

This is the peer reviewed version of the following article:

Fountain, K. I., Stevens, K. B., Lloyd, D. H. and Loeffler, A. (2016), Skin disease in captive bats: results of an online survey of zoos and rehabilitators in Europe, North America and Australasia. Vet Dermatol. doi:[10.1111/vde.12410](https://doi.org/10.1111/vde.12410)

This article may be used for non-commercial purposes in accordance with [Wiley Terms and Conditions for Self-Archiving](#).

The full details of the published version of the article are as follows:

TITLE: Skin disease in captive bats: results of an online survey of zoos and rehabilitators in Europe, North America and Australasia

AUTHORS: Kay I. Fountain, Kim B. Stevens, David H. Lloyd, Anette Loeffler

JOURNAL TITLE: Veterinary Dermatology

PUBLISHER: Wiley

PUBLICATION DATE: December 2016 (online)

DOI: 10.1111/vde.12410

1           **Skin disease in captive bats: results of an online survey of zoos and**  
2           **rehabilitators in Europe, North America and Australasia**

3  
4   KAY I. FOUNTAIN\*, KIM B. STEVENS†, DAVID H. LLOYD†, ANETTE LOEFFLER†

5  
6   *\*Top Cat Veterinary Centre, 146 Mackie Avenue, Brighton, BN1 8SB, United*  
7   *Kingdom*

8  
9   *†14Department of Clinical Sciences and Services, Royal Veterinary College,*  
10   *Hawkshead Lane, Hatfield, North Mymms, Hertfordshire AL9 7TA, United Kingdom*

11  
12   Corresponding author: Kay Fountain

13  
14   Funding: European Society of Veterinary Dermatology Training Grant 2014

15  
16   Conflict of interest: None declared.

17  
18   The study was presented at the 8<sup>th</sup> World Congress of Veterinary Dermatology,  
19   Bordeaux, France, 4<sup>th</sup> June 2016.

20   Acknowledgements:

21   The authors would like to thank Anne-Marie Roberts, Ximo Perez and Eili Dettmering  
22   for translations, and staff and students at Top Cat Veterinary Centre and Royal  
23   Veterinary College for trialling the questionnaire.

24   Running title: Skin disease in captive bats

25 **Abstract**

26 **Background** - Bats may be held captive in zoos and breeding programmes, and for  
27 rehabilitation due to illness, abandonment or injury.

28 **Objectives** - To describe the frequency and characteristics of skin disease in captive  
29 bats.

30 **Methods** – Zoos (n=164) in Europe, America, Australia and New Zealand, Wildlife  
31 Disease Association members and rehabilitators were invited to complete an online  
32 questionnaire on skin lesions and housing. Associations between lesion type and  
33 site, frequency, species, age, suspected cause and season, and their association  
34 with housing in zoos were tested using chi-squared and 2-sample z-tests.

35 **Results** – Skin lesions were seen by 38.5% (15/39) of responding zoos and more  
36 frequently by rehabilitators (66.7%, 18/27;  $p=0.024$ ). Of the total of 153 lesions of  
37 any type reported by zoos and rehabilitators, almost two thirds occurred on pinnae  
38 (49/153, 32%) or wing-membranes (45/153, 29%). Amongst pinnal lesions, crusting  
39 (27%), swelling and redness (25%) and necrosis (20%) were most frequent. In zoos,  
40 pinnal ( $p=0.001$ ) and wing lesions ( $p=0.045$ ) were associated with 'season', being  
41 more common in winter. Pruritus was rare but more often reported from rehabilitation  
42 (12/77 observed lesions) than from zoos (1/76) ( $p=0.0015$ ). Lesions most often  
43 affected adult and geriatric bats in zoos, and juveniles and adults in rehabilitation.  
44 Eight respondents reported that skin disease necessitated euthanasia in individual  
45 bats. Type of housing and lesions were not correlated.

46 **Conclusion** - Pinnal and wing lesions were common in captive bats often with  
47 necrosis. Further research into the causes is needed to improve health and welfare  
48 in captive bats.  
49

## 50 Introduction

51 Bats are the second largest order of mammal with around 1240 species described  
52 worldwide. Approximately 25% of bat species are threatened with extinction and as  
53 part of endangered species recovery plans, bats may be brought into captivity.<sup>1,2</sup>  
54 They may also be kept in captivity for public display, for research or while  
55 undergoing rehabilitation following rescue. Megachiroptera are large bats found in  
56 the Old World tropics which usually eat fruit and flowers, while microchiroptera are  
57 small bats found worldwide with a varied diet including insects, fruit, fish and blood.<sup>3</sup>  
58 Their practical needs differ substantially and facilities for captive bats vary from  
59 large, professional organisations such as zoos to small cages for occasional casualty  
60 bats cared for by an individual layperson.

61 Skin disease in bats can have serious functional consequences such as loss of flight,  
62 where it affects the delicate membranes of the wings, or loss of echolocation where  
63 the ear-flap (pinna) is damaged.<sup>2</sup> In addition, skin disease is an important welfare  
64 issue and can cause debility resulting in the need for euthanasia. Apart from white  
65 nose syndrome (WNS), a fungal disease affecting the skin and wing membranes of  
66 hibernating bats leading to over a million fatalities since it was first recognised in  
67 2006,<sup>4</sup> little has been reported on bat skin disease. Individual cases of skin disease  
68 are described in captive bats held in zoos<sup>5</sup> and for rehabilitation<sup>6</sup> including reports on  
69 alopecia, atopic dermatitis, vitiligo and fungal dermatitis.<sup>5,7-10</sup> Necrotic disease of the  
70 pinna was reported in a translocation project in New Zealand short-tailed bats  
71 (*Mystacina tuberculata*).<sup>2</sup> However, little has been reported on the overall burden of  
72 skin disease amongst captive bats.

