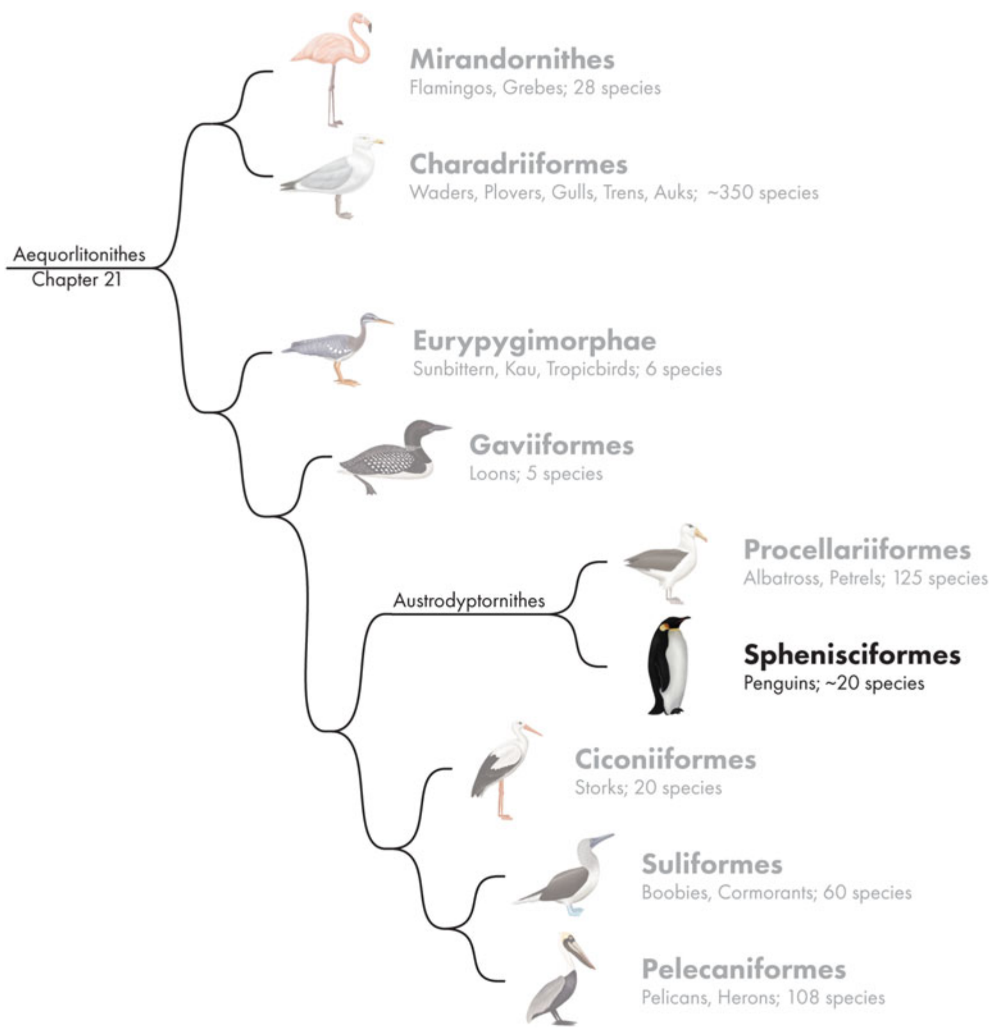
22 Ophthalmology of Sphenisciformes: Penguins

Melanie Landry Church



© Chrisoula Skouritakis

Introduction

Penguins (order Sphenisciformes, family Spheniscidae) are flightless aquatic birds commonly exhibited in aquarium and zoological facilities. Almost all species are native to the Southern Hemisphere, the exception being the Galapagos

M. L. Church (✉)
Animal Eye Care Associates - Virginia Beach, Virginia Beach, VA, USA
e-mail: virginiabeach@associates.com

F. Montiani-Ferreira et al. (eds.), *Wild and Exotic Animal Ophthalmology*, https://doi.org/10.1007/978-3-030-71302-7_22

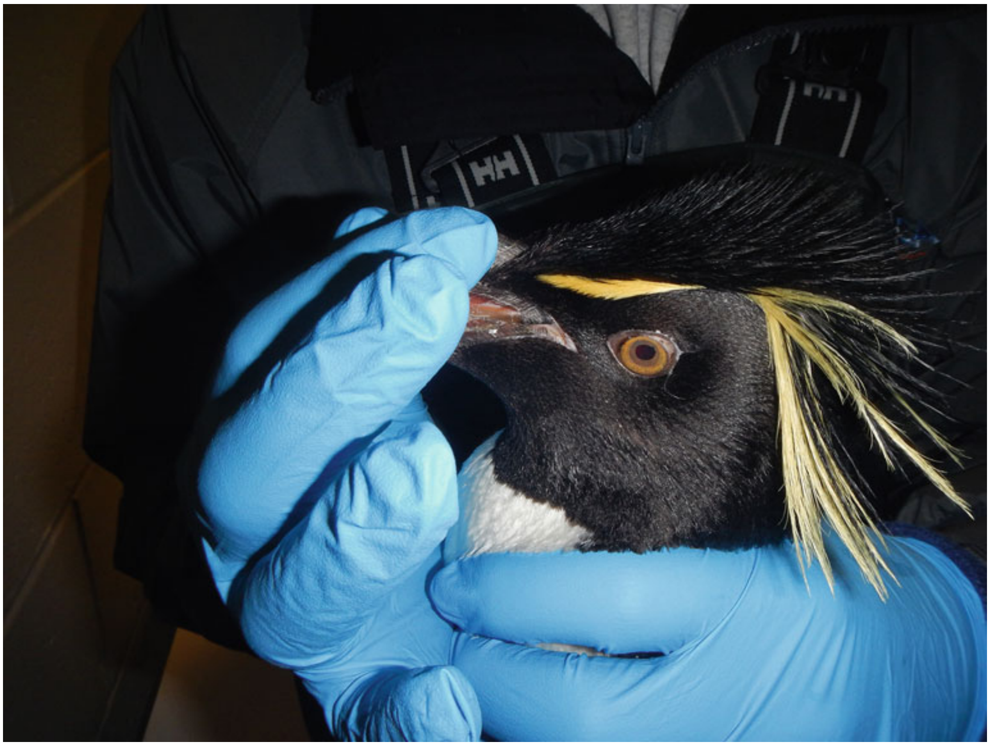


Fig. 22.1 Manual restraint of a Rockhopper penguin, done by holding the beak while supporting the body and back of the head

penguin that lives near the equator. In general, the 17 penguin species can be categorized into those that live in warm-temperate or cold weather zones.

