Ecological factors influencing winter field sign abundance of Korean water deer Hydropotes inermis argyropus in a temperate forest in South Korea

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Ecological factors influencing winter field sign abundance of Korean water deer *Hydropotes inermis argyropus* in a temperate forest in South Korea

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Abstract. The objective of this study was to clarify ecological factors influencing winter field sign abundance of Korean water deer *Hydropotes inermis argyropus* in a temperate forest on Mt. Maehwa, Hongcheon, South Korea. There were significant differences in four variables of cover and three variables of forage between the different topographic features, part from the midstory vegetation coverage. Most of the winter field signs of Korean water deer were observed on the ridge. The abundance of feces and total field signs of Korean water deer varied considerably between the topographical features. The understory vegetation, midstory vegetation, forb and shrub coverage, topography, understory vegetation × topography, midstory vegetation × topography, and shrub × topography were higher value of relative variable importance among habitat variables. Understory and midstory vegetation coverage, forage and topography were important ecological factors for affecting winter field sign abundance of Korean water deer.

Key words: conservation, cover, forage, habitat, management

Introduction

Habitat selection is the process by which an animal chooses resources. Because it can affect the survival and reproduction of individuals, it also influences population dynamics (Gaillard et al. 2010, Mancinelli et al. 2015). Various ecological factors, such as season, topography, social structure, and competition can affect habitat selection (Manly et al. 2002, Hirzel & Le Lay 2008). In addition, habitat selection can be considered as the results of diet (Mysterud et al. 1999).

The deer may try to maximize energy intake and minimize predation risk through habitat selection (Bailey et al. 1996, Mysterud & Ims 1998). Although there are numerous studies on the ecology of roe deer (Lone et al. 2014, Mancinelli et al. 2015), there are few studies on water deer (*Hydropotes inermis*). Two subspecies of water deer occur in East Asia – the Chinese water deer (*H. inermis inermis*) and the Korean water deer (*H. inermis argyropus*) (Guo & Zhang 2005). Both range and abundance of Chinese water deer have been greatly reduced because of habitat loss and poaching in China (Wang 1998). The species is classified as vulnerable on the Red List of the International Union for Conservation of Nature (IUCN) (IUCN 2015).

Korean water deer are endemic to the Korean peninsula and are one of the most common ungulates in South Korea. Korean water deer occur in various habitats, including forest, grassland, lowland mountainous, riparian, agricultural, and urban areas, and also at high and low altitudes (Won & Smith 1999, You 2000). However, although they are generalist mammals with a wide ecological niche, Korean water deer favor specific habitats that provide not only forage but also protection from predators (Said et al. 2005).

Currently, the Korean water deer has a high population density and is widely distributed in South Korea. Damage to agriculture by the deer has dramatically increased during the past few decades (Lee et al. 2017); thus, population management of the species is urgently required. Moreover, winter season is an unfavorable period for Korean water deer, because of food shortage, low temperature, and increased predation (You 2000). However, there is a lack of information on the ecology of Korean water deer in South Korea.

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Because of the agricultural importance of the species, understanding of the factors influencing the distribution of Korean water deer is reasonable for sustainable population management. In this study, we examine the winter abundance of field signs in different topographies. We tested two parameters: 1) habitat variations across different topographies and 2) the influence of habitat variables and topography on the field sign abundance of Korean water deer.

Material and Methods

This study was carried out from October 2015 to March 2016 in a temperate forest (37°38′-37°42′ N, 127°50′-127°54′ E) on Mt. Maehwa, Hongcheon, South Korea. The annual mean temperature was 10.8 °C (range 35.7-–19.6 °C) and annual precipitation was 828 mm. The altitude of the study area ranged from 250 to 450 m above sea level. The study area was mixed forest and dominated by Chinese cork oak (*Quercus variabilis*), Mongolian oak (*Q. mongolica*), Korean red pine (*Pinus densiflora*), Korean pine (*P. koraiensis*), and Japanese larch (*Larix kaempferi*) (Korea Forest Service 2012). We selected the study area according to topography, including ridge, slope, and valley. There were three transects per topographic unit, each 1 km long and 4 m wide. The three transects were maximum number of transects according to the size of study area. A total of nine transects was selected in the study area. Each transect was spatially separated from other transects by a distance of 500 m.