73 This study aimed to describe the frequency and occurrence of skin disease in  
74 captive bats as observed by zookeepers and rehabilitators.

## 75 Materials and Methods

### 76 Identification and recruitment of participants

77 Zoos in Europe, North America, Australia and New Zealand with captive bats were  
78 identified through publicly available mammal inventories.<sup>11,12</sup> Effort was concentrated  
79 in these geographical areas since they were considered most likely to have zoos  
80 with dedicated health staff and good record keeping. One hundred and sixty-four  
81 zoos were e-mailed directly with a link to an electronic questionnaire, inviting them to  
82 participate in the survey. Members of the Wildlife Disease Association, Wildlife  
83 Veterinary Section, were contacted through an invitation circulated to their June  
84 2015 mailing list (Appendix S1). In addition, open invitations were distributed via  
85 social media groups dedicated to bat rehabilitation,<sup>13,14</sup> whose members are mostly  
86 UK and USA based, and through the UK Bat Conservation Trust bat carer's bulletin  
87 to people involved in rescue and rehabilitation of bats. Directly invited participants  
88 were sent one reminder e-mail after one month.

### 89 Questionnaire design and administration

90 An electronic questionnaire (Appendix S2) was designed using Smart Survey  
91 (Smartsurvey.co.uk), and translated into English, French, Spanish and German. A

92 link to the survey was sent to all recruited zoos and rehabilitators. The questionnaire  
93 comprised both closed and open (free text) questions on three sections relating to:

- 94 (i) *bat populations and husbandry* including number and species of bats  
95 kept at their establishment, primary purpose of the captive bat  
96 population and housing facilities (type, heating, access to sunlight and  
97 potential for flight),
- 98 (ii) *types and distribution of skin lesions* including species and age-group  
99 most commonly affected, season of occurrence (respective season in  
100 the respondent's country), frequency (never seen, one or two cases,  
101 several per year, most bats affected), treatment and outcome (as free  
102 text),
- 103 (iii) *suspected or confirmed causative factors* such as parasites, trauma,  
104 temperature, housing, and bacteria isolated.

105 Multiple answers were allowed for lesion types seen, sites affected and housing  
106 type. Lesion-type and site terminology was chosen appropriate for lay people, i.e.  
107 blister to include pustules and vesicles, and toe and claw to indicate digits. All  
108 questions referred to the zoo or rehabilitator's captive bat population as a group  
109 rather than pertaining to individual bats. Zoos were asked to provide estimations of  
110 bat numbers as they were describing stable populations, but rehabilitators were  
111 commenting on populations that changed throughout the year due to admissions and  
112 releases.

### 113 [Statistical analysis](#)

114 Questionnaire responses were collated in Microsoft Office Excel 2013 (Version;  
115 15.0.4833.1000). Responses were anonymized but participants could voluntarily add  
116 their contact details for further clarification. All statistical analyses were performed in  
117 SPSS 22.0.0.1. Descriptive statistics were calculated for all variables and chi-square  
118 tests were used to identify significant associations between X and Y. A p-value of  
119 0.05 was considered significant for all analyses. A two sample z-test was used to  
120 analyse the difference in frequency of reporting of skin lesions and pruritus by zoos  
121 and rehabilitators.<sup>15</sup>

122 This study had been approved by the Royal Veterinary College Clinical Research  
123 Ethical Review Board (CRERB) URN 2015 1332.

### 124 [Results](#)

125 Responses were received from a quarter of zoos (24 %; n/N = 39/164) and from 27  
126 rehabilitators. Zoos responded from the United States and Canada (n=12), Australia  
127 and New Zealand (n=10), continental Europe (n=10) and the United Kingdom (n=7);  
128 rehabilitators were mainly from the UK (n=17), but also from the United States (n=6),  
129 Canada (n=1), Australia (n=1), South Africa (n=1), and Austria (n=1).

### 130 [Bat populations and housing](#)

131 Information from zoos referred to a total of approximately 4500 bats of 26 species,  
132 with colony sizes varying from 1 to 1650 (median = 14). The most common captive  
133 species was *Rousettus aegypticus* housed by 23 % of zoos, although the most

134 numerous was *Carollia perspicillata* with 3000 bats in six colonies (Table 1).  
135 Responses from rehabilitators included information on at least 1250 bats of 33  
136 species with number of bats per rehabilitator varying from 1 to 200 (median=2). The  
137 most common rehabilitating species in the UK and Europe were pipistrelles  
138 (*Pipistrellus pipistrellus* and *P. pygmaeus*) and in North America, *Eptesicus fuscus*.  
139 Bats were kept exclusively for research at one establishment and for research and  
140 captive breeding at one other. Most facilities had more than one type of housing with  
141 regard to flight opportunities and temperature control. In addition, five zoos and 25  
142 rehabilitators reported the use of hospital cages, while seven facilities allowed full  
143 hibernation and six allowed periods of torpor.