Penguins are best kept in groups, and the enclosure should include land space, pool for swimming, isolation/nesting areas, and a separate location for quarantine of sick animals (AZA Penguin Taxon Advisory Group 2014). Most penguins spend roughly half their time on land and the other half in the water; as such, their eyes are adapted for both the aquatic and terrestrial environments. In captivity, a high standard of air quality is crucial in prevention of general and ocular disease. Penguins are highly susceptible to systemic aspergillosis, which is most likely to occur in stressed or debilitated animals (AZA Penguin Taxon Advisory Group 2014). For that reason, the application of systemic steroids for ocular (or other) inflammation is not recommended, as it may increase the risk for fungal infection (M.L. Church, personal observation). Treatment and/or prophylaxis for fungal infection typically involves the use of oral itraconazole or other antifungal medications.

For ophthalmic examination, proper restraint is important not to overly stress or injure the penguins, handlers, or examiner, and individual penguins should be separated from the colony for examination. Initial restraint is done by supporting the penguin's body and back of the head (Fig. 22.1). Smaller species may be placed between the handler's legs so that the flippers can be secured. The beak may be used to help keep the bird still and gently guide head direction for facilitation of ocular exam. A speedy thorough exam helps to minimize patient stress. For King and Emperor penguins, handlers and examiners should wear eye protection to avoid injury from the bird's beak.

Transportation requirements may vary depending on the size and species of penguin. Antarctic and subantarctic species are susceptible to overheating and require ambient temperatures of 0–11.5 °C (32–52 °F). Therefore, for transporting from one facility to another (e.g., from a zoo to the ophthalmologist's office) these species will require the use of a climate controlled refrigerated truck. Individual transport containers should allow a penguin to stand fully erect without touching the roof and sides of the container, suitable substrate (i.e., rubber mats, AstroTurf, ice, or cat litter) is necessary to provide adequate footing during transport (AZA Penguin Taxon Advisory Group 2014).

Ophthalmic Anatomy

All penguin species are similar in morphology and physiology due to their adaptation to a marine environment. Penguins lack nasolacrimal ducts and have small lacrimal glands. They possess a lateral nasal gland (the supraorbital gland), which is surrounded by a capillary bed. The role of this gland is to extract sodium chloride from the blood

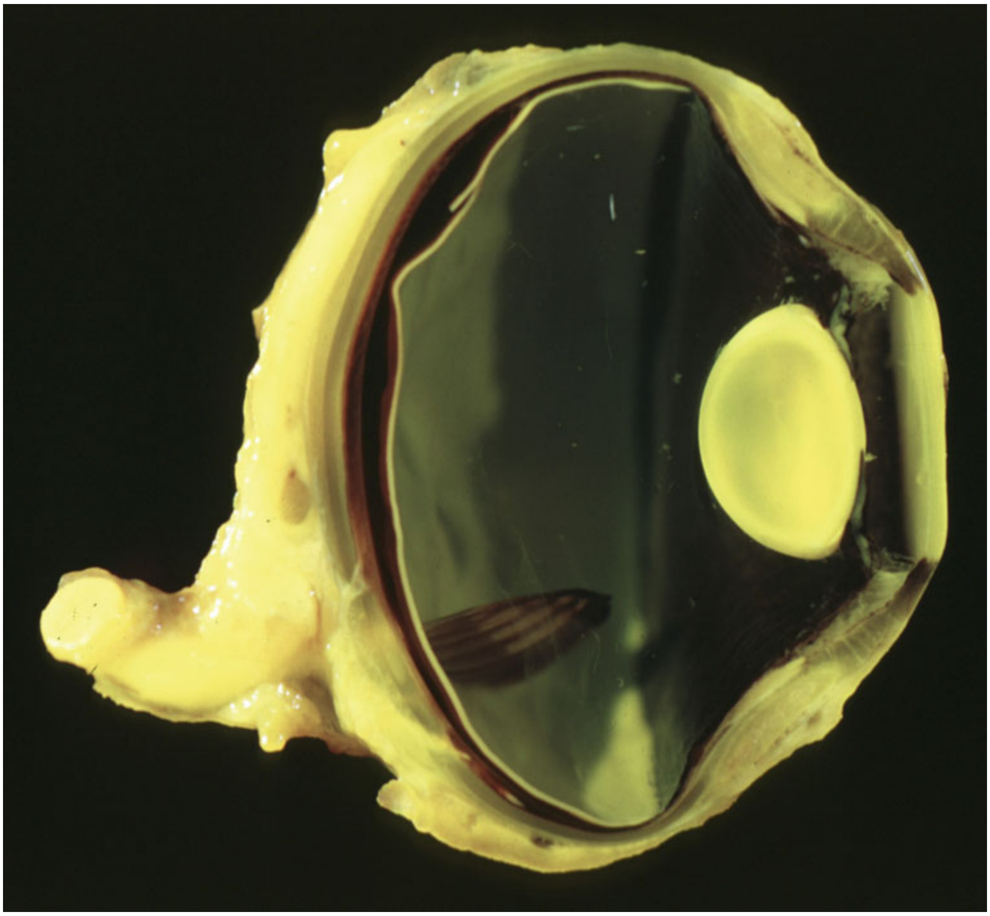


Fig. 22.2 A cross section of an African (Black-Footed) penguin *Spheniscus demersus*. The flattened cornea is clearly noted. Courtesy of the Comparative Ocular Pathology Laboratory of Wisconsin

