENCES

1. Chiaradia A, McBride J, Murray T, Dann P. Effect of fog on the arrival time of little penguins *Eudyptula minor*: a clue for visual orientation? J Ornithol. 2007;148(2):229–33.
2. Nesterova AP, Bohec C, Beaune D, Pettex E, Le Maho Y, Bonadonna F. Do penguins dare to walk at night? Visual cues influence king penguin colony arrivals and departures. Behav Ecol Sociobiol. 2010;64(7):1145–56.
3. Heintz RM, Fuller GA, Woodhouse SJ, Murray A, Allard SM. Case studies of the impacts of cataract surgery on crested penguin welfare. J Appl Anim Welf Sci. 2019;22(4):329–41.
4. Swinger RL, Langan JN, Hamor R. Ocular bacterial flora, tear production, and intraocular pressure in a captive flock Humboldt penguins (*Speniscus humboldti*). J Zoo Wildl Med. 2009;40:430–36.
5. Kern TJ, Colitz CMH. Exotic animal ophthalmology. In: Gelatt KN, editor. Veterinary ophthalmology. 5th ed. USA: Wiley-Blackwell; 2013. p. 1750–819.
6. Bliss CD, Aquino S, Woodhouse S. Ocular findings and reference values for selected ophthalmic diagnostic test in the macaroni penguin (*Eudyptes chrysolophus*) and southern rockhopper penguin (*Eudyptes chrysocome*). Vet Ophthalmol. 2015;18:86–93.
7. Church ML. Ophthalmology of sphenisciformes: penguins. In: Montiani-Ferreria F, Moore BA, Ben-Shlomo G, editors. Wild and exotic animal ophthalmology. Vol 1. Switzerland: Springer Nature Switzerland AG; 2022. p. 537–49.
8. Woodhouse SJ, Peterson LE, Schmitt T. Evaluation of potential risk factors associated with cataract in captive macaroni (*Eudyptes chrysolophus*) and rockhopper penguins (*Eudyptes chrysocome*). J Zoo Wildl Med. 2016;47(3):806–19.
9. Church ML, Priehs DR, Denis H, Croft L, DiRocco S, Davis M. Technique, postoperative complications, and visual outcomes of phacoemulsification cataract surgery in 21 penguins (27 eyes): 2011–2015. Vet Ophthalmol. 2018;21(6):612–21.
10. Davidson MG, Nelms SR. Diseases of the lens and cataract formation. In: Gelatt KN, editor. Veterinary ophthalmology. 5th ed. USA: Wiley-Blackwell; 2013. p. 1199–233.
11. Rafferty JP. Emperor penguin. Encyclopedia Britannica. Available from: https://www.britannica.com/animal/emperor-penguin. Accessed 20 Sep 2023.
12. Woodhouse SJ, Peterson LE, Schmitt T, Aquino S. Intraocular pressure in southern rockhopper (*Eudyptes chrysocome*) and macaroni penguin (*Eudyptes chrysolophus*): evaluation of influencing factors. J Zoo Wildl Med. 2016;47(1):223–35.
13. Leiva M, Peña T. Diseases of the lens and cataract formation. In: Gelatt KN, editor. Veterinary ophthalmology. 6th ed. USA: Wiley-Blackwell; 2021. p. 1317–70.

14. Park SA, Yi NY, Jeong MB, Kim WT, Kim SE, Chae JM, et al. Clinical manifestations of cataracts in small breed dogs. Vet Ophthalmol. 2009;12(4):205–10.
15. Wilcock BP, Peiffer PL. The pathology of lens-induced uveitis in dogs. Vet Pathol. 1987;24:549–53.
16. van der Woerdt A. Lens-induced uveitis. Vet Ophthalmol. 2000;3:227–34.
17. Gonzalez-Alonso-Alegre EM, Martinez-Nevado E, Caro-Vadillo A, Rodriguez-Alvaro A. Central corneal thickness and intraocular pressure in captive black-footed penguins (*Sphenicus demersus*). Vet Ophthalmol. 2015;18:94–97.
18. Mercado JA, Wirtu G, Beaufrere H, Lydick D. Intraocular pressure in black-footed penguins (*Sphenicus demersus*) measured by rebound tonometry. J Avian Med Surg. 2010;24(2):138–41.
19. Collins BK, Moore CP. Diseases and surgery of the canine anterior uvea. In: Gelatt KN, editor. Veterinary ophthalmology. 3rd ed. Philadelphia: Lippincott/Williams & Wilkins; 1999. p. 755–95.
20. van der Woerdt A, Nasisse MP, Davidson MG. Lens-induced uveitis in dogs: 151 cases (1985–1990). JAVMA. 1992;201:921–26.
21. Leasure J, Gelatt KN, MacKay EO. The relationship of cataract maturity to intraocular pressure in dogs. Vet Ophthalmol. 2001;4:273–76.

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