#### 144 Observed skin disease

145 Skin or pinnal lesions had been noted by half of all respondents (50%; n/N = 33/66)  
146 and were reported significantly less frequently from zoos (38.5%; n/N = 15/39) than  
147 by rehabilitators (66.7%; n/N = 18/27) ( $p=0.024$ ). The frequency of occurrence of  
148 skin or pinnal disease was reported to be one or two cases per year by around a half  
149 of the 33 respondents (skin disease 55%; n/N = 18/33, pinnal disease 45%; n/N =  
150 15/33, zoos and rehabilitators combined), and several cases per year by up to a  
151 quarter of respondents (skin disease 27%; n/N = 9/33, pinnal disease 12%; n/N =  
152 4/33).

153 Not all respondents commented on seasonal distribution. From the completed  
154 answers, almost two-thirds of skin lesions were reported as non-seasonal by zoo  
155 keepers and rehabilitators combined (60 %; n/N = 15/25). Pinnal disease was  
156 reported to occur in winter (44 %; n/N = 7/16) or as non-seasonal (38 %; n/N = 6/16)  
157 but there was no significant association between season and occurrence of skin or  
158 pinnal disease either with ( $\chi^2 p = 0.497$ ) or without ( $\chi^2 p = 0.721$ ) non-seasonal  
159 occurrences included. However, for zoos alone, ten of which reported skin disease  
160 and 8 of which reported pinnal disease, there was a significant association between  
161 wing lesions and season (30%; n/N = 3/10) ( $\chi^2 p=0.045$ ), and between pinnal lesions  
162 and season (50%; n/N = 4/8) ( $\chi^2 p=0.001$ ) with a tendency for winter to be the  
163 season most often associated with lesions. Three respondents reported in free text  
164 that lesions occurred during hibernation.

165 Of the 26 different species held in zoos, 15 had never been observed with skin  
166 disease. Livingstone's fruit bat (*Pteropus livingstonii*) and the New Zealand lesser  
167 short-tailed bat (*Mystacina tuberculata*) were the species recorded most frequently  
168 with skin disease (Table 1). Information on numbers of rehabilitating bats with skin  
169 disease could not be related to species due to the questionnaire design and  
170 fluctuating bat populations at rehabilitator facilities. Rehabilitators in the UK and  
171 Europe reported as free text that they felt skin lesions were most often seen in  
172 pipistrelles and mouse-eared bats (*Myotis spp.*), whereas pinnal lesions were  
173 particularly seen in serotines (*Eptesicus serotinus*), brown long-eared (*Plecotus*  
174 *auritus*) and noctule bats (*Nyctalus noctula*). In North America, *Carollia perspicillata*  
175 and the pallid bat (*Antrozus pallidus*) were affected with skin lesions. In Australasia,  
176 in rehabilitation, the fruit bats *Pteropus conspicillatus* and *P. Alecto*, and in zoos  
177 *Mystacina tuberculata*, were especially affected by pinnal lesions.

178 A total of 153 lesions of any type were reported by zoos and rehabilitators with  
179 almost two-thirds (61.4%; n/N = 94/153) occurring on either the wing-membrane or  
180 pinna (Table 2). Lesions occurred least frequently on digits (12%; n/N = 18/153).  
181 There was no significant association between lesion site and bats being either in  
182 zoos or rehabilitation ( $\chi^2$  p = 0.846).

183 The lesion type reported most frequently by all respondents was crusting (20%, n/N  
184 = 31/153) and this was seen at all sites. Swelling and redness, and necrosis, were  
185 also frequently reported by both zookeepers and rehabilitators, but necrosis was only  
186 reported on the wing, ear flap and digit (Table 2). Pinnae and wing membranes  
187 experienced the widest range of lesion types. Pruritus was reported significantly  
188 more frequently by rehabilitators (16% n/N = 12/77) than in zoos (2% n/N = 1/76)  
189 (p=0.0015), and blisters were reported on the wing membrane by zoos (31% n/N =  
190 8/26) but never by rehabilitators. Additionally, two rehabilitators reported as free text  
191 that facial scent glands had become impacted and abscessed in some species such  
192 as pipistrelles and *Eptesicus fuscus* and two rehabilitators in USA reported lesions  
193 and scarring compatible with WNS. There was a significant association between  
194 lesion type and lesion site, both in zoos ( $\chi^2$  p = 0.003) and in rehabilitation ( $\chi^2$  p =  
195 0.001).

196 Age categories were given for 64 occurrences of skin and pinnal disease seen by  
197 zookeepers and rehabilitators. Adult bats were most frequently reported as affected  
198 by both respondent groups (61 %; n/N = 39/64) but age group was not significantly  
199 associated with occurrence of skin or pinnal disease ( $\chi^2$  p = 0.791). Skin disease  
200 was reported to occur in juveniles (23 %; n/N = 9/40), and in the free text four  
201 respondents related this to soiling with milk replacer and mealworm juices, which  
202 was a particular problem in pipistrelles.

203 In zoos, for the variables type of heat ('artificial heat', 'ambient temperature'),  
204 'sunlight' and flight ('full flight', 'restricted flight', 'no flight'), there was no significant  
205 association with the presence or absence of lesions for each body site.

