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(Research note)

Relationships between Habitat and Renal Function in Water Conservation in the Anderson's Red-backed Vole, *Eothenomys andersoni** on the Kii Peninsula, Japan

By

KITAHARA, Eiji(1)

Summary : The present study on the distribution and renal structure of *E. andersoni* on the Kii Peninsula revealed the following : 1) the distribution of *E. andersoni* was vertically broad and horizontally limited to a certain range in a part of Nara, Mie and Wakayama Prefectures ; 2) the distribution was strongly influenced by the amount of annual rainfall in areas of the Kii Peninsula. *E. andersoni* alone occurred in areas whose annual rainfall exceeded 3 000mm and coexisted with *E. smithii* in areas of about 2 500 to 3 000mm, while only *E. smithii* was caught in areas with a rainfall of less than 2 000mm ; and 3) there were significant differences ($P<0.05$) in the thickness and area of the renal medulla measured at the midsagittal section between *E. andersoni* (PMT 73.1±2.3, PMA 41.3±3.6, n=6)and *E. smithii* (PMT 77.7±4.6, PMA 48.4±4.9, n=9) ; consequently *E. andersoni* had the weaker kidney against water shortage stress in comparison with *E. smithii*.

1 Introduction

There have been few reports on the distribution of the small mammals or the fauna inhabiting the Kii Peninsula, most of which consist only of fragmentary trapping records (JAMESON, 1961; KOBAYASHI *et al.*, 1970; TOMITA, 1979; SHIMIZU, 1984; SHIBATA, 1987; KITAHARA and YAMADA, 1987; KITAHARA, 1988). Ecological knowledge about the distribution and habitat of Anderson's vole, *Eothenomys andersoni* (THOMAS) 1905, is particularly scarce. However, *E. andersoni* has begun to attract the attention of foresters as a result of the forest damage it causes.

The aim of this study is to clarify the distribution and habitat peculiarity of this vole on the Kii Peninsula in relation to the amount of annual rainfall. The kidney helps to maintain water balance in the bodies of animals, and renal structure is understood to be closely related to habitat (SPERBER, 1944; YABE, 1983). Thus, another purpose of this study is to elucidate the close relationship between habitat and renal structure of *E. andersoni* in humid areas, by comparison with those of *E. smithii* and *Microtus montebelli*.

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* The scientific name of this vole followed the opinion of Aimi (1980).

(1) Kansai Research Center

2 Materials and Methods

1) Survey of Distribution

Study area

The survey was mainly carried out in the district of Owase Forestry Office (Owase City, Mie Pref.) situated on the east side of the Taikoh Mountain Range lying from south to north on the border between Nara and Mie Prefectures, in the Kumano River Basin (Kami-and Shimo-kitayama Villages, Nara Pref.) on the west side of the range, and at Kiwa Town, Mie Pref. and Shingu City close to Nachi, Wakayama Pref., where *E. andersoni* was caught for the first time on the Kii Peninsula (IMAIZUMI, 1960 ; JAMESON, 1961). The survey sites were Hinoki (*Chmaecyparis obtusa*) plantations aged 5years or less, whose understory consisted of bamboo grass, the so-called 'suzutake', in the Owase District, and mainly of eulalia (*Miscanthus sinensis*) and raspberry (*Rubus palmatus*) in the Kumano River Basin. At the study sites on the Ohdaigahara Plateau, including Mt. Hidegatake, the highest peak in this region, the vegetation is regarded as virgin forest composed of Japanese spruce (*Picea hondoensis*), Japanese hemlock (*Tsuga sieboldii*) and fir (*Abies firma*), and is partially invaded by bamboo grass.

Trapping Procedure

Capture survey was carried out with traps baited with small pieces of sweet potato from May 1985 to January 1990. Cage- and snap-traps were generally used, and occasionally 'panchu' traps. In total, about 350 traps were set 10 m apart in lines and checked early every morning. All rodents captured (Table 1) were brought back to the laboratory for identification, measurement and autopsy.

Table 1. Number of four rodent species captured at different sites.

