



**ECOLOGY AND CONSERVATION OF
THE RACCOON DOG (*Nyctereutes procyonoides*)
IN JAPAN**

by
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ABSTRACT

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ECOLOGY AND CONSERVATION OF THE RACCOON DOG (*Nyctereutes procyonoides*) IN JAPAN

Raccoon dogs (*Nyctereutes procyonoides viverrinus* Temminck) were used as a model species to study wildlife management and conservation issues in the countryside of Japan. Radio-tracking data were used to analyse habitat use, movements, home range configuration and stability, social aspects, and factors influencing raccoon dog behaviour. Comparisons were drawn with European badgers (*Meles meles* Linnaeus) in the UK in order to highlight aspects of movements and habitat use of omnivorous Carnivores. Two key issues concerning the conservation of raccoon dogs in Japan were investigated: road-kills and agricultural damage. The Japan Highway Public Corporation provided road-kill data on the National Expressways, and a questionnaire survey was conducted on agricultural damage to local governments, authorities of wildlife administration. Socio-cultural issues on wildlife conservation in Japan were critically reviewed and discussed.

Two types of habitat users appeared to exist in the study area. One type of raccoon dogs ('mountain type') inhabited a more semi-natural environment, including secondary forest and herbaceous areas, whereas a second type ('village type') inhabited more managed environments, such as rice fields and cropland. The results suggested that habitat selection occurred at home-range and location scales and differed between the two types of raccoon dogs.

The mean size of home range of the raccoon dogs was 111 ± 16.9 ha (95% kernel estimate) and 160 ± 34.5 ha (95% maximum convex polygon (MCP)). There was no significant difference in home-range size between age classes or sexes. Seasonal home ranges were larger in yearlings than adults, and largest in autumn; and there was no difference between sexes. Season affected nightly movements, i.e. mean inter-fix speed, mean 100% MCP, and mean range span over the night; however, sex and age did not. All variables of nightly movement were smallest in winter. The mean fractal dimension of movements, i.e. degree of 'tortuosity' with self similarity, was 1.226 and significantly differed from 1.0 (a straight line) and 2.0 (a Brownian random movement). The mountain type had significantly larger fractal dimension than the village type, possibly reflecting habitat complexity and/or heterogeneity.

Badgers generally preferred pasture and avoided arable habitat, but showed some variability by year and at scales of selection. A Badger Removal Operation may have influenced habitat selection of the badgers. The mean size of home range of badgers was 56.1 ± 7.7 ha (95% kernel estimates) and 56.2 ± 7.3 ha (95% MCP). The mean fractal dimension of the badgers' movements was 1.198 and was significantly different from 1.0 and 2.0. The raccoon dogs and the badgers showed similarities in movements, such as nightly home range, range span over night, and fractal dimension of movements. Sexual differences in spatial use existed in badgers but not in raccoon dogs.

Road-kills of raccoon dogs appeared to be the highest, in percentage terms, of all wildlife species in Japan and this figure was linearly related to the traffic. Some road-features, such as whether the road was in a cutting and its proximity to water, were positively associated with road-kills, while the presence of coniferous plantations as roadside habitat was dissociated with road-kills. Nationwide estimates of road-kills of raccoon dogs, based on available data for National Expressways only, were made with different assumptions. Conservative estimates put the number of road-kills at 110,000 - 370,000 per year. The potential for road-kill numbers to be used, after controlling for traffic data, as an index of population trends, is discussed.

In a questionnaire survey of agricultural damage sent to 46 prefectures, all respondents (96%) reported some damage by wildlife, and over 80% of respondents reported macaque and boar damage, while nearly 70 % reported raccoon dog and deer damage. Sixty-nine agricultural products were reported to have been damaged by wildlife, and 41 of these by raccoon dogs. Maize and fruits were major crops damaged by raccoon dogs. Although about a half of respondents employed culling, its effectiveness is unclear.

Although Japan seems far behind other developing countries in its approach to wildlife conservation issues, the situation could be substantially improved through increased scientific understanding and education. Radical changes may be also required in the legal status of wildlife and its management schemes.

To my dog Ken
and those days we spent together

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CHAPTER 1

GENERAL INTRODUCTION

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Summary

This chapter describes the general background and current knowledge of the raccoon dog (*Nyctereutes procyonoides*) and problems concerning conservation of the subspecies (*N. p. viverrinus*) in Japan. The purposes and goals of this study are summarised.

Poko, raised by humans.
She was pregnant when this
photo was taken. A wild male often
visited her and provisioned food to her
and, later, to their pups. Note her four pairs of
teats and dog-like paws, also her submissive posture.
(Photo by Yayoi Hayashida)



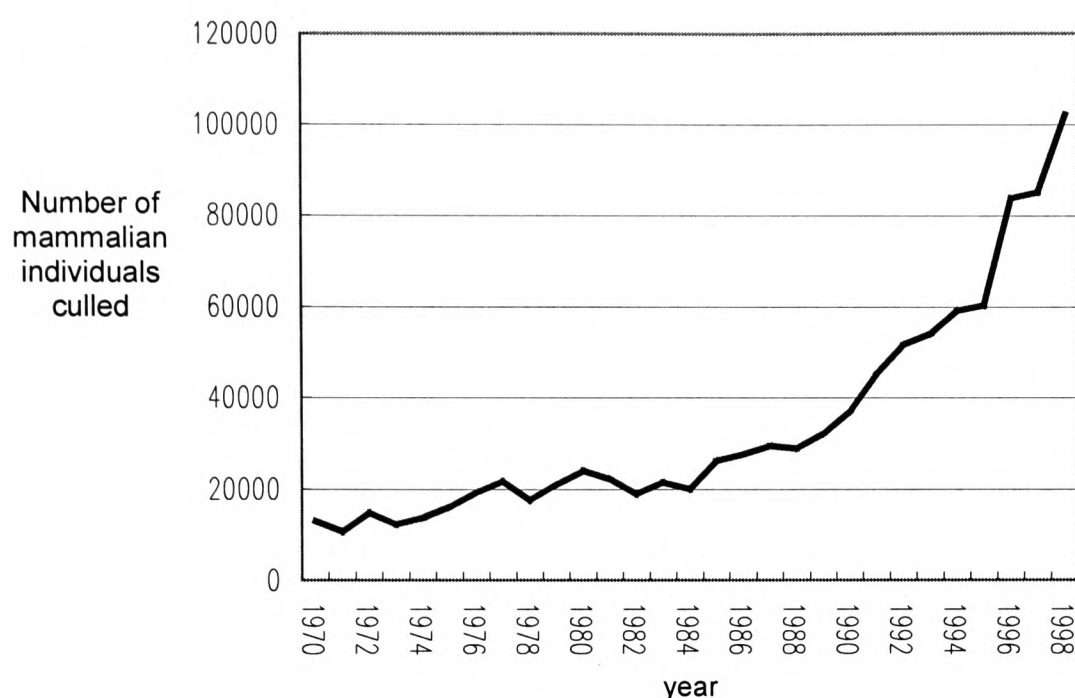
Chapter 1 General Introduction

1.1 INTRODUCTION

Japan has frequently been accused of irresponsible activities relating to wildlife conservation, particularly by the United States and Europe (Stewart-Smith, 1987; Potter, 1994; Danaher, 1999; Cryanski, 2000; Normile, 2000; Saegusa, 2000). There is some evidence to suggest that attitudes towards wildlife in Japan do seem to differ from those of developed Western nations (Kellert, 1991; Chapter 8). Whilst wildlife engenders both strong empathy and utilitarian viewpoints, a lack of ecological knowledge and resentment against pressures from the West are common amongst the Asian nations (McDowell, 1989). Wildlife conservation in Japan faces conceptual and logistic difficulties. For example, nature conservation has generally focused on maintaining greenery by planting or preserving vegetation, and on reducing pollution, without much attention to wildlife and its habitat. Legal enforcement for wildlife crimes, such as poaching and smuggling wildlife and its products, is far from being adequate (Japan Wildlife Conservation Society, 2000, 2001; Chapter 8; Appendix III). Levels of wildlife culled have grown exponentially since the 1970s (Figure 1.1); however, no nationwide scheme or system has been established for wildlife conservation and management in Japan (Lawyers' Association of Japan, 1999). In order to improve current conditions, awareness of wildlife conservation issues needs to be raised and considered at a national level. In this thesis, I use raccoon dogs (*Nyctereutes procyonoides viverrinus* Temminck), known as *tanuki*ⁱ in Japan, as a model species to consider some of the key issues facing wildlife conservation in Japan and to explore how conflicts associated with the co-existence of humans and wildlife in Japan may be addressed.

ⁱ Note is given at the end of the chapter.

Figure 1.1 Total number of mammalian individuals, excluding hareⁱⁱ (*Lepus brachyurus* and *L. timidus ainu*) culled in Japan between 1970 and 1998. (data from the Environment Agency)



Raccoon dogs were chosen for this study because, in Japan, 1) they represent common, wide-ranging wildlife, 2) scientific knowledge of the species is limited, and 3) the habitats they occupy bring them into conflicts with human activities. Raccoon dogs are a native species and not considered to be rare in Japan. They are the species most hunted for their fur (Environment Agency, 1972-1999; Figure 8.2 in Chapter 8) and are major victims of road-kills (Chapter 6). In addition, levels of culling have increased (Environment Agency, 1972-1999; Figure 1.7). The wide range of habitat types they occupy exposes the species to influences from development and habitat degradation. Raising awareness of conservation issues relating to raccoon dogs is a particular challenge because of the general view that wildlife conservation should be considered only when species become rare; in Japan, conservation or restoration of habitats seldom takes place even for endangered species (Chapter 8). By increasing understanding of the species, conflicts between people and raccoon dogs may be addressed by developing better management systems. Research findings related to this species may also be applicable to other wildlife species in Japan, such as badgers (*Meles meles* Linnaeus) and foxes (*Vulpes vulpes* Linnaeus). Furthermore, raccoon dogs may provide excellent opportunities to study wildlife ecology and conflicts with human in quite different ecosystems (e.g. high mountains, urban areas, and countryside) because of their wide distribution in Japan.

Outcomes of the study on raccoon dogs will enhance general understanding for

ⁱⁱ Note is given at the end of the chapter.

wildlife and may help conservation of other species in Japan. I believe that the establishment of wildlife conservation is best realised through considering co-existence with common native species, such as the raccoon dog. Because scientific research on native wildlife is very limited in Japan (Chapter 8), studies such as this are very valuable.

1.2 THE RACCOON DOG

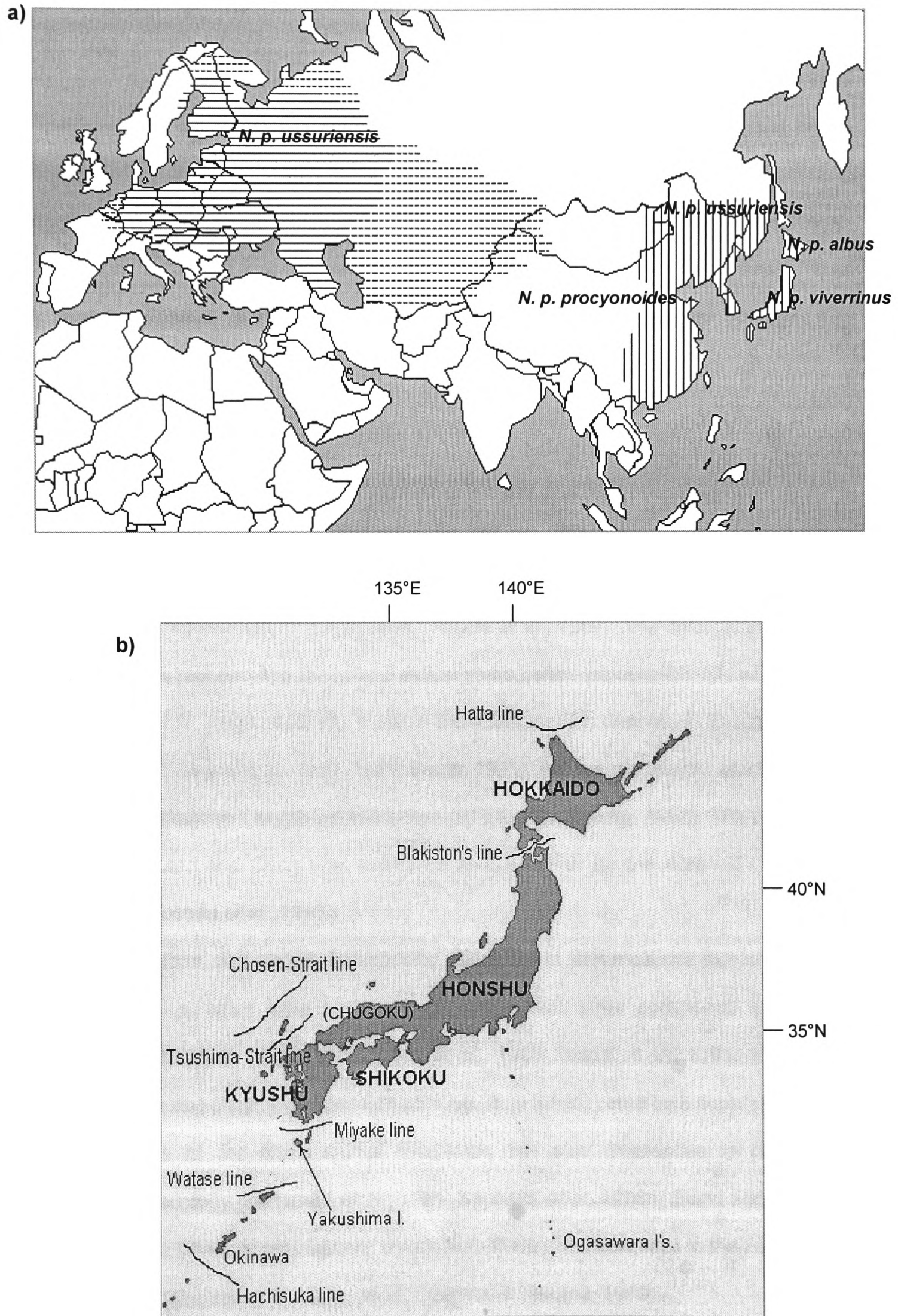
1.2.1 General background and status

Distribution

Raccoon dogs (*Nyctereutes procyonoides* Gray) are medium-sized (3 to 10 kg) canids endemic to eastern Asia. They inhabit a range of environments from urban to sub-alpine zones and from sub-tropical to sub-arctic areas, although their original range was restricted to eastern Siberia, central to eastern China, the Korean peninsula, northern Indochina, and the Japanese Archipelago (Allen, 1938; Granger, 1938; Kuroda, 1939; Bibrinskii, 1944; Stains, 1975; Corbet, 1978; Corbet and Hill, 1992; Figure 1.2a).

The single genus comprises one species with at least five or six subspecies (Ellerman and Morrison-Scott, 1951; Heptner *et al.*, 1974; Ward *et al.*, 1987; Zhao *et al.*, 1994; Figure 1.2a). The subspecies *N. p. ussuriensis* Matschie was introduced into the European part of the former USSR from the 1920s to the 1950s (Lavrov, 1971), thereby expanding their range (Lever, 1985; Mitchell-Jones *et al.*, 1999; Figure 1.2a). Two subspecies inhabit Japan: *N. p. viverrinus* is found on the main Island (Honshu), two other major islands (Shikoku and Kyushu) and many islets between the Blakiston's line and the Miyake line, while *N. p. albus* Hornaday inhabits Hokkaido (Figure 1.2b). A breeding population of raccoon dogs (most likely the subspecies *N. p. viverrinus*) was recently found on Yakushima Island, where they had not previously been known to occur (S. Azuma, personal communication; Figure 1.2b).

Figure 1.2 (a) Endemic (vertical line) and introduced (horizontal line) ranges of raccoon dog in the world and (b) Japanese Islands with zoogeographic lines. The dashed lines indicate a lack of information or no breeding populations confirmed.



Palaeontology

The fossil record of the raccoon dog in Japan (e.g. *N. viverrinus genitor*, *N. p. okuensis*, and *N. p. nipponicus*), and the land bridge formation indicate that the raccoon dog probably entered Japan in the Pleistocene between 18,000 and 12,000 years before present from Korea through the Tsushima and Korean land bridge and/or from Sakhalin through the Soya land bridge (Shikama, 1949; Ward *et al.*, 1987; Kawamura, 1991). Raccoon dogs may be an "expanding Hondo endemic," a species that differentiated by the Middle Pleistocene (Dobson, 1994) or an "early colonist," a species that colonised but had not speciated in Hondo, i.e. a larger unit of three islands, Honshu, Shikoku, and Kyushu, by the Middle Pleistocene (Dobson and Kawamura, 1998).

Phylogeny and Karyotypes

Chromosomes of the raccoon dog show a high homology to the Arctic fox (*Alopex lagopus* Linnaeus), the kit fox (*V. macrotis* Merriam), the red fox, and the grey wolf (*Canis lupus* Linnaeus), and some of the racoon dog's metacentric autosomes are homologous to the felids, suggesting the primitive origin of this species (Wayne *et al.*, 1987). The divergence between the red fox and the raccoon dog occurred 5 million years before present (MYBP) according to the fossil record of *N. megamastoides* found in the Villafranchian deposits in Europe (Wayne and O'Brien, 1987; Wayne *et al.*, 1987, 1991; Bauer, 1991); this is supported by examination of mtDNA restriction fragment length polymorphism (RFLP) (Shi Li-ming, 1996). The divergence between *Nyctereutes* and *Canis* was estimated as 6.6 MYBP by the rDNA-RFLP method (Hosoda, 1993; Hosoda *et al.*, 1993).

The raccoon dog shows intraspecific variability in chromosome numberⁱⁱⁱ. *N. p. viverrinus* and *N. p. albus* have fewer chromosomes than other continental subspecies (Makinen, 1974; Makinen *et al.*, 1986; Ward *et al.*, 1987; Wada *et al.*, 1991, 1998). The Japanese raccoon dog (*N. p. viverrinus* and possibly, *N. p. albus*) could be a separate species not only because of the chromosomal difference, but also differences in physiology, morphology, and ecology (Korhonen *et al.*, 1991; Kauhala, *et al.* 1998b; Saeki and Kauhala, 2001; Kauhala and Saeki, in preparation). In addition, there are differences in the karyotypes^{iv} in *N. p. viverrinus* (Yoshida and Wada, 1984; Obara and Nakano, 1989).

ⁱⁱⁱ & ^{iv} Notes are given at the end of the chapter.

Tanuki vs. the Finnish raccoon dog

Body size and litter size of *N. p. viverrinus* tend to be smaller than in continental subspecies (Bannikov, 1964; Judin, 1977; Ikeda, 1983; Korhonen *et al.*, 1991; Kauhala, 1996a; Kauhala *et al.*, 1998b). The mean body weight of raccoon dogs in Honshu was 4.5 kg for both sexes (n = 43 for males and n = 29 for females)(Saeki in preparation), whereas the Finnish raccoon dogs weighed 5 to 10 kg (Kauhala, 1993). There are several comparative studies on physiology and morphology in Finnish and Japanese raccoon dogs. The pattern of seasonal body-weight is similar in both Finnish and Japanese raccoon dogs; however, the magnitude of seasonal change differs greatly. A study by Korhonen *et al.* (1991) showed the Finnish raccoon dog to gain twice as much weight in early summer (May-July) as the Japanese raccoon dog, and have a greater energy intake. Insulating fur, fat reserves, and an efficient metabolic response to cold stress enable the Finnish raccoon dog to tolerate extremely low temperatures (Korhonen and Harri, 1984; Korhonen *et al.*, 1984, 1985; Korhonen, 1987). Skulls and teeth of the Finnish raccoon dog are larger than those of the Japanese raccoon dog, except for the larger molars (in relative measurements for all molars and absolute measurements for M2) in the Japanese raccoon dog (Kauhala *et al.*, 1998b). The diets also differ between the subspecies. Although both are omnivorous, the Finnish raccoon dog is more carnivorous, feeding on more small mammals, while the Japanese raccoon dog is more omnivorous, feeding on harder foods such as insects and coarse plant materials. The diet difference probably led to the overall larger tooth size (in absolute measurements) in the Finnish raccoon dog and the larger molars in the Japanese raccoon dog (Kauhala *et al.*, 1998b). The larger body size of the Finnish raccoon dog is probably adaptations to the colder climate (Kauhala *et al.*, 1998b) additional to the fat reserve that makes them winter sleep possible (Kauhala, personal communication).

Reproductive ecology and physiology

The raccoon dog is basically monogamous, although Ward and Wurster-Hill (1990) noted that an oestrous female may be courted by several males. Pair bonds may last consecutive years (Yashiki, 1987; Yachimori, 1997). In Japan, mating (lasting a few days) takes place between February and April, followed by parturition two months later. Both males and females exhibit parental care (Stroganov, 1962; Bannikov, 1964; Okuzaki, 1979; Ikeda, 1983; Yamamoto, 1984b). Parents take turns attending the den site for 30 to 50 days (Fukue, 1991; Kauhala *et al.*,

1998a; Chapter 4), and they move together with the pups for another month or so after the pups emerge from the den site.

The basic reproductive physiology of the raccoon dog is similar to that of other canids^v. Testosterone levels in males peak in February-March in Japan, and progesterone levels in females coincide, even in the absence of males, suggesting that the raccoon dog is a monoestrous, seasonal and spontaneous ovulator (Yoshioka *et al.*, 1990). Raccoon dogs reach sexual maturity at 9 to 11 months, although yearling females tend to ovulate later than older females (Helle and Kauhala, 1995; M. Saeki, pers. obs.). The raccoon dog also shows a back-to-back copulatory posture due to a copulatory tie like most Canidae (Ikeda, 1982).

Home range and Habitat

The home-range size of the raccoon dog varies enormously (Ikeda *et al.*, 1979; Ikeda, 1982; Ward and Wuster-Hill, 1989; Fukue, 1991; Kauhala *et al.*, 1993a; Yamamoto, 1993; Yamamoto *et al.*, 1994; Table 4.1 in Chapter 4), even taking into consideration the different methods and the different periods used for estimation. The home-range sizes of breeding pairs during a nursing season were smaller than those of non-breeding individuals and home ranges in other seasons (Fukue, 1991; Yachimori, 1997; Chapter 4). In addition, home ranges may be restricted in those months when snow is on the ground (Yachimori, 1997), and the animals may undergo winter sleep where winter climate is severe (Bannikov, 1964).

Raccoon dogs are known to use areas close to water (Allen, 1938), much like raccoons (*Procyon lotor* Linnaeus) (Fritzell, 1978). Seasonal difference in habitat use was reported in Finland, where raccoon dogs favoured shore areas in summer and used more of the old moist heaths in autumn where food was abundant (Kauhala, 1996b). In Japan, raccoon dogs use a range of habitats, including deciduous forests, broad-leaved evergreen forests, mixed forests, farmland and urban areas, from coastal to sub-alpine zones throughout the country (Ikeda, 1992; Environment Agency, 1992). In urban habitats, raccoon dogs have been shown to inhabit areas which have forest cover, varying from $\geq 20\%$ in Tokyo (Nojima, 1988) to $\geq 5\%$ in Kawasaki-city (Yamamoto *et al.*, 1995). Animals killed by traffic accidents were older in areas with $\geq 15\%$ of forest cover than in areas with $< 15\%$ of forest cover (Yamamoto *et al.*, 1995), suggesting the importance of forest cover for long-term survival.

^v Note is given at the end of the chapter.

Social aspects

The social unit is a breeding pair, and some non-paired adult individuals may stay in a group or within the same area (Kauhala and Helle, 1994; Yachimori, 1997; M. Saeki, pers. obs.). Non-paired adults usually travel alone. Latrine sites are shared by several individuals (Ikeda, 1982, 1984), and raccoon dogs can distinguish faeces of unknown conspecifics from their own (Yamamoto, 1984a). However, they probably do not use latrines as territorial boundary markings (Yamamoto and Hidaka, 1984).

Offspring start to move independently from the parents within the same range in late summer to autumn. Some juveniles start to disperse in the same autumn while others remain in the area. In Japan, juvenile dispersal was found to range from 2 to 10 km (Yamamoto *et al.*, 1994; Yachimori, 1997; M. Saeki, pers. obs.), although in Finland, 17% of juveniles moved >40 km, as far as 200 km (Kauhala and Helle, 1994). There was no difference in the distance of dispersal between sexes (Kauhala and Helle, 1994; Yachimori, 1997).

They do not bark like domestic dogs (*Canis familiaris* Linnaeus) but, in captivity at least, they growl or groan (M. Saeki, pers. obs.); their vocalisations are higher in tone than those of domestic dogs and more or less resemble those of domestic cats (Ikeda, 1985; M. Saeki, pers. obs.). The threatening posture is similar to that of felids, with an arched back, but the submissive posture is a lowered body consistent with that of canids (Ikeda, 1982; Masui, 1987), and, in captivity, they may show their belly (photograph on page 2).

Population in Japan

Although there are no nationwide data on the population density of the raccoon dog in Japan, the harvest density (Figure 1.3) and the road-kill density (Figure 1.4) may provide some indication of geographical variation in the population density in Japan. The harvest density was calculated from the annual legal harvest (mainly for fur and as a sport with some local culling) summed up by prefecture (data from the Ministry of Environment), and road-kill density was calculated from the reported number of road-kills on the National Expressways by roads (data from the Japan Highway Public Corporation). Kyushu and Chugoku (i.e. western part of Honshu) regions were relatively high; Hokkaido and two big cities, Osaka and Tokyo, appeared to be low in both density indices (Figures 1.3 and 1.4). The densities exhibit a clinal trend, with

lower densities in the north-east and higher densities in the south-west. Several factors may contribute to this trend: food availability, the length of the snowbound period, and extreme urbanisation. In addition, the population of the raccoon dog may have been fragmented slightly, according to the comparison of the distribution maps between the second survey (1979) and the fourth survey (1989-1992) (Environment Agency, 1979, 1992).

Figure 1.3 Average annual harvest density (animal/km²) of the raccoon dog in 1990-1998. (*N. p. albus* in Hokkaido)

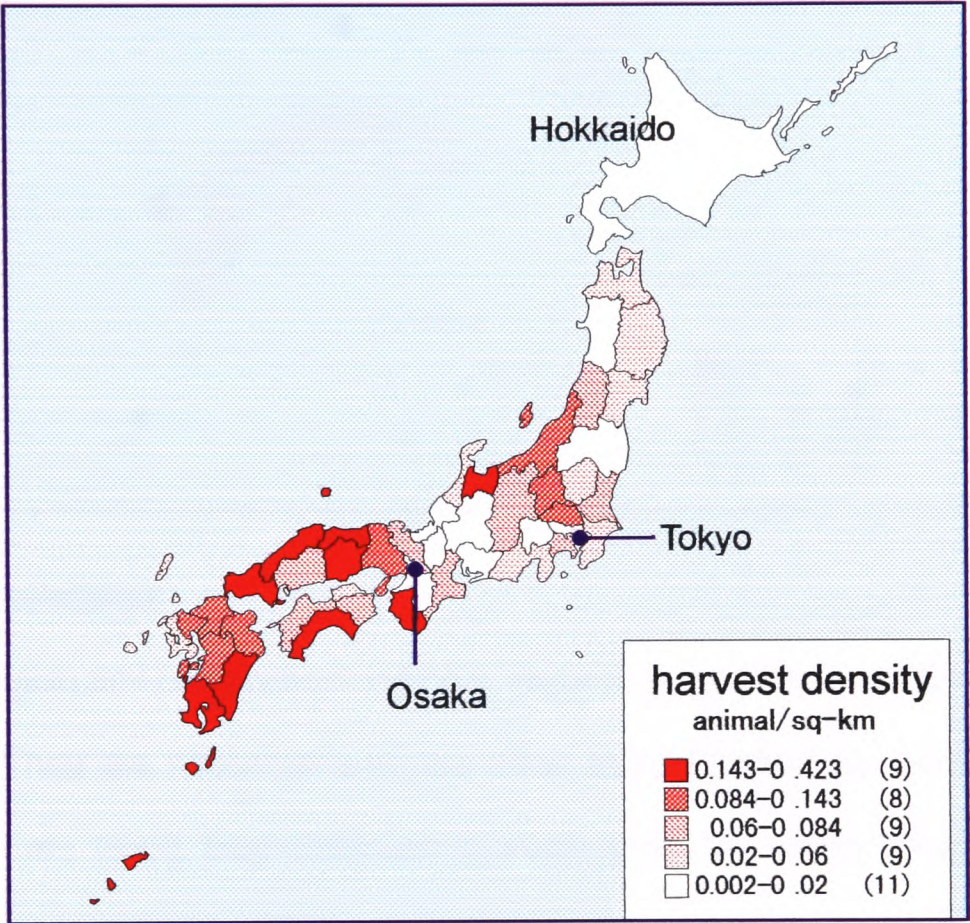
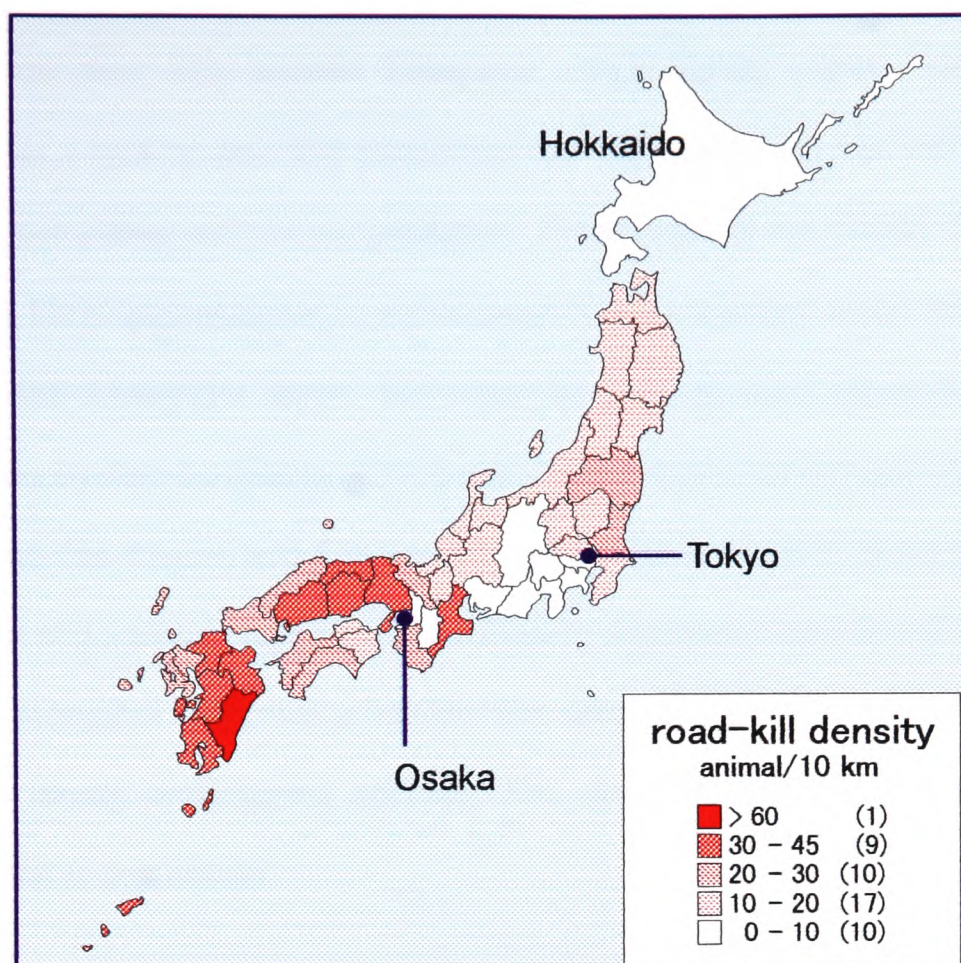


Figure 1.4 Road-kill density (animal/10-km) of the raccoon dog on the National Expressways in 1998. (*N. p. albus* in Hokkaido)



Other characteristics

As both English and Latin names indicate, raccoon dogs share the dark facial mask common to raccoons. They are nocturnal and can climb trees (Yoshimura, 1940) but, unlike raccoons (Mugaas *et al.*, 1993), they hibernate in areas where the winter climate is severe (Bannikov, 1964; Kauhala and Helle, 1994).

The raccoon dog used to be raised on farms for fur in Japan, which was largely exported to the USA before World War II (Kitamura, 1934). They are considered to be a game species, but no conservation or management plans are in place for raccoon dogs, except for removal operations and culling. Only one population, on Mukojima island, has been designated as a natural monument and is protected from hunting; however, for reasons as yet unknown, the population on the island recently has suffered a decline (H. Ikeda, personal communication).

Ecological studies in Japan

Ecological studies of raccoon dogs have been conducted in Japan on islets (Ikeda *et al.* 1979; Ikeda 1982), in urban areas (Fukue, 1991; Yamamoto, 1993; Yamamoto *et al.*, 1995), in a sub-alpine zone (Yamamoto *et al.*, 1994; Yachimori, 1997), in a plateau with garbage sites

(Ikeda, 1982; Ward and Wurster-Hill, 1989), in a forest ridge (Ward and Wurster-Hill, 1989) and at feeding sites (Izumi, 1982; Fukue, 1996). However, the ecology of populations in a *satoyama* habitat has been little studied. *Satoyama*, which literally means “village mountain,” can be defined as a type of area that consists of low mountains and hills with coppices, rice fields in valleys, and plains with human habitation. These habitats are usually located in the outskirts of suburbs, forming transitional zones between highly populated areas and remote areas, and are widespread throughout Japan. *Satoyama* has recently been recognised as an important and unique ecosystem consisting of coppices and farmlands which have been used by local people over centuries (Osumi and Fukamachi, 2001). These habitats serve as wildlife networks and corridors and maintain high biological diversity (Nakamura and Short, 2001). Studying raccoon dogs in *satoyama* may provide habitat information crucial for the survival of common wildlife as well as locally endangered species. The research described in this thesis was largely conducted in this habitat.

1.2.2 Problems facing the raccoon dog in Japan

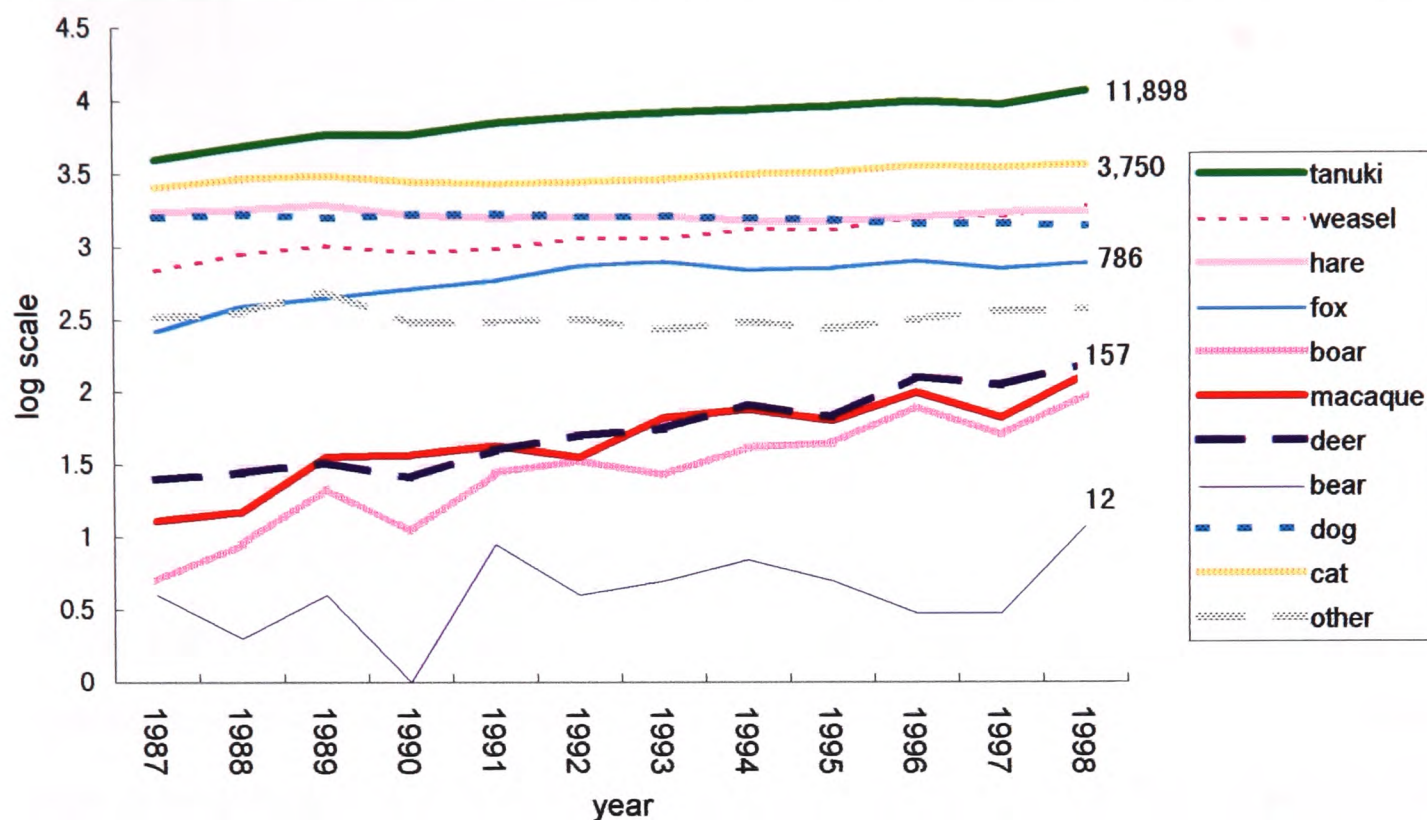
The universal problems for wildlife have been habitat loss, degradation, and fragmentation (Dobson, 1996; Primack, 1998). Raccoon dogs in Japan also face a number of other serious problems, which are described in the following paragraphs. Evidence from national data suggests that death and injury from traffic and culling may have the most significant impacts on raccoon dog populations, and these two issues are addressed in detail in later chapters. These, and the other problems listed here, have many implications for raccoon dogs and other wildlife conservation in Japan, and discussed further in Chapter 8.

1.2.2.1 Road-kills

In Japan, more raccoon dogs have been victims of traffic accidents than any other medium-sized mammal (Ohwada, 1996; Tsukada, 1997; Yanase, 1999) (Figure 1.5). For example, in 1998, 11,898 corpses of raccoon dogs were collected on the 6,418-km of the National Expressways. Road-kills appear to be the major cause of mortality in urban areas (Fukue, 1992; Yamamoto and Kinoshita, 1994a), in mountain foothills (Iimura, 1986), and in the countryside (this study). Road-kills appear to be an important factor for the conservation of raccoon dogs and some other species in Japan. However, few ecological studies on road-kills

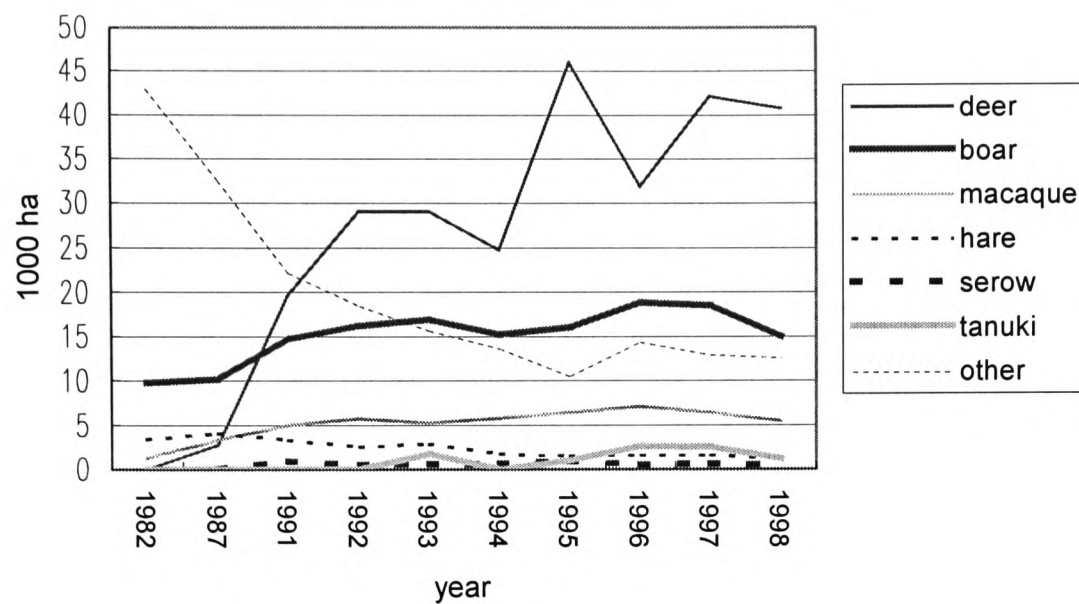
have been conducted. The detailed statistics and effects of road-kills are investigated in Chapter 6.

Figure 1.5 Road-kills of 10 mammals on the National Expressways in Japan (log-scale).

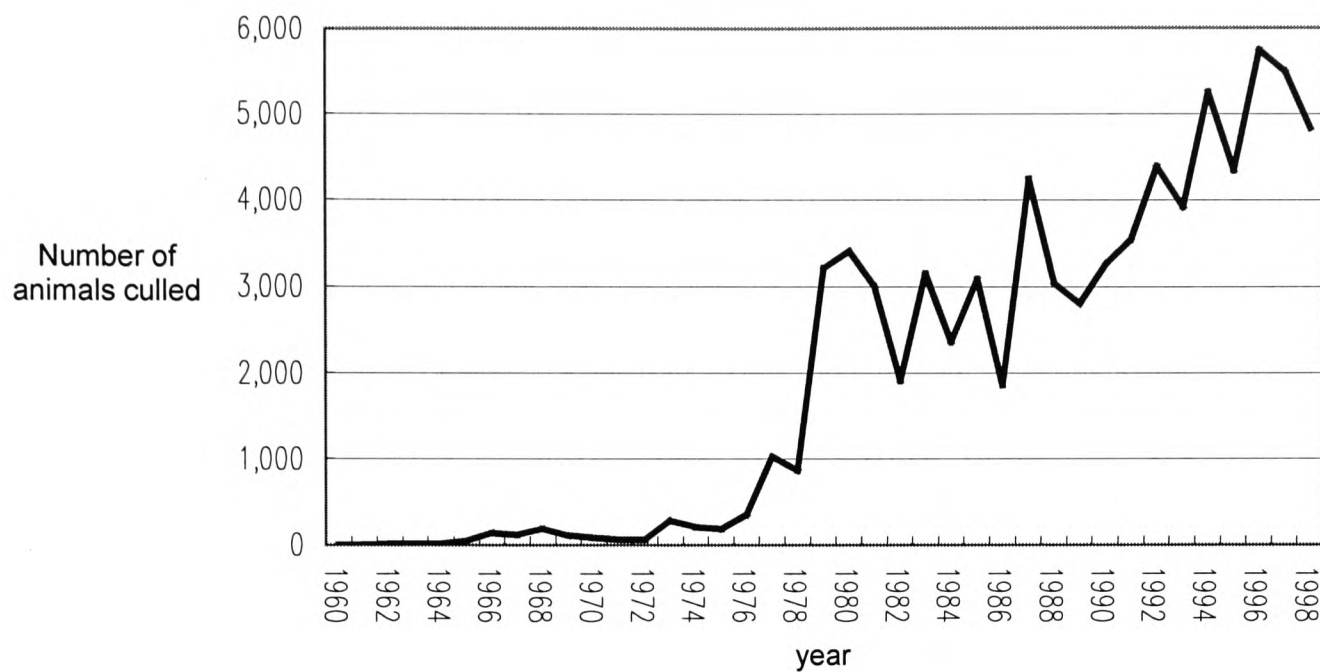


1.2.2.2 Agricultural Damage and Persecution

Agricultural damage by raccoon dogs appears to be significant in some areas (Iimura, 1986; Miyagawa *et al.*, 1993), which brings them into conflict with humans. Agricultural damage causes farmers economic and emotional loss, and at the same time it is a trigger for culling, both legal and illegal. However, at the national level, crop damage by the sika deer (*Cervus nippon* Temminck) and the wild boar (*Sus scrofa* Linnaeus) far exceeds that of the raccoon dog (Ministry of Agriculture, Forestry and Fisheries, 1999b; Figure 1.6). Perceptions of the raccoon dog as an agricultural pest and their consequences are studied in detail in Chapter 7.

Figure 1.6 Number of hectares of farmland claimed to be damaged by mammals.

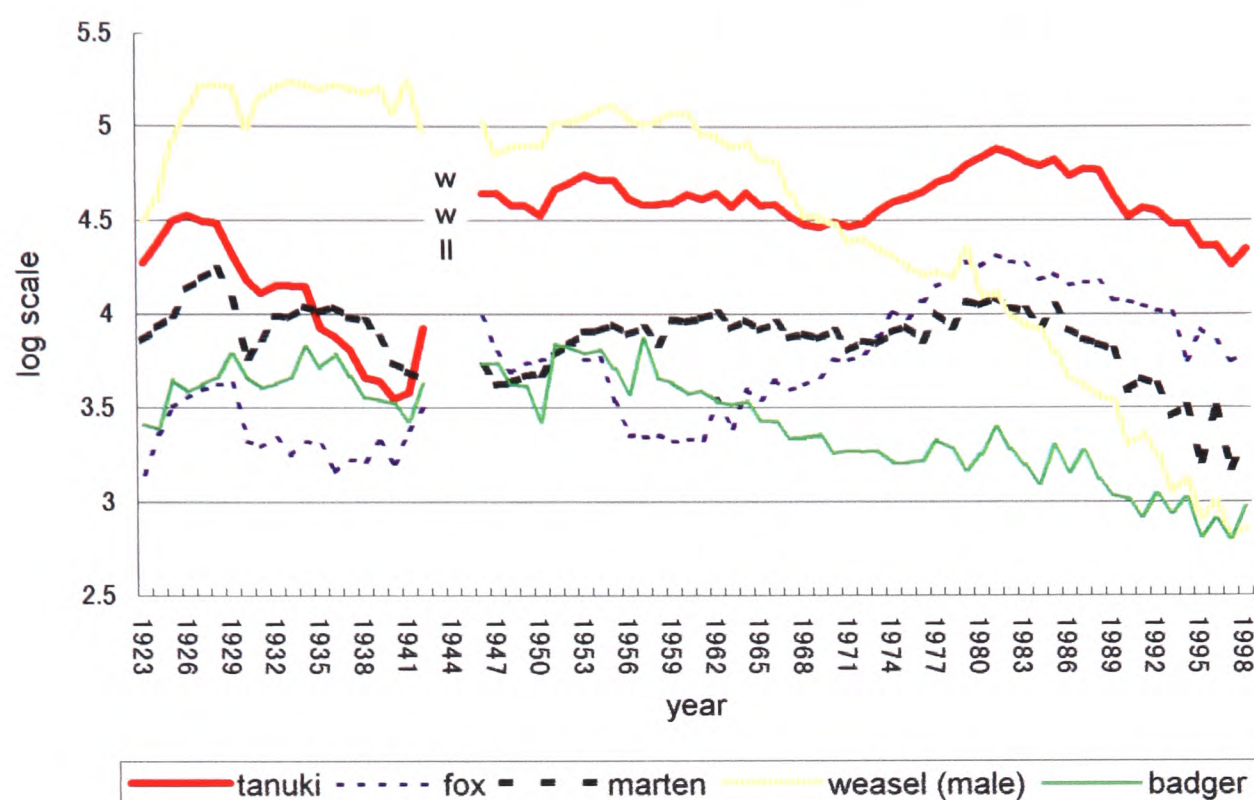
Raccoon dogs can be legally killed as vermin in Japan. A pest control system is prescribed in the *Wildlife Protection and Hunting Law*, and the regulations for its application are in the *Outline for Treatments of Pest Control*. This recommends a minimum number of operators, minimum area, minimum number of target animals, and minimum period without limits or obligations. The levels of legal culling have increased since the 1970s (Figure 1.7; data from the Environment Agency). In 1998, for example, 4,839 raccoon dogs were killed legally as vermin. Permission for culling can be issued from local governments or municipal offices without investigation, and follow-up investigation seldom takes place (Lawyers' Association of Japan, 1999). The number of poaching (illegal culling) incidents is not clear, but it could be significant because farmers are not usually aware of the law that prohibits capturing/killing wildlife without a licence or permission. Japan needs a firm Wildlife Protection Law and needs to establish a management scheme based on scientific knowledge (Saeki, 1995, 1999; Chapter 8).

Figure 1.7 Number of raccoon dogs legally culled in Japan.

1.2.2.3 Legal Harvest

In addition to culling, raccoon dogs are also harvested as a game species during a hunting season with a licence. Legal harvest records show that between 18,000 and 76,000 raccoon dogs have been harvested each year since World War II, and since 1970, that the number harvested has been the largest among five fur-bearer species (Figure 1.8). Reasons for harvesting raccoon dogs are not always clear; as well as being harvested for their fur, raccoon dogs are also killed for sport and possibly as local culling during a hunting season. When data from the Ministry of Environment were analysed, harvest trends of the raccoon dog were similar to those of the fox and the marten (*Martes melampus* Wagner)(Pearson correlations $r = 0.738$ and 0.650 for the post-war period; $r = 0.942$ and 0.847 after 1970, respectively) but different from those of the weasel (*Mustela itatsi* Temminck)(male only) and badger (Pearson correlations $r = -0.156$ and 0.006 , respectively). The causes of harvest decrease after 1981 are unknown. It could be either decreasing population level or decreasing harvest intensity. The number of gun-hunting licences (B class^{vi}) has dropped substantially since 1977, while the number of trapping licences (A class^v) has steadily increased since 1970 (the ratio of gun-hunting to trapping raccoon dogs is about 1.8 : 1.0; calculated with data from the Environment Agency).

^{vi} Note is given at the end of the chapter.

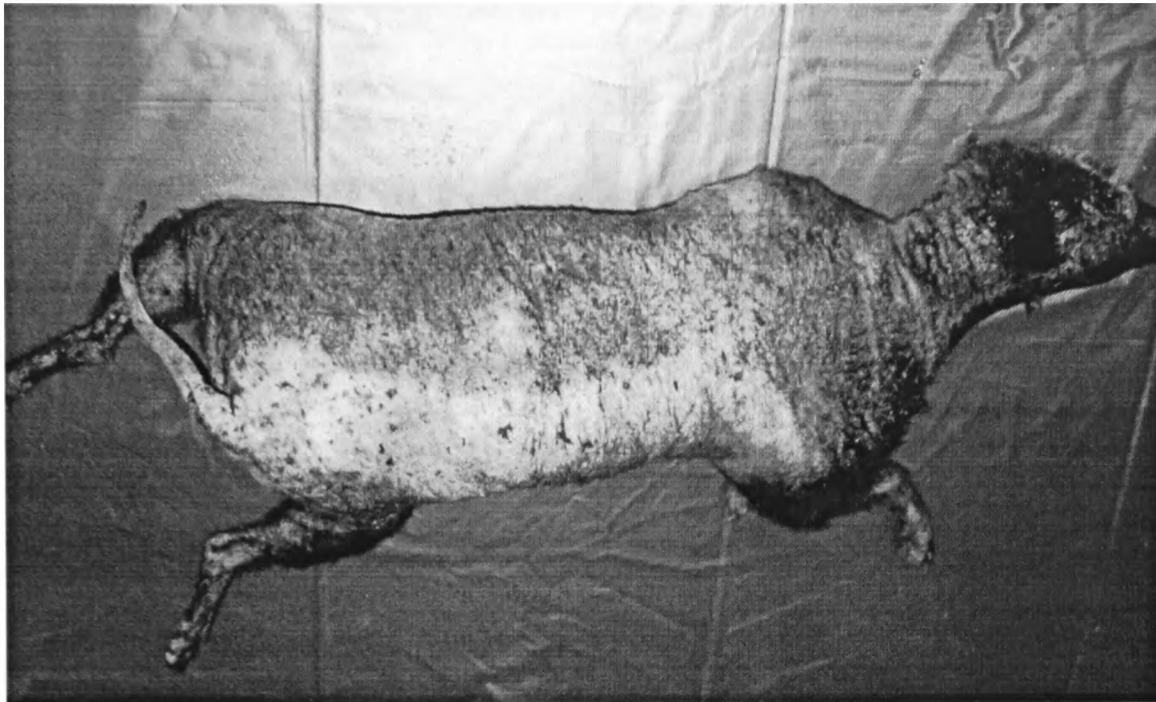
Figure 1.8 Legal harvest records of fur-bearers in Japan from 1923-1998 (log-scale).

1.2.2.4 Epidemic Issues

The raccoon dog faces a serious problem of infestation with scabies (*Sarcoptes scabiei*) (Figure 1.9) in many parts of Japan (Suzuki *et al.*, 1981; Kodutsumi *et al.*, 1988; *Asahi Newspaper*, 1991, 1992, 1996a, 1997; Yachimori and Yamamoto, 1992; *Yomiuri Newspaper*, 1993a; Wildlife Management Office, Ltd., 1998; Shibata and Kawamichi, 1999). Yamamoto *et al.* (1998) conducted autopsies on wild raccoon dogs with prominent hyperkeratosis^{vii}, acanthosis^{viii} and papillomatosis^{ix}, and found numerous cross-sections of *S. scabiei* in the horny layer from histopathological examinations. According to a questionnaire survey conducted by the Wildlife Management Office, Ltd. (1998), scabies in the raccoon dog was first reported in 1975 in the eastern part of Japan, and the reports have increased in number and range, especially between 1985 and 1990. Effective treatments, such as ivermectin, are available (Burgess, 1994). However, the Wildlife Management Office, Ltd. (1998) suggested that treating wildlife in this way presents great practical difficulties, and may have possible adverse effects on the natural immune system of wild populations. Their recommendation is to take no action.

vii & viii & ix Notes are given at the end of the chapter.

Figure 1.9 A raccoon dog infected with scabies (photograph by Yuko Fukue).



Antibodies of canine distemper (30%) and *Toxoplasma gondii* Nicolle et Manceaux (3.3%) were found in samples from 30 raccoon dogs in the suburb of Kanagawa, Japan (Neagari *et al.*, 1998). Kanda (*Mainichi Newspaper*, 1992) reported that deaths of the raccoon dog probably caused by canine distemper were found in nearly half of the Japanese prefectures. Machida *et al.* (1993) examined raccoon dogs that died from an outbreak of canine distemper in Tokyo in 1991 and noticed prominent bronchiolointerstitial pneumonia and acute catarrhal gastroenteritis in the samples. More than 70% of the local population in the Nishi-Tama area was probably killed by distemper during a three-month epizootic (Machida *et al.*, 1993).

Rabies has not been recorded in Japan since 1956 (when six domestic dogs and a human were reported to die from rabies). However, only domestic dogs are subject to annual vaccination for rabies, and no quarantine is required for the importation of pet animals except for the dog, fox, raccoon, and skunk. When rabies reappeared in Finland in 1988 after 30 years of absence, the raccoon dog was an important vector of the disease (Nyberg *et al.*, 1992). In Poland, the highest percentage among wild animals suspected of being infected with the disease was confirmed in the raccoon dog (Ostrowska and Hermanowska-Szpakowicz, 1997).

Because raccoon dogs groom each other, use communal latrines, and may live at high density with overlapping home ranges, they are more vulnerable to infection by parasites or disease than are solitary species. In addition, they often share resting/den sites and trails not

only with conspecifics but also with other species, such as badger and fox (Kowalczyk, *et al.* 1999; M. Saeki, pers. obs.). Free-ranging dogs also come into contact with raccoon dogs and have been known to kill them (M. Saeki, pers. obs.).

1.2.2.5 Pollution

Little is known about the effects of pollution on wildlife in Japan. A high concentration of lead (Pb) was found in femurs of raccoon dogs from an islet in the Ehime prefecture (Itoh *et al.*, 1993). Organotins such as butyltin compounds (BTs), including mono- (MBT), di- (DBT) and tributyltin (TBT), were detected in raccoon dogs from Tokyo (*Mainichi Daily News*, 1998; Takahashi *et al.*, 1999). Pollutants (PCDDs + PCDFs + Coplanar PCBs)^x in samples from raccoon dogs, were reported to contain mean amounts of 23pg-TEQ/g-wet^{xi} in the liver (n = 4) and 34pg-TEQ/g-wet in the liver and fat (n = 5). These values were only surpassed by the levels in the large Japanese field mouse (*Apodemus speciosus* Temminck) among the five terrestrial mammals examined (Environment Agency, 2000b).

1.2.2.6 The Urban Raccoon Dog

The raccoon dog recently has appeared in urban areas (Nojima, 1988; Yamamoto, 1991; Murata, 1994). Although the urban raccoon dogs themselves are not problematic, they may suffer from high mortality and human disturbance, and are usually automatically translocated from the Tokyo metropolitan area. A low average age at death (1.173 ± 0.091) was reported for urban raccoon dogs in Kawasaki City with 82.4% of the mortality due to road-kills (Yamamoto and Kinoshita, 1994a). Translocated animals are often released in remote mountainous areas without taking the necessary sanitary or conservation genetics precautions (*Yomiuri Newspaper*, 1993b).

1.2.2.7 Feeding of Raccoon dogs by Humans

Feeding of raccoon dogs by humans (often with an intention to tame them; called *eduke*) is common in Japan, and this practice could lead to potential problems. Transmission of diseases and parasites common in pets is often associated with *eduke* (Yachimori and Yamamoto, 1992; Wildlife Management Office, Ltd., 1998, for scabies). *Eduke* may increase local population densities to a level where the animals depend on human feeding to survive, and may change their behaviour and physiology. For example, when raccoon dogs have become accustomed to

^{x & xi} Notes are given at the end of the chapter.

being fed by people, they are often seen during the day, whereas wild raccoon dogs are normally nocturnal. Fed animals tend to be overweight. The effects of high concentrations of salt, fat, and preservatives in human or dog food, as well as the effects of alcohol, which is often given as *sake* (e.g. Fukuda, 1996), are unknown. Animals fed by people may be more likely to feed on crops and poultry, due to their acclimatisation to human scent and light, and they may be more vulnerable to traffic injury and trapping/poaching.

1.2.2.8 Introduced Mammalian Species

Medium-sized omnivorous carnivores, such as the masked palm civet (*Paguma larvata* Hamilton-Smith) and the common raccoon, have been introduced into Japan (Yamada, 1998). The effects of these species on native fauna are not clear, although populations of the raccoon dog and the red fox might have decreased due to the introduction of the raccoon in Hokkaido (Ikeda, 1999). Yuko Fukue (personal communication) observed a masked palm civet enter a nursing den of a pair of raccoon dogs, possibly to predate on the pups; the pair subsequently abandoned the den site. Epidemic issues are another concern because exotic animals may be carriers of parasites or pathogens to which the native wildlife have not been exposed.

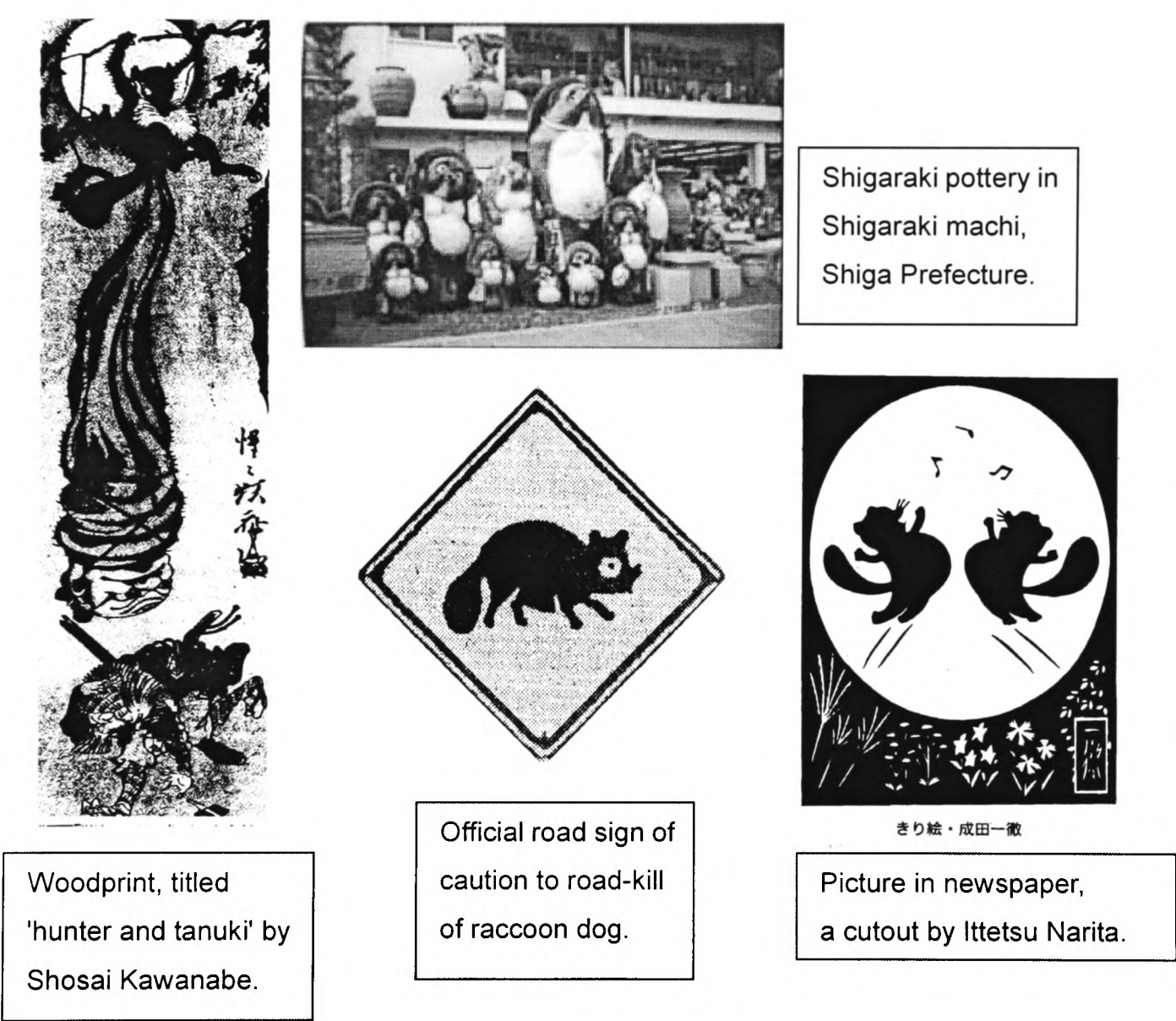
1.2.2.9 Public Misunderstandings of the Raccoon dog

The raccoon dog has often appeared in Japanese folklore (Nakamura, 1990; Matsutani, 1995) and the Shigaraki pottery (Figure 1.10) where it is given a comical image. These images (Figure 1.10) have contributed to its popularity but have also created negative perceptions of the species. For example, folklore and fairy tales have implanted frightening and inaccurate notions in the minds of both children and adults. These may relate, for example, to the ability of raccoon dogs to bewitch or transform people, or their power of imitation (Nakamura, 1990). In Japanese folklore, the raccoon dog is often presented as having a comical personality, in contrast to the fox, which is often presented as having a clever personality (Ikeda, 1985; Akatsuka, 1998). The raccoon dog is often cast as male and the fox as female (Nakamura, 1990). The confusion between the raccoon dog as a folklore character and as a living wild animal needs to be addressed.

As well as the role of the raccoon dog in folklore, there is a variety of ecological and biological misunderstandings pertaining to the species. For example, it is widely believed

among hunters that raccoon dogs impact on wild bird populations, and more generally, raccoon dogs are often confused with raccoons and badgers. Some trappers still believe that the raccoon dog and the badger are the same species (called *mujina*), with the raccoon dog as female and the badger as male (T. Ichihara, personal communication). The media often spread such misunderstandings (e.g. *Kitaguni Newspaper*, 1999). Journalists need to be educated about elementary ecology and the consequences of irresponsibly broadcasting and publishing inaccurate information about wildlife.

Figure 1.10 Images of *tanuki*.



Woodprint, titled 'hunter and tanuki' by Shosai Kawanabe.

Official road sign of caution to road-kill of raccoon dog.

Picture in newspaper, a cutout by Ittetsu Narita.

1.3 PURPOSES AND GOALS OF THE STUDY

In this thesis, I use the raccoon dog as a model species in a study concerned with the minimisation of wildlife and human conflicts in Japan. In order to tackle this task I have three objectives: 1) to describe the ecology of raccoon dogs in the *satoyama* habitat in Japan, 2) to investigate the effects of two examples of areas of wildlife-human conflict, road-kills and agricultural damage on raccoon dogs, and 3) to consider applications of ecological data to wildlife-related problems. In addition, I discuss some socio-cultural aspects, which may play an important role for wildlife conservation in Japan, from a wildlife biologist's viewpoint.

I address these aims using the following approaches. In Chapter 2, I describe the natural environment and current status of mammalian wildlife in Japan. Chapters 3 and 4 provide baseline ecological data on the raccoon dog. In Chapter 3, I use radio-tracking data to investigate habitat use and selection by raccoon dogs and the factors influencing this. In Chapter 4, I use the same radio-tracking data to obtain home ranges and to investigate the animals' movements. From these spatial use and movement patterns, I go on to discuss social organisation of the raccoon dogs. In Chapter 5, I compare the data on habitat ecology, spatial use, and movement patterns of the raccoon dog with data from a study of the badger in the UK. The chapter gives insights into the behaviour of generalist carnivores, in particular concerning habitat selection and movements. Chapters 6 and 7 focus on two issues which have important implications for conservation of the raccoon dog and other wildlife in Japan: road-kills and agricultural damage. Finally, in Chapter 8, I critically review the legal status of wildlife in Japan and attitudes towards and perception of wildlife by the Japanese. Implications and recommendations are listed to solve problems addressed in the chapter. The chapter summarises major findings and topics in this thesis with concluding remarks.

Note

In this thesis, **tanuki** is used when referring to raccoon dog in the legend of Tables and Figures. Scientific names of some wildlife used in text are shown in Appendix IV. Photographs were taken by M. Saeki, unless stated otherwise.



Winter coat



Summer coat

ⁱ Strictly speaking, *Nyctereutes procyonoides viverrinus* is called 'hondo-tanuki' and *N. p. albus* 'ezo-tanuki.' However, people usually do not distinguish them.

ⁱⁱ Hares were the most frequently culled wild mammals in the 1970s, when they were the major species damaging saplings of coniferous plantation. As artificial plantations have decreased (Appendix I), claims for hare damage also may have decreased. Population cycles might play a part in the decrease of culling although there is no study to show the population trend in Japan.

ⁱⁱⁱ *N. p. viverrinus* and *N. p. albus* have fewer chromosomes than other continental subspecies (Makinen *et al.*, 1986; Ward *et al.*, 1987; Wada *et al.*, 1991, 1998); *N. p. viverrinus* and *N. p. albus* have $2n = 38 + Bs$ ($2K = 26 \overline{M} + 10 \overline{A} + (\overline{M})X + (\overline{A})Y + Bs$) (Wada *et al.*, 1991, 1998), while the Chinese, *N. p. procyonoides*, the Finnish, *N. p. ussuriensis*, originally from Ussuri-region, and the Korean, *N. p. koreensis*, raccoon dogs have $2n = 54 + Bs$ ($2K = 10 \overline{M} + 42 \overline{A} + (\overline{M})X + (\overline{A})Y + Bs$) (Ward *et al.*, 1987; Wada *et al.*, 1991; Makinen, 1974; Makinen *et al.*, 1986). $\overline{M}$ is a metacentric autosome, $\overline{A}$ is an acrocentric autosome, and X and Y are sex chromosomes. B chromosomes are nonsense chromosomes, which vary from 2 to 5 between individuals and may vary within an individual.