#### 206 [Description of suspected causes, treatment and outcome of skin disease](#)

207 Twenty-six respondents completed the question on suspected causes for skin  
208 disease (multiple answers allowed) and 20 respondents on causes for pinnal  
209 disease, resulting in nine causes suspected by all respondents. Sixteen respondents  
210 provided a suspected cause for skin or pinnal disease in the free text box: humidity  
211 (44%; n/N = 7/16), poor hygiene (31%; n/N = 5/16), cage trauma leading to wing  
212 injuries (25%; n/N = 4/16), poor diet (19%; n/N = 3/16), and WNS (6%; n/N = 1/16).  
213 Suspected causes for skin disease were distributed to four main causal factors (type  
214 of housing (27 %; n/N = 7/26), external parasites (23 %; n/N = 6/26), trauma (23 %;  
215 n/N = 6/26) and other (19 %; n/N = 5/26)) while extreme cold (8% n/N = 2/26) was  
216 rarely suspected. Conversely, cause of pinnal disease in particular was attributed to  
217 external parasites (25 %; n/N = 5/20), type of housing (20 %; n/N = 4/20) and  
218 extreme cold weather (20 %; n/N = 4/20), with other causes and trauma in the  
219 remainder. No instances of either skin or pinnal disease were attributed to extreme  
220 hot weather. There was no significant association between different suspected  
221 causal factors and occurrence of skin and pinnal disease ( $\chi^2$  p = 0.724).

222 Twenty-two respondents completed the question on bacteria isolated from skin  
223 lesions and 18 on pinnal lesions. For skin lesions, bacteria were isolated from four  
224 (18%; n/N = 4/22), not isolated from 10 (45%; n/N = 10/22) and eight were not tested  
225 (36%; n/N = 8/22). For pinnal lesions bacteria were isolated from four (22%; n/N =  
226 4/18), not isolated from four (22%; n/N = 4/18) and 10 were not tested (56%; n/N =  
227 10/18). Four respondents reported the bacteria isolated, two of which were  
228 coagulase-negative staphylococci, one was *Staphylococcus aureus* and one  
229 reported *Proteus mirabilis*, *Pseudomonas aeruginosa*, *Enterococcus spp*, alpha-  
230 haemolytic *Streptococcus*, *Providencia rettgeri* and *Morganella morganii*.

231 Reported treatments included husbandry changes, hygiene measures, ectoparasite  
232 control and topical therapies (emollients and antimicrobials). In severe cases,  
233 systemic antimicrobial treatment (15%; n/N = 10/66) and amputation of affected  
234 extremities (6%; n/N = 4/66) were reported.

235 Eight respondents (six zookeepers and two rehabilitators) reported that euthanasia  
236 had become indicated in individual bats as a result of skin disease, with general  
237 debility (8%; n/N = 5/66) or loss of wing membrane (3%; n/N = 2/66) stated as  
238 specific causes. One zookeeper reported closing their bat colony of insectivorous  
239 pallid bats (*Antrozus pallidus*) due to medical problems including skin disease.

## 240 Discussion

241 The findings of this study suggest that skin disease, in particular involving the wing  
242 membrane and pinna, is common in captive bats and more likely to be seen in  
243 rehabilitation than zoos. Necrosis was reported frequently, whereas pruritus was only  
244 reported by rehabilitators. There was a significant association of skin disease with  
245 season in zoos and, anecdotally, some species association in both zoos and  
246 rehabilitation.

247 Online surveys are an inexpensive, rapid and efficient way of obtaining data from  
248 specific groups of people, in this case bat carers. However, limitations such as  
249 language barriers, access to a computer or self-exclusion, for example by those who  
250 had not seen skin disease, may have created a biased sample.<sup>16</sup>

251 The quality of the data gathered here is limited by factors such as the quality of  
252 record keeping by respondents and the questionnaire design, which aimed to be  
253 short and easily answered, but which may, as a result, have sacrificed statistical  
254 robustness.

255 Some questions were asked which were likely to produce highly subjective answers  
256 which repeated prevailing wisdom. However, it appears that some species are over-  
257 represented in the reports of pinnal lesions and, if genuine, this finding warrants  
258 further investigation. Likewise, most carers reported that skin disease was “not  
259 seasonal”, but in zoos there was a significant association between wing and pinnal  
260 lesions and season, with a tendency for winter to be the most common season.  
261 However, in both cases the sample sizes were small and those reporting these  
262 associations all housed bats at ambient temperatures. It is possible that the  
263 remaining zoos would not have noticed a seasonal association because artificial  
264 heating removes most temperature seasonality for the bats.



265 Rehabilitators were significantly more likely to have seen skin or pinnal disease than  
266 zoos, which is not unexpected since young, sick and injured bats are often  
267 immunocompromised by being freshly captive, and subjected to handling and  
268 medication.<sup>17</sup> These bats are also more likely to be immobile and less able to groom  
269 properly, hence reducing skin health and defence against infection. In addition,  
270 rehabilitators report that the need to confine injured bats in plastic containers, or to  
271 wrap pups in fabric can result in high humidity and wing membrane infections.<sup>9</sup> The  
272 practical difficulties of hand-feeding orphaned baby bats is reported to lead to soiling  
273 of the fur and subsequent skin disease.<sup>7</sup> In addition, providing a normal diet to  
274 insectivorous bats in captivity is challenging.<sup>18</sup> In contrast, zoo colonies usually are  
275 predominantly healthy, active bats kept in enclosures which allow more normal skin  
276 and pelage function, and providing correct nutrition to fruit bats is far less  
277 problematical than for insectivorous bats.

278 The distribution of lesion type and lesion site was broadly similar in both groups,  
279 however it is unclear why rehabilitators reported pruritus whereas zoos did so  
280 infrequently, and zoos reported blisters on wing membranes whereas rehabilitators  
281 did not. Pruritus has previously been reported in a single case of presumptive atopic  
282 dermatitis in a captive Malayan flying fox (*Pteropus vampyrus*).<sup>5</sup> Alopecia has been  
283 previously reported in both captive and free-ranging bats.<sup>7,19,20</sup> These authors  
284 suggested that causes of alopecia were androgen activity, nutritional imbalance and  
285 metabolic stress due to pregnancy and lactation or anthropogenic pressures. A role  
286 for nutrition in the development of alopecia in bats, as suspected by several  
287 respondents in this study based on hair regrowth following improved diets, is  
288 plausible but has not been discussed in the published literature.