Locality	Species *			
	E. a.	E. s.	A. a.	A. s.
Nara Pref.				
Kumano River Basin (800 m alt.)	8	40	47	40
Mie Pref.				
Owase District (From 600 to 1 600 m alt.)	25	0	2	6
Kiwa (300 m alt.)	1	0	0	7
Mt. Takami (500 m alt.)	0	14	2	0
Wakayama Pref.				
Shingu (100 m alt.)	2	0	4	3
Mt. Kohya (900 m alt.)	0	7	0	0

* E. a. = *Eothenomys andersoni*, E. s. = *E. smithii*, A. a. = *Apodemus argenteus*, A. s. = *A. speciosus*

2) Renal Morphology

Tissues of the fresh kidneys taken from snap-trapped voles (*E. andersoni*, 3 ♂ 1 ♀; *E. smithii*, 4 ♂ 2 ♀) and cage-trapped ones (*E. a.*, 2♀; *E. s.*, 1 ♂ 2 ♀) were fixed with 10% formalin or FAA solution (formalin : acetic acid : 80% alcohol=5 : 90 : 5), and embedded in paraffin wax. Serial sections (10μm) were stained with Mayer's hematoxylin and eosin, and examined with a microscope at approximately 100 magnification. The thickness of the renal cortex and medulla was measured at the midsagittal section on the screen of the shadow equipment. Renal structure indices were represented by the percentage of medullary thickness (PMT) (HEISINGER and BREITENBACH, 1969; HEISINGER *et al.*, 1973) and the percentage of medullary area (PMA) (BROWNFIELD and WUNDER, 1976). In order to enable comparison with 2 *Eothenomys* species, the kidneys fixed with FAA solution from cage-trapped *Microtus montebelli* (4 ♂ 3 ♀) from Kyoto Prefecture were dealt with in the method described above.

3 Results

1) Capture Records

The results of the capture survey are summarized in Table 1. Four species of rodents (*E. andersoni*, *E. smithii*, *Apodemus speciosus* and *A. argenteus*) were captured in the Kumano River Basin, including Kami- and Shimo-kitayama Villages in Nara Prefecture. Although *E. andersoni* as well the *Apodemus* species was caught in the Owase District on the east side of Mt. Hidegatake, Kiwa Town and Shingu City, *E. smithii* was not captured there. Considering the vertical distribution of *E. andersoni*, it widely inhabited Shingu City (100m alt.), Yanoko (600m alt.) and Mt. Hidegatake (1 600m alt.) in the Owase District, but its horizontal distribution was limited to the Kumano River Basin, the area around Nachi and a part of the Owase District. Capture sites of *E. andersoni* and *E. smithii*, whose ecological niches resemble each other, are shown in Fig. 1. It may be readily comprehended from Fig. 1 that *E. andersoni* was distributed on the borders between Mie and Nara Prefectures and between Mie and Wakayama Prefectures, but that the capture site of this vole alone was limited to the Owase District situated on the east side of Mt. Hidegatake in Mie Prefecture and the northwest region of Shingu City in Wakayama Prefecture.

2) Renal structure of the three vole species

With respect to renal structures (Fig. 2), out of the 3 species concerned, *E. smithii* had the thickest medulla (PMT 77.7±4.6, PMA 48.4±4.9, n=9), conversely *M. montebelli* had the thinnest (PMT 68.9 ±5.0, PMA 36.2±5.5, n=7), and *E. andersoni* an intermediate thickness (PMT 73.1±2.3, PMA 41.3±3.6, n=6). There were significant differences ($P<0.05$) between them, although samples were not really sufficient in number.