In January 2016, 40 sampling points were selected at 25 m intervals in each transect. We measured five cover variables and three forage variables describing vegetation structure in each sampling point (Table 1). Circles measuring 5.64 m in diameter (0.01 ha) were established at each random sampling point (Kang et al. 2013, Rhim et al. 2015). The area of 0.01 ha was convenient for calculation and analysis. We recorded coverage of v0 (0-1 m), v1 (1-2 m), v2 (2-8 m), v8 (8-20 m) and v20 (20-30 m) vegetation. The vegetation coverage was classified into the following four categories based on the percentage of foliage cover in each vertical layer: 0 (percentage coverage = 0 %), 1 (1-33 %), 2 (34-66 %), and 3 (67-100 %) (Son et al. 2017). As forb, shrub, and graminoid are the major forage resources for water deer (Kim et al. 2011b), we measured the forb, shrub, and graminoid cover (%) within each of the circles (Rhim 2013, Hwang et al. 2014).

We counted all field signs of Korean water deer once a month from October 2015 to March 2016; feces, footprints, feeding signs, hairs in bark of trees, antler rubbing signs and resting signs. There was no other species of deer occurring in the study area, so field signs can be attributed safely to species based on purely visual inspection. One trail of footprints was counted as one sign. In addition, monthly field survey was conducted in this study area for other seasons. There were no seasonal patterns in aggregation for this species. Moreover, cases of multiple deer together were handled as one sign. In each of the nine study transects, we conducted six tracking sessions during the study period. To avoid duplicating the records, we cleaned the field signs after recording their GPS coordinates for no duplication of field sign counting. There is no risk that this will lead to change in deer behaviour. The Korean water deer do not defecate more when feces are removed (personal communications). We recorded fresh field signs of the deer in each session and used the number of field signs recorded per tracking day in each transect as the variable for analysis (Rhim & Lee 2007, Hwang et al. 2014). The study area was showed at low altitude and at less altitudinal differences. Moreover, the counted field signs were cleaned by surveyors and covered by snow fall before the next survey.

The SPSS statistical package for Windows was used for statistical analyses in this study. We converted field sign counts to number of signs per 100 m, and compared these data. Habitat variables and field sign abundances between study sites were compared using the Kruskal-Walis test. Before model analysis, we reduce five cover variables (v0, v1, v2, v8, v20) to three variables (understory cover, mid-story cover, overstory cover) with Principle Component Analysis (PCA) to prevent multicollinearity of variables in the habitat use models. We used Generalized Linear Models (GLMs) to model the field sign abundance of Korean water deer. To assess the topographical differences in field signs of water deer within the home-range scale, the model included topographical

Table 1. Descriptions of habitat variables.

	Variable	Description
Cover	v0	Coverage (0, 1 , 2 , 3) of 0-1 m vegetation
	v1	Coverage (0, 1 , 2 , 3) of 1-2 m vegetation
	v2	Coverage (0, 1 , 2 , 3) of 2-8 m vegetation
	v8	Coverage (0, 1 , 2 , 3) of 8-20 m vegetation
	v20	Coverage (0, 1 , 2 , 3) of 20-30 m vegetation
Forage	for	Coverage (%) of forb (0-2 m)
	shr	Coverage (%) of shrub and sapling (0-2 m)
	grm	Coverage (%) of graminoid (0-2 m)

Table 2. Differences in winter coverage of habitat variables (mean ± SE) between topographic units on Mt. Maehwa, Hongcheon, South Korea, as determined a Kruskal-Walis test.