circulation and excrete the salt through the bill as a brine nasal secretion, allowing penguins to survive in the saltwater environment, without access to freshwater. In general, avian eyes are classified as flat, globose, or tubular. The shape of the penguin eye can be classified as globose (more rounded), since its anterior and posterior segments do not meet at an angle. However, the typical avian globose eyeball shows a scleral depression around the cornea which is not present in penguins; hence, a fourth category of quasi-spherical eye has been suggested for penguins (Suburo and Scolaro 1990). The cornea of penguins is flattened relative to the overall size of the eye in comparison with the standard avian model (Fig. 22.2); this minimizes the optical effect of submergence, and together with a more rounded lens (see below) and a powerful accommodative mechanism, results in near emmetropia in both air and water under natural conditions (Howland and Sivak 1984).). Specifically in King Penguins (*Aptenodytes patagonicus*), the cornea possesses a radius 32.9 mm, a low refractive power (10.2 diopters in air) and this may be correlated with the amphibious nature of penguin vision. The large size of the eye and of the fully dilated pupil may be correlated with activity at low light levels. In air, the binocular field is long (vertical extent 180°) and narrow (maximum width 29°), with the bill placed approximately centrally—a topography found in a range of bird species which employ visual guidance of bill position when foraging (Martin 1999). Mean central corneal thickness, as reported in the black-footed penguin, was 384 ± 31 μm (Gonzalez-Alonso-Alegre et al. 2015). Penguin eyes include a region of opaque sclera extending from the cornea to the anterior border of the scleral ossicle ring. This region is composed of a very dense fibrous tissue which is broader in penguins compared to other avian species (Suburo and Scolaro 1990). The scleral ossicles form a ring that in some avian species have only one or two pairs of over- and underplates scleral ossicles; penguins, on the other hand, have three pairs, similar to loons (Gaviidae) and ducks (Anatidae) (Suburo and Scolaro 1990). The configuration, shape, and size of the scleral bones suggest that the specialized anterior segment of the penguin eye would counteract the distortion tendencies of hydrodynamic pressure when swimming underwater at high speed. The penguin lens is large and more spherical than aerial birds (Howland and Sivak 1984). Lens accommodation compensates for loss of corneal refractive power in the water (Sivak et al. 1987).

Refractive studies have shown that penguins are near-emmetropic both in the water and on land, as mentioned above (Howland and Sivak 1984). Average monocular and binocular visual fields of penguins are reduced in comparison with non-diving birds. This appears to be related to the development of flattened corneas as a means of limiting the refractive changes of moving from air to water (Howland and Sivak 1984). The behavioral correlate of low binocular vision often results in penguins moving their heads side to side when observing a frontal target. Retinal ganglion cell topography in several penguin species demonstrates horizontal visual streak. The horizontal visual streak allows panoramic view of the horizon which aids with the detection of predators, prey, and conspecifics (Coimbra et al. 2012). An area of dense aggregation of giant retinal ganglion cells (gigantocellularis) that forms an additional vertical visual streak has been noted in the temporal retina of several penguin species (Suburo et al. 1991). This temporal vertical visual streak improves penguins' visual function in the three-dimensional marine environments by allowing better vertical sampling in the frontal visual field, which aids with prey location across different depths in the water column (Coimbra et al. 2012).

Tear production, when measured with Schirmer tear test, ranged from 1 to 12 mm/min with a mean of 6.5 ± 3 mm/min (Swinger et al. 2009). Penguins housed in a freshwater habitat typically have a higher mean Schirmer tear test compared with those in saltwater. When comparing ocular bacterial flora, penguins housed in saltwater had fewer bacteria species and positive culture results when compared to those housed in freshwater. *Corynebacterium* spp. and *Staphylococcus* spp. were the most prevalent organisms, similar to studies in other avian species (Swinger et al. 2009). Available reference values for lacrimal testing are displayed in Appendix A.

Mean intraocular pressure (IOP) values for penguins vary with species and tonometry technique. Southern Rockhopper penguins had mean IOP of 20.0 ± 5.8 mmHg and 24.1 ± 5.1 mmHg for applanation and rebound tonometry, respectively, showing a significant difference in measurement between the two instruments (Bliss et al. 2015). Humboldt penguins had similar mean IOP of 20.4 ± 4.1 mmHg using applanation tonometry (Swinger et al. 2009). Another study showed slightly higher mean IOP values using rebound tonometry in black-footed penguins at 31.8 ± 3.3 mmHg (Gonzalez-Alonso-Alegre et al. 2015). In cataractous penguin eyes mean IOP value using applanation tonometry was 6 mmHg compared to 16 mmHg with rebound tonometry (Church et al. 2018). Available reference values for tonometric testing are displayed in Appendix A.

Ophthalmic Diseases

Adnexa

Adnexal diseases are generally not common, reported in 2/104 penguin eyes (1.9%) over a 4-year period (M. L. Church, unpublished data) (Fig. 22.3). In cases of blepharitis and/or conjunctivitis, culture may be helpful in determining an underlying etiology and treatment plan. Most cases of blepharitis or conjunctivitis in penguins spontaneously resolve and are thought to be due to environmental concerns such as high ammonia levels, the use of chemical cleaning agents without proper ventilation, filtration system contamination, and/or stress.

Granulomatous inflammation of the supraorbital glands, conjunctivitis, and ocular discharge were reported in a group of young Humboldt penguins that had local and systemic infection with *Pseudomonas aeruginosa*. The infected birds showed various other clinical signs including lethargy, inappetence, dyspnea from airsacculitis and pneumonia, and in one case seizures. Six of the nine penguins died or were euthanized and three responded to systemic tobramycin treatment. Epidemiologic investigation showed that the insufficient filtration system, biofilm formation on pipe surfaces, and other factors promoted pathogen buildup in the pool water and led to this outbreak (Widmer et al. 2016). Inflammation of the supraorbital glands can also occur in penguins after ingestion of water with an excessively high sodium level (Kern 1989).

Cutaneous wart-like lesions were seen around the eyes, beak, flippers, feet, and cloaca in penguins affected by avian pox virus. Infections have been documented in wild and captive Magellanic, African, Humboldt, Gentoo, and Rockhopper penguins (Stidworthy and Denk 2018). Fleas were the most likely arthropod vectors in a colony of affected wild Magellanic penguins (Kane et al. 2012). Avian pox typically affects chicks (and is often fatal), suggesting adults may have acquired immunity (Kane et al. 2012). Concurrent infections with common pathogens, such as *Aspergillus*, worsen clinical course (Stidworthy and Denk 2018).

Cornea

Corneal disease is more common in penguins, reported in 13/104 eyes (12.5%) over a 4-year period (M.L. Church, unpublished data). The most common corneal disease was in the form of ulcers or ruptures due to trauma; other conditions reported included keratopathy, stromal degeneration (Fig. 22.4), and infantile corneal dystrophy (Fig. 22.5).