289 Necrosis was reported only on the wing, pinna, and digit. In bats, the wing distal to  
290 the carpus is particularly at risk of necrosis due to the anatomical paucity of collateral  
291 circulation.<sup>8</sup> The skin of the wing membrane is extremely thin with a histologically  
292 indistinguishable hypodermis reported in thin areas,<sup>21</sup> which may render them less  
293 able to withstand ischaemia due to microthrombi or damage by bacterial or other  
294 toxins.<sup>22</sup> Vasculitis is a recognised cause of skin and pinna necrosis in dogs and  
295 other species, which is thought to involve type III hypersensitivity reactions, often  
296 associated with underlying causes such as infections, drug reactions, or food  
297 hypersensitivity.<sup>23</sup> In contrast and by comparison, porcine ear pinnal necrosis  
298 syndrome rarely involves vasculitis and the involvement of staphylococcal toxins has  
299 been proposed as a cause.<sup>24</sup> For bats, an association with cold has been proposed  
300 by bat workers in Australia for ear lesions in black flying foxes at the southern end of  
301 their range; pinnal lesions in free-ranging bats in Germany were ascribed to 'frost  
302 damage' in winter roosts<sup>25</sup> although the evidence for this remains scant.  
303 Cryoglobulinaemia in humans can result in skin necrosis and a case of cold-  
304 associated cryoglobulinaemia in a dog which resulted in pinnal necrosis has been  
305 reported.<sup>26</sup> Further studies are needed to elucidate the nature of the necrotic lesions  
306 reported in this study.

307 The observations reported in this online survey suggest that skin disease affects a  
308 substantial number of captive bats, that pinnae and wing membranes are  
309 predisposed to skin disease, and that some species may be more susceptible than

310 others. As for other nondomestic animals, husbandry and housing are likely to be  
311 contributing to some skin disease. Although this survey does not provide information  
312 about the aetiology of skin disease in captive bats, it represents a starting point in  
313 understanding the frequency and type of skin disease affecting bats. To assist those  
314 caring for bats, better diagnostics and more research into the different aetiologies of  
315 skin disease are needed to provide prognoses, targeted treatment, and better  
316 welfare and conservation for captive bats.

## 317 References

- 318 1. IUCN. Species Action Plan for Livingstone's Fruit Bat, IUCN Species Survival  
319 Commission Chiroptera Specialist Group. Durrell Wildlife Conservation Trust,  
320 Jersey 1995.
- 321 2. Gartrell B. Dermatitis of the pinnae in lesser short-tailed bats, *Mystacina*  
322 *tuberculata*, translocated to Kapiti Island. *Kokako* 2007; 14: 25-31.
- 323 3. Bat Conservation Trust website. Bats of the World. Available at:  
324 [http://www.bats.org.uk/publications\\_download.php/211/BoW\\_English\\_version.pdf](http://www.bats.org.uk/publications_download.php/211/BoW_English_version.pdf).  
325 Accessed 24th March 2016.
- 326 4. Cryan P, Meteyer C, Blehert D *et al*. Electrolyte Depletion in White-nose  
327 Syndrome Bats. *J Wildl Dis* 2013; 49: 398-402
- 328 5. Goodnight A. Diagnosis and palliative management of atopic dermatitis in a  
329 Malayan flying fox (*Pteropus vampyrus*). *J Zoo Wildl Med* 2015; 42: 386-392.
- 330 6. Routh A. Bats. In: Mullineaux E, Best R, and Cooper J. eds. *BSAVA Manual of*  
331 *Wildlife Casualties*. British Small Animal Veterinary Association. 2003; 95-108.
- 332 7. Olsson A, Barnard S. Alopecia. In: SM Barnard, ed. *Bats in Captivity. Volume 1:*  
333 *Biological and Medical Aspects*. Washington DC: Logos Press, 2009; 111-120.
- 334 8. Olsson A. Wing Membranes. In: SM Barnard, ed. *Bats in Captivity. Volume 1:*  
335 *Biological and Medical Aspects*. Washington DC: Logos Press, 2009; 245-249.
- 336 9. Australian Registry of Wildlife Health website. No 17. Pathology of Bats. Available  
337 at: [http://www.arwh.org/sites/default/files/files-](http://www.arwh.org/sites/default/files/files-uploads/17%20Pathology%20of%20Bats.pdf)  
338 [uploads/17%20Pathology%20of%20Bats.pdf](http://www.arwh.org/sites/default/files/files-uploads/17%20Pathology%20of%20Bats.pdf). Accessed 3rd July 2016.
- 339 10. Stringer E, Han S, Larsen RS. Vitilligo associated with hypovitaminosis D in  
340 Malayan flying fox (*Pteropus vampyrus*) and island flying fox (*Pteropus*  
341 *hypomelanus*). *Vet Rec* 2016; Published online: May 11, 2016 doi:10.1136/vetreccr-  
342 2016- 000297
- 343 11. Zoological society London website. ZSL London zoo animal inventory. Available  
344 at: [https://www.zsl.org/about-us/animal-](https://www.zsl.org/about-us/animal-inventory?awc=2887_1465574549_f7acf384a954fc67a7ecdd0fbf0743be)  
345 [inventory?awc=2887\\_1465574549\\_f7acf384a954fc67a7ecdd0fbf0743be](https://www.zsl.org/about-us/animal-inventory?awc=2887_1465574549_f7acf384a954fc67a7ecdd0fbf0743be). Accessed  
346 22<sup>nd</sup> June 2016.
- 347 12. Lincoln Park zoo website. Animal inventory. Available at:  
348 <http://www.lpzoo.org/animals/mammals>. Accessed 22<sup>nd</sup> June 2016.
- 349 13. Facebook website. Facebook bat rehabilitators. Available at;  
350 <https://www.facebook.com/groups/batcare/>. Accessed 22<sup>nd</sup> June 2016.

