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Ophthalmological abnormalities in wild European hedgehogs (*Erinaceus europaeus*): a survey of 300 animals

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Abstract

In this study we aimed to examine wild European hedgehogs (*Erinaceus europaeus)* in rescue centres and to determine ocular abnormalities in this animal population. Three hundred animals varying in age from 2 months to 5 years were examined, 147 being male and 153 female. All animals were evaluated with direct and indirect ophthalmoscopy and slit lamp biomicroscopy in animals where lesions were detected. Tonometry using the Tonovet rebound tonometer was undertaken in selected animals as was assessment of tear production using the Schirmer I tear test. Four animals were affected by orbital infection, 3 were anophthalmic, 2 unilaterally and one bilaterally, 3 by conjunctivitis, 3 by non-ulcerative keratitis and 4 by uveitis with corneal oedema. Fifty seven animals were affected by cataract, 54 with bilateral nuclear lens opacities. Twenty six of these animals were young animals considered too small to hibernate. This report documents the first prospective study of ocular disease in the European hedgehog. The predominant finding was bilateral nuclear cataract seen particularly in young poorly growing animals. Investigation into the potential causation of cataracts by poor nutrition or poor feeding ability by lens opacification requires further study.

Keywords: Cataract, Conservation, Eye abnormality, Hedgehog, Rehabilitation.

Introduction

The European hedgehog (*Erinaceus europaeus)* is a familiar creature among the rural hedgerows of Britain and, more recently, also in the urban environment. The species is postulated to have changed relatively little in the last 15 million years (Reiter and Gould, 1998) and thus the hedgehog visual system is considered relatively primitive. However, there is little reported data on the anatomy of physiology of the eye in this species (Dinopoulos *et al*., 1987).

The hedgehog is endemic in Europe (Morris, 1993; Amori *et al*., 2011) and has few natural predators, with the badger , fox and polecat among the few species with regular predatory success (Reeve, 1994). The increase in badger numbers in the UK over the past decades may be having an adverse effect on hedgehog numbers (Young, *et al*., 2006; Trewby *et al*., 2014) while changes in agricultural practice over the last half century with a decrease in pastureland and increase in pesticide use has influenced the invertebrate diet of the hedgehog with potential effects on hedgehog populations (Stoate *et al*., 2001).

Road traffic accidents are cited as the most common cause of death (Bunnell, 2001) with annual casualties are estimated between 100,000 to 1.3 million in the UK alone (Morris and Throughton, 1993). Together, these factors seem to be leading to an increase in injured and displaced hedgehogs that are subsequently rescued and rehabilitated. European hedgehogs, while not an endangered species under International Union for the Conservation of Nature (IUCN) criteria (Amori *et al*., 2011), are experiencing a significant reduction in population size and, given this, assessment of the health of wild and rescued hedgehogs is important. Prior to this study, there has been no information available relating to the prevalence of eye disease in wild hedgehogs. There are a small number of studies on animals in captivity mostly involving the African pygmy hedgehog, predominantly involving exophthalmos (Wheeler *et al*., 2001; Kuonen *et al*., 2002; Fukuzawa *et al*., 2004).

A recent study has documented Schirmer tear test and intraocular pressure measurements in the long-eared hedgehog (*Hemiechinus auritus*) (Ghaffari *et al*., 2012) a species found in Eastern Europe and Asia. None of the animals in that study had any ocular abnormalities and the small number of animals examined would have precluded assessment of prevalence of ocular disease in this population. The aim of the current study was to survey a sizeable number of ‘rescued’ wild European hedgehogs in the UK, to determine the prevalence of common ophthalmological diseases in this species and to investigate whether there may be a relationship between this and other factors such as weight, age or sex.

The hedgehog diet is primarily insectivorous, with 90% consisting of annelids (predominantly earthworms) and arthropods (mostly insects) and 6% accounted for by gastropods such as snails and slugs (Reeve, 1994). The fact that their favoured invertebrate prey is more

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abundant at night probably accounts for hedgehogs' crepuscular and nocturnal behaviour. Given this scotopic lifestyle, it has to be asked what relevance vision has to the species. The hedgehog retina, given the limited data available, appears predominantly rod rich, as one might expect, but 2% of photoreceptors in the nocturnal lesser hedgehog *Echinops telfairi* were middle to long-wave cones showing some degree of color vision (Peichl *et al*., 2000).

