Title

Overpasses intended for human use can be crossed by middle and large-size mammals

Authors

Yushin Asari, Misako Noro, Yoshiki Yamada and Ryuichi Maruyama

Informative title

Human overpasses crossed by mammals

Affiliations and E-mail

YA: Obihiro University of Agriculture and Veterinary Medicine
Inada 2-11, Obihiro, Hokkaido, 080-8555, Japan
asari@obihiro.ac.jp
MN: Hokkaido Development Engineering Center
noro@decnet.or.jp
2-17, Kita 11, Nishi 2, Kita-ku, Sapporo, Hokkaido, 001-0011, Japan
YY: Docon Co., Ltd.
4-1, Atubetu chuou 1-5, Atubetu-ku, Sapporo, Hokkaido, Japan
yy1372@docon.jp
RM: KOKEN ENGINEERING Co., Ltd.
1-1, Kita 18, Higashi 17, Higashi-ku, Sapporo, Hokkaido, Japan
r.maruyama@koken-e.co.jp

Corresponding author (Yushin Asari)

TEL: +81-155-49-5500
FAX: +81-155-5499

Abstract

Road overpasses cost more than underpasses and can be built for most terrestrial mammals to resolve and/or minimize effects from habitat fragmentation. Many overpasses intended for human activity might also allow wildlife passage. Using digital infrared cameras from 2015 to 2016 in Hokkaido, Japan, we evaluated such use in three overpasses where two were designed for humans and one for wildlife. Nine mammal species were detected at the three overpasses. Three middle-sized mammals—raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*), and raccoon dogs (*Nyctereutes procyonoides*)—and a large mammal species, the sika deer (*Cervus nippon*), frequently used all of the overpasses. Our results showed that the overpass designed for wildlife was richer in species than the two overpasses for humans. However, results also showed that there were no significant differences in use among four animal species in the three overpasses. We propose the construction of small overpasses without plants to conserve habitat reconnection of middle-sized to large mammals. Arboreal species' habitats need structural change with additional of plants.

Keywords: arboreal species, small overpass, wildlife passage

Introduction

Road construction has expanded worldwide, and road length is projected to increase by >60% from 2010 to 2050 (Dulac 2013). Roads and traffic cause ecological effects such as pollution, noise, disruption of the physical environment, and the spread of exotic species (Spellerberg 1998, Trombulak and Frissell 2000). The population and habitat of wildlife living around roads are negatively affected in several ways: habitat loss, habitat degradation, barrier or filter to movement, wildlife mortality, avoidance, attraction (van der Ree et al. 2015). Wildlife crossing structures are important for reconnecting the fragmented habitats of numerous species (Sawaya et al. 2014, Pell and Jones 2015, Soanes et al. 2015, Carvalho et al. 2016, Simpson et al. 2016).

Overpasses and underpasses can be constructed for most terrestrial mammals to resolve and/or minimize local population decreases and mortality have been caused by habitat fragmentation and road kill. Effective overpasses and underpasses have been constructed at appropriate sites for target species (Glista et al. 2009). In general, overpasses are significantly more expensive and require more maintenance than underpasses. However,

62 overpasses are effective for middle-sized and large mammals (van Wieren and Worm
63 2001, Renard et al. 2008, Krauze-Gryz and Gryz 2016, Simpson et al. 2016), yet they
64 have not been internationally popularized.
65 General overpasses connect residential areas with agricultural land and forestry land.
66 These are not designed for wildlife. However, overpasses for human activity might
67 function for wildlife passage.
68 Using digital infrared cameras, we evaluated the effectiveness of animal passage at three
69 different overpasses where two passes are for humans and one is for wildlife. Our results
70 concerning the effectiveness of overpasses for humans that might be useful for
71 redesigning crossing measures based on cost-effectiveness of their construction.
72
73 Materials and Methods
74 *Study area*
75 This study was conducted on the Hokkaido Expressway at Iwamizawa City, western
76 Hokkaido, Japan. We monitored three overpasses (43°11′ N, 141°47′ E); one pass with a
77 gravel surface for wildlife use (B1) on which trees of 3 m height were planted along
78 concrete walls and two asphalt-paved passes for human activity (B2 and B3) (Fig. 1). The
79 concrete wall height of the three overpasses was 1.1-1.2 m, and the width and length of
80 three overpasses were 44.6-58.0 m and 6.0-8.0 m, respectively (B1: 45.6 m, 8.0 m; B2:
81 44.6 m, 6.0 m; B3: 58.0 m, 6.0 m). The distances between B1 and B2 and between B2
82 and B3 were 300 m and 160 m, respectively (Fig. 2). Wildlife freely used all three. The
83 overpasses were about 10 m above the road level. Both ends of the overpasses had forests
84 of conifer and deciduous trees of 10 to 30 m height, and all overpass entrances were close
85 to forest cover. Road maintenance workers occasionally visited these overpasses, but we
86 did not see frequent use by human residents.
87 *Overpass use*
88 From mid-September 2015 until late September 2016, digital infrared cameras (SG-007,
89 HGC) were set at both ends of the three overpasses at a height of 2.5 m. Each camera was
90 focused on an entrance and set for image not video to capture overpass use by wildlife.
91 Camera intervals were set at two minutes to avoid photoduplication of individuals stopped
92 in front of the camera. We recorded mammal species captured by each camera and
93 categorized the data by month and species.
94 *Statistical analysis*