^{iv} Wada and Imai (1991) reported $2n = 39 + Bs$ ($2K = 25 \overline{M} + 12 \overline{A} + XY + Bs$) and $2n = 41 + Bs$ ($2K = 23 \overline{M} + 16 \overline{A} + XY + Bs$) with the standard karyotype of $2n = 38 + Bs$ ($2K = 26 \overline{M} + 10 \overline{A} + (\overline{M})X + (\overline{A})Y + Bs$). The Robertsonian polymorphism that has occurred in the raccoon dog has raised controversy concerning the ancestral origin and the direction of karyotypic changes (either fusion or fission) (Todd, 1970; Yoshida and Wada, 1984; Wurster-Hill *et al.*, 1986; Ward *et al.*, 1987; Wada and Imai, 1991; Imai, 1992). There is insufficient evidence to resolve the dispute. However, if the Chinese subspecies is the ancestor of the Japanese subspecies, it is more likely to be the result of a series of centric fissions or fission burst because of the pattern in karyotypic polymorphism in *N. p. viverrinus* (Imai, 1992).

^v In captive animals, pro-oestrus, apparent with a swelling of the vulva and a mucopurulent discharge, last 7.6 ± 3.5 days, oestrus 3.9 ± 1.2 days, gestation 61.0 ± 2.0 days (Valtonen *et al.*, 1977). The authors report a litter size of 5.0 ± 2.3 in captivity although embryonic litter size was found to be 9.6 ± 2.0 in a wild population in Finland (Helle and Kauhala, 1995). Canids are characterised by a significant increase in progesterone levels during oestrus, no significant changes in oestradiol-17 β during pregnancy and parturition, and similar patterns in hormonal levels in both pregnant and non-pregnant females, which all are present in the raccoon dog (Valtonen *et al.*, 1978).

^{vi} The licences are classified as: A Class for hunting without gun (using traps and nets), B Class for hunting with shotgun and rifle, and C Class for hunting with airgun and firearm using compressed gas. (Article 4 in the *Wildlife Protection and Hunting Law*)

^{vii} hypertrophy of the horny layer of the skin, or any disease characterised by it. (From Miller-Keane Medical Dictionary)

^{viii} diffuse hypertrophy or thickening of the prickle cell layer of the skin. (From Miller-Keane Medical Dictionary)

^{ix} development of multiple papillomas, i.e. a benign tumour derived from epithelium. Papillomas may arise from skin, mucous membranes, or glandular ducts. (From Miller-Keane Medical Dictionary)

^x **PCDD** is polychlorinated dibenzo-*p*-dioxin, **PCDF** is polychlorinated dibenzofurans and **PCB** is polychlorinated biphenyl.

^{xi} **TEQ** (Toxicity Equivalent) was calculated by multiplying each concentration of congener with I-TEF (International Toxicity Equivalent Factor).

CHAPTER 2

NATURAL ENVIRONMENT AND STATUS OF WILDLIFE IN JAPAN

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Summary

This chapter describes the natural environment of Japan and summarises the current status of wildlife in Japan with a particular focus on mammalian species.



Chapter 2 Natural Environment and Status of Wildlife in Japan

2.1 GEOGRAPHY AND CLIMATE

Japan (377,855 km²) consists of four major islands and 6,848 islands/islets (Statistical Bureau, 2001), ranging from sub-arctic to sub-tropical zones. It is about 3,000 km long and lies off the coast of Eurasia in the north-western Pacific Ocean. Three quarters of its area is mountainous, with many of its peaks being over 2,000 m and 21 mountains being over 3,000 m (max. 3,776 m). Japan has nearly 1/10 of the active volcanoes in the world, creating seismic phenomena along with active faults. Rivers tend to be short with rapid water due to the topographic configuration. There are 109 water systems with 480 natural lakes and marshes (>1 ha) and a total river length of 87,452 km (Statistical Bureau, 2001).

Japan has distinct seasons: four seasons and a rainy period, *baiu*, between spring and summer except for the sub-tropical islands and Hokkaido, the northernmost island, where there is no *baiu*. The Japanese climate varies greatly depending upon the regions. However, it can be roughly separated into two types: the Japanese Sea side and the Pacific Ocean side, divided by a mountainous backbone through the main island, Honshu. The former is characterised by heavy snowfall in winter and the latter by heavy rainfall carried on tropical monsoons in summer. The average annual temperature ranges from 5.9 °C (Nemuro in Hokkaido) to 22.4°C (Naha in Okinawa). The total annual precipitation averages 1,852 mm, ranging from 917 mm (Obihiro in Hokkaido) to 4,291 mm (Yakushima island) and is greater than that of most countries in the temperate zones (Observations Department, 1992). Typhoons affect Japan every year with heavy precipitation and/or strong winds. On average, 3.2 typhoons strike Japan per year (Ministry of Construction, 2001).

Steep slopes and a snowbound environment in winter may have served as determinants for species distributions as well as being important barriers against development and exploitation of the wildlife inhabiting those areas. The overall mild and humid maritime climate helps rapid regeneration of vegetation after disturbance.

2.2 VEGETATION

The variability in latitude, altitude, and climate supports diverse vegetation relative to the land area. More than 7,000 species of vascular plants, about 5,500 species of liverwort, 1,800 species of moss, 1,000 species of lichen and 16,500 species of fungus have been identified (Environment Agency, 1991).

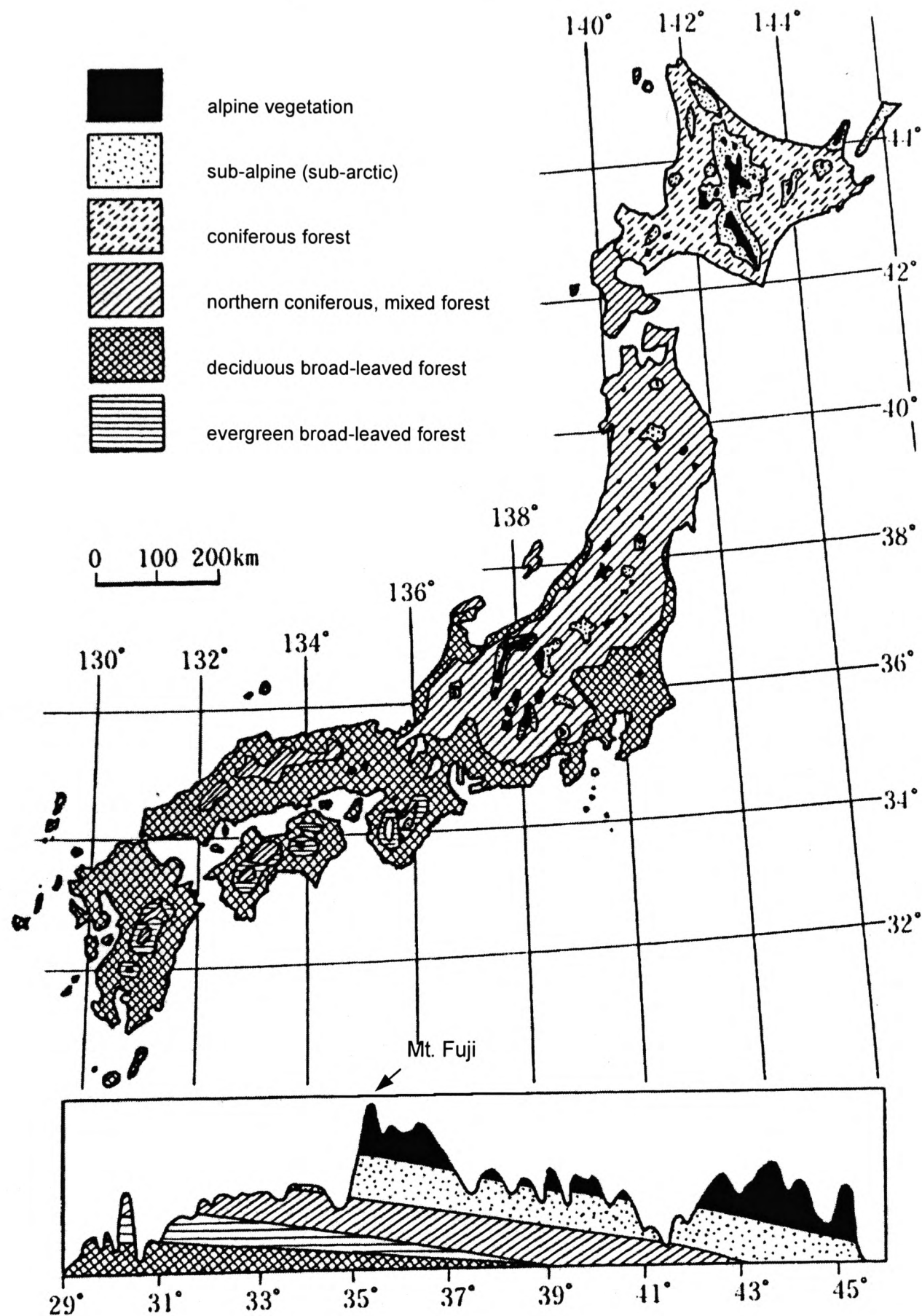
There are six major types of forest: alpine, sub-alpine, northern coniferous/broad-leaved mixed, deciduous broad-leaved, evergreen broad-leaved, and fir-hemlock spruce (Table 2.1; Figure 2.1). The total area of forest is 251,460 km², comprising 67% of the total land area. Human populations are concentrated on the plains, and consequently, forests are found mainly in the mountainous areas. In 1995, the Japanese Forestry Agency estimated that natural forests, including secondary forests, comprised 53.2% of the total forest areas, whereas artificial forests comprised 41.4% (Forestry Agency, 1998; details in Figure A.1 in Appendix I). Northern fir (*Abies sachalinensis* Friedr. Schmidt) and Northern spruce (*Picea jezoensis* Carriere) are mostly planted in Hokkaido; Japanese cypress (*Chamaecyparis obtusa* Sieb. et Zucc) and Japanese cedar (*Cryptomeria japonica* D. Don) are the major species of the artificial forests on the three other islands. Seventy percent of planted stands are younger than 35 years, and a lack of proper management is apparent in many parts of Japan (National Forestry Union, 1997; Forestry Agency, 1998). Long-term vegetational changes and human impacts on forests are described in detail in Appendix I.

Table 2.1 Major species in forest composition by vegetation types in Japan.

Vegetation type	Dominant species in natural forest	Main species in artificial forest
Sub-Arctic forest (boreal forest)	<i>Abies veichii</i> <i>Tsuga dirersifolia</i> * <i>Abies sachalinensis</i> ** <i>Picea jezoensis</i>	<i>Larix kaempferi</i> <i>Abies sachalinensis</i>
Cool-temperate forest (summer-green)	<i>Fagus crenata</i> <i>Quercus crispula</i>	<i>Cryptomeria japonica</i> <i>Chamaecyparis obtusa</i> <i>Larix kaempferi</i> <i>Pinus densiflora</i>
Warm temperate and Sub-tropical forests (Laurel forest)	<i>Castanopsis cuspidata</i> <i>Persea thunbergii</i> <i>Quercus acuta</i>	<i>Cryptomeria japonica</i> <i>Chamaecyparis obtusa</i> <i>Pinus densiflora</i>

* found in Honshu Island; ** found in Hokkaido Island (Forestry and Forest Products Research Institute 1996)

Figure 2.1 Forest distribution in Japan.



Because it is mountainous, Japan has only a small lowland area. Many wetlands have been converted into fields for production of rice (*Oryza sativa* L.) for hundreds of years, or have been land-filled to provide residential areas. For example, cattails (*Typha latifolia* L.), which were abundant after shorelines subsided 2,000 years ago, were largely displaced with rice fields 1,500 years ago and only scattered patches now remain (Miyoshi, 1988). The largest

wetland, Kushiro Shitsugen (226.6 km²), is situated in Hokkaido, where rice was not a suitable crop, and human density has been low, even though it lost 30% since Taisho era (Table A.1)(Geographical Survey Institute, 2001). However, rice fields and abandoned rice fields can be considered as artificial and secondary wetlands, respectively. In 1997, agricultural officials estimated that 55% of the total cultivated area were rice fields (27,010 km²) (Ministry of Agriculture, Forestry and Fisheries, 1998).

Historically, grasslands have never been a major landscape type in Japan. Continental relic species grow in alpine and sub-alpine grasslands. Secondary grasslands comprise 3.2% of the land (Environment Agency, 1992).

Almost 20% of Japan's vascular plant species are listed as endangered, vulnerable, or rare in the *Red Data Book of Japan* (Environment Agency, 1991). According to IUCN (1994), 222 species of trees in Japan are globally threatened.

2.3 WILDLIFE

More than six zoogeographic lines (Figure 1.1b in Chapter 1) are known to divide the Japanese vertebrate and invertebrate fauna. For examples, Blakiston's line at the Tsugaru Strait separates the Siberian sub-region and the Manchurian sub-region, and the Watase line at the Tokara Strait separates the Old Northern region and the Eastern sub-region. The fauna in Hokkaido, north of the Blakiston's line, is similar to that of Siberia, whereas Honshu has 16 endemic mammalian species and three endemic mammalian genera (Kawamichi, 1996).

Although two subspecies of wolf (*Canis lupus hattai* Kishida and *C. l. hodophilax* Temminck) have been extinct in Japan since the early 20th century, large mammals such as the wild boar (*Sus scrofa* Linnaeus), sika deer (*Cervus nippon* Temminck), Japanese serow (*Naemorhedus crispus* Temminck), and two species of bear, brown bear (*Ursus arctos* Linnaeus) and Asiatic black bear (*Selenarctos thibetanus* G. Cuvier) still inhabit the country. The Japanese archipelago is located on the migration route of many avian species that breed in Siberia and winter in the south-east of continental Asia, Indonesia, and Australia, as well as itself providing wintering and breeding grounds for other species (Brazil, 1991). Its diverse geography and climate support nearly 100 terrestrial mammalian species, over 40 marine mammalian species (Kawamichi, 1996), 524 avian species (Sonobe and Robinson, 1982), 97

amphibian species, 64 reptilian species, and about 300 species of brackish and freshwater fishes (Environment Agency, 1993, 1995b). With sub-tropical islets, the Japanese archipelago is home to number of endemic genera, species, and subspecies across taxa.

Today in Japan, approximately 18 to 30% of vertebrate species (including some subspecies) per taxonomic class are listed as Threatened I, Threatened II, or Near Threatened in the *Red Data Book of Japan* (Environment Agency, 1991, 1999a). Two subspecies of the Japanese wolf and two species of bat are known to have become extinct around the turn to the 20th century. Three species of Carnivora are listed as Threatened I (i.e. Endangered); only <110 individuals of the Iriomote cat (*Felis iriomotensis* Imaizumi) and <100 individuals of the Tsushima leopard cat (*Felis bengalensis eupilura* Elliot) have survived into the modern era, and the last corpse of the Japanese otter (*Lutra nippon* Imaizumi et Yoshiyuki) was collected in 1973, although faeces containing otter's fur were found in 1992. Both the brown bear and the Asiatic black bear are considered to be game species and can be killed as pests any time with permission, although they are listed in Appendix II and I, respectively, of the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* (CITES), and some local populations are designated as threatened by the Ministry of Environment. Fourteen avian species are known to have become extinct, including the recent extinction of the Japanese crested ibis (*Nipponia nippon* Temminck); 42 species (including some subspecies) are listed as Threatened I (Environment Agency, 1991, 1999a).

As for non-native species, 40 mammalian species (Mammalogical Society of Japan cited in *Yomiuri Newspaper*, 1998b), seven avian, four reptilian, three amphibian and 20 freshwater fish species have been identified (Washitani and Morimoto, 1993). Approximately 20% of introduced mammals are Carnivores. The Javanese Mongoose (*Herpestes javanicus* E. Geoffroy Saint-Hilaire), the Siberian weasel (*Mustela sibirica coreana* Domaniewski), masked palm civet (*Paguma larvata* Hamilton-Smith), rabbit (*Oryctolagus cuniculus* Linnaeus), coypu (*Myocastor coypus* Molina), and muskrat (*Ondatra zibethicus* Linnaeus), were introduced before World War II; the American mink (*Mustela vison* Schreber) and common raccoon (*Procyon lotor* Linnaeus) were found in the 1960s; and there have been recent confirmations of the presence of a species of skunk (*Mephitinae* Bonaparte), ferret (*Mustela putorius fuso* Rempe et Volobuev), the European hedgehog (*Erinaceus europaeus* Linnaeus), and capybara

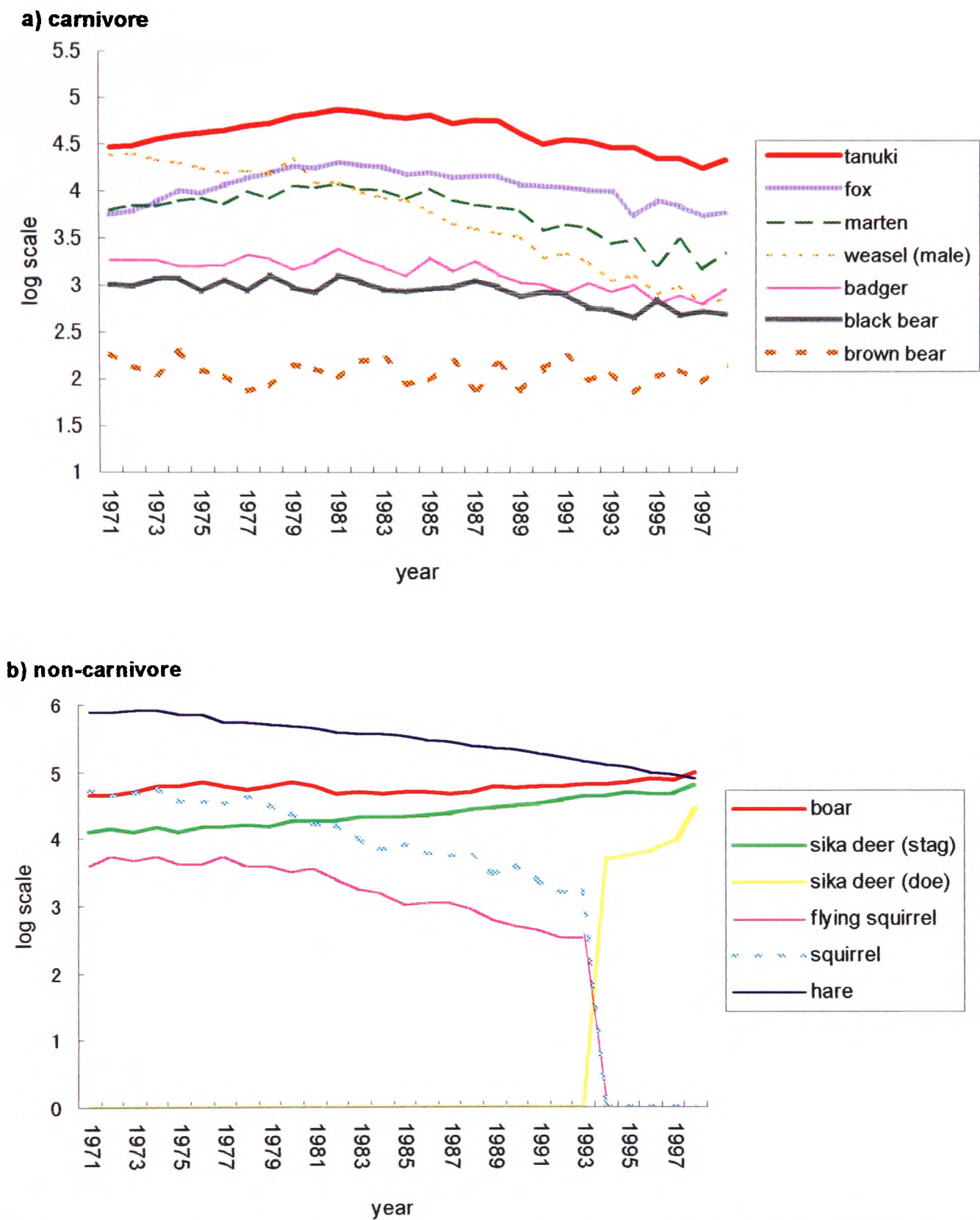
(*Hydrochoerus hydrochaeris* Linnaeus)(Yamada, 1998).

Six mammalian species were moved into areas within Japan where they are not native (Yamada, 1998; S. Azuma, personal communication). For example, just before World War II, the Japanese marten (*Martes melampus* Wagner) was introduced from the main island to a breeding farm near Sapporo in Hokkaido. When food became unavailable during the War, the animals were released or escaped into the wild (Inukai, 1975). The Japanese marten is still living sympatrically with the native Japanese sable (*M. zibellina brachyura* Temminck) in south-western Hokkaido. The two species are karyologically and molecular phylogenetically close enough to each other to hybridise, although there has been no sign of hybridisation in the samples from Hokkaido (Hosoda *et al.*, 1993, 2000).

Limited information is available for nationwide trends in population densities and species distributions of wildlife in Japan. The former Environment Agencyⁱ, the Ministry of Environment, conducted surveys on wildlife distribution by questionnaire and literature surveys with some *in situ* confirmations in 1979 (eight mammalian species, 257 avian species, 34 reptile and amphibian species, and 71 freshwater fish species) and 1989-92 (all species) as a part of the National Survey of the Natural Environment. The survey for mammals was conducted based on reports and sightings by local professionals, e.g. hunters and forestry personnel, per 5 km². The Forestry Agency (1923-1967) and the Environment Agency (1968-1999) published annual records of legal harvest, i.e. number of animals harvested, from individual hunters' report (Figure 2.2). The Ministry of Environment has recorded the number of animals culled with permission (Figure 2.3). The Ministry of Agriculture, Forestry and Fisheries receives claims of wildlife damage to agriculture from farmers via prefectures (damaged farmland area in Figure 1.3 in Chapter 1), and the Forestry Agency has statistics of wildlife damage to forestry reported by people engaged in forestry (damaged plantation area in Figure 2.4).

ⁱ The Environmental Agency was upgraded to the Ministry of Environment in 2001.

Figure 2.2 Change in legal harvest of (a) carnivore and (b) non-carnivore species in Japan from 1971 to 1998 (number of harvest in log scale).



In 1994, harvest of female sika deer was opened, and harvest of giant flying squirrel and squirrel was closed.

Figure 2.3 Change in culling of (a) carnivore and (b) non-carnivore species in Japan from 1971 to 1998 (number of culling in log scale).

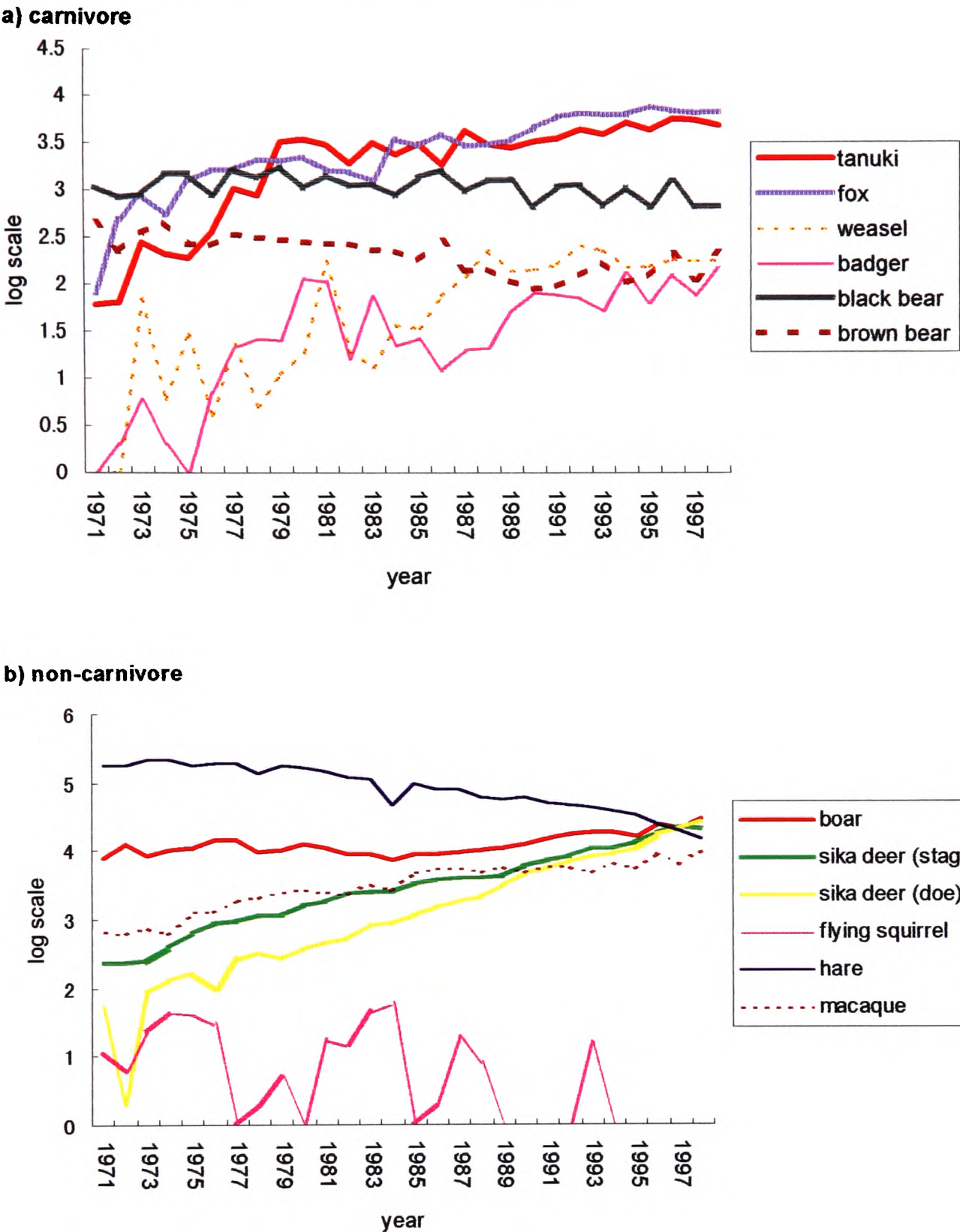
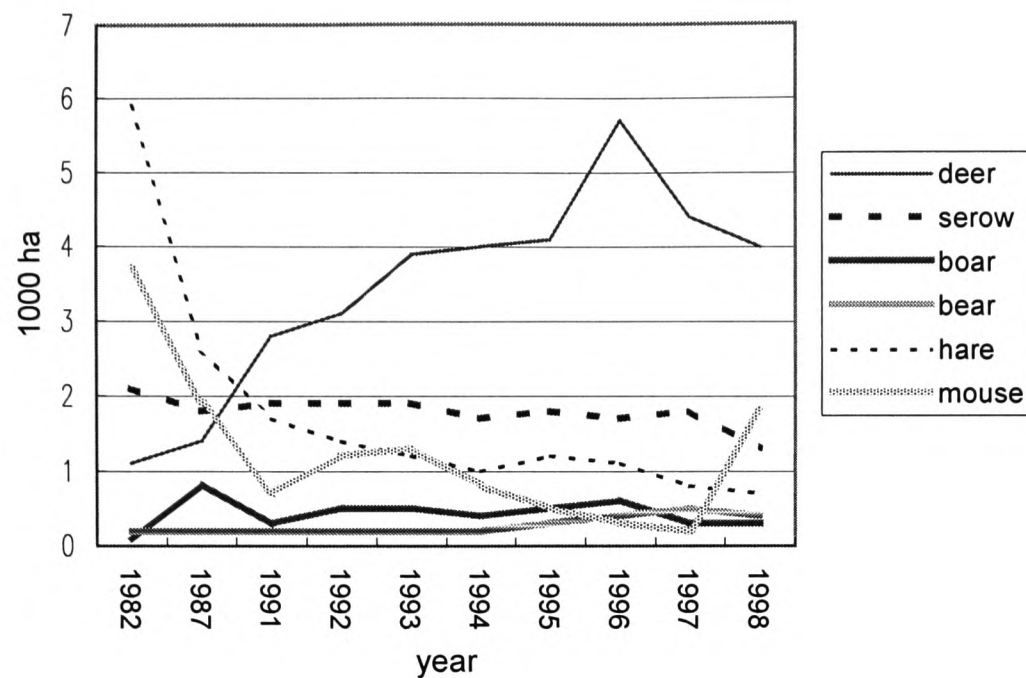


Figure 2.4 Number of hectares of artificial forest claimed to be damaged by mammals.

In order to produce national trends and distributions of some mammalian wildlife species, I compiled data from legal harvest records (Figure 2.2; data 1 in Table 2.2), culling records (Figure 2.3; 2 in Table 2.2), road-kills on the National Expressways adjusted with traffic volume (Figure 6.6 in Chapter 6; 3 in Table 2.2), crop damage claims (Figure 1.3 in Chapter 1; 4 in Table 2.2), forest damage claims (Figure 2.4; 5 in Table 2.2), and population distribution surveys by the Environment Agency (6 in Table 2.2). Wildlife species were grouped into four categories: 1) increasing or expanding, 2) no apparent change, 3) decreasing or shrinking, and 4) unknown or undetermined, depending upon the available data (Table 2.2). Contrary to common thought that raccoon dogs have recently increased, all variables of population indicators except the culling level have remained unchanged or decreased for raccoon dogs (Table 2.2). I classified raccoon dog population trend as no apparent change based on road-kill trend and the national distribution surveys, which showed a slight decrease. Except for the sika deer and the wild boar, the species with increasing damage claims and increasing culls, population trends of all species listed in Table 2.2 were considered to be unchanged, downward, or undetermined due to insufficient data. According to distribution surveys by the Environmental Agency (1979, 1989-1992), even the deer and boar had a small decrease in distribution over the 10-year period. In these surveys, all eight mammalian species (asterisked in Table 2.2) decreased their distributions, especially two species of bear, the Japanese badger, and the Japanese macaque. Although the available data are not comprehensive, it is clear that,

for most species, populations have become more fragmented, especially in the Kyushu, Shikoku and Chugoku regions, i.e. the south-western parts of Japan (Figure 1.1b in Chapter 1).

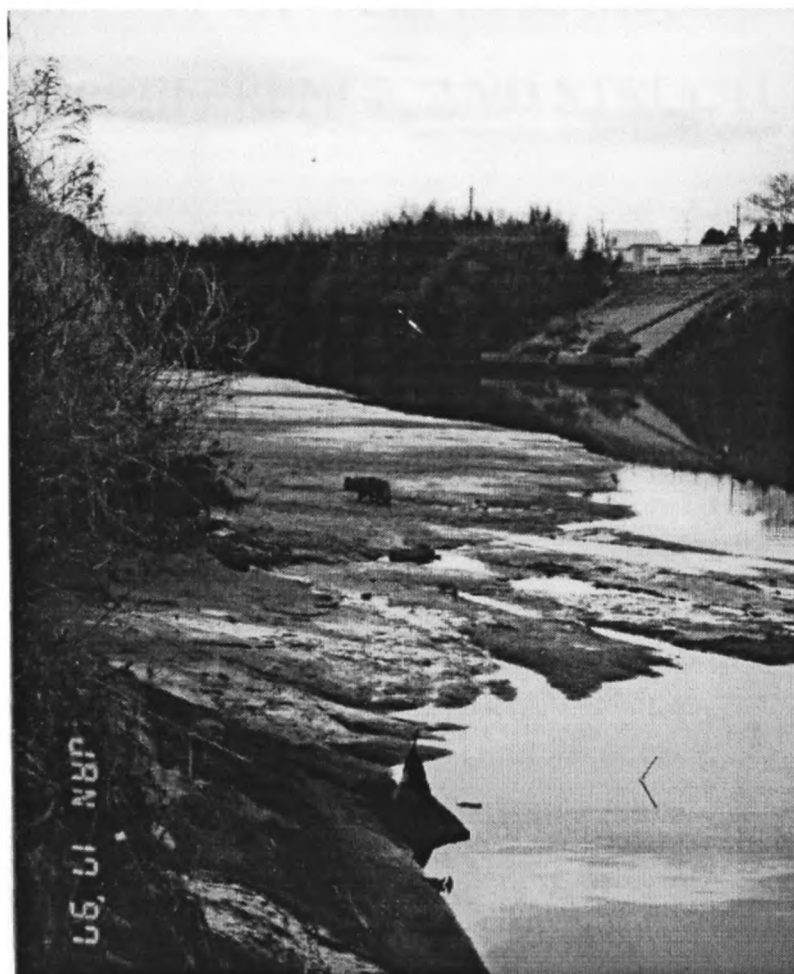
Table 2.2 Status and population trend of native mammalian wildlife in Japan.

Species	Status	Harvest	Culling	Road-kill	Farmland damage	Forest damage	Range	Population trend
data		1	2	3	4	5	6	
tanuki*	G	--	+	0	0	N/A	- 0	0
red fox*	G	--	+	-	U/K	N/A	-	down
Iriomote cat	E, SN	N/A	N/A	U/K ⁱⁱ	N/A	N/A	(0)	U/D (down?)
leopard cat	E, N	N/A	N/A	U/K ⁱⁱ	N/A	N/A	(0)	U/D (down?)
marten	G ⁱⁱⁱ	--	N/A	U/K	U/K	N/A	U/K	U/D
sable	^{iv}	N/A	N/A	U/K	U/K	N/A	(-)	down
weasel	G(♂)	--	+	0	N/A	N/A	U/K	0
ermine	R	N/A	N/A	U/K	N/A	N/A	U/K	U/D
least weasel	LP	N/A	N/A	U/K	N/A	N/A	U/K	U/D
badger*	G	-	+	U/K	+ 0	N/A	--	down
otter	E, SN	N/A	N/A	U/K	N/A	N/A	U/K	extinct?
black bear*	G, LP	0	+	0	+ 0	+	-	down
brown bear*	G, LP	0	-	U/K	U/K	+	--	down
wild boar*	G	0	++	+	+	0	- 0	up
sika deer*	G	+	++	++	++	++	- 0	up
serow	SN	N/A	U/K	U/K	0	0	U/K	U/D
macaque*	LP	N/A	++	+	++	N/A	--	U/D
dormouse	R, N	N/A	N/A	U/K	N/A	N/A	U/K	U/D
Amami rabbit	E, SN	N/A	N/A	U/K	N/A	N/A	(-)	down
hare	G	--	--	+	--	--	U/K	down?
squirrel	LP	--	-	U/K	N/A	U/K	U/K	down
chipmunk		N/A	N/A	U/K	N/A	U/K	U/K	down?
giant flying squirrel		--	-	U/K	N/A	N/A	U/K	down
small flying squirrel	R	N/A	N/A	U/K	N/A	N/A	U/K	U/D (down?)

R = rare, T = threatened, E = endangered, N = natural monument, SN = special natural monument, G = game, LP = with threatened local populations (designated by the Government).
+ = increased, ++ = greatly increased, 0 = no apparent change, - 0 = slightly decreased, - = decreased, -- = greatly decreased, N/A = not applicable, U/K = unknown. Population trend: up = increasing or expanding, down = decreasing or shrinking, 0 = no apparent change, U/D = undetermined due to lack of information.
*species with distribution data in both 1979 and 1989-92 surveys. See scientific names in Appendix IV.
Sources of data 1, 2 and 6 = the Environmental Agency, data 3 = the Japan Highway Public Corporation, data 4 = the Ministry of Agriculture, Forestry and Fisheries, and data 5 = the Forest Agency.

ⁱⁱ Road-kills are reported as the major cause of mortality (Yasuda *et al.*, 1999 for Iriomote cat; Yasuda *et al.*, 2000 for leopard cat)
ⁱⁱⁱ except for the Tsushima marten (*Martes melampus tsuensis*), which is designated as a 'Rare' species by IUCN.
^{iv} undetermined status by IUCN and a species at risk by the Ministry of Environment.

Despite being a highly developed and populated country, Japan still maintains a fauna and flora relatively rich in diversity. However, wildlife has been facing difficult situations, including habitat loss, degradation and fragmentation, which are often overlooked in conservation efforts in Japan. Mono-culture plantation of softwoods in mountains and substantial urbanisation on plains with road networks throughout the country have degraded habitat quality for most wildlife species. In addition, a unique ecosystem of the Japanese countryside, *satoyama*, needs more protection from overall habitat degradation.



Walking on the river bed at low tide at dawn

CHAPTER 3

HABITAT ECOLOGY OF THE RACCOON DOG: HABITAT USE, PREFERENCE, AND STRUCTURE

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Summary

This chapter investigates habitat availability, and its selection and use by raccoon dogs inhabiting the countryside, *satoyama*, in Japan. Two types of habitat users existed in the study area. One type ('mountain type') inhabited semi-natural areas, such as secondary forest and herbaceous areas, whereas the second type ('village type') occupied a more managed agricultural environment. Habitat preference differed within each, though both used less Japanese cedar (*Cryptomeria japonica*) plantation in the home range. Habitat selection process seemed to occur at different scales and differed between the two types of raccoon dogs. Regarding home range placement, rice fields and cropland were preferred by the village type and avoided by the mountain type, whereas regarding habitat preference within home ranges, rice fields were used less by the village type and preferred by the mountain type. Habitat selection and habitat management are discussed in relation to the importance of conserving biological diversity in *satoyama* habitat.

Chapter 3 Habitat Ecology of the Raccoon Dog

3.1 INTRODUCTION

3.1.1 *What is the raccoon dog's habitat?*

In spite of the diverse variability in climate, vegetation, elevation, and human density in the Japanese Archipelago (Chapter 2), the raccoon dog (*Nyctereutes procyonoides* Gray) is found throughout most of Japan, including islets and urban areas. Other species of Carnivora, such as the red fox (*Vulpes vulpes japonica* Gray) and the Japanese badger (*Meles meles anakuma* Temminck) do not show this flexibility of habitat usage. Foxes and badgers are usually absent from small islets and city centres, although the badger may be found in suburbs and the outskirts of cities (Kaneko, 1996, 2001), and the red fox in Hokkaido (*V. v. schrencki* Kishida) has been sighted in the city of Sapporo (1,548 people/km²) (Ikeda, 1996). The raccoon dog, however, is repeatedly found in (and removed from) Tokyo's most populated 23-ward area (12,963 people/km²) (*Yomiuri Newspaper*, 1993b), and can occur at high density on small islets (Ikeda *et al.*, 1979; Masui, 1980).

Studies on the habitat of raccoon dogs are very limited (Bannikov, 1964 in Russia; Yamamoto *et al.*, 1995 in the Japanese urban area; Kauhala, 1996b in southern Finland), and the mechanism of habitat selection in this species is totally unknown. I considered that studying the habitat selection and habitat requirements in the countryside of Japan was essential for a number of reasons. First, research of this nature has never been conducted in Japan, and the findings will fill in part of the huge gap in our knowledge of this species. Second, the Japanese countryside is a crucial area for the future of the raccoon dog in Japan. Urban populations face many threats while the carrying capacity of the high mountains may be insufficient to maintain stable populations. The countryside habitat is essential in order to maintain their genetic diversity nationwide. Lastly, because the countryside is located between urban areas and remote areas, understanding habitat use by the raccoon dog in the transitional zone may have important implications for the conservation of the raccoon dog in both urban and remote areas. For management purposes, knowledge and data on habitat ecology are essential.

I thus selected my study area in the relatively unchanged countryside identified as *satoyama* habitat where raccoon dogs have co-habited with humans for centuries without major conflicts, but where significant conflicts have started to emerge. Although *satoyama*

does not have a scientific definition, its ecological importance has recently been recognised (Tabata, 1997; Fukamachi *et al.*, 1998). Osumi and Fukamachi (2001) defined *satoyama* as "a landscape of core forests and the surroundings which have been maintained through utilisation and disturbance by local people with their daily life, self-sustainable agriculture, and other traditional industries." *Satoyama* is a locus of both co-existence of and conflicts between people and wildlife.

3.1.2 Habitat availability, use, and selection

Estimating or measuring habitat availability for animals is crucial for habitat analysis (Manly *et al.*, 1993); yet it is often arbitrary (Aebischer *et al.*, 1993) because one cannot understand animals' perceptions of available habitat (White and Garrott, 1990). Measurement is also difficult because the availability of habitat for the animals may change over time (Arthur *et al.*, 1996) in response to ecological factors, such as interspecific competition and human disturbance, as well as physical factors, such as temporally inaccessible deep snow and temporally accessible ice on lake. In addition, changes in delineating an available area have significant effects on habitat analysis when the environmental patterns are aggregated (Porter and Church, 1987). Therefore, using the total study area and analysing it at one scale may be unsuitable for habitat analysis (Aebischer *et al.*, 1993).

When available habitat is not uniform and animals use a habitat type differentially, components of the habitat are said to be "selected." Habitat selection can occur at different scales, i.e. geographical scale (the first-order selection), home range scale (the second-order selection), and habitat component scale (the third-order selection), and habitat preference can be analysed accordingly (Johnson, 1980; Manly *et al.*, 1993). Jones (2001) clarified confusions among terms of habitat use, habitat selection, and habitat preference, defining habitat selection as "a hierarchical process of behavioural responses that may result in disproportionate use of habitats to influence survival and fitness of individuals." In this thesis, habitat preference is used to refer the phenomena of disproportionately more use of particular habitat types, whereas habitat selection is not studied because the decision-making process cannot be elucidated from this sampling scheme.

Habitat structure is usually measured by profiles of vegetation which have functional relationships with the species in focus (McCoy and Bell, 1991). However, I use habitat

components prerequisite for survival and reproduction in order to measure habitat structure. Food, water, day-time shelters, den sites for nursing, and paths for connecting these were considered to be the important habitat components for the raccoon dogs under study.

What parts and how much of an area an animal is actually using as a habitat usually cannot be measured with precision. Habitat use, therefore, must be assessed by the amount of time the animals spend in each habitat (Palomares and Delibes, 1992). Continuous radio-tracking with habitat data is one method of sampling the time spent in a particular habitat. However, caution is needed when using radio-fixes because sampling time and/or period and the activity pattern of animals may lead to bias in estimating habitat use (Palomares and Delibes, 1992). Problems may also arise in analysis. First, it is difficult to obtain random independent samples of radio-fixes. Most statistics for habitat analyses assume independent observations (White and Garrott, 1990). Second, errors in radio-locations decrease the efficiency of the analysis and may create bias in results (Nams, 1989).

Despite these problems, radio-tracking remains the most suitable method to estimate animal's locations with minimal disturbance. In this study, continuous radio-tracking data during the night were used to estimate habitat use of raccoon dogs, and habitat availability was determined from a subset of the study area. Compositional analysis (Aebischer *et al.*, 1993) enabled the problem of dependent observations in my radio-tracking data to be overcome to obtain habitat preferences of raccoon dogs.

3.1.3 Chapter Objectives

In this chapter, my main aim is to elucidate the habitat ecology of the raccoon dogs which inhabit the countryside, *satoyama*, in Japan. This chapter has four objectives:

- to ascertain habitat use
- to assess habitat preference at different scales
- to evaluate factors influencing habitat preference
- and to discuss habitat structure and requirements for the raccoon dogs.

3.2 METHODS

3.2.1 Study Area

The study area ($140^{\circ} 18'E$, $35^{\circ} 22'N$), roughly 25 km^2 , was located mainly in Mutsuzawa-machi (population ca. 8,500), Chiba Prefecture in the Boso Peninsula, approximately 70 km south-east of Tokyo, Japan (Figure 3.1). To the north, the area was adjacent to a moderately developed city (population ca. 94,000); there were no major urban areas to the south. The climate was mild because of its proximity to the warm current, the Kuroshiwo, in the Pacific Ocean, with an average annual temperature of 15.0°C , an average total precipitation of 1,700 mm, and an annual average of relative humidity of 75% (Observations Department, 1992).

Figure 3.1 Location of the study area in Japan.

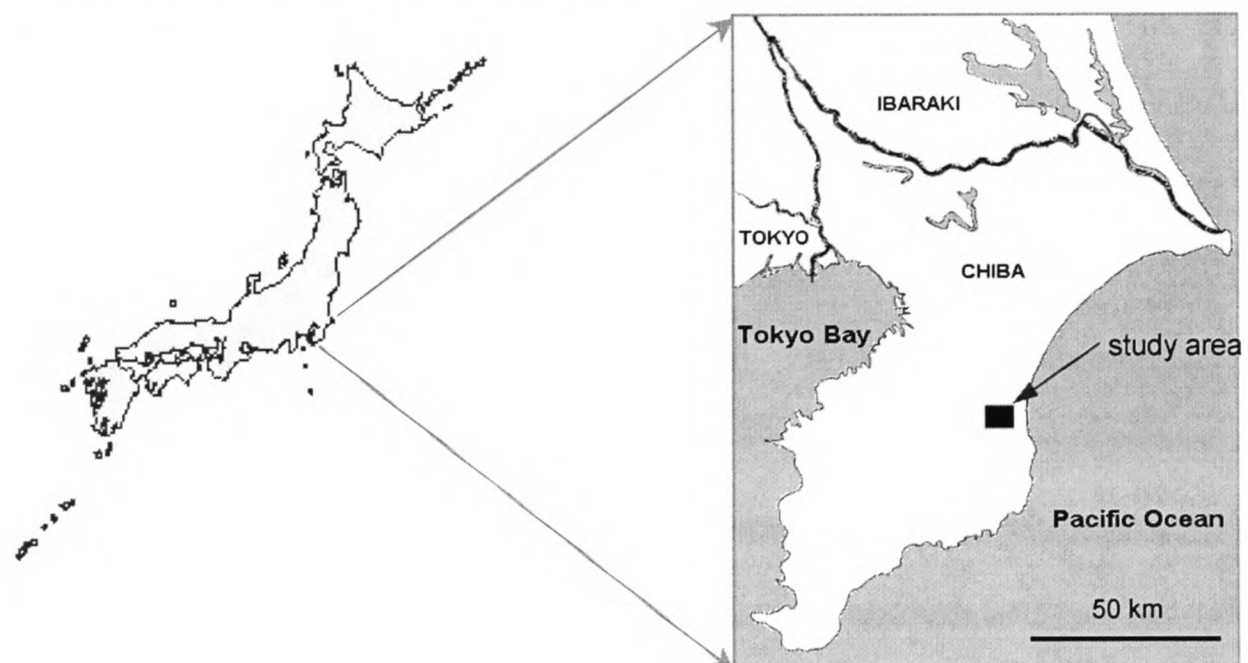
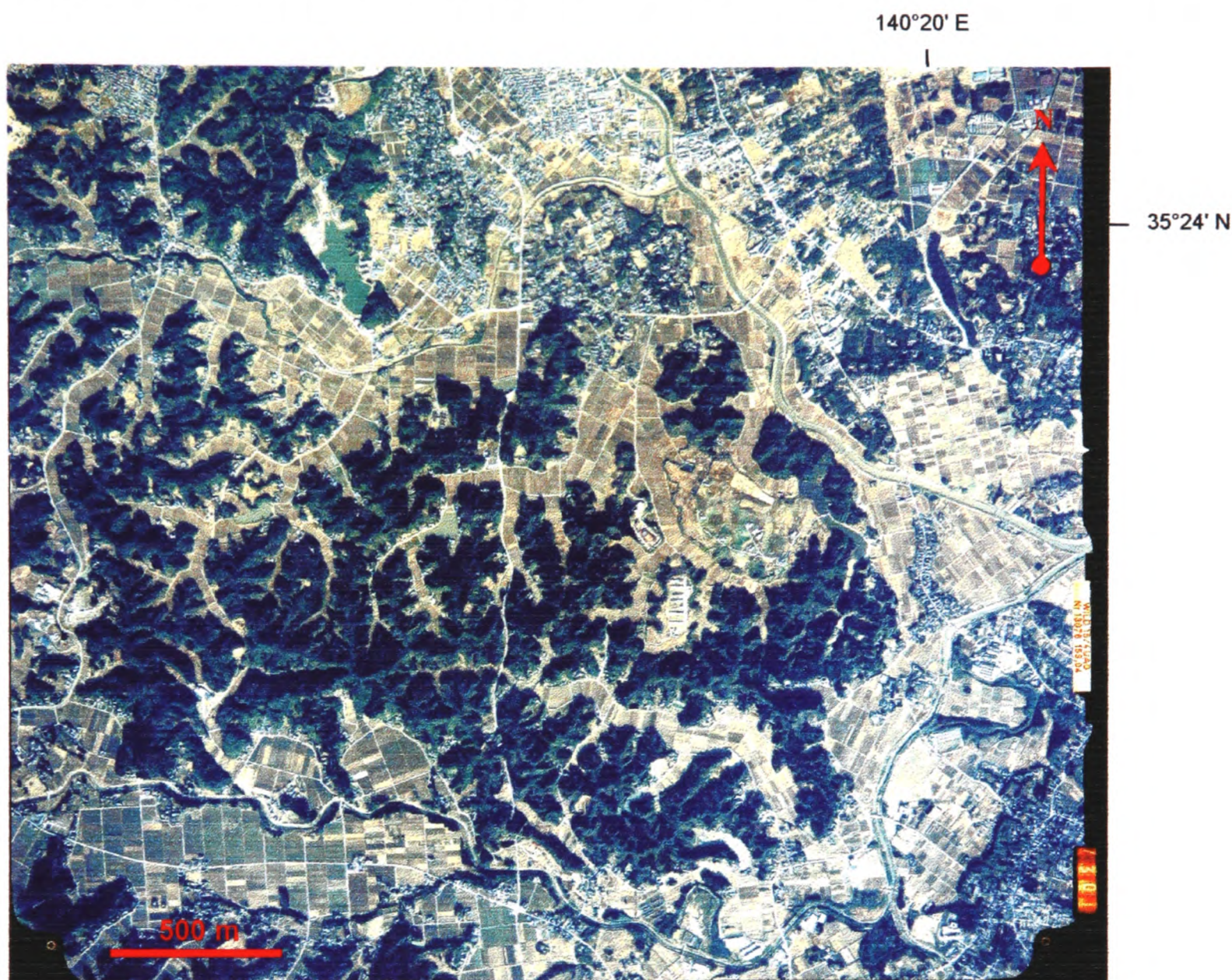


Figure 3.2 Aerial photograph of a part of the study area. (Reproduced by permission of the Geographical Survey Institute of Japan; taken on January 11, 1992)



The area comprised flat plains, consisting of a mosaic of rice (*Oryza sativa* L.) fields, riparian rushes (*Phragmites* spp. Steud. and *Typha* spp. L.) and houses, and low hills (<100 m alt.) with a mixture of forests and pasture fields. Broad-leaved evergreen species (e.g. *Castanopsis cuspidata* Schottky, *Quercus serrata* Thunb. and *Q. glauca* Thunb.) and broad-leaved deciduous species (e.g. *Carpinus tschonoskii* Maxim and *Prunus jamasakura* Sieb.) remained on ridges and slopes while coniferous plantations of Japanese cedar (*Cryptomeria japonica* D. Don) and bamboo (*Phyllostachys heterocycla* Matsumura and *P. bambusoides* Sieb. et Zucc.) were mainly found in valleys or close to human residences. Abandoned rice fields were often located in valley bottoms. Forest edges without management were usually covered with dense bamboo grass (*Pleioblastus chino* Makino) or kudzu vine (*Pueraria lobata* Ohwi.). Reed grasses (*Phragmites communis* Trin. and *Miscanthus sacchariflorus* Benth.) grew on riparian zones and abandoned rice fields. Eight hundred and seventy-four vascular plant species (130 families) were recently confirmed in the area (Chiba

Prefecture, 1996a, 1996b).

Two tidal streams (Class B rivers) ran through the area with a confluence at a point 6-km from the mouth of river. The landscape, especially at the heads of valleys, was studded with artificial ponds and reservoirs for rice farming.

Rice farming was the major land use in the region (approximately a quarter of the land area). The rice fields were ploughed and flooded in late March to April before planting rice sprouts, which have been grown in special nurseries. Aerial spray of pesticides was conducted twice during May. The water levels were maintained through a month-long rainy season between spring and summer. The fields were drained before harvest in late August to September. Machinery, such as tractors and combines, were used for planting and harvest. The fields were left as muddy open areas during the rest of the year.

Free-ranging domestic dogs (*Canis familiaris* Linnaeus) were often seen in the study area, sometimes forming a pack during night. The domestic cat (*Felis catus* Linnaeus), the Japanese badger, the masked palm civet (*Paguma larvata* Hamilton-Smith) (an introduced species), the Japanese weasel (*Mustela itatsi* Temminck), and the Japanese marten (*Martes melampus* Wagner) were occasionally captured in live-traps intended for raccoon dogs and released when found. One common raccoon (*Procyon lotor* Linnaeus) which could have been an abandoned or escaping pet, was killed by a car in the area in 1994. The red fox was absent in the area although a fox was killed by a car in the 1990s in Isumi-machi, situated adjacent to the south of Mutsuzawa-machi (Isumi-machi Public Office, personal communication). Other mammalian species inhabiting the area are listed in Appendix V (in bold). Besides those mammals, confirmed species in the area at the time of the study included 131 benthic invertebrate species (57 families), 844 insect species (190 families), 11 freshwater-fish species (7 families), 9 amphibian species (5 families), 10 reptilian species (5 families) and 76 avian species (28 families) (Chiba Prefecture, 1996a, 1996b). Possible avian predators to the raccoon dog, especially to young, were the great owl (*Strix uralensis* Clark), the Northern goshawk (*Accipiter gentilis* Swann et Hartert), the black kite (*Milvus migrans* Gray), the grey-faced buzzard-eagle (*Butastur indicus* Gmelin), the jungle crow (*Corvus macrorhynchos* Wagler), and the carrion crow (*C. corone* Parrot). The species of fish and amphibian are also shown in Appendix V because of their importance as potential food items for the raccoon dogs.

3.2.2 Trapping and Handling

Raccoon dogs were captured between August 1993 and April 1998 in order to have radio-collars fitted for the study. Box-traps (26 x 32 x 81cm, Tomahawk Live Trap Co. Wisconsin, USA) were used. Ten traps were used from August 1993 (until two traps were stolen), and eighteen were used from December 1997 to April 1998. Three to five trapping days per week were conducted until all available radio-collars were used at the time (total of 21 animals fitted with radio-collars). Trapping was not carried out during parturition and early nursing periods (mid-April to mid-June). Because of the limited number of traps, traps were located where raccoon dogs were most likely to be captured in the study area. These sites included forest edges, riparian areas, concrete gutters, and scrub. The choice of possible sites was based on local knowledge and field signs. Traps were baited with peanuts, fish, dog food or dried fruits. The traps were staked and covered with straw mats made from bamboo (Saeki, 1998) to protect them from free-ranging domestic dogs, after an incident in which a raccoon dog in a trap was attacked and severely injured. The traps were opened in the evening, just before sunset, checked at around midnight, and closed at dawn.

Captured animals in traps were brought back to a field station. They were weighed in a jute bag and anaesthetised with a ketamine hydrochloride (0.2 ml/kg BW) and xylazine hydrochloride (0.1 ml/kg BW) mixture 10 minutes after an injection of atropine sulfate (0.1 - 0.2 ml). After sedation, they were measured, sexed, and equipped with radio-collars (144 - 147 MHz; Biotrack Ltd. Dorset, UK; 80 - 120 g; 1.3 - 3.3 % BW) and ear-tags (1005-3, National Band and Tag Co. Kentucky, USA). The animals were released after recovery at the site where they had been captured.

Permission for live-trapping raccoon dogs for scientific research was granted by the Environment Agency of Japan.

3.2.3 Radio-tracking

I tracked radio-collared animals first with a receiver (improved Mark II, Yaesu, Japan) and a whip antenna attached to a 4 x 4 vehicle (Escude-Nomado, Suzuki Motor Co., Japan) and then, on foot, obtained 2 or more bearings with a compass (Ranger-15, Silva, USA) for triangulation using a receiver (TR-2 Telonics, Arizona, USA) and a hand-antenna (RA-2A, Telonics, Arizona,

USA). I tried to take fixes every 15 minutes on an animal (a focal animal during the night) and additional fixes of other animals when possible. Two or three bearings that were taken within 3 minutes were used for triangulation. Activity levels were recorded by signal strength (**I**: inactive--the signal strength does not vary; **A**: active--the signal strength varies; **AA**: very active--the signal strength varies to the point where some beeps are not heard). The signal strength was coded from 1 to 5 (**1**: barely audible; **2**: weak; **3**: loud; **4**: very loud; **5**: audible without antenna), and reliability was coded from 1 to 5 (**1**: not reliable because signals are bouncing or seem to be coming from many directions; **2**: probably reliable because supported by other cues, such as previous movement; **3**: reliable; **4**: very reliable; **5**: animal visually identified). Reliability levels of 1 and 2 were not used in analyses.

A temporal microclimate code (three digits) was recorded for every fix. The first number was a weather code (**1**: cloud cover <10% of the sky; **2**: cloud cover between 10 and 60%; **3**: cloud cover >60%; **4**: shower or rain; **5**: thunder storm; **6**: snow; **7**: hail; **8**: heavy mist). The second number was a wind-velocity code estimated from movements of grasses and branches of tree (**1**: 0-1; **2**: 2-5; **3**: 6-10; **4**: >10 meters/second), and the third number was an ambient-temperature code (**1**: <0; **2**: 0-10; **3**: 11-20; **4**: 21-30; **5**: >30 °C); this last was estimated and periodically checked using a watch with a thermal sensor (PRO TREK Triple Sensor, CASIO Computer, Co. Ltd., Japan).

Daytime resting sites were determined by locations during a day when the animals were confirmed not to be moving. A den site, which is defined as a frequently used site of either natural or artificial structure, was noted as den use when used during daytime.

Error was estimated in the case of dropped collars and dead animals when I was unaware of their status when bearings were obtained. The mean distance between my estimated locations and the actual locations was 11 m with the distance between me and the objects of <150 m. The error could be larger when the objects were moving and the distance from the objects was greater. However, most bearings were taken from the distance of <100-m within 2 - 3 minutes. The average number of fixes per animal was 955.4, ranged from 137 to 3377. For continuous sessions, the average number of fixes per animal 575.9, ranged from 110 to 1,873 fixes per animal. Because I took all fixes, the error can be assumed consistent.

3.2.4 Defining habitat availability, use, and quality

A subset of the study area (approximately 4.5 km²; 18% of the study area) was chosen for habitat analysis on the basis of the physical features and the tracked animals' home ranges: the area was surrounded by two rivers (north-east and south sides) and two paved roads (north and west sides), and contained 14 home ranges for analysis. A digitised habitat cover-map (Figure 3.3) was constructed based on scanned land-use maps (1:2,500; Mutsuzawa-machi Public Office, Chiba Prefecture, Japan) on which additional information of vegetation cover and their boundaries was added from two aerial photographs (Geographical Survey Institute, the Minister of Construction of Japan, 1991) with folding mirror stereoscopes (C F Casella & Co. Ltd., London) and a magnifying lens (10 X; Hilkinson, Japan) and data from ground surveys conducted by M. Saeki. Twelve habitat types (Table 3.1b) were delineated on the digital map from 14 vegetation cover types, open water, bare ground, and human development (Table 3.1a); the habitat types were further grouped into 7 categories for compositional analysis (Table 3.1c). The secondary forests were not homogeneous, with a tendency for more mature hardwood species to be found on ridges and mixed stands to be found on slopes, but, they were nonetheless treated equally in one category. Small patches that could not be detected on the aerial photographs were not included. The digital map was geo-registered (i.e. geometrically corrected) with 64 ground control pointsⁱ. The error of the map, i.e. the difference between distances on a mapping plane and on the ground, was 3.784 m with the resolution of 0.4962 m per pixel.

Habitat type of each fix location (n = 8,308) in continuous tracking sessions was identified using the digital map. Each fix location was plotted on the habitat map using IDRISI for Windows (Clark Labs, 1998). The vector files of fixes were overlaid on the magnified image file, i.e. the digital habitat map, and habitat type was confirmed for each fix by eye. This was done because some fixes taken from a short distance (about <5 m, confirmed by direct observation or sound of the animal and receiving signals without an antenna) were recorded on co-ordinates of the radio-tracker (M. Saeki) and needed to be corrected into true habitat types.

ⁱ Note is given at the end of the chapter.

Figure 3.3 Digital habitat map used for habitat analysis.

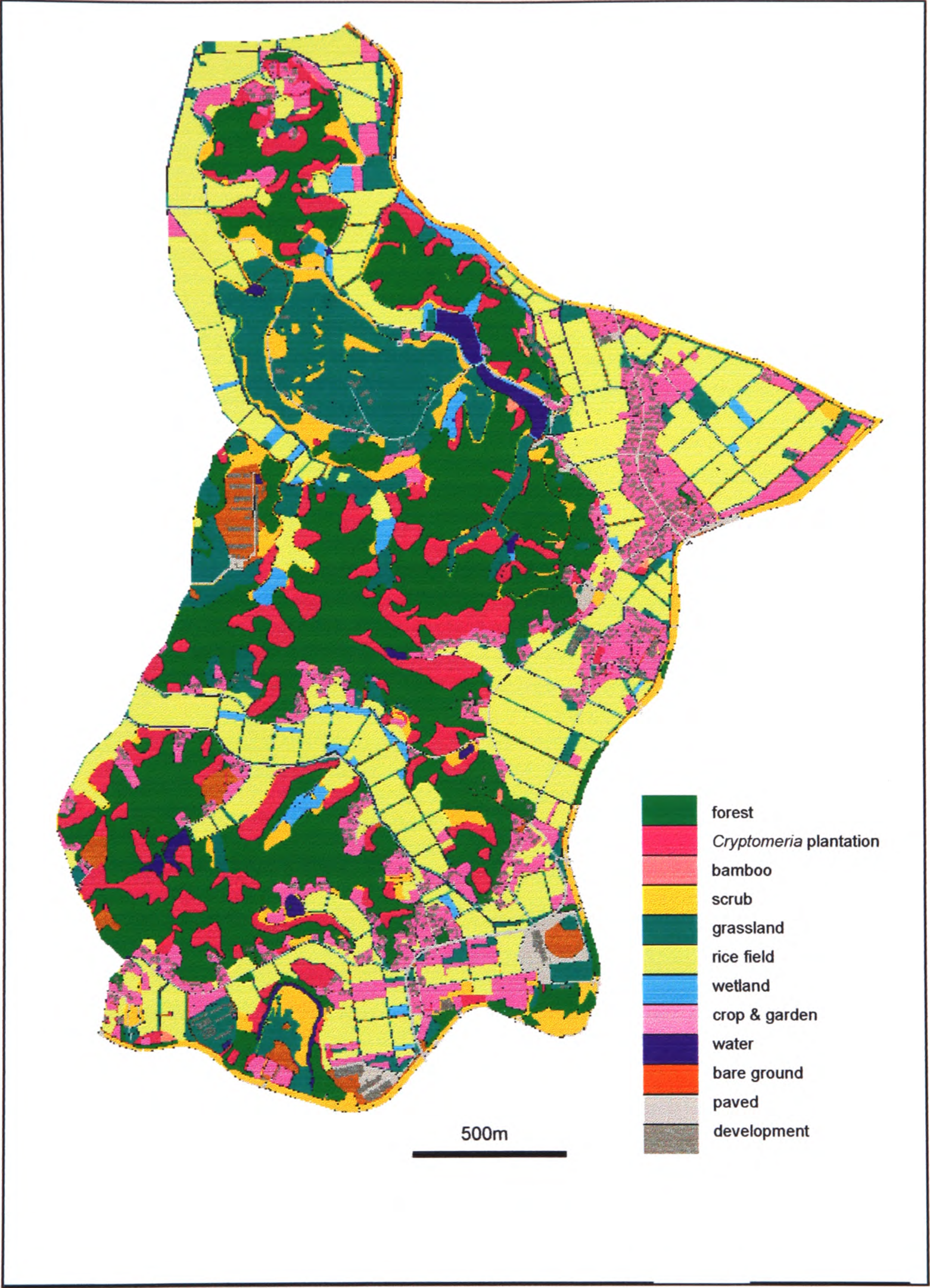


Table 3.1 Definitions of (a) cover types, (b) habitat types, and (c) habitat categories of the study area.

a)	code	cover type	dominant plant species
	1	Broad-leaved evergreen	<i>Castanopsis cuspidata</i> , <i>Quercus</i> spp., <i>Eurya japonica</i>
	2	Broad-leaved deciduous	<i>Carpinus tschonoslii</i> , <i>Prunus jamasakura</i>
	3	Mixed forest	broad-leaved, <i>Cryptomeria japonica</i> , <i>Phyllostachus</i> spp.
	4	<i>Cryptomeria</i> plantation	<i>C. japonica</i>
	5	Bamboo	<i>Phyllostachus</i> spp.
	6	Scrub 1: sasa bush	<i>Pleioblastus chino</i>
	7	Scrub 2: kudzu bush	<i>Pueraria lobata</i>
	8	Scrub 3: butakusa bush	<i>Ambrosia trifida</i>
	9	Short grassland	<i>Echinochloa crus-galli</i> , <i>Isachne globasa</i>
	10	Tall grassland	<i>Miscanthus sinensis</i>
	11	Rice field	<i>Oryza sativa</i>
	12	Wetland	<i>Phragmites communis</i> , <i>Typha</i> spp.
	13	Cropland	vegetables, beans, corn, etc.
	14	Orchard	<i>Purunus ume</i> , <i>Pyrus pyrifolia</i> , garden
	15	Water, incl. lotus pond	<i>Nelumbo nucifera</i> , <i>Epirodela polyrhiza</i>
	16	Bare ground	unpaved road, ball field, quarry, etc
	17	Paved road	incl. paved parking lot and concrete ground
	18	Human development	houses, buildings
b)	cover type	code	habitat type
	1+2+3	A	Natural and secondary forests
	4	B	<i>Cryptomeria</i> plantation
	5	C	Bamboo plantation
	6+7+8	D	Scrub
	9+10	E	Grassland
	11	F	Rice field
	12	G	Wetland
	13+14	H	Cropland and garden
	15	I	Water
	16	J	Bare ground
	17	K	Paved road
	18	L	Human development
c)	habitat type	habitat category	
	A	Forest	
	B+C	<i>Cryptomeria</i> Plantation	
	D+E+J	Herbaceous	
	F+G	Rice field and Wetland	
	H	Crop and garden	
	I	Water	
	K+L	Urban	

Invertebrates in soil and litter were sampled monthly at 4 random plots (50 x 50 x 5 cm; litter on the ground was excluded from the depth) in each of 3 cover types: grassland, *Cryptomeria* plantation, and secondary forest. Four invertebrate box-traps with adhesive floor and bait (Gokiburi-hoi-hoi, Earth Pharmaceutical Co., Japan) were set overnight in each of the 3 cover types, and also in the wetland habitat. The purpose of this survey was to detect seasonal and cover-type differences in relative abundance and species composition of the potential food items of soil macrofauna species, e.g. earthworms and insect larva, and of surface invertebrates, e.g. snails, ground beetles, and millipedes. Soil and litter were weighed and hand-sorted with two types of sieves (10 x 10 mm and 5 x 5 mm), and organisms >5 mm were counted within taxonomic groups, e.g. insect family, earthworm, slug, snail, centipedes, and insect larvae. Variables recorded at each plot were habitat type, dominant plant species, %

canopy closure (ocular estimates), % ground cover (ocular estimates), maximum tree/grass height, slope direction, slope inclination, elevation (estimated from locations on topographic maps), and soil temperature. Japanese persimmon trees (*Diospyros kaki* Thunb.), the fruits of which appeared to be an important food source in autumn to early winter (Yamamoto, 1991; M. Saeki, pers. obs.), were also plotted on maps (1: 2,500) during the fruiting season of 1995.

Environmental features of den sites, i.e. size and direction of the entrance, slope, substrates, elevation, vegetation cover, and number of entrances, were recorded, and the locations were mapped.

For diet analysis, I collected road-kills of raccoon dogs in the area. The stomach and intestines were weighed and frozen until being fixed with alcohol. The stomach contents were measured in volume and weight, and examined using two sizes of sieve (2.0 x 2.0 mm and 0.5 x 0.5 mm). Animal, plant and artificial matters were separated. Parts of legs, antennae, and wings etc. of insects were sorted on cotton mats for further identification.