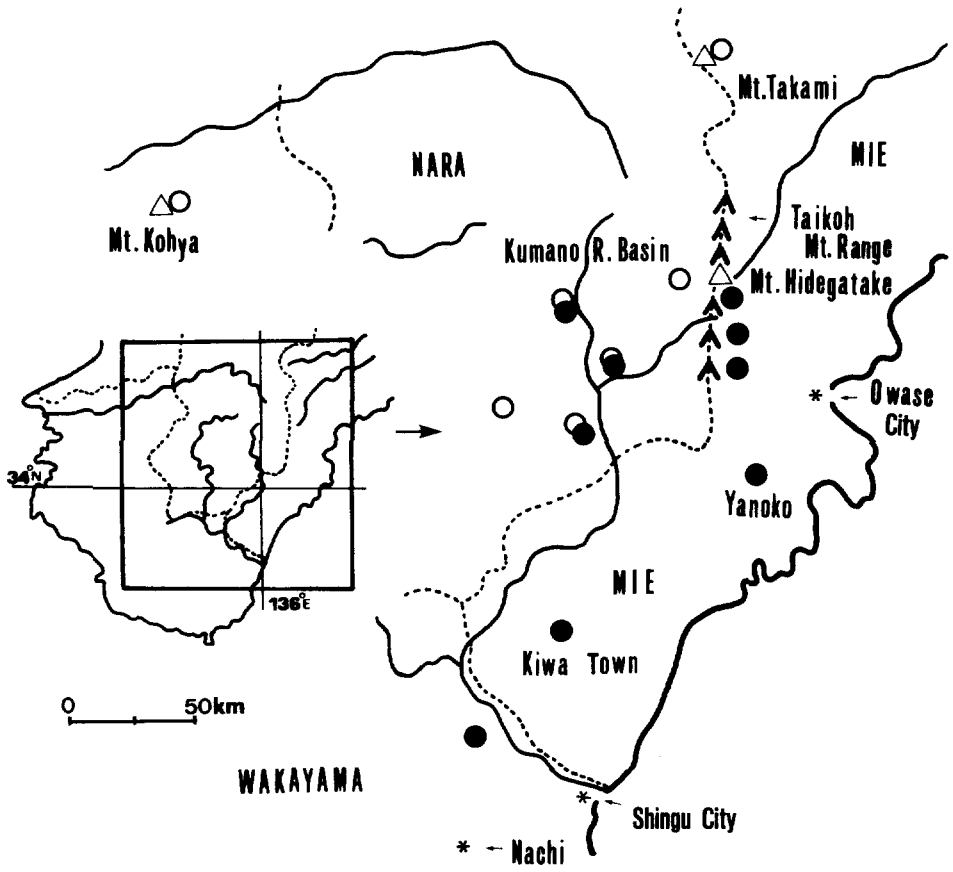

Fig. 1. Study areas and capture sites of *Eothenomys andersoni* (●) and *E. smithii* (○) in the Kii Peninsula.