Two cameras at the same overpass captured different wildlife use such as passage direction and passing time, though we could not determine the species of individuals found in some pictures. As a result, the number of photos taken with the two cameras were different. Therefore, we compared the number of photos of each species taken with the two cameras at the same overpass in every month, and adapted the greater number of photos as the effective monthly number of the species. We defined one photo of an individual as a one-time use of the overpass.

The Kruskal-Wallis rank sum test was used to examine the difference in monthly overpass use by mammals among three overpasses.

Results

During 2015 and 2016, nine mammal species were detected in three overpasses: Eurasian red squirrels (*Sciurus vulgaris*), raccoons (*Procyon lotor*), red foxes (*Vulpes vulpes*), raccoon dogs (*Nyctereutes procyonoides*), sables (*Martes zibellina*), least weasels (*Mustela nivalis*), sika deer (*Cervus nippon*), dogs (*Canis familiaris*), and cats (*Felis catus*). Three middle-sized mammals—raccoons of an invasive species in Japan, red foxes, and raccoon dogs—frequently used all overpasses (Table 1). Sika deer also used the overpasses.

The richness of mammal species

Seven wild mammal species were detected at B1 (Table 1); Eurasian red squirrels, raccoons, red foxes, raccoon dogs, sables, least weasels, and sika deer. Four wild mammal species were found at B2 and B3; raccoons, red foxes, raccoon dogs, and sika deer.

Crossing frequency of mammals

Raccoons, red foxes, and raccoon dogs were most frequently observed (Table 2). There was no significant difference in the overpass use of these common middle-sized mammals ($P > 0.05$), although the number of photos per month at B2 (mean±SD; 20.17±20.03) was larger than B1 (16.17±15.10) and B3 (13.50±10.68).

Passage by sika deer also did not significantly differ among overpasses, although sika deer at B1 (mean±SD; 0.92±1.56) were detected more than at B2 (0.25±0.62) and B3 (0.58±1.24) (Table 2).

Seasonal change of overpass use

Three middle-sized mammal species commonly used overpasses through the year. However, mammals showed a seasonal change in use with an autumn (October to November) peak (Fig. 2).

Sika deer were only detected in two periods between May and June (10 times) and September and November (11 times).

Discussion

Our results showed that overpasses were equally functional for humans and wildlife in large and middle-sized mammals. Furthermore, overpasses for wildlife were most effective for arboreal and multiple other species. Ward et al. (2015) reported that road crossing structures designed for wildlife might be more effective than other measures, because of less disturbance from humans. Our results showed that an overpass designed for wildlife was richer in species compared to two overpasses for humans. However, these results also showed that there were no significant differences in the use of three overpasses by four species, and three middle-sized mammals commonly found in three overpasses frequently used B2 (an overpass for humans). Therefore, we suggest that overpasses designed for humans were effective for the road crossing of middle-sized mammals.

Three common middle-sized mammals frequently used bridges with a seasonal peak of autumn. We considered that the autumn peak was caused by their seasonally higher activity, especially for juvenile dispersal (Urban 1970, Clark et al. 1989, Kauhala et al. 1993, Doncaster and Macdonald 1997, Baker et al. 2007). One reason for this pattern might be that red fox males move widely in autumn for breeding (Cavallini 1996).