Data analyses

The five most common habitat categories (in terms of percentage contribution of area) were ranked according to their relative abundance of food items and cover. This was done separately for each season. Habitat categories were ranked using average abundance of soil and surface invertebrates (the group richness, and the numbers of earthworms, ground beetles, centipedes, slugs, snails, and insect larvae) to produce the score. Relative abundance of amphibians and plant food (fruits, acorns, and berries) was also scored using data from the literature (Fujioka and Lane, 1997; Lane and Fujioka, 1998), plant species distributions (Chiba Prefecture, 1996a, 1996b), and my field observations (Table 3.2a) for each season: food quality rating = invertebrate score + amphibian score + plant food score. Cover scores (Table 3.3b) were used to rate the quality of cover of the habitat: cover quality rating = ground cover score + canopy closure score.

Inter-fix speed, calculated from consecutive fix locations with approximately 15-minutes interval, was compared between individuals, habitat types, and type of habitat users, i.e. individuals that predominantly used areas of semi-natural habitat (= 'mountain type') and those that occupied areas near human settlements (= 'village type'). The interfix speed was logarithmically transformed before being tested with the General Linear Models Procedure

(GLM) using SAS (SAS Institute, Inc., 1989-1996).

Habitat composition was obtained for 3 levels: 1) the total area 2) home ranges estimated with 95% Kernel estimates, and 3) fix locations in each home range, using PaintShop Pro 4 (Jasc Software, 1991-1998), RANGES V (Kenward and Hodder, 1996) and IDRISI. Habitat preference was obtained at three scales: 1) home range in the total area, 2) fixes in the home range and 3) fixes in the total area, with ranking matrices for 7 habitat categories, using compositional analysisⁱⁱ of habitat use (Aebischer *et al.*, 1993). The SAS system for Windows was used for the computation; the programme was written by P. Johnson and adapted by M. Saeki. While climate, prey density, and fruit abundance may have varied between years, data were available from too few animals to include 'year' as a categories factor in statistical models.

The compositional analysis (Aebischer *et al.*, 1993) offers several advantages for analysing habitat. First, it uses individual animals as samples, not radio-fixes pooled across animals, and MANOVA/MANOCOVA-type models can be performed at the animal level. Therefore, the frequent autocorrelated radio-fixes increase accuracy of habitat use without imposing the independence problem, and individual difference can be taken into account (Aebischer *et al.*, 1993). In this study, habitat analysis was conducted using only continuous radio-fixes at approximately 15-minute intervals for equal or ≥ 4 hours during night, and all-night sessions were conducted on every animal. Two hundred and ninety-nine night-sessions ($\bar{X} = 21.4$ night/animal) and 228.7 fixes per season and animal, ranged 53 from fixes 788. These fixes represent the largest collectable range of habitat use by including little-used habitat types. Second, using the log-ratio transformation makes the linear independence of the ratios; the preference of one habitat type is not influenced by proportions of habitat types, of which the sum is always 1.0 (Aebischer *et al.*, 1993). Third, analysing at more than one scale makes it more likely to detect the animals' perception of habitat availability and use, and consequently, habitat selection (Aebischer *et al.*, 1993).

ⁱⁱ Note is given at the end of the chapter.

3.3 RESULTS

Twenty-four raccoon dogs were captured between August 1993 and April 1998, and 21 animals (7 females and 14 males) were fitted with radio-collars and were tracked (Table 3.2). Two juveniles (females) were released only with ear-tags. Ten animals (5 females and 5 males) were subadult when they were captured and large enough for radio-collars. Home range analysis was conducted for 18 animals with sufficient data. A total of 17,465 fixes met the precision criteria over a period of 55 months, and 16,155 fixes were used for movement and utilisation distribution analyses. Body measurements of these individuals and some road-kills are given in Appendix V.

Table 3.2. Twenty-one raccoon dogs that were radio-tracked.

Name	Sex	Age class	Period of tracking
Aoi	female	adult	August - September 1993
Bokuden	male	adult	September 1993 - December 1995
Cojiro	male	yearling	October - November 1993
Daphne	female	yearling	November 1993 - December 1995
Echo	female	adult	February 1994 - June 1996
Fujitsubo	female	yearling	April - June 1994
Gaia	female	yearling	April - June 1994
Heiji	male	adult	July 1994
Ittohsai	male	adult	October 1994 - January 1996
Jirokichi	male	yearling	November 1994 - August 1996
Kudon	male	adult	November 1994 - March 1995
Luna	female	yearling	April - August 1995
Musashi	male	adult	April - May 1995
Nobutsuna	male	adult	August 1995 - September 1998
Oribenosuke	male	yearling	May 1996 (three nights)
Poseidon	male	yearling	January - July 1997
Q-taro	male	yearling	February 1997 (one night)
Ryoma	male	adult	January - May 1998
Shusaku	male	yearling	March - September 1998
Tesshu	male	yearling	June - July 1998
Utena	female	yearling	April - August 1998

3.3.1 Habitat availability and quality

3.3.1.1 Habitat Availability

Total availability of habitat in the study area was limited to the area of the habitat map (Figure 3.3), and subsequently referred to as the "total area." Although arbitrary to some degree, the delineation is made from the physical and ecological boundaries. I also assumed that the area was equally available to all animals analysed. Two habitat types, forests (mostly secondary forests) and rice fields, comprised more than a half of the total area (Figure 3.4). Figure 3.5 shows habitat category composition, used in the preference analysis.

Figure 3.4 Habitat composition of the total area.

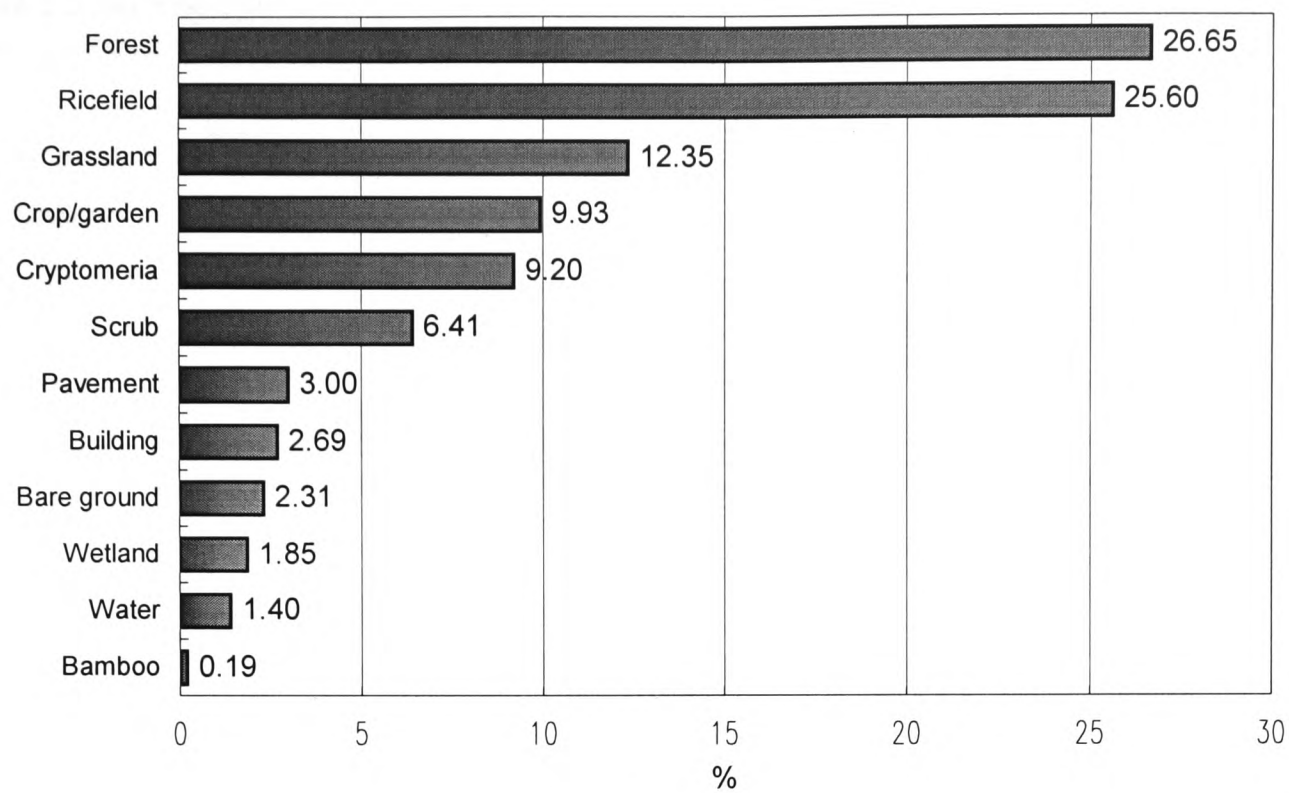
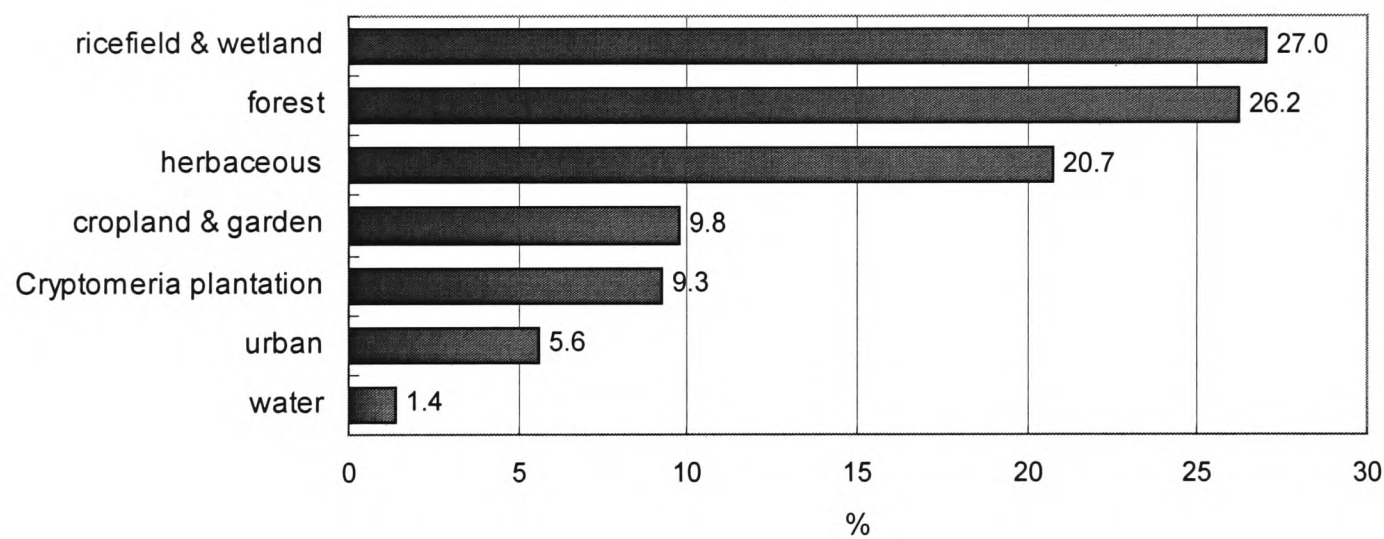


Figure 3.5 Habitat category composition in the total area.



3.3.1.2 Habitat Quality

Habitat quality is spatially and temporally heterogeneous. Because distinct seasons and agricultural activities were prominent in the study area, habitat quality was considered to be influenced by seasons.

Five habitat categories were scored depending upon abundance of food sources and also upon the degree of providing cover by season (Table 3.3). Food abundance peaked in spring in the herbaceous habitat, in summer in forest, plantation and rice field habitats, and in autumn in cropland (Figure 3.6a). The rice field habitat provided cover only in summer, whereas other three habitats provided relatively stable cover throughout the year (Figure 3.6b).

Table 3.3 (a) Food (b) and cover scores in each habitat type in each season. (See text for detail of how scores were obtained)

a)

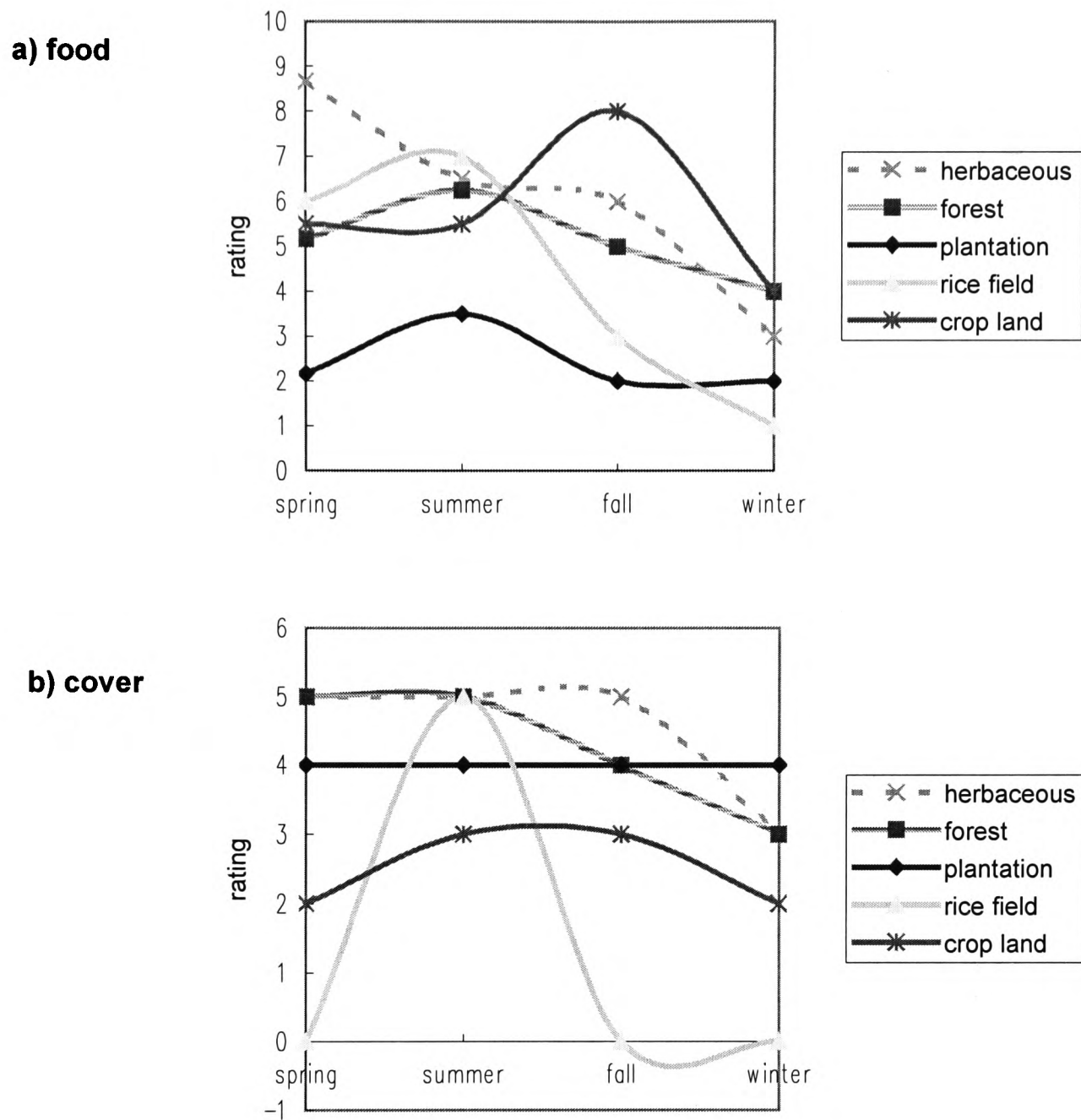
	spring	summer	fall	winter
soil macrofauna				
herbaceous	2.67	2.5	3.0	3.0
forest	2.17	2.25	2.0	2.0
plantation	1.17	1.5	1.0	1.0
rice field	1.0	2.0	2.0	1.0
cropland	1.5	2.5	2.0	1.0
amphibian				
herbaceous	2	2	2	0
forest	2	2	2	1
plantation	1	2	1	1
rice field	5	5	1	0
cropland	1	1	1	0
berries & acorns				
herbaceous	2	1	0	0
forest	0	1	1	1
plantation	0	0	0	0
rice field	0	0	0	0
cropland	0	0	0	0
fruits				
herbaceous	2	1	1	0
forest	1	1	0	0
plantation	0	0	0	0
rice field	0	0	0	0
cropland	3	2	5	3

b)

ground cover		closure	
%	score	%	score
95-100	5	95-100	4
75-95	4	50-95	3
45-75	3	30-50	2
20-45	2	15-30	1
5-20	1	0-15	0
0-5	0		

Ground cover was scored only where vegetation was >40 cm height.

Figure 3.6 Seasonal changes in habitat quality rating for (a) food abundance and (b) cover for the raccoon dogs.



3.3.2 Habitat use

Fourteen animals with sufficient data from continuous tracking for at least one season were used for analysis. Seasonal habitat use was pooled by season across years. Habitat use of four animals tracked >2 years was obtained individually by season.

3.3.2.1 General Use

Habitat composition in each home range (95% kernel estimate) is shown in Figure 3.7. Home range is the second-order use and the third-order availability for habitat selection process (Johnson, 1980). Individual home-range placement varied greatly (Figure 3.7). However, results showed that the animals could be grouped into two types: those that predominantly used areas of semi-natural habitat and those that occupied areas near human settlements. The

habitat composition of individual home ranges (Figure 3.7) was used for the classification; if the percentage of herbaceous and forest habitats exceeded the percentage of rice field and cropland habitats, the individual was classified as mountain type, since herbaceous and forest habitats were common in the mountains. If the percentage of rice field and cropland habitats was greater, the individual was classified as village type (Table 3.4; Figure 3.8). This classification was also associated with an observed level of shyness towards humans. The village-type individuals were often sighted by local people and myself, while the mountain-type individuals were only seen when they were trapped, even when radio-tracking effort was similar.

Figure 3.7 Percentage of each habitat category in individual home ranges.

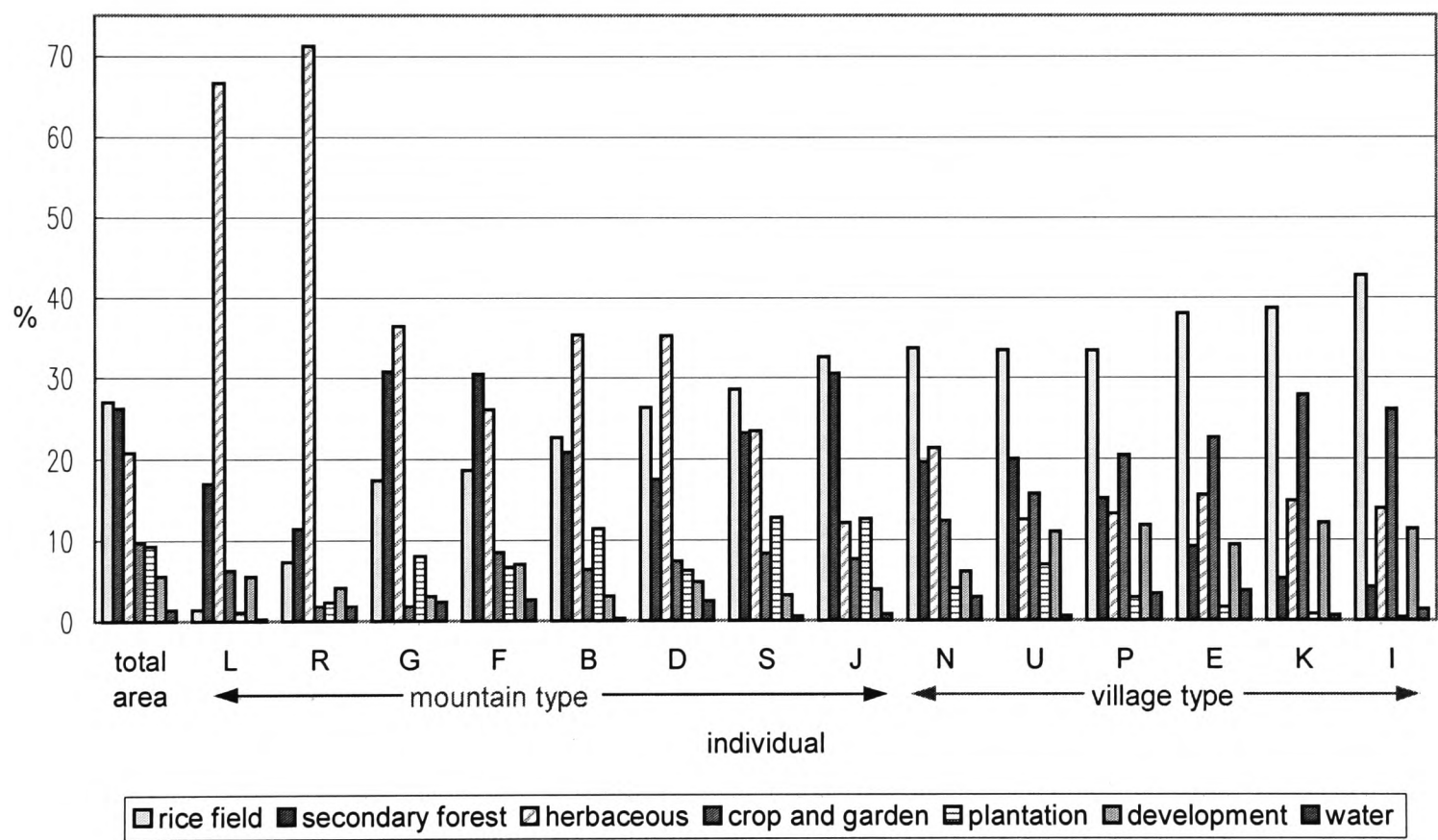


Figure 3.8 Individual habitat use of animals with more than two seasons tracked (percent of fixes in each category).

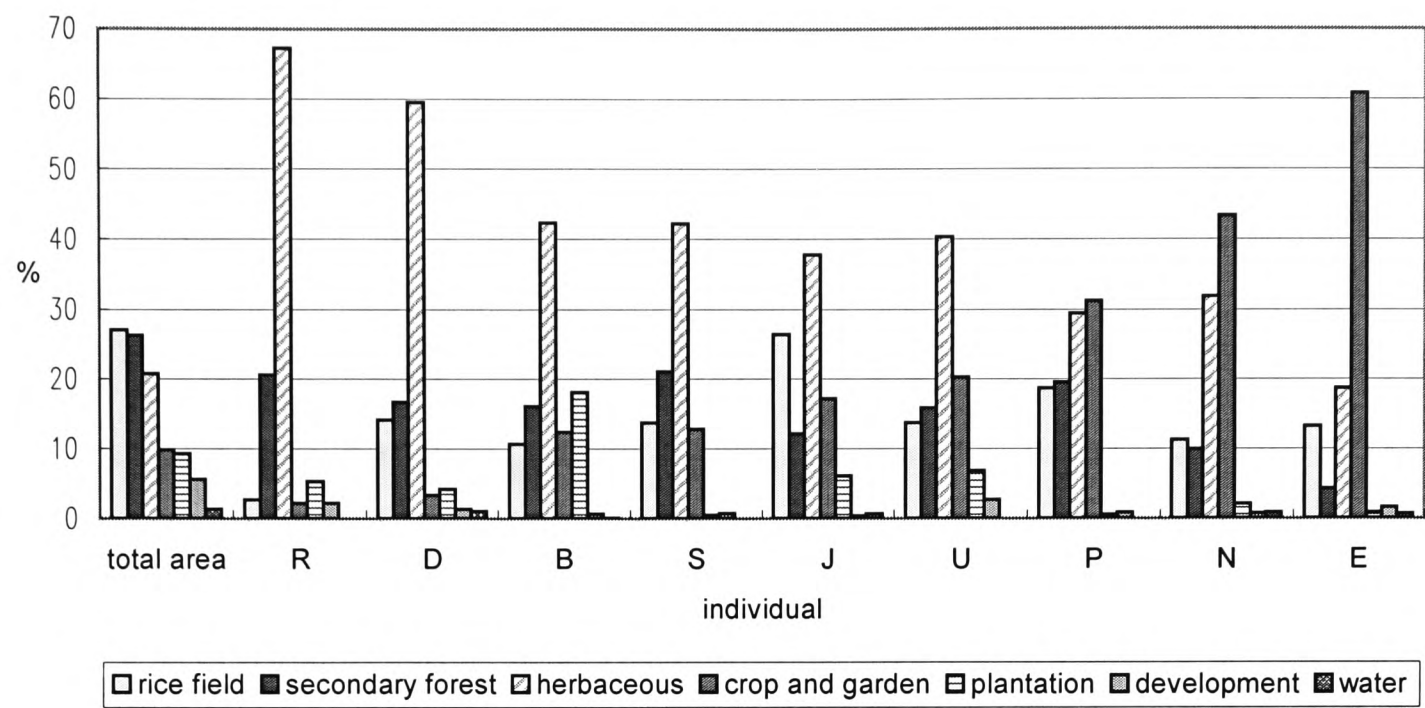


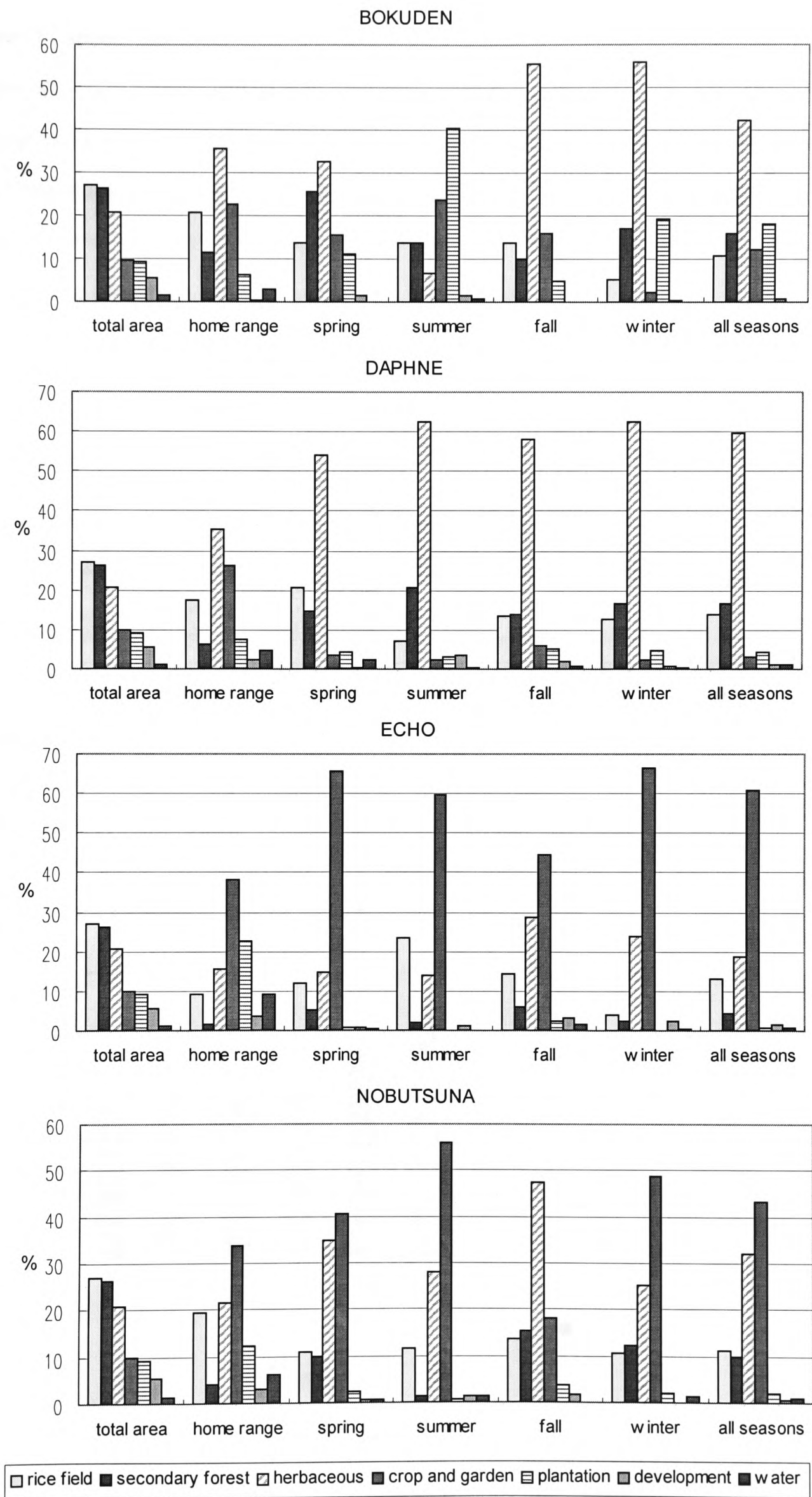
Table 3.4 Percentage of habitat categories in the total area and individual home ranges of the raccoon dogs.

individual	r	f	h	c	p	d	w	(f+h)-(r+c)	type
L	1.38	16.97	66.67	6.27	1.08	5.51	0.23	75.99	m
R	7.34	11.39	71.22	1.84	2.28	4.12	1.81	73.43	m
G	17.36	30.85	36.48	1.83	8.02	3.10	2.35	48.14	m
F	18.64	30.50	26.10	8.47	6.70	7.02	2.57	29.49	m
B	22.62	20.86	35.38	6.34	11.41	3.07	0.32	27.28	m
D	26.36	17.48	35.29	7.37	6.23	4.81	2.47	19.04	m
S	28.58	23.22	23.40	8.35	12.77	3.14	0.54	9.69	m
J	32.60	30.57	12.08	7.61	12.55	3.83	0.76	2.44	m
N	33.70	19.56	21.34	12.38	4.02	6.09	2.91	-5.18	v
U	33.46	19.97	12.47	15.64	6.95	10.97	0.55	-16.66	v
P	33.38	15.07	13.21	20.42	2.83	11.81	3.28	-25.52	v
E	38.08	9.18	15.48	22.59	1.67	9.33	3.68	-36.01	v
K	38.67	5.15	14.76	27.90	0.81	12.09	0.61	-46.66	v
I	42.78	4.18	13.87	26.10	0.40	11.29	1.38	-50.83	v
total area	27.02	26.23	20.74	9.77	9.25	5.60	1.38	10.18	

r = rice field, f = forest, h = herbaceous, c = cropland, p = plantation, d = development, w = water
m = mountain type, v = village type (detail in the text)

Four animals (two mountain-type and two village-type) which were tracked continuously for over 2 years showed some consistency in habitat use throughout the year, and data were pooled over the 2 years (Figure 3.9).

Figure 3.9 Habitat use through the seasons for four animals tracked over 2 years.



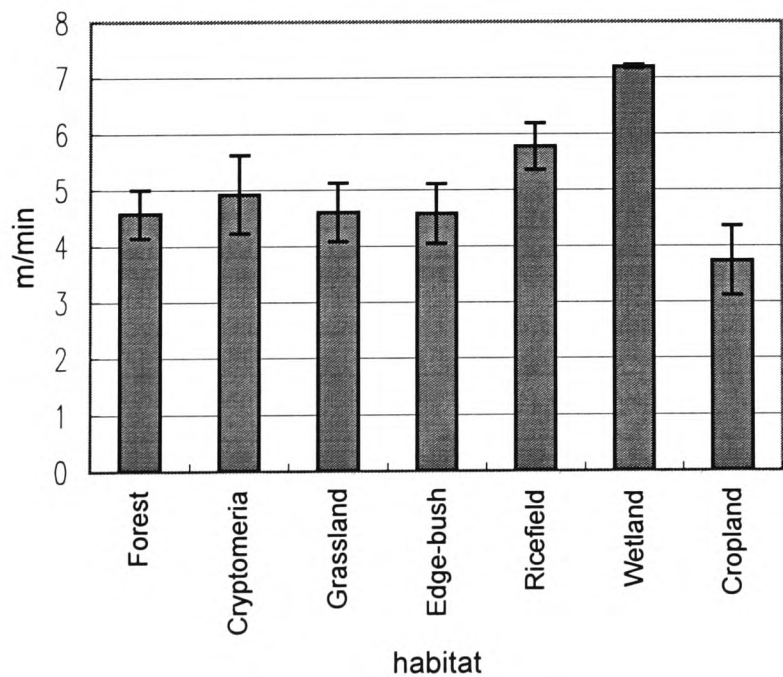
3.3.2.2 Inter-fix Speed

Inter-fix speed, calculated from two consecutive locations on each 15-minute interval using 18 animals (309 nights), differed significantly between individuals, habitat user types (i.e. mountain type and village type), and habitat types but not between the two habitat user types for type III analysis (Table 3.5, Figure 3.10). These show that although the effect of habitat user type on inter-fix speed is not significant when other effects of variables were removed, the significant interaction between habitat and user type suggests that both are important factors when considered together. This infers that inter-fix speed varies depending upon habitats and the effect of habitat differs between the mountain type and the village type, suggesting differential use of habitat by the two types of raccoon dogs.

Table 3.5 General Linear Models Procedure for inter-fix speed.

Source	DF	Sum of Squares	Mean Square	F Value	p
Model	35	167.37156855	4.78204482	7.20	0.0001
Error	96	63.71669482	0.66371557		
Corrected Total	131	231.08826337			
Type I					
Type of user	1	12.04085598	12.04085598	18.14	0.0001
ID	12	69.23656854	5.76971404	8.69	0.0001
Habitat	11	63.76188566	5.79653506	8.73	0.0001
Habitat*Type	11	22.33225837	2.03020531	3.06	0.0015
Type III					
Type of user	1	1.03906251	1.03906251	1.57	0.2139
ID	12	39.45685872	3.28807156	4.95	0.0001
Habitat	11	28.66273558	2.60570323	3.93	0.0001
Habitat*Type	11	22.33225837	2.03020531	3.06	0.0015

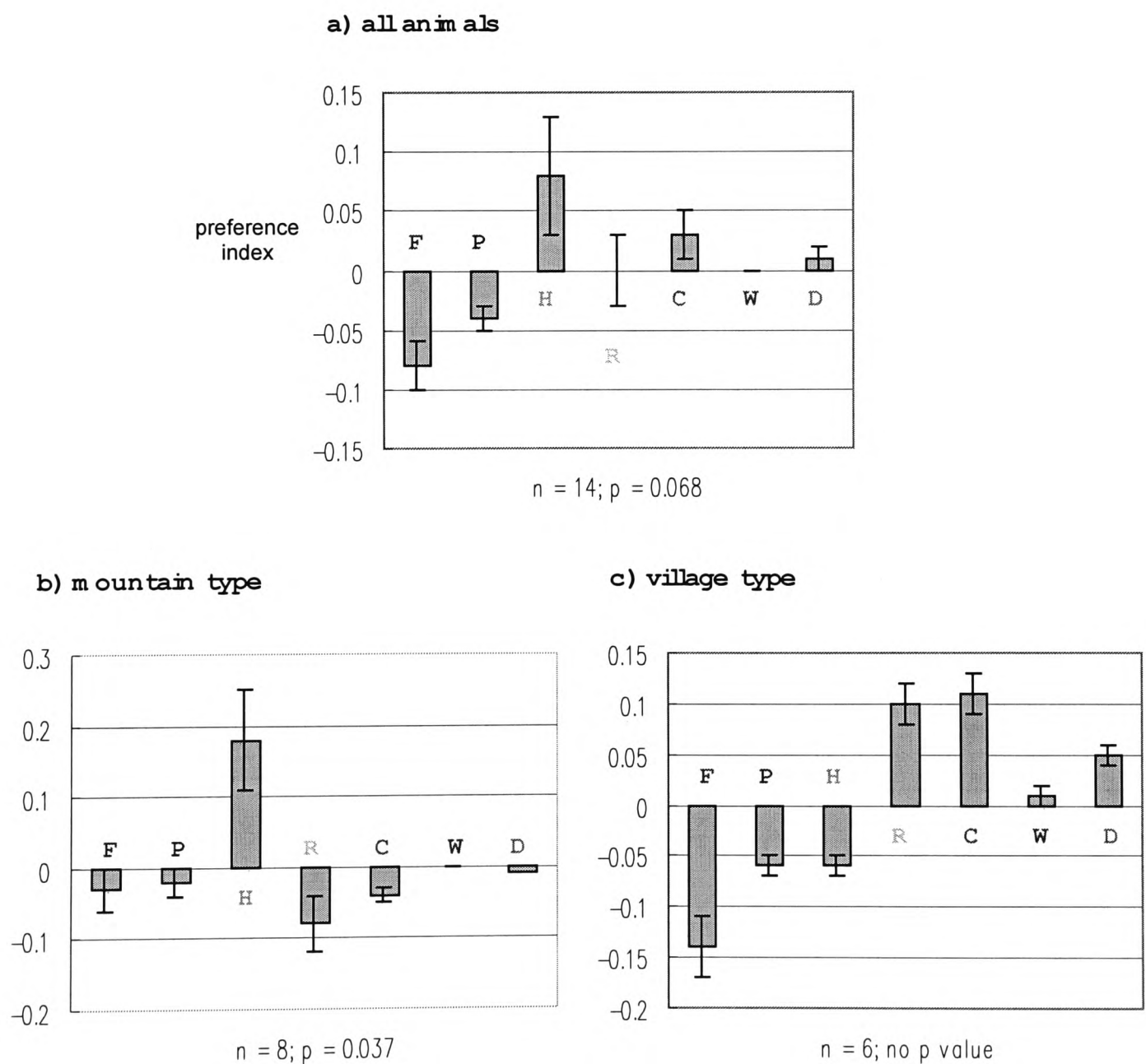
Figure 3.10 Inter-fix speed by habitat (mean ± SE).



3.3.3 Habitat preference

Mountain-type raccoon dogs showed a significant preference for herbaceous habitats ($p = 0.037$)(Figure 3.11b). Because the number of animals, i.e. sample size, was smaller than the number of habitat categories, a significant test for preference could not be performed for the village type. However, the trend appeared to differ between the habitat-type users. Rice fields and cropland were preferred by the village type and used less by the mountain type, whereas there were prominent preference for herbaceous habitats by the mountain type and less use of forest by the village type (Figure 3.11b and c). When all animals were considered together, no preference for particular habitats was demonstrated (Figure 3.11a).

Figure 3.11 Preference index for home range (second order) selection of the raccoon dogs.



F = secondary forest, P = plantation, H = herbaceous, R = rice field, C = crop and garden, W = water, D = development.

Figure 3.12 shows habitat preference by season and by habitat-type user for fixes in the home range (the third-order selection). The preference was similar for all seasons. Herbaceous habitat was the most preferred, and rice field habitat was the most avoided. However, when the two habitat user types were analysed separately, preference for herbaceous habitats by the mountain-type and preference for cropland and gardens by the village-type animals were more prominent (Figure 3.12 f and g) although the statistical test for significance could not be performed on the small sample size.

Figure 3.12 Preference index for habitat selection (third order) of the raccoon dogs.

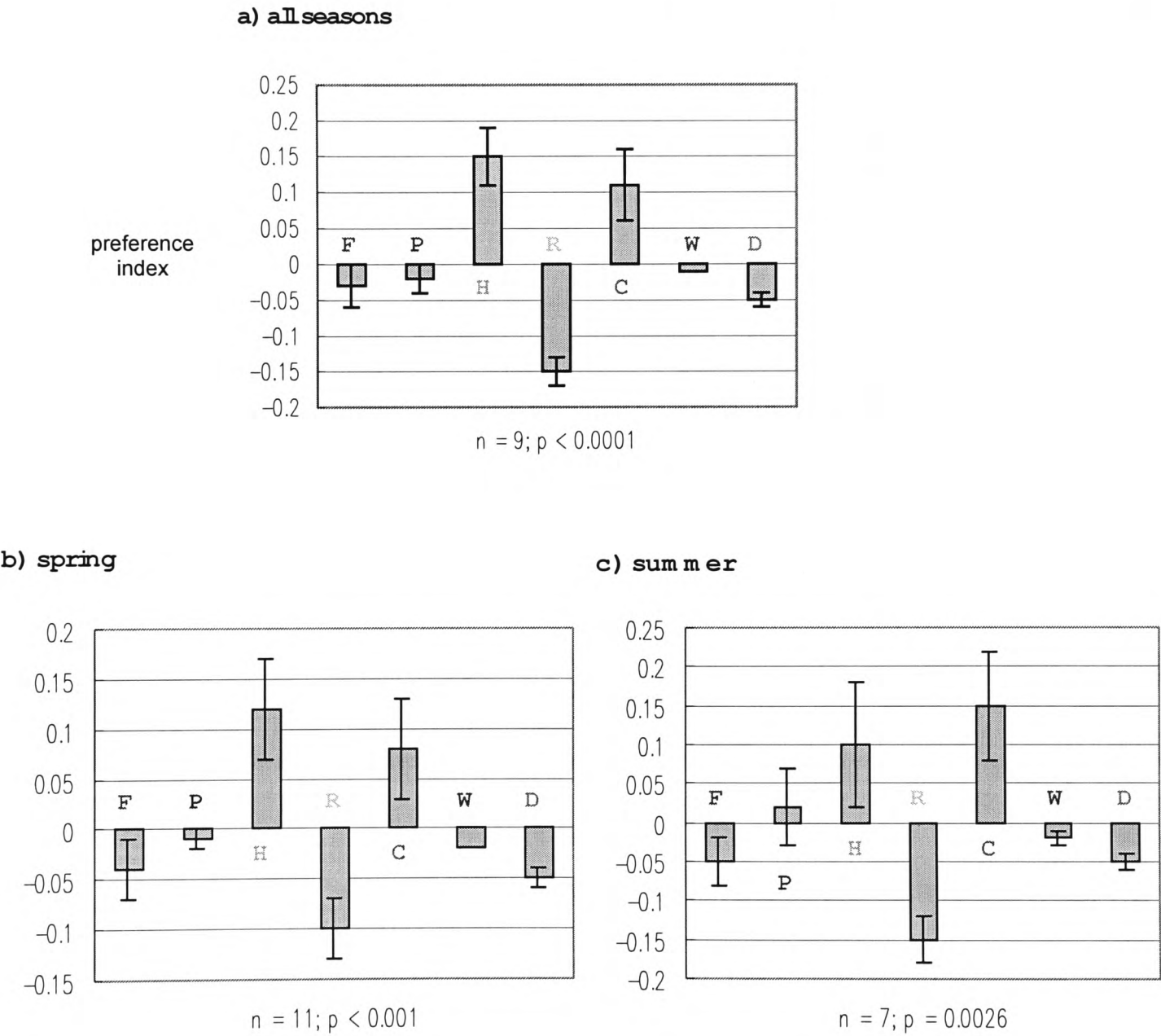
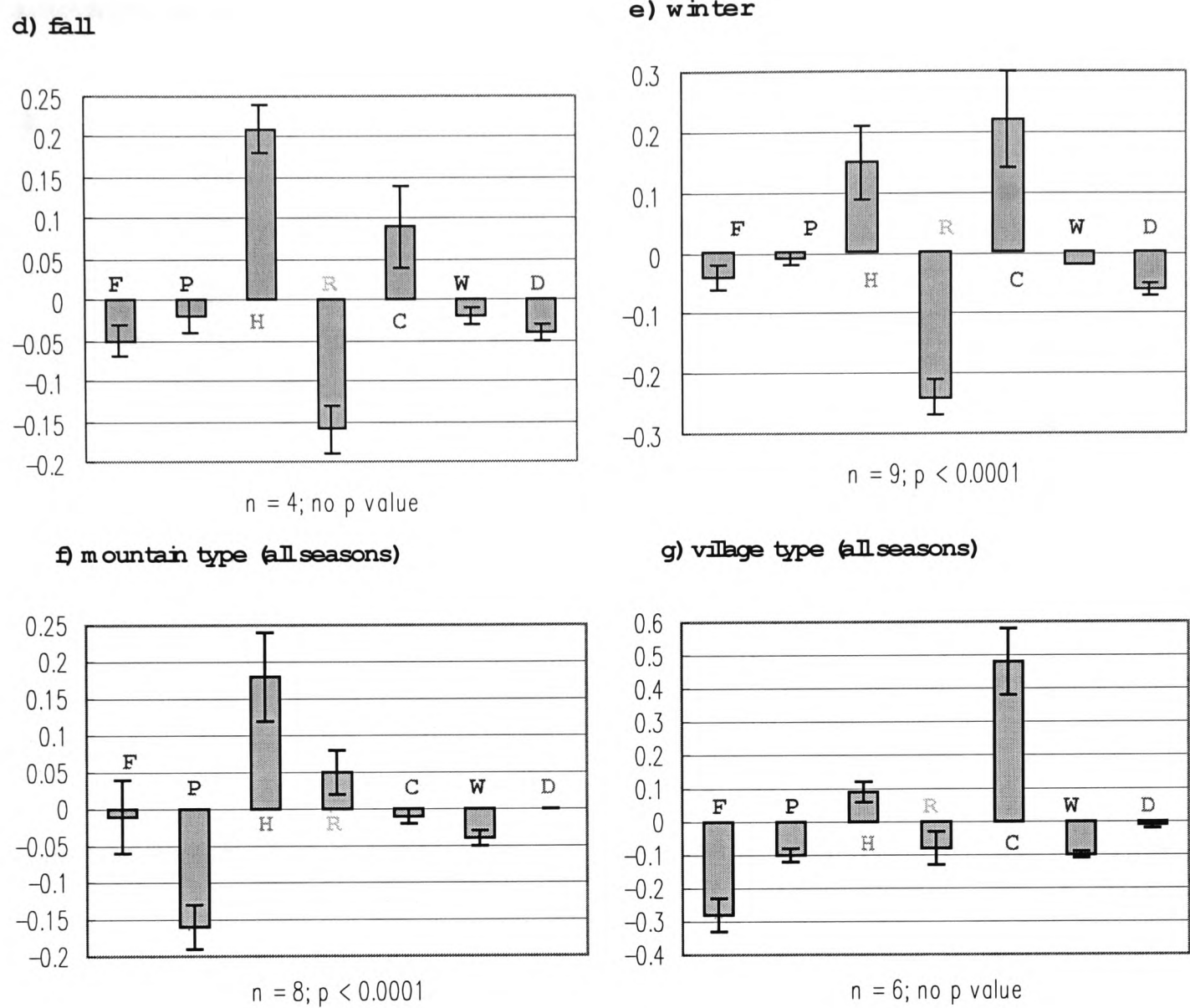


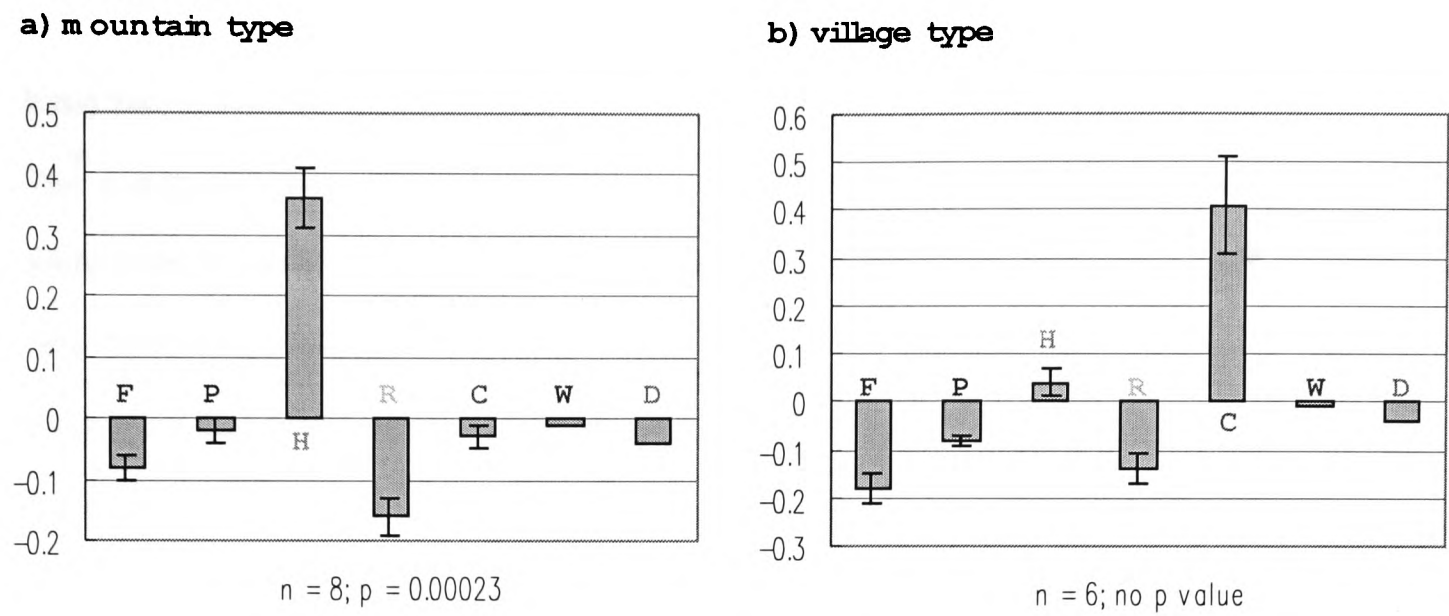
Figure 3.12 continued.



F = secondary forest, P = plantation, H = herbaceous, R = rice field, C = crop and garden, W = water, D = development.

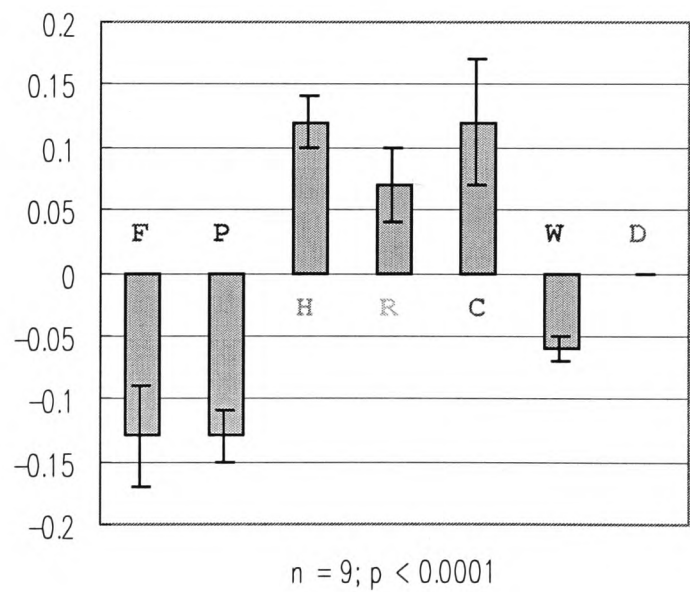
Habitat preference by season for fixes in the total area was consistent with that of preference for fixes in the home range; the significance was greater: $p < 0.001$ for all seasons, spring, summer and winter, respectively. However, there was inconsistency in the preference trend when analysed by the two habitat users. Figure 3.13 shows habitat preference for fixes in the total area by two habitat-type users.

Figure 3.13 Preference index for fixes in the area of the raccoon dogs.



Habitat preference for active fixes in home range differed from preference for all fixes (Figure 3.14). For example, rice fields were preferred, in contrast to all fixes and home range selection.

Figure 3.14 Preference index for habitat selection with active fixes of the raccoon dogs.



F = secondary forest, P = plantation, H = herbaceous, R = rice field, C = crop and garden, W = water, D = development.

3.3.4 Den sites and resting sites

Fourteen den sites were found in the area: 8 earths and 6 artificial structures. All earths had at least two entrances, and were usually located near ridges on hills or utilising natural mounds. The substrates were the alteration of sandstone and mudstone, common semi-consolidate sediments on the hills in the area, and the soil type was the brown forest soils (dry) classified as "Eta 1," (Chiba Prefecture, 1975a,b). These earths were probably dug by badgers, and one of them had been known to the local people more than 80 years (T. Ichihara, personal communication). There was no consistency in the direction that the entrance faced, although none of those near the ridge was located on the north slope. Secondary hardwoods and mixed forests were the major cover types around these earths; the Japanese cedar (dbh <15 cm) was planted at two sites.

Artificial structures for dens included an abandoned barn, concrete irrigation corners and channels. Most these structures also contained more than two entrances.

Some day-time resting sites did not have apparent structures. One animal returned to exactly the same location (confirmed by the flattened ground with hair signs) in dense bamboo-grass bush every morning for more than a week, whereas others rested roughly in the same vicinity in grassland or bush. Den sites were also often used for resting. Gutters (40-cm wide) with concrete lids were often used in the human residential area.

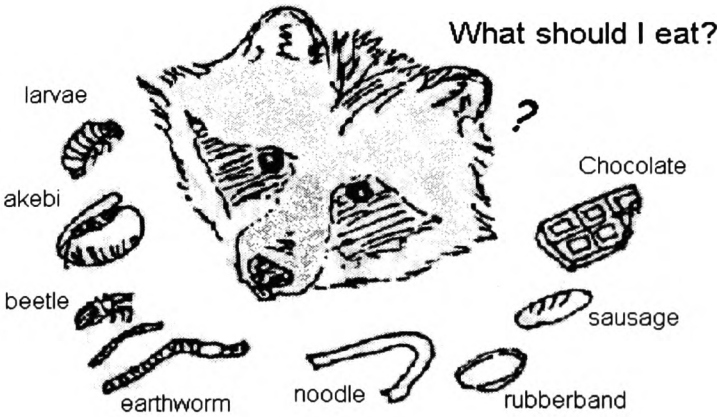
3.3.5 Diet Composition

Table 3.6 lists the pooled stomach contents of 7 raccoon dog road-kills in the area. The mean volume of stomach contents was 88.6 ml (20.0 -170.0 ml), and the mean weight was 107.0 g (27.5 -190.0 g). Fish and mulberries in spring, and insects and persimmon fruit in autumn, appeared in relatively high abundance. In these samples, one stomach contained a rubber band, indicating that the raccoon dogs fed on garbage, but it also contained mulberry and snail. In contrast, many rubber bands were found in the stomach of a specimen from a camp ground in Osaka (M. Saeki, unpublished data). In addition, only pear was found in the stomach of a subadult male which was collected in the autumn, south of the study area, Maruyama-cho, Chiba, where pear growing is the major industry (Saeki, 1996).

Table 3.6 Stomach contents of seven road-kill raccoon dogs.

CLASS/Order etc.	Family	item	scientific name	no.
Rodentia	MURIDAE	mouse	unknown	1
Squamata		snake	unknown	1
Anura		frog	unknown	1
Crpriniformes	CYPRINIDAE	carp	<i>Cyprunus carpio</i>	1
		non-identified fish	unknown	2
Orthoptera	ACRIDIDAE	locust	<i>Oxya yezoensis</i>	1
Orthoptera	ACRIDIDAE	grasshopper	<i>Locusta migratoria</i>	1
Orthoptera	RHAPHIDOPHORIDAE		<i>Diestrammena japonica</i>	2
Orthoptera	GRYLLIDAE	cricket	<i>Velarifictorus mikado</i>	1
Orthoptera	TETTIGONIIDAE		unknown	1
Coleoptera	CARABIDAE		<i>Carabus insulicola</i>	1
Coleoptera	CARABIDAE		unknown	1
Coleoptera	CARABIDAE		unknown	1
		non-identified insects	unknown	4
OLIGOCHAETA		earthworm	unknown	3
STYLOMMATOPHORA		snail	unknown	1
	EBENACEAE	persimmon	<i>Diospyros kaki</i>	2
	VITIDACEAE	grape	<i>Vitis vinifera</i>	1
plant material	MORACEAE	mulberry	<i>Morus bombycis</i>	2
	GRAMINEAE	bamboo grass leaf	<i>Pleiolblastus chino</i>	1
	GRAMINEAE	grass leaf	unknown	2
		tree leaf	unknown	1
Artificial matter		shred of cotton*		1
		rubber band		1
Other		raccoon dog's hair		2
		roundworm	unknown	2

no. = frequency occurrence; * a piece of cotton work glove



3.4 DISCUSSION

The results from this study supported the existence of seasonal changes in habitat quality, but not in habitat use, and the magnitude of the changes appeared to differ among habitat types. Cropland (which included areas where vegetables, potato, pulses, and grains were grown in soil rather than rice fields, where the ground is flooded during the growing season) and herbaceous habitats showed a high availability of food during the autumn. For both mountain-type and village-type raccoon dogs, food abundance in autumn may be a critical factor for survival and successful recruitment. Food intake has been shown to be greatest during autumn in captive juvenile raccoon dogs (Korhonen, 1988). However, the two habitats were preferred not only in autumn, but throughout the year. One reason may have been the cover that they provided. Cover is needed against free-ranging domestic dogs, humans, vehicles and, for juveniles, possibly avian predators. Dense bamboo-grass bush can provide good cover, even against domestic dogs (M. Saeki, pers. obs.). Although difficult to quantify, rice fields appeared to provide poor quality cover except for a brief period during the growing season, although the narrow ditches separating fields may have functioned as cover. Concrete lids on gutters along or across roads also act as cover for the raccoon dogs.

Comparison of the preference indices of the two habitat-type users (Figure 3.10b and c; 3.11f and g) suggested that habitats were selected at different spatial scales. The selection of home range (second order selection) by the mountain-type users was based on a preference for herbaceous habitats and the avoidance of rice fields and cropland. At the scale of location selection in their home range (third order selection) the results showed, in addition to the consistent preference for herbaceous habitat, the emergence of a slight preference for rice fields and a strong avoidance of plantations. In contrast to the mountain-type animals, village-type users based their home-range selection on a preference for rice fields and cropland and an avoidance of forest, plantation and herbaceous habitats. Within the home range, they still showed a strong preference for cropland and an avoidance of forest, but a slight preference for herbaceous habitats also emerged, and the preference for rice fields was no longer apparent.

Preferences differed between the two habitat-type users at both scales, except for the consistent avoidance of plantations in the third-order selection process. Habitat selection,

however, may not be a discrete process of decision-making at each scale because animals can simultaneously choose habitat components or a combination of them across scales. The American marten (*Martes americana* Turton), for example, has been shown not to select cover types at the scale of the forest stand; instead, selection appears at the landscape scale, indicating the importance of functional habitat quality and structure (Bissonette *et al.*, 1997).

Despite the fact that forests were a major habitat type available to the raccoon dogs (forming 26.7% of the area), the results suggested that the mountain-type animals showed no preference for this habitat and the village type showed avoidance. In the habitat classification, pure stands of *Cryptomeria* were described as plantation, while the forest category included evergreen and deciduous hardwoods, and mixed stands including *Cryptomeria* and bamboo. This was necessarily the case because, in the compositional analysis, the number of habitat categories had to be less than or equal to the number of animals. However, use of this broad category may have resulted in preference or avoidance of certain types of forest being difficult to detect. Topography also varied to a greater extent within forests compared with other habitat types. If topography and species composition could have been quantified more precisely within forests, habitat preferences may have been detected.

The significant difference in inter-fix speed between habitat types implied different use of habitat types by the animals. However, individual differences were too large to explain the general pattern of use. The different trends in habitat preference between all fixes and active fixes supported this differential use, indicating an inactive (possibly resting) state in forest and plantation, in contrast to an active (travelling or foraging) state in a rice field. Herbaceous and cropland habitats were preferred for both active and inactive states of the animals.

Habitat selection can theoretically reduce inter- and intraspecific competition (Rosenzweig, 1981). If the two types of habitat users that appeared to exist in the study area are indeed different behavioural phenotypes, differential home-range selection may also act to minimise intraspecific competition by reducing territory defence or direct interference.

Raccoon dogs are known to share den sites, especially during the winter (M. Saeki, pers. obs.). Sharing a winter den could be because of the limited availability of sites or the advantage of warmth. Winter den sites may be an important component for survival, even in

areas with relatively mild climates such as the study area. Although they do not hibernate in most parts of Japan, raccoon dogs tend towards an inactive state and restricted movements during the colder months (Yachimori, 1997; Chapter 4); safe and warm den sites are therefore crucial. The winter den was often the same as the den for parturition and nursing, and the nursing den was probably used exclusively by a pair (Chapter 4). Therefore, each pair would require at least one den site within their home range. From a management point of view, it is possible that village-type animals might have a greater choice of den sites because of their tendency to be more tolerant of human activity. Mountain-type animals used natural structures and artificial structures that were abandoned by humans as dens, and would be highly sensitive to the loss of these from habitat change.

Figure 3.15 Schematic layout of a habitat for raccoon dogs, based on actual situations.

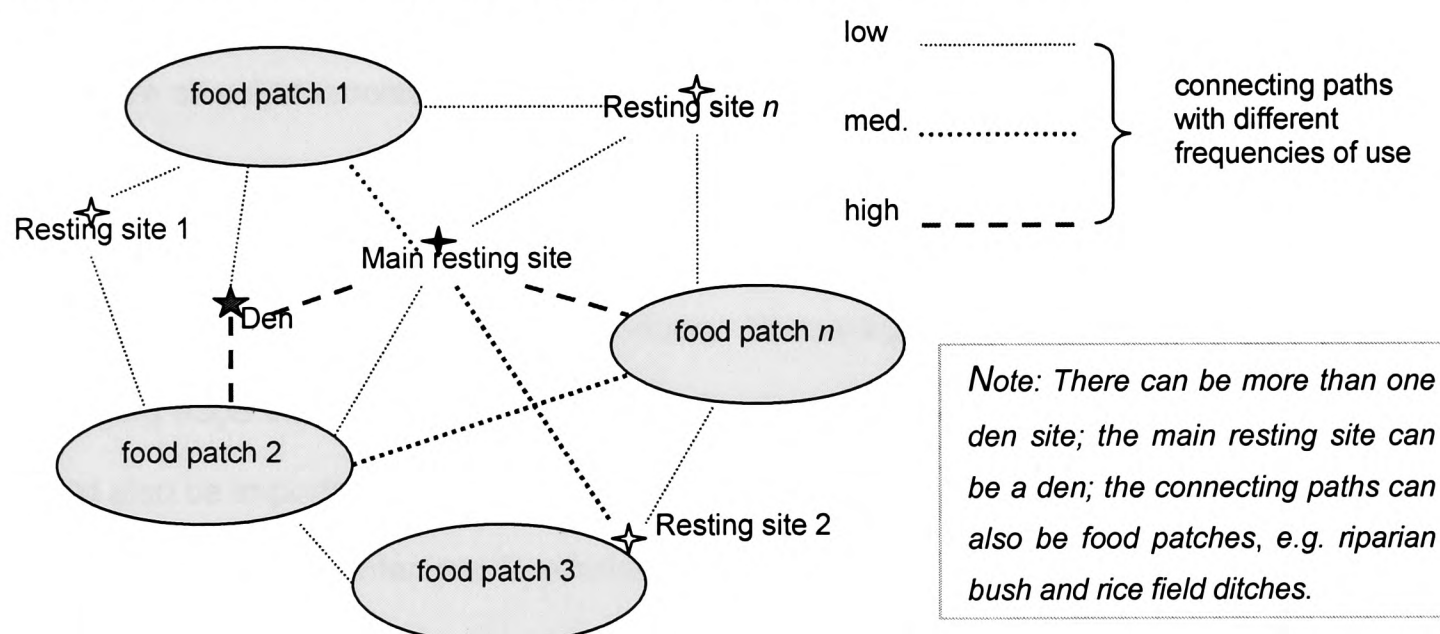


Figure 3.15 is a schematic model of the raccoon dog's habitat, based on the results of this study, which can fit both types of habitat user. The habitat structure of raccoon dogs consists of food patches, den sites, resting sites, and connecting paths. Water was not a limiting resource in the study area. Large open areas and buildings occupied by humans are probably of little use to the animals, while roads with heavy traffic could be considered as a negative component of the habitat. The arrangement and patterns of habitat components influence food distribution and cover connectivity and are an essential factor for determining habitat suitability.

Habitat management for the raccoon dog in the wider countryside *satoyama* must

take account of the needs of both types of habitat users, providing the necessary habitat structure for the maintenance of populations and dispersal of individuals. Consideration of the needs of the two habitat-user types may provide a useful means of developing appropriate conservation programmes. For example, mountain-type raccoon dogs are less likely to damage agricultural products, and may therefore be less vulnerable to culling. However, they may be more vulnerable to anthropogenic alteration to the habitat, particularly loss of den sites, because they are not as well adapted to managed landscapes and greater human activity as the village-type animals. Similarly, primary food sources may differ between the two types, and conservation measures should reflect this. Forest management may be particularly important for mountain-type animals. *Cryptomeria* plantations, for example, provided little or no ground cover, and had the lowest abundance of food items of all habitat types. Further research may show that other tree species or forest production methods provide more resources. Fruits, which are closely associated with human residence, are probably used mainly by the village type animals; encouraging people to grow fruiting trees, especially persimmon, in their gardens may be one simple action that would help to support raccoon dog populations in this habitat and reduce damage to agricultural products. Discouraging feeding of raccoon dogs, and managing edge bush, riparian vegetation and natural ditches to maintain habitat connectivity would also be important for raccoon dog conservation.

In the future, interspecific relationships between sympatric populations of the raccoon dog and badger would be a scientifically interesting topic to pursue, and would produce useful knowledge for wider countryside management.

ⁱ An aerial photograph is a geometrically coherent image with positional errors due to rotations and movements of an aeroplane and the greater distance at edges and corners than at points directly below from the aeroplane. Its geometric correction can be done by rotating and scaling the image using the relative position of known ground control points.

ⁱⁱ The analysis procedures are as follows:

$$\sum_{i=1}^D x_i = 1.0 \text{ (the unit-sum constraint),}$$

where individual proportional habitat availability or use x_i in D habitat types. Then, the log-ratio transformation is performed on the ratio x_i/x_j , where $i = 1, \dots, D$, $i \neq j$:

$$y_i = \ln(x_i/x_j) \text{ (independent of the component } x_j \text{ chosen).}$$

Pair-wise differences between matching log-ratios of availability and use were obtained:

$$d_D = y_{UD} - y_{AD} = ([y_{U1} - y_{A1}], \dots, [y_{UD-1} - y_{AD-1}]),$$

where $y_{UD} = (y_{UD1}, \dots, y_{UD-1})$ and $y_{AD} = (y_{AD1}, \dots, y_{AD-1})$; y_{AD} is availability ratio and y_{UD} is utilisation ratio. With the null hypothesis $d \equiv 0$, $d_i > 0$ indicates that habitat i is used more than expected relative to habitat D .



rice fields in summer



rice fields in winter



Cryptomeria plantation (back)

CHAPTER 4

BEHAVIOURAL ECOLOGY OF THE RACCOON DOG: HOME RANGE, MOVEMENTS, AND SOCIAL ORGANISATION

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Summary

This chapter presents results from analyses of home range, nightly movements (mean inter-fix speed, nightly home range, and maximum range span for a night), and movement patterns of the raccoon dogs. Mean home-range size was 111 ha (95% kernel estimate) and 160 ha (95% MCP). No significant differences in home-range size between age classes or sexes were detected. Seasonal home ranges, however, were larger in yearlings than were those of adults and largest in autumn. Adults showed stable home ranges, unless they were disturbed by human activities such as riverbank constructions, whereas yearlings showed a period of unstable home ranges. Inter-fix speed differed significantly between individuals and seasons. Season also affected nightly movements, but sex and age did not. All variables of nightly movement were smallest in winter. The mean fractal dimension of movement was 1.2264 ± 0.0122 and significantly differed from straight line or Brownian-like random movement. Raccoon dogs with more semi-natural habitat in their home ranges had significantly larger fractal dimensions than those with more agricultural land in their home ranges, possibly reflecting habitat complexity and or heterogeneity. Home range overlap was greatest between pair mates, followed by yearlings and adult-yearlings. Non-paired adults had the smallest home range overlap. Both the Resource Dispersion Hypothesis and the Passive Range Exclusion Hypothesis are compatible with the observed behaviour of this opportunistic generalist species.