Female hedgehogs produce one to two litters per year with an average of 4 hoglets per litter. These youngsters are independent by 8 weeks and must weigh a minimum of 450g by autumn as suggested by Robinson and Routh (1999) or 650g as suggested by Bunnell (2001) to survive the winter. Low weights are usually accompanied by large burdens of ectoparasites (fleas and ticks) (Thamm *et al*., 2009) and endoparasites (most particularly lungworm) (Majeed *et al*., 1989) which can fatally exacerbate any underlying problems. Most hedgehogs rescued are underweight, injured or found out during the day due to disease, dehydration or high parasite burden (Thamm *et al*., 2009). The reasons for being found outside in the day vary between the age groups.

Young animals may have lost contact with their dam, juveniles may have been feeding insufficiently so are still foraging in an attempt to gain weight. Older animals and those of any age may have been unable to nest through systemic illness or injury and those that are blind may not be able distinguish day from night (Reeve, 1994).

It might thus be argued that the animals examined in this study do not constitute a normal wild population since they have been found during daylight hours. The high prevalence of lens opacities noted below may then represent a biased sample. Nevertheless it is hoped that this publication will be of interest both to veterinary ophthalmologists and those involved in wildlife conservation.

Materials and Methods

A total of 300 hedgehogs were examined from seven rescue centres ranging from large wildlife hospitals (St Tiggywinkles Wildlife Hospital, Aylesbury, Bucks UK and East Wynch Wildlife Hospital, Kings Lynn, UK) to five individuals caring for small groups of animals (<20) in their homes and gardens. Approximate age, gender and reason for rescue were ascertained. Age was estimated from information obtained from the rescue centre and from the appearance of the animal, following the criteria set out by Robinson and Routh (1999).

Each hedgehog underwent a non-dilated ophthalmological examination with direct and indirect ophthalmoscopy (Keeler Practitioner direct ophthalmoscope, Keeler Vantage All Pupil indirect ophthalmoscope, Keeler, Windsor UK) and slit lamp biomicroscopy (Kowa SL14 slit lamp, Nagoya, Aich, Japan) where necessary. Photographic documentation was achieved with a Nikon Coolpix 4500 (Nikon, Tokyo, Japan) for adnexal lesions and a Genesis D fundus camera (Kowa, Nagoya, Aichi, Japan) Examination of retinal detail was thus somewhat compromised but in a darkened environment sufficient mydriasis occurred to allow evaluation of lens opacities although photography of lens lesions was somewhat difficult. The Schirmer tear test proved of little value due the relatively low fluid production of the eye compared to larger species but tonometry with the rebound tonometer (Tonovet, ICare, Helsinki) on calibration p was possible to provide a normal range of intraocular pressures in twenty normal eyes and values for animals with exophthalmos or uveitis. Anaesthesia, although reported as necessary in a previous study (Ghaffari *et al*., 2012) was not required with careful gentle handling encouraging the animals to unroll onto a rough surface (Robinson and Routh, 1999). Globe size and pupil diameter was measured with a Vernier caliper. Ocular function was evaluated by assessing pupillary light reflexes and behavioural responses to objects in the accommodation in which animals were housed, although more precise assessment of vision was difficult.

Data was recorded using an Excel spreadsheet with differences in weight in animals with and without cataract compared using a Student's T test. Normality of globe and pupil size was determined using the Kolmogorov–Smirnov test.

Results

Three hundred animals were examined ranging in age from 2 months to 5 years with a median age of 12 months and a mean age of 12.6±9.2 months. One hundred and forty seven animals were male and 153 female. Intraocular pressure measurements on both eyes of 10 adult animals with unremarkable eyes gave a mean value of 12.6±1.8mmHg, this data being normally distributed. Schirmer I tear tests, undertaken in 20 animals with unremarkable eyes gave values of less than 1mm/min in normal eyes and thus were not considered particularly valuable.

Normal sighted animals often had eyes that appeared somewhat proptotic in the resting state (Fig. 1) but on handling all animals retracted their globes as they curled up. The globes, as measured with a Vernier calliper in 10 immature animals and 20 normal adult animals, had an average equator to equator diameter of 7.2±0.2 mm for the adult animals, this data being normally distributed with a range from 6.8 to 8.0mm, while smaller globes with a range from 5.5mm to 6.5mm were recorded in immature animals, these data not being normally distributed. The iris is brown with little variation between individuals with a pupil of maximum observed diameter in scotopic conditions of 3.0mm, again this measured in 20 normal adult animals.

Fig. 1. The somewhat propototic eyes of a normal 2 year old male hedgehog.

Eighty seven hedgehogs (29%) had some degree of ocular abnormality. Three animals had orbital infection and abscessation (Fig. 2). In six no ocular structures visible in the orbit, two bilaterally, with inflammatory tissue filling the orbit (Fig. 3).