Eurasian red squirrels, sables, and least weasels were only detected at B1. Use by the Eurasian red squirrel was relatively frequent. Therefore, trees planted at B1 would likely have a positive effect on road crossing by this arboreal species. Sika deer use was observed only in spring and autumn, coinciding with their seasonal migration in Hokkaido (Uno and Kaji 2000). This result suggests that our study site was on a seasonal migration route of sika deer. Thus, overpasses functioned to mitigate their migration between seasonal habitats. All three overpasses were used by sika deer, although the frequency of use varied at each overpass. Uzal et al. (2013) reported that sika deer used cover to avoid humans when moving between foraging sites. Borkowski (2001) also suggested that this species avoided non-resident humans such as tourists. Sika deer at

159 overpasses might be fearless of humans due to the presence of few users (such as tourists
160 and residents), high installation positions and concrete walls screening them from cars,
161 and their high activity in migration season.
162
163 Implications
164 Our results showed the effectiveness of human overpasses for wildlife, especially middle-
165 sized mammals (except arboreal species). Arboreal species, such as Eurasian red squirrels,
166 were only detected at the wildlife overpass. Therefore, graveled overpasses with plants
167 play an important role in habitat reconnection for certain mammalian species.
168 Considering construction and maintenance costs, overpasses without vegetation would be
169 useful to mitigate crossing of terrestrial mammals commonly found in the target area.
170 Karison et al. (2017) suggested that it would be more effective to construct several small
171 fauna passages instead of a single large passage to minimize the barrier effect. The
172 overpasses we studied were smaller in width (distance between walls) than those of
173 previously studied overpasses deemed effective (e.g., 8.3 m and 20.1 m: Simpson et al.
174 2016; 24 m: Seidler et al. 2018).
175 We propose the construction of small overpasses without plants to conserve habitat
176 reconnection of middle-sized to large mammals. For arboreal species, however, plants
177 would be needed.
178
179 Acknowledgements
180 We thank Mr. Masatoshi Ogawa of NEXCO MEINTEINANCE for providing
181 information of our study site. We also thank Dr. Hisashi Yanagawa and Dr. Fumihiro
182 Hara for advising to our study and Miki Nakazono for helping field survey. We would
183 like to thank Mr. Glen Hill for helping in English proofreading of the manuscript.
184 Declaration of interest statement
185 The authors declare no conflicts of interest associated with this paper.
186
187 References
188 Baker PJ, Dowding CV, Molony SE, White PCL, Harris S (2007) Activity patterns of
189 urban red foxes (*Vulpes vulpes*) reduce the risk of traffic-induced mortality. Behav Ecol.
190 18:716–724.

191 Borkowski J (2001) Flight behaviour and observability in human-disturbed sika deer.
192 Acta Theriol. 46:195–206.
193 Carvalho F, Carvalho R, Mira A. Beja P (2016) Assessing landscape functional
194 connectivity in a forest carnivore using path selection functions. Landscape Ecol.
195 31:1021–1036.
196 Cavallini P (1996) Variation in the social system of the red fox. Ethol Ecol Evol. 8:323–
197 342.
198 Clark WR, Hasbrouk JJ, Kienzler JM, Glueck TF (1989) Vital statistics and harvest of an
199 Iowa raccoon population. J Wildlife Manage. 53:982–990.
200 Doncaster CP, Macdonald DW (1997) Activity patterns and interaction of red foxes
201 (*Vulpes vulpes*) in Oxford city. J Zool. 241:73–87.
202 Dulac J (2013) Global land transport infrastructure requirements. Estimating road and
203 railway infrastructure capacity and costs to 2050. International Energy Agency, Paris,
204 France.
205 https://www.iea.org/publications/freepublications/publication/TransportInfrastructure
206 Insights_FINAL_WEB.pdf. Accessed 20 January 2019.
207 Glista DJ, DeVault TL, DeWoody JA (2009) A review of mitigation measures for
208 reducing wildlife mortality on roadways. Landscape Urban Plan. 91:1–7.
209 Karison M, Seiler A, Mörtberg U (2017) The effect of fauna passages and landscape
210 characteristics on barrier mitigation success. Ecol Eng. 105:211–220.
211 Kauhala K, Helle E, Taskinen K (1993) Home range of the raccoon dog (*Nyctereutes*
212 *procyonoides*) in southern Finland. J Zool. 231:95–106.
213 Krauze-Gryz D, Gryz J (2016) Evaluation of a new wildlife overpass on S7 expressway
214 (central Poland). Annals of Warsaw University of Life Science-Forestry and Wood
215 Technology:224–230.
216 Pell S, Jones D (2015) Are wildlife overpasses of conservation value for birds? A study
217 in Australian sub-tropical forest, with wider implications. Biol Conserv. 184:300–309.
218 Renard MR, Visser AA, de Boer F, van Wieren SE (2008) The use of the 'Woeste Hoeve'
219 wildlife overpass by mammals. Lutra 51:5–16.
220 Sawaya MS, Kalinowski ST, Clevenger AP (2014) Genetic connectivity for two bear
221 species at wildlife crossing structures in Banff National Park. P R Soc B. 281:20131705.