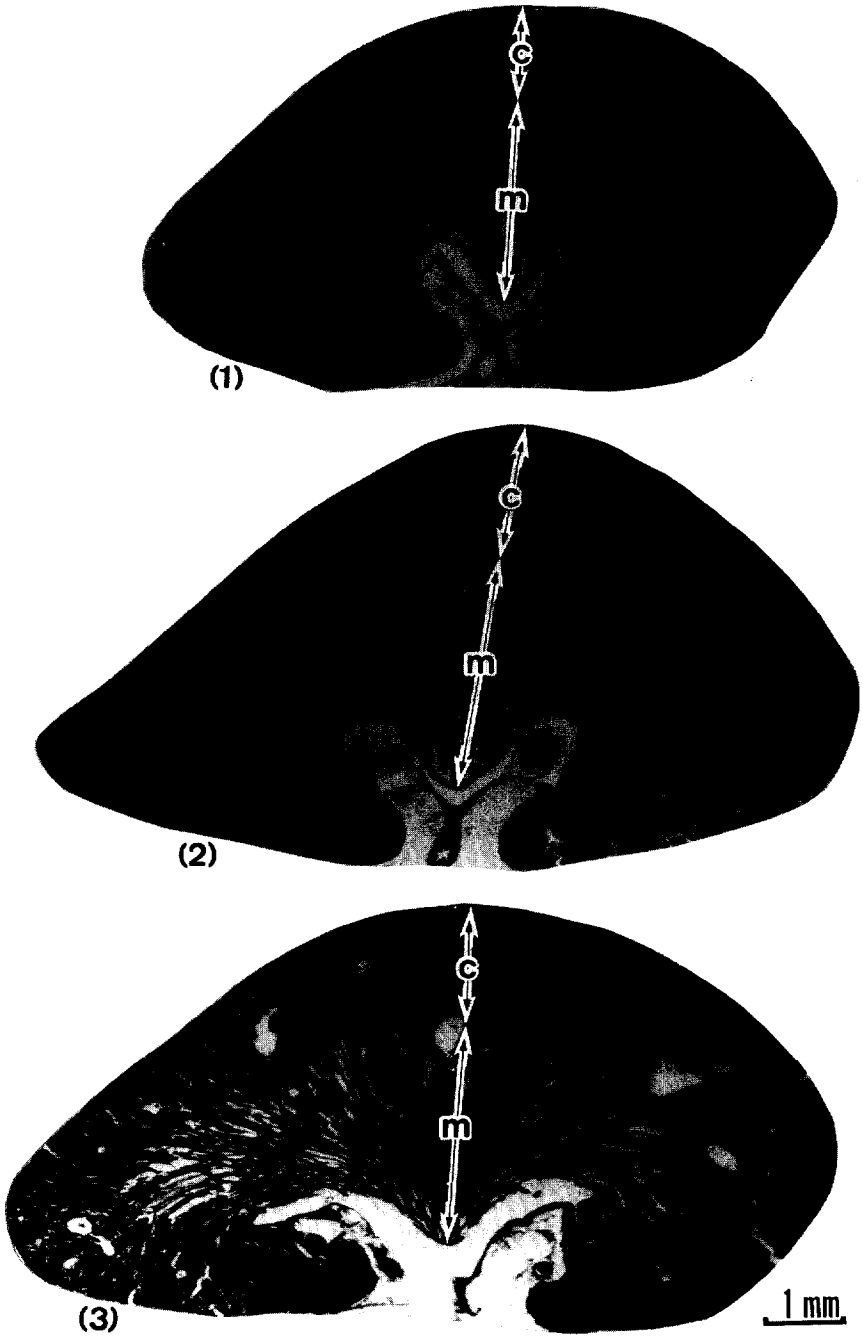

Fig. 2. Renal midsagittal sections of *Eothenomys smithii* (1), *E. andersoni* (2) and *Microtus montebelli* (3)
c, Cortex: m, Medulla.

4 Discussion

1) Relationships between the peculiar distribution of *E. andersoni* and annual rainfall in the Kii Peninsula

Earlier reports are simply of capture results or fauna records of small mammals and do not deal with causes of distribution in depth. *E. andersoni* has been reported to be distributed over a horizontally broad area in the Kii Peninsula (SHIMIZU, 1984, 1987). The present study, however, revealed that *E. andersoni* inhabited a certain range on the borderlines between Mie and Nara Prefectures and between Mie and Wakayama Prefectures. It is well known that the area concerned has a heavy annual rainfall and produces timber of high quality. According to the annual rainfall data in meteorological reports published by each of the three prefectural branches (MIE, NARA and WAKAYAMA BRANCHES of JPN WEATHER ASSOC., 1988), the heaviest rainfall is that of the Owase District with more over 4 100mm, the second that of Mt. Hidegatake with about 3 800mm, and the next that of Shingu City with 3 700mm. Kami- and Shimo-kitayama Villages, where both *E. andersoni* and *E. smithii* were caught, have a rainfall of about 2 500mm. Thus, it was revealed that *E. andersoni* alone occurred in areas whose rainfall exceeded 3 000mm and coexisted with *E. smithii* in areas with a rainfall of about 2 500 to 3 000mm. Upon considering in more detail the areas with a rainfall of less than 2 000mm, it can be seen that only *E. smithii* was caught on Mt. Takami on the northern most edge of the Taikoh Mountain Range, Mie Prefecture and on Mt. Kohya, Wakayama Prefecture.