Chapter 4 Behavioural Ecology of the Raccoon dog

4.1 INTRODUCTION

4.1.1 Home range

Home range size, shape and stability are important aspects of life history and are the evolutionary outcome of animals' interactions with their habitats. The effect of several ecological factors on animal home ranges has been studied, including food availability and distribution (Macdonald, 1981, 1983), habitat type (Genovesi *et al.*, 1997), reproductive stage (Laundré and Keller, 1984), age (Kauhala *et al.*, 1993a; Balharry, 1993; Genovesi *et al.*, 1997), sex (Sandell, 1989; Goodrich and Buskirk, 1998; Salvatori *et al.*, 1999), body mass (Harestad and Bunnell, 1979), season (Goodrich and Buskirk, 1998; Judas and Henry, 1999), neighbouring conspecifics (Stewart *et al.*, 1997; Genovesi *et al.*, 1997), interspecific interaction (Harrison *et al.*, 1989), population density (Bond and Wolff, 1999), temporal variation in environment (Ferguson *et al.*, 1999), physical barriers (Geffen *et al.*, 1992), and human perturbation (Tuytens, 2000).

A number of studies have been conducted on the range size of the raccoon dog (*Nyctereutes procyonoides* Gray). These have shown that home range size varies with habitat: home ranges were smaller on islets and in urban areas but largest in subalpine zones in Japan (Table 4.1). In Japan, latitude does not appear to influence home range size, although few studies are available. Population density indices, e.g. harvest density and road-kill density, had a clinal trend and showed possible latitude effects (Figure 1.2; Figure 1.3 in Chapter 1).

In this chapter, I investigate within-site variations in home-range size and stability to identify the factors influencing spatial use of the raccoon dog. Because of the distinctive seasonal pattern and agriculture in the study area, I also consider these factors, and differences in individual life stages among radio-tracked animals.

Table 4.1 Comparison of home-range sizes of the raccoon dog from studies in Japan and Finland.

Home range (ha)	Habitat & Location	Estimating Method	no. of animals used	Period	Ref.
2.8 (1.1-4.3)	islet, alt. 0-50m 33° 11'N; 129° 20'E (Japan)	bait-marking	N/A	5 times from May 1974-Oct. 1975	1
6.9 (1.7-12.2)	urban, university campus, alt. 30-60 m 36° 33'N; 136° 39'E (Japan)	100%MCP	3	3 - 8 months	2
10.3 (8-12)	islet, alt. 0-30m 33° 14'N; 129° 66'E (Japan)	100%MCP	3	4 - 12 days	3
30.0 (13-51)	plateau, with garbage sites alt. 1150-1350m 31° 41'N; 130° 51'E (Japan)	100%MCP	4	4 - 12 days (selected fixes >35)	3
30.7(15-44)	urban 35° 31'N; 139° 40'E (Japan)	100%MCP	5	9 - 37 days (Aug. 1992 - Jan. 1993)	4
49.0 (31-63)	plateau, with garbage sites alt. 1150-1350m 31° 41'N; 130° 51'E (Japan)	100%MCP	4	5 - 20 days (Sept. - Oct. 1987)	5
59.0 (47-81)	forest ridges 39° 48'N; 140° 13'E (Japan)	100%MCP	5	5 - 20 days (Nov. - Dec. 1987)	5
278 (29-1252) 160 (16-560) 237 (49-742) 111 (23-228)	countryside alt. 0-80m 35° 22'N; 140° 20'E (Japan)	100%MCP 95%MCP 100%Kernel 95%Kernel	18	2 months - 2.4 years	this study
609.5	subalpine alt. 800-2000 m 35° 53'N; 138° 10'E (Japan)	100%MCP	12	3 - 8 months	6
700 950 340	boreal forest 61° 14' N; 25° 10' E (Finland)	100%MCP 100%H.M. 85%H.M.	23	2 months - 3 years (spring 1989 - autumn 1991)	7

1: Ikeda et al. 1979, 2: Fukue 1991, 3: Ikeda 1982, 4: Yamamoto 1993, 5: Ward and Wuster-Hill 1989; 6: Yamamoto et al. 1994; 7: Kauhala et al. 1993a.
MCP = Minimum Convex Polygon, Kernel = fixed kernel estimate, H.M. = harmonic mean. Range in parentheses.

4.1.2 Animal movements

Home range and utilisation distribution indicate spatial use of animals for a period but do not shown how animals utilise resources. The study of movements, on the other hand, can be useful to assess animal's activity and behaviour. For example, if an animal does not move for a certain period, a resting site and resting time may be identified. Similarly, speed and turning frequency combined may be used to indicate foraging behaviour and dispersal (relatively rapid movement in a straight line is more likely to indicate dispersal, while slower movement with many turning events may be associated with foraging for omnivores).

Movements are the consequences of an animal's response to internal status and external environment. Physical activity of locomotor apparatus, sensory recognition, and memory proximately construct movements. Alt (1990) generalised locomotive patterns i.e. movements of organisms, to "searching: namely for food, space, hosts, sexual partners or just a favourable environment." Long-term gain and total fitness ultimately shape movement patterns for a species in its environment.

Mechanistically, movements can be defined by velocity vectors (instantaneous speeds and angles) derived consecutively via differential displacements (Alt, 1990). With radio-tracking data, movement parameters are derived from fixes (co-ordinates) from which successive displacements are obtained at specific time intervals.

In this chapter, I examine movement patterns of the raccoon dog in detail, using continuous radio-tracking data. Movements are described at two spatio-temporal scales: firstly, inter-fix measurements taken with a interval of about 15 minutes provide data on inter-fix speed and turning angle, and second, nightly movements give mean inter-fix speed, 100% MCP, range span (maximum length of range), and total distance travelled during the night.

4.1.3 Fractal dimension

Fractal dimensionⁱ is, in essence, a measure of complexity: It is a broader definition of dimension which has been extended from Euclidean geometry (Mandelbrot, 1967). It can be roughly defined as the non-Euclidean dimension of objects or phenomena to describe their degree of complexity. Fractal dimension of movements can be explained as 'tortuosity with self-similarity' as greater tortuosity for higher fractal dimension. The derived concept of fractal dimension has been applied in ecology to describe animal movements (e.g. Dicke and Burrough, 1988; Gautestad and Mysterud, 1993; Cole, 1995; Bascompte and Vilà, 1997; Atkinson *et al.*, in press), species/population distribution (e.g. Morse *et al.*, 1985; Milne, 1997; Ferguson *et al.*, 1998) and habitat/landscapes (e.g. Milne, 1997; With *et al.*, 1999; Schmid, 2000). For two-dimensional movements, it can be said that higher fractal dimensions indicate more intense use of the plane.

In mathematical theory, the concept of fractal dimension has been established (Mandelbrot, 1991a) and exemplified by many figures, such as Cantor sets, Peano lines, Koch triadic islands, and Sierpinski gaskets (Takayasu and Takayasu, 1988; Kaye, 1994). The

ⁱ Note is given at the end of the chapter.

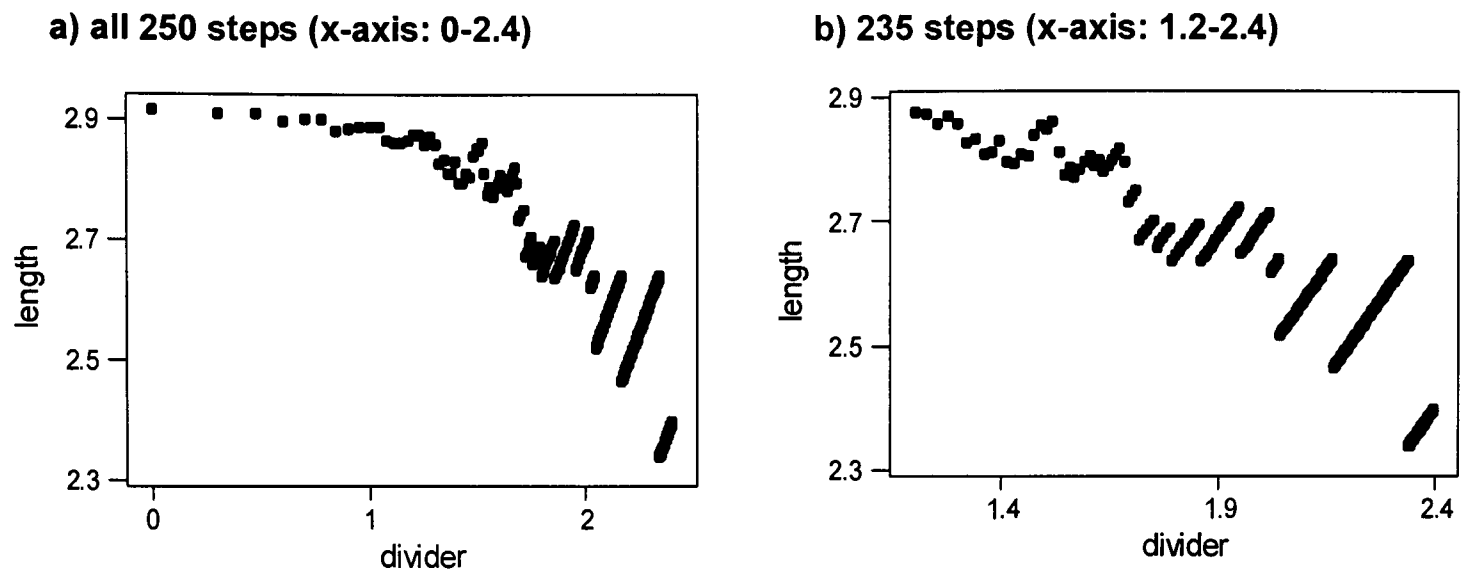
mathematical framework was developed by Henri Poincaré, Félix Hausdorff, A. S. Besicovich, A. N. Kolmogorov, Gaston Julia, Paul Lévy and others, even before Mandelbrot (1967, 1977) introduced the concept (Lauwerier, 1991). However, other than describing mathematical and natural structures, applications of fractal dimensions outside computer graphics have only recently extended to economics, metallurgy, medicine, quantum theory, etc. (Kaye, 1994).

A natural fractal, found throughout natural environments, is different from an ideal (mathematical) fractal because it "can only be used to describe a real boundary over a specified range of resolution" (Kaye, 1994, p. 33). Furthermore, values of fractal dimension may vary in parts within a structure, and the dimension is defined locally in such multi-fractal structures (Takayasu and Takayasu, 1988; Kaye, 1994). The distribution of fractal sets itself can be fractal (e.g. oil deposit distribution in the world; Mandelbrot, 1991b). Several methods are available for estimating fractal dimensionⁱⁱ.

Animal movements can be measured as natural fractals because the resolution is physically limited by the animals' stride length (highest resolution) and the maximum speed of travel (lowest resolution). Animal movement measurements are also constrained by observer perception and by the measuring device (e.g. radio-tracking locations with arbitrary time intervals and errors). It is known that the Richardson-Mandelbrot's log-log graphs often result in upper concave curves instead of straight lines, of which slopes indicate fractal dimensions (Figure 4.1). The curves tend to be straight and steep at the lower end of resolution, i.e. larger 'divider lengths' (Rigaut, 1984, 1991). Consequently, the large maximum divider length used is associated with the large fractal dimension estimates (Dicke and Burroughs, 1988; Creed, 1998). The slope might be very different depending upon where it is taken or the maximum length employed. Turchin (1996) suggested that fractal dimensions of movements can be used only after self-similarity is tested (i.e. there is a constant fractal dimension). Thus, caution is required in comparing fractal dimensions that are obtained by different methods and for different species. Nevertheless, fractal dimensions can be powerful tools to investigate spatial and temporal complexities.

ⁱⁱ Note is given at the end of the chapter.

Figure 4.1. Richardson-Mandelbrot's log-log graphs and fractal dimension. (The graphs are derived from actual raccoon dog's movements, using a programme by Creed, 1998)



The graph **a** shows a curvilinear trend, whereas graph **b** (a sub-set of the data in 'a' with low divider lengths excluded) shows a relatively straight line. The form of graph **a** may be a fundamental condition of data derived from radio-tracking data, while the form of relationship in graph **b** may be a necessary condition for a scale invariant slope, and thus constant fractal dimension (Turchin, 1996; Creed, 1998). (Fractal dimension will be tested scale variance at different scales later.)

4.1.4 Lévy flights

The mathematical concept of Lévy flightsⁱⁱⁱ was developed by Paul Lévy and later adopted by Mandelbrot to describe the fractal structure of galaxies in outer space (Mandelbrot, 1983). Lévy statistics are random statistics without a specific scale or normal distribution of scales (Shlesinger *et al.*, 1993). Lévy flights are a certain type of random walk characterised by a small but finite probability of large step-lengths at any time (Mandelbrot, 1967) and thus operate with a long-range power law (Viswanathan *et al.*, 1996). Organisms with Lévy flight-type of movements may have advantages in encountering prey items that are sparsely and randomly distributed, as well as to find sites that have not been previously visited, especially useful for organisms forming flocks, swarms and/or schools (Cole, 1995; Viswanathan *et al.*, 1996, 1999).

4.1.5 Social behaviour

Carnivora social systems have been studied and compared in depth (e.g. Gittleman, 1989; Creel and Macdonald, 1995). In particular, sociality in Canidae has been extensively studied because of the group's diverse range of social behaviours, mating systems, body size, diet, and habitat (e.g. Moehlman, 1986, 1989; Ikeda, 1991; Geffen *et al.*, 1996; Nel, 1999). According to Moehlman's allometric analysis (1989), as a smaller canid (<6.0 kg), the raccoon

ⁱⁱⁱ Note is given at the end of the chapter.

dog is expected to be monogamous, occasionally polygynous with a tendency to female sex-bias, have female helpers and male dispersers, and hunt solitarily. Also, smaller females are expected to produce fewer, more developed neonates with less paternal care. However, Geffin *et al.* (1996) stressed the importance of resource availability and phylogeny to account for inter- and intraspecific variations in canid social system, restating Moehlman's allometric trend by the 'environmental variation mechanism hypothesis.'

If intraspecific variation in social system exists in the raccoon dog, environmental variations, food availability and climate, need to be sought out for the explanation. If not, the plasticity may be of phylogenetic origin as a canid prototype or other adaptive features in this species.

In this chapter, I focus on environmental factors and individual differences to describe social organisation of raccoon dogs.

4.1.6 Resource Dispersion Hypothesis

The Resource Dispersion Hypothesis (RDH) postulates that dispersion of resources determines territory size, whereas mean richness of resource patches limits group size, independently (Macdonald, 1981, 1983; Carr and Macdonald, 1986; Macdonald and Carr, 1989). The RDH predicts facultative formation of groups without functional benefits, namely 'spatial group' (Macdonald, 1983) when temporal and/or spatial heterogeneity exists in resource availability (Carr and Macdonald, 1986; Macdonald and Carr, 1989). Raccoon dogs feed on relatively small prey, such as invertebrates, fruits, amphibians, and fish which have distributions that are temporally and spatially heterogeneous (Ikeda *et al.*, 1979; Yamamoto, 1991; Yamamoto, 1994; Yamamoto and Kinoshita, 1994b; Sasaki and Kawabata, 1994; Table 3.5 in Chapter 3).

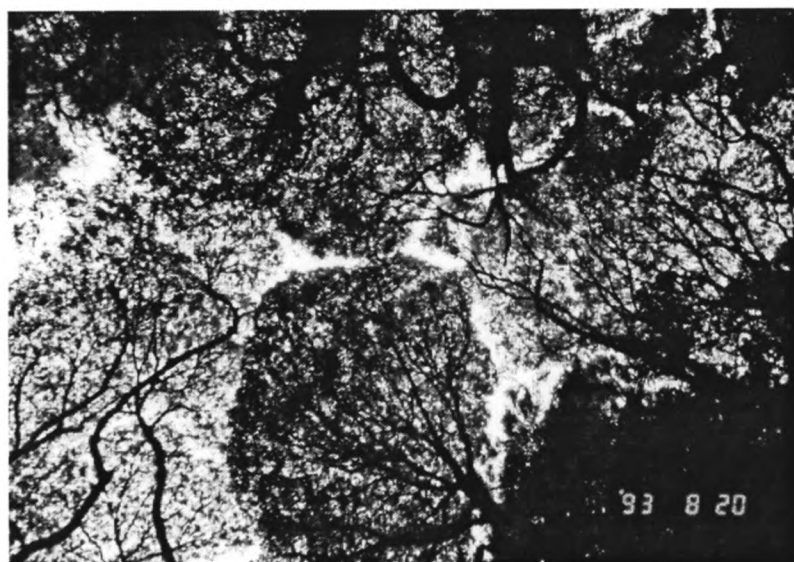
To test whether the RDH can explain the raccoon dog's sociality, I examine home-range size variation amongst individuals or habitat-type users (detail in Chapter 3) and investigate group size using observations of sharing of resting sites and field observations of coalitions. Food security and dispersion are difficult to estimate. Therefore, only qualitative comparisons were made, using ranking of habitat types as in habitat analysis results (Chapter 3).

4.1.7 Chapter objectives

The main aim of this chapter is to provide baseline data on spatial use and movements of raccoon dogs, and to investigate their ecological significance for the species behaviour and social system in the study area, the traditional countryside, referred to in Japan as the *satoyama* (Chapter 3). This chapter has six objectives:

- to estimate home range and utilisation distribution to investigate spatial use by the raccoon dog
- to assess factors that influence the spatial use with emphasis on the behaviour of individuals
- to examine movement patterns
- to assess factors that influence movement patterns
- to present social aspects of the raccoon dogs to describe the social system in relationship to the spatial use of habitats: home range overlap, location and use of den and resting sites
- and to elucidate basic behavioural ecology of the species with these findings.

Canopy closure of an evergreen
broad-leaved forest in the study area
Fractal, fractal, fractal...



4.2 METHODS

Field work started in August 1993 and was terminated in September 1998. The study area and procedures of trapping, handling, and radio-tracking are described in Chapter 3. Direct observations were made and recorded whenever possible. In October 1992, a trip was made to observe raccoon dogs that had become accustomed to being fed at a camp ground in Nose-cho, Osaka, Japan. A camera trap was set experimentally in front of the main entrances of three den sites in 1998.

Data analyses

Home range

Estimates of home-range size vary depending upon the method used to define them (Laundré and Keller, 1984; Boulanger and White, 1990; Seaman and Powell, 1996; Ostro *et al.*, 1999). The classical method is a Minimum Convex Polygon (MCP) (Mohr, 1947), which has some advantages including universal comparison and simplicity (Harris *et al.*, 1990; White and Garrott, 1990). However, this method tends to overestimate home-range size by including areas that were never visited; 95% MCP is commonly used to eliminate 'outliers,' but it is arbitrary and the estimated area depends on the points eliminated (White and Garrott, 1990). Utilisation distribution can be used to define home range more precisely based on "the bivariate probability density function that gives the probability of finding an animal at a particular location on a plane" (Anderson, 1982, p103). Harmonic mean (Dixon and Chapman, 1980) and kernel estimate^{iv} (Worton, 1989) are non-parametric methods to estimate utilisation distribution; they are better than parametric methods which assume shape and normality (Worton, 1989).

Boulanger and White (1990) evaluated harmonic mean, Fourier series, MCP, and two ellipse methods with Monte Carlo simulation, using four types of movement data randomly generated, and found that harmonic mean was the least biased but the least precise as a home-range estimator. Worton (1995) evaluated kernel density estimators as home range estimators with the same method above and found that kernel estimators performed better than harmonic mean. Seaman and Powell (1996) further examined fixed and adaptive kernel estimators and noticed that fixed kernel estimators had little bias and lowest error of estimates whereas adaptive kernel had higher error in terms of mean integrated squared error. The

^{iv} Note is given at the end of the chapter.

smoothing parameter is important for kernel estimators (Worton, 1989) and yields the best results when selected by least squares cross validation (Seaman and Powell, 1996). Seaman *et al.* (1999) recommended sample sizes of at least 30 fixes, preferably ≥ 50 fixes, to reduce average size bias.

Data were analysed using MCP and the fixed kernel estimate for 18 animals, using RANGES V (Kenward and Hodder, 1994). Home ranges were calculated with fixes that were taken continuously for ≥ 4 hours or ≥ 40 minutes apart if not taken continuously for ≥ 4 hours. Using Schoener's index (Swihart and Slade, 1985) calculated with RANGES V, autocorrelations were examined. Statistical independence of fixes varied greatly among subsets of the data; independence of fixes that were taken continuously over a night was sometimes reached at 15 minutes-intervals, but others never become independent. Reynolds and Laundrè (1990) showed that data with independent sampling intervals underestimated both home-range size and daily distance travelled for pronghorn (*Antilocapra americana* Ord) and coyote (*Canis latrans* Say) and recommended using autocorrelated data for better estimates. De Solla *et al.* (1999) found that the fixed kernel estimates were more accurate with maximum numbers of autocorrelated fixes than independent subsets of data. Therefore, I used the continuous tracking fixes for home-range estimates. For both 50% and 95% MCPs and 50% and 95% kernel estimates, I used kernel centres, i.e. equivalent Gaussian kernel estimators, as cores from which 50% or 5% of furthest fixes are excluded (Kenward and Hodder, 1994). Home-range size was square-root transformed for normality (Kolmogorov-Smirnov Z test, $p > 0.15$) in statistical analyses, and the two-way Analysis of Variance (ANOVA) was performed to test the effect of sex and age on home-range size, using MINITAB (Minitab, Inc., 1996).

For four animals tracked over 2 years, I compared seasonal home range size, using 95% kernel estimates. The estimates were logarithmically transformed for normality (Kolmogorov-Smirnov Z test, $p > 0.15$) before conducting a General Linear Model (GLM) using Minitab. Home range with excursions for two animals were excluded from the analysis (Daphne's first two seasons and Nobutsuna's last two seasons).

Inter-fix measurements

For 18 animals (309 nights) inter-fix measurements, i.e. distance, heading and turning angle, were calculated, using RANGES V. The inter-fix speed was calculated with EXCEL because RANGES V often (not always) calculated inter-fix time and speed incorrectly at midnight and the following fix. The inter-fix turning angles were tested for randomness, based on runs (the number of runs about the median and the number of runs up or down), using MINITAB. Nightly movement was summarised with total estimated distance travelled, mean inter-fix speed, range span (maximum length across nightly home range), and 100% MCP for a night. Mean inter-fix speed and range span were square root transformed and MCP was logarithmically transformed (Zar 1984) before conducting a weighted General Linear Models Procedure (GLM) using SAS (SAS Institute, Inc., 1989-1996).

Fractal dimension and Lévy flight

Sequential locations were obtained from fixes taken at 14 to 16 minutes intervals, and used for the fractal analysis. Fractal dimension and Lévy flight analyses were conducted for 15 animals (68 and 80 nights, respectively) by a divider method, using a program developed by J. Creed (1998). The calculated fractal dimensions and Lévy's α values were compared between individuals, years, age classes, sexes, seasons, and habitat user types (Chapter 3). The mean fractal dimension was tested for a difference from 1.0 (straight line) and 2.0 (Brownian-like random movement), and the mean α was tested for a difference from 0.5 (Brownian motion under a Gaussian distribution) and 1.0 (Ballistic motion under a perfect long-range power law). The data of fractal dimensions deviated significantly from normality (Kolmogorov-Smirnov Z test, $p < 0.01$) and transformations did not improve the normality, but the α values did not deviate from normality (Kolmogorov-Smirnov Z test, $p > 0.15$).

Fractal dimensions of two habitat types were calculated by a box-counting method (Block, 1990). Two 840 x 840 pixel-squares were cut from a digital habitat map (0.4962 m per pixel, see Chapter 3) at points where rice fields and cropland ('sato') and hills and valleys ('yama') were representative (Figure 4.2). Only habitat boundaries (including ditches and dykes in rice fields) were considered regardless of habitat types. Five scales ($\lambda = 105/840, 84/840, 56/840, 40/840$ and $28/840$, where $\lambda \times 840$ is grid length in pixels) were used. A logarithm was

taken of each λ and the corresponding number of boxes $N(\lambda)$, and

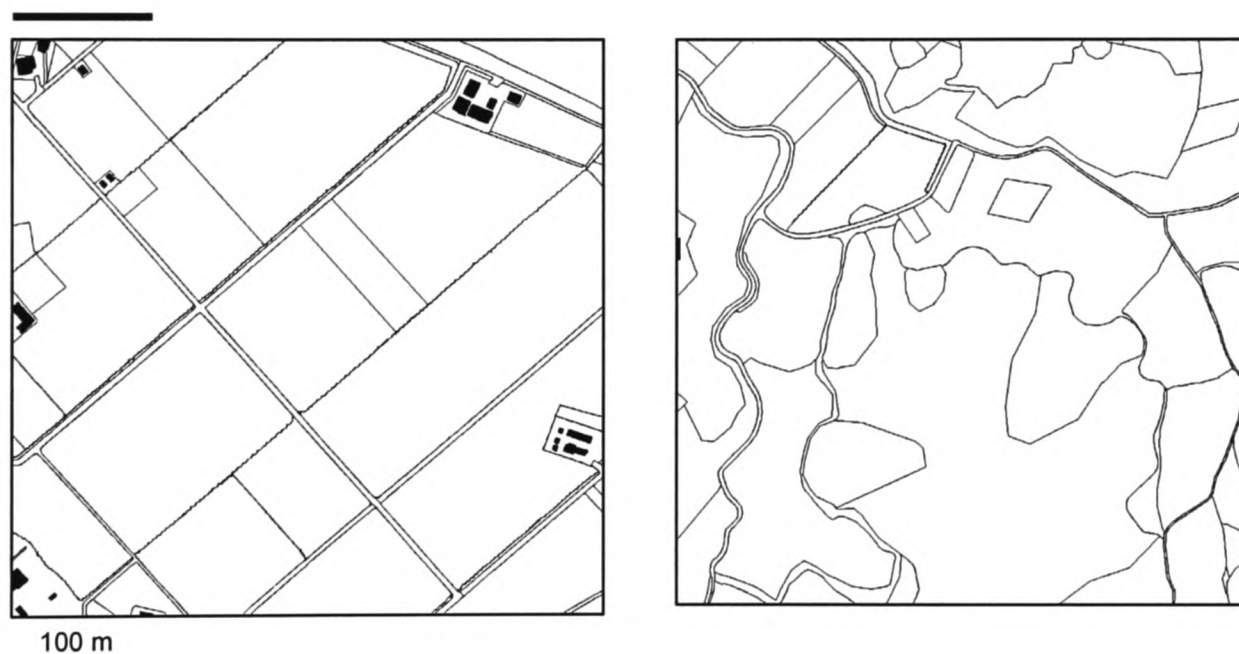
$$\log N(\lambda) = -k \log \lambda + \log \mu$$

when $N(\lambda)$ and λ^{-k} has a straight relationship.

Therefore, $y = -k x + \log \mu$.

Then a regression analysis was performed with the five points to obtain the slope a (equivalent to $-k$ in above equation), of which the negative value is an estimated fractal dimension. Strictly speaking, it is necessary to employ a grid orientation with the minimum number of boxes that will contain parts of the boundary; however, the *sato* habitat, which mostly consisted of straight-line boundaries that oriented diagonally to N-S (approximately 45°), naturally contained the minimum number of boxes. There was little difference in *yama* habitat depending upon orientation. Therefore, I used the original orientation for both habitat types.

Figure 4.2 Two habitat types, *sato* (left) and *yama* (right). (*Lines show habitat boundaries.*)



To clarify, I define *sato*, which means 'village' in Japanese, as a certain habitat of artificial landscape, mostly rice fields and residential areas, whereas the village type is used for animals who mainly (>50%) inhabit agricultural lands (Table 3.4 in Chapter 3). Similarly, I define *yama*, which means 'mountain' in Japanese, as a certain habitat of semi-natural landscape, mostly secondary forest on the hills and scrubs, whereas the mountain type is used for animals who mainly (>50%) inhabit semi-natural habitat (Table 3.4 in Chapter 3).

4.3 RESULTS

Twenty-one raccoon dogs (Table 3.2 in Chapter 3) were radio-tracked between August 1993 and September 1998.

4.3.1 Home range

4.3.1.1 Size

Overall home-range size estimated by 100% MCP varied greatly among individuals from 29 to 1,252 ha (n = 18). There was no significant difference in the mean home range sizes (Table 4.2) between sexes and age classes (two-way ANOVA; Table 4.3). All four methods of estimation gave this result.

Table 4.2 Mean home-range size of the raccoon dogs by sex and age class.

	n	95% MCP	100% MCP	50% Kernel	95% Kernel	100% Kernel
Adult	9	107.9±24.5	177.2±41.8	10.92±2.69	91.1±195	205.4±44.6
Yearling	11	192.5±46.8	319.0±88.4	11.36±2.61	121.6±23.4	255.9±57.0
Male	13	130.1±23.0	188.4±32.2	10.34±1.81	97.6±16.0	201.1±33.2
Female	7	199.5±71.5	379.0±134.0	12.69±4.17	127.0±34.0	292.7±81.9

MCP is estimated by a maximum convex polygon method; Kernel is estimated by fixed Kernel distribution estimators. Units are hectares ± SE; n is sample size and totaled 20 because 3 animas being yearling and adult.

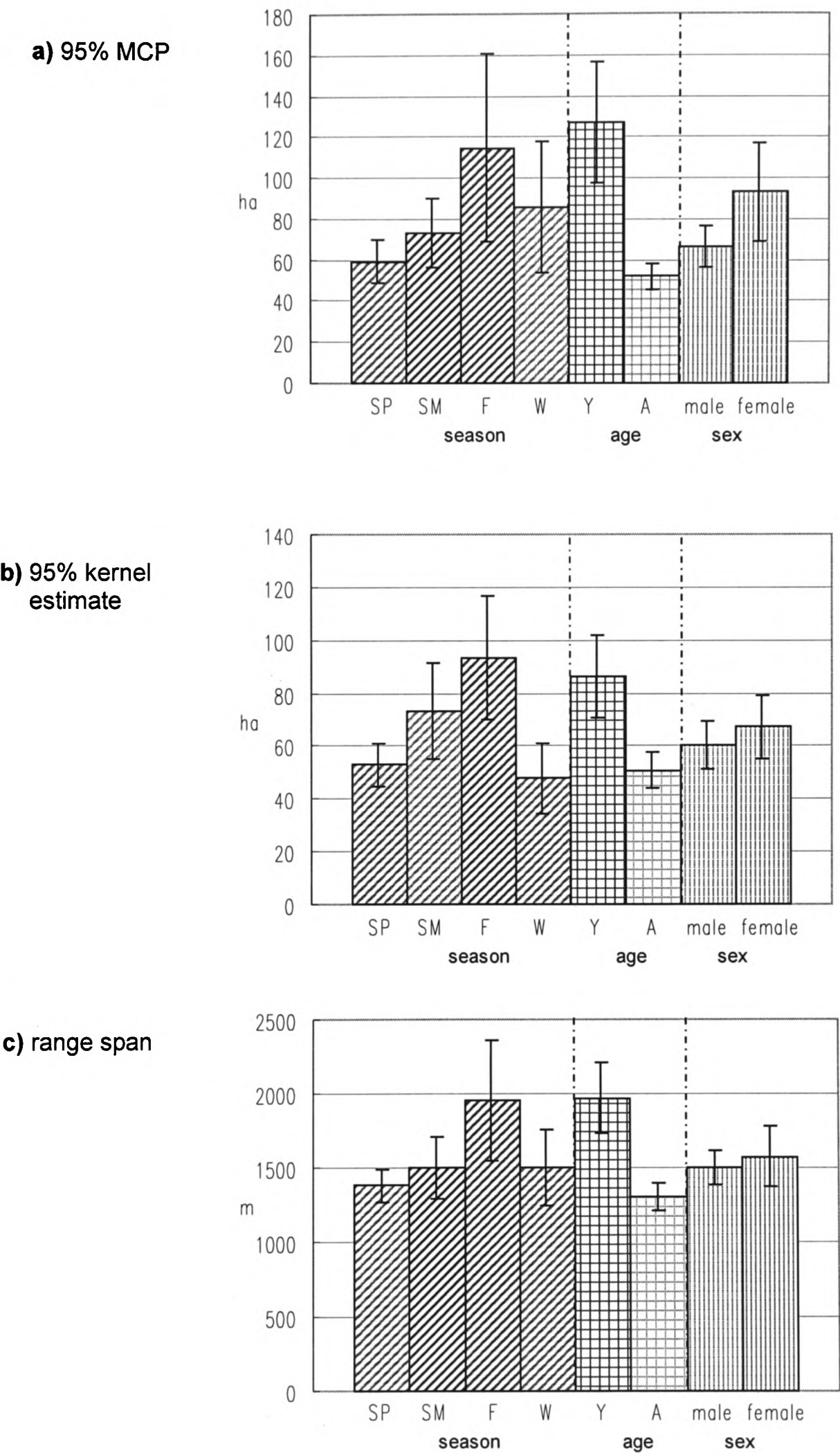
Table 4.3 Two-way Analysis of Variance for home-range size by sex and age class.

Source	DF	Sum of Square	Mean Square	F	p
95% MCP					
sex	1	23.43	1.95	0.07	0.794
age	1	78.19	64.21	2.34	0.149
sex*age	1	1.41	1.41	0.05	0.824
Error	14	384.70	27.48		
Total	17	487.74			
95% Kernel					
sex	1	3.03	0.76	0.06	0.817
age	1	8.47	16.72	1.23	0.287
sex*age	1	9.03	9.03	0.66	0.429
Error	14	190.86	13.63		
Total	17	211.39			

Seasonal home-range sizes were calculated by 95% MCP, 95% kernel estimates and range span for each animal in each season ($\bar{X}$ = 78.2 ± 12.0 ha for 95% MCP; $\bar{X}$ = 63.3 ± 7.34 ha for 95% kernel; $\bar{X}$ = 1533.6 ± 110.6 m for range span; n = 54). There was considerable variation between individuals and years because of differences in the age of animals and the seasons tracked. For example, some animals were tracked only in the yearling age class because they died (n = 2), or dropped the collar (n = 1), or due to transmitter failure (n = 1). Because of the unbalanced nesting and non-hierarchical data set, appropriate inferential

statistical tests could not be conducted for differences between sexes, age classes, seasons, and their interactions. Still, descriptive statistics showed a consistent tendency in all home-range size measurements according to sex, age, and time of year (Figure 4.3). Ninety-five percent kernel estimate was largest in the autumn (Kruskal-Wallis Test, $H = 7.09$, $DF = 3$, $p = 0.069$), yearlings had significantly larger home ranges than adults ($H = 6.11$, $DF = 1$, $p = 0.013$), and there were no apparent differences between sexes ($H = 0.67$, $DF = 1$, $p = 0.412$).

Figure 4.3 Seasonal home-range size (mean $\pm$ SE) of the raccoon dogs by season, age class and sex. (*S* is spring, *SM* is summer, *F* is autumn, *W* is winter, *Y* is yearling, *A* is adult)



4.3.1.2 Configuration, Stability, and Constraints

Figure 4.4 and 4.5 show configuration of home ranges. Daphne (D), a subadult when captured in November 1993, had several excursions until settling in her original area the following spring. She moved between the two stable home ranges of Bokuden (B) and Echo (E) (Figure 4.4a; Figure 4.5a) and established a stable home range there with an adult male, Heiji (H) (Figure 4.4b). Graphical simplicity of MCP may be more appropriate to visually display configurations and stability than kernel estimates (Figure 4.4; Figure 4.5). However, quantification for spatial use is probably more sophisticated in kernel estimates because they detect area which was probably used, but in which no fixes were recorded. In contrast, MCP may include areas which were not used. Both methods using the same data sets are given in Figure 4.4c and 4.5b for comparison.

Figure 4.4 Configuration and overlaps of home range (100% MCP) of the raccoon dogs.

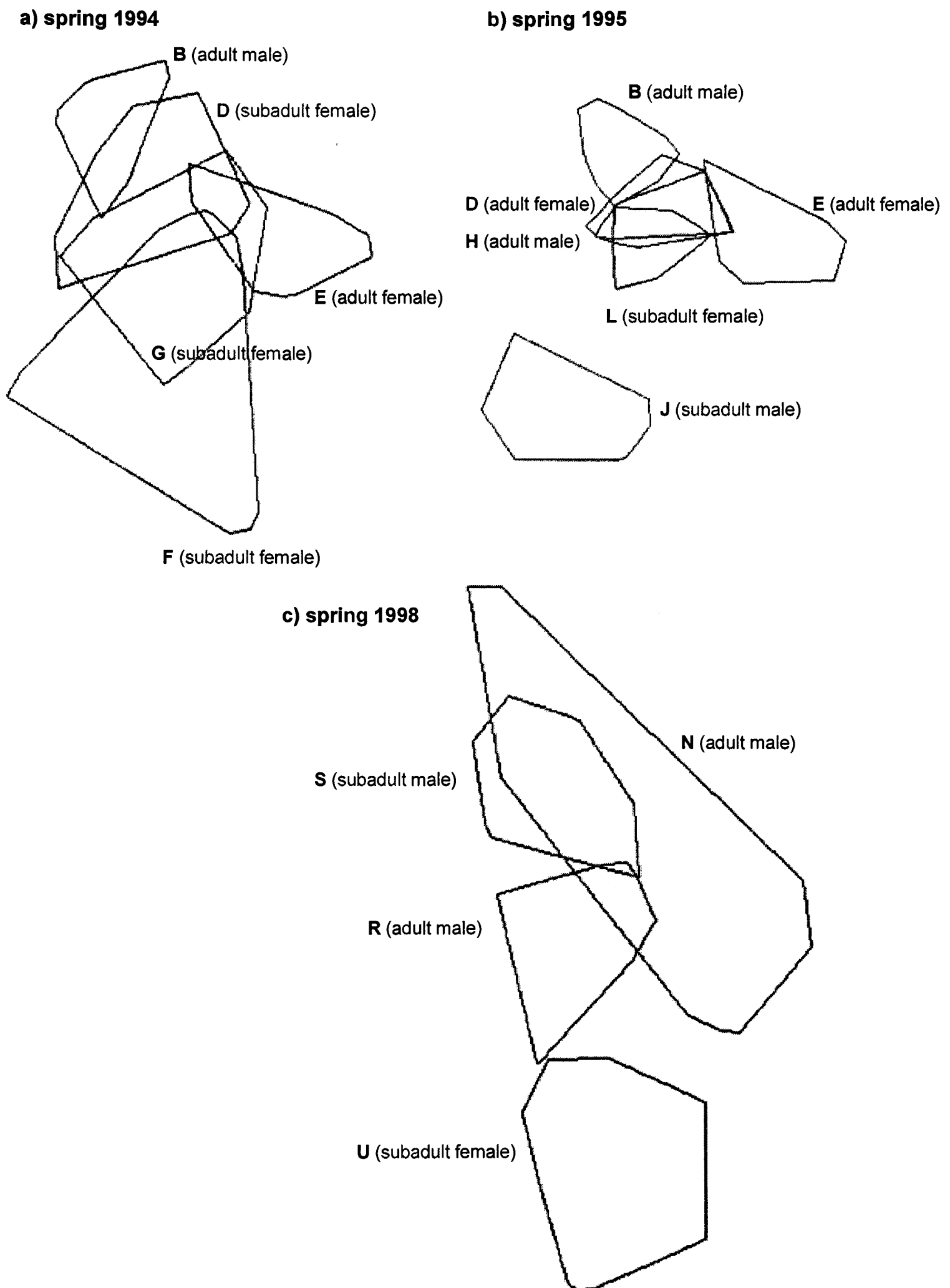
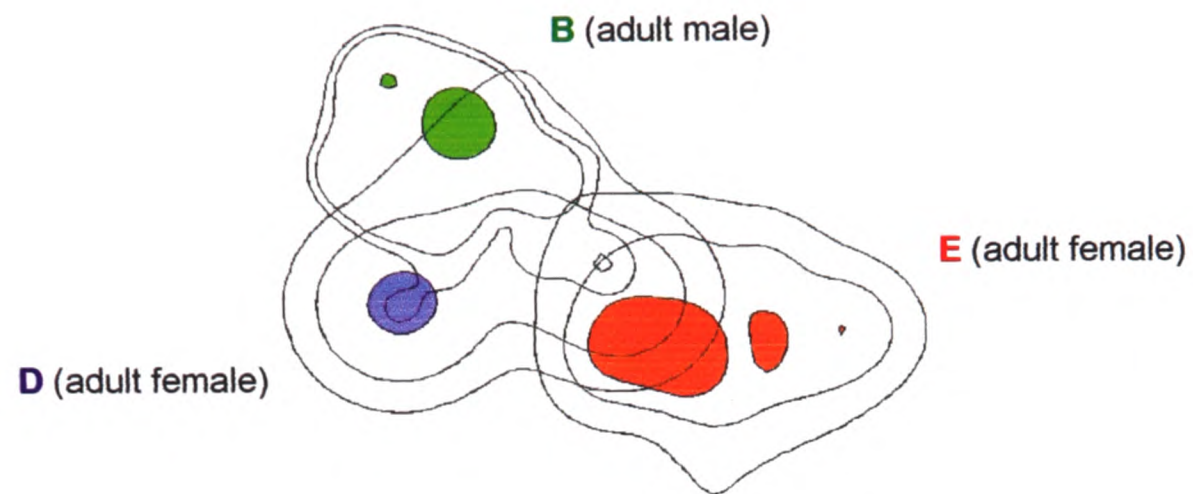
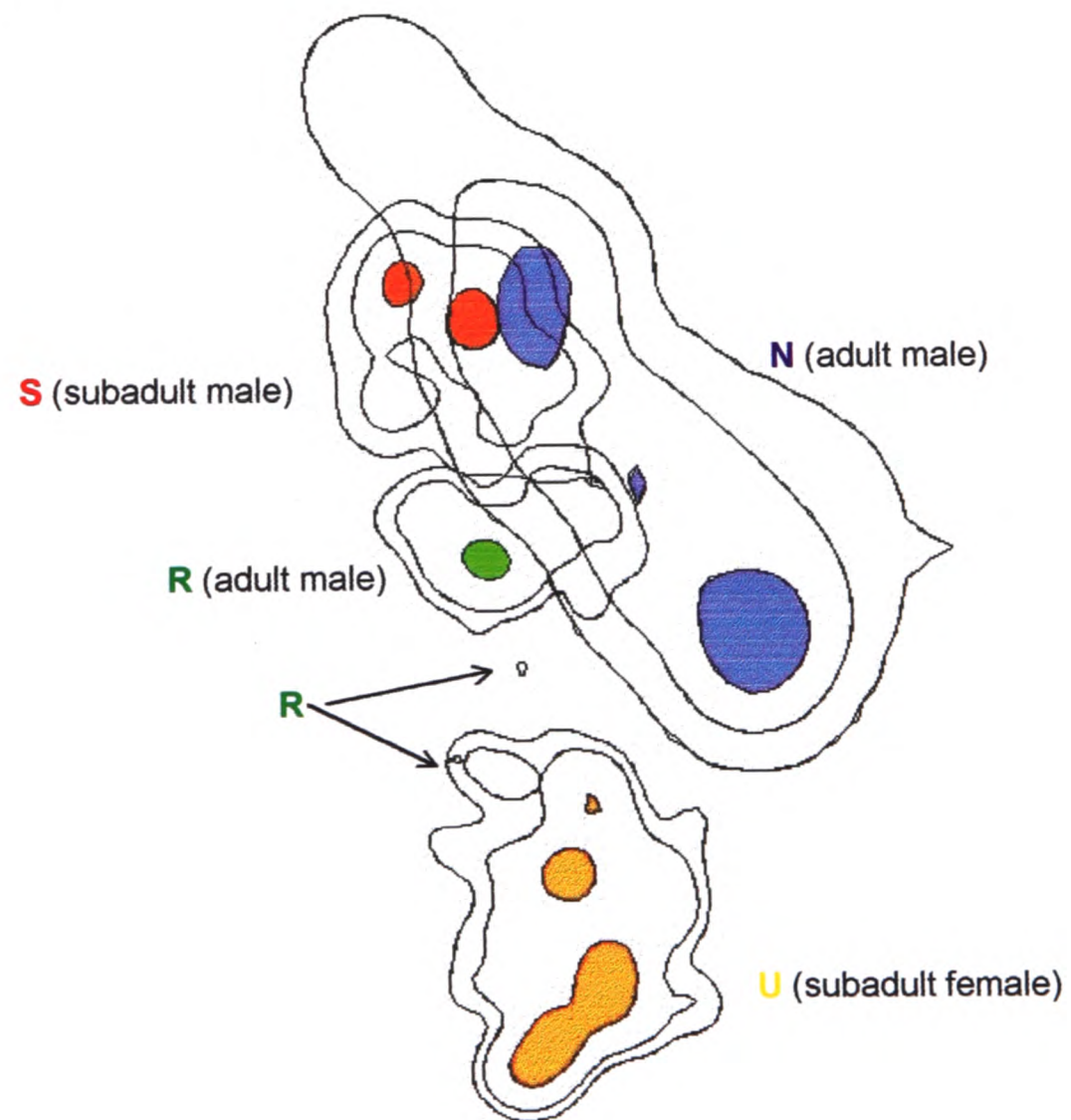


Figure 4.5 Configuration and overlaps of utilisation distribution (100%, 95%, and 50% kernel estimates) of the raccoon dogs.

a) autumn 1994

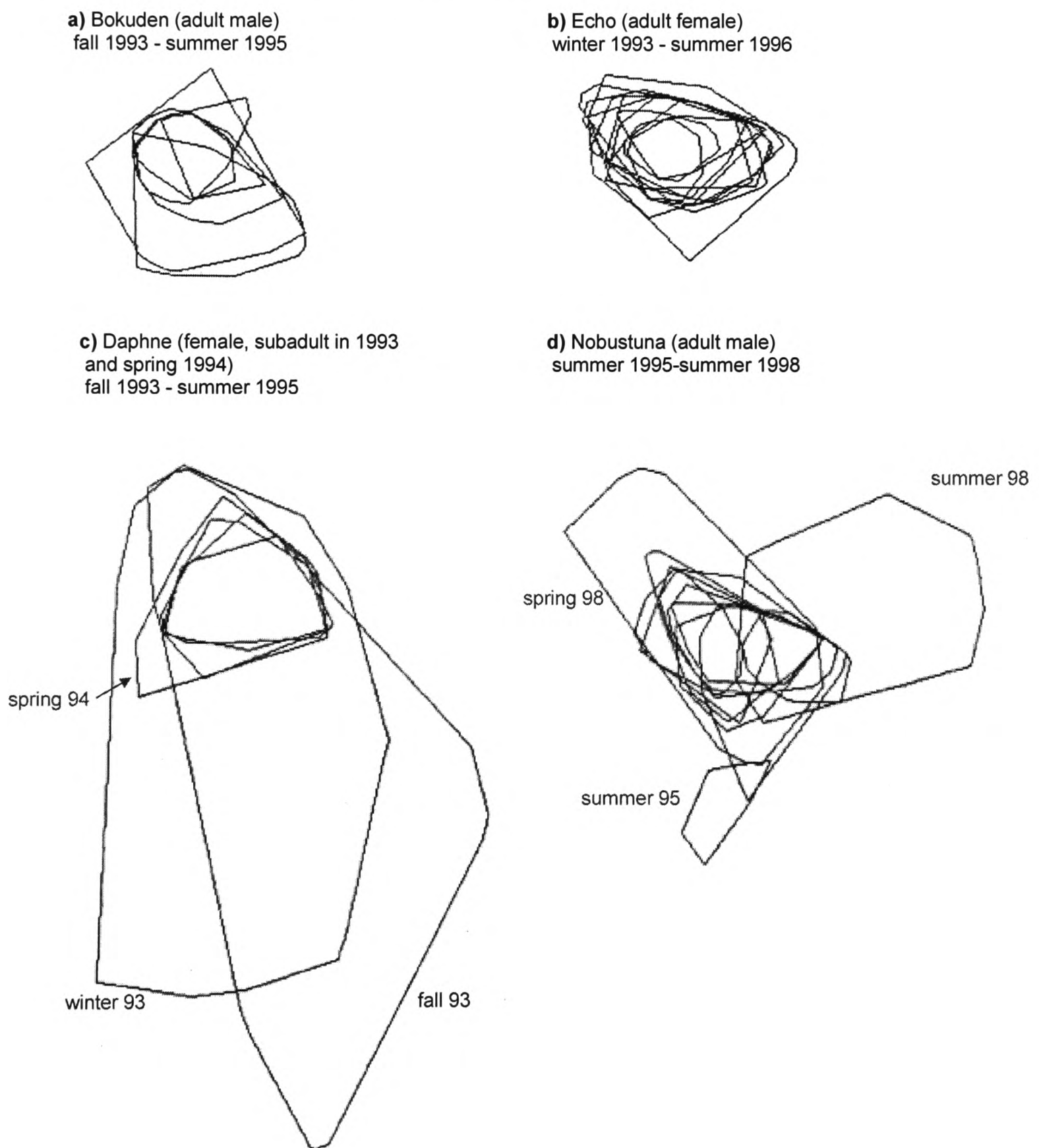


b) spring 1998



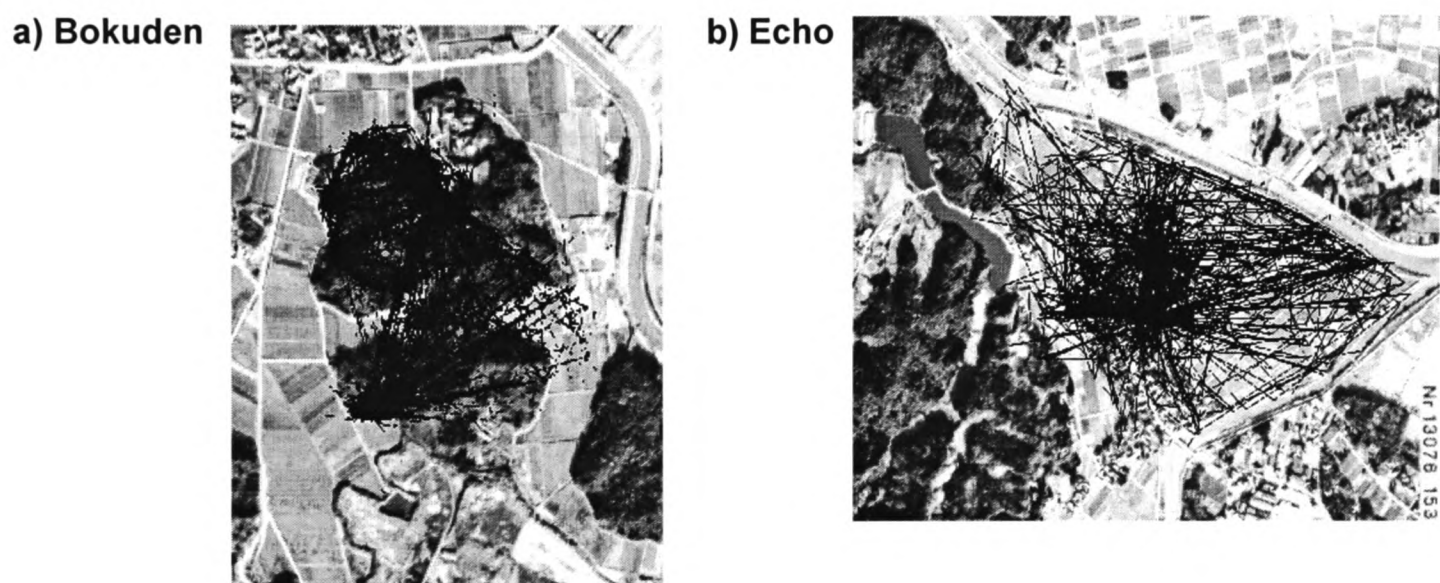
The stability of home ranges over time was examined, using seasonal home ranges from the 4 animals that were tracked for longer than 2 years (Figure 4.6). The adult male Bokuden and adult female Echo showed the most stable home ranges through the tracked periods, while a yearling female Daphne had the largest home range during the first year of tracking. Another adult male Nobutsuna changed home range size and location during the study period, enlarging his range towards the end of the study.

Figure 4.6. Home range stability of four raccoon dogs (95% MCP).



Environmental features, such as streams, open areas, and roads with relatively heavy traffic, functioned as clear constraints for those animals with stable home ranges (Figure 4.7). Only excursions and dispersal occurred across these physical boundaries. Raccoon dogs were observed to use car and pedestrian-bridges to cross streams and possibly swam across during low tides when currents are slow. Sometimes raccoon dogs walked on or ran across roads and used underground drainage pipes and covered gutters to cross roads (M. Saeki, pers. obs.). On one occasion, an animal entering a pipe <18 cm in diameter was observed.

Figure 4.7 Movements of two individual raccoon dogs, Bokuden and Echo, constrained by environmental features. (The background aerial photograph is not geo-registered^v, therefore, co-ordinates have some error; the lines show inter-fix movements.)



4.3.1.3 Individual Utilisation Distribution

Figures 4.8 to 4.11 show the seasonal utilisation distribution of four raccoon dogs. All year round, these animals had one to three core areas (50% use) which contained resting sites. Fragmented utilisation areas suggest some areas within home ranges (as obtained by MCPs) were not used. Animals with relatively stable home ranges, like Bokuden and Echo (Figure 4.6a and b, respectively), however, have utilisation distributions which suggest differential use of the space between seasons (Figure 4.8 and 4.10, respectively). Clear contrasts can be seen between Daphne (Figure 4.9) and Nobutsuna (Figure 4.11). For Daphne, the utilisation distribution showed an unstable phase in the first two seasons with larger areas and more core areas than the last four seasons (when the distribution became compact with fewer and smaller core areas than in the previous seasons). Nobutsuna stabilised his utilisation distribution after pair formation with Echo in autumn 1995 (Figure 4.11b shows a transient

^v Note is given in chapter 3 (p.71).

phase), and his home range remained stable immediately after his mate, Echo, was killed by car in June 1996. His distribution area and core areas were enlarged during the last two seasons (Figure 4.11k and l), coincident with riverbank construction in the vicinity of his original home range in March 1998.

Figure 4.8. Utilisation distribution (50%, 95% and 100% kernel estimates) of Bokuden, an adult male, from autumn 1993 to winter 1994.

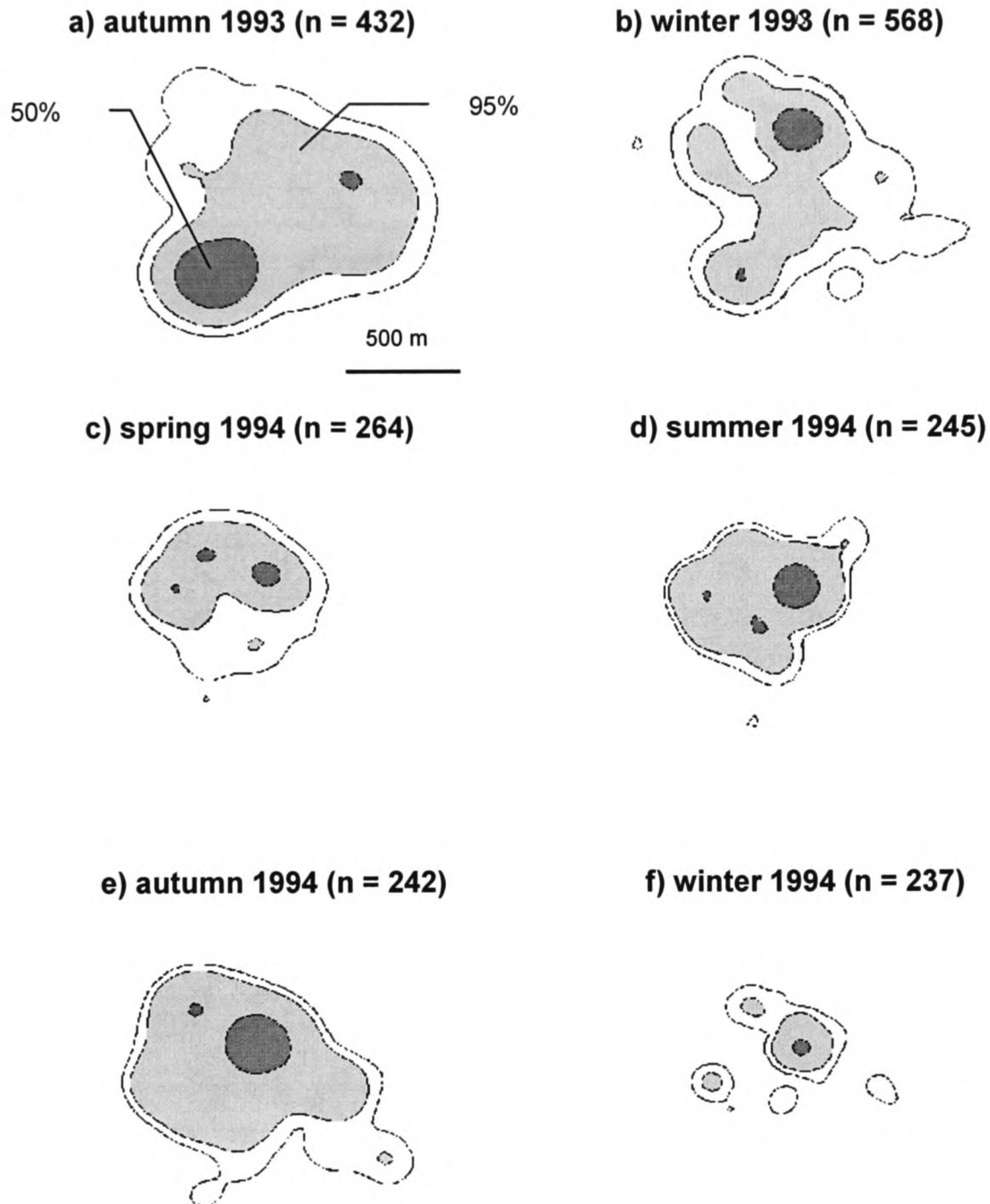


Figure 4.9. Utilisation distribution (50%, 95% and 100% kernel estimates) of Daphne, a subadult female when captured, from autumn 1993 to winter 1994.

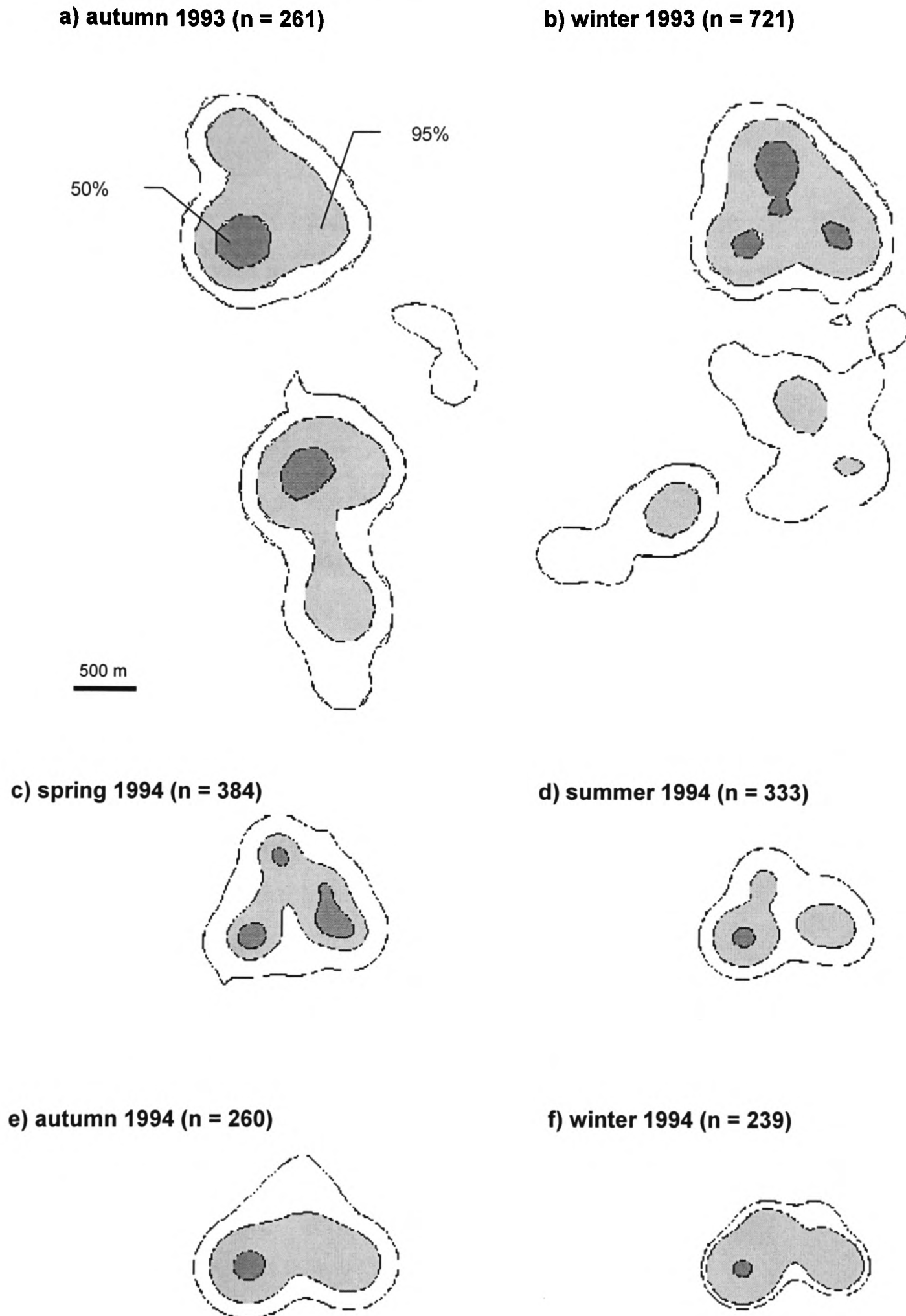
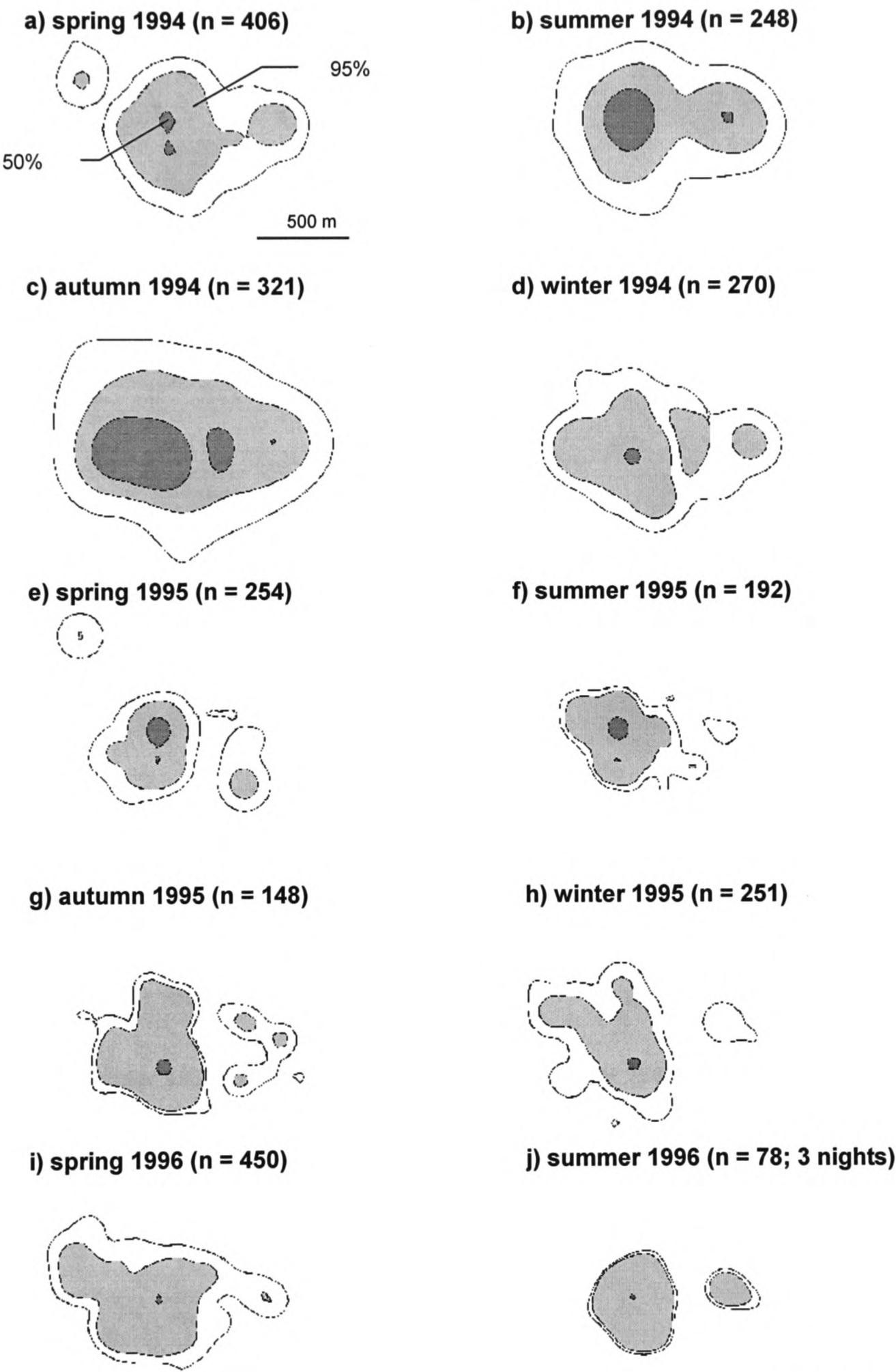


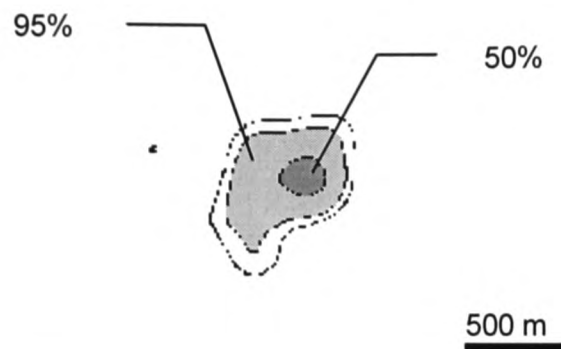
Figure 4.10. Utilisation distribution (50%, 95% and 100% kernel estimates) of Echo, an adult female, from spring 1994 to summer 1996.



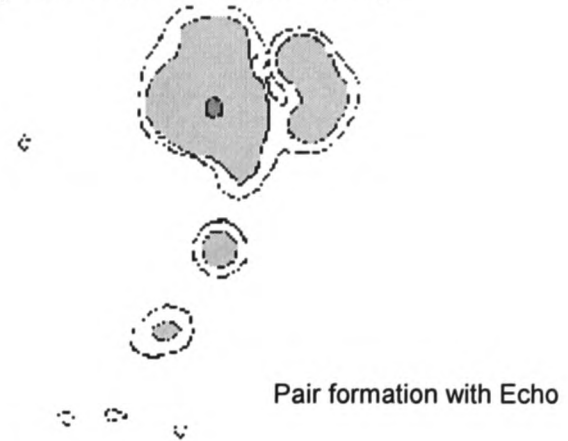
Echo was killed by car on 18 June.