	Variable	Topography			χ^2	p
		Ridge	Slope	Valley		
Cover	v0	1.54 ± 1.04[a]	0.84 ± 1.05[b]	1.66 ± 1.06[a]	46.05	< 0.001
	v1	0.38 ± 0.51[b]	0.38 ± 0.54[b]	0.70 ± 0.79[a]	13.83	< 0.01
	v2	1.03 ± 0.83	1.27 ± 0.79	1.09 ± 1.01	4.66	0.10
	v8	1.36 ± 0.86[a]	1.28 ± 1.08[a]	0.58 ± 0.74[b]	46.72	< 0.001
	v20	0.00 ± 0.00[b]	0.04 ± 0.24[b]	0.11 ± 0.34[a]	14.69	< 0.01
Forage	for	0.00 ± 0.00[b]	0.00 ± 0.00[b]	0.09 ± 0.59[a]	12.18	< 0.01
	shr	4.18 ± 4.60[a]	3.06 ± 6.11[b]	3.04 ± 7.73[b]	18.76	< 0.001
	grm	0.25 ± 0.94[a]	0.10 ± 0.62[ab]	0.00 ± 0.00[b]	10.57	< 0.01

[a, b, c] means in rows with different superscripts are significantly different.

Table 3. Differences in the winter abundance of feces, feeding and total field signs (no./100 m, mean ± SE) of Korean water deer (*Hydropotes inermis argyropus*) between topographic units on Mt. Maehwa, Hongcheon, South Korea, as determined a Kruskal-Walis test.

Field sign	Topography			χ^2	p
	Ridge	Slope	Valley		
Feces	7.38 ± 8.53[a]	1.20 ± 3.13[b]	3.39 ± 6.06[c]	151.56	< 0.001
Feeding	0.19 ± 0.90	0.26 ± 1.15	0.17 ± 1.08	2.68	0.26
Total	8.16 ± 8.85[a]	1.77 ± 3.76[c]	4.11 ± 6.86[b]	172.37	< 0.001

[a, b, c] means in rows with different superscripts are significantly different.

Table 4. Models based on the correlated Akaike Information Criterion (AIC_c) developed to explain the abundance of Korean water deer (*Hydropotes inermis argyropus*) in each topographic feature ranked by the ΔAIC_c value resulted with the generalized linear model.

Topography	Model	AIC_c	ΔAIC_c	ω	R^2
Ridge	(intercept + under + for + shr)	1512.86	0.00	0.43	0.11
	(intercept + under + over + for + shr)	1514.24	1.38	0.21	0.11
	(intercept + under + mid + for + shr)	1514.46	1.60	0.19	0.11
Slope	(intercept + under + mid + shr)	686.87	0.00	0.32	0.04
	(intercept + under + shr)	687.49	0.62	0.24	0.03
	(intercept + under + mid + over + shr)	688.32	1.45	0.16	0.04
Valley	(intercept + mid + for)	1150.59	0.00	0.18	0.20
	(intercept + mid + for + grm)	1151.15	0.56	0.14	0.21
	(intercept + mid + over + for)	1151.24	0.65	0.13	0.20

variables, habitat variables and two-way interactions between topographic and habitat variables. The Akaike Information Criterion (AIC), corrected for a small sample size (Burnham & Anderson 2002) that included habitat variables, was used. The AIC model weights (ω) were determined for each of the variables that were present in at least one selected model resulting from the GLM. After model selection based on AIC ($\Delta AIC_c < 2$), we calculated the averaged regression coefficients and relative variable importance using MuMIn R package (Mancinelli et al. 2015). Values were considered statistically significant at $p < 0.05$.

Results

Apart from the midstory vegetation coverage (Kruskal-Walis test, $\chi^2 = 4.66$, $p = 0.10$), the other habitat variables differed significantly between topographies ($\chi^2 > 10.57$, $p < 0.01$). Coverage of v0 was significantly higher in the ridge and valley than in the slope. Coverage of v8, shrub and graminoid were significantly higher on the ridge. Coverage of v0, v20 and forb were higher in the valley compared to other topographies (Table 2). The abundance of feces ($\chi^2 = 151.56$, $p < 0.001$) and total ($\chi^2 = 172.37$, $p < 0.001$) field signs of Korean water deer were significantly different between topographies.

Table 5. Average coefficients and relative variable importance, including the models explaining the variability in the relative abundance of each model's categories in each topographic feature.