The majority of corneal ulcers in that report were caused by trauma and were superficial and non-infected. The most

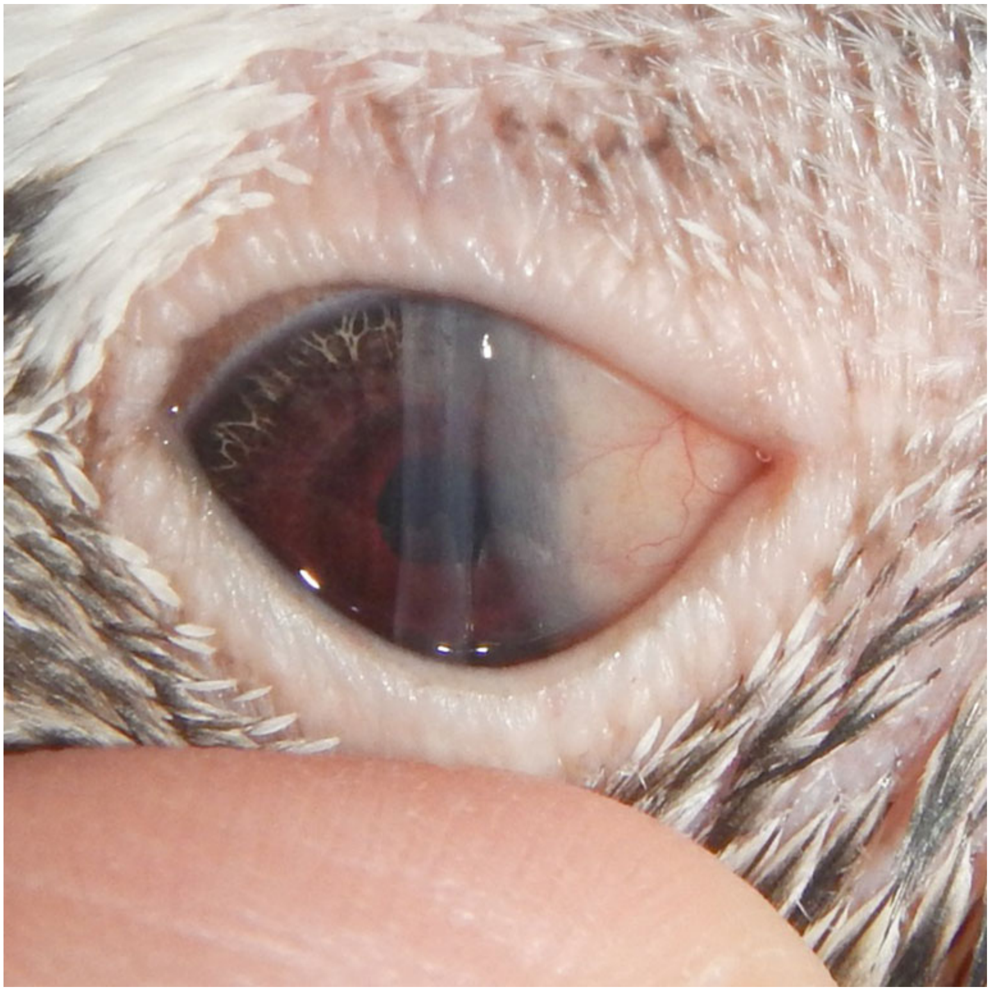


Fig. 22.3 Conjunctivitis in a penguin sp. presumably due to high ammonia levels and disinfectants used in quarantine. The condition resolved with symptomatic treatment

common time to observe corneal ulcers in penguins was during breeding season. In a 4-year period two birds (2/104 eyes, 1.9%, M.L. Church, unpublished data), a Chinstrap and King penguin housed in separate areas, developed traumatically-induced corneal ruptures from being pecked by another male during breeding or pre-breeding dominance struggles. The Chinstrap penguin's corneal rupture healed with medical management but resulted in vision loss due to corneal scarring and anterior/posterior synechiation. The male King penguin initially responded to medical therapy but developed painful recurrent corneal ruptures due to lack of vision and suspected recurrent trauma. A modified evisceration was performed; post-operative recovery was uneventful, and the King penguin maintained good quality of life long-term.

Keratoconjunctivitis was reported in close to 90% of Magellanic penguins due to a colony outbreak of *Chlamydophila psittaci* (Jencek et al. 2012). Infection was confirmed with immunohistochemistry and tissue polymerase chain reaction assay. In addition to ocular signs, affected penguins may have inappetence, lethargy, cardiac insufficiency, dermatitis, seizures, and/or light green urate; treatment included oral or intramuscular doxycycline. Necropsy findings included hepatomegaly, splenomegaly, and vasculitis (Jencek et al. 2012).

Three penguins (3/104 eyes, 2.9%) were reported to have unilateral corneal stromal degeneration (M.L. Church, unpublished data). All three penguins had normal fasted blood work, no known history of trauma and were considered geriatric. One of the three penguins underwent cataract surgery 3 years prior to the development of stromal degeneration (Fig. 22.4). None of the penguins' vision seemed to be adversely affected and no neovascularization or pain was associated with the chronic focal stromal mineralization.

One hand-reared King penguin chick (1/104 eyes, 0.9%) was evaluated with slit lamp biomicroscopy starting at 1 month of age, for unilateral congenital corneal disease. The appearance was typical of infantile corneal dystrophy

Fig. 22.4 Corneal degeneration in a penguin sp. noted 3 years post phacoemulsification surgery around the incision site