Figure 4.11. Utilisation distribution (50%, 95% and 100% kernel estimates) of Nobutsuna, an adult male, from autumn 1995 to summer 1998.

a) summer 1995 (n = 43; 2 nights)



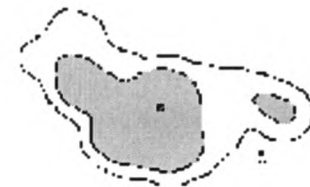
b) autumn 1995 (n = 141)



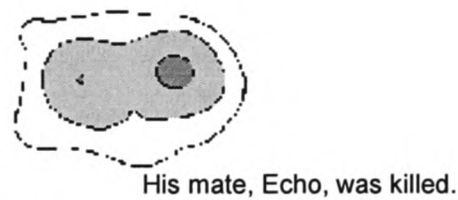
c) winter 1995 (n = 233)



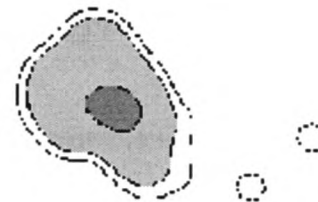
d) spring 1996 (n = 405)



e) summer 1996 (n = 360)



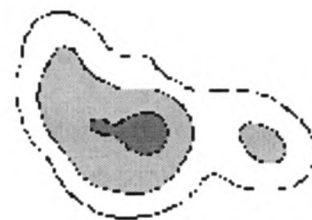
f) autumn 1996 (n = 131)



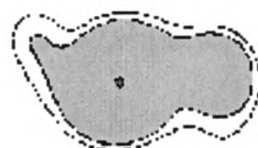
g) winter 1996 (n = 434)



h) spring 1997 (n = 388)



i) summer 1997 (n = 58; 1.5 nights)

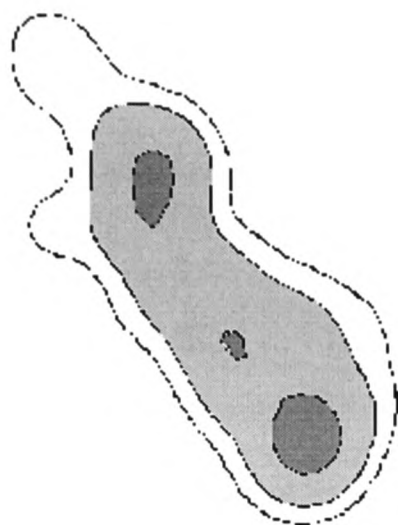


j) winter 1997 (n = 138)

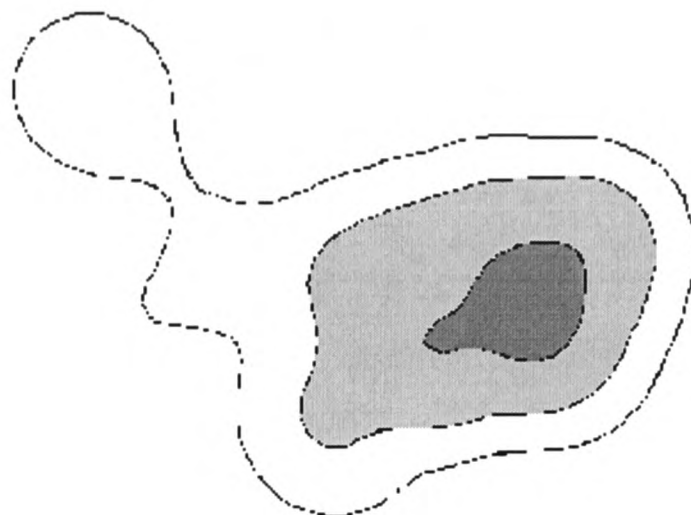


Figure 4.11. continued.

k) spring 1989 (n = 409)



l) summer 1998 (n = 277)



From these four animals and the other animals tracked for shorter periods, though too few for confident generalisation, it appears that adult home ranges are generally stable but may become unstable with disturbance, whereas yearling home ranges are unstable due to excursions and dispersal until stable home ranges are established.

4.3.1.4 Resource Dispersion Hypothesis

Seasonal home range size differed significantly between individuals (two-way ANOVA, $F_{3,3} = 3.95$, $p = 0.024$; Figure 4.12), and a significant difference in range size existed between Daphne and Echo (Tukey test, $q = 5.0282$, $p < 0.001$), but did not differ between seasons (two-way ANOVA, $F_{3,40} = 2.37$, $p = 0.103$). There was no significant difference in home range size between animals with more semi-natural habitat in home range (mountain type; Table 3.4 in Chapter 3) and animals with more agricultural land in their home range (village type; Table 3.4 in Chapter 3) (one-way ANOVA, $F_{1,42} = 1.38$, $p = 0.246$ for 95% kernel estimates; Figure 4.13). Nightly 100% MCPs also did not differ between the mountain type and the village type animals ($F_{1,304} = 0.01$, $p = 0.916$). However, if three-dimensional areas are considered, the mountain-type users had larger home-range areas than the village-type users because of the difference in topography between the habitats. Group size observed ranged from one to three, excluding young. In one case, the group size of three (one female and two males) with considerable home-range overlap was confirmed, suggesting a 'spatial group.'

Figure 4.12 Comparison of home-range size (95% kernel estimate) of four individuals.

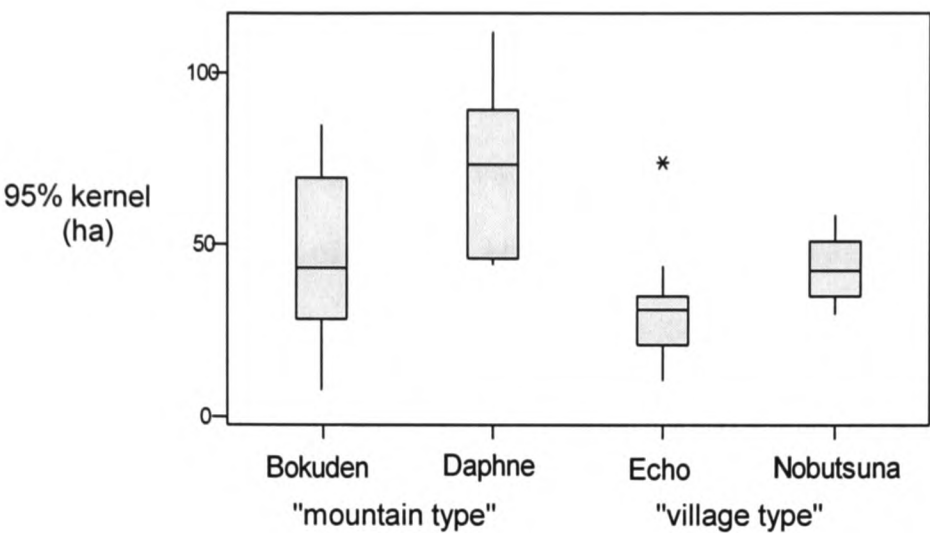
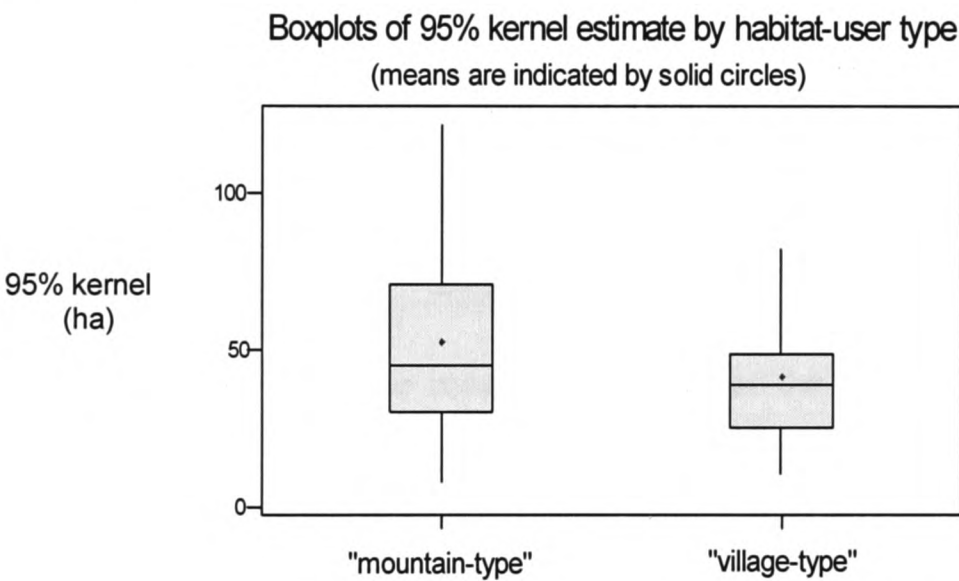


Figure 4.13 Comparison of home-range size (95% kernel estimate) between two habitat-type users.



4.3.2 Movements

4.3.2.1 Inter-fix Measurements

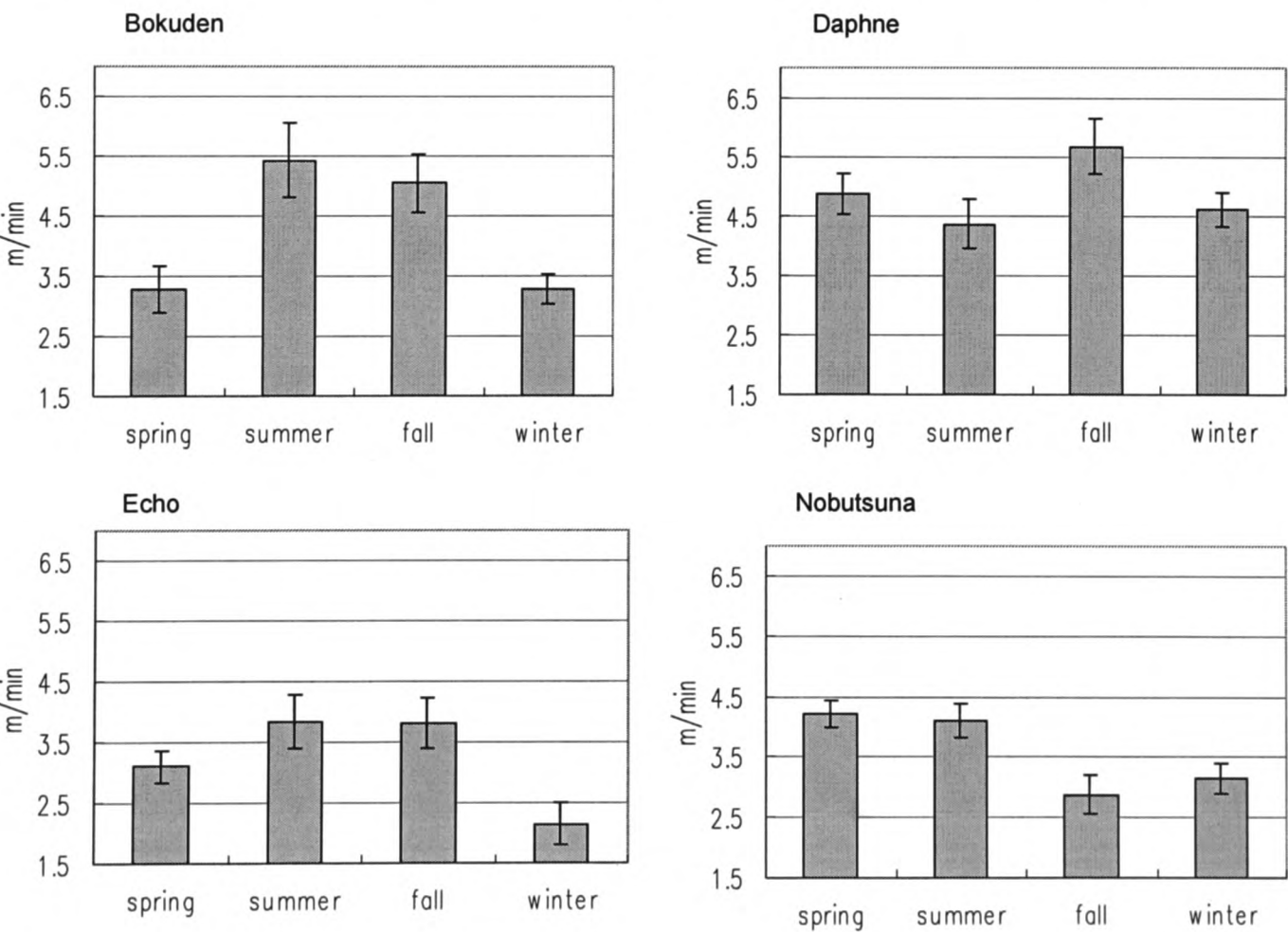
Individual mean inter-fix speed ranged from 1.86 to 6.96 m/min; the maximum inter-fix speed recorded was 68.7 m/min. There was a significant difference in inter-fix speed between individuals (one-way ANOVA, $F_{17,7981} = 25.74$, $p < 0.001$) Inter-fix speed did not differ significantly between the mountain type the village type (weighted GLM, $F_{1,12} = 2.10$, $p = 0.1725$). Mean speed differed significantly between seasons for 4 animals that were tracked >2 years (Table 4.4; Figure 4.14). Bokuden and Echo, both with stable home ranges throughout the study, showed similar seasonal trends in inter-fix speed, slow in spring and winter and fast in summer and autumn. Inter-fix speeds of Echo and Nobutsuna, both

village-type animals, were smaller than those of Daphne and Bokuden, both mountain-type animals. Distribution of inter-fix turning-angle was bimodal, suggesting that the raccoon dogs mostly moved forward with some angles after each 15 minute period. Preliminary analysis of turning angles for randomness showed that angles were not significantly different from randomly distributed over a night; however, when these angles were combined over several nights, the observed number of runs up and down from the median was less than expected, suggesting some trends in the data ($p = 0.028$ for 8 nights).

Table 4.4 One-way Analysis of Variance for inter-fix speed (log transformed) by seasons for four animals.

ID	Source	DF	Sum of Square	Mean Square	F	p
Bokuden	season	3	1.952	0.651	3.73	0.011
	Error	794	138.512	0.174		
	Total	797	140.464			
Daphne	season	3	1.754	0.585	3.73	0.011
	Error	1141	178.954	0.157		
	Total	1144	180.709			
Echo	season	3	4.390	1.463	7.39	0.000
	Error	1116	221.003	0.198		
	Total	1119	225.393			
Nobutsuna	season	3	2.390	0.797	3.89	0.009
	Error	1814	371.831	0.205		
	Total	1817	374.221			

Figure 4.14 Seasonal difference in mean inter-fix speed for four animals.



4.3.2.2 Nightly Movements

Nightly movements were analysed for 18 animals totalling 309 nights. The average mean inter-fix speed of tracked raccoon dogs was $4.24 \text{ m/min} \pm 0.14$; mean nightly home range was $16.7 \text{ ha} \pm 1.29$; and mean nightly range span was $670.4 \text{ m} \pm 25.6$. Examples of nightly movements are shown in Figure 4.15. Individual variation appeared to be great in all three parameters, and greater variability can be seen among subadults than adults (Figure 4.16). Comparisons were made between sexes, age classes and seasons (Table 4.5; Figure 4.17). Only season significantly affected movements, along with an interaction between age and sex. The interaction may be produced due to the unbalanced samples of age and sex ratio (i.e. more yearling females and more adult males).

Table 4.5 General Linear Models for nightly movements of the raccoon dogs.

Source	DF	Type III Sum of Square	Mean Square	F	p
mean inter-fix speed					
Sex	1	0.452	0.452	0.01	0.9293
Season	3	527.862	175.954	8.05	0.0009
Age	1	11.304	11.304	0.21	0.6633
sex*season	3	90.491	30.164	1.40	0.2770
sex*age	1	235.756	235.756	14.70	0.0186
season*age	3	19.909	6.637	0.09	0.9577
sex*season*age	2	144.002	72.001	.	.
mean 100% MCP					
Sex	1	0.2653	0.0265	0.05	0.8325
Season	3	2.9977	0.9992	5.57	0.0057
Age	1	0.0369	0.0369	0.09	0.7710
sex*season	3	0.2881	0.1737	0.82	0.5008
sex*age	1	1.3776	1.3776	7.15	0.0556
season*age	3	0.2881	0.0960	0.15	0.9188
sex*season*age	2	1.2487	0.6243	.	.
mean range span					
Sex	1	11.114	11.114	0.07	0.7910
Season	3	1000.772	333.591	4.40	0.0150
Age	1	78.949	78.949	0.70	0.4418
sex*season	3	235.074	78.358	1.23	0.3305
sex*age	1	257.588	257.588	5.94	0.0714
season*age	3	88.875	29.625	0.39	0.7760
sex*season*age	2	152.076	76.038	.	.

Figure 4.15 Examples of nightly movements of the raccoon dogs. (Time of some fixes is given.)

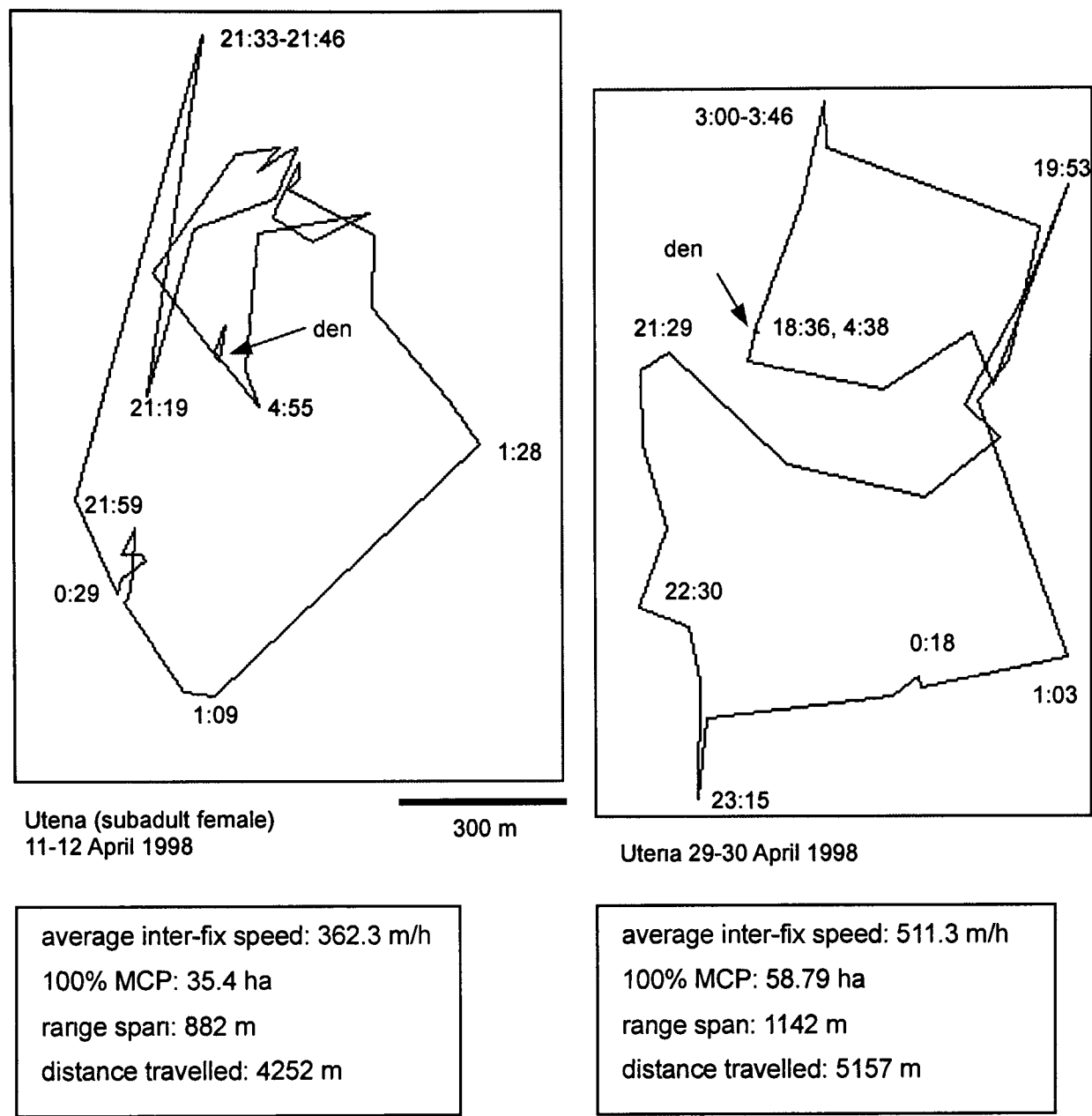


Figure 4.16 Nightly movements of the raccoon dogs, (a) average inter-fix speed, (b) mean 100% MCP, and (c) mean range span by individuals.

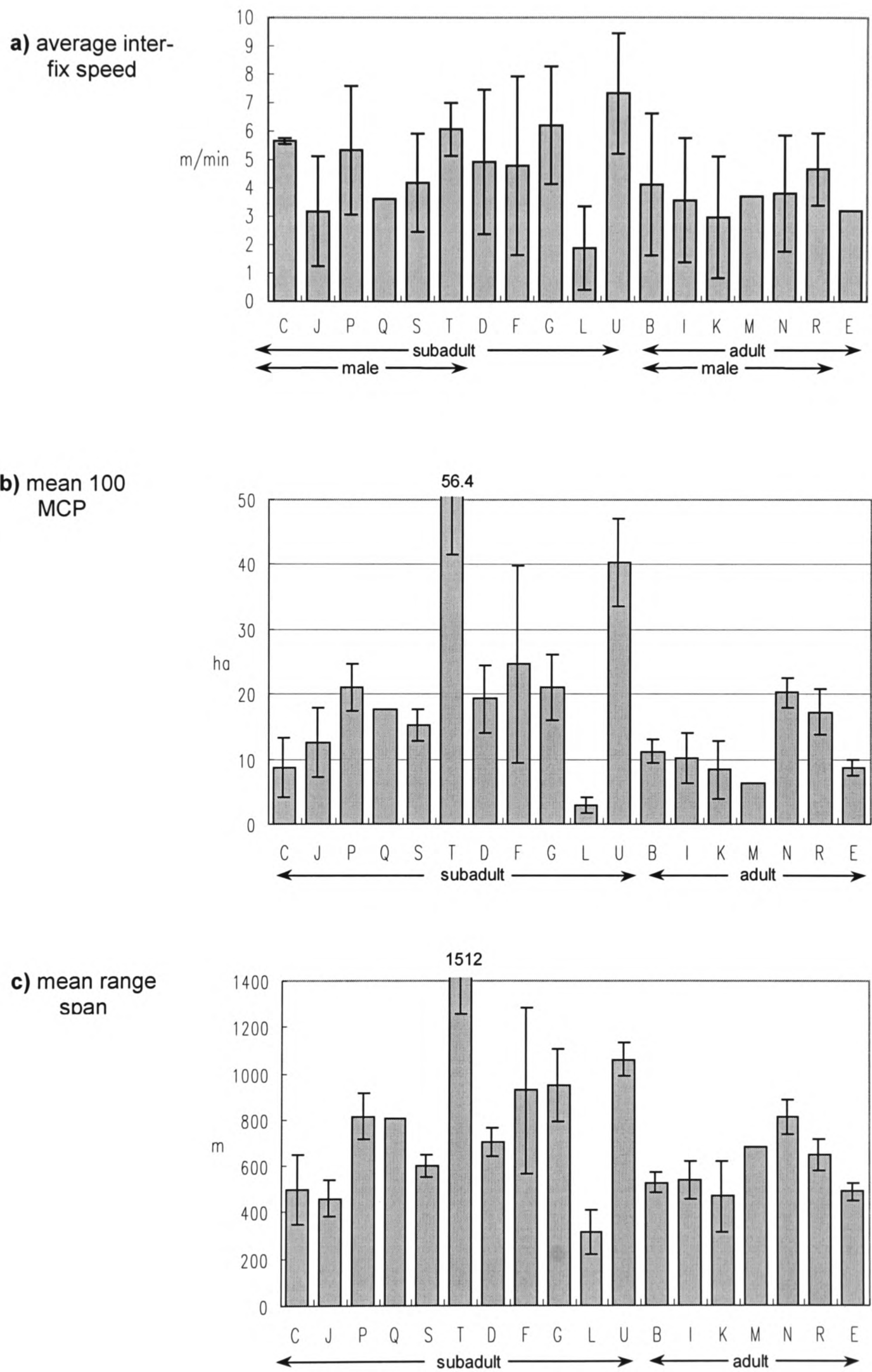
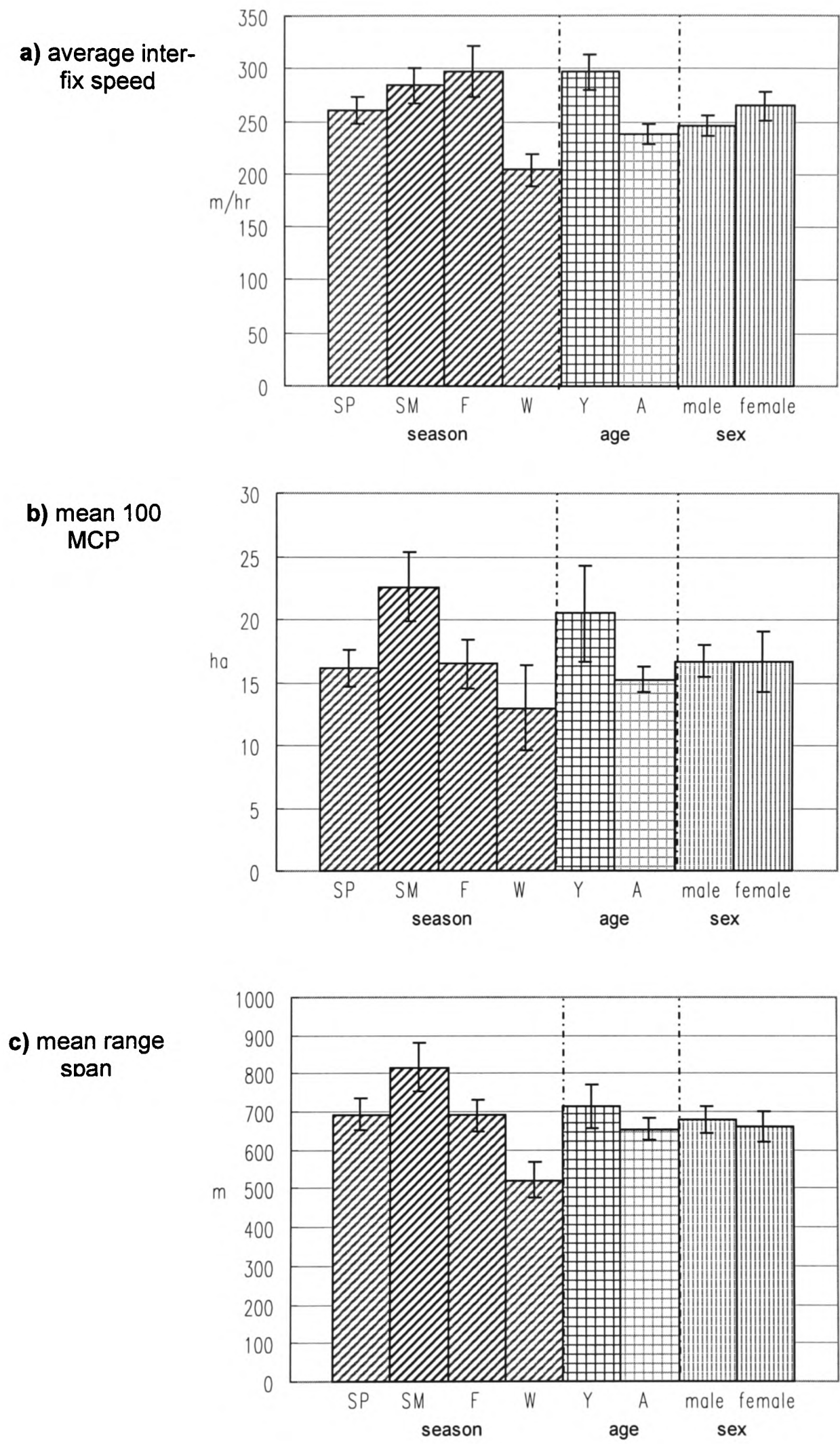


Figure 4.17 Nightly movements of the raccoon dogs, (a) average inter-fix speed, (b) mean 100% MCP, and (c) mean range span. Comparisons between seasons, age classes, and sexes. The graphs show mean $\pm$ SE. See text for details.



4.3.2.3 Microclimatic Effects on Movements

Inter-fix speed was used to evaluate the effect of microclimatic variables on raccoon dog movements because its calculation is not influenced by differences of several minutes in time intervals between fixes, as opposed to inter-fix distance. The data were not pooled due to large individual variability but, instead, analysed separately for the 8 animals with the longest tracking period. Effects of microclimate variables differed between the individuals (Table 4.6). Weather did not significantly affect the speed of movements of Bokuden, Daphne, or Shusaku (all three were the mountain type), while wind speed did not affect Daphne, Jirokichi, Shusaku, or Utena. Low temperature, however, appeared to be associated with low speed in all but Shusaku, who was not tracked during the winter.

Table 4.6 Effects of weather, wind, temperature and month on inter-fix speed of eight raccoon dogs.

Individual	number of nights	Source	DF	F	p
Bokuden	798	Weather	4	2.37	0.051
		Wind	3	4.95	0.002
		Temperature	3	8.02	0.000
		Month	11	4.89	0.000
Daphne	1145	Weather	4	0.50	0.734
		Wind	3	0.35	0.791
		Temperature	3	7.12	0.000
		Month	11	5.97	0.000
Echo	1120	Weather	4	3.56	0.007
		Wind	3	2.61	0.050
		Temperature	3	5.13	0.002
		Month	11	5.99	0.000
Jirokichi	285	Weather	4	5.12	0.001
		Wind	3	0.77	0.464
		Temperature	3	3.88	0.022
		Month	11	4.47	0.001
Nobutsuna	1818	Weather	4	3.54	0.007
		Wind	3	22.03	0.000
		Temperature	3	10.64	0.000
		Month	11	4.33	0.000
Poseidon	570	Weather	4	4.63	0.001
		Wind	3	7.54	0.000
		Temperature	3	3.17	0.024
		Month	11	7.28	0.000
Shusaku	561	Weather	4	1.28	0.275
		Wind	3	2.33	0.098
		Temperature	3	1.95	0.144
		Month	11	10.95	0.000
Utena	338	Weather	4	3.75	0.005
		Wind	3	0.64	0.525
		Temperature	3	6.43	0.012
		Month	11	2.68	0.047

4.3.2.4 Fractal Dimension

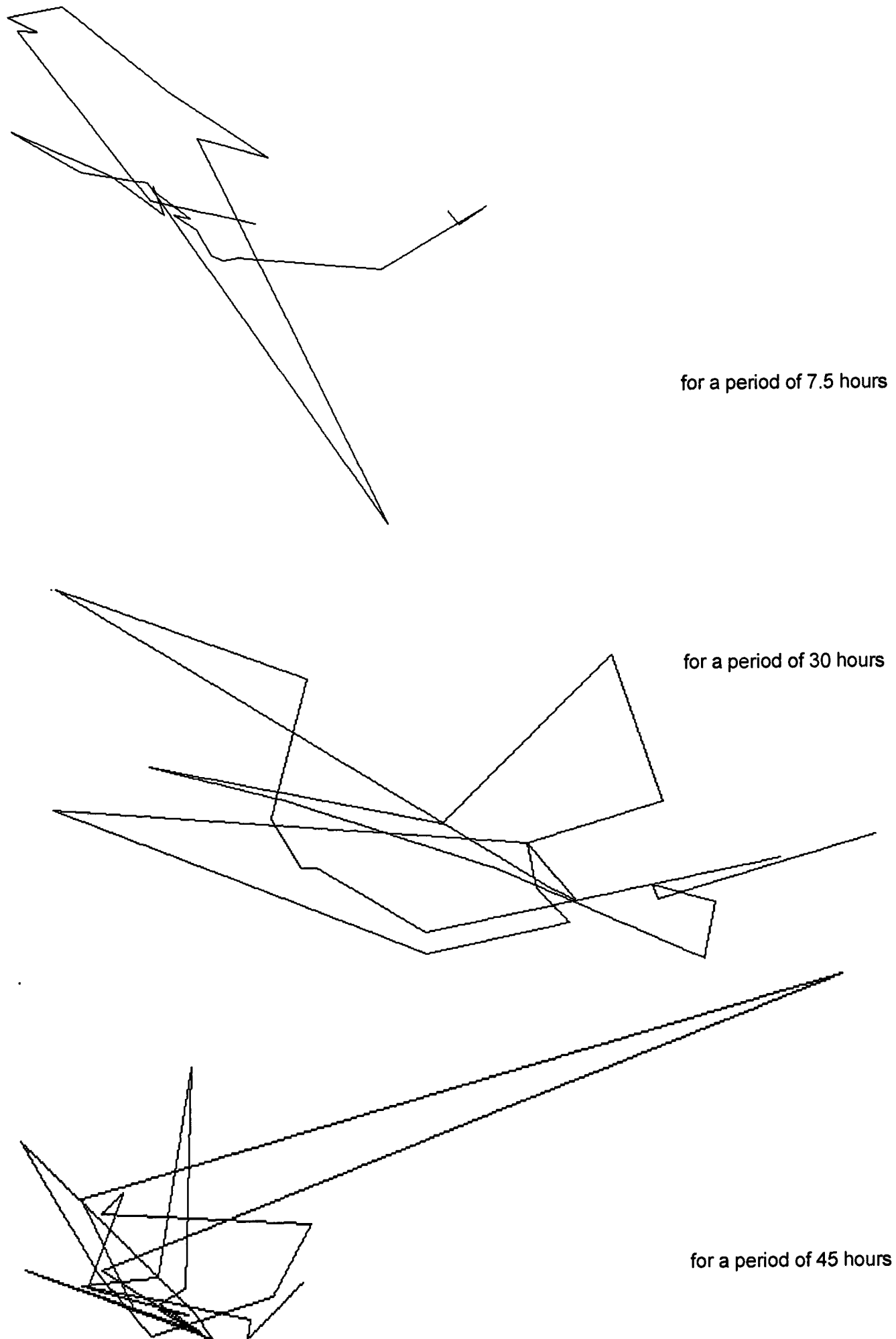
The mean fractal dimension of movements was 1.2264 ± 0.0122 ($n = 68$ nights). This is significantly different from 1.0, i.e. a straight line, and 2.0, i.e. Brownian-like movement throughout a plane (t-test, $T = 18.57$, $p < 0.00001$ and $T = -63.47$, $p < 0.00001$, respectively). Because of the significant deviation from normality, a nonparametric Wilcoxon signed rank test was also applied, resulting in an estimated median of 1.1986, also significantly differed from 1.0 and 2.0 (both $p < 0.0001$). Fractal dimensions were significantly different between individuals (Table 4.7) but not amongst seasons, years, age classes and sexes (Table 4.7); but, age had an effect which approached significance (median for adults = 1.221 and for subadults = 1.167). Fractal dimensions also differed between the mountain type and the village type (Table 4.7). Mean fractal dimension of movements was 1.2705 ± 0.0175 for mountain type and 1.1934 ± 0.0153 for village type. The higher fractal dimension of movements indicated that spatial use of the mountain type appeared to be more complex and intense than that of the village type.

Table 4.7 Kruskal-Wallis Tests for fractal dimension of movements.

Factor	DF	H	<i>p</i>
individual	10	20.99	0.021
sex	1	2.35	0.126
age	1	2.91	0.088
year	4	7.64	0.106
season	3	2.06	0.561
habitat user type	1	11.69	0.001

Figure 4.18 shows an example of an animal's displacement paths (30 steps) at three different time scales. The series were created by connecting sequential paths from different nights with adjusted locations, by uniting the end point and the start point of the next bout. Calculated fractal dimensions were 1.1623, 1.1489 and 1.1385 for 15-minute, 1-hour and 1.5-hour intervals, respectively. The fractal dimension of the whole path of 15-minute intervals (186 steps) was 1.1657. Although there was a steady increase (around the overall SE = 0.012) over the range, no large differences (greater than the overall SD = 0.101) were found between the three scales. This supports the scale-independence (self-similarity) at least within the resolution of 6 times. This also shows that the large maximum divider length used is not associated with large fractal dimension estimates, suggesting self-similarity (Dicke and Burroughs, 1988; Turchin, 1996).

Figure 4.18 An example of movements at three scales, 15-minutes (top), 1-hour (middle), and 1.5-hour (bottom) intervals.



The fractal dimensions of *sato* and *yama* habitats (Figure 4.2) were estimated as 1.41788 ± 0.01443 ($r^2 = 0.998$, $p < 0.0001$) and 1.52048 ± 0.01848 ($r^2 = 0.998$, $p < 0.0001$), respectively.

For five animals with their fractal dimensions calculated with ≥ 6 -nights, mean fractal dimension had a significant negative relationship with a sum of % cover of rice fields and cropland in each home range ($r^2 = 0.961$, $p = 0.00386$; Figure 4.19; Table 4.8). Fractal dimension of movements decreased as artificial land use increased, suggesting raccoon dog movements on artificial land ('*sato*') were less complex, more straightforward than those on semi-natural habitat ('*yama*').

Figure 4.19 Relationship between fractal dimension and artificial land use.

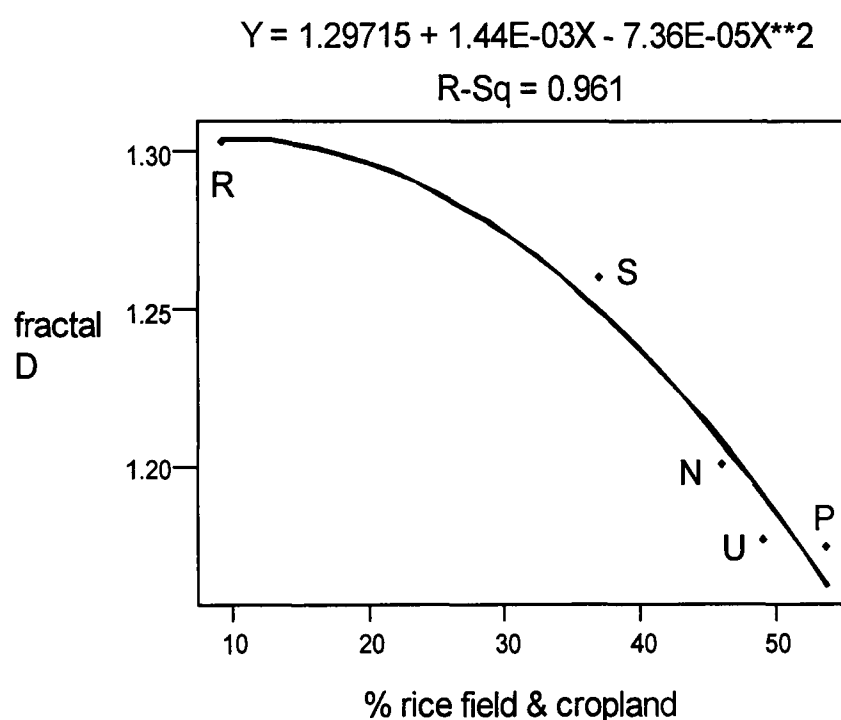


Table 4.8 Analysis of variance for the polynomial regression analysis of fractal dimension on artificial land use.

Source	DF	Sum of Square	Mean Square	F	p
Regression	2	0.012400	0.006200	24.9063	0.00386
Error	2	0.000498	0.000249		
Total	4	0.012900			

Source	DF	Sequential Sum of Square	F	p
Linear	1	0.016000	26.3138	0.001030
Quadratic	1	0.000822	3.30254	0.210809

4.3.2.5 Lévy Flights

The mean α value for Lévy Flight power-law was 0.5421 ± 0.0173 ($n = 80$). This differed significantly from 0.5 (t-test, $T = 2.43$, $p = 0.017$) and from 1.0 (t-test, $T = -26.45$, $p < 0.00001$). This observation, and the existence of characteristic long step lengths in the radio-tracking

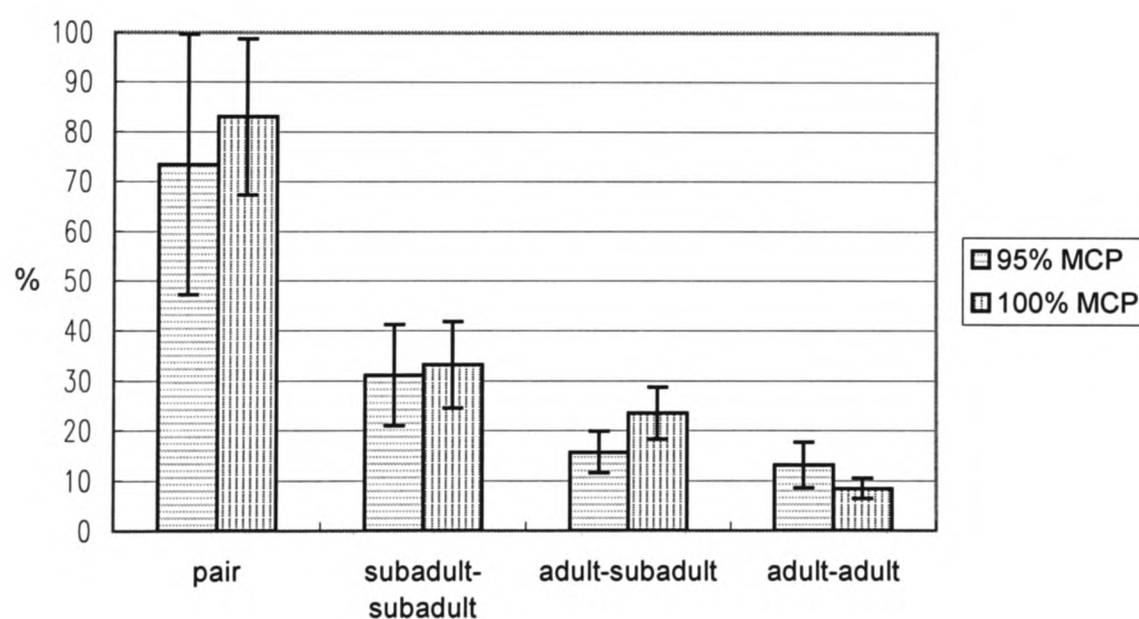
data of individuals (Fig 4.18), suggests that long-range power-law correlations may exist for the overall data, even though it may not operate with a perfect power law. There was no significant difference between individuals in the Lévy's α 's. Lévy's α did not differ between sexes ($F_{1,35} = 1.94$, $p = 0.1721$), age classes ($F_{1,17} = 0.68$, $p = 0.4213$), years ($F_{5,31} = 1.19$, $p = 0.3364$), seasons ($F_{3,22} = 0.93$, $p = 0.4415$) or habitat user types ($F_{1,11} = 1.74$, $p = 0.2135$).

4.3.3 Social aspects

4.3.3.1 Home Range Overlap and Centre Spacing

Overlap of home range was calculated between pairs, non-pair adults, adult-yearling and yearlings by season. In the spring, there were no overlaps amongst 50% MCP of non-pair adults or adults and yearlings. Mean percentages of overlap between yearlings was 27.7 ± 18.2 ($n = 4$) and 76.2 ± 0.64 ($n = 2$) for a pair. The mean percentage of overlap in 95% MCP and 100% MCP between age classes and pair status decreased in the order of pair, yearlings, adult-yearling and adults (Figure 4.5; Figure 4.20).

Figure 4.20 Percentage overlap of home range of the raccoon dogs in spring.



4.3.3.2 Group Formation and Den resting/Site Sharing

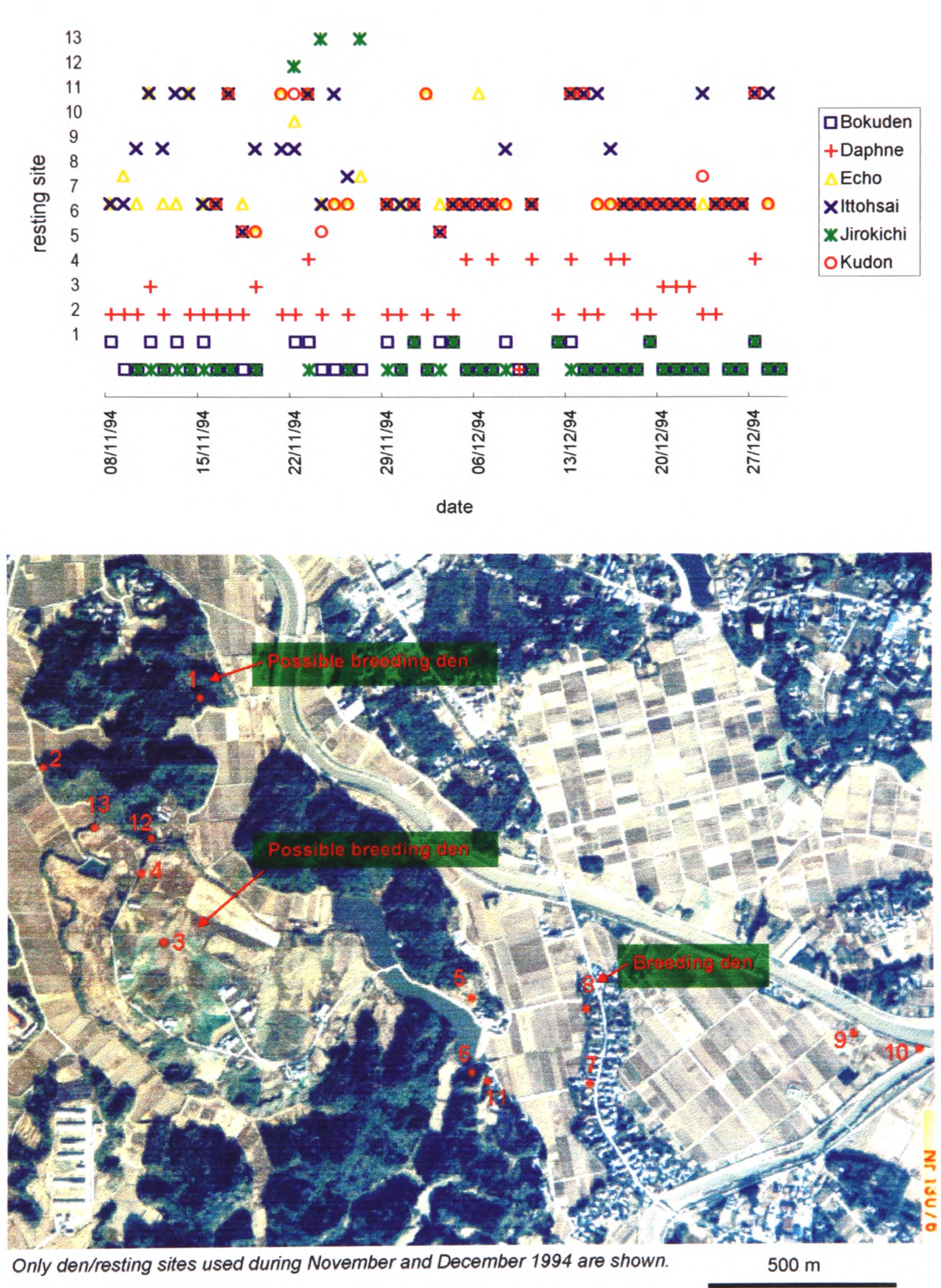
During this study, the social groups detected consisted of no more than a pair and their offspring. Three adult-sized animals were often observed to emerge from the same resting site although the third animal (male) may have been the offspring of the pair remaining in the area. Two adult males, and also a male and a female who were not paired, shared dens and resting

sites during the winter. The female and the male separated just before the mating season (and they originated from the same den a year apart). In both cases, non-paired individuals did not feed or travel together.

Den or resting site sharing during the daytime was detected throughout the year. Once four adults and/or yearlings were observed emerging from the same resting site. A badger was confirmed (using a camera trap) to emerge from a den three hours after a raccoon dog had emerged. During 1994, two groups were identified by their resting-site sharing behaviour, while two yearling females, Fujitsubo and Gaia, did not share resting sites with any other radio-collared animals. Figure 4.21 shows an example of resting-site sharing in November and December 1994. Resting sites 1 and 2 were used by the adult male Bokuden and the subadult male Jirokichi, while resting sites 6, 7, and 11 were used by the adult female Echo, an adult male Ittohsai, and an adult male Kudon. Resting sites 3 to 5 were used exclusively by the adult female Daphne, and Daphne once shared resting site 1 (possibly a breeding den) with Bokuden. Daphne was originally from resting site 1 in 1993 when she was subadult and shared it with Bokuden before she undertook excursions. In summary, there were two definite groups: 1) Bokuden, Jirokichi, and Daphne (although she can be separated) and 2) Echo, Ittohsai, and Kudon. Breeding den 8 was not used often during November and December 1994; it was used by Echo from 1994 to 1996 during the breeding season.

In October 1992, in Nose-cho, Osaka Prefecture, two groups that were living closely together, and sharing a feeding site, were observed at a camp ground. One group waited in the woods while another group fed on food provided by the personnel at one o'clock in the afternoon. Each group consisted of at least ten individuals, and there was a dominant group, which always fed first. The individuals varied in their degree of shyness towards humans; some animals took food directly from humans whereas other animals stayed in the bush until the people left.

Figure 4.21 Change in resting sites of six animals in November and December 1994.



4.3.3.3 Pair Formation and Parental Care

The formation of a pair was observed in September 1995 between an adult female with experience of reproduction, Echo, and an adult male, Nobutsuna. Nobutsuna moved into Echo's home range, and they subsequently stayed together from 10 September 1995 to 18 June 1996 when Echo was killed by a car.

The parturition date of Echo was recorded as May 2 1996 when she briefly went out from the den for around 1 hour. After this, Echo and Nobutsuna took turns to leave the den. The male attended the den significantly more than the female during the nursing period of 1996 (GLM, $F_{17,313} = 3.12$, $p < 0.0001$; Table 4.9). Nobutsuna was seen with the pups after Echo's death, at least until 1 August 1996, 43 days since Echo's death and 90 days since parturition.

Table 4.9 Analysis of variance for time allocation between sexes. Time is the number of fixes at den site.

Source	DF	Sum of Square	Mean Square	F	p
Model	17	20.53544	1.207967	3.12	0.000
Error	313	121.18977	0.371878		
Corrected Total	330	141.72521			
Type I					
sex	1	9.19325	9.193250	23.74	0.000
time	8	2.15842	0.269803	0.70	0.6944
sex*time	8	9.18377	1.147971	2.96	0.0033
Type III					
sex	1	11.00316	11.003163	28.42	0.0001
time	8	2.158980	0.269873	0.70	0.6942
sex*time	8	9.183766	1.147971	2.96	0.0033

Provision of food for the young by both parents was also observed. Remains of an American bull frog (*Rana catesbeiana* Shaw) and a chicken foot were found at the entrance of the den site, and Echo was carrying a small Japanese mole (*Mogera minor* Kuroda) when she was killed by the car near the den site (presumably, carrying the mole was a reason why she did not use the underground gutter to cross the road as usual). Both occurred late in the nursing season, and Echo was still lactating when she was killed.

4.4 DISCUSSION

4.4.1 Home range and movements

Ikeda (1982) found that the home-range size of raccoon dogs was smaller than that predicted from their body weight, using an equation for omnivores (Harestad and Bunnell, 1979). However, the mean home-range size in the current study was much larger than those from other studies in Japan except one in sub-alpine habitat (Table 4.1) and was close to that predicted by Harestad and Bunnell's empirical relationship. This might indicate that, in this study, habitat quality in terms of productivity meets an average level for the metabolic requirements of omnivores in general. Additional food sources (garbage sites, food-rich shorelines) were a characteristic of the small home ranges observed in the other Japanese studies. Also, urban areas and small islets physically confine home ranges by inaccessible developed areas and the ocean, respectively.

A combination of habitat heterogeneity and variation in age, sex and size probably accounts for the observed large differences in the home ranges of individuals (the non-statistical significance of the latter effects notwithstanding). The effects of habitat composition on home-range size may have been confounded with topography because forest habitat was located on the hills, whereas agricultural lands were located on the plains. Three-dimensional areas may be required to compare home-range sizes in areas with distinct topography, such as the study area. To detect seasonal difference, 95% kernel estimates appeared to be more suitable than 95% MCP or range span because 95% kernel estimates detected limited spatial use during winter, which were indicated by nightly movements.

Movements measured by inter-fix speed also varied greatly among individuals, and season appeared significantly to influence movements. The two adults with stable home ranges showed similar trends in seasonal difference, and Nobutsuna also showed this when conspicuous excursions were excluded. This implies that adult raccoon dogs move, on average, more slowly in spring and winter. This is probably accounted for by the frequency of inactive periods in these seasons, rather than slower movement speeds when active. Attending of dens early in the nursing season and remaining inactive during cold periods probably resulted in the low figure. However, field observation and recorded activity levels suggest that higher mean inter-fix speed during excursion/dispersal was due to faster

movements. Thus, caution is required to interpret inter-fix speed because it is not a continuous measurement of velocity of the movements. Variance of inter-fix speed may be useful in detecting unusual movements.

Although raccoon dogs did not hibernate in the study area, nightly movements suggested lower winter activity: mean inter-fix speed, nightly home range and range span were smaller in winter, compared to other seasons. Badgers (*Meles meles anakuma* Temminck) in Japan, on the other hand, undergo hibernation with a lower metabolic rate (Tanaka, 2000) occasionally emerging from the den on warm days (Kaneko, 1996). In Finland, both the raccoon dog and the badger become dormant in winter, and it probably enables raccoon dogs to establish populations without causing a decline of native badger populations (Kauhala, 1995; Kauhala *et al.*, 1998c). The milder climate in the study area (and most of Japan) allows the raccoon dogs to forage through the winter, conserving energy because they can sustain themselves with less effort on foraging. Circumstantial evidence for this hypothesis is provided by the significantly smaller inter-fix speeds in colder temperatures shown by all animals tracked in winter.

4.4.2 Fractal Dimension and Lévy Flights

Food distribution with both spatial (patchiness) and temporal (predictability) heterogeneity influence animals' movements to a large extent (Wallin, 1991; Viswanathan *et al.*, 1996). In the extreme case of animals are fed at the same place and the same time of day, the animals' path may be a straight line from a resting site to the feeding site ($k \cong 1$). However, if the path is restricted by physical objects (e.g. body of water or buildings) or an area with a risk to predation (e.g. avoiding open space), the path will deviate from a straight line. Animal movements cannot therefore be interpreted by simply considering food distribution. Strict comparisons for such effects are only legitimate if we can control for confounding factors, both physical and biological. In the field, however, these factors frequently cannot be disentangled. So, how is it possible to interpret fractal movement patterns in fractal environments where we find evidence that they exist? In addition, a fundamental question still remains: if it is fractal, is it an intrinsic characteristic or some artefact of the analysis (Cherbit, 1991)? What selection pressures would give rise to fractal characteristics?

Distribution and scarcity of food items are most likely to vary between seasons in the

areas with distinct seasons and agricultural activities. Food distribution did not seem to influence directly the fractal dimension of nightly movements of the raccoon dogs in this study because there was no significant difference between seasons. The fractal dimensions of the movements appeared to be a reflection of the habitat complexity. The fractal dimension of the *yama* (mountain) habitat was higher than that of the *sato* (village) habitat, and the fractal dimensions of movement of the raccoon dogs of two habitat users showed a similar difference, in which the dimension of the mountain type (*yama* users) was higher than that of the village type (*sato* users). There could be two explanations for this, which are not mutually exclusive. First, the 'straightness' of *sato* habitat itself can create straight paths of the animals; when the animals move in or along straight, artificial gutters, (concrete) riverbanks and ditches, the fractal dimensions are identical to these of the structures. Second, the agricultural activities in the *sato* habitat give rise to more predictable, more evenly dispersed food items than in natural environments. Brownian-like wiggling movements to find food may not be optimal for animals living in an area with food that is temporally predictable, evenly distributed, in spatially predictable agglomerations, and/or superabundant.

The fractal dimensions of the raccoon dogs' movements ranged from 1.056 to 1.459, and there were overall differences between the highest and the lowest figures larger than 0.2 within some individuals. However, the fractal dimensions were similar for the first half and the second half on the same night, suggesting that the raccoon dogs did not change the fractal dimension much during a night, consistent with the idea that the fractal dimension is determined by local resource characteristics. However, small differences and changes in fractal dimension would have significant effects because fractal dimensions are exponent in scale (Milne, 1997). There is a question as to the extent to which animals can change the 'tortuosity' of their movements, or whether it is predetermined at the level of individual or species. There is evidence that age and sex can be influential. In female wolves (*Canis lupus signatus* Cabrera) significant differences in fractal dimension of movements were observed according to life stage, while males had a higher fractal dimension than non-breeding females (Bascompte and Vilà, 1997). The restricted mobility of females with pups was thought to have resulted in higher fractal dimensions. Variability in fractal dimensions within an individual or a species may also have significant importance for feeding ecology. Three species of beetle with

different body sizes showed similar fractal dimensions in their movements across different cover types and areas of different grazing intensity, whereas the net displacements were positively associated with body size (Crist *et al.*, 1992). In contrast, With *et al.* (1999) found that the fractal dimensions of the common cricket showed responded linearly to the abundance of grass. In addition, motile benthic organisms with different body lengths and feeding modes that were placed in graticules with food patches, exhibited a negative correlation of fractal dimensions of movement with body length (Schmid, 2000). Body size or length, i.e. an index of spatial perception of the animals as well as a determinant of the minimum stride, may have significant effects on distribution or density of animals in fractal environments (Morse *et al.*, 1985). Body mass may be important for temporal scales because it determines metabolic rate in general.

In the field, naturalists distinguish the tracks of raccoon dog from those of fox by their sinuosity: raccoon dog's tracks are more staggered whereas fox's tracks are more straight (Koyasu and Narukawa, 1993). Therefore, at least at the highest resolution (of strides), raccoon dogs naturally seem to have a higher fractal dimension of movement than foxes. Also, raccoon dogs are known to use well-used trails. These habits need to be investigated in conjunction with movement patterns to assess their ecological significance.

The raccoon dogs appeared to be able to change their fractal dimension of movements depending on the habitat complexity. If so, the fractal dimension of raccoon dogs' movements would be an indicator of the complexity of habitat use and habitat itself. As human activities might decrease habitat heterogeneity, and thus possibly degrade habitat quality in the long term not only for raccoon dogs, the habitat may become more vulnerable to environmental changes and less biologically diverse. Obtaining fractal dimensions of movement from radio-tracking data may offer new opportunities to gain insights into animals' behavioural ecology, in addition to home range analysis and habitat use.

Although the nightly home-range size of the two types of raccoon dogs was similar, the mountain type had larger home ranges on a 2-dimensional ranges on a plane in 3-dimensions because their home ranges were dominated by hills, whereas the village type mainly stayed in flat areas. A non-stop movement pattern, not yet confirmed, might be a factor in the mountain-type raccoon dogs' more complex movements with larger nightly home ranges

compared to the village type. If the village type needs to stop more often due to human disturbance or crossing open areas than the mountain type, they would have less complex movements and smaller nightly home ranges. These differences in movement between the habitat users warrant further detailed examinations related to movement patterns.

It was not clear whether Lévy flights-like movements exist for raccoon dogs because α values differed significantly from both 0.5 and 1.0. There was some evidence for Lévy-like movements the α values were significantly larger than 0.5, and characteristic long step lengths were frequently observed. If Lévy flights-like movements exist in the species, a possible explanation is that, if a fractal dimension of animal's movement is constrained, say, by the distribution of food resources or habitat complexity, Lévy flights-like movements may be a way to keep the home range size large enough to find mates or to include the required number of resting sites. Movements which consist of a majority of small steps with a few longer steps connecting ecological requirements can produce Lévy flights-like movements. In other words, Lévy flights may be the consequence of the animals' response to habitat structure, even without other advantages such as finding new places and successfully finding sparsely distributed food.

Yearlings disperse to find new places to live, although a few animals return to the natal ranges. Excursions by both yearlings and adults to other areas may be considered a large jump because the speed of these travels is usually faster than normal movements, such as foraging. However, I could not obtain fixes with exact intervals for these travels, because it was difficult to locate them under the field conditions with fast movements into new locations. It would be worth testing for Lévy flight in these movements.

4.4.3 Social aspects

Ikeda (1982, 1985, 1987) described the social system of the raccoon dog as a loose and primitive one (*sensu* in Canidae) with a high mutual tolerance towards conspecifics, and suggested a long-term pair bond in the species. Yachimori (1997) found the exclusive use of resting sites by family members was supported by their genetic relationship (analysed by DNA restriction fragment length polymorphism (RFLP)), but home ranges overlapped considerably among non-family individuals.

Core areas (50% MCP) of non-paired adults did not overlap whereas 95% MCP and

95% kernel estimates often overlapped in this study. Agonistic behaviour is rarely seen in the raccoon dog except during the mating season when some fights, although not severe, would take place (Izumi, 1982; Ikeda, 1991; Fukue, 1996). Although an atypical situation, I observed that two captive subadult males (4 - 5 months old) i, stayed close to each other from the first day of introduction into a cage (3 x 6 m; see photograph in p.3). They were both captured in the same area (in September) but were presumably unrelated because of their difference in fur colour and food preference. This indicates they can form a group readily without much antagonism. Stewart *et al.* (1997) proposed a hypothesis potentially accounting for this kind of system. The Passive Range Exclusion (PRE) hypothesis posits the formation of a 'ridge' in the food gradient near boundaries, and the shaping of home ranges without direct territory defence. Raccoon dogs meet at least three of five criteria for the formation of PRE: 1) group living in a restricted location, 2) foraging solitarily or in a pair, and 3) feeding on food that is not highly mobile and can be depleted within a foraging bout. The relatedness of neighbouring groups is not known.

Indeed, the raccoon dog is known to form large groups when they become accustomed to being fed every day (e.g. *Asahi Newspaper*, 1999a). This group formation may be strictly artificial with limited dispersal in most cases but it indicates the behavioural adaptability of this species. Creel and Macdonald (1995) described the conditions for group formation, i.e. tolerance to conspecifics, to evolve: 1) decreased cost in tolerance due to abundant food and constrained dispersal and 2) benefit of tolerance in ecological terms, e.g. hunting success, territorial defence and competition for food, decrease in predator risk, and gaining paternal care. Raccoon dogs appear to be able to tolerate conspecifics with only the condition of decreased cost of tolerance, without any detectable benefit. Although group forming in the raccoon dog has only been reported under conditions of abundant food at one location, different social interactions between intra- and inter-group members suggests coalition of group members, and thus the potential in this species to form social groups. This also indicates that the raccoon dogs do not just tolerate each other, but may possess social organisation.

Heterogeneity in resource dispersion is necessary to form a facultative group, i.e. more than a primary pair, under the RDH. However, as an opportunistic generalist, resources

for raccoon dogs may appear to be homogeneously distributed at scales relevant to the raccoon dog, in the sense that animals can utilise a wide range of alternative resources rather than being restricted to specific resource patches. For the raccoon dogs in the study area, temporal heterogeneity in resources would be an influential factor.

Raccoon dogs do not seem to have firm territoriality (Ikeda, 1982; Yachimori, 1997). So, why do raccoon dogs show a wide range of sociality, from solitary or a pair to large groups, without defending territories and co-operative foraging? This is not necessarily contradictory to the predictions of the RDH. Spatial heterogeneity of resources is probably larger in the *yama* (hills and valleys) habitat (Figure 4.3), where the mountain type animals mainly inhabit (Chapter 3), while temporal heterogeneity of resources is probably larger in the *sato* (rice fields and cropland) (Figure 2.6 in Chapter 3), where the village type animals mainly inhabit. This could result in overall similarity in group size of the mountain and village types. In addition, the heterogeneity may not be large enough to show group size difference between these types. However, home-range size on 3-dimensional area was larger in the mountain type than in the village type; the variability of home-range sizes was also larger in the mountain type. More dispersed and unpredictable food resources in the *yama* habitat were probably responsible for larger home ranges there. When food security is completely predictable, for example, regular feeding by people, or at garbage sites, group size will become larger according to the additional food, higher mean richness (Carr and Macdonald, 1986). For opportunistic generalists, like the raccoon dog, group size is sensitive to mean richness under conditions of high food security, whereas heterogeneity of the environment may not have a substantial influence on their group size. In addition, because of their high tolerance to conspecifics, raccoon dogs can have individual home ranges which have large overlaps, without forming a group. Further investigations on territoriality and ecological functions of latrines for this species are needed.

Raccoon dogs exhibit intensive male parental care (Okuzaki, 1979; Ikeda, 1983). In this study, a male spent more time at the den than did a female during the nursing period. This result was similar to that found from a study in Finland, in which 5 pairs of *N. p. ussuriensis* were tracked (Kauhala *et al.*, 1998a). The female usually emerged from the den first, while the male stayed with the young, suggesting a greater demand for food in the female due to the

energy required for recovery from pregnancy and lactation. However, there was no difference in time allocation between sexes at a nursing den between sexes in a pair in Kanazawa, Japan (Fukue, 1991). Ikeda (1983) observed some division of role in parental care in a pair under captivity; a female stayed closely to the young while a male guarded the nest box in the early days. Kauhala (1993) and Kauhala *et al* (1998a) noted the division of labour between parents: females' lactation and males' "babysitting," which may explain the male-biased time allocation at den. It is safe to conclude that male raccoon dogs spend at least an equivalent time attending young as females. In addition, it is worth noting that early pair formation, lasting pair bond, and synchronised movement of a pair throughout year ensure paternity more than mere monogamy.

The raccoon dog is a successful species in Japan and its introduced areas, and the key to its success lie at least partly in its behavioural ecology. However, successful species often conflict with humans and become victims as a consequence (Bekoff, 1995). Understanding behavioural ecology is the first step towards mitigating conflicts between humans and wildlife without wildlife species coming off worst.

ⁱ A definition of dimension can be extended from the Euclidean geometry to the broader concept (Mandelbrot, 1967): when a figure X is decomposed into a^k non-overlapping similar figures (e.g. line segments and rectangles) with a similarity ratio of $1/a$, the figure X 's dimension is k . This can be mathematically expressed as: when a figure X is composed of N similar figures with a similarity ratio of $1/a$, $k = \log_a N$. For example, when a straight line of 4 km is decomposed into 5 segments of 800 m with the similarity ratio of $1/5$, $k = \log_5 5 = 1$. Similarly, when a flat rectangular field of 4 km x 6 km is decomposed into 4 rectangles of 2 km x 3 km with the similarity ratio of $1/2$, $k = \log_2 4 = 2$. Furthermore, the N th order Koch's triadic island, i.e. a figure composed of 4 similar figures with the similarity ratio of $1/3$ at any places, has the dimension $k = \log_3 4 \cong 1.2618$. The k is called the fractal dimension (Mandelbrot, 1977, he called it a fractional dimension in 1967), which can be non-integer. Conversely speaking, a figure is fractal when it can be decomposed into self-similar (self-affine) figures in different scales.

ⁱⁱ In practice, fractal dimensions can be estimated in several ways (Sugihara and May, 1990; Kaye, 1994; Schmid, 2000). The Divider (also called segment, caliper or Richardson) method can be used for quasi-1 dimensional figures, e.g. curves and ragged lines. The Box (also called mosaic amalgamation, grid or Kolmogorov) method can be used for both quasi-1 dimensional and quasi-2 dimensional figures, e.g. habitat and distribution maps. Both method use the same algorithm:

$$N(\lambda) = \mu \lambda^{-k}$$

where N is the number of self-similar figures (perimeter estimates or number of boxes containing parts of a figure) with the length of λ (stride or side of box), μ is a positive constant and k is a fractal dimension.

ⁱⁱⁱ A random walk with infinite mean-squared step length $\langle R^2 \rangle$ creates the net displacement of steps $y(t) \equiv \sum_{i=1}^t u(i)$, where $u(t)$ is the time series. Then the root mean square fluctuation of the displacement (from the expected) is $R^2(t) \equiv (\langle (\Delta y(t))^2 \rangle - \langle \Delta y(t) \rangle^2)^{1/2}$, where $y(t) \equiv y(t_0 + t) -$

$y(t_0)$. The measurements of time-dependent relationships are required for it to be meaningful as:

$$\langle R^2(t) \rangle \cong t^{\lambda/2} \quad (t \leftarrow \infty)$$

because without the time-dependence, it will be always $\langle R^2 \rangle = \infty$ (Shlesinger *et al.*, 1993). It is expected from the central limit theorem that $\alpha = \gamma/2 = 0.5$ as $\gamma = 1$ due to a Brownian motion under a Gaussian distribution. However, it can be $\gamma = 2$ as Ballistic motion under a perfect long-range power law. It also can be $\gamma = 3$ in an open system with energy that flows into it (Shlesinger *et al.*, 1993), but it is not considered with terrestrial mammals, although there might be a possibility to employ such a system in movements of aquatic organisms that inhabit current or whirl water.