- 351 14. Yahoo website. UK Bat Care Group. Available at:  
352 <https://uk.groups.yahoo.com/neo/groups/UKbatcare/info>. Accessed 22<sup>nd</sup> June 2016.
- 353 15. Ausvet animal health services website. Epitools. Available at:  
354 <http://epitools.ausvet.com.au/content.php?page=home>. Accessed 22<sup>nd</sup> June 2016.
- 355 16. Wright, K. B. Researching Internet-Based Populations: Advantages and  
356 Disadvantages of Online Survey Research, Online Questionnaire Authoring Software  
357 Packages, and Web Survey Services. *J Comput Mediat Commun* 2005; 10: 00.  
358 doi: 10.1111/j.1083-6101.2005.tb00259.x
- 359 17. Dickens M, Delehanty D, Romero L. Stress and translocation: alterations in the  
360 stress physiology of translocated birds. *Proc Biol Sci* 2009; 276: 2051-2056.
- 361 18. Traylor-Holzer, K., Tawes, R., Bayless, M. *et al* (eds.). *Insectivorous Bat Captive*  
362 *Population Feasibility Workshop Report*. IUCN/SSC Conservation Breeding  
363 Specialist Group: Apple Valley, MN. 2010.
- 364 19. Bello-Gutiérrez J, Suzán G, Hidalgo-Mihart M *et al*. Alopecia in Bats from  
365 Tabasco, México. *J Wildl Dis* 2010; 46: 1000-1004.
- 366 20. Tang Z-H, Zhang G-L, Sheng L-Z *et al*. Alopecia in Rickett's big-footed bat  
367 *Myotis ricketti* (Chiroptera: Vespertilionidae) in relation to age and sex. *Zool Stud*  
368 2012; 51: 494-499.
- 369 21. Madej J, Mikulova´ L, Gorosˇova´ A, *et al*. Skin structure and hair morphology of  
370 different body parts in the common pipistrelle (*Pipistrellus pipistrellus*). *Acta Zool*  
371 2013; 94: 478–489.
- 372 22. Weissenbacher-Lang C, Voglmayr T, Waxenecker F *et al*. Porcine ear necrosis  
373 syndrome: A preliminary investigation of putative infectious agents in piglets and  
374 mycotoxins in feed. *Vet J* 2012; 194: 392-397.
- 375 23. Griffin C. Dermatologic diseases of the auricle. In: Proceedings of the world  
376 congress of WSAVA/FECAVA/CSAVA. 2006. Available at:  
377 <http://www.ivis.org/proceedings/wsava/2006/lecture26/Griffin4.pdf?LA=1>
- 378 24. Park J, Friendship R, Poljak Z, *et al*. An investigation of ear necrosis in pigs. *Can*  
379 *Vet J* 2013; 54: 491-495.
- 380 25. Kiefer A. Frostscha-den an den Ohren und andere Verletzungen bei  
381 Fledermäusen (Mammalia, Chiroptera) aus dem Regierungsbezirk Koblenz (BRD,  
382 Rheinland-Pfalz). *Fauna und Flora in Rheinland-Pfalz* 1996; 21: 77-86.
- 383 26. Nagata M, Nanko H, Hashimoto K, *et al*. Case Report. Cryoglobulinaemia and  
384 cryofibrogenaemia: a comparison of canine and human cases. *Vet Derm* 1998; 9:  
385 277-281.

386

387

388 [Tables](#)

389 Table 1: Frequency of skin and pinnal disease in different species of captive bats in zoos (shading = disease present)

Genus	Species	Total number in captivity	Number of zoos with colonies	Number of zoos reporting skin disease (%)	Number of zoos reporting pinna disease (%)
Bats with Skin Disease					
<i>Antrozous</i>	<i>pallidus</i>	41	2	1 (50)	
<i>Carollia</i>	<i>perspicillata</i>	3000	6	2 (33)	1 (17)
<i>Macroderma</i>	<i>gigas</i>	13	2	1 (50)	1 (50)
<i>Mystacina</i>	<i>tuberculata</i>	42	2	2 (100)	2 (100)
<i>Pteropus</i>	<i>giganteus</i>	52	5	1 (20)	1 (20)
	<i>livingstonii</i>	56	2	2 (100)	2 (100)
	<i>lylei</i>	64	2	1 (50)	
	<i>poliocephalus</i>	136	6	1 (17)	
	<i>rodricensis</i>	39	4	1 (25)	1 (25)
	<i>vampyrus</i>	17	3	1 (33)	
<i>Rousettus</i>	<i>aegypticus</i>	700	9	2 (22)	
Bats With No Reported Skin Disease					
<i>Artibeus</i>	<i>jamaicensis</i>	1	1		
<i>Desmodus</i>	<i>rotundus</i>	145	2		
<i>Eidolon</i>	<i>helvum</i>	113	4		
<i>Glossophaga</i>	<i>soricina</i>	91	3		
<i>Leptonycterus</i>	<i>curasoae</i>	20	1		
<i>Noctilio</i>	<i>leporinus</i>	3	1		
<i>Phyllostoma</i>	<i>discolor</i>	1	1		
	<i>hastatus</i>	15	1		
<i>Pteropus</i>	<i>alecto</i>	2	1		
	<i>hypomelanus</i>	5	1		
	<i>pumilis</i>	8	2		
	<i>scapulatus</i>	21	4		
	<i>voeltzkowi</i>	1	1		
<i>Rousettus</i>	<i>lanosus</i>	55	1		
<i>Tadarida</i>	<i>brasiliensis</i>	1	1		

