

Summary of Doctoral Thesis

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UGAS Specialty: Biotic Environmental Science

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Title	Biogeography of carnivore species occurring extensively in the Northern Hemisphere based on ecomorphological and phylogeographic patterns
<p>Biogeography is the investigation of varied environmental determinants that related to the aspects of historical and contemporary distribution of species. Adaptation traits are indicated as the combined result of various aspects such as phylogenetic, morphological, and ecological relationships. Therefore, the historical and contemporary aspects are inseparable. Biogeographic studies have been separated heretofore into historical and biological disciplines, but most practitioners now realize that both perspectives are necessary to explain geographic patterns of inter- or intra-species. Morphological characteristic is one of important phenotypes that reflect on geographic differences of organisms and their adaptations to varying environmental conditions. Morphological variation over different geographics often exhibits predictable patterns caused by environmental adaptation. Of the external morphological characteristics, body size difference is often linked to specific environmental factors, such as climatic difference, food availability, and geographic range. Ecogeographic variation in body size of homeotherms has been demonstrated by skull length as an index of body size. Geographic phenomena explained by specific ecological determinants are called as ecogeographic rule. Ecogeographic rules are often observed in mammals. One of ecogeographic phenomena that explained by adaptation to large body size in conditions of lower temperature and lower humidity called Bergmann's rule. Ecogeographic phenomenon is also observed in the island populations which shows adaptation</p>	

to gigantism or dwarfism of body size in island populations and this called island rule. Adaptation to these ecogeographic rules may explain evolutionary adaptation of mammalian species. Terrestrial carnivore species occurring in wide geographic ranges have remarkable geographic variation in body size due to their high mobility and generalist habits. These species are the most challenging groups to resolve biogeographic patterns. Their high adaptability to various environmental conditions influenced on polymorphic characteristics and variety of phylogeographic outcomes. Of carnivores, raccoon dog (*Nyctereutes procyonoides*) and red fox (*Vulpes vulpes*) have opportunistic feeding habits depending on food availability in various geographic areas. Also, the strong adaptability of these species might be related to their moderate locomotive ability in wide distribution range. Therefore, raccoon dogs and red foxes could be the most ideal model to demonstrate patterns of historical biogeography and ecomorphology influenced by various environmental factors. This study focused on two generalist, raccoon dog and red fox that are distributed in the Northern Hemisphere. To estimate biogeographic and ecomorphological patterns of raccoon dogs and red foxes influenced by various environmental factors, I compared skull morphological variation to various environmental determinants.

This study demonstrated environmental factors that determine the morphogeographic pattern of skull on both species. Firstly, phylogeographic pattern was reflected in the morphogeographic difference of raccoon dog and red fox. Significant correlation between genetic and morphological distances was observed especially between land types. Also, the disparity between phylogenetic and morphological patterns within the land types was interpreted as strong influence on morphological distance with geographic difference. It might be due to the multiple migrations of red foxes, which have high mobility and adaptability to severe winter. This study supports that the raccoon dog and red fox are suitable for speciation model due to the phylogenetic and morphogeographic differences between the land types. Secondly,

morphogeographic patterns of raccoon dog and red fox showed strong conformity to Bergmann's rule and island rule by significant relation to ecological determinants such as geographic gradients, climatic factors, and vegetation differences. Larger skull size of raccoon dog and red fox in cold conditions in continental populations strongly reflected Bergmann's rule. In Japanese Islands, clear influence of Bergmann's rule was observed in the raccoon dogs. However, red foxes showed opposite tendency on the temperature difference between continental and island populations with relatively smaller skull size of Hokkaido population due to the island dwarfism. Although these two species of Japanese Islands had distinct skull morphological characteristics on the temperature, the significantly different influence between continents and islands on the temperature reflects on island effect on Japanese raccoon dogs and Japanese red foxes. These ecogeographic rules for carnivore species could be supported by the present results that cover wide distribution range. Lastly, allometric scaling of mandible measurements in southern populations of raccoon dogs implies similar evolutionary pattern. Raccoon dogs of southern populations had similar allometric scaling in the specific skull characteristics. Also, those similar allometric patterns were observed in the southern populations of red foxes in two continents (the Eurasian and North American Continents). Unique allometric pattern in the mandible of broadly distributed terrestrial mammal species were not always reflect in the phylogenetic background. The present study demonstrated influence of Bergmann's rule and island rule on the raccoon dogs and red foxes. Also, powerful evidences for adaptation was observed between phylogenetically separated taxa were found in the red fox populations. Species that have wide distribution range according to high ability of adaptation show various morphological variations. This could be interpreted as consequence of similar evolutionary pattern within a species. The present study will contribute to understand other mammal species, which are extensively distributed and

have not been fully resolved their biogeographic history.