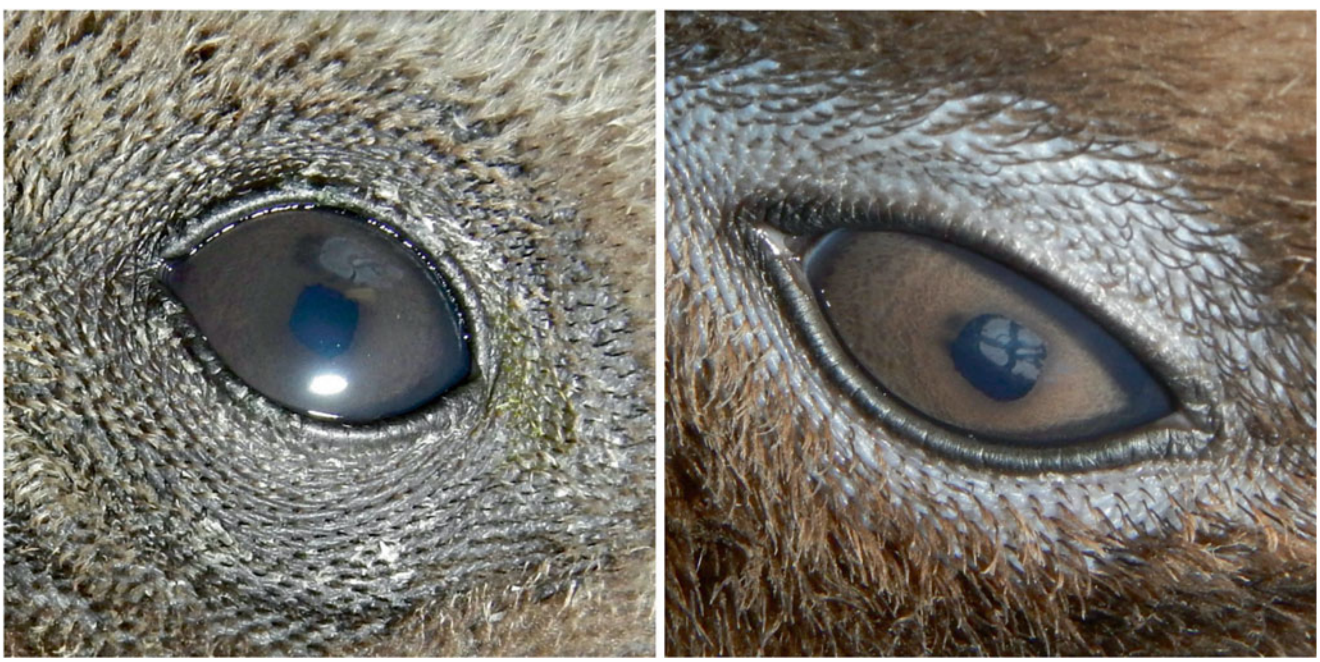


Fig. 22.5 Infantile corneal dystrophy in a King penguin *Aptenodytes patagonicus* chick. Left photo was taken at 1 month of age; the same eye (on the right) was photographed again 2 months later, at 3 months old

and was evaluated with slit lamp biomicroscopy and photographed monthly for the first 3 months of age, then every 2–3 months for the following year (Fig. 22.5). Subepithelial geographic corneal opacities slowly diminished, but never completely resolved with time. Topical treatment with cyclosporine 0.2% (Optimmune® Ophthalmic Ointment, Merck Animal Health, USA), EDTA, or artificial lubrication did not show a significant change in the corneal opacities; however, vision and ocular comfort was not affected (M. L. Church, personal observation). The parents were evaluated and found to have normal ocular exams with no history of corneal disease. As such, the lesion was not believed to be hereditary, although a recessive mode of inheritance could not be ruled out.

Uvea

Lens-induced uveitis has been reported in penguins (Bliss et al. 2015; Church et al. 2018). In general, it seems to be less prevalent and severe compared with non-avian species. Following cataract removal, typically minimal anti-inflammatory treatment is needed. A topical non-steroidal anti-inflammatory drug or corticosteroid q 6–8 h and systemic meloxicam and enrofloxacin for 1–2 weeks are routinely used after penguin cataract surgery with good success (Church et al. 2018). A previous study evaluating cataract surgery in other avian species stated that the inability to medicate a bird after cataract removal should not preclude the bird from being considered a candidate for surgery as post-operative anti-inflammatory treatment may not be needed (Rainwater et al. 2015). One King penguin (2/34 eyes (5.9%); 1/28 penguins (3.6%) was reported to have prolonged lens-induced uveitis, 2 months post cataract surgery in the right eye and 3 months post-op in the left eye (Swinger et al. 2009). The surgeries were performed by different board-certified veterinary ophthalmologists and separated by a period of 3 years. This penguin was maintained on topical prednisolone acetate and oral meloxicam until signs resolved. As mentioned, systemic use of corticosteroids is not recommended in penguins due to the increased risk for complications, including the development of serious infections such as aspergillosis. Long-term follow-up, 2–6 years post-operative, of penguins that underwent cataract surgery without capsular removal showed the presence of dyscoria due to posterior synechiation in 10/24 (41.7%) of the eyes (Fig. 22.6), which has likely occurred due to previous post-operative uveitis.

One Rockhopper penguin (1/104, 0.9%) had unilateral phthisis bulbi, reported at the time of routine annual eye examination (Fig. 22.7); the contralateral eye had a hypermature cataract, but no uveitis was noted and the eye was normotensive based on rebound tonometry (M.L. Church, unpublished data). Possible causes for the phthisis bulbi included uveitis secondary to cataract or trauma, although no obvious trauma was known. The cataractous eye underwent cataract surgery without any short- or long-term complications.

Uveitis and/or choroiditis may be a clinical feature of various systemic diseases in penguins including aspergillosis (*A. fumigatus* and *A. flavus*), the most common systemic fungal infection (Alvarez-Perez et al. 2010). In addition to

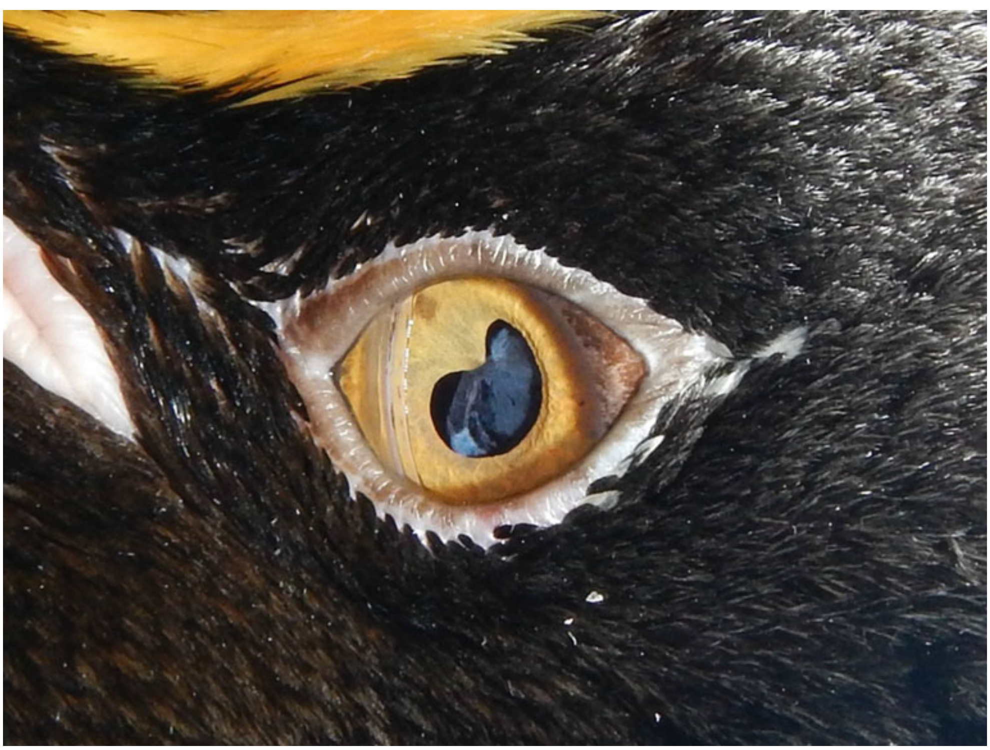


Fig. 22.6 Dyscoria due to posterior synechiation and moderate capsular opacification is noted in a Rockhopper penguin 2 years post phacoemulsification