As for the vertical distribution of *E. andersoni*, the vole was widely captured from Shingu City (100m alt.) to Mt. Hidegatake (nearly 1 600m alt.). In Nagano Prefecture, it was reported that *E. andersoni* ranged from sub-alpine to alpine zones, whereas *E. smithii* occured from low mountains to sub-alpine zones (MIYAO *et al.*, 1963; MIYAO, 1967). It is worthy of note that *E. andersoni* coexisted with *E. smithii* in the low land (360m alt.) with a rainfall of 2 700mm in the Tohoku region (OHTSU, 1969; YAMAGATA BRANCH of JPN WEATHER ASSOC., 1988). The peculiar distribution of *E. andersoni*, which is vertically broad, but horizontally limited to a small range, well explains an assumption that it is closely related to the amount of annual rainfall at each site in the Kii Peninsula. According to MIYAO *et al.* (1979), *E. andersoni* in central Honshu is fond of wet slopes facing the north or west, where bamboo grass and other grasses grow densely as a habitat. Mt. Yatsugatake (Mt. Akadake), which *E. andersoni* inhabits, also has annual precipitation of 3 300mm (NAGANO PREFECTURAL ENTERPRISE BUREAU, 1972). This fact seems to supply important ground for the assumption that the distribution of *E. andersoni* is closely associated with the amount of rainfall in the Kii Peninsula.

2) Relationships between peculiar distribution and renal structure in *E. andersoni*

The mammalian kidney consists basically of the cortex and medulla. Since the long and short

loops of Henle in the medulla act to concentrate urine (DANTZLER, 1989), animals are able to maintain body water balance. Therefore, a large ratio of medulla thickness against total renal thickness represents a high water conservation ability in the animal body (SPERBER, 1944; SCHMIDT-NIELSEN and O'DELL, 1961). SPERBER (1944) discussed the relationship of the renal structure with mammal habitats, and concluded that animals inhabiting a more arid habitat possess kidneys with a thicker medulla. Afterward, the same conclusions were drawn concerning the relation between urine concentrating ability and the renal structure in several species (NORMAN and BAUDINETTE, 1969 for *Rattus rattus*; HEISINGER *et al.*, 1973 for 9 species of Cricetidae; YABE, 1983 for *Mus molossinus* and *Rattus norvegicus*; RICKARD, 1989 for *Spermophilus townsendii* complex; GELUSO, 1978 for 11 species of insectivorous bats; BASSETT, 1986 for 24 species of insectivorous bats).

The differences between the 3 species concerned indicated that *E. smithii* had the strongest ability to conserve body water, *Microtus montebelli* had the weakest and that of *E. andersoni* lay between them. As for the 2 *Eothenomys* species, *E. andersoni* is fond of inhabiting humid sites, whereas *E. smithii* can live even in arid places. Consequently, the peculiar (vertically broad but horizontally limited) distribution of *E. andersoni* is regarded as being related to the difference in precipitation in areas of the Kii Peninsula, and the cause of the distributional disparity between the 2 species seems due to the difference in renal structure. In other words, this suggests that *E. andersoni* experiences difficulty physiologically living in habitats suitable for *E. smithii*. However, the reason why *E. smithii* did not invade habitats suitable for *E. andersoni* is not clear and is difficult to explain only by means of resistance against water shortage stress; it may be concerned with the extent of interspecific competition between them.

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（研　究　資　料）

紀伊半島産ヤチネズミにおける生息環境と腎臓の水分保持力との関連性

北原英治

摘　　要

最近、三重県尾鷲営林署管内においてヤチネズミによる林木被害が見られるようになり注目されている。そこで、紀伊半島産ヤチネズミの分布と、それを規制すると思われる水分保持力の一指標としての腎臓構造について調べた結果、以下のことが分かった。1)ヤチネズミの分布は垂直的には幅広いが、水平的には三重・奈良・和歌山3県の一部の狭い地域に限られていること、2)その分布は紀伊半島各地での年間雨量の多寡によって影響されており、ヤチネズミは年間3 000 mmを越す地域では単独で生息し、2 500～3 000 mmの地域ではスミスネズミと混棲し、2 000 mm以下の地域にはスミスネズミだけが分布していること、3)ヤチネズミ（PMT 73.1±2.3, PMA 41.3±3.6, n=6)とスミスネズミ(PMT 77.7±4.6, PMA 48.4±4.9, n=9)との間には水分利用効率（水分保持力）の一指標である腎臓髄質部の厚さと面積に差異が認められ(P<0.05)、ヤチネズミはスミスネズミに比して水分ストレスに弱いことが明らかとなった。