Topography	Variable	Averaged coefficient	SE	Z	p	Relative variable importance
Ridge	intercept	0.49	0.06	8.06	< 0.001	
	under	–0.14	0.06	2.48	0.01	1.00
	mid	0.06	0.09	0.67	0.50	0.19
	over	0.04	0.05	0.82	0.41	0.21
	For	0.07	0.03	2.66	< 0.01	1.00
	shr	0.03	0.01	4.67	< 0.001	1.00
	grm	–0.01	0.02	0.41	0.68	0.17
Slope	intercept	–1.16	0.17	6.79	< 0.001	
	under	–0.22	0.11	2.11	0.04	1.00
	mid	–0.26	0.16	1.56	0.12	0.62
	over	0.09	0.10	0.90	0.37	0.30
	For	0.07	0.12	0.60	0.55	0.14
	shr	0.02	0.01	2.92	< 0.001	1.00
	grm					
Valley	intercept	–0.33	0.09	3.51	< 0.001	
	under	0.05	0.06	0.86	0.39	0.16
	mid	–0.40	0.09	4.28	< 0.001	1.00
	over	–0.07	0.06	1.15	0.25	0.30
	for	0.04	0.01	6.29	< 0.001	1.00
	shr	–0.01	0.01	1.10	0.27	0.31
	grm	0.02	0.02	1.22	0.22	0.39

Table 6. Models based on the correlated Akaike Information Criterion (AIC_c) built to explain the abundance of Korean water deer (*Hydropotes inermis argyropus*) ranked by the ΔAIC_c value resulted with the generalized linear model.

	Model	AIC_c	ΔAIC_c	ω	R^2
1	under + mid + for + shr + topo + under × topo + mid × topo + shr × topo	3352.88	0.00	0.53	0.41
2	under + mid + over + for + shr + topo + under × topo + mid × topo + shr × topo	3354.40	1.52	0.25	0.41
3	under + mid + for + shr + grm + topo + under × topo + mid × topo + shr × topo	3354.66	1.78	0.22	0.41

Most of the winter field signs of Korean water deer were observed on the ridge. The abundance was significantly higher on the ridge than on the slope and valley. There were no differences in the abundance of feeding field signs between topographies (Table 3). The other field signs were rare and not different between topographies.

The top-ranked models for winter field sign abundance of the deer were different in each type of topography. On the ridge, the top-ranked model was 0.48-0.49 × understory vegetation + 0.07 × forb + 0.03 × shrub (χ^2-test, $p < 0.001$). The second model on the ridge contained the overstory vegetation, forb and shrub. The top-ranked model on the slope was –1.21-0.24 × understory vegetation – 0.26 × midstory vegetation + 0.02 × shrub ($p = 0.01$). In the second-ranked model, understory vegetation and shrub coverage dominated as two predictor variables for abundance of field signs on the slope. On the valley, the top-ranked model was –0.34-0.42 × midstory vegetation + 0.04 × forb ($p < 0.001$). Moreover, the second model contained midstory vegetation, forb and graminoid coverage on the valley (Table 4). The understory vegetation coverage showed a highly negative correlation with the winter field sign abundance of Korean water deer on the ridge and slope. The midstory vegetation coverage showed a highly negative correlation with the winter field sign abundance in the valley. However, forb and shrub coverage were highly positive correlated with the abundance in all topographies (Table 5).

The best models of winter field sign abundance of Korean water deer in the temperate forest had an Akaike weight (ω) of 0.22-0.53. Three models fulfilled

Table 7. Average coefficients and relative variable importance, including the models explaining the variability in the relative abundance of each model's categories.

Variable	Averaged coefficient	SE	Z	p	Relative variable importance
intercept	0.52	0.07	7.61	< 0.001	
under	–0.16	0.06	2.88	< 0.01	1.00
mid	0.08	0.09	0.85	0.39	1.00
over	0.03	0.04	0.73	0.47	0.25
for	0.04	0.01	7.46	< 0.001	1.00
shr	0.03	0.01	4.63	< 0.001	1.00
grm	0.01	0.01	0.53	0.60	0.22
topo2	–1.74	0.18	9.70	< 0.001	1.00
topo3	–0.83	0.12	6.84	< 0.001	
under × topo2	–0.08	0.12	0.72	0.47	1.00
under × topo3	0.22	0.08	2.59	0.01	
mid × topo2	–0.34	0.19	1.82	0.07	1.00
mid × topo3	–0.47	0.14	3.45	< 0.001	
over × topo2					
over × topo3					
for × topo2					
for × topo3					
shr × topo2	–0.01	0.01	1.17	0.24	1.00
shr × topo3	–0.04	0.01	4.12	< 0.001	
grm × topo2					
grm × topo3					