Fig. 22.7 Phthisis bulbi in a penguin sp. due to previous corneal trauma and uveitis

ocular findings, these birds usually have respiratory, neurologic, and/or gastrointestinal signs. Histologically, fibrinosuppurative or granulomatous pneumonia, airsacculitis, syringitis, sinusitis, encephalitis, hepatitis, osteomyelitis, pericarditis, and generalized vasculitis may be present.

There is a report of a unilateral pyogranulomatous panophthalmitis in a Gentoo penguin (*Pygoscelis papua*) chick, living in its natural habitat in Antarctica. Samples were obtained and conventional culture methods and phenotypic and molecular tests were used for bacterial isolation and identification. The resulting bacterial isolates were Pasteurellaceae bacterium, *Corynebacterium ciconiae*, Cardiobacteriaceae bacterium, *Actinomyces* sp., and Dermabacteraceae bacterium (Cakir-Bayram et al. 2021).

Choroiditis has been reported in avian species infected with the protozoal parasite Toxoplasma gondii; however, only a few cases have been diagnosed histologically in penguins (Dubey 2002). Other clinical signs of toxoplasmosis may include blindness and ataxia due to central nervous disease with histopathology findings including peritonitis, pneumonia, hepatomegaly, splenomegaly, and renomegaly (Ploeg et al. 2011).

Lens

Cataracts are commonly reported in captive penguins. In one study, cataract incidence in a population of Macaroni penguins was 64% (16/25 birds, mean age 15.8 years) and 68% in Rockhopper penguins (11/16 birds, mean age 23.2 years) (Bliss et al. 2015). When evaluating larger populations of the same species from multiple zoological institutions, cataracts were reported in 46.5% of the Macaroni penguins (74/160 birds, mean age 14.3 years) and 45.5% of the Rockhopper penguins (40/90 birds, mean age 16.8 years) (Woodhouse et al. 2016). Cataracts were incidentally reported in 14% of Humboldt penguins (4/28 birds, mean age 11.4 years) in another study (Swinger et al. 2009). When reviewing ocular exam findings from multiple species housed in the same facility over a 4-year period, 93.3% (97/104) of adult/geriatric penguin eyes had cataracts (Fig. 22.8) (M. L. Church, unpublished data). Of these, 43% were hypermature, 26% mature, 2% immature, and 22% incipient.

Risk factors for cataract development in captive penguins include age, diet, hand-feeding (vs. free-feeding), increased population density, history of trauma, fluorescent exhibit lighting, and increasing length of minimum photoperiod (Woodhouse et al. 2016). Dietary risk factors associated with cataracts in Macaroni penguins were smelt and hand-feeding, and dietary capelin in Rockhopper penguins; whereas, Rockhoppers that consumed krill and herring had decreased odds of cataract development (Alvarez-Perez et al. 2010). In Macaroni penguins the use of fluorescent lighting increased odds of cataract development in contrast to the higher intensity metal halide bulbs which decreased risk (Woodhouse et al. 2016). Replication of natural photoperiod