Seidler RG, Green DS, Beckmann JP (2018) Highways, crossing structure and risk: behaviors of greater Yellowstone pronghorn elucidate efficacy of road mitigation. Global Ecology and Conservation 15:e00416.

Simpson NO, Stewart KM, Schroeder C, Cox M, Huebner K, Wasley T (2016) Overpasses and underpasses: effectiveness of crossing structures for migratory ungulates. J Wildlife Manage. 80:1370–1378.

Soanes K, Vesk PA, van der Ree R (2015) Monitoring the use of road-crossing structures by arboreal marsupials: insights gained from motion-triggered cameras and passive integrated transponder (PIT) tags. Wildlife Res. 42:241–256.

Spellerberg IF (1998) Ecological effects of roads and traffic: a literature review. Global Ecol Biogeogr. 7:317–333.

Trombulak SC, Frissell C (2000) Review of ecological effects of roads on terrestrial and aquatic communities. Conserv Biol. 14:18–30.

Uno H, Kaji K (2000) Seasonal movements of female sika deer in eastern Hokkaido, Japan. Mamm Study. 25:49–57.

Urban D (1970) Raccoon populations, movement patterns, and predation on a managed waterfowl marsh. J Wildlife Manage. 34:372–382.

Uzal A, Walls S, Stillman RA, Diaz A (2013) Sika deer distribution and habitat selection: the influence of the availability and distribution of food, cover, and threats. Eur J Wildlife Res. 59:563–572.

van der Ree R, Smith DJ, Grilo C (2015) The ecological effects of linear infrastructure and traffic: challenges and opportunities of rapid global growth. In: van der Ree R, Smith DJ, Grilo C (ed) Handbook of road ecology. Wiley-Blackwell, London, pp 1–9.

van Wieren SE, Worm PB (2001) The use of a motorway wildlife overpass by large mammals. Neth J Zool. 51:97–105.

Ward AI, Dendy J, Cowan DP (2015) Mitigating impacts of roads on wildlife: an agenda for the conservation of priority European protected species in Great Britain. Eur J Wildlife Res. 61:199–211.

Figure captions

Figure 1. Three overpasses we monitored. Left upper is pass for wildlife use (B1), right pictures show passes for human activity (B2 and B3).

Figure 2. Study area. Black squares numbered B1, B2 and B3 shows three bridge location. Gray area shows forest area.

Figure 3. Seasonal changes of the frequency used by common three middle sized mammals in three bridges

260 Table 1. Occurrence and absence of wild mammals on each bridge

Site	Eurasian red Squirrel	Raccoon	Red fox	Raccoon dog	Sable	Least weasel	Sika deer
B1	+	+	+	+	+	+	+
B2	-	+	+	+	-	-	+
B3	-	+	+	+	-	-	+

261

262

263 Table 2. Species detected on three bridges and used frequency

Species	Site	Number of use / month		
		Mean	SD	Range
Eurasian red squirrel	B1	1.42	2.68	0-9
	B2	-	-	-
	B3	-	-	-
Raccoon	B1	4.33	4.54	0-15
	B2	4.67	5.74	0-20
	B3	1.58	2.39	0-8
Red fox	B1	9.33	10.18	0-30
	B2	12.00	13.78	1-39
	B3	10.67	7.88	2-23
Raccoon dog	B1	2.50	2.94	0-9
	B2	3.50	3.63	0-11
	B3	1.25	3.14	0-11
Sable	B1	0.08	0.29	0-1
	B2	-	-	-
	B3	-	-	-
Least weasel	B1	0.08	0.29	0-1
	B2	-	-	-
	B3	-	-	-
Sika deer	B1	0.92	1.56	0-4
	B2	0.25	0.62	0-2
	B3	0.58	1.24	0-4
Dog	B1	0.17	0.58	0-2
	B2	0.08	0.29	0-1
	B3	0.17	0.39	0-1
Cat	B1	0.50	1.00	0-3
	B2	0.17	0.39	0-2
	B3	0.25	0.62	0-1
Bird	B1	-	-	-
	B2	1.08	1.98	0-5
	B3	0.33	0.49	0-1
Unknown	B1	5.17	6.13	0-22
	B2	5.08	7.33	0-26
	B3	3.75	6.84	0-24