the criteria defined as the best models ($\Delta AIC_c < 2$) for the species (Table 6). The understory vegetation, midstory vegetation and shrub coverage, topography, understory vegetation × topography, midstory vegetation × topography, and shrub × topography showed higher values of relative variable importance among habitat variables. The midstory vegetation, forb and shrub coverage were highly positively correlated with the winter field sign abundance of Korean water deer (Table 7).

Discussion

Water deer are known to be well adapted to various habitat types, including forest and grassland in temperate climate (Geist 1998, Kim et al. 2011a). To investigate the spatial or geographical characteristics of winter habitat selection, we analyzed field sign abundance in different topographies. In the present study, we found large differences in field sign abundances between topographies. In our study area, field signs were much more abundant on the ridge than on the valley or on the slope. Understory and sub-overstory vegetation, and the shrub and graminoid coverage were higher on the ridge. For Korean water deer, understory vegetation, shrub and graminoid would be good cover and food resources.

In this study, the impact of habitat variables on winter abundance of field signs of Korean water deer varied with topography. We suggest that these topographical differences in resource selection are caused by a trade-off strategy of habitat use (Godvik et al. 2009). The trade-offs between the selection of forage and cover have been reported in the habitat preferences of many species of deer (Mysterud et al. 1999). Because food shortage is a serious problem for deer in winter, Korean water deer need to exploit high-quality foraging area during these months.

The deer need to seek habitats that provide an abundance of forage (Mysterud et al. 1999, Van Beest et al. 2010). In the present study, Korean water deer selected the site with more shrub and graminoids coverage on the ridge during the winter period. Cover, especially forage cover, is essential for Korean water deer because it provides food resources for survival (Lee et al. 2017). Moreover, it was easier for the deer to spot approaching predators from the ridge than the valley and slope. In addition, understory and midstory vegetation coverage were negatively correlated with winter field sign abundance. The deer tend to prefer the ridge and lower coverage in winter because, under these topographic and vegetational conditions, it is easier to spot approaching predators (You 2000).

Understory and midstory vegetation coverage, forage and topography would be important ecological factors affecting winter field sign abundance of Korean water deer. In general, the present study seems to indicate that, while Korean water deer show high ecological plasticity, they are selective with respect to potential winter foraging sites. It has been established that, in lowland area, Korean water deer tend feed on a few specific plants, particularly forbs and grasses (Kim et al. 2011a). Future studies could assess the effect of habitat characteristics on the deer in various environments of South Korea to assist with management of the species.

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Literature

Bailey D.W., Gross J.E., Laca E.A. et al. 1996: Mechanisms that results in large herbivore grazing distribution patterns. *J. Range Manag. 49: 386–400.*

Burnham K.P. & Anderson D.R. 2002: Model selection and multi-model inference: a practical information-theory approach. *Springer, New York, U.S.A.*

Gaillard J., Hebblewhite M., Loison A. et al. 2010: Habitat-performance relationships: finding the right metric at a given spatial scale. *Philos. Trans. R. Soc. Lond. B 365: 2255–2265.*

Geist V. 1998: Deer of the world: their evolution, behaviour, and ecology. *Stackpole Books, Mechanicsburg, U.S.A.*

Godvik I.M.R., Loe L.E., Vik J.O. et al. 2009: Temporal scales, trade-offs, and functional responses in red deer habitat selection. *Ecology 90: 699–710.*

Guo G. & Zhang E. 2005: Diet of the Chinese water deer (*Hydropotes inermis*) in Zhoushan Archipelago, China. *Acta Theriol. Sin. 25: 122–130.*