Fig. 2. Orbital infection and periorbital abscessation in a one year old male hedgehog.

Fig. 3. A bilaterally anophthalmic hedgehog with inflammatory tissue filling the orbit.

Two of the three hedgehogs with orbital infection as defined by cytology and bacteriology (data not shown) and four animals with no ocular structures visible had previous histories of myiasis with eye loss after maggot infection, although none was affected with a viable infection at the time of examination.
Four animals exhibited blepharitis associated with periocular ringworm infection (Fig. 4), with *Trichopyton mentagrophytes* cultured on Sabaroud's dextrose agar after sampling with a standard bacteriology swab (English *et al*., 1962).

Fig. 4. Periorbital *Tricophyton* infection in an emaciated hedgehog.

Fourteen hedgehogs had ocular and adenexal injuries. Three animals had a non-ulcerative keratitis. These animals were affected with trichiasis but this finding was also evident in many animals with a normal ocular surface where normal periocular hair, with short and bristly spines impinged on the ocular surface (Fig. 5).

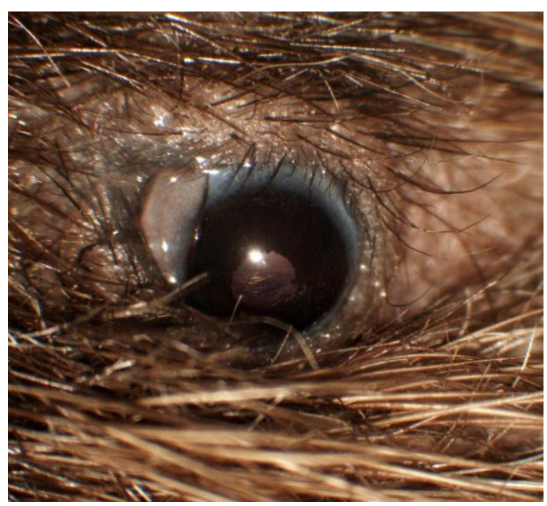

Fig. 5. A hedgehog with trichiasis, a common finding in otherwise normal eyes.

Many of these animals exhibited moderate to marked epiphora. Conjunctivitis with hyperaemia with or without a mucopurulent discharge was seen in six animals. Four hedgehogs had unilateral corneal oedema and central ulceration with presumed uveitis (Fig. 6). In these animals, although intraocular detail was difficult to observe, uveitis was presumed given that the eyes were hypotonous with a mean intraocular pressure 6.3±1.7mmHg compared with the intraocular pressures of 12.6±1.8mmHg in normal eyes as reported above.

Fig. 6. Hedgehog with corneal oedema and presumed uveitis with a hypotonous globe.

The most common ocular condition was cataract with 57 animals (19%) exhibiting lens opacities, 54 of them bilateral and 51 nuclear (Fig. 7, Table 1).

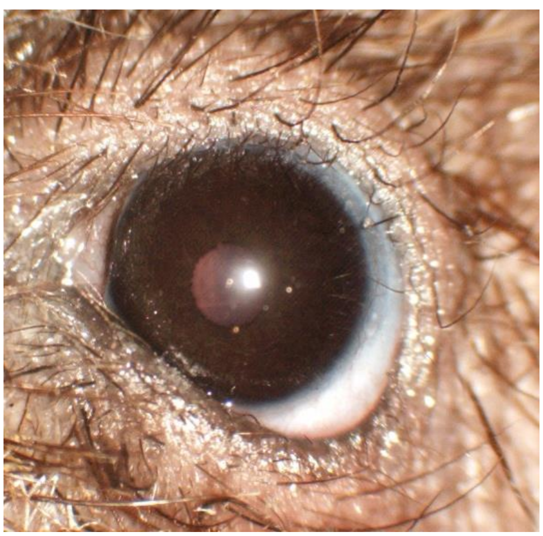

Fig. 7. Nuclear cataract in a 3 month old hedgehog.

There was no sex predeliction for presence of lens opacity with 20% of males and 17% of females affected. There was no significant difference in prevalence in animals of different ages (Fig. 8). The majority of animals examined (194 of 300) were under one year of age but the prevalence of cataract in this group was not higher than in older animals (64 estimated between 1 and 3 years and 42 hedgehogs estimated to be aged 3 years or older).

Table 1. Number of animals affected and overall prevalence of ocular conditions.