264

265

Figure 1. Three overpasses we monitored. Left upper is pass for wildlife use (B1), right pictures show passes for human activity (B2 and B3).

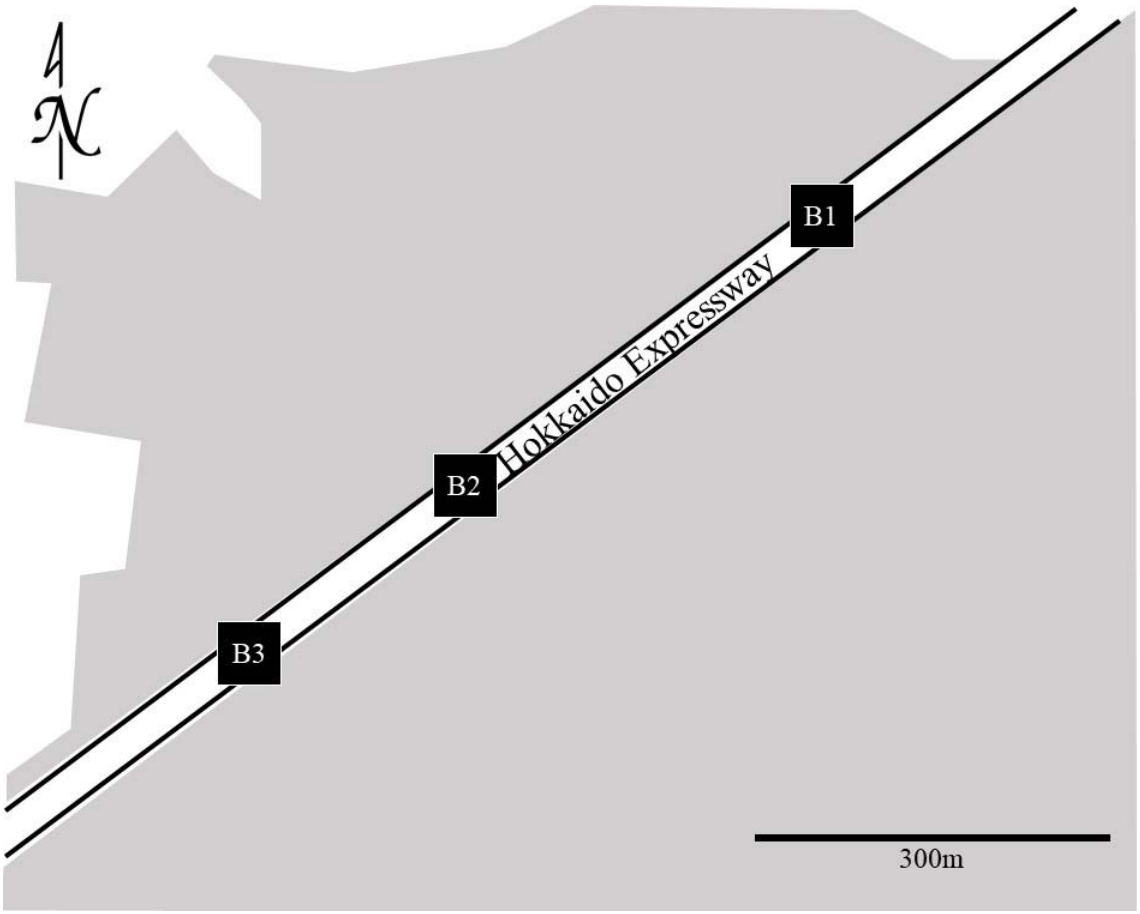

Figure 2. Study area. Black squares numbered B1, B2 and B3 shows three bridge location. Gray area shows forest area.