^{iv} The fixed kernel distribution can be calculated as follows:

when $\mathbf{X}_1 = [X_1^{(1)}, X_1^{(2)}]'$, $\mathbf{X}_2 = [X_2^{(1)}, X_2^{(2)}]'$, ..., $\mathbf{X}_n = [X_n^{(1)}, X_n^{(2)}]'$ is a random sample of n points, estimated probability density function of fixed kernel estimator is:

$$f_h(\mathbf{x}) = 1/nh^2 \sum K[(\mathbf{x}-\mathbf{X}_i)/h],$$

where the kernel K is a unimodal symmetrical bivariate probability function, of which volume under the curve integrates to 1, and h is the smoothing factor, a bandwidth (Worton, 1989; Seaman and Powell, 1996).

^v See note in Chapter 3 (page 71).

CHAPTER 5

**COMPARISONS BETWEEN THE RACCOON DOG
IN JAPAN AND THE BADGER IN THE UK**

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Summary

Habitat ecology and movements of raccoon dogs in Japan and badgers in the UK were compared. In general, badgers preferred pasture and avoided arable habitat, but showed some variability with year and scale of selection. A Badger Removal Operation may have influenced habitat selection of the badgers. Mean home range size of badgers (n = 28) was 56 ha for both 95% kernel estimates and 95% MCP. Unlike raccoon dogs, there was a significant difference in home-range size between sexes, but not between age classes. The mean fractal dimension of the badgers' movements was 1.1977 ± 0.0184 (n = 7) and was significantly different from a straight line or a Brownian random movement. Raccoon dogs and badgers showed similarities in movements, such as nightly home-range size, range span and fractal dimension of movements, while home-range size and mean interfix speed were significantly greater in raccoon dogs. Although populations in the same area were not studied, similarities in spatial use and movements of the two species indicate that a niche overlap may be considerable between species where sympatric populations occur, such as the study area in Japan. Lastly, similarities and differences between species are discussed in relation to management applications.

Chapter 5 Comparisons between the Raccoon dog in Japan and the Badger in the UK

5.1 INTRODUCTION

In Japan, people often consider badgers (*Meles meles* Linnaeus) and raccoon dogs (*Nyctereutes procyonoides* Gray) to be the same species (Chapter 1). The two species can, in one sense, be treated as an ecological group because they share some ecological similarities, and conservation and management practices may be administered together where the species sympatrically occur. In order for this to happen, similarities and differences in ecology, such as habitat requirements and social aspects, need to be clarified through comparative study.

A subspecies of the Eurasian badger (*M. m. anakuma* Temminck) inhabits Japan sympatrically with raccoon dogs, and so is in the study area. However, only a small number of ecological studies on badgers have been conducted in Japan (Itoh, 1992; Yamamoto, 1995; Tanaka, 2000; Kaneko, 2001), whereas studies have been conducted in many parts of Europe, especially in the UK. Because of the scale of this study, I did not collect data on the badgers. Instead, I used radio-tracking data in the UK to obtain basic information in habitat ecology, home ranges, and movements of badgers.

The raccoon dog is a canid, and the Eurasian badger is a mustelid. Both species are basically nocturnal and omnivorous, feed on relatively small prey, such as invertebrates and fruits, and do not hunt co-operatively (Ciampalini and Lovari, 1985; Lüps *et al.*, 1987; Roper and Lüps, 1995; Neal and Cheeseman, 1996). Although the English badger is around twice as heavy as the raccoon dog in Japan (7 - 11 kg; Neal and Cheeseman, 1996) and has a longer body (head-body length: about 700 - 900 mm; Neal and Cheeseman, 1996) than that of raccoon dogs (about 600 mm in this study), both have short legs and walk close to the ground (Kruuk, 1989; M. Saeki, pers. obs.). Their reproductive physiology differs in that raccoon dogs show spontaneous ovulation once a year (Yoshioka *et al.*, 1990), while badgers show delayed implantation (Neal and Harrison, 1958). Badgers' mating is observed throughout the year with a spring peak in Britain (Page *et al.*, 1994; Neal and Cheeseman, 1996). Badgers exhibit sexual dimorphism in size, unlike raccoon dogs. Nonetheless, there are some similarities in their ecology. The two species are comparable in feeding ecology and possibly in their niche despite of the differences in their physiology and phylogeny.

Food habits of badgers have been studied in many places, including France (Henry, 1984), Scotland (Kruuk and Parish, 1985), Switzerland (Lups *et al.*, 1987; Roper and Lüps, 1995), the Mediterranean region (Ciampalini and Lovari, 1985; Martin *et al.*, 1995), England (Shepherdson *et al.*, 1990), Japan (Yamamoto, 1994), Hungary (Lanszki *et al.*, 1999), Poland (Goszcynski *et al.*, 2000) and in Russia (Roper and Mickevicius, 1995 for a review). Although badgers may specialise on some prey items, such as earthworms (Kruuk and Parish, 1985), olives (Kruuk and de Kock, 1981) or wheat (Shepherdson *et al.*, 1990), Shepherdson *et al.* (1990) and Roper (1994) argue that badgers are opportunistic or generalist foragers with an adaptive ability of specialisation.

Tuytens (1999) found that the home-range size of the badgers varied greatly according to individual, season, sex, and year in North Nibley, UK, with significantly larger home ranges in June-August than in October, in males compared to females, and in 1995 (the year a 'Badger Removal Operation' (BRO) (details in section 5.2) was conducted in the area) than in 1997. He also found that the social group ranges were expanded for those which were not immediately adjacent to removed groups by the BRO, suggesting complex mechanisms that might operate for social organisation in badgers.

In this chapter, I compare habitat selection, spatial use, and nightly movements between raccoon dogs in Japan and badgers in the UK. This chapter has six objectives:

- to ascertain habitat use of badgers
- to assess habitat preference at different scales for badgers
- to compare habitat selection between raccoon dogs (Chapter 3) and the badgers
- to estimate home range and utilisation distribution to investigate spatial use by the badgers
- to examine movement patterns of badgers
- and to compare movements between raccoon dogs (Chapter 4) and the badgers.

5.2 METHODS

Radio-tracking data from a study of badgers at one site in the UK were used for analyses (Tuytens 1999). Details of methods of collection of these data are given in Tuytens (1999).

Study area

The study area (16.6 km²) was located in North Nibley (2° 22'W, 51° 39'N) in Gloucestershire, approximately 80 km west of Oxford, UK. The average annual maximum and minimum temperatures were 13.7°C and 6.3°C, respectively; the average annual precipitation was 717 mm (at the Cheltenham weather station, 1961-1990, data from the Meteorological Office).

The UK Ministry of Agriculture, Fisheries and Food (MAFF) conducted BROs following positive tests for bovine tuberculosis (TB), caused by the bacillus (*Mycobacterium bovis*), in cattle (Krebs *et al.*, 1997; MAFF, 2001). In September 1995, a BRO was conducted in the study area due to two TB positive cows being found during routine intradermal skin testing in January 1995. Eighteen badgers with a positive ELISA test or from ELISA-positive setts were killed during the BRO in 1995 (Tuytens, 1999). Social groups were determined by bait-marking in early spring. The social groups of badgers were classified as: 1) groups that were removed during a BRO (=removed), 2) groups that bordered the removed groups (=neighbouring), and 3) groups that were separated from the removed groups by at least one social group (=other)(Table 5.2).

Data analyses

Radio-tracking data of 36 badgers in 1995, 1996 and 1997 were analysed using methods equivalent to those conducted on raccoon dog data in Chapters 3 and 4.

Continuous tracking data from 32 animals were selected for habitat analysis. Thirteen habitat types were identified (Figure 5.1) and grouped into 7 categories (Table 5.1) for the compositional analysis (Aebischer *et al.*, 1993). Habitat preference was obtained by year, due to an insufficient sample size in the spring, and no winter data. For this analysis, the number of animals has to be equal or greater than the number of habitat categories (Aebischer *et al.*, 1993). Most fixes were obtained in summer and autumn.

For yearly home-range estimates, I used 47 home ranges from 33 individuals. Home-range size and range span were compared between age classes, sexes and years.

Maximum convex polygon and maximum range span were logarithmically transformed for normality (Kolmogorov-Smirnov Z test, both $p > 0.15$) before conducting an analysis of variance (ANOVA).

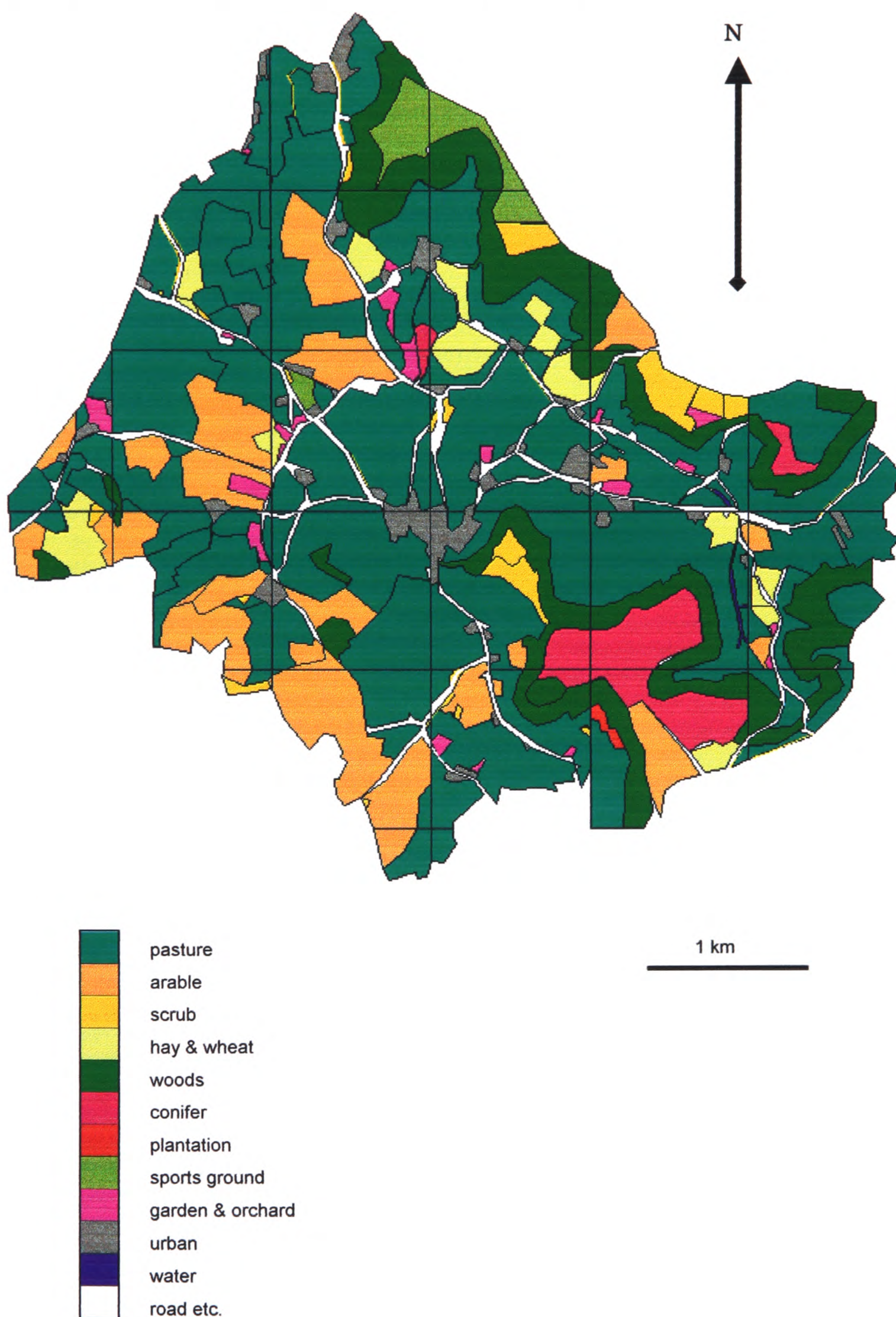
Nightly movements were analysed for 464 nights from 36 animals. Mean inter-fix speed, 100% MCP, and maximum range span were logarithmically transformed. Fractal dimensions and Lévy Flights were estimated for 7 animals (9 nights) that had sufficient fixes with intervals of 14 to 16 minutes. The fractal dimension and α values were normally distributed (Kolmogorov-Smirnov Z test, both $p > 0.15$). Total daily rainfall was coded from 1 to 4 (1: <1 ; 2: 1-3 ; 3: 3-10; 4: >10 mm), and the effects of rainfall on nightly movements were examined. A weighted General Linear Model (GLM) was conducted for above analyses, using SAS (SAS Institute, Inc. 1989-1996) to weight sample-size difference between individuals (i.e. number of nights).

A weighted GLM was also used for comparisons between raccoon dogs and badgers.

Table 5.1 Habitat types and categories for the badgers.

Habitat Types	Habitat Category
pasture	pasture
woods	woods
arable	
wheat & hay	arable
plantation	
conifer	conifer
scrub	scrub
urban	
road	urban
sport	
garden	other
orchard	
water	

Figure 5.1 Habitat map for the badger in North Nibley, UK.



5.3 RESULTS

Radio-tracking data from 36 badgers (21 females and 15 males) were used. Individuals used for analysis are listed in Table 5.2.

Table 5.2. Badgers used for analysis.

ID	Sex	1995	1996	1997	Group
3	female			subadult	2
6	female			subadult	1
8	female			adult	2
9	female			adult	1
11	female		adult	adult	3
12	female	(adult)			1
13	female	adult			1
14	male			(subadult)	3
16	female		(adult)		3
18	female		adult	adult	2
20	male		(adult)		3
22	female		adult	adult	1
23	female	adult	adult		2
26	female	adult	adult	adult	2
30	female		adult	adult	2
31	male	adult			2
33	male	adult			2
34	female	adult			1
36	male		subadult	adult	3
37	male		(subadult)	adult	2
38	male		subadult	adult	3
39	male			adult	2
44	male			subadult	2
52	male		subadult		2
54	male	adult			3
55	female	adult	adult		3
56	female	adult	adult		2
61	male	adult			1
62	female	adult	adult		2
67	female		subadult		1
70	female		subadult		2
126	female			adult	2
131	male		adult	adult	2
138	male			subadult	2
160	male	adult			1
162	female	adult	adult		2

Data used are indicated with age class shown by year, and the parentheses indicate animals only used for nightly movement analysis because of the small number of continuous fixes. Group: removed = 1, neighbour = 2, other = 3 in BRO (see detail in the description of the study area.)

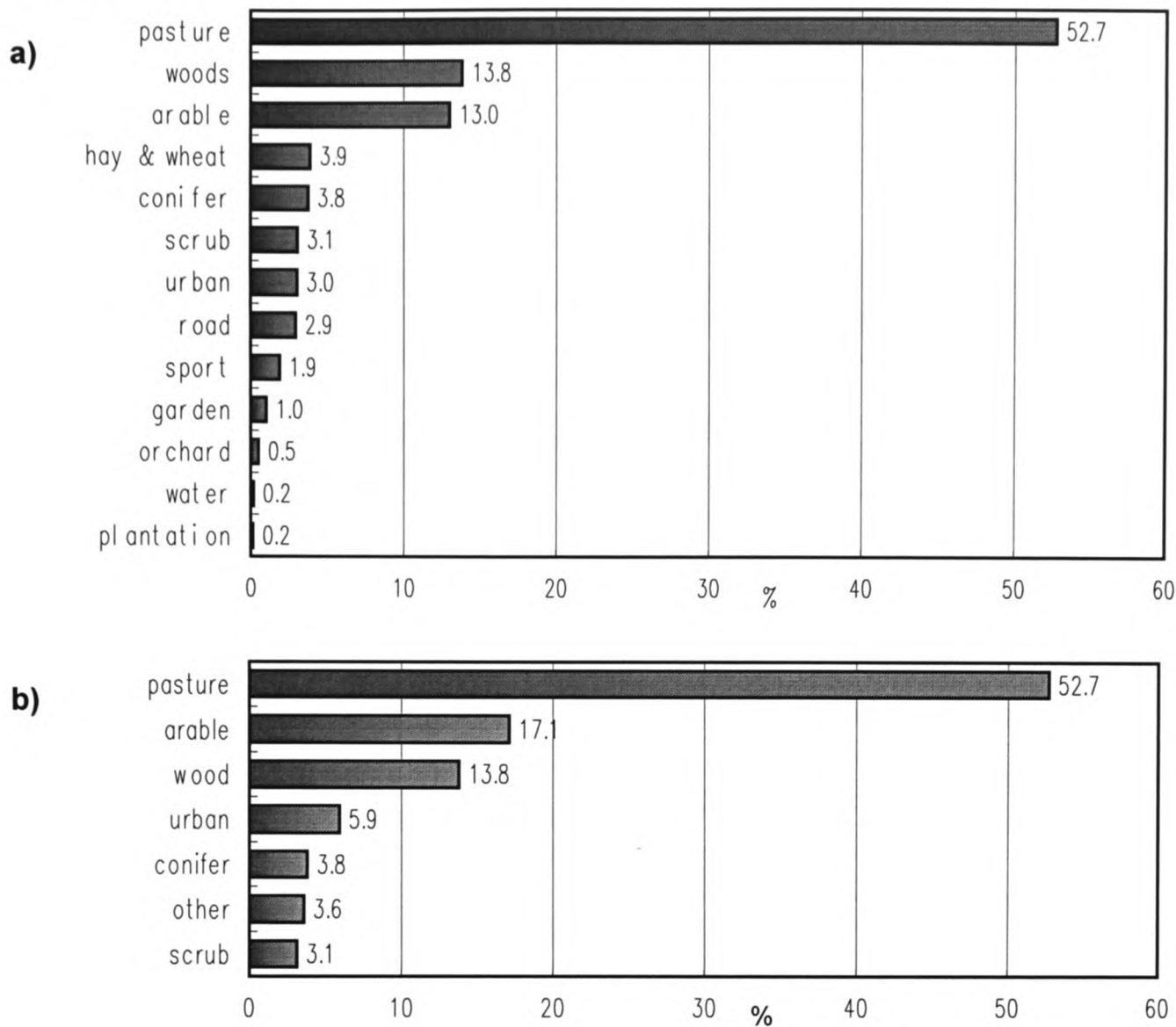
5.3.1 Habitat ecology of badgers

Forty-seven yearly home ranges of 32 animals were used for habitat analysis (individuals without parenthesis in Table 5.2).

5.3.1.1 Habitat Availability

Figure 5.2 shows percent composition of habitat types in the habitat map (Figure 5.1) and percent composition of the habitat categories (Table 5.1). Pasture comprises more than a half of the area.

Figure 5.2 Habitat composition of (a) habitat types in the habitat map and (b) habitat categories for analysis.



5.3.1.2 Habitat Use and Selection of Badgers

Figure 5.3 shows habitat selection for home range (the second-order selection) of the badgers by year. In 1995, the badgers had more pasture and less arable land in their home ranges than expected. In 1996, in contrast, there was no preference shown for any habitat category within their home ranges. In 1997, the badgers showed a strong preference only for pasture. In contrast, location selection in their home ranges (the third-order selection) indicated that the badgers showed a strong preference for pasture in 1996, whereas there was no apparent preference in 1997 (Figure 5.4). In other words, habitat preference was only consistent at both scales in 1995. In 1995, the badgers appeared to favour pasture in the third-order selection, i.e. locations in home range, whilst in 1997, the badgers showed favour for pasture in the second-order selection, i.e. home-range selection in the area. Habitat preference by year for fixes in the total area was consistent with the preference for pasture (Figure 5.5).

Figure 5.3 Preference index for home range selection of the badgers. (This is the preference in the second-order selection, i.e. home range compared to the total area.)

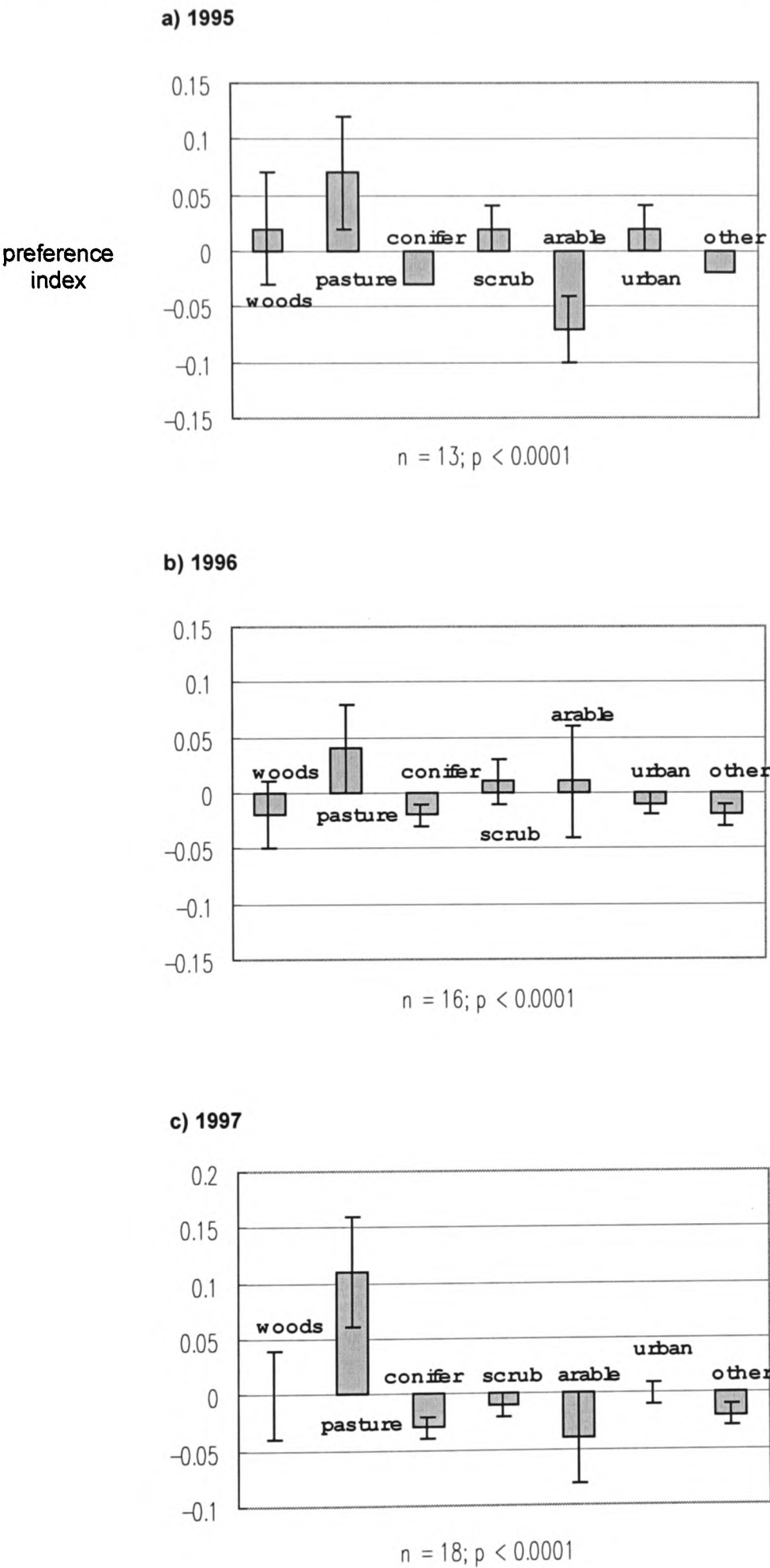


Figure 5.4 Preference index of habitat selection of the badgers. (This is the preference in the third-order selection, i.e. what habitat id used within a home range.)

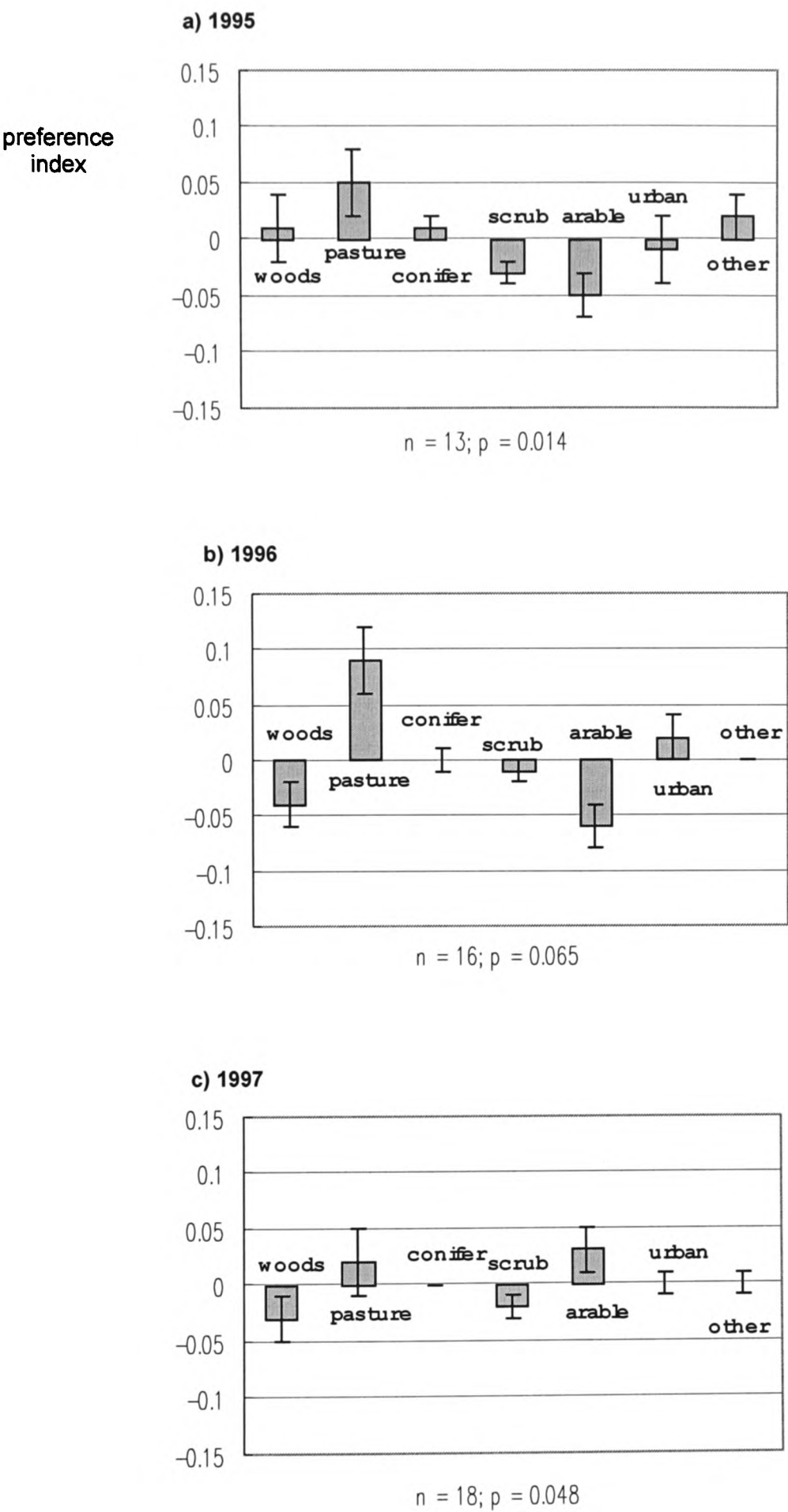
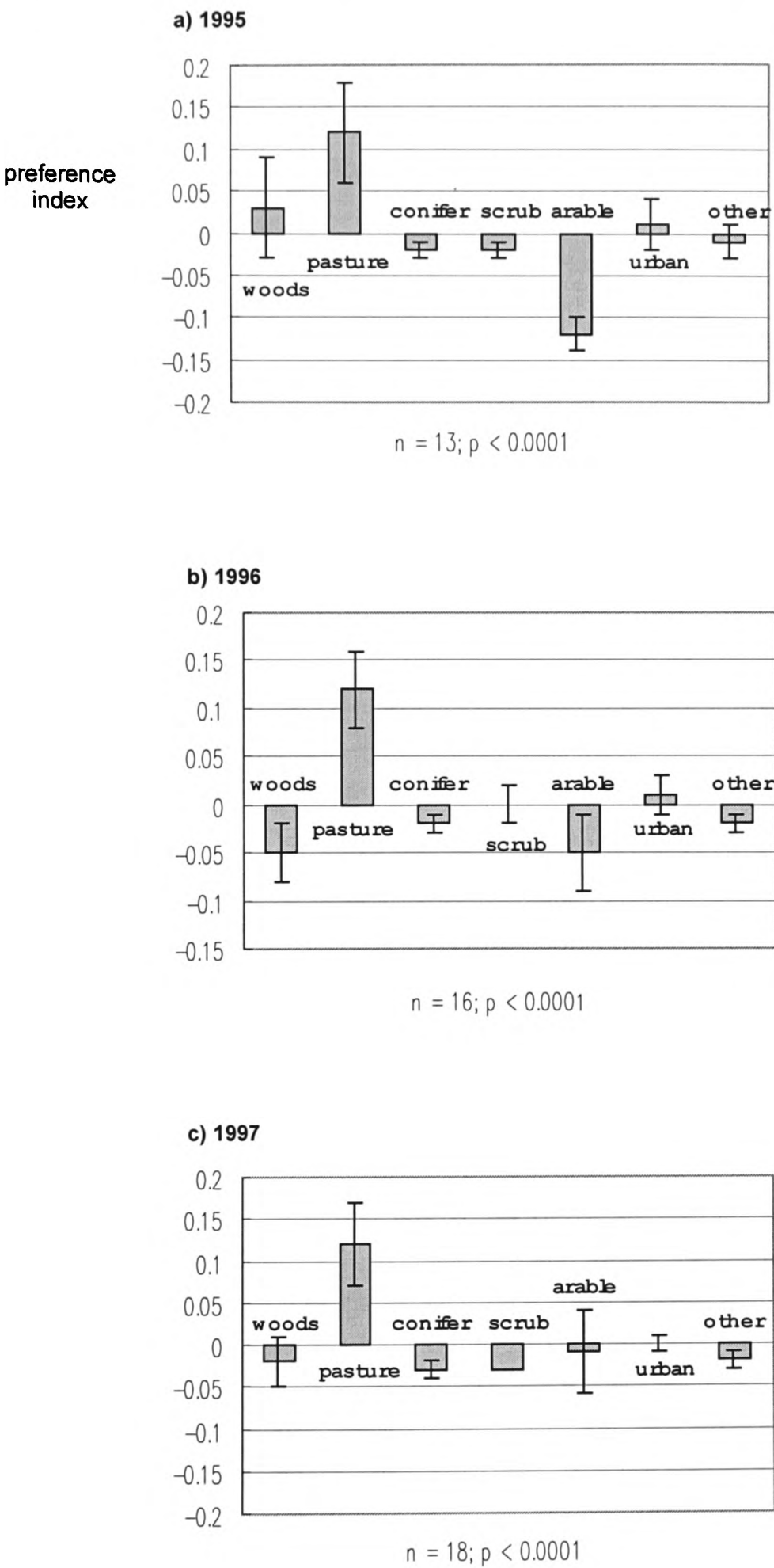


Figure 5.5 Preference index for fixes in the area of the badgers. (This is the preference, comparing the locations to what is available in the total area.)



5.3.2 Home range of badgers

Home-range sizes using 95% fixes were consistent for both estimates, but 100% kernel estimates were larger than 100% MCP (Table 5.3). Male badgers in 1995 had larger home ranges than females and males in other years (Figure 5.6). There were significant differences in yearly home-range sizes (95% kernel estimates) between individuals and sexes, but not between age classes (Table 5.5).

Table 5.3 Mean home-range size of the badgers by sex and age class.

	n	95% MCP	100% MCP	95% Kernel	100% Kernel
Total	28	56.1±7.73	67.5±8.61	56.2±7.25	93.5±12.8
Adult	21	56.9±9.53	69.4±10.6	53.9±9.47	87.5±14.9
Yearling	7	53.6±12.8	61.9±14.2	61.2±11.0	106.1±24.9
Male	11	66.9±15.1	78.3±16.4	67.6±13.9	122.6±26.0
Female	17	49.0±8.09	60.5±9.46	48.8±7.6	74.6±11.1

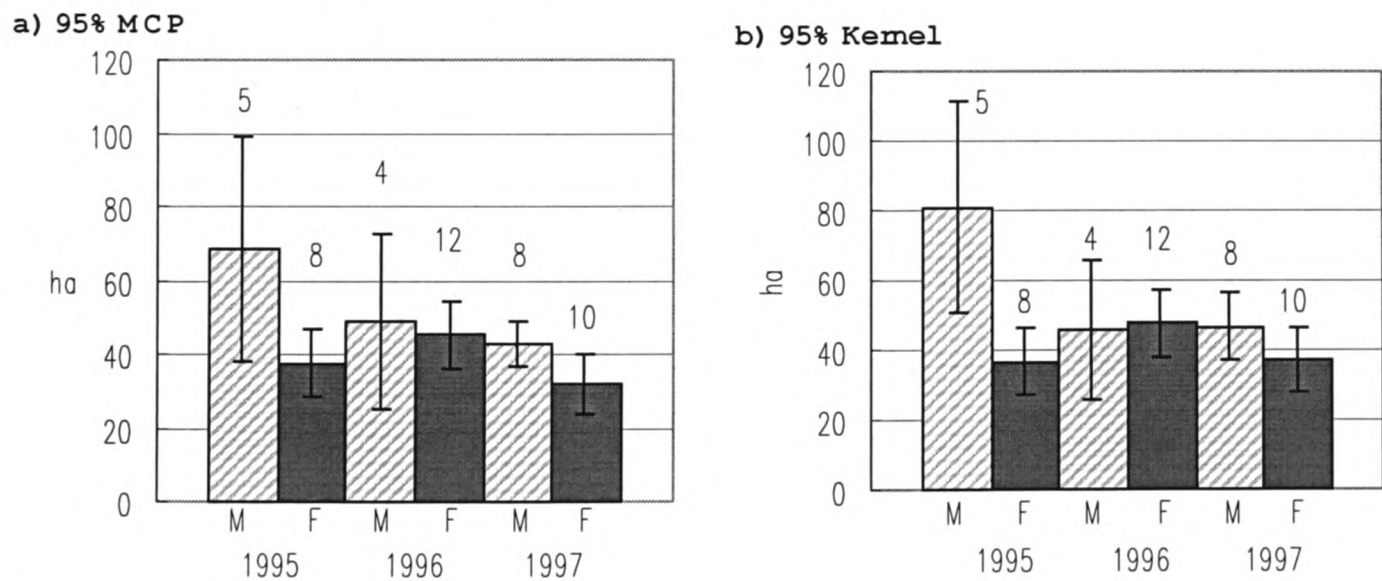
MCP is estimated by a maximum convex polygon method; Kernel is estimated by fixed kernel distribution estimators. Units are hectares ± SE; n is sample size.

Table 5.4 Mean yearly home-range size of the badgers by year, sex and age class.

	n	95% MCP	95% Kernel
Total	47	46.8±5.32	43.44±5.02
1995	13	53.8±13.8	49.4±12.9
1996	16	47.2±8.49	46.0±8.79
1997	18	41.3±6.56	36.9±5.29
Male	17	56.5±10.9	51.7±10.4
Female	30	41.2±5.48	38.7±5.17
Adult	36	47.6±6.42	43.4±5.93
Yearling	11	44.9±9.14	43.4±9.57

MCP is estimated by a maximum convex polygon method; Kernel is estimated by fixed kernel distribution estimators. Units are hectares ± SE; n is sample size.

Figure 5.6 Home-range size by year and sex.



The number is sample size.

Table 5.5 General Linear Models Procedure for 95% kernel estimates of the badgers.

Source	DF	Sum of Square	Mean Square	F	p
Model	34	4.63567	0.13634	4.03	0.0065
Error	12	0.40555	0.03380		
Corrected Total	46				
Type I					
ID	31	4.38475	0.14144	4.19	0.0058
Sex	1	0.22882	0.22885	6.77	0.0231
Age	1	0.01960	0.01960	0.58	0.4610
Type III					
ID	31	4.39739	0.14658	4.34	0.0050
Sex	1	0.33637	0.33637	9.95	0.0083
Age	1	0.01960	0.01960	0.58	0.4610

Figure 5.7 shows utilisation distributions of 6 animals, for which sufficient fixes (>100 fixes of continuous sessions) were obtained over two years for analysis. All showed relatively stable configuration except badger 62, whose utilisation distribution shrank in the following year, and badgers 11 and 162, whose utilisation distributions slightly expanded in the following year.

Figure 5.7 Utilisation distribution (50%, 95% and 100% kernel estimates) of 6 badgers tracked for two years. Legend: ID and year, followed by 95% kernel estimate in parenthesis, number of fixes, age class, sex, and group regarding to a BRO in 1995 (2 = neighbour; 3 = other).

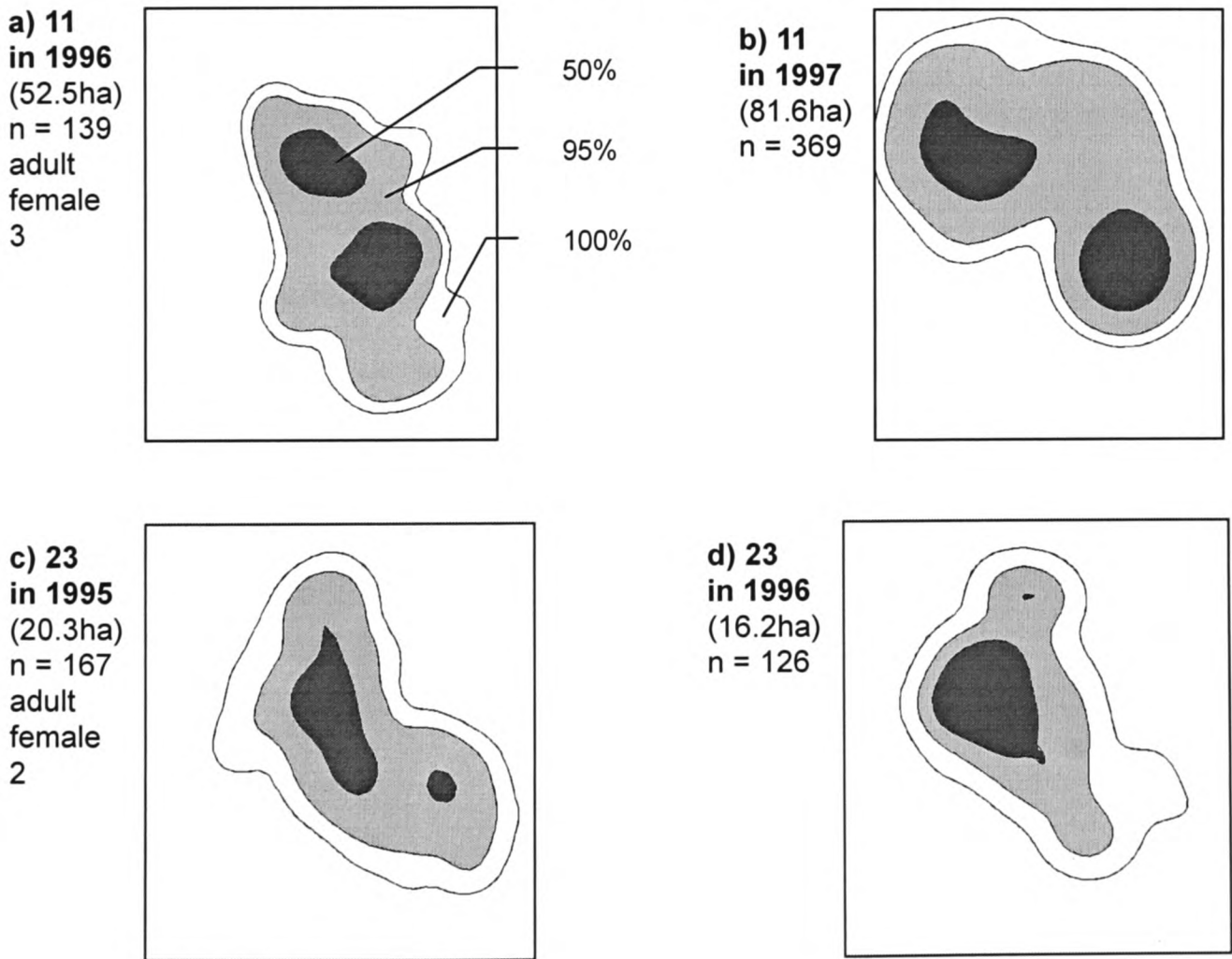
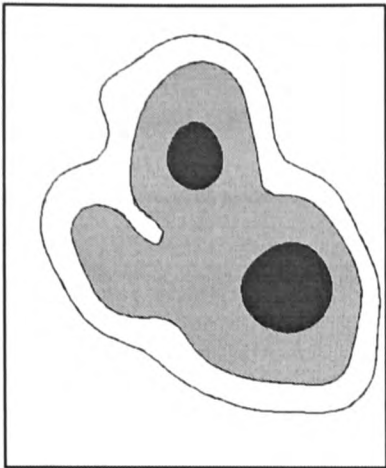
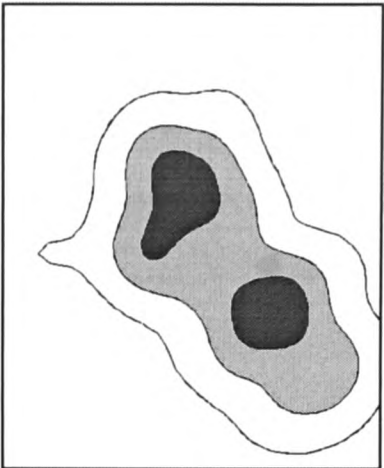


Figure 5.7 continued.

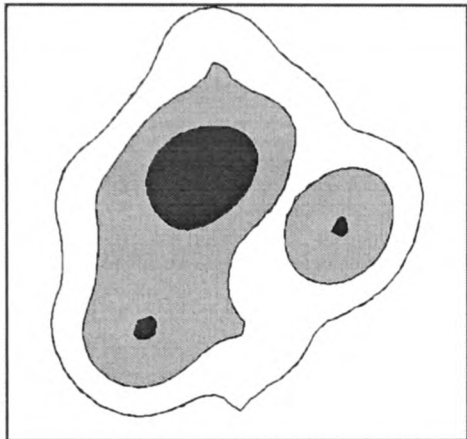
e) 55
in 1995
(74.6ha)
n = 188
adult
female
3



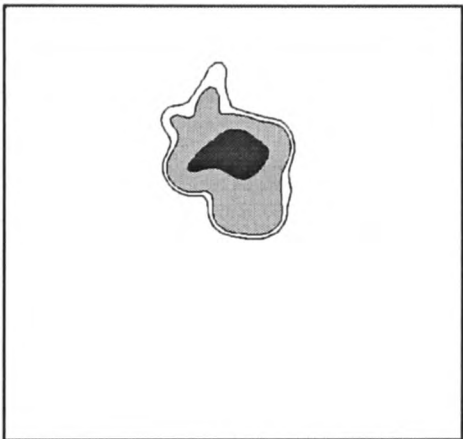
f) 55
in 1996
(51.5ha)
n = 392



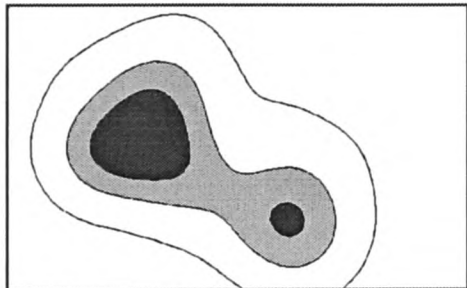
g) 62
in 1995
(81.7ha)
n = 256
adult
female
2



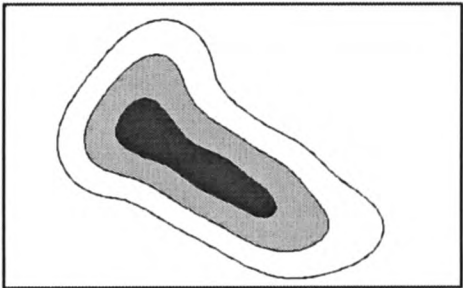
h) 62
in 1996
(18.2ha)
n = 135



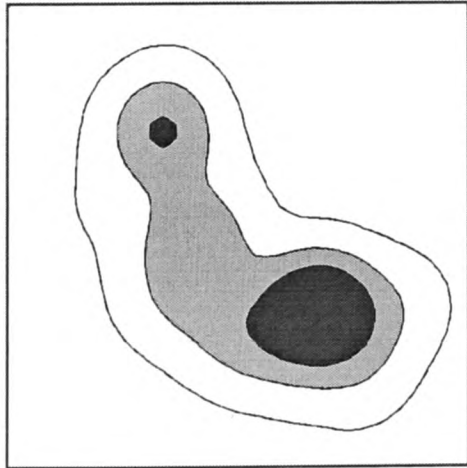
i) 131
in 1996
(21.1ha)
n = 425
adult
male
2



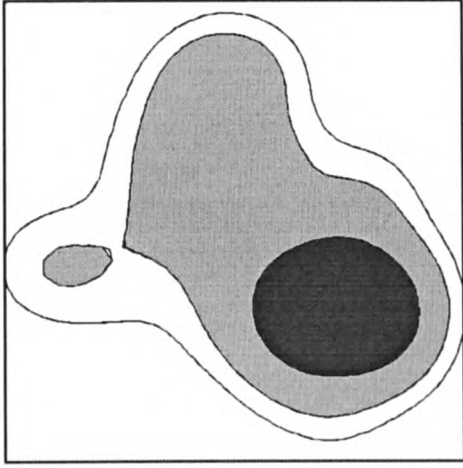
j) 131
in 1997
(18.9)
n = 203



k) 162
in 1995
(15.8ha)
n = 188
adult
female
2



l) 162
in 1996
(30.3ha)
n = 139



5.3.3 Movements

5.3.2.1 Interfix Movements of Badgers

Individual interfix speed ranged from 1.98 to 10.2 m/min, and maximum interfix speed recorded was 103.1 m/min. There was a significant difference in interfix speed between individuals (one-way ANOVA; $F_{33,7064} = 11.89$, $p < 0.0001$).

5.3.2.2 Nightly Movements of Badgers

Nightly movements, i.e. mean interfix speed, nightly home range (100% MCP), and range span for a night, were obtained for 35 animals and 466 nights. Average of nightly mean interfix speed of the badgers was $5.8 \text{ m/min} \pm 0.12$; mean nightly home range was $13.0 \text{ ha} \pm 0.57$; and mean range span was $626.90 \text{ m} \pm 12.6$. All three variables of nightly movements significantly differed between individuals, but not between sex, age classes, and years (Table 5.6).

Table 5.6 General Linear Models for nightly movements of the badgers.

Source	DF	Type III Sum of Square	Mean Square	F	p
mean interfix speed					
ID	34	5.57632192	0.16400947	2.13	0.0164
YEAR	2	0.04189237	0.02094619	0.27	0.7640
AGE	1	0.00408938	0.00408938	0.05	0.8194
SEX	1	0.02340603	0.02340603	0.27	0.6053
ID*YEAR	10	0.29492171	0.02949217	0.38	0.9456
SEX*AGE	1	0.00461078	0.00461078	0.02	0.9017
ID*AGE	1	0.01768336	0.01768336	0.23	0.6353
ID*AGE(SEX)	2	0.02304673	0.01152336	0.13	0.8745
mean 100% MCP					
ID	34	19.47973064	0.57293325	2.14	0.0154
YEAR	2	0.74972813	0.37486406	1.40	0.2603
AGE	1	0.00883291	0.00883291	0.03	0.8569
SEX	1	0.09318314	0.09318314	0.31	0.5798
ID*YEAR	10	4.02901743	0.40290174	1.51	0.1807
SEX*AGE	1	0.00368302	0.00368302	0.04	0.8372
ID*AGE	1	0.00040709	0.00040709	0.00	0.9691
ID*AGE(SEX)	2	0.04340076	0.02170038	0.07	0.9295
mean range span					
ID	34	7.25301792	0.21332406	1.90	0.0343
YEAR	2	0.32451321	0.16225660	1.44	0.2506
AGE	1	0.00402600	0.00402600	0.04	0.8511
SEX	1	0.03744782	0.03744782	0.34	0.5629
ID*YEAR	10	1.12041896	0.11204190	1.00	0.4659
SEX*AGE	1	0.00413967	0.00413967	0.04	0.8470
ID*AGE	1	0.00895962	0.00895962	0.08	0.7795
ID*AGE(SEX)	2	0.00977300	0.00977300	0.04	0.9562

5.3.2.2 Effects of Rainfall on Nightly Movements

Rainfall had no significant effect on mean interfix speed, nightly home-range size, or range span for a night, but individual differences were significant for all three variables, and there were significant differences between years in nightly home range and range span (Table 5.7). These suggested that daily rainfall did not affect nightly movements, while individual and yearly differences were apparent on their movements. Because of the presence of substantial individual differences, rainfall might have affected differently on individual movements.

Table 5.7 General Linear Models for effects of rainfall on movements of badgers.

Source	DF	Type I Sum of Square	Mean Square	F	p
mean interfix speed					
ID	34	5.81886801	0.17114318	4.52	0.0001
YEAR	2	0.06706693	0.03353347	0.88	0.4145
RAIN	3	0.06529871	0.02176624	0.57	0.6326
ID*YEAR	13	0.40574389	0.03121107	0.82	0.6349
ID*RAIN	49	1.17336756	0.02394628	0.63	0.9706
YEAR*RAIN	6	0.19161411	0.03193568	0.84	0.5384
ID*YEAR*RAIN	8	0.08705823	0.01088228	0.29	0.9697
mean 100% MCP					
ID	34	22.67558688	0.66692903	8.11	0.0001
YEAR	2	1.26684274	0.63342137	7.70	0.0006
RAIN	3	0.27578925	0.09192975	1.12	0.3430
ID*YEAR	13	4.23288496	0.32560654	3.96	0.0001
ID*RAIN	49	3.81563388	0.07787008	0.95	0.5772
YEAR*RAIN	6	0.74200013	0.12366669	1.50	0.1787
ID*YEAR*RAIN	8	0.40872797	0.05109100	0.62	0.7595
mean range span					
ID	34	8.06385612	0.23717224	7.47	0.0001
YEAR	2	0.39509244	0.19754622	6.22	0.0024
RAIN	3	0.08997933	0.02999311	0.94	0.4200
ID*YEAR	13	1.26893893	0.09761069	3.08	0.0004
ID*RAIN	49	1.32651678	0.02707177	0.85	0.7411
YEAR*RAIN	6	0.21643035	0.03607173	1.14	0.3426
ID*YEAR*RAIN	8	0.29273991	0.03659249	1.15	0.3299

5.3.2.4 Fractal Dimension and Lévy Flight

The mean fractal dimension of the badgers' movement was 1.1977 ± 0.0184 ($n = 7$) and was significantly different from 1.0, i.e. a straight line, and 2.0, i.e. Brownian-like movement throughout a plane (t-test, $T = 10.76$, $p < 0.0001$ and $T = -43.69$, $p < 0.0001$, respectively). There was no significant difference between individuals in the fractal dimension.

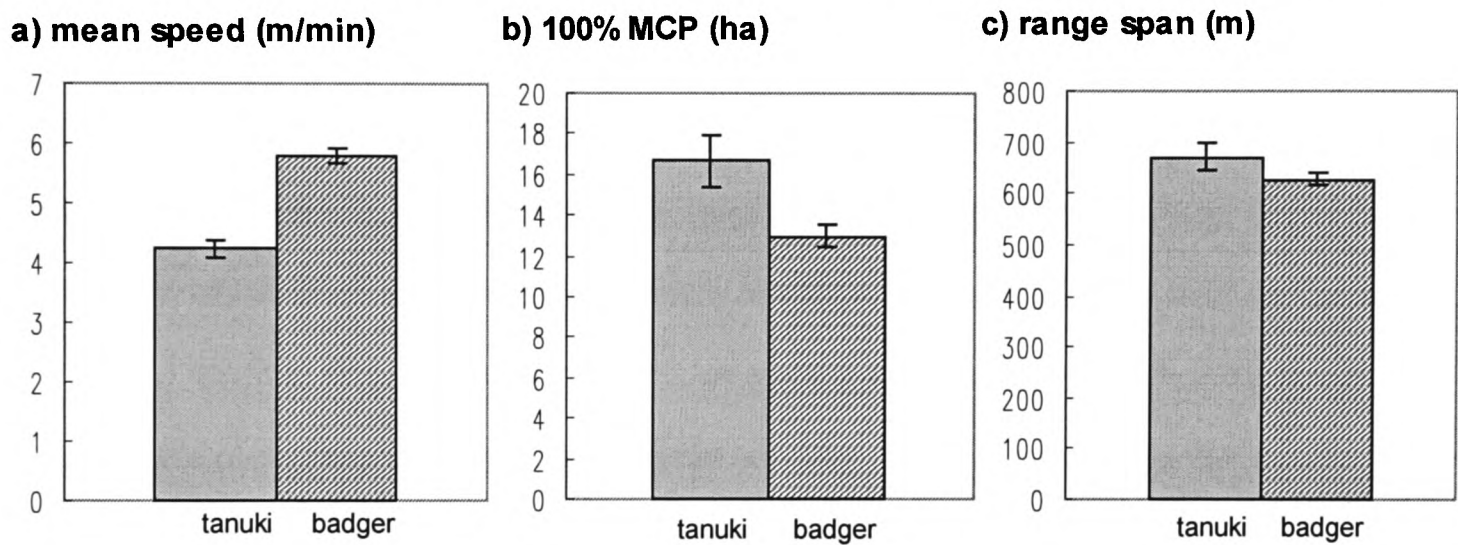
The mean α value for Lévy Flight power-law was 0.4867 ± 0.0374 ($n = 9$) and did not differ significantly from 0.5 (t-test, $T = -0.36$, $p = 0.730$), suggesting that long-range power-law correlations do not exist for the overall data. There was no significant difference in the Lévy's α between individuals.

5.3.2.5 Comparisons between Raccoon dogs and Badgers

Home-range size in whole tracked periods was significantly larger for raccoon dogs than badgers (one-way ANOVA; $F_{1,44} = 5.85$, $p = 0.020$ for 95% MCP, $F_{1,44} = 5.51$, $p = 0.023$ for 95% kernel estimate).

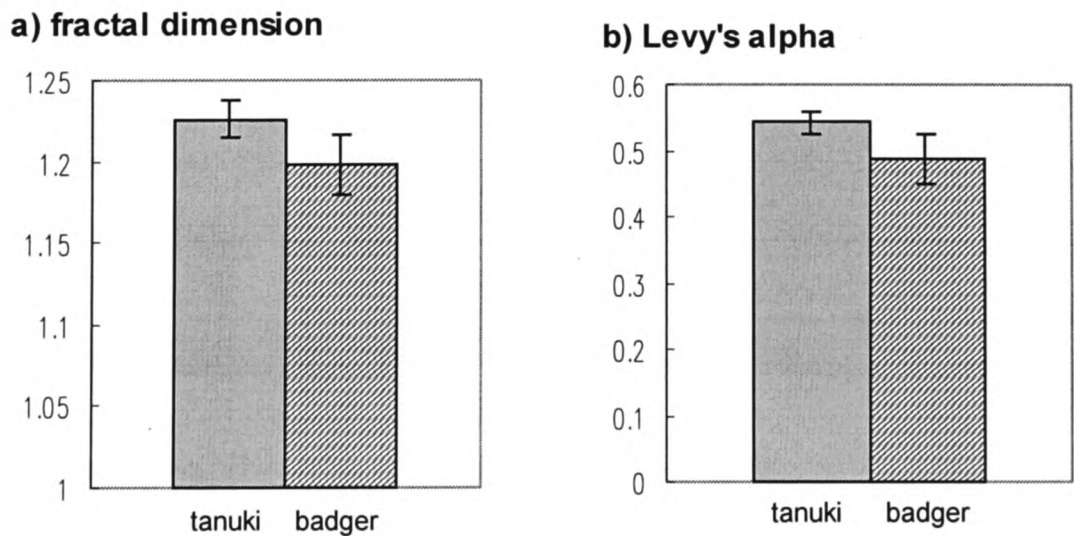
Mean interfix speed for a night was significantly faster for badgers than raccoon dogs (GLM, $F_{1,51} = 42.04$, $p < 0.0001$; Figure 5.8a), whereas 100% MCP and maximum range span for a night did not differ significantly between the species (GLM, $F_{1,51} = 0.04$, $p = 0.8502$ and $F_{1,51} = 0.00$, $p = 0.9858$, respectively; Figure 5.8b and c).

Figure 5.8 Comparisons of nightly movements between raccoon dogs and badgers.



Both fractal dimensions and α values did not differ between raccoon dogs and badgers (GLM, $F_{1,14} = 0.34$, $p = 0.5687$ and $F_{1,18} = 0.79$, $p = 0.3848$, respectively; Figure 5.9).

Figure 5.9 Comparisons of fractal dimension and Lévy Flight α between raccoon dogs and badgers.

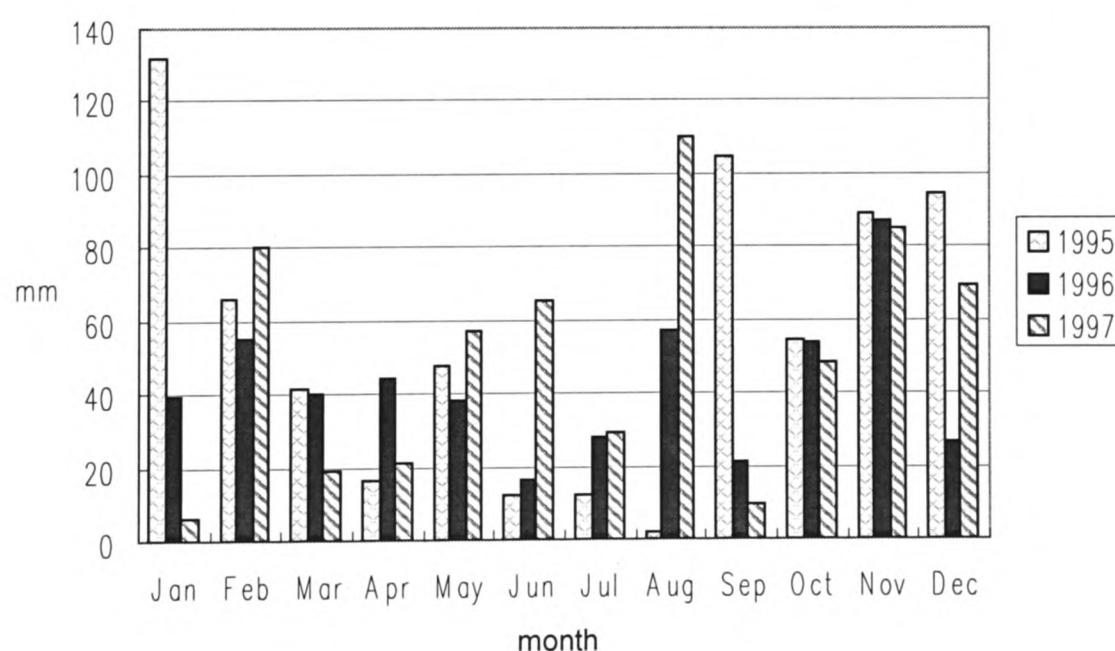


5.4 DISCUSSION

5.4.1 Habitat selection

In general, badgers preferred pasture and avoided arable habitat. Pasture was the most abundant habitat type in the study area and was still preferred. However, the badgers exhibited a different pattern in home-range selection in 1996, a year after a BRO in 1995, showing no preference for any habitat category (Figure 4.7b). The BRO in 1995 could have disturbed group territoriality, and consequently their stable social organisation, even though badgers still showed a preference for pasture and avoidance of arable habitat within individual home ranges (Figure 4.8b). In 1997, the home range selection appeared to be similar to that in 1995. However, within home ranges, the badgers showed little preference for any habitat category (Figure 4.8c). The cause of this is not known, although the wet summer of 1997 (Figure 5.10) might have influenced habitat selection for feeding, for example, choosing locations during the night. Shepherdson *et al.* (1990) found that, despite a significant difference in number of "worm nights" (i.e. nights when earthworms are readily available, due to at least 2 mm of rainfall within at least 72 hours at temperature above 0°C, according to Kruuk and Parish (1985)) between years, intake of earthworms by the badgers did not differ. Therefore, badgers may compensate for varying food availability by allocating time spent in different habitat types.

Figure 5.10 Monthly rainfall in 1995, 1996, and 1997. (data from the Meteorology Office)



Habitat selection of raccoon dogs showed scale specific selection (Chapter 3), with different preferences for particular habitats at the scale of home-range selection and location selection within the home range. The badgers also showed scale specific difference except in 1995 when clear preference for pasture and avoidance for arable habitat were prominent at all scales. This scale-invariant selection could be either a general state of badgers or a consequence of the BRO. In badgers, home-range selection and its stability may be determined by their defending group territories, whereas home-range selection of raccoon dogs may be more influenced solely by resource abundance and its distribution.

5.4.2 Home range

A notable difference between the species was that the overall and yearly home-range size of badgers differed between sexes, while those of the raccoon dogs did not. The larger body mass of male badgers might have resulted in their larger home ranges compared to females. However, nightly home-range size did not differ between sexes for either badgers or raccoon dogs. Therefore, other sexual differences in behaviour, such as scent marking, may have contributed the difference in the badgers. Adult male badgers travel greater distances and spend more time on territorial boundaries than females, yearling males, and male cubs (Brown *et al.*, 1993 cited by Neal and Cheeseman, 1996). Male badgers are known to visit boundary latrines more often than do females (Roper *et al.*, 1993). Such territory defending behaviour may contribute to the larger home-range sizes in male badgers. In contrast, raccoon dogs do not show firm territoriality in either sex (Ikeda, 1979; Yachimori, 1991, 1997); indeed functions of latrine sites are still not clear, although they may serve as landmarks in home ranges and information exchanging sites among conspecifics (Ikeda, 1984; Yamamoto and Hidaka, 1984). Badgers, in contrast, are known to use latrines as territory markers (Kruuk, 1989).

Home ranges of raccoon dogs were larger than were those of badgers in this study. Although both species exhibited a wide range of home-range size, the minimum and maximum home ranges reported were similar, with a magnitude of 10 to 10³ ha (Table 4.1 in Chapter 4; Brøseth *et al.*, 1997).

5.4.3 Movements

Raccoon dogs and badgers showed similarities in their movements. Because badgers were neither tracked in winter nor through the night, not all inactive periods were likely to have been detected. This might explain why interfix speed was larger in badgers than in raccoon dogs, despite the similarity in nightly home-range size and range span for a night.

The fractal dimensions of movements were also similar for the two species. Considered together with the similarities in nightly home-range size and maximum range span, spatial use of the raccoon dogs and the badgers appeared to be similar. However, because of the small sample size of fractal dimension of the badgers, I could not test effects of sex and age class. It is possible that male badgers may possess lower fractal dimension of movements because of their patrolling behaviour along the territorial boundaries (Brown *et al.*, 1993; Roper *et al.*, 1993). Sexual differences in fractal dimension were found in wolves (*Canis lupus signatus* Cabrera), in which males had higher fractal dimensions than non-breeding females, and females had higher fractal dimensions during the breeding season with cubs (Bascompte and Vilà, 1997). In this case, scent marking and patrolling of males with longer travel distance may have resulted in higher dimensions within the same size of home ranges of females and males (Bascompte and Vilà, 1997).

Total daily rainfall did not influence nightly movements of the badgers. The scale of analysis might not be appropriate in this study to detect rain effects on movements, and variation between individuals and years may obscure the effects. Weather affects badger movements in complex ways, with different effects in different seasons and interactions of effects (Cresswell and Harris, 1988). In addition, Cresswell and Harris (1988) point out that badgers are unlikely to be influenced by rainfall and/or humidity if their diet does not consist largely of earthworms, although light rain or a warm, humid atmosphere provide ideal conditions for feeding on worms (Kruuk and Parish, 1985; Neal and Cheeseman, 1996).

In summary, raccoon dogs and badgers appeared to move in a similar fashion, with a similar range and tortuosity of movements during each night; however, badgers exhibited distinct sexual differences in overall home-range size and possibly other behaviours. The mechanism of habitat selection of badgers is still not clear; however, it seems to relate to both feeding strategy and social organisation of badgers. Comparisons in this study indicate that

raccoon dogs and badgers show similar spatial use but may not select habitats at the same scale. Studies of movements and habitat ecology of sympatric populations of raccoon dogs and badgers would clarify these aspects and their niche overlap.

5.4.4 Management and conservation implications

The population distribution surveys by the Environment Agency (1979, 1989-1992) indicate that badgers have suffered a drastic reduction in their distribution in Japan. However, hundreds of badgers have still been culled every year (Environment Agency, 1989-1999; Figure 2.3 in Chapter 2). Ecological information about agricultural damage and methods for its prevention can be applied from studies in Europe (e.g. Wilson, 1993; Roper *et al.*, 1995; Moore *et al.*, 1999) and the study of raccoon dogs (Chapter 7).

Comparisons of environmental changes between areas where badgers have disappeared and raccoon dogs still remain and areas where both species inhabit may produce insights for both species ecology and keys to protect badgers. Because the two species co-existed since the prehistoric era in Japan, recent artificial changes are the prime suspects for the badgers' decline. However, interspecific competition may have become intense under such changes.

From a management point of view, it would be interesting to investigate if the two species can be treated as meta-specific populations where they occur sympatrically. Badgers move and forage alone, except for mothers and cubs, which may move together, and raccoon dogs move alone, in a pair, or a pair and their pups (M. Saeki, pers. obs.). A pair of raccoon dogs weighs as much as a badger, suggesting that calorific requirements for a raccoon dog pair may be equivalent to a badger. Yamamoto (1994) found that diet overlap between raccoon dogs and badgers was highest among raccoon dogs, badgers, foxes and martens (*Martes melampus* Wagner) in a sub-alpine zone. In addition, a camera trap revealed that a raccoon dog and a badger emerged from the same den site on the same night (M. Saeki, pers. obs.). Den and/or resting sites may be a limiting resource, even more so in areas under development. Direct and indirect competition and differential influences by human activities warrant further studies. Treating two species together with knowledge of their similarities and differences may save labour and budgets for management and conservation, as both labour and budgets are very limited in Japan.



A raccoon dog (above) and a Japanese badger (*M. m. anakuma*); these photographs were taken at the same spot at the same night. (a camera trap by Akira Nawa)

CHAPTER 6

RACCOON DOG ROAD-KILLS IN JAPAN:

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Summary

The current scale and trend of wildlife road-kills in Japan, with a particular focus on raccoon dogs, are described. Factors influencing road-kills of raccoon dogs are identified, and preventative measures are discussed. Road-features, such as road in a cutting, and proximity to water are positively associated with road-kills, while coniferous plantations as roadside habitat are dissociated with road-kills. Approximately 1.6 raccoon dogs are killed per km on the National Expressways (>6,400 km) every year. The nationwide estimates of road-kills of raccoon dogs are made with different assumptions. Conservative estimates put the number of road-kills at 110,000 - 370,000 per year. In addition, road-kills can be used, after controlling for traffic data, as an index of population trends.

Chapter 6 Raccoon Dog Road-kills in Japan

6.1 INTRODUCTION

The negative effects of roads on wildlife have long been of concern to conservationists. In both terrestrial and aquatic ecosystems the ecological effects are diverse and extensive (Trombulak and Frissell, 2000). These include mortality caused by construction and collisions, modification of behaviour, alteration of the physical and chemical environment, the facilitation of spreading exotic species, and increasing habitat alteration and habitat use by humans (Forman, 2000; Forman and Deblinger, 2000; Trombulak and Frissell, 2000).