Condition	Number of animals affected (prevalence)
Orbital cellulitis/abscessation	4 (1.3%)
Anophthalmos	6 (2%)
Conjunctivitis	4 (1.3%)
Keratitis	3 (1%)
Uveitis	4 (1.3%)
Cataract	57 (19%)

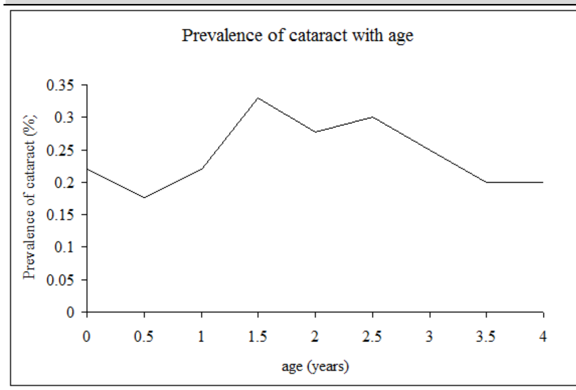

Fig. 8. Prevalence of cataract across age groups of hedgehogs in this study.

Considering all hedgehogs, there was no difference in weight of animals with and without lens opacity (mean weight of hedgehogs with cataract 596±271g, weight of hedgehogs without cataract 654±221g, not significant at p=0.11), while when evaluating only those under one year of age, the weight of hedgehogs with cataracts was substantially lower (384±275g) compared with those with clear lenses (510±258g) this difference significance at p=0.033. This is shown in the graph of weight at different ages (Fig. 9) where in juvenile hedgehogs the filled dots are at the lower end of the weight range while at later stages they are distributed more evenly across the weight range.

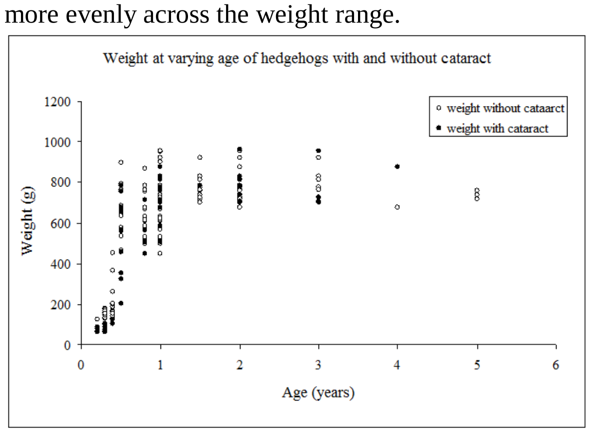

Fig. 9. Graphical representation of age and weight of hedgehogs with and without cataract.

Discussion

The detailed ocular anatomy of the European hedgehog has yet to be published but as a predominantly nocturnal mammal it is deemed to have a primitive optic system and no data on ophthalmic disease in the species has been available until now. However, the anatomically similar African pygmy hedgehog (*Atelerix albiventris*) is an increasingly popular pet, therefore published information relating to ocular procedures and disease is available (Fukuzawa, *et al*., 2004; Johnson-Delaney, 2006). The European hedgehog *Erinaceus europaeus* belongs to a different genus *(Erinaceus)* from the African pigmy hedgehog which is from the genus *Atelerix* and although they are all from the same subfamily *Erinaceinae* they have quite different environmental requirements. Nevertheless we may be able to extrapolate somewhat from diseases of the African species to those of the European animals examined here.

The combination of wide palpebral fissure and shallow orbits occurring in both species predispose them to injury and proptosis (Wheeler *et al*., 2001). Additionally, trauma from hedgehog spines, cages, tooth root infections, neoplasia and retrobulbar abscesses are considered contributory factors (Stocker, 1987). Captive obesity can lead to increases in the retrobulbar fat pad, further increasing the risk of proptosis (Stocker, personal communication, 2016), although this was not a problem in the wild animals examined here. In the European hedgehog, prolapse of the eyeball has been noted as a relatively common occurrence (Stocker, personal communication, 2016) and the prevalence of orbits devoid of ocular structures, presumably post-traumatic, in rescued wild hedgehogs here may give weight to concerns regarding the incidence of globe prolapse and subsequent injury. Infection and inflammation of the orbit and adnexa are also relatively commonly seen in the animals examined in this study together with ocular trauma. Injury to other parts of the animal was common in the rescued hedgehogs in the major rescue centres involved in this study with around 15% of the animals examined having some injury to the body (Stocker, personal communication, 2016). Causative factors in those animals included dog attacks, strimmer and lawnmower injuries and road traffic accidents. Many of the ocular conditions seen here, from adnexal defects through keratitis, corneal oedema and uveitis could quite conceivably have originated through trauma. Uveitis was associated with a lower intraocular pressure, although these findings must be interpreted with caution as the rebound tonometer has yet to be validated in this species.