Hirzel A.H. & Le Lay G. 2008: Habitat suitability modelling and niche theory. *J. Appl. Ecol. 45: 1372–1381.*

Hwang H.S., Son S.H., Kang H. & Rhim S.J. 2014: Ecological factors influencing the winter abundance of mammals in temperate forest. *Folia Zool. 63: 296–300.*

IUCN 2015: The IUCN Red List of threatened species. *IUCN, Gland, Switzerland. http://www.iucnredlist.org*

Kang J.H., Son S.H., Kim K.J. et al. 2013: Effects of logging intensity on small rodents in deciduous forest. *J. Anim. Vet. Adv. 12: 248–252.*

Kim B.J., Lee N.S. & Lee S.D. 2011b: Feeding diets of the Korean water deer (*Hydropotes inermis argyropus*) based on a 202 bp rbcL sequence analysis. *Conserv. Genet. 12: 851–856.*

Kim B.J., Oh D.H., Chun S.H. & Lee S.D. 2011a: Distribution, density, and habitat use of the Korean water deer (*Hydropotes inermis argyropus*) in Korea. *Landsc. Ecol. Eng. 7: 291–297.*

Korea Forest Service 2012: Characteristics of forest structure and wildlife caused by forest practices. *Korea Forest Service, Daejeon, Korea. (in Korean)*

Lee W.S., Park C.R., Rhim S.J. et al. 2017: Wildlife ecology and management, 2nd ed. *Life Science Publishing, Seoul, Korea. (in Korean)*

Lone K., Loe L.E., Gobakken T. et al. 2014: Living and dying in a multi-predator landscape of fear: roe deer are squeezed by contrasting pattern of predation risk imposed by lynx and humans. *Oikos 123: 641–651.*

Mancinelli S., Peters W., Boitani L. et al. 2015: Roe deer summer habitat selection at multiple spatio-temporal scales in an alpine environment. *Hystrix 26: 132–140.*

Manly B.F.J., McDonald L.L., Thomas D.L. et al. 2002: Resource selection by animals: statistical design and analysis for field studies. *Chapman & Hall, London, U.K.*

Mysterud A. & Ims R.A. 1998: Functional responses in habitat use: availability influences relative use in trade-off situations. *Ecology 9: 1435–1441.*

Mysterud A., Lian L.B. & Hjermann D.Ø. 1999: Scale-dependent trade-offs in foraging by European roe deer (*Capreolus capreolus*) during winter. *Can. J. Zool. 77: 1486–1493.*

Rhim S.J. 2013: Hazel grouse winter habitat selection and conservation in temperate forest. *For. Ecol. Manag. 295: 38–42.*

Rhim S.J. & Lee W.S. 2007: Influence of forest fragmentation on the abundance of mammals in Mt. Chirisan National Park, South Korea. *J. Wildlife Manage. 71: 1404–1408.*

Rhim S.J., Son S.H., Hwang H.S. et al. 2015: Characteristics of mammal abundance relative to habitat variables in temperate forests. *For. Sci. Tech. 11: 61–64.*

Said S., Gaillard J.M., Duncan P. et al. 2005: Ecological correlates of home-range size in spring-summer for female roe deer (*Capreolus capreolus*) in a deciduous woodland. *J. Zool. Lond. 267: 301–308.*

Son S.H., Hwang H.S., Lee J.K. et al. 2017: Influence of tree thinning on the abundance of mammals in a Japanese larch *Larix kaempferi* plantation. *Anim. Cells Syst. 21: 70–75.*

Van Beest F.M., Mysterud A., Loe L.E. & Milner J.M. 2010: Forage quantity, quality and depletion as scale dependent mechanisms driving habitat selection of a large browsing herbivore. *J. Anim. Ecol. 79: 910–922.*

Wang S. 1998: China Red Data Book of endangered animal (mammal volume). *Science Press, Beijing, China. (in Chinese)*

Won C.M. & Smith K.G. 1999: History and current status of mammals of the Korean peninsula. *Mammal Rev. 29: 3–36.*

You B.H. 2000: Wildlife take after the green. *Dareunsesang Publishing, Seoul, Korea. (in Korean)*