Traffic accidents affect fitness of individuals due to mortality and injuries and may impact on population structures through age and/or sex specific vulnerability. Traffic accidents involving wildlife are a serious problem on developed and developing road networks all over the world (Broekhuizen and Derckx, 1996; Coulson, 1997; Drews, 1995; U.S. Department of Transportation, 2000). Road-kills are a major component of mortality in many vertebrate and invertebrate species (e.g. Kushlan, 1988; Seibert and Conover, 1991; Drews, 1995; Fahrig *et al.*, 1995). In addition, road-kills may obstruct seasonal migration (van Gelder, 1973) and may interfere with the recovery of rare or endangered species (Kushlan, 1988; Philcox *et al.*, 1999). Collisions with large animals may also be costly in terms of human injuries or fatalities, and expensive vehicle repairs (Romin and Bissonette, 1996; U.S. Department of Transportation, 2000). Fences, overpasses, underpasses or culverts, and road signs have been installed in some places. Nevertheless, no cost-effective methods to prevent adverse effects of roads and road-kills on extensive road networks are currently available (Trombulak and Frissell, 2000).

Although road-kills may be a major cause of unnatural death for wildlife, only a small number of nationwide estimates of road-kills have been conducted. In the USA, Romin and Bissonette (1996) found that at least a half million deer (*Odocoileus* spp.) were killed in vehicle collisions in 1991. In the Netherlands, 0.2 - 0.5 road-kills per km of European hedgehogs (*Erinaceus europaeus* Linnaeus) were estimated to have occurred, accounting for 113,000 - 340,000 hedgehogs per year (Meijer and Smith, 1999), whilst in Belgium, 2.3 road-kills per km of hedgehogs were estimated to have occurred, accounting for 230,000 - 350,000 hedgehogs per year (Holsbeek *et al.*, 1999). Around 50,000 - 60,000 badgers (*Meles meles*) are estimated to be killed by cars every year in Britain (cited by Clarke *et al.*, 1998).

6.1.1 Raccoon dog road-kills

A high number of raccoon dog (*Nyctereutes procyonoides* Gray) road-kills have been reported on the National Expressways (Yanase, 1999), the National Highways (Tsukada, 1997) and the Prefectural and other roads (Ohwada, 1986; Machidanuki Executive Committee, 1995) in Japan. Numerous newspaper articles on wildlife road-kills focus on raccoon dogs (e.g. *Asahi Newspaper*, 1994, 1996b, 1998). It appears that raccoon dogs are the most frequent victims of vehicle collision among mammals in Japan. However, there are no assessments of the impacts on any populations of this species.

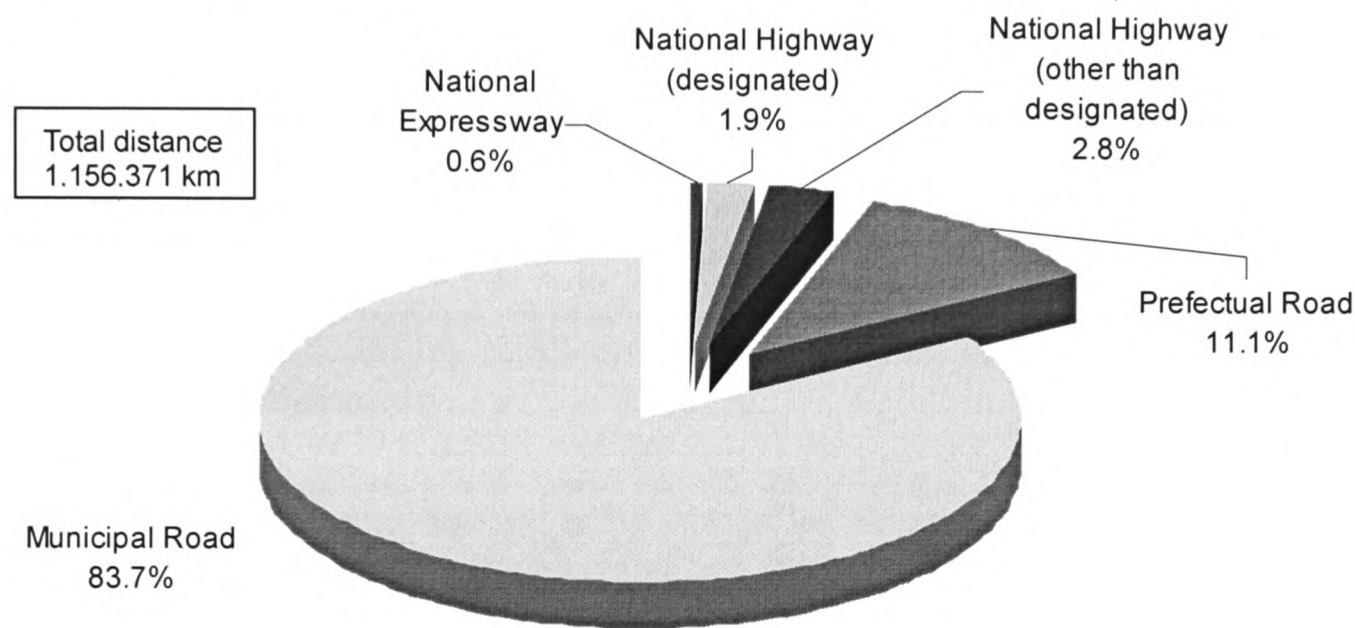
6.1.2 Traffic and road systems in Japan

The Japanese road system has developed rapidly since the 1950s when the toll road system and gasoline tax were employed to finance development through five-year road improvement programmes. There are four basic categories of public roads in Japan (Figure 6.1): the National Expressways (6,402 km in 1998), under the responsibility of the Japan Highway Public Corporation; the National Highways (53,628 km in 1998), the Prefectural roads (127,911 km in 1998), and the Municipal roads (961,430 km in 1998), administered by National and local governments and municipalities. Seventy-six percent of these roads were paved by 1999. In addition, >130,000 km of forest roads (Figure A1.b in Appendix I) and >180,000 km of agricultural roads, which are not designated as 'road' by the *Road Law 1952*, have been developed in forested and agricultural areas respectively (Ministry of Agriculture, Forestry and Fishery, 2001a). The total area of roads (excluding forest and agricultural roads) has been steadily increasing and covered 3.3% of the land area of Japan in 1997. The number of registered vehicles grew 80-fold from 1955 to 1998, reaching 73,688,389 (Ministry of Transportationⁱ, 2000), while the total road length increased almost tenfold during the same period (Ministry of Constructionⁱ, 2000) (Figure 6.2).

ⁱ The Ministry of Transportation and the Ministry of Construction were merged into the Ministry of Land, Infrastructure and Transportation in 2001.

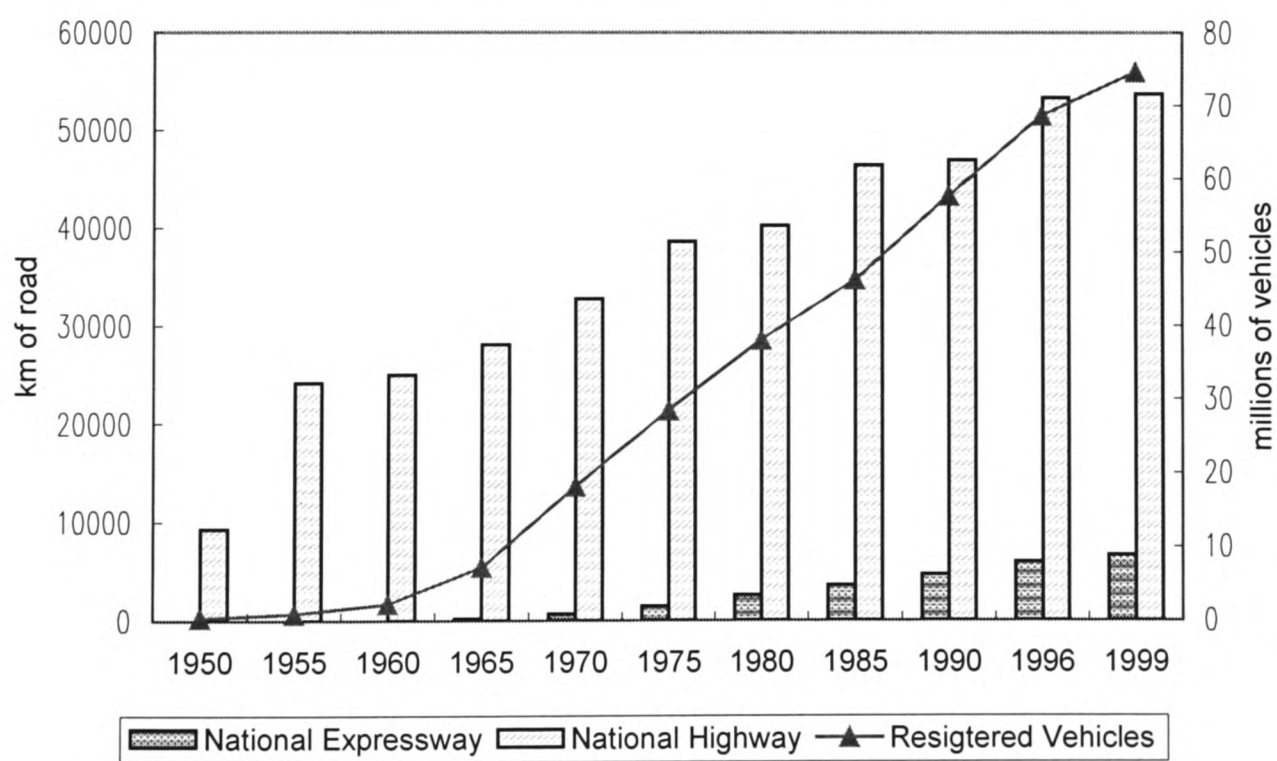
The Expressways are the most improved roads among public roads, being 100% paved, having central reservations, roadside verges, land bridges, and long tunnels. Physical access to roads by wildlife was considered to be lower on the Expressways than other types of roads.

Figure 6.1 Road composition in Japan in 1998 (data from the Ministry of Land, Infrastructure and Transport).



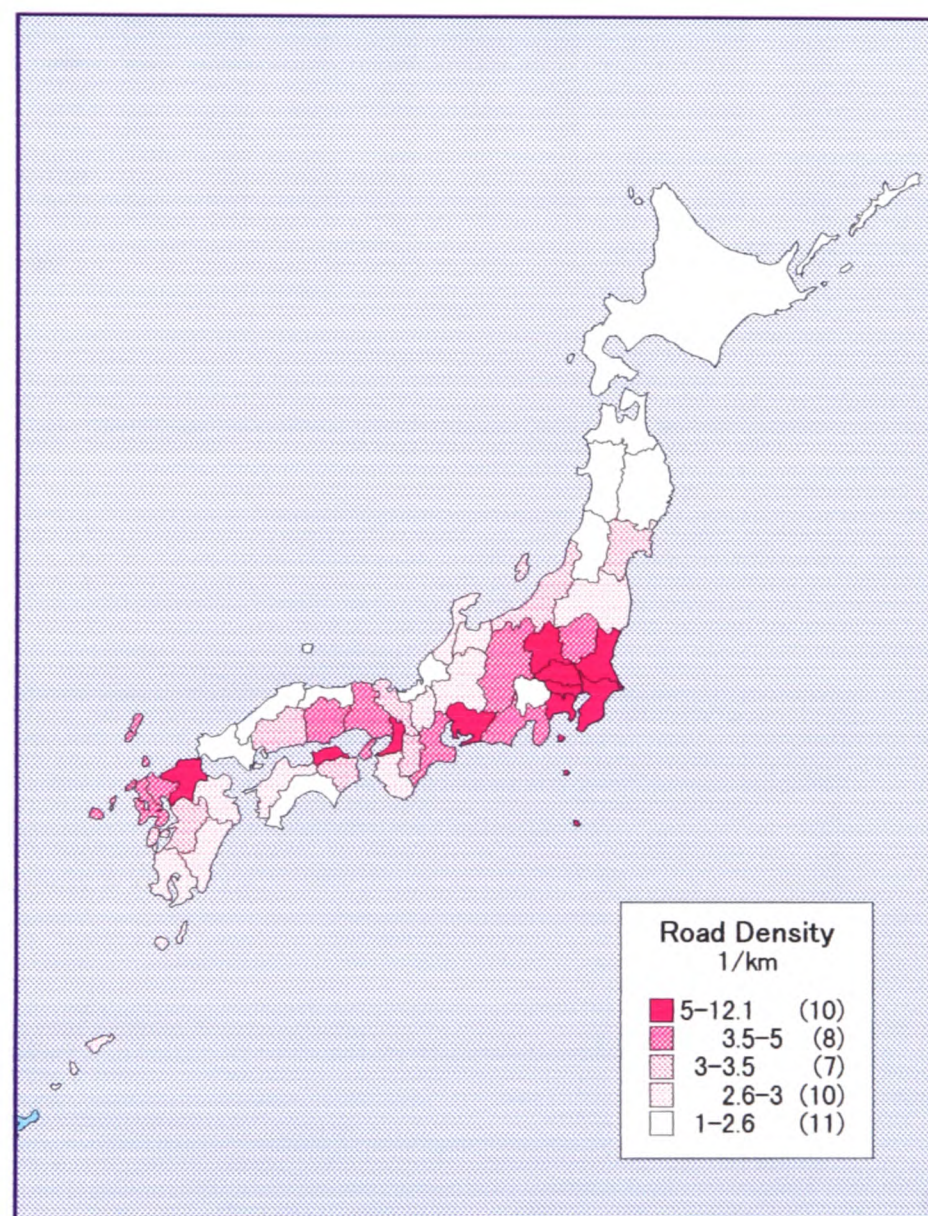
Designated National Highways (mostly single and double-digit numbered roads) are managed by the National government; the other National Highways (mostly three-digit) are managed by prefectures.

Figure 6.2 Road development and registered vehicles in Japan.



Road density by prefecture, i.e. local government regions, ranged from 1.02 to 12.04 km^{-1} , with an overall density of 3.11 km^{-1} , in 1999, as shown in Figure 6.3. The overall road density falls into the same magnitude as that of the Netherlands (3.7 km^{-1} , cited by De Vries, 1999) and Germany (3.6 km^{-1} , cited by Gerlach and Musolf, 2000), and is greater than that of Great Britain (1.6 km^{-1} calculated using data from the Department of Environment, Transport and the Regions, 1999). However, because of the Japanese topography (Chapter 2) and concentrated urbanisation, road density in Japan varies greatly by location (Figure 6.3).

Figure 6.3 Road density by prefecture in 1999 in Japan (excluding Okinawa).



Traffic in general has increased over time, especially running distance, i.e. kilometric performance (Figure 6.4), which contribute both traffic volume and road density, two of the most influential factors for number of road-kills (Clarke *et al.* 1998; Philcox *et al.*, 1999). Traffic volume, i.e. the number of vehicles per any 12-hour period, has steadily increased on most roads except the National Expressways, which showed a decrease in the 1970s (when economic depression due to two oil crises occurred; Figure A.4 in Appendix I) and an increase afterwards (Figure 6.5). The National Expressways, the total distance of which comprised only

0.6% (Figure 6.1), held in the 1990s, on average, a traffic volume of about 2.7 times that of the National Highways and 5.3 times that of major regional roads (Figure 6.5).

Figure 6.4 Trends of kilometric performance (total distance that vehicles travelled per year) of passenger car and truck in Japan.

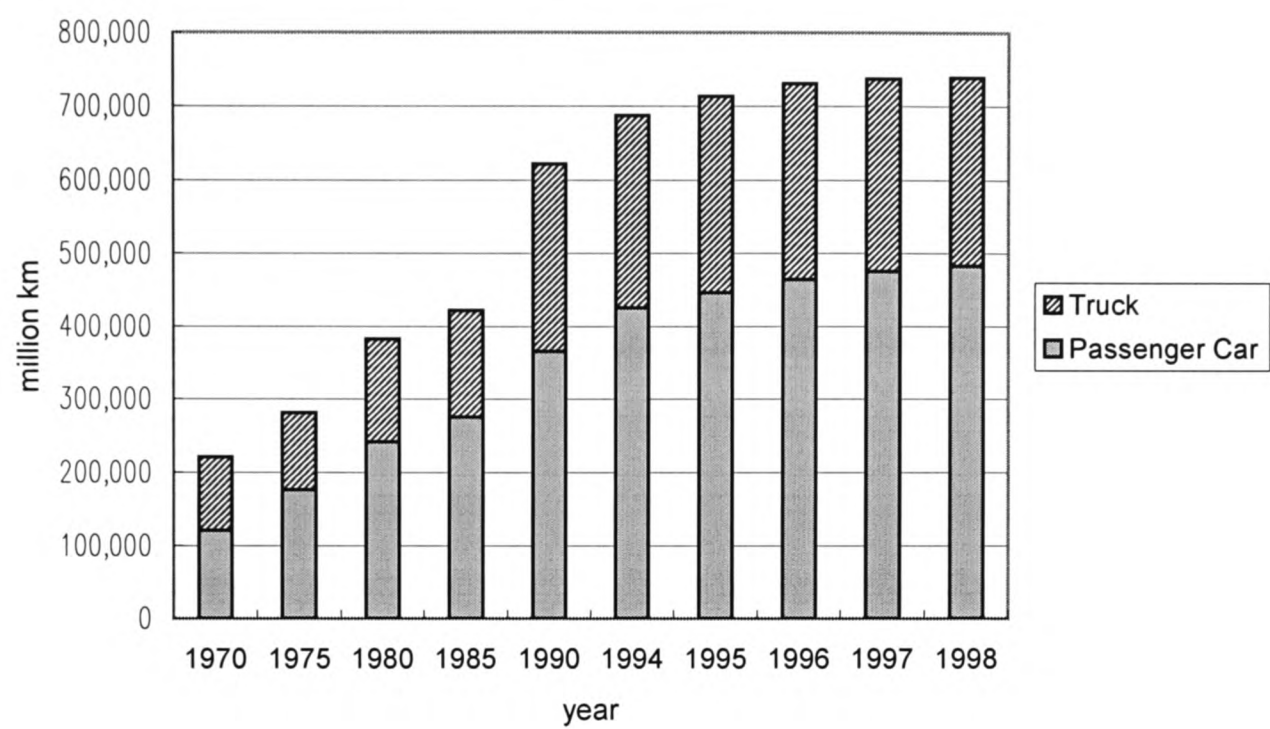
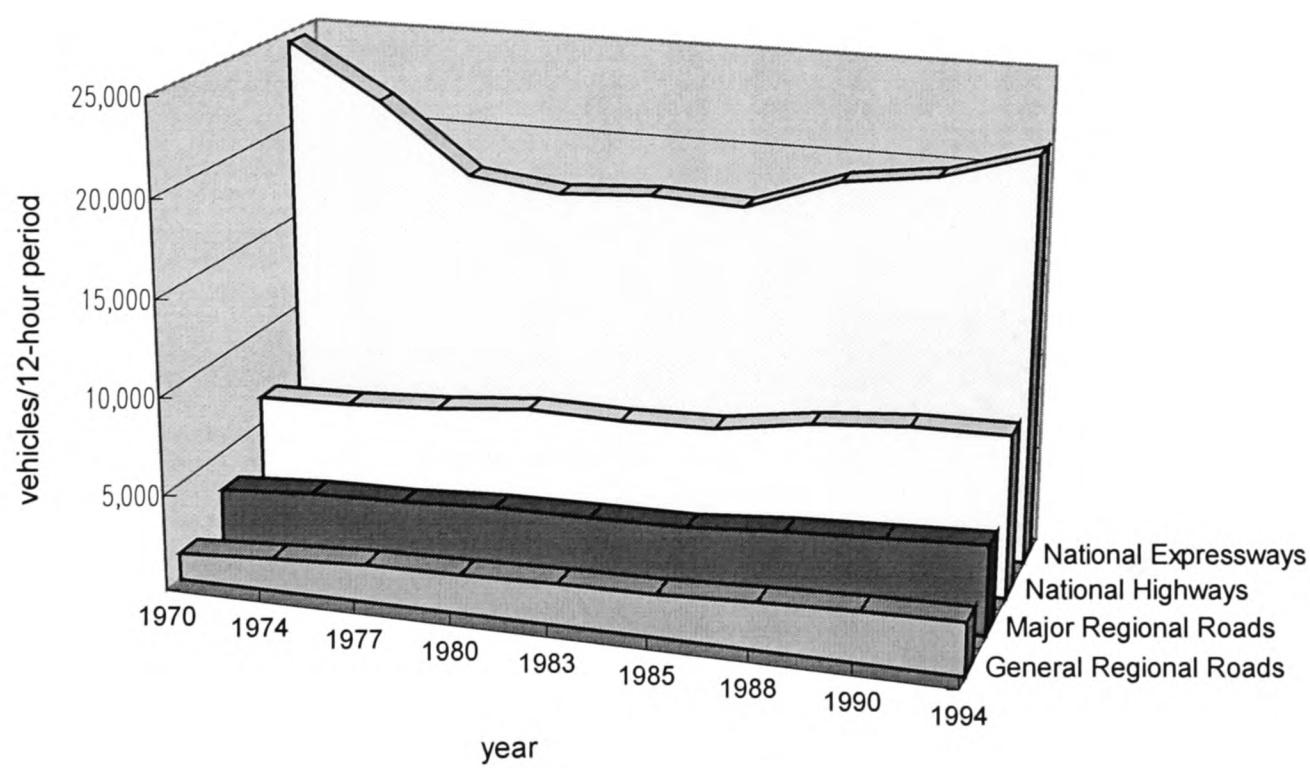


Figure 6.5 Trends of traffic volume by road category in Japan.



6.1.3 Chapter Objectives

In this chapter, I describe the nature and extent of wildlife road-kills in Japan, focusing particularly on raccoon dogs. The chapter has four objectives:

- to assess the scale and trend of road-kills of wildlife on the Expressways
- to identify the factors influencing road-kills of raccoon dogs
- to estimate nationwide road-kills of raccoon dogs
- and to discuss effective measures to prevent raccoon dog road-kills.

I address these aims through analysis of data on road use and road-kills on the National Expressways from the Japan Highway Public Corporation, and through estimation of total road-kills on the National and regional roads. I analyse spatial and temporal trends of road-kills at different scales, as well as road-kill rate by segments of road between interchanges, by road, and by prefecture.

Cojiro, killed by a car in November, 1993. The reflective tape on the radio-transmitter did not help him.



6.2 METHODS

Data on road-kills on the National Expressways and some toll roads (total 44 roads; 6,402 km in 1998) are compiled annually by the Japan Highway Public Corporation. Road-kills were collected by corporation staff during regular road checks. Consequently, only corpses on roads, i.e. instantaneous deaths, were recorded. Recorded information included species and number of road-kills, location (per 100-m segment), and date and time of collection. When compiled, these data provide information on the following: 1) the number of road-kills by species by road in each fiscal year between 1995 and 1998, 2) total number of road-kills by species, in the fiscal years from 1987 to 1998 nationwide 3) the total length of roads and the traffic volume and traffic load in the fiscal years from 1987 to 1998 nationwide, 4) the location and time of collection of road-kills by species on the National Expressways (563.8 km) and the toll roads (63.5 km) in the Kyushu area, where the highest number of road-kills of raccoon dogs occurred, in 1989, and 5) traffic volumes between interchanges in 1989 of those roads.

There was a possibility of misidentification of species, for example, the Japanese badger (*M. m. anakuma* Temminck) being identified as the raccoon dog. Because I was not able to estimate the probability of misidentification, the original data were used as they were. I assumed that the probability of misidentification was similar by locality and year; therefore, the analysis of trends of raccoon dog road-kills by area and year is legitimate. Furthermore, badgers are much rarer in terms of population density and road-kills than raccoon dogs.

The Miyazaki-do, a road known to have the highest road-kill rate of raccoon dogs in Japan (data from the Japan Highway Public Corporation) was used to analyse factors influencing road-kills of raccoon dogs. Land use maps (1:200,000; Geographical Survey Institute of Japan, 1985), topographic maps (1:50,000; Geographical Survey Institute of Japan, 1998), and an electronic map (Zenrin Co., Ltd., 1997) were used to obtain detailed features of roads and environmental factors around the roads. The road features (Figure 6.6) and the environmental factors used for analysis are given in Table 6.1. These features and factors were recorded on every 100 m on both line 1 and line 2 (carriageways) with the distance from the closest body of water, such as streams and ponds, measured with a map measurer.

Figure 6.6 Cross section of some road features used in the analysis.

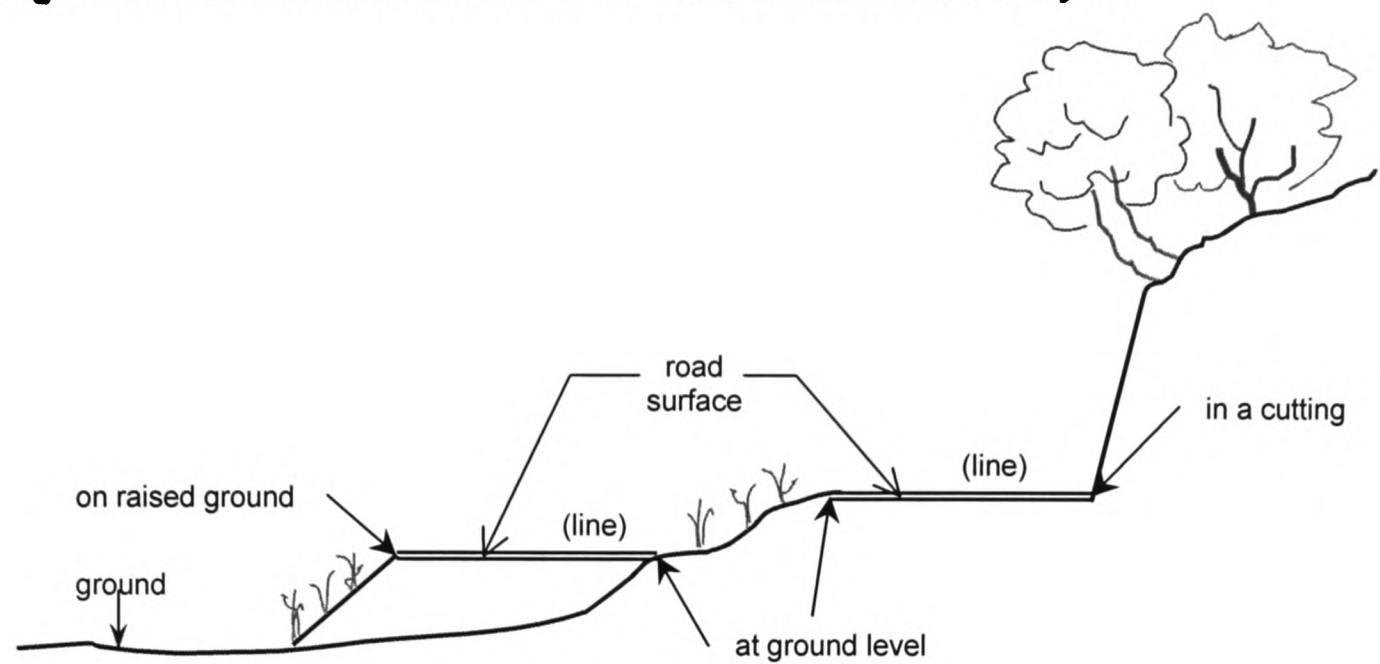


Table 6.1 Road features and environmental factors of the Miyazaki-do.

Code	Road features	Code	Environmental factors	Code	Other road factors
road attribute		adjacent habitat		crossing	
1	Road is on raised ground.	1	rice field	1	another road under-passing
2	Road is in a cutting.	2	cropland	2	another road over-passing
3	Road is at ground level.	3	orchard	3	railroad under-passing
4	Road is in a tunnel.	4	conifer forest	4	railroad over-passing
5	Road is on a bridge.	5	broad-leaved forest		
6	Road side is walled.	6	development		
7	Inter-change/Junction	7	other		
8	Service area	8	road		
9	Parking area	distance from water (m)			

Based on the data from the National Expressways, I estimated a figure for nationwide raccoon dog road-kills. General road and traffic statistics used in this analysis were obtained from the Japan Highway Public Corporation's homepage (<http://www.japan-highway.go.jp>), the Ministry of Land, Infrastructure and Transportation's homepage (<http://www.mlit.go.jp>), the Japan Institution of Construction Engineering's homepage (<http://www.jice.or.jp>), and the Japan Statistical Yearbook 2001 (<http://www.stat.go.jp>). Harvest density, calculated with data from the Ministry of Environment, was used to regress to road-kill density by prefecture. Road-kills on forest and agricultural roads (total >310,000 km) were not considered in my estimates because of a lack of available information.

Data analysis

In order to obtain the trends of road-kills for nine species over 10 years from 1987 to 1998, a trend analysis was performed to find if the trends differed by species. In order to investigate the relationships between road-kills and total distance of roads and traffic volume, a regression

analysis was performed with total road-kills (y), total road length (x_1) and traffic volume (x_2), i.e. 100 million vehicle-km, per fiscal year, of the National Expressways. The analyses were performed separately for raccoon dog, fox (*Vulpes vulpes* Linnaeus), deer (*Cervus nippon* Temminck), boar (*Sus scrofa* Linnaeus), macaque (*Macaca fuscata* Blyth), weasel (*Mustela itatsi* Temminck and *M. sibirica coreana* Domaniewski), hare (*Lepus brachyurus* Temminck and *L. timidus* Linnaeus), domestic dog (*Canis familiaris* Linnaeus), and domestic cat (*Felis catu* Linnaeus), using MINITAB for Windows (Minitab, Inc., 1996).

For three Expressways in Kyushu, distributions of road-kills/km were tested for a random distribution with a Poisson series to determine whether road-kills occurred randomly (Elliott, 1977).

For the Miyazaki-do in Kyushu, the Chi-square test of independence (contingency table) was used to detect if the road features and the habitat types along the road had any effect on raccoon dog road-kills. Logistic regression was used to identify factors influencing raccoon dog road-kills on the road, i.e. presence or absence of road-kills per 100-m segment. Both analyses were performed using the SAS system for Windows (SAS Institute, 1989-1996).

A regression analysis was used to test whether raccoon dog road-kills depended on traffic volume by road. Eight Expressways were used in the analysis. Seven other Expressways appeared as outliers and were excluded from the analysis. These were: Meishin and Tohmei - with an exceptionally large traffic volume (>70,000 vehicles/day); Chuoh - in a mountainous area with many tunnels; Kinki - in an extremely urban area; Kanku - being entirely a bridge; Chugoku and Kyushu - with high road-kill rates.

To compensate for the effect that the Expressways are more improved than other roads with more land bridges and tunnels, one of the assumptions made in estimating total road-kills nationwide was that road-kills were proportional to the reciprocal of road width. In addition, regression analysis was performed to investigate the relationship between traffic volume and road-kill rate by segment between interchanges, using three Expressways in Kyushu, where such data were available.

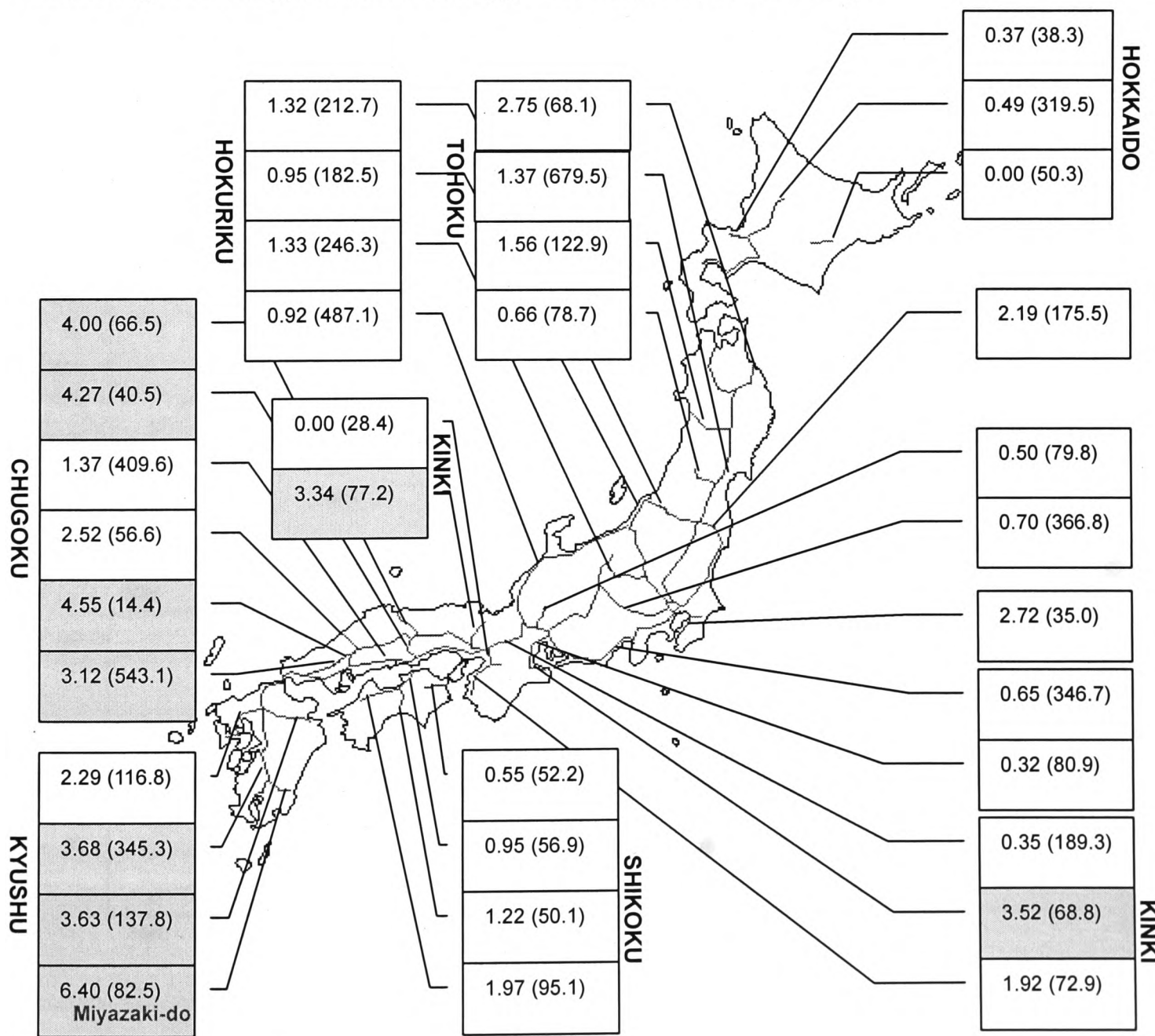
6.3 RESULTS

6.3.1 Spatial and temporal trends in road-kills on the National Expressways

6.3.1.1 Spatial Trend

Raccoon dog road-kills on the Expressways appeared to be the highest in the Kyushu region of Japan (Figure 6.7), according to the data from the Japan Highway Public Corporation. On average, 4.04 raccoon dogs were killed every kilometre on the National Expressways (total approximately 682.4 km) on Kyushu island in 1998. This far exceeded the national average of 1.89 road-kills/km for the same species. The average road-kills/km were also calculated using the data from 1995 to 1998 (the road distance in 1997 was used for each road) and the high road-kill roads were identified, namely Chugoku and Kyushu regions and a small number of roads in Kinki region (Figure 6.7).

Figure 6.7 Annual average road-kill density (road-kills/km) of the raccoon dog on the National Expressways from 1995 to 1998. Length of road (1997) in parentheses. Shaded boxes represent high road-kill rate (greater than 3 road-kills/km).



6.3.1.2 Temporal Trend

Of the 10 mammalian species (Figure 1.4 in Chapter 1), 4 avian species and identified reptiles recorded as being killed on the National Expressways, raccoon dog casualties were the highest and have increased over time. Among the mammalian species, there were several trends in the number of road-kills from 1987 to 1998. The raccoon dog and weasel showed linear increases; deer, boar, macaque and the domestic cat showed growth curve or S-curve upper-swing increases; foxes showed a S-curve asymptote; the domestic dog showed a quadratic drop; and the hare showed a quadratic upper concave as the lines of best fit (Figure 6.8). The total road length showed a linear increase, whereas the traffic volume showed a non-linear increase, indicating that road construction has been carried out on the basis of development plans (Japan Highway Public Corporation, 2000) whereas the traffic may have been influenced by other factors, such as economics and recreational events.

Figure 6.8 Trend of road-kills of nine species on the Expressways in Japan from 1987 to 1998. (Y-axis is annual total of road-kills. The dotted lines are the best fit with their equations given.)

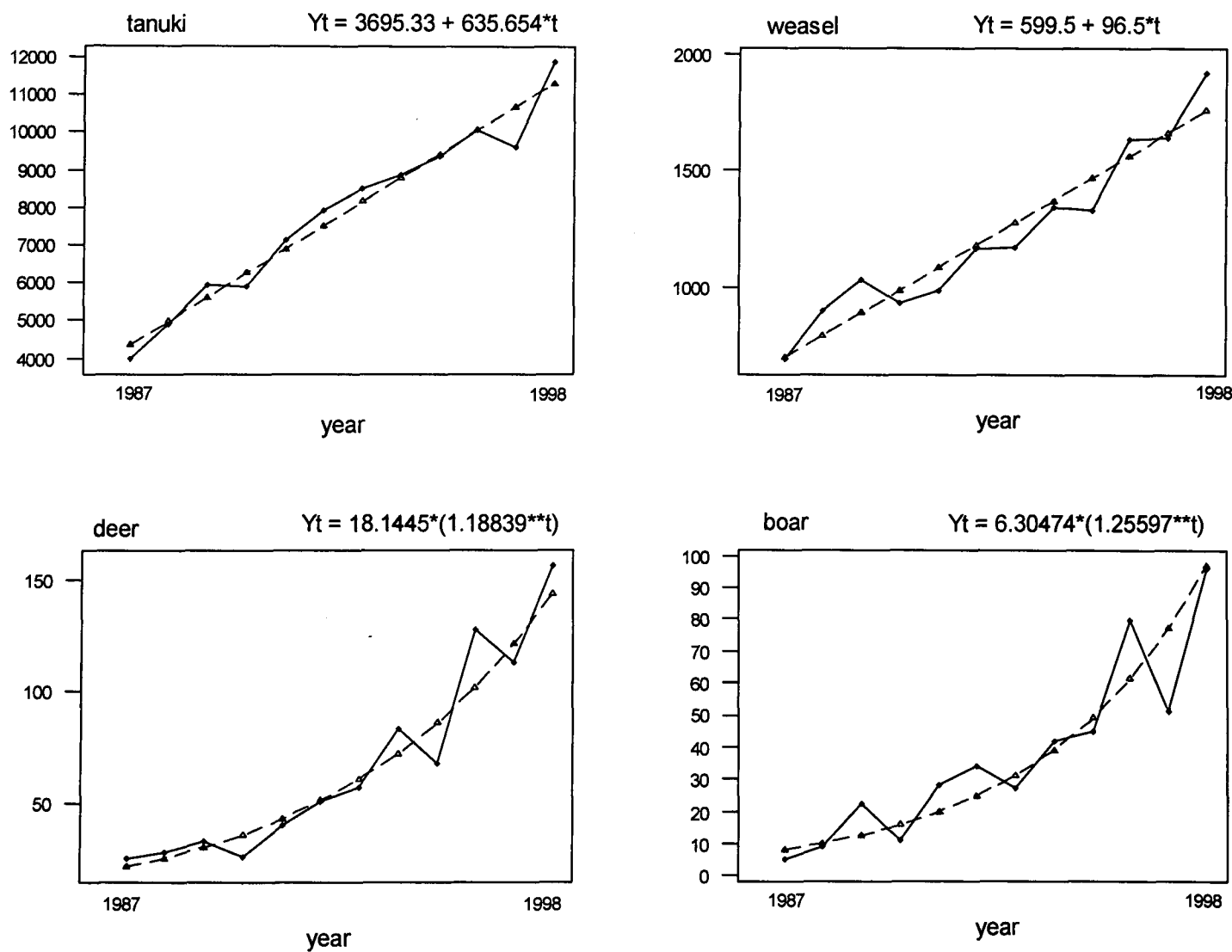
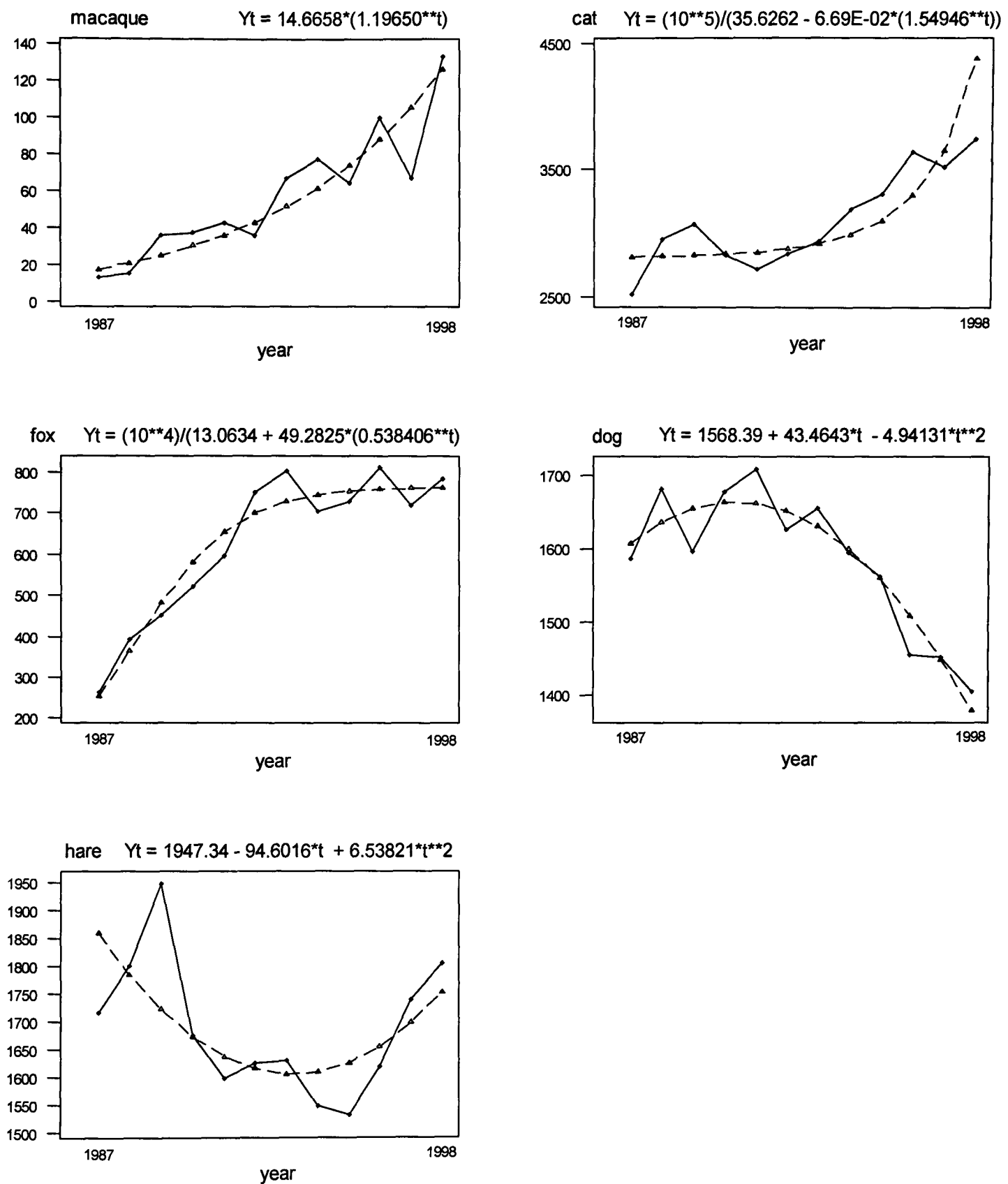


Figure 6.8 continued.



6.3.2 Factors influencing road-kills

Road-kills/km exhibited non-random distributions, except for the eastward line (carriageway) of the Miyazaki-do (Table 6.2), and in all cases the sample variance was greater than the sample mean, indicating that road-kills occurred in a non-random contagious (negative binomial) distribution.

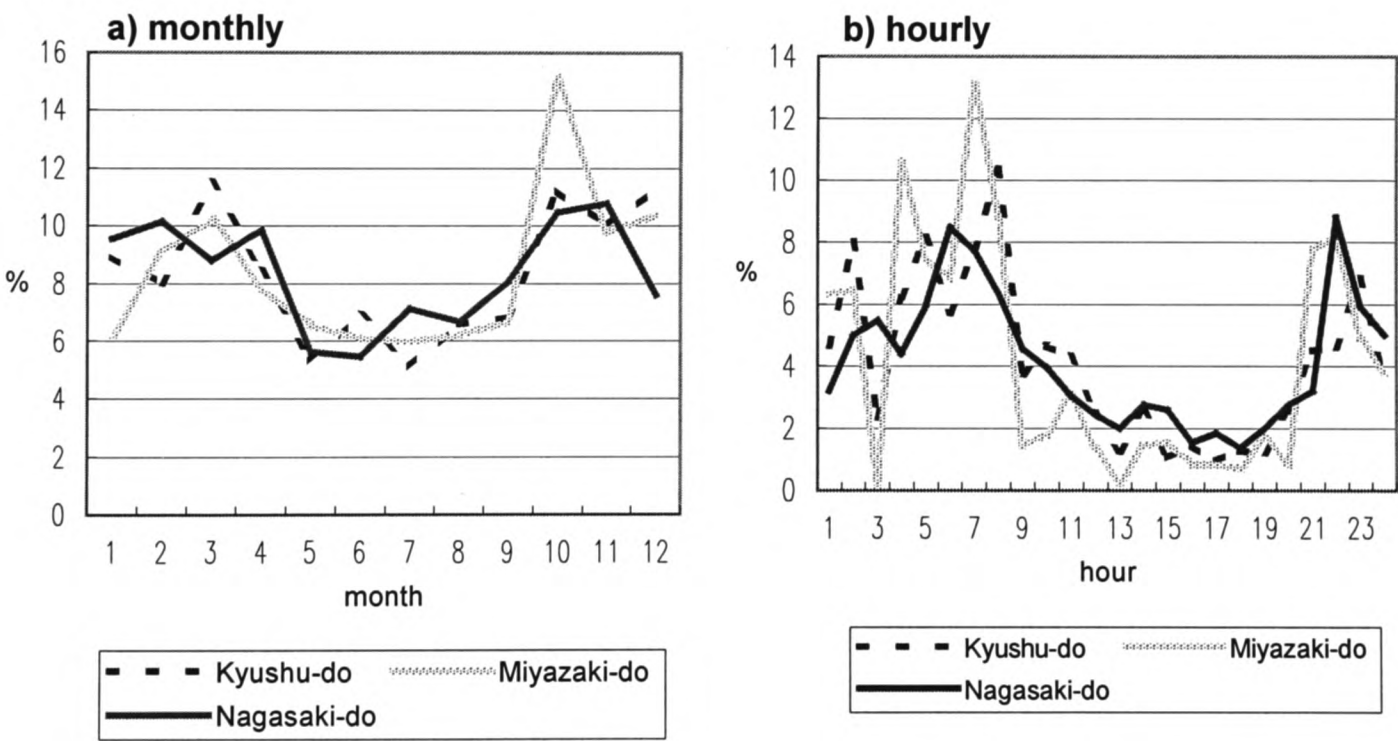
Table 6.2 Chi-square tests for a random distribution in road-kills on the Miyazaki-do, the Kyushu-do, and the Nagasaki-do.

Road	Carriage-way (line)	DF	mean	variance	χ^2	d	p	k*
Miyazaki	eastward	82	1.6386	1.9653	98.353	1.258	0.102	8.216
	westward	82	2.3373	4.3726	153.400	4.749	<0.001	2.684
Kyushu	northward	284	1.0386	1.6147	441.534	5.905	<0.001	1.872
	southward	284	1.2105	2.2654	531.479	8.791	<0.001	1.389
Nagasaki	eastward	70	1.3944	2.2137	111.131	3.119	<0.001	2.373
	westward	70	1.7746	3.2628	128.699	4.254	<0.001	2.116

*k is an index of clumping in a population, estimated by $k = (\text{sample mean})^2/(\text{sample mean} - \text{sample variance})$

On the Expressways studied in Kyushu, the monthly road-kills of raccoon dogs peaked in early spring and autumn (Figure 6.9). The hourly road-kill trend must be interpreted with caution because the effort (frequency) of checking roads cannot be assumed to be constant or random. However, the morning peak (between 6:00 and 8:00) and the evening peak (between 21:00 and 23:00) in percentage of road-kills (Figure 6.9) seem to reflect the high rate of early-morning and early-evening deaths expected for most mammals.

Figure 6.9 The (a) monthly and (b) hourly collection distribution of raccoon dog road-kills in Kyushu in 1989. (The percentage of total road-kills over 12 months or 24 hours)



Raccoon dog deaths per road were significantly associated with daily traffic volume, i.e. total number of vehicles per day per kilometre, on the Expressway ($F_{1,6} = 63.16, p < 0.0001$). The regression equation obtained was: $y = -0.123 + 0.0579x$ ($r^2 = 91.3\%, p < 0.001$; Figure 6.10) where x is 1000 vehicles/km, and y is number of road-kills/km.

Figure 6.10 Regression plot of road-kill rate of raccoon dogs and traffic volume by road.

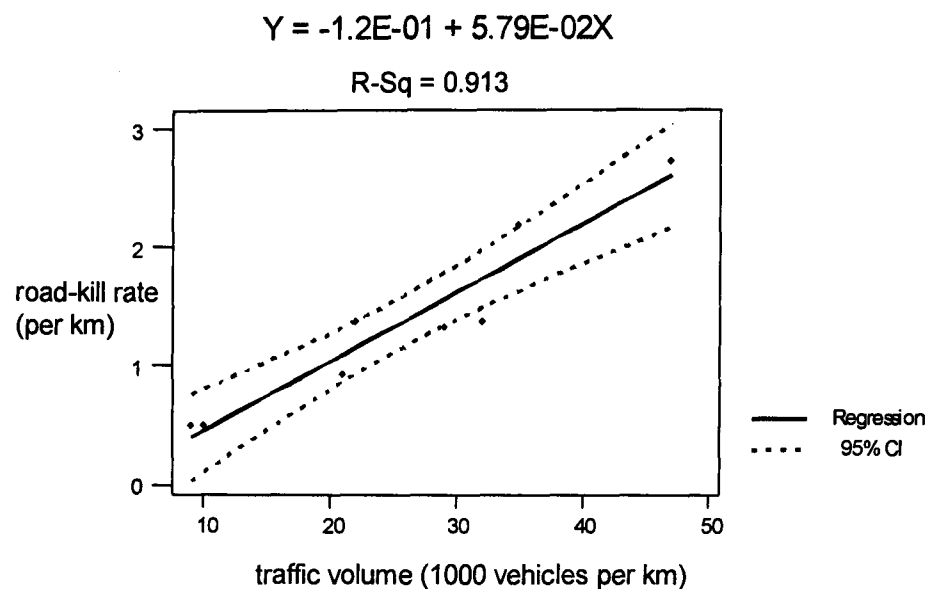
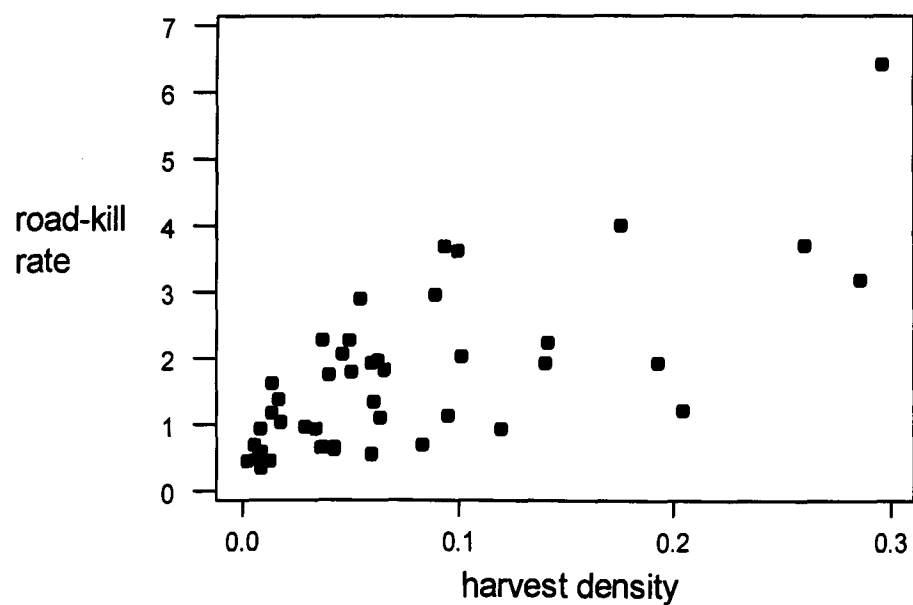


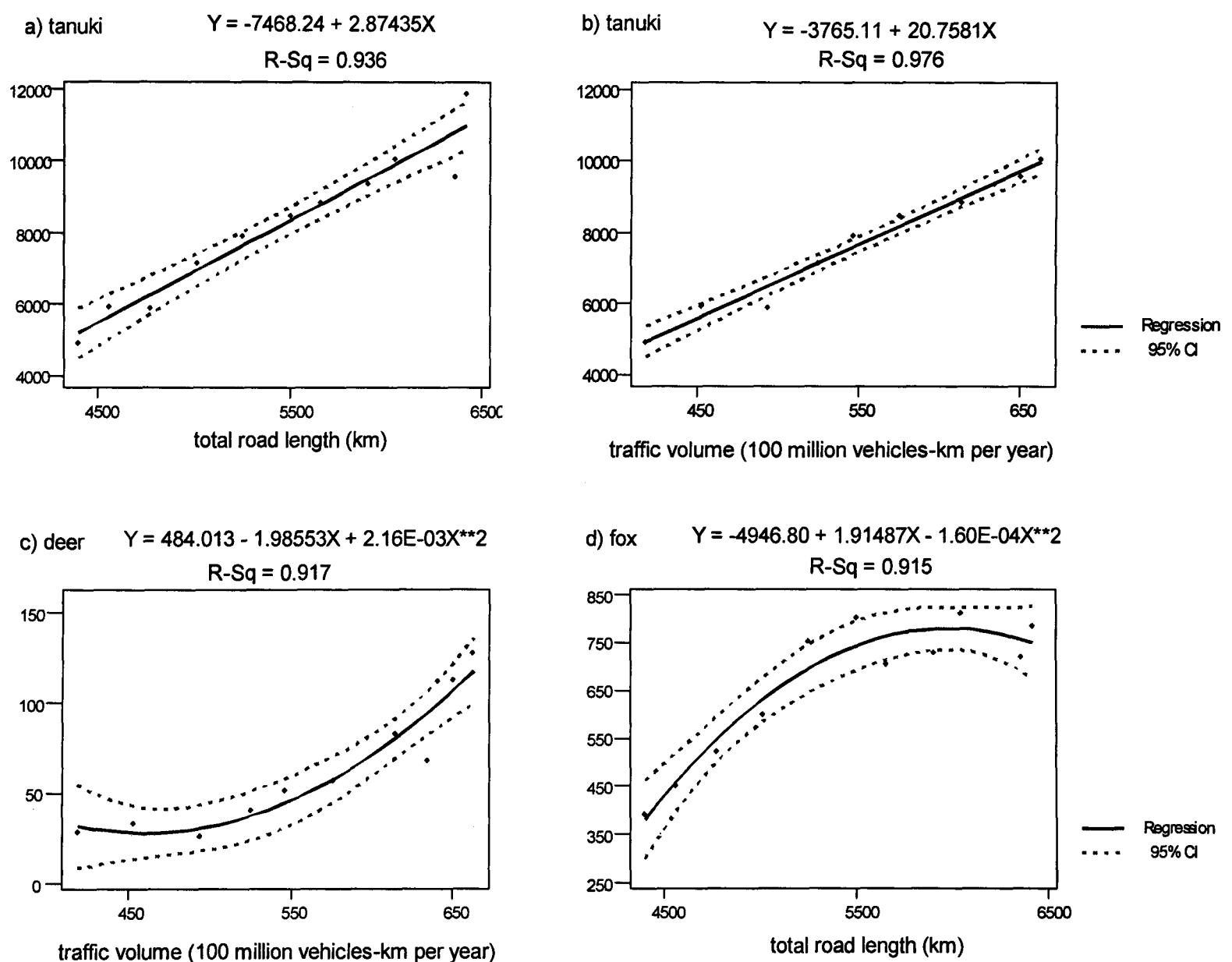
Figure 6.11 shows the relationship between the average harvest density by prefecture from 1995 to 1998 (calculated with data from the Ministry of Environment) and the average road-kill rate on the National Expressways adjusted by prefecture during the same period (Spearman rank correlation, $r_s = 0.720$, $p < 0.001$, $n = 46$). The harvest density was also significantly correlated with annual temperature and precipitation (data from the Meteorological Agency) ($r_s = 0.460$ and $r_s = 0.408$, $p < 0.05$, $n = 46$, respectively), and the road-kill rate was significantly correlated with temperature ($r_s = 0.376$, $p < 0.05$, $n = 46$) and negatively correlated with human density ($r_s = -0.495$, $p < 0.001$, $n = 46$).

Figure 6.11 Positive linear correlation between road-kill rate (road-kill/km) and harvest density (animal/km²) of raccoon dogs by prefecture.



The linear relationships between road-kills, the total road length ($F_{2,8}=131.23$, $p < 0.0001$), and the traffic volume ($F_{2,7} = 323.06$, $p < 0.0001$) showed that the road-kills of raccoon dogs increased as the road length or the traffic volume increased (Figure 6.12a and b). Traffic volume had a better fit ($r^2 = 0.976$) than the length ($r^2 = 0.936$). The road-kills of other species showed different dependencies on the length and the traffic. For example, quadratic relationships were found for deer ($F_{2,7} = 38.5526$, $p = 0.000166$; Figure 6.12c) and fox ($F_{2,8} = 43.0389$, $p < 0.0001$; Figure 6.12d). Traffic volume had a better fit than the length for deer, while the length had a better fit than the traffic volume for fox, although both were significant.

Figure 6.12 Regression analyses of road-kills as a function of traffic volume and/or road length with a 95% confidence band for raccoon dog, deer and fox. (y-axis is the total number of road-kills from 1989 to 1997.)



6.3.3 Raccoon dog road-kills on the Miyazaki-do

The Miyazaki-do (Figure 6.7) extends for 82.5 km between Ebino Junction and Miyazaki Interchange in Miyazaki prefecture, Kyushu. In 1989, 134 raccoon dog road-kills were recorded at 116 100-m segments (14.1% of total segments) on line 1 (the eastward carriageway) and 195 kills at 162 100-m segments (19.6% of total segments) on line 2 (the westward carriageway). Road-kills were recorded at nearly every kilometre, i.e. ten 100-m segments, for both lines, but the distribution of kills was not uniform and differed significantly between lines (Table 6.2; Figure 6.13). The distributions also differed between spring and autumn with more peaks in road-kills in autumn (Figure 6.14). "Hot spots" for road-kills could be identified. The 43 and 44 km road posts recorded high road-kills in both seasons and on both directions (A in Figure 6.15). In addition, spring and autumn hot spots could be identified (B and C in Figure 6.15, respectively).

Figure 6.13 Frequency distribution of raccoon dog road-kills on the Miyazaki-do in 1989.

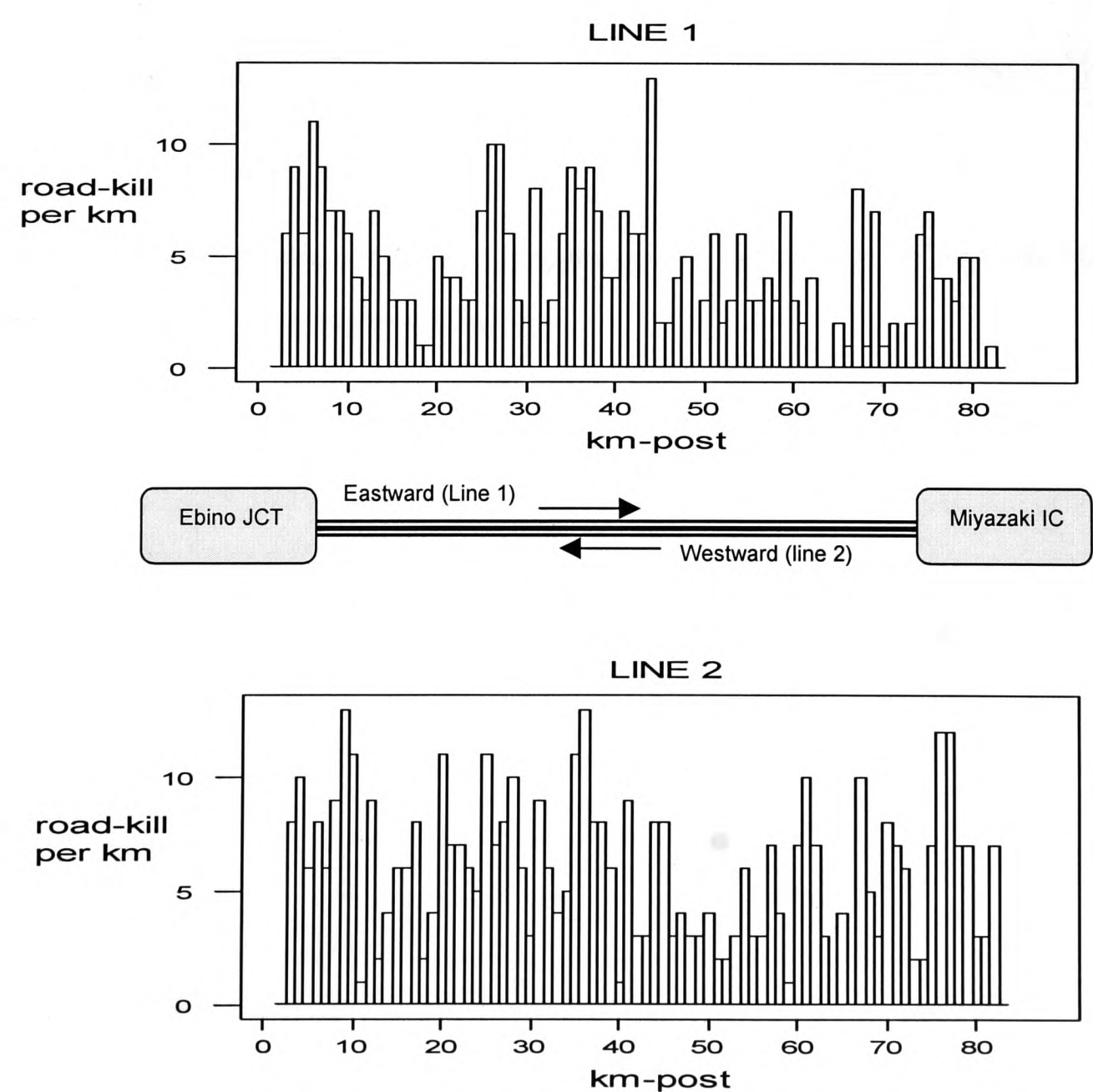
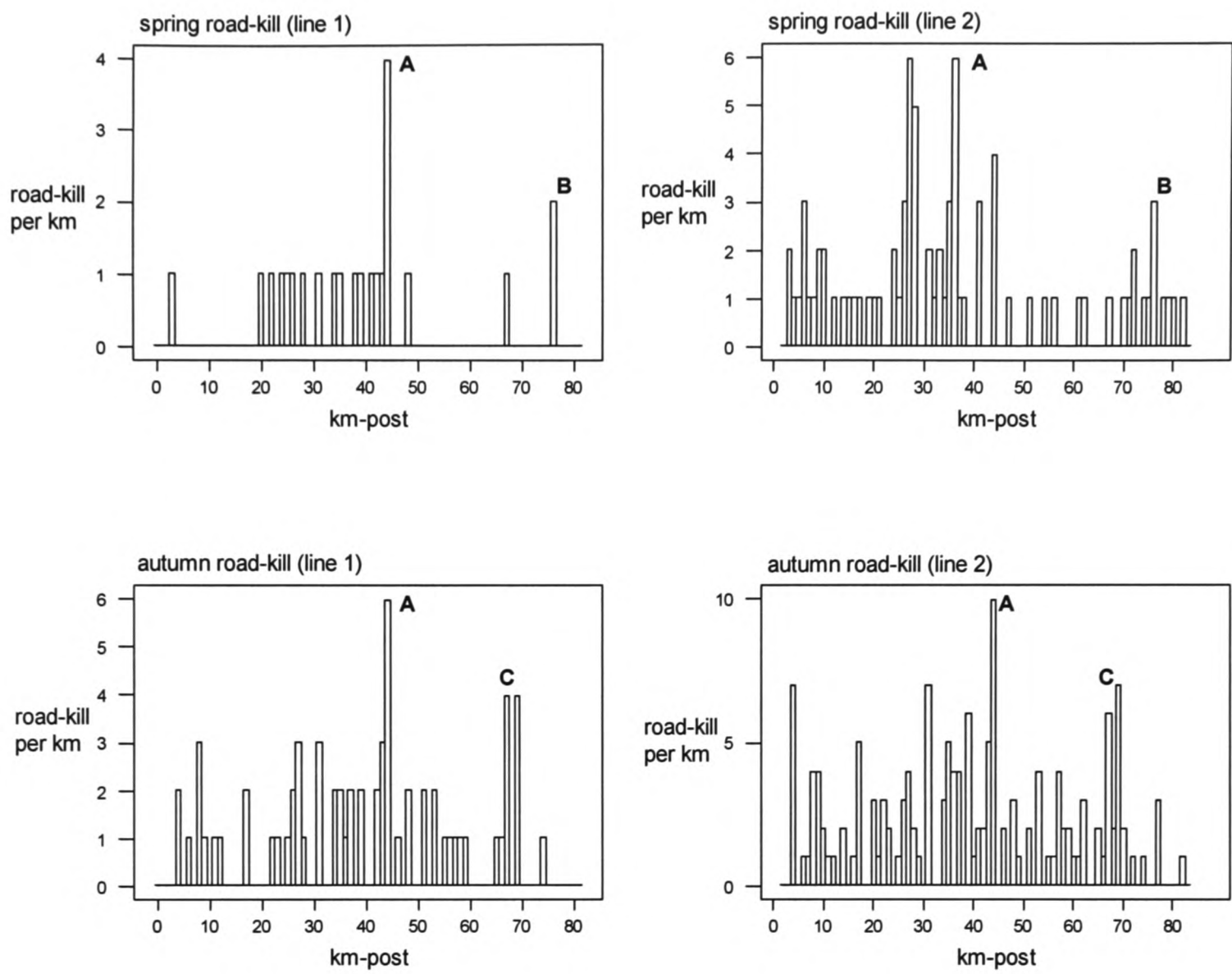
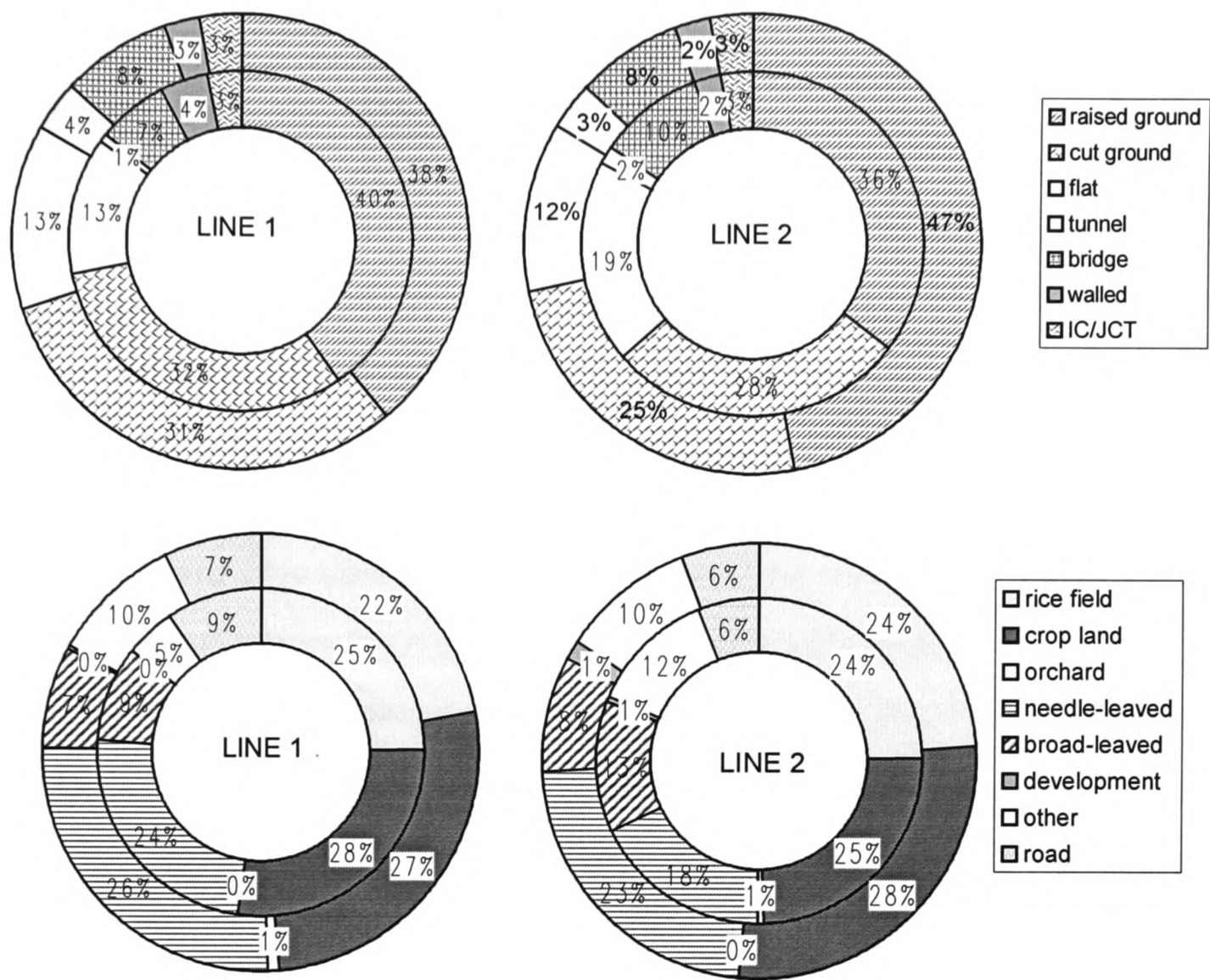


Figure 6.14 Frequency distribution of raccoon dog road-kills on the Miyazaki-do in spring and autumn, 1989.