The most striking finding seen in this study though, is one unlikely to have been caused by trauma. Finding nuclear cataracts in a sizeable minority (19%) of the animals examined was not at all expected. The prevalence of cataract did not vary with age, suggesting that these cataracts are congenital or early onset rather than age-related in which case the prevalence of cataract would have increased with age The apparent association with low weight and nuclear cataract could be explained either as a low weight juvenile developing nuclear cataract or as animals with early onset or congenital nuclear cataracts being unable to feed adequately. We consider this latter explanation to be unlikely, as these animals are nocturnal and probably need vision relatively little to search for their invertebrate prey. In addition the hedgehogs rescued which were completely blind were nevertheless in good or at least reasonable body condition suggesting that they were eating well before capture.

The association between poor nutrition and cataract development is acknowledged with regard to poor antioxidant status of the lens predisposing to cataractogenesis in humans and some laboratory rodent studies (Williams, 2006). But generally poor nutrition is correlated with pediatric cataract in several studies (Bamashmus and Al-Akily, 2010; Courtright *et al*., 2011) often related to oxidative stress (Granot and Kohen, 2004). Other possibilities could involve specific nutritional deficiencies (Hall *et al*., 1948; Tarwadi *et al*., 2008), but in wild caught hedgehogs this is considered unlikely. Previous reports have noted cataracts in orphaned puppies fed on mild replacer (Martin and Chambreau, 1982), a factor which might have been significant in underweight juvenile hedgehogs in a rescue facility. Having said that there was no apparent correlation between cataract incidence and feeding of either goat's milk or Esbilac kitten mild replacer in the main rescue centre involved in this study, with all hoglets being fed one or other of these milk substitutes and only a proportion developing cataracts. We thus consider that a link between diet and these lens opacities is not likely, although clearly more work is needed in a prospective study to determine if this is indeed the case.

Other aetiological possibilities for such nuclear cataracts could be genetic with such lens opacities reported in the mouse (Arora *et al*., 2008) the dog (Heinrich *et al*., 2006) and the horse (Beech and Irby, 1985). While such a genetic trait is unlikely in a wild population, especially in animals seen in different areas of the country, an inherited agency cannot be ruled out. A final environmental factor which should be considered is ultraviolet light exposure. Animals brought in at a young age or born in captivity are more likely to experience higher levels of UV exposure than those in the wild. The rescue centres operate with artificial light and windows in most rooms which could be resulting in higher exposure to UV light on a daily basis. However UV bulbs or bright fluorescent lights were not used in the facilities where these animals were housed and thus this source of irradiation was not relevant in this study.

Each hedgehog is provided with a towel and nesting material, but despite this many sick hedgehogs may still experience higher exposure due to inability to roll up familiarisation with surroundings. As they become less timid they tend to spend more time waiting with their heads resting on the cage door, facing into the lighted rooms and giving significantly more illumination than they would be used to in the wild. Even so the level of UV-B illumination was very low in these facilities and the glass front of the cages filter out the vast majority of wavelengths which might be considered to cause lens opacification. In addition the cataracts which would be expected to result from excessive ultra-violet light exposure are not nuclear opacities, and so this agency is exceptionally unlikely to be central in their genesis. No mydriatics were used in this study due to unknown effects and safe dose rate in this small species where a single drop of parasympathomimetic absorbed across the conjunctiva into the small blood volume of the animal may have unforeseen effects. This might be considered a limitation of the study since it precluded evaluation of the peripheral lens and optimal fundoscopy, yet even so in a darkened room adequate ophthalmic examination was possible.

Intraocular pressure measurement was readily achieved using the Tonovet rebound tonometer designed initially for use in small eyes of laboratory rodents. The Schirmer tear test strip was, however, found to be too large for such a small globe with so limited a tear production. This limitation could have been overcome by use of the phenol red tear test strip as reported in other small mammals (Lange *et al*., 2012; Rajaei *et al*., 2013) but the test was not available to us at the time of this study and we look forward to evaluating it in due course. The major limitation in this study however in our opinion, is that the group of animals examined are in no way a representative sample of the wild population. The animals are likely to be a group biased towards those with disabling conditions both ocular and systemic, the very sort of features which render the hedgehogs liable to be 'rescued' and rehabilitated. Nevertheless given the gradually reducing number of hedgehogs in the British population, it is important to assess the population in rescue centres, to assess the prevalence of potentially debilitating ocular conditions in these animals. A key next step is examination of hedgehogs trapped in the wild to determine whether animals in the truly wild population have the same prevalence of ocular lesions, and particularly nuclear cataracts, than do the animals examined in this study.

Conflict of interest

The Authors declare that there is no conflict of interest.

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