391 Table 2. Lesion types reported in bats suffering from skin disease on the face, body, wing membrane, ear flap, and toe and claw by  
 392 15 zoos and 18 rehabilitators in response to a questionnaire.

Lesion Type	Number of times lesion type was reported at any site (%)		Number of times lesion reported at site (%)									
			Head and face		Body		Pinna		Wing membrane		Toe and claw	
	Zoo	Rehab	Zoo	Rehab	Zoo	Rehab	Zoo	Rehab	Zoo	Rehab	Zoo	Rehab
Crusting	16 (21)	15 (20)	2 (25)	1 (13)	1 (13)	2 (12)	6 (26)	7 (27)	4 (15)	3 (16)	3 (27)	2 (29)
Swelling & redness	17 (22)	12 (16)	2 (25)	1 (13)	2 (25)	nr	6 (26)	6 (23)	4 (15)	3 (16)	3 (27)	2 (29)
Necrosis	13 (17)	16 (21)	nr	nr	nr	nr	5 (22)	5 (19)	5 (19)	9 (47)	3 (27)	2 (29)
Blisters	10 (13)	2 (2)	nr	nr	nr	nr	2 (9)	2 (8)	8 (31)	nr	nr	nr
Alopecia	9 (12)	12 (16)	2 (25)	3 (38)	5 (63)	9 (53)	1 (4)	nr	1 (4)	nr	nr	nr
Discharge of pus	7 (9)	2 (2)	2 (25)	nr	nr	1 (6)	3 (13)	1 (4)	nr	nr	2 (19)	nr
Itchiness	1 (2)	12 (16)	nr	3 (38)	nr	4 (23)	nr	2 (8)	1 (4)	3 (16)	nr	nr
Depigmentation	3 (4)	6 (8)	nr	nr	nr	1 (6)	nr	3 (11)	3 (12)	1 (5)	nr	1 (13)
Totals	76 (100)	77 (100)	8 (100)	8 (100)	8 (100)	17 (100)	23 (100)	26 (100)	26 (100)	19 (100)	11 (100)	7 (100)

393 nr: not reported

394

Appendix S1. Invitation to Wildlife Disease Association, Veterinary Division members to complete the survey.

Message uploaded to WDA VD mailing list:

Survey on skin disease and ear flap disease in captive bats: Request for assistance from all involved in keeping bats in captivity. To assess the incidence and type of skin and ear flap disease in captive bats we would appreciate it if you would complete the online survey about your experience of any problems in your bats. Replies are anonymous. It is useful for us to know if you do not see any skin disease and your reply will only take a few minutes. I am particularly interested to hear from anyone seeing bats which lose part of the ear flap as a result of disease.

## Appendix S2. Questionnaire; “Skin disease in captive bats”.

### 1. Introduction

This survey was designed by (identifying information removed). The results of the survey will provide valuable data about the type and incidence of skin disease in captive bats. Responses to this survey are anonymous and will be used for research purposes only (Data Protection Act 1998). Should you provide any contact details these will be held in a secure database in order to contact you regarding our research and will not be used for marketing or passed to any third parties.

### 2. About your bats

Tell us about the bats you have, and how and why you keep them.

#### 1. What is the purpose of your captive bat population?

- Zoo Exhibit
- Rescue and Rehabilitation
- Captive Breeding
- Research

#### 2. Which species of bat do you keep in your collection? (Please estimate numbers for each species)


#### 3. In which type of housing are your bats kept?

	Ambient temperature	Artificial heat	Access to full sunlight
Full flight enclosure	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Restricted flight enclosure (some flight possible)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No flight enclosure (flight not possible)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Hospital cage	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Other factors eg hibernation allowed?