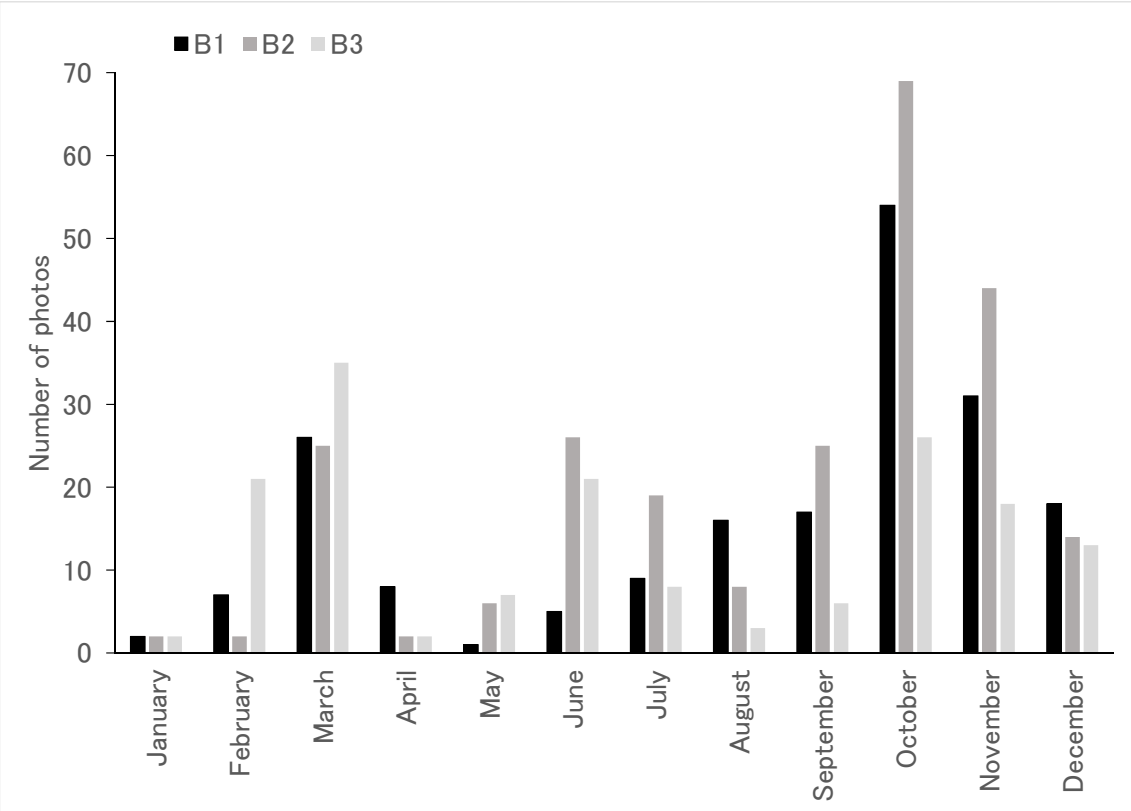

Figure 3. Seasonal changes of the frequency used by common three middle sized mammals in three bridges

Species	Site	Number of use / month		
		Mean	SD	Range
Eurasian red squirrel	B1	1.42	2.68	0-9
	B2	-	-	-
	B3	-	-	-
Raccoon	B1	4.33	4.54	0-15
	B2	4.67	5.74	0-20
	B3	1.58	2.39	0-8
Red fox	B1	9.33	10.18	0-30
	B2	12.00	13.78	1-39
	B3	10.67	7.88	2-23
Raccoon dog	B1	2.50	2.94	0-9
	B2	3.50	3.63	0-11
	B3	1.25	3.14	0-11
Sable	B1	0.08	0.29	0-1
	B2	-	-	-
	B3	-	-	-
Least weasel	B1	0.08	0.29	0-1
	B2	-	-	-
	B3	-	-	-
Sika deer	B1	0.92	1.56	0-4
	B2	0.25	0.62	0-2
	B3	0.58	1.24	0-4
Dog	B1	0.17	0.58	0-2
	B2	0.08	0.29	0-1
	B3	0.17	0.39	0-1
Cat	B1	0.50	1.00	0-3
	B2	0.17	0.39	0-2
	B3	0.25	0.62	0-1
Bird	B1	-	-	-
	B2	1.08	1.98	0-5
	B3	0.33	0.49	0-1
Unknown	B1	5.17	6.13	0-22
	B2	5.08	7.33	0-26
	B3	3.75	6.84	0-24