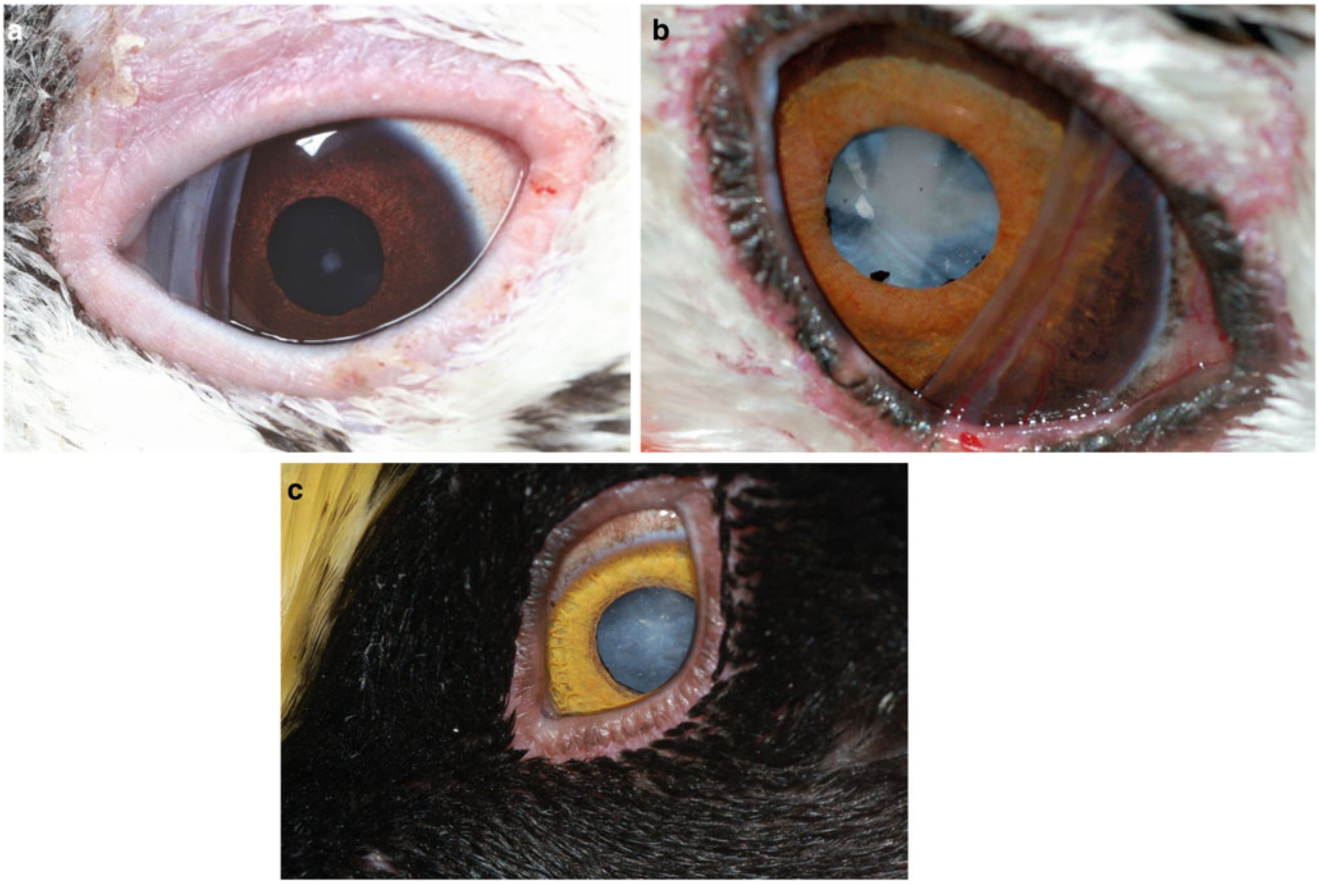


Fig. 22.8 Cataract. Incipient anterior cortical cataract in a 12-year-old Magellanic penguin *Spheniscus magellanicus* (**a**); mature cataract with prominent lens-suture clefts in a Chinstrap penguin *Pygoscelis antarcticus* (**b**)); Hypermature cataract in a Rockhopper penguin (**c**). (**a**)—Courtesy of the University of California Davis Comparative Ophthalmology Service

is beneficial in reducing risk for cataract development. The odds of cataracts increased in Rockhopper penguins exposed to increased day length during typical minimum photoperiod time (i.e., winter) and decreased when day length was increased during maximum photoperiod (i.e., summer) (Woodhouse et al. 2016). Both Macaroni and Rockhopper penguins showed decreased odds of cataract development with increased light intensity and UV spectrum lighting (Woodhouse et al. 2016). There is no existing data to support inheritance of cataracts in penguins. The etiology of cataracts in penguins is often unknown but senile, or age-related, cataracts are most commonly suspected due to advanced age, appearance of cataracts, and no evidence or history of trauma. For information about cataract surgery in penguins, please see the Surgery section below.

Lens luxation was reported in 15.4% (16/104) of penguin eyes, observed over a 4-year period; 10% were subluxated and 5% were posteriorly luxated (Fig. 22.9). All luxated lenses were cataractous, and the eyes did not show obvious signs of uveitis or glaucoma at the time of examination (M.L. Church, unpublished data).

Retina

Retinal detachment is less commonly reported in penguins compared with other avian species, particularly raptors. A traumatically induced retinal detachment was diagnosed in only 1/104 eyes (1%) over a 4-year period (M. L. Church, unpublished data).

Ophthalmic Surgery

When transportation is needed for surgical treatment (e.g., transportation to the ophthalmologist's office for cataract surgery), special transportation and arrangements should be considered for Antarctic/subantarctic species that require

Fig. 22.9 Subluxated lens with mature cataract in a Rockhopper penguin

ambient temperatures of 0–11.5 °C (32–52 °F). This would include the use of a refrigerated truck, ice bins for individual birds while transported and kept in the hospital, and ice packs to aid in temperature regulation during surgery. A general recommendation for penguins is to avoid elective surgical procedures during their yearly molt or nesting season due to increased physiological stress (M. L. Church, personal observation). Timing for this may be individual or species specific. For penguin ocular surgery, gas anesthesia maintenance is typically higher than usual in order to prevent third eyelid movement and blepharospasm. For example, the majority of penguins undergoing cataract surgery at one facility were pre-medicated with midazolam (intranasal or intramuscular), induced with sevoflurane, intubated and maintained around 5–7% sevoflurane (Swinger et al. 2009). Post-operative recovery typically consists of dry docking for at least 1 week. This is believed to help with ocular healing via reduction in potential pool contaminants as well as improve compliance for medication administration and patient monitoring. Due to potential for stress with complete self-isolation, one or more other penguins may be kept in close proximity if deemed socially appropriate and safe.

Cataract Surgery

Cataracts are the most common ocular abnormality reported in penguins; therefore, it is not surprising that cataract surgery is the most common surgical procedure performed in this species. Although pre-surgical electroretinography and ocular ultrasound may be considered, these diagnostic tests are often not performed in cataract patients with positive visual responses due to prolonged anesthesia concerns and lack of baseline ERG parameters (M. L. Church, personal observation). Similar to other species, penguins undergoing phacoemulsification surgery are placed in dorsal recumbency, head positioned in a vacuum pillow, under operating microscope. Depending on species and globe size, a pediatric eyelid speculum may be needed. Surgeons may consider placement of a stay suture (5–0 nylon) in the leading edge of the nictitating membrane if elevation is preventing surgical approach (M. L. Church, personal observation). Caution should be used during entry into the penguin's shallow anterior chamber by way of a clear corneal, perilimbal (~2 mm from the limbus), two step incision. To combat intraoperative miosis, viscoelastic (e.g., 1.8% sodium hyaluronate) is typically sufficient (M. L. Church, personal observation). As with other avian species, the use of intracameral neuroparalytic may be considered with caution due to systemic concerns. In 12/14 (80%) penguin eyes, 1:5 intracameral atracurium resulted in some level of mydriasis (Swinger et al. 2009). The majority of penguins undergo a short phacoemulsification time; 70% were less than 60 seconds, with a mean time of 72 seconds in 27 eyes (Swinger et al. 2009). Due to capsular fibrosis with residual lens capsule, it is recommended to remove either the entire lens capsule following phacoemulsification, via gentle retraction using Utrata forceps, or perform a

Fig. 22.10 The left picture depicts a mature cataract in a King penguin *Aptenodytes patagonicus*. The right picture shows the same eye 1 year following cataract surgery and complete lens capsule removal

Fig. 22.11 Mild-moderate capsular opacification is noted in a Rockhopper penguin that underwent phacoemulsification with anterior capsulorhexis alone; the picture was taken 3 years post-op

planned posterior capsulorhexis (Church et al. 2018; Swinger et al. 2009).