--

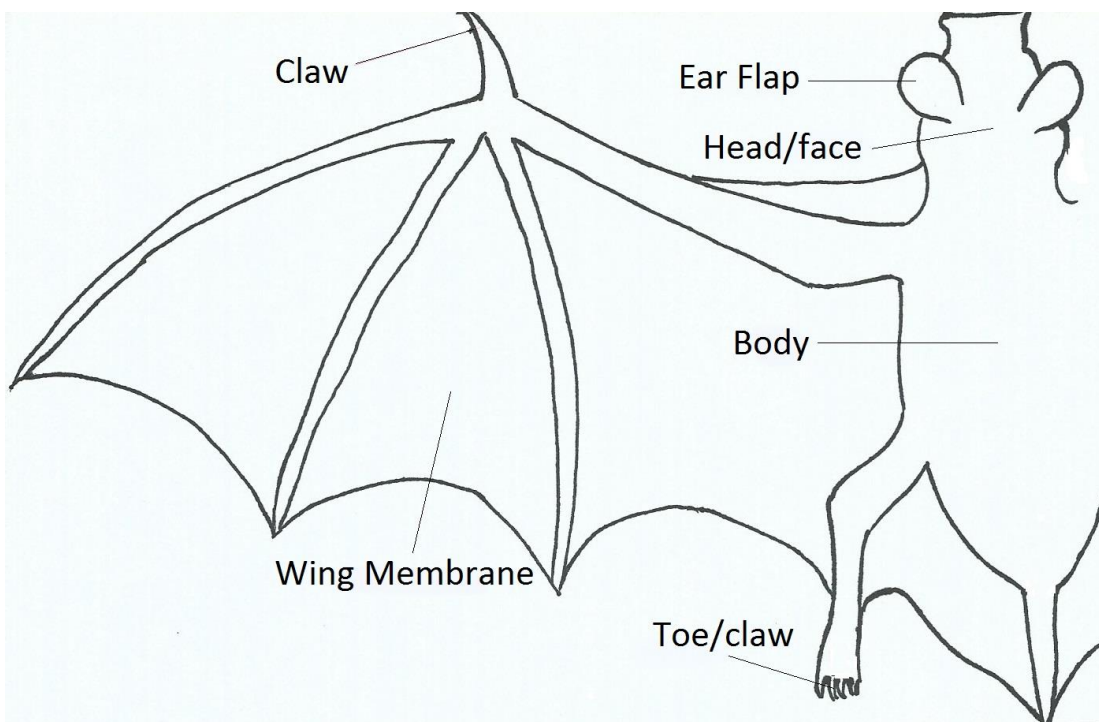
### 3. Skin Disease and Ear Flap Lesions

Types of skin disease you see and which bats are affected

4. Have you seen skin disease or ear flap disease in any of your bats? \*

Yes

No



5. Which area of the skin has been affected? \*

Body

Wing membrane

Toes/claws

Ear Flap

Head/face

6. Which type of skin changes or behaviour changes have you seen in each area?

	Body	Wing membrane	Toe/claw	Ear Flap	Head/face
Alopecia (loss of hair)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Crusting	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>



	Body	Wing membrane	Toe/claw	Ear Flap	Head/face
Blisters	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Necrosis (death of tissue)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Swelling and Redness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Discharge of pus	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Itchiness	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (Please describe)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Please describe any other skin changes seen.

**7. How often have you seen skin disease and ear flap disease?**

	Skin Disease	Ear Flap Disease
One or two cases	<input type="checkbox"/>	<input type="checkbox"/>
Several cases per year	<input type="checkbox"/>	<input type="checkbox"/>
Most bats affected	<input type="checkbox"/>	<input type="checkbox"/>
Never	<input type="checkbox"/>	<input type="checkbox"/>

**8. Are any species more often affected by skin disease than others?**

**9. In which species do you see ear flap disease?**

**10. How old are bats which have skin disease and ear flap disease?**

	Skin Disease	Ear Flap Disease
Neonate (0-2 weeks)	<input type="checkbox"/>	<input type="checkbox"/>
Juvenile (2wks-1 year)	<input type="checkbox"/>	<input type="checkbox"/>
Adult (1 year-15 years)	<input type="checkbox"/>	<input type="checkbox"/>
Geriatric (	<input type="checkbox"/>	<input type="checkbox"/>
Other (Please specify)	<input type="checkbox"/>	<input type="checkbox"/>

Other comments about the age of bats affected

**11. Did the skin disease or ear flap disease result in the need for euthanasia of the affected bat?**

	Skin Disease	Ear Flap Disease
Yes	<input type="checkbox"/>	<input type="checkbox"/>
No	<input type="checkbox"/>	<input type="checkbox"/>

Please describe why euthanasia was necessary

## 4. Causative Factors

Any factors which have been suspected or confirmed as the cause of skin disease or ear flap lesions. (What do you or your vet think is the cause)

**12. Were skin disease and ear flap disease associated with any cause?**

	Skin Disease	Ear Flap Disease
External parasites	<input type="checkbox"/>	<input type="checkbox"/>
Trauma including fighting	<input type="checkbox"/>	<input type="checkbox"/>
Extreme hot weather	<input type="checkbox"/>	<input type="checkbox"/>
Extreme cold weather	<input type="checkbox"/>	<input type="checkbox"/>
Type of Housing (Please specify)	<input type="checkbox"/>	<input type="checkbox"/>
Other (Please specify)	<input type="checkbox"/>	<input type="checkbox"/>

Type of housing or other causes:

**13. Have any bacteria been isolated from cases of skin or ear flap disease?**

	Skin Disease	Ear Flap Disease
Yes	<input type="checkbox"/>	<input type="checkbox"/>
No	<input type="checkbox"/>	<input type="checkbox"/>
Not tested	<input type="checkbox"/>	<input type="checkbox"/>

Which bacteria were isolated? (Please state site)

**14. Are skin disease or ear flap disease seen at a particular time of year?**

	Skin Disease	Ear Flap Disease
Spring	<input type="checkbox"/>	<input type="checkbox"/>
Summer	<input type="checkbox"/>	<input type="checkbox"/>
Autumn (Fall)	<input type="checkbox"/>	<input type="checkbox"/>
Winter	<input type="checkbox"/>	<input type="checkbox"/>
Not Seasonal	<input type="checkbox"/>	<input type="checkbox"/>

Any other information on the time of year lesions occur

## 5. More Information

**15. Would you be willing to provide more information on the skin disease seen in your bats?**

**If so please enter an e-mail address so that we may contact you.**

**The e mail address will remain confidential and will not be passed to any third party.**