The prognosis for vision and behavioral improvement after phacoemulsification surgery in penguins is good, with low incidence of vision-threatening complications (Fig. 22.10) (Church et al. 2018). The most common short-term post-operative complication was temporary mild blepharospasm and/or epiphora, reported in 8 eyes (29.6%) from

Fig. 22.12 A King penguin *Aptenodytes patagonicus*, 1 year post cataract surgery by means of phacoemulsification. The anterior and posterior capsulorhexis sites are clear with surrounding moderate capsular opacification

7 penguins (33.3%) (Church et al. 2018). Long-term complications, 2–6 years post-operatively, included posterior synechiation resulting in dyscoria (10/24 eyes, 41.7%) and capsular fibrosis in all penguins with residual lens capsule (19/19, 100%) (Figs. 22.11 and 22.12). All 34 eyes from 28 birds (14 Southern Rockhopper penguins, 5 Gentoo penguins, 3 King penguins, 3 Chinstrap penguins, and 3 Magellanic penguins, over a 7-year period) have been functionally visual after phacoemulsification surgery (M. L. Church, personal observation). Based on evaluations by penguin keeper staff, 81% (17/21) of penguins showed immediate improvements in overall quality of life and 90% (19/21) of penguins exhibited improvement in mobility and behavior within their exhibit following cataract removal (Church et al. 2018). Another study assessed behavioral impacts after cataract removal surgery in geriatric Macaroni and Southern Rockhopper penguins showing positive responses which included increased habitat use, time spent swimming, and increased rates of affiliative interactions (Heintz et al. 2018).

Other Surgeries

Modified evisceration surgery was done in 2/104 (1.9%) penguin eyes, from the same facility, examined over a 6-year period (M. L. Church, unpublished data). Both penguins underwent unilateral surgery due to blinding corneal rupture(s) that were suspected to be traumatically induced. Post operatively, no complications were noted. Good cosmetic outcome was achieved, and one of the birds continued to enjoy and be used as an educational ambassador that closely interacted with the public.

References

Alvarez-Perez S, Mateos A, Dominguez L, Martinez-Nevado E, Blanco J, Garcia M (2010) Polyclonal *aspergillus fumigatus* infection in captive penguins. Vet Microbiol 144:444–449

AZA Penguin Taxon Advisory Group (2014) Penguin (*Spheniscidae*) care manual. Association of Zoos and Aquariums, Silver Spring, MD

Bliss C, Aquino S, Woodhouse S (2015) Ocular findings and reference values for selected ophthalmic diagnostic tests in the macaroni penguin (Eudyptes chrysolophus) and southern rockhopper penguin (Eudyptes chrysocome). Vet Ophthalmol 18(s1):86–93

Cakir-Bayram L, Abay S, Saticioğlu IB, Güvenç T, Ekebaş G, Aydin F (2021) Panophthalmitis in a Gentoo penguin (Pygoscelis Papua) from the Antarctic peninsula: evaluation of microbiological and histopathological analysis outcomes. Research Square. https://doi.org/10.21203/rs.3.rs-190292/v1

Church ML, Priehs D, Denis H, Croft L, DiRocco S, Davis M (2018) Technique, postoperative complications, and visual outcomes of phacoemulsification cataract surgery in 21 penguins (27 eyes): 2011-2015. Vet Ophthalmol 21(6):612–621

Coimbra J, Nolan P, Collins S, Hart N (2012) Retinal ganglion cell topography and spatial resolving power in penguins. Brain Behav Evol 80(4):254–268

Dubey J (2002) A review of toxoplasmosis in wild birds. Vet Parasitol 106:121–153

Gonzalez-Alonso-Alegre E, Martinez-Nevado E, Caro-Vadilo A, Rodriguez-Alvaro A (2015) Central corneal thickness and intraocular pressure in captive black-footed penguins (*Spheniscus dermersus*). Vet Ophthalmol 18(s1):94–97

Heintz M, Fuller G, Woohouse S, Murray A, Allard S (2018) Case studies of the impacts of cataract surgery on crested penguin welfare. J Appl Anim Welf Sci 8:1–13

Howland H, Sivak J (1984) Penguin vision in air and water. Vis Res 24 (12):1905–1909

Jencek J, Beaufrere H, Tully T, Garner M, Dunker F, Baszler T (2012) An outbreak of *Chlamydophila psittaci* in an outdoor Colony of Magellanic penguins (*Spheniscus magellanicus)*. J Avian Med Surg 26(4):225–231

Kane O, Uhart M, Rago V, Pereda A, Smith J, Van Buren A, Clark J, Boersma P (2012) Avian pox in Magellanic penguins (*Spheniscus magellanicus)*. J Wildl Dis 48(3):790–794

Kern J (1989) Disorders of the special senses. In: Altman R, Clubb S, Dorrestein G, Quesenberry K (eds) Avian medicine and surgery. W.B. Saunders Company, Philadelphia, pp 563–589

Martin GR (1999) Eye structure and foraging in king penguins Aptenodytes patagonicus. Ibis 141:444–450

Ploeg M, Ultee T, Kik M (2011) Disseminated toxoplasmosis in black-footed penguins (*Spheniscus demersus*). Avian Dis 55(4):701–703

Rainwater K, Sykes J, Sapienza J (2015) Retrospective investigation of cataract management in avian species in a zoologic collection. J Zoo Wildl Med 46(4):858–869

Sivak J, Howland H, McGill-Harlestad P (1987) Vision of the Humboldt penguin (Spheniscus humboldti) in air and water. Proc R Soc Lond B Biol Sci 229(1257):467–472

Stidworthy M, Denk D (2018) Sphenisciformes, Gaviiformes, Podicipediformes, Procellariiformes, and Pelecaniformes. Pathology of Wildlife and Zoo Animals:653–686

Suburo A, Scolaro J (1990) The eye of the Magellanic penguin (*Spheniscus magellanicus)*: structure of the anterior segment. Am J Anat 189:245–252

Suburo AM, Herrero MV, Scolaro JA (1991) Regionalization of the ganglion cell layer in the retina of the Magellanic penguin *(Spheniscus magellanicus)*. Colon Waterbirds 14:17–24

Swinger R, Langan J, Hamor R (2009) Ocular bacterial Flora, tear production, and intraocular pressure in a captive flock of Humboldt penguins (*Spheniscus humboldti)*. Journal of Zoo and Wildlife Mdicine 40(3):430–436

Widmer D, Ziemssen E, Schade B, Kappe E, Schmitt F, Kempf H, Wibbelt G (2016) Pseudomonas aeruginosa infection in a Group of Captive Humboldt Penguins (*Spheniscus humboldti)*. J Avian Med Surg 30(2):187–195

Woodhouse S, Peterson E, Schmitt T (2016) Evaluation of potential risk factors associated with cataract in captive macaroni (*Eudyptes Chrysolophus*) and Rockhopper penguins (*Eudyptes Chrysocome*). J Zoo Wildl Med 47(3):806–819