The compositions of the road features and the habitat types for the entire length and the road-kill sites are shown in Figure 6.15.

Figure 6.15 Road features (top) and habitat (bottom) on entire roads (outer circle) and road-kill sites (inner circle) of the two lines of the Miyazaki-do.



In order to investigate which factors influenced occurrence of road-kills, I used 4 predictors (variables) in a logistic regression: road feature, road-crossing type, roadside habitat type, and the distance to water (Table 6.1). The number of observations was 825 for each line. The logistic regression analysis yielded different results for each line. The distance to water significantly influenced the road-kills (presence or absence) on line 1 ($p < 0.0207$) whereas the road feature had a significant influence on line 2 ($p < 0.0467$) (Table 6.3).

Table 6.3 Analysis of Maximum Likelihood Estimates for the factors affecting on road-kills of the raccoon dog on the Miyazaki-do.

Variable	DF	Parameter Estimate	SE	Wald Chi-Square	p > Chi-Square	Standardised Estimate	Odds Ratio
line 1							
Intercept1	1	1.4198	0.2532	31.4333	0.0001	.	.
Intercept2	1	3.5401	0.3419	107.1872	0.0001	.	.
Intercept3	1	5.6375	0.7446	57.3186	0.0001	.	.
road feature	1	0.0150	0.0649	0.0533	0.8174	0.013042	1.015
water	1	0.6822	0.2950	5.3478	0.0207	0.142167	1.978
crossing	1	0.0191	0.1774	0.0116	0.9142	0.006138	1.019
habitat	1	0.0126	0.0467	0.0723	0.7881	0.015308	1.013
line 2							
Intercept1	1	1.6644	0.2191	57.6834	0.0001	.	.
Intercept2	1	3.5736	0.2774	165.9734	0.0001	.	.
Intercept3	1	5.5885	0.5408	106.7807	0.0001	.	.
road feature	1	-0.1021	0.0513	3.9554	0.0467	-0.091006	0.903
water	1	0.1148	0.2587	0.1968	0.6573	0.021525	1.122
crossing	1	-0.0032	0.1494	0.0004	0.9832	-0.001011	0.997
habitat	1	-0.0211	0.0395	0.2859	0.5929	-0.025677	0.979

Using Chi-square analysis, I tested whether the presence of road-kills on 100-m segments was independent of road features or roadside habitat type.

There was a significant effect of road features ($\chi^2 = 19.025$, $DF = 6$, $p < 0.004$) and an effect of road-side habitat types on road-kills which approached a significant level ($\chi^2 = 13.849$, $DF = 7$, $p < 0.054$) on line 2. On line 2, there were more road-kills on bridges, in cuttings and ground-level roads and fewer road-kills on raised roads than expected (Table 6.4b). There were also more road-kills on roads adjacent to broad-leaved forest and fewer road-kills on roads adjacent to coniferous forest and cropland than expected (Table 6.4d). However, on line 1, there were no significant effects of road feature ($\chi^2 = 4.785$, $DF = 6$, $p < 0.572$) or habitat type ($\chi^2 = 7.402$, $DF = 7$, $p < 0.388$) although the effects of broad-leaved and coniferous forests on road-kills showed a similar trend to line 2 (Table 6.4c).

Table 6.4 Contingency tables testing independence of the road feature and road-kills, and habitat type and road-kills on the line 1 and line 2 of the Miyazaki-do.

a) road features of line 1

Observed Expected	road-kill site	no road-kill	Total
risen	47 45.524	274 275.48	321
cutting	37 36.447	220 220.55	257
ground level	15 15.175	92 91.825	107
tunnel	1 4.2545	29 25.745	30
bridge	8 9.0764	56 54.924	64
walled	5 2.9782	16 18.022	21
IC/JCT/PA/SA	4 3.5455	21 21.455	25
Total	117	708	825

$\chi^2 = 4.785$, DF = 6, $p < 0.572$

b) road features of line 2

Observed Expected	road-kill site	no road-kill	Total
risen	57 75.933	330 311.01	387
cutting	46 40.255	159 164.75	205
ground level	31 19.047	66 77.953	97
tunnel	3 5.4982	25 22.502	28
bridge	16 12.371	47 50.629	63
walled	4 3.7309	15 15.269	19
IC/JCT/PA/SA	5 5.1055	21 20.895	26
Total	162	663	825

$\chi^2 = 19.025$, DF = 6, $p < 0.004$

Table 6.4 continued.

c) habitat type along line 1

Observed Expected	road-kill site	no road-kill	Total
rice field	29 25.811	153 156.19	182
crop land	32 30.916	186 187.08	218
orchard	0 1.1345	8 6.8655	8
conifer	28 30.916	186 183.65	214
broad-leaved	11 8.5091	49 51.491	60
development	0 0.4255	3 2.5745	3
road	11 8.3673	48 50.633	59
other	6 11.487	75 69.513	81
Total	117	708	825

$\chi^2 = 7.402$, DF = 7, $p < 0.388$

d) habitat along line 2

Observed Expected	road-kill site	no road-kill	Total
rice field	40 38.880	158 159.12	198
crop land	40 44.378	186 187.08	226
orchard	1 0.1964	0 0.8036	1
conifer	29 36.916	159 151.08	188
broad-leaved	21 13.745	49 56.255	70
development	1 2.3564	11 9.6436	11
road	10 9.6218	39 39.378	49
other	20 15.905	61 65.095	81
Total	162	663	825

$\chi^2 = 13.849$, DF = 7, $p < 0.054$

6.3.4 Estimates of total road-kills of raccoon dogs

Using the data on the National Expressways, total estimates of road-kills (on four types of roads: the National Expressways, the National, Prefectural and Municipal roads) were obtained with combinations of assumptions. Estimates of total road-kills of raccoon dogs varied greatly depending upon a combination of assumptions. The essential assumption is that road-kills are proportional to road distance (assumption 1). Assumptions for traffic volume (assumptions 2, 5, 6, 7, and 8) are difficult to be selected because road-kills may respond non-linearly to traffic volume, or the response may be scale-dependent on measurements of traffic volume. The general attributes of the different categories of road used for estimations are shown in Table 6.5. Based on data available for the National Expressways, estimates of raccoon dog road-kills with a combination of assumptions are shown in Table 6.6. These estimates were nationwide averages that do not take into consideration the difference in raccoon dog densities. Assumptions 6 and 7 were made because road-kill rate had a significant relationship with traffic volume by road segment between interchanges on Kyushu, Miyazaki and Nagasaki Expressways (Linear regression, $r^2 = 29.0\%$, $F_{1,37} = 15.13$, $p < 0.001$; Figure 6.16), suggesting that traffic volume negatively influences road-kills at this scale. Table 6.6 also indicates that road-kills on the municipal roads influence substantially on total road-kills that vary according to assumptions employed due to their long distance.

Table 6.5 Road attributes by road type in 1997 in Japan. (data from the Ministry of Land, Infrastructure and Transportation).

Attribute	National Expressway	National Highway (designated)	National Highway (other)	Prefectural road	Municipal road
total distance (km)	6359.5	20654.4	32626.9	126833.1	961406.1
ratio	1.00	3.23	5.10	19.81	150.17
traffic volume (vehicle/day)	32661	18360	7916	4847	574
ratio	1.00	0.562	0.242	0.148	0.018
average speed (km/h)	82.8	29.3	33.7	28.5	28.5
ratio	1.00	0.354	0.407	0.344	0.344
average road width (m)	14	9	10	6	4
average total width (m)	23	14	10	6	5
1/road-width ratio	1.00	1.56	1.40	2.33	3.50
nightly traffic (%)	31.5	27.5	22.8	no data	
ratio	1.00	0.873	0.724		
nightly average speed	no data				
1/traffic-volume ratio	1.00	1.78	4.13	6.74	56.9
kill rate (road-kill/km) obtained with regression	2.615	3.073	3.407	3.505	3.642
ratio	1.00	1.175	1.303	1.340	1.393

The data for traffic and speed are on weekdays.

Table 6.6 Estimates of annual total road-kills of raccoon dogs in Japan based on the 1997 data on the National Expressways, with several assumptions.

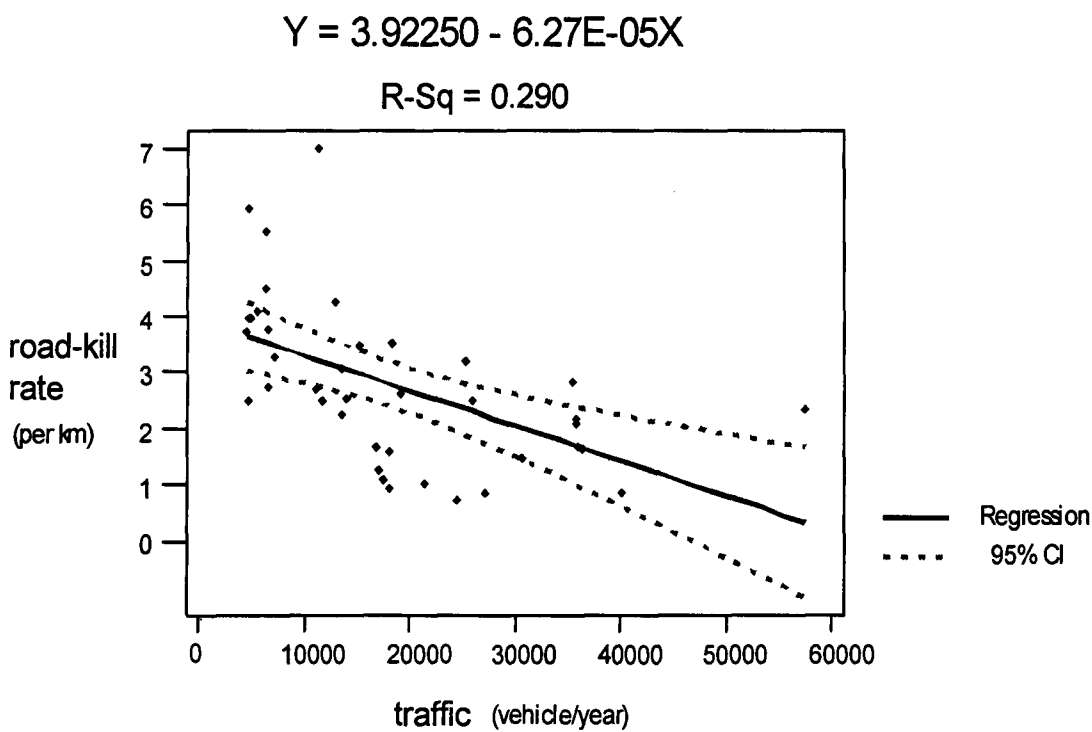
National Expressway	National (designated)	National (other)	Prefectural road	Municipal road	Total road-kills	Assumption(s)
9598	30965	48915	190151	1441358	1,730,585	1
	10958	19909	65450	496120	611,632	1,3
	26977	46087	28219	25331	145,810	1,2
	6160	4825	9713	8719	58,211	1,2,3
	17045	27872	152718	1736419	1,953,250	1,3,4
	27077	16598	65845	88659	217,375	1,2,4
	9582	6755	22664	30517	88,714	1,2,3,4
	8365	4891	16409	18310	57,573	1,2,3,4,5
	55088	201823	1281235	1441358	2,989,101	1,6
	19494	82143	441005	496120	1,048,359	1,3,6
	14881	20174	96964	551244	702,458	1,3,4,5
	17018	59456	280003	157498	523,573	1,3,5,6
	36384	63736	254802	1441358	1,815,477	1,7
	12875	25941	87704	496120	641,825	1,3,7
	17485	26287	129931	551244	744,143	1,3,4,5,7
	11240	18776	55685	157498	262,396	1,3,5,7
	26473	83238	653340	551244	1,323,893	1,3,4,5,6
	14881	20174	96964	92058	243,272	1,3,4,5,8

The number of road-kills are:

- 1 proportional to distance.
- 2 proportional to traffic volume.
- 3 proportional to average speed.
- 4 proportional to the reciprocal of road width (=accessibility to road).
- 5 proportional to nightly traffic volume.
- 6 adjusted by traffic volume with the regression equation, $y = 3.92 - 0.0000627x$, where y is road-kill rate and x is traffic volume.
- 7 adjusted by traffic volume with the regression equation, excluding municipal roads.
- 8 independent from traffic volume except municipal roads where road-kill rate is 1/6.

20% and 10% were used as the nightly traffic for prefectural road and municipal road, respectively.
Assumption 8 was made based on Clarke et al. (1998).

Figure 6.16 Regression plot of road-kill rate and traffic volume between interchanges.



Differences in assumptions have different effects on road-kill estimates by region due to the composition of road categories and road-kill rates. Table 6.7 displays estimates of road-kills by prefecture based on prefectural road-kill rate, i.e. the average road-kills/km from 1995 to 1998 on the Expressways. Because wildlife administration and road management are often the jurisdiction of prefectures, road-kill estimates need to be conducted at the prefectural scale. In addition, the order of estimates by prefecture differ depending upon assumptions due to the different road compositions between prefecture (Table 6.7). I selected two combinations of assumptions: one employed relatively complicated assumptions on traffic volume and speed, and another employed simple combinations. Both assumed a linear relationship between road-kills and road distance and one-sixth of road-kill rate on the municipal roads of that on other road categories. The formula for the estimates with assumptions 1, 3, 5, and 8 are:

$\Sigma K = drn$, where K is number of road-kills, d is road distance, r is road-kill rate, n is nightly traffic ratio; all ratios are to the Expresswaysⁱⁱ. With assumptions 1 and 8, $K = dr$ for National Highways and Prefectural roads and $K = dr/6$ for Municipal roads were used (the divider of 6 was employed according to Clarke *et al.*, 1998).

ⁱⁱ For example, the number of road-kills in Hokkaido was calculated as: $K = 6,322 \text{ km} \times 0.431 \times 0.407 \times 0.724 + 11,622 \text{ km} \times 0.431 \times 0.344 \times 0.635 + 68,048 \text{ km} \times 0.431 \times 0.344 \times 0.317 \div 6 = 2430$ (see the ratios in Table 6.5).

Table 6.7 Estimates of the annual road-kills of the raccoon dog by prefecture in Japan based on the prefectural road-kill rate (road-kill/km) on the National Expressways.

Prefecture	National roads (km)	Prefectural roads (km)	Municipal roads (km)	Road-kill rate	Assumptions 1,3,5,8	Assumptions 1,8
Hokkaido	6322	11622	68048	0.431	2430	8035
Aomori	1336	2404	14978	2.061	2455	8283
Iwate	1706	2994	27285	1.759	2907	11365
Miyagi	1159	2257	18573	1.018	1194	4568
Akita	1282	2412	18650	1.155	1437	5329
Yamagata	1119	2496	11538	0.664	720	2254
Fukushima	1988	4046	31646	1.625	3323 (10)	12563
Ibaraki	1082	3292	50280	1.109	2165	11273
Tochigi	916	2763	19614	1.373	1688	6543
Gunma	919	2456	30546	1.329	1810	8589
Saitama	862	2476	42262	0.681	1065	5724
Chiba	1137	2562	34409	1.780	2705	12886 (10)
Tokyo	321	2304	20550	0.460	447	2066
Kanagawa	693	1414	22439	0.645	594	2964
Niigata	2010	4575	29053	1.129	2393	8493
Toyama	486	2158	9971	0.922	734	2524
Ishikawa	596	1876	9723	0.922	703	2421
Fukui	753	1549	7761	0.922	646	2056
Yamanashi	596	1362	8573	0.701	441	1559
Nagano	1746	3826	40595	0.631	1317	5699
Gifu	1519	3104	24363	0.515	808	3060
Shizuoka	1233	3140	31159	0.645	1041	4495
Aichi	1273	4093	42108	0.436	888	4015
Mie	1263	2868	19711	1.918	2602	9525
Shiga	657	1795	8653	0.346	257	844
Kyoto	859	2194	11539	1.841	1734	5827
Osaka	598	1739	15472	0.603	505	2129
Hyogo	1407	4370	27800	2.041	3825 (9)	14252 (8)
Nara	798	1291	9770	0.597	415	1481
Wakayama	1028	1860	9658	1.920	1699	5349
Tottori	536	1607	6041	1.945	1204	3655
Shimane	917	2474	14091	4.000	4267 (7)	14915 (7)
Okayama	1021	3584	26119	3.189	4969 (4)	19856 (4)
Hiroshima	1436	3576	21900	2.887	4625 (6)	16425 (6)
Yamaguchi	1100	2727	11591	2.240	2533	7818
Tokushima	699	1768	11743	0.546	439	1615
Kagawa	369	1550	7570	0.953	558	1948
Ehime	1083	2910	13042	1.966	2344	7470
Kochi	1050	2083	9757	1.223	1151	3547
Fukuoka	1079	3461	30797	2.957	4831 (5)	20644 (2)
Saga	593	1245	8039	2.286	1355	4773
Nagasaki	940	1621	14840	2.286	2059	8037
Kumamoto	1234	2987	20102	3.678	5081 (3)	18641 (5)
Oita	1011	2529	13286	3.625	3958 (8)	13249 (9)
Miyazaki	1166	1985	15664	6.397	6793 (1)	24904 (1)
Kagoshima	1276	3531	21149	3.678	5633 (2)	20160 (3)
Total	53,174	126,936	962,458		96,748	363,825
Total number of road-kills including Expressways					106,955	374,032

The number in parenthesis is a ranking in top 10 by prefecture.

6.4 DISCUSSION

6.4.1 Trends in road-kills and road-kills as an index of population trend

Except for the domestic dog and hare, the temporal trends of road-kills for all species analysed have increased over time on the National Expressways. Deer, for example, showed an upper-swing increase, and deer densities have apparently increased in many parts of Japan (Kaji, 1995; Nakamura and Ono, 1999; Matsuda *et al.*, 1999; Takayanagi, 2000). In contrast, the domestic dog showed a curvi-linear drop, and programmes to exterminate stray dogs and the increasing practice of keeping dogs on a leash have effectively decreased free-ranging domestic dog densities. The upper concave curve indicates an increase in population density whereas the upper convex curve indicates a decrease. If the two examples can be considered respectively as standards for species with density increases and decreases, population trends of other species may be assessed in a similar way.

However, where information is available on traffic levels, other conclusions may be drawn. In the case of raccoon dogs, an increase in road-kills was not necessarily evidence of a concomitant population increase, because the increase had a linear relationship with an increase in traffic volume (Figure 6.5b). In contrast, road-kills of sika deer had a greater rate of increase than traffic volume (Figure 6.5c), suggesting that the deer population may have increased. However, caution is required because density increase does not necessarily mean total population increase when concentrations occur locally, and new roads may result in more road-kills than old ones. Other population parameters such as recruitment rate and survival rate are also needed to confirm the population trajectory. None the less, trends in road-kills may be a useful index for short-term population trend, especially in conjunction with traffic data. An example of this demonstrated by McCaffery (1973), who found regional and temporal correlations between buck harvest and road-kills in Wisconsin, USA. He adjusted road-kills with percent changes in annual traffic volume for a long-term trend analysis, and the state has operated an elaborate population survey system along with hunting management, further supporting his results. Although reaction to traffic changes probably varies with species, it is still useful for temporal comparisons within species when traffic is measured at an appropriate scale for the species. In contrast, harvest data - another widely used method of estimating population trends - often include more species specific complications. For example, pelt price

and/or number of hunters, which may differ by species and year, often influence harvest effort; an accurate estimate of these effects is difficult. The average road-kill rate on the Expressways by prefecture was correlated significantly with the average harvest density from 1995 to 1998 (Figure 6.11), suggesting that road-kill rate can be used as an index of population density of raccoon dogs.

A great deal of variation in geographic distribution of road-kills was observed. One of the factors may have been regional density of animals. Density estimation of raccoon dogs is difficult and has not been conducted at a large scale in Japan. If the relationship between road-kill rate and density is obtained, the information can be used for both road-kill prevention and monitoring populations.

6.4.2 Factors influencing road-kills

The data in this study showed two seasonal peaks in road-kill frequency: a larger peak from September to November and a smaller peak from February to April (Figure 6.10). Other authors have also reported peaks of raccoon dog road-kills in autumn (Iimura, 1986; Kinoshita and Yamamoto, 1993; Machidanuki Executive Committee, 1995; Tsukada, 1998) and early spring (Iimura, 1986; Kinoshita and Yamamoto, 1993). Kinoshita and Yamamoto (1993) found that more males (85% of 20 corpses collected, including unknown cause of death) than females had been killed in March. Fukue (1992) and the Machidanuki Executive Committee (1995) postulated that increases were due to the increasing dispersal of young in the autumn. Sub-adults, which do not have stable home ranges, would be more prone to suffering traffic accidents than adults with their stable and familiar home ranges (Chapter 4). In the case of Florida scrub-jays (*Aphelocoma coerulescens* Bosc), road-naïve immigrants to roadside habitat, were killed by car more frequently than immigrants to a non-roadside habitat and resident survivors (>3 years) of a roadside habitat (Mumme *et al.*, 2000).

The bimodal distribution in seasonal road-kill frequency could also result from low activity during the cold months and restricted movements of nursing pairs and small pups during the nursing season (Chapter 4). Bimodal distributions of road-kills have also been reported for rabbit (*Lepus* Linnaeus and *Sylvilagus* Gray), skunk (*Mephitis mephitis* Schreber and *Spilogale putorius* Linnaeus), opossum (*Didelphis marsupialis* Linnaeus), deer (*Odocoileus virginianus* Zimmermann and *O. hemionus* Rafinesque), muskrat (*Ondatra*

zibethicus Linnaeus) (Case, 1978), and the Eurasian badger (Davies *et al.*, 1987).

Average speed and traffic volume during the night, particularly at dusk and dawn, could be more critical for nocturnal species than the 24-hour average of both (Figure 6.10). If roads lie between resting/den sites and foraging sites, commuting humans and nocturnal animals are likely to coincide, increasing the probability of road-kills. In such cases, local roads used for human commuting can be dangerous to wildlife even with a relatively low traffic volume. Inbar and Mayer (1999) found that road-kills of the armadillo (*Dasypus novemcinctus* Linnaeus) in the USA correlated with night traffic volume but not daytime traffic volume, and more road-kills occurred in summer when armadillos are more strictly nocturnal (diurnal activity was observed in winter). They also found a relationship between road-kills and climatic factors and soil pH, implying that activity of the animals influenced road-kills. Rolley and Lehman (1992) found that road-kills of the raccoon (*Procyon lotor* Linnaeus) were not significantly correlated with traffic volume, but with the speed of passenger cars. Inbar and Mayer (1999) noted that the sampling scale of traffic volume data might be important.

In this study, two opposite relationships were found between road-kills and traffic: traffic volume by road had a positive effect on total road-kill rate by road (although two extremely busy roads with >70,000 vehicles/day and two roads with high road-kill rates were excluded from the analysis)(Figure 6.10), whereas traffic by segment between interchanges had a negative effect on road-kill rate by segment (Figure 6.16). Traffic volume above some threshold may have an effect on animals crossing, or animals may react to traffic at a fine scale by individual decision. In contrast, total road-kills depend on traffic volume; road-kills may be a coarse-scale phenomenon dependent upon probability of collisions.

The high road-kill rates at sites in a cutting on line 2 were consistent with my personal observations in the Chiba prefecture. Also, the dissociation of road-kills with coniferous forests agreed with the results from the habitat selection study (Chapter 3). Crossing roads in a cutting and dissociation with coniferous forests are probably general characteristics associated with the species' ecology. However, different results from the line 2 of the Miyazaki-do also suggest that the occurrence of road-kills is spatially and temporally unique in each situation, making predictions difficult. The hot spot (43 - 44 km-post) lay between streams, and the road was mainly in a cutting. The spring hot-spot also included a stream; and small tributaries and ponds

were located near the autumn hot-spot. The presence of bodies of water appeared to increase road-kills because raccoon dogs often move along water (M. Saeki, pers. obs.) and/or food may be abundant near water. Yanase (1999) noted that numerous small-scale livestock sheds near Miyazaki-do may have influenced road-kills by attracting animals to available food. Data resolution of 100 m may not be appropriate to detect such effects.

6.4.3 Prevention of road-kills

In this study, there were no roads without road-kills nor roads with perfect permeability, except where they were confined to a bridge or tunnel with no entrances. According to Yanase (1999), the Japan Highway Public Corporation's goal for protecting wildlife is to secure the same level of movement of wildlife as existed before the road construction, despite the lack of knowledge of effects of roads on the ecosystem. A key factor in the prevention of road-kills is the concept of allowing safe wildlife movements, and this needs to be considered in road planning.

During planning, rigorous environmental assessments may reveal critical habitat and corridors for species, and cutting off traditional wildlife movement routes should be avoided. Needless to say, it is important for planners to incorporate ecological and environmental information in deciding where to install fences and passage facilities (culvert, overpass, underpass). For existing operational roads, mitigation measures may be useful, such as lowering speed limits, posting signs, building preventive facilities in high-risk areas, and providing road-kill information, such as locations and times of high risk. Overpasses or underpasses accommodating other roads and railways did not appear to have any value in providing safe passage across the Expressway for raccoon dogs as there was no significant effect of these road features in the logistic regression analysis ('crossing' in Table 6.2). Modifications of these, as well as the installation of new crossings for wildlife, may be needed.

Recent development of road networks and fast moving vehicles is likely to have been too rapid to allow wildlife species to adapt behaviourally or to evolve a 'road-kill resistant phenotype.' Any preventive methods need to be employed after consideration of the behaviour of the species. For example, providing trees and cover along side roads might encourage animals to escape towards them, instead of staying on the road. Lowering speed limits between dusk and dawn in autumn would also help. In contrast, installing fences alone may create habitat fragmentation, and underpasses are not effective in preventing road-kills unless

they exist at appropriate intervals and with properly built fences (Foster and Humphrey, 1995). Maintenance of the facilities is also essential. The cost of road-kills, both in terms of prevention cost and potential economic loss (economic value of wildlife, vehicle damage, etc.), needs to be included in the cost-benefit analysis in road construction.

6.4.4 Estimates of road-kills

Even with few data available, the total number of raccoon dogs estimated to be killed on National, Prefectural and Municipal roads exceeded the number of road-kills recorded on the National Expressways, the total distance of which comprises only 0.55% of the total public roads in Japan (Figure 6.1). Several assumptions were required to estimate total road-kills without quantitative data on National Highways, Prefectural and Municipal roads. These assumptions need to be validated and refined in the future. Depending upon the assumptions used, nationwide estimates varied from less than 60,000 to over 2 million (Table 6.6), indicating their importance in the calculations. The road attributes in the assumptions also interact with each other, causing further complications. For example, traffic volume is related both to road width and to average speed.

In addition, road-kills possibly have non-linear relationships with these road features. Clarke *et al.* (1998) found similar road-kill rates of badgers on 4 types of roads with different traffic volumes, but a lower road-kill rate (about 1/6) on Class C roads with low traffic volume (530 vehicles/day; cf. 574 vehicle/day on Municipal roads), suggesting that high traffic flow on motorways and dual carriageways (34,040 vehicle/day; cf. 32,661 vehicle/day on the Expressway) may discourage badgers from crossing roads. Although the raccoon dog in Japan and the badger in the UK differ in phylogeny, physiology, and habitat preference, some aspects of behaviour, especially movement patterns, appear to be similar (Chapter 5). Therefore, one of the assumptions in this study was based on the ratio of road-kill rate among road types from the above badger study. The same road-kill rate was applied to the Expressways, National Highways and Prefectural roads, whereas the Municipal roads were assigned 1/6 of the road-kill rate of the other roads.

Some of these calculated estimates may be too conservative because they were based on records of instantaneous deaths. For example, of the four radio-collared study animals killed by car (Chapter 4), only two were found on the road; the other two were found in

nearby woods and in a gutter.

6.4.5 Impact of road-kills on population

The impact of road mortality on wildlife populations has not been assessed in Japan. If 110,000 - 370,000 raccoon dogs are killed each year and the number of road-kills increases as traffic volume increases, the impact of road mortality on the population cannot be ignored. In Britain, traffic casualties were considered to account for 30 - 66% of all adult and post-emergence cub mortality of badgers (Skinner *et al.*, 1991; Clarke *et al.*, 1998). Mumme *et al.* (2000) noted that highways can act as a demographic sink for the Florida scrub-jay.

Age structure and social organisation can be altered by high anthropogenic mortality. Yamamoto and Kinoshita (1994) found the average age of raccoon dogs to be 1.173 years ($n = 131$), of which 82.4% were road-kills in Kawasaki-city (population ca. 1.2 million). Furthermore, indirect effects of road accidents such as poor survival rate, reproductive failure of individuals with permanent injuries and orphaned young, cannot be measured.

In future studies, demographic and physiological information of road-kills is essential for assessment of impact of road-kills on populations. If administrators and road-management personnel in local governments can co-operate to collect data on road-kills, monitoring status of wildlife, not only raccoon dogs but also other species, can be carried out at a population level.

CHAPTER 7
AGRICULTURAL DAMAGE
BY THE RACCOON DOG

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Summary

In 1999, I conducted a questionnaire survey of agricultural damage caused by wildlife in Japan, with a particular focus on the raccoon dog. All responding prefectures, i.e. local governments, (95.7%) reported some damage by wildlife, and 68.2% reported raccoon dog damage. Sixty-nine agricultural products were reported to be damaged by wildlife, and 41 of these by raccoon dogs. I will discuss here interactions between human and ecological factors which lead to agricultural damage by the raccoon dog, and then propose preventive measures, and discuss compensation programmes.



Chapter 7 Agricultural Damage by the Raccoon dog

7.1 INTRODUCTION

7.1.1 *Agricultural damage by wildlife*

Conflicts between farmers and wildlife occur in both developed and developing countries. Financial losses through livestock predation are extensive in the USA: losses of cattle worth \$40 million (1995), sheep worth \$16.5 million (1999), and goats worth \$3.4 million (in three major states in 1999) forced ranchers to spend \$8.8 million on non-lethal predator control to protect sheep and \$10 million to protect goats (National Agricultural Statistics Service, 1996, 2000). Crop damage can also be considerable. For example, in 1998, the economic damage inflicted by wildlife on the apple, grape and blueberry industries was estimated at \$41 million over seven major fruit-producing states in the USA, with approximately \$10 million spent on preventive measures including pyrotechnics, fencing, frightening devices, flagging and repellents (National Agricultural Statistics Service, 1999). In 1997, the state of Oregon lost \$158 million due to agricultural damage by wildlife (92% as crop damage); 47% of farmers in the state reported some damage, and \$6.0 million was spent on attempted prevention (Oregon Agricultural Statistics Service, 1998).

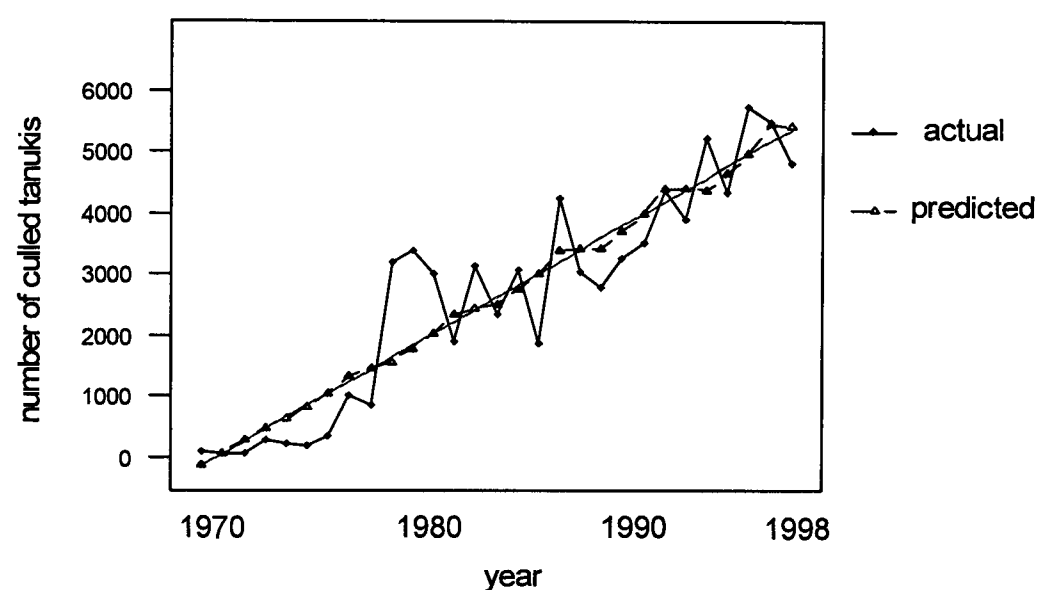
In developing countries, many local people living close to protected areas experience conflicts with wildlife. In India, nearly half of village households adjacent to the Sariska Tiger Reserve suffer crop and livestock damage by wildlife, and over two-thirds of the villagers spend substantial time and money on attempted prevention, mainly by guarding and fencing (Sekhar, 1998). In Tanzania, over 71% of people living adjacent to five National Parks and one Game Reserve reported wildlife problems, of which 86% were crop damage and 10% involved loss of livestock and poultry (Newmark *et al.*, 1994).

In Japan, wildlife has rarely posed a problem for livestock farming. Damage to the rice crop, however, has been a problem for farmers for centuries. Historically various measures have been used in an effort to reduce such crop damage by wildlife. During ancient times, stone walls were built to prevent damage by deer or boar, and more recently traditional counter-measures have consisted mainly of frightening devices, guarding, and fencing. Today the decreased farm labour force and the advanced age of most farmers (>50% were 65 years old or older in 2000) has forced them to resort to killing wildlife in an effort to save time and

labour. Furthermore, nationwide habitat fragmentation and degradation may have led to increased contact between wildlife and the primary industries, such as agriculture, forestry, and fisheries. One estimate of wildlife damage to agriculture was recently conducted in Hokkaido. This concluded that deer caused crop damage costing 5 US billion (10^9) yen (approximately £31 million) in 1998 (National Land and Environment Committee, 1999).

Figure 7.1 shows a trend of culling raccoon dogs (*Nyctereutes procyonoides* Gray) (Environment Agency, 1971-1999). A conspicuous increasing trend in kills ($Y_{(t)} = -324.446 + 196.184t$) is apparent. If this trend reflects the amount of damage by raccoon dogs, the level of damage is considered to have increased for last 30 years or so. If not, other factors need to be investigated.

Figure 7.1 Trend of raccoon dog culling in Japan from 1970 to 1998.



7.1.2 Agriculture and the agricultural damage policy in Japan

In 1999, there were 2,475,000 farming households in Japan (only 17.5% full-time farmers). These accounted for 8.7% of the total population and 7.4% of the total labour force; 52.6% of the farming households produced solely rice (Ministry of Agriculture, Forestry and Fisheries, 2000b). The price of farmland in Japan (67,900 yen/hectare) is considerably higher than that of many other countries - 17.9 times more expensive than farmland in the UK and 48.5 times that in the USA (Central Union of Agriculture Corporation of Japan, 1999). This high price inflates the cost of agricultural products and encourages farmers to quit farming and sell their properties. The area under cultivation has decreased over time to 49 thousand km² (13% of total land area) in 1998 (Ministry of Agriculture, Forestry and Fisheries, 1999a). Excluding

Hokkaido, 62.0% in total farmers (37.8 - 87.3% by prefecture, i.e. local government) were small-scale farmers (those owning less than or equal to 1.0 ha of farmland) in 1995 (calculated with data from the Ministry of Agriculture, Forestry and Fisheries, 1996). The percentage of farming households was higher in Tohoku and Hokuriku regions (northern nine prefectures in Honshu) and was lower in Hokkaido, Kanto, and Kinki regions (Ministry of Agriculture, Forestry and Fisheries, 1995).

It is stated in the enforcement section of the *Law for Prevention of Epidemics on Plants*, 1972, that governors of prefectures should report to the Minister of Agriculture, Forestry and Fisheries all agricultural damage and prevention measures taken under their jurisdiction each year. The report requires the name of each wildlife species causing damage, the name of the crop, and the area, extent and period of damage. The area is defined as that which has been decreased or degraded compared to a standard harvest (i.e. harvest without damage); the extent of financial damage is that which has been decreased or degraded compared to a standard harvest. The period is defined in terms of stages of crop growth and agricultural activities. Prevention methods and associated problems and counter-measures are also required in the report.

Conflicts between wildlife and human activities often occur in the countryside in Japan, where agriculture and forestry are mainly practised. In particular, *satoyama* habitat (Chapter 3) has long been used for agriculture, and land use there has been integrated into an ecosystem (Osumi and Fukamachi, 2001). Changes in agriculture and land use may result in conflicts with wildlife because the ecosystem might become unbalanced through rapidly changing human activities (Appendix I). Agricultural damage by wildlife is a direct conflict, in which both farmers and wildlife can be victimised by ineffective countermeasures and management malpractices.

In order to investigate the scale, extent, and trend of raccoon dog damage in relation to overall damage by wildlife in Japan, I conducted a questionnaire survey of local prefectural governments, which administrate wildlife conservation and management.

7.1.3 Chapter Objectives

This chapter, then, has five objectives:

- to evaluate the significance of damage by the raccoon dog among agricultural damage by mammalian wildlife in Japan
- to identify current problems in wildlife management with respect to agriculture
- to describe factors contributing to damage caused by raccoon dogs
- and to examine damage-prevention methods.



7.2 METHODS

In December 1999, a postal questionnaire survey was conducted on the agricultural damage caused by wildlife, with a particular focus on the raccoon dog. The questionnaire used is shown in Appendix VI. It was sent to 46 prefectures (Figure 7.5 bottom), i.e. all except Okinawa, where the raccoon dog does not occur. Non-respondents were followed up by telephone in late January 2000. Any prefectures which had not responded by February 2000 were sent e-mails or faxes.

Data analysis

When replies to the questionnaires were analysed, the brown bear (*Ursus arctos* Linnaeus) which, in Japan, occurs only in Hokkaido, and the Asiatic black bear (*Selenarctos thibetanus* G. Cuvier) which does not occur in Hokkaido, were counted as 'bear.' Similarly, the mountain hare (*Lepus timidus ainu* Barrett-Hamilton) and the Japanese hare (*L. brachyurus* Temminck) were not distinguished and were counted as 'hare.' The small Japanese mole (*Mogera minor* Kuroda) which mostly inhabits the northern half of Honshu, and the large Japanese mole (*M. wogura* Temminck) which inhabits the southern half of Japan, were counted as 'mole.' Animals were not separated at the sub-species level. The one incident by a domestic dog (*Canis familiaris* Linnaeus) was excluded from the analysis.

Cluster analysis using Minitab was used to group wildlife species and prefectures depending upon the occurrence of damaging species reported by the responding prefectures, using MINITAB (Minitab, Inc., 1996).

A two-tailed Fisher's Exact test was conducted on the number of prefectures with respect to the trend of damage extent caused by wildlife, the history of ecological survey/research conducted (e.g. population estimates and species distribution), and the propensity for compensation programmes of prefectures.

Quadratic discriminant analysis was performed using Minitab to determine whether the occurrence of raccoon dog damage could be predicted from prefecture profile. Discriminant analysis is commonly used to predict group members through classification functions using predictors, i.e. independent variables (Tabachnick and Fidell, 1989). Quadratic discriminant analysis does not require the assumption of equal covariance matrices in all groups (Minitab, Inc., 1996). Prefecture profile consisted of the variables: percentage of farming households,

percentage of small-scale farming (equal or less than 1.0 ha), area, human density, percentage of natural forest, average annual temperature, average annual precipitation, percentage of lowland, and harvest density of the raccoon dog (an average of yearly harvest record/prefecture area from 1990 to 1998). Hokkaido was excluded because this prefecture differed from the others in both environmental and sociological aspects: three-quarters of farming households are classified as business farms (Ministry of Agriculture, Forestry and Fisheries, 1995), the farms are much larger (an average of 16.1 hectare per farmer) than in other prefectures, and it produces the largest share of food supplies in Japan (e.g. 70.2% of wheat, 71.4% of potatoes, 42.0% of milk, and 100% of sugar beet), according to Ministry of Agriculture, Forestry and Fisheries data (cited by the Hokkaido Prefecture, 2001).



7.3 RESULTS

Forty-four prefectures (95.7%) responded to the questionnaire. The following paragraphs describe and summarise responses from the prefectures in the order in that the questions were presented in the questionnaire (Appendix VI).

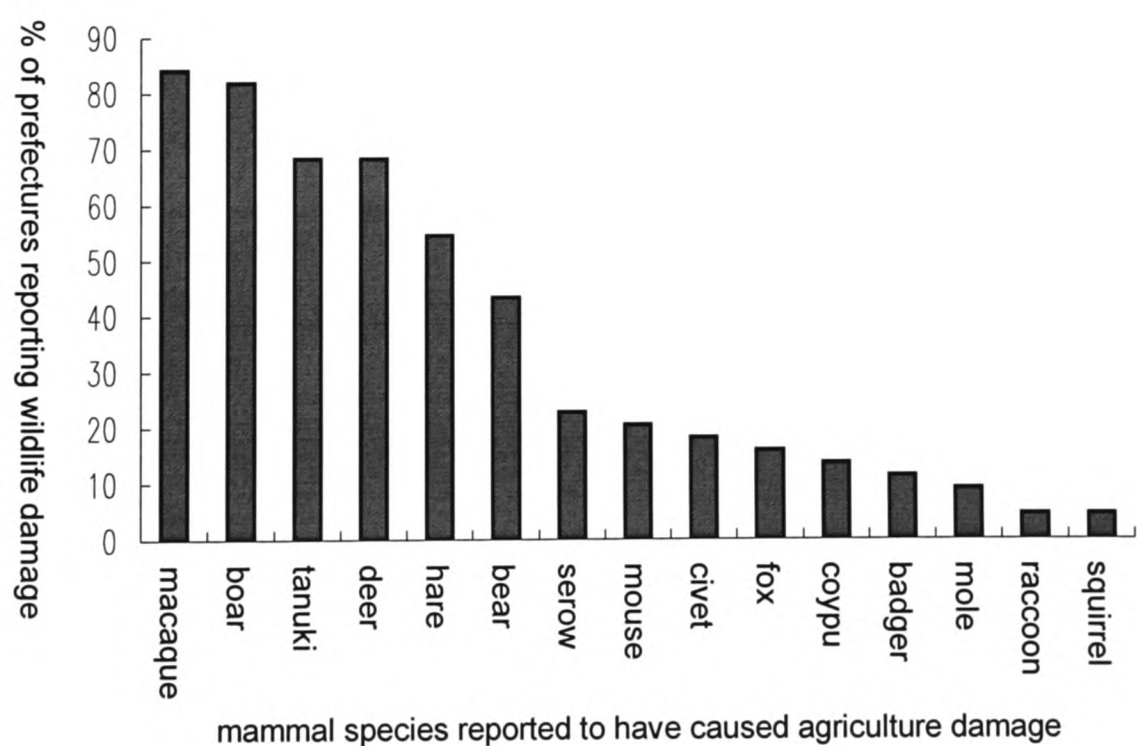
7.3.1 Agricultural damage by wildlife in the past 5 years (Q1)

All responding prefectures reported some damage by wildlife.

7.3.2 What kind of agricultural damage by which kind of wildlife? (Q2)

Eighteen mammalian species were reported to have caused damage. The mean number of species reported by a prefecture was 5.2 (n = 44, SE = 0.336), ranging from 1 to 10 species. More than 80% of responding prefectures reported the Japanese macaque (*Macaca fuscata* Blyth) and the wild boar (*Sus scrofa* Linnaeus), while nearly 70% reported the sika deer (*Cervus nippon* Temminck) and the raccoon dog (Figure 7.2) to have caused damage. Four species of introduced mammals were also reported: the masked palm civet (*Paguma larvata*), the common raccoon (*Procyon lotor* Linnaeus), the coypu (*Myocaster coypus* Molina), and the squirrel, introduced from Taiwan (*Callosciurus erythraeus taiwanensis* Bonhote).

Figure 7.2 Percentage of prefectures reporting each wildlife species for causing agricultural damage.



Sixty-nine crops, vegetables, fruits and other agricultural products were reported to have been damaged by mammalian wildlife in general, and 41 by raccoon dogs (Table 7.1). Fruit was the most frequently damaged category, followed by vegetables (Figure 7.3).

Table 7.1 Agricultural products reported damaged by mammalian wildlife and the number of prefectures reporting these damaged by raccoon dogs.

category	name	no.	category	name	no.
grain	sweet corn	15*	pulse	soybean	5
	dent corn	1		green soybean	1
	wheat	0		azuki bean	0
	rice	5		broad bean	1
	buckwheat	0		kidney bean	0
	hop	0		peanut	2*
		(25*)			(13*)
potato	potato	4*	fruit	melon	4*
	sweet potato	6*		apple	1
	taro	1*		grape	6*
	yam	3		peach	3*
		(14*)		pear	4
root vegetable	daikon radish	1		water melon	11
	horseradish	0		plum	1
	carrot	0		fig	2
	beet	0		strawberry	6
		(1)		quince	0
leaf/stalk/flower vegetable	cabbage	3		damson	1
	Chinese cabbage	0		chestnut	1*
	broccoli	0		persimmon fruit	2
	cauliflower	0		kiwi fruit	1*
	green onion	0		tangerine	6*
	onion	1		yuzu lemon	0
	udo	0		sudachi lemon	0
	tomato	5*		kumquat	1
	eggplant	2*		mulberry	1
	cucumber	3*		loquat	0
	gourd	1			(59*)
	pumpkin	2	other plants	bamboo shoot	0
	edible chrysanthemum	1		tea	0
	chingensai	0		silage	0
	spinach	0		pasturage	0
		(33*)		Devil's tongue	0
fish	char	1		myoga	0
		(1)		Hercule's club (bud)	0
poultry	chicken	2*		gingko nut	0
	chicken egg	2*			(0)
	duck	1	fungi	black mushroom	1
		(5*)	bee-keeping		0

*Including a combined number with masked palm civet. Total numbers in each category (in parentheses) are sometimes greater than the sum of each category because some prefectures reported only by category.

Figure 7.3 Percentage of prefectures reporting agricultural products damaged by raccoon dogs.

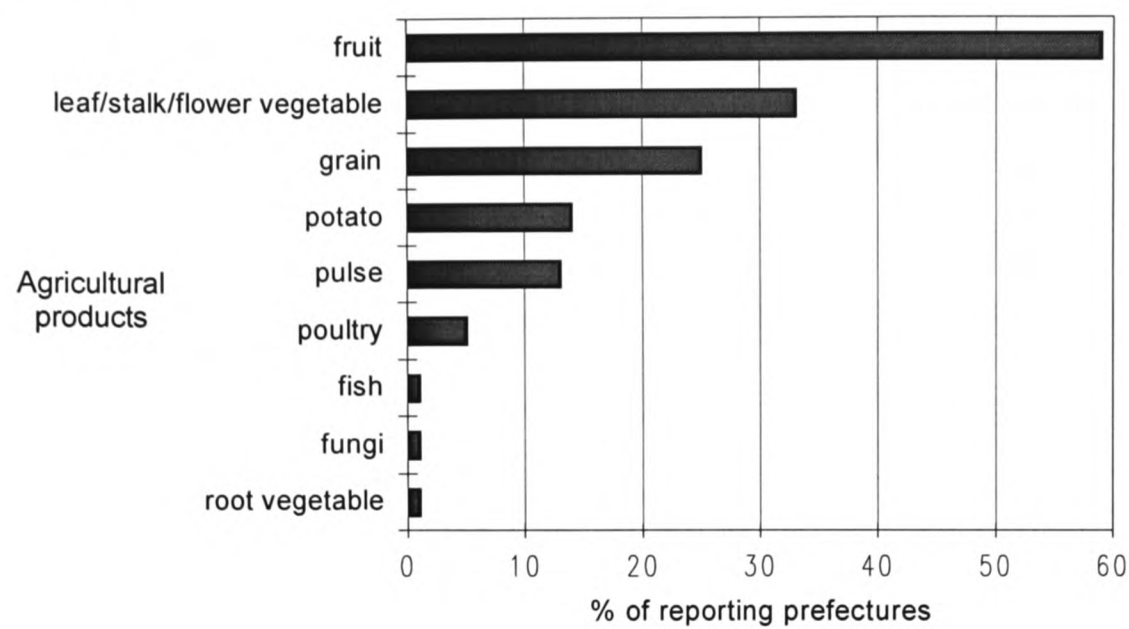
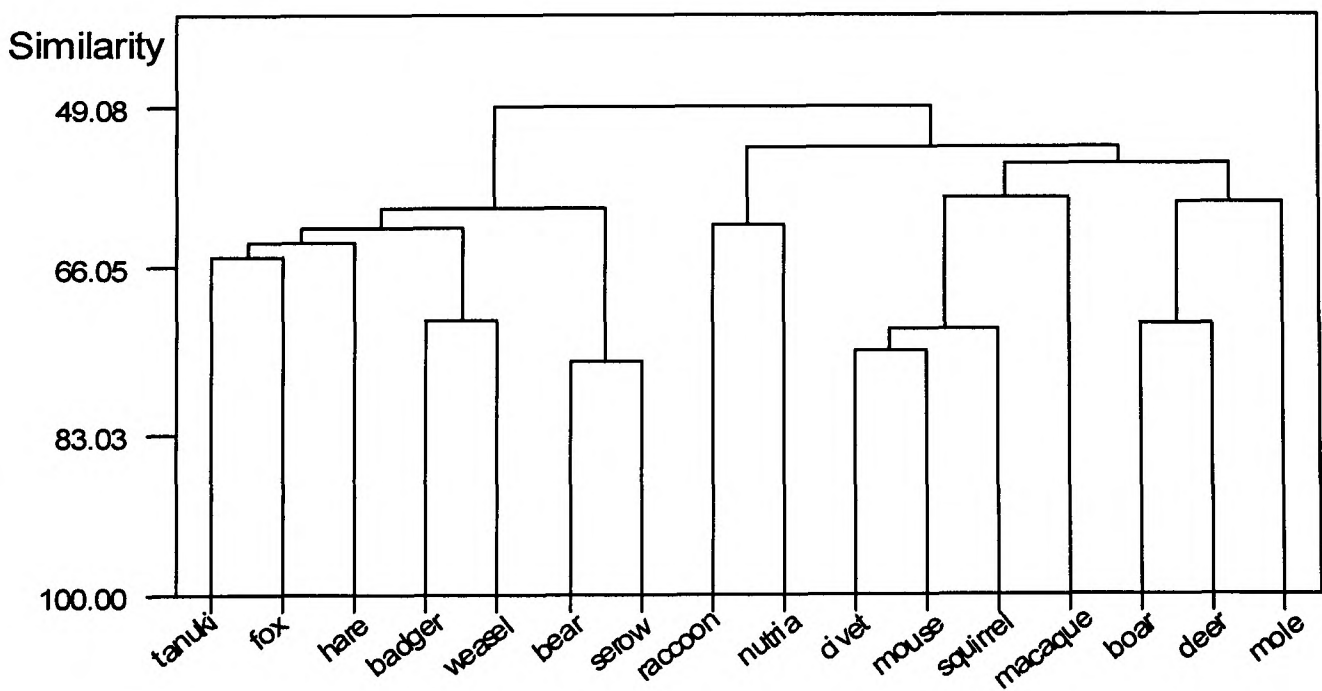


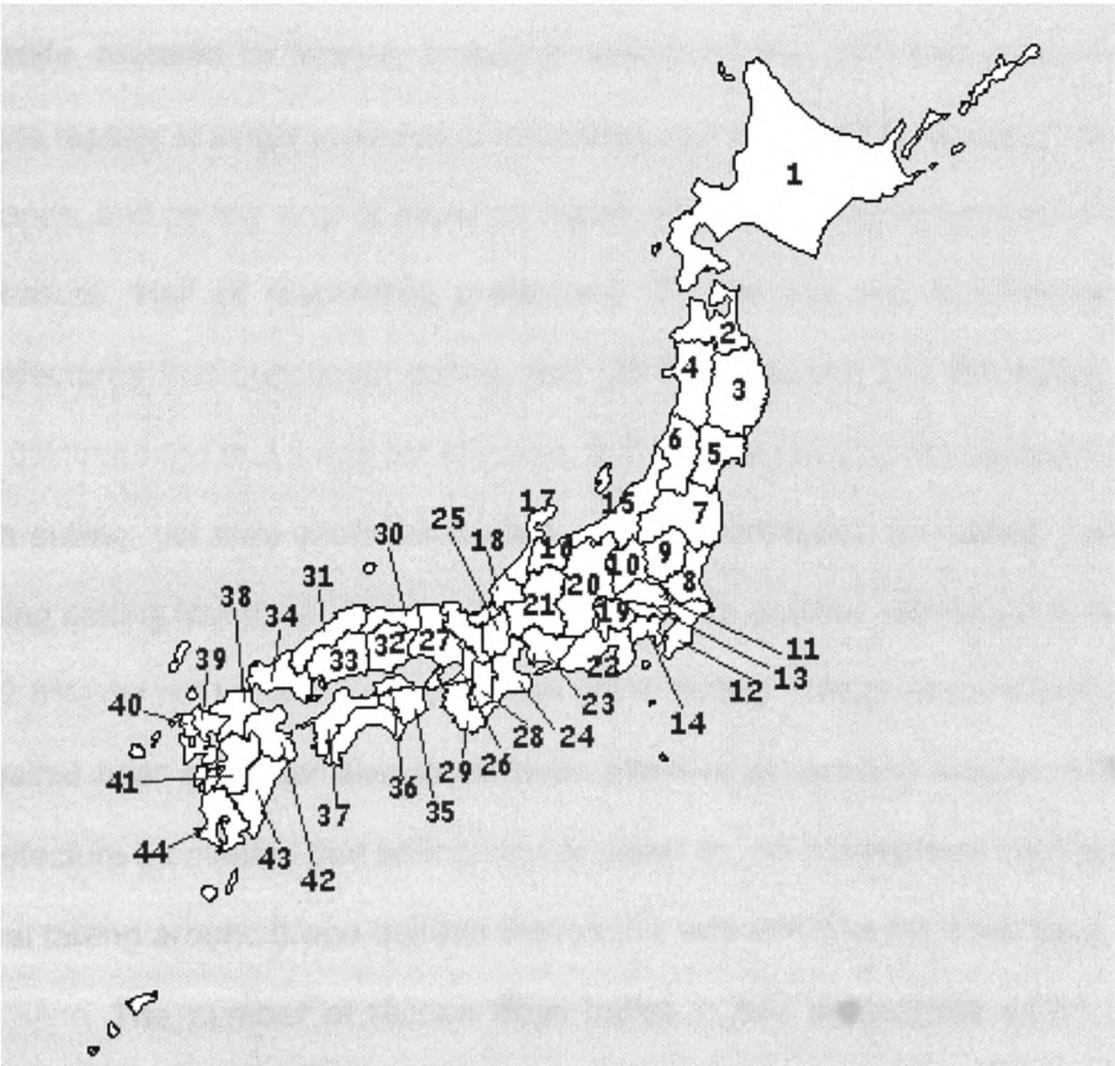
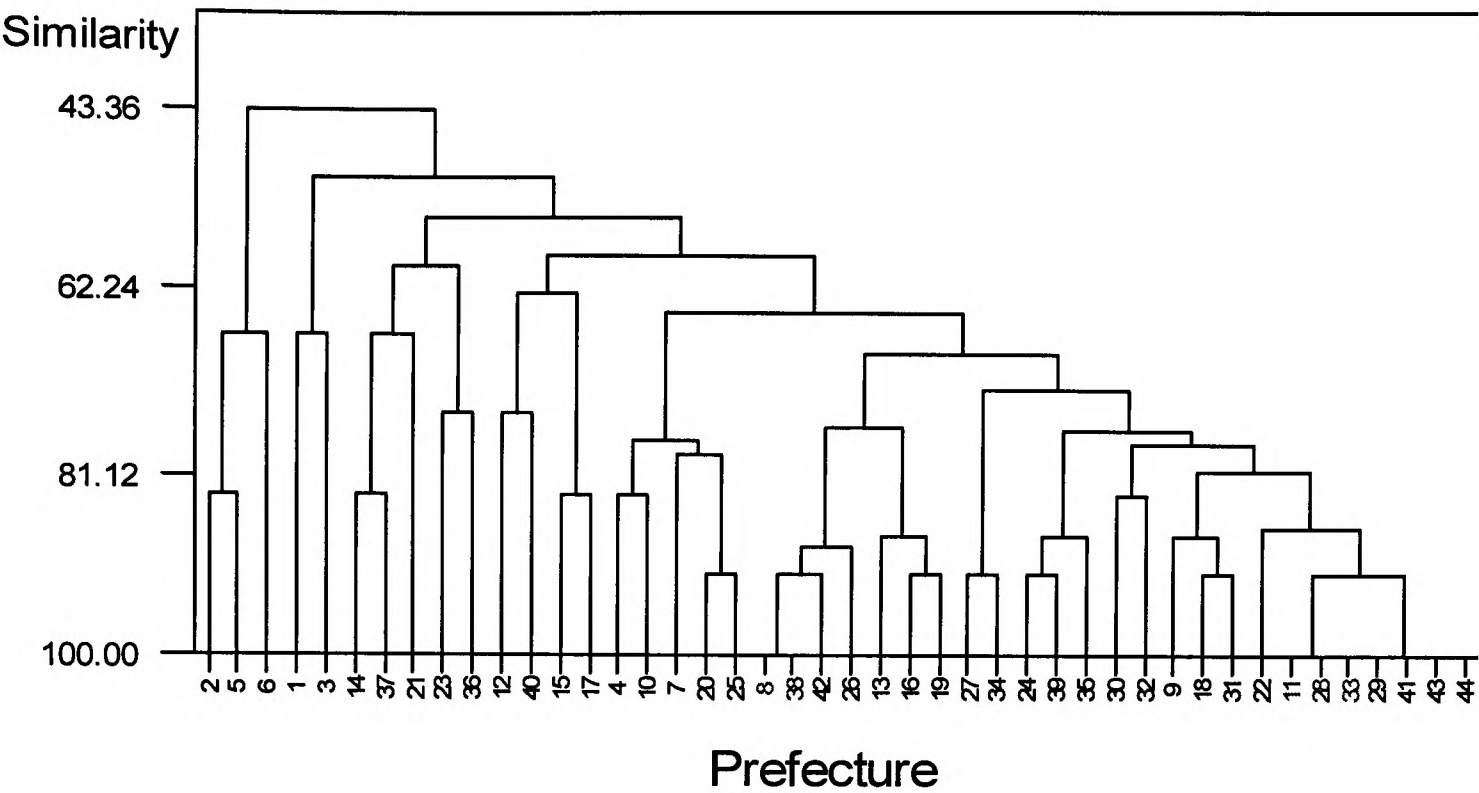
Figure 7.4 shows the level of similarity among prefectures in terms of wildlife species causing damage. Some of the similarities can be explained by the geographical distribution of wildlife species. For example, bear and serow are forest dwelling species with similar distributions, with the exception of Hokkaido where serow do not occur. Deer and boar also share similar distributions except in Hokkaido, where boar do not occur. Interestingly, taxonomic family members were classified together in the same cluster: canids (raccoon dogs and foxes) and mustelids (badgers and weasels); as were the two introduced species, raccoons and coypus (Figure 7.3).

Figure 7.4 Similarity dendrogram of species reported by the prefectures.



Similarity of prefectures, in terms of the occurrence of species that cause damage, is shown in Figure 7.5. The damaging species composition appeared to be similar in northern Honshu and Hokkaido, and three prefectures in Kyushu exhibited exactly the same species occurrences. Combinations of wildlife species present and farming products may affect the regional trends. These indicate that management of agricultural damage may be considered regionally, and information exchanges among prefectures may be useful, although the local governments seldom co-operate each other.

Figure 7.5 Similarity dendrogram of prefecture in the damaging species occurrence.



- 1 Hokkaido
- 2 Aomori
- 3 Iwate
- 4 Miyagi
- 5 Akita
- 6 Yamagata
- 7 Fukushima
- 8 Ibaraki
- 9 Tochigi
- 10 Gunma
- 11 Saitama
- 12 Chiba
- 13 Tokyo
- 14 Kanagawa
- 15 Niigata
- 16 Toyama
- 17 Ishikawa
- 18 Fukui
- 19 Yamanashi
- 20 Nagano
- 21 Gifu
- 22 Shizuoka
- 23 Aichi
- 24 Mie
- 25 Shiga
- 26 Osaka
- 27 Hyogo
- 28 Nara
- 29 Wakayama
- 30 Tottori
- 31 Shimane
- 32 Okayama
- 33 Hiroshima
- 34 Yamaguchi
- 35 Tokushima
- 36 Kagawa
- 37 Ehime
- 38 Fukuoka
- 39 Saga
- 40 Nagasaki
- 41 Kumamoto
- 42 Oita
- 43 Miyazaki
- 44 Kagoshima

7.3.3 Scale of damage by the raccoon dog (Q3)

Thirty prefectures (68.2% of the respondents) reported some damage by raccoon dogs. Two prefectures, Hiroshima and Yamaguchi in the Chugoku region, reported significant raccoon dog damage of 39,800,000 yen (approximately £237,000) and 76,362,000 yen (approximately £455,000) respectively, in 1998. Ten prefectures (27.9%) reported damage costing over a million yen (approximately £6,000) in 1998. Most prefectures reporting raccoon dog damage commented that this was on a much smaller scale than damage by other wildlife, specifically macaque, boar, and deer. In Hiroshima prefecture, which reported the second highest raccoon dog damage (and provided detailed data), this accounted for just 8.3% (in 1997) and 10.6% (in 1998) of the total economic damage by mammalian wildlife. In other prefectures with detailed data, the economic damage attributed to raccoon dogs accounted for between zero and 2.84% of the total (n = 7).

7.3.4 Counter-measures taken against wildlife (Q.4)

Culling (48.0%) was the major counter-measure used against damage by medium-sized wildlife, followed by fencing, including netting (15.9%), and use of repellents (6.8%). There were reports of single incidents of relocation, use of a night light, use of vinyl netting to protect grapes, and coiling vinyl or paper on maize. Some prefectures reported use of more than one measure. Half of responding prefectures did not use any counter-measures. Of the 20 prefectures that conducted culling, five (25.0%) reported that this killing was effective, one (5.0%) reported that it was not effective, and the rest (70.0%) did not know the effectiveness of the culling, yet they either conducted, or gave permission for culling. Two (28.6%) of those using netting found that it had some positive effect, another two reported no effect, and the rest (42.8%) did not know the effectiveness of the netting. One prefecture that used electric fences against boar and bear also found them effective at repelling medium-sized mammals. One prefecture mentioned that coiling vinyl or paper on individual maize cobs was effective, as was coal tarring around grape trellises though this was effective for three days.

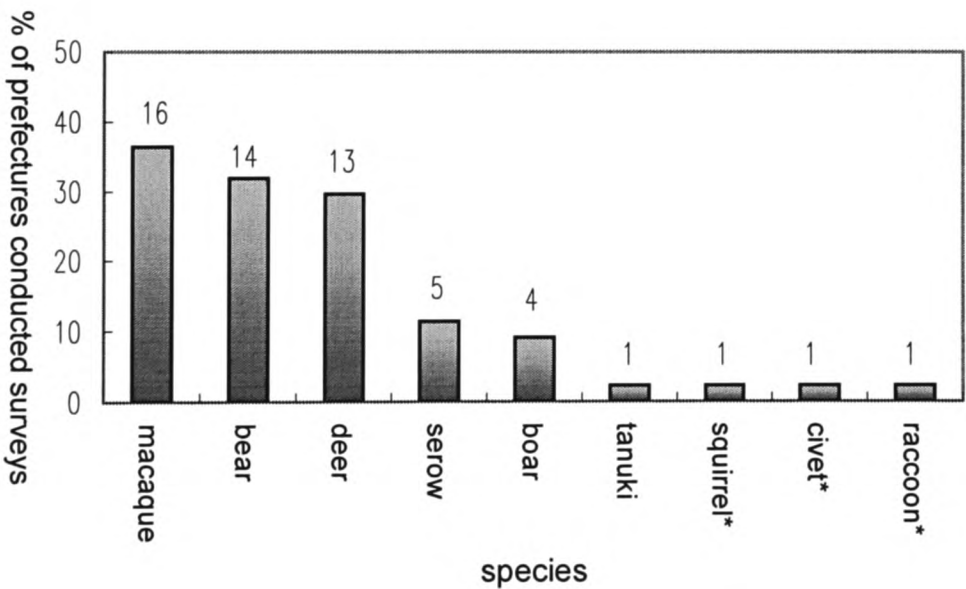
The number of racoon dogs culled in two prefectures which reported increased damage by the raccoon dog contributed only 2.9% of the average of total culled raccoon dogs from 1990 to 1998 and 6.8% of the total in 1998; Yamaguchi prefecture alone accounted for 47.4% of the average total culled animals between 1990 and 1998 and 42.4% of the total in

1998 (calculated from the data from the Ministry of Environment). Most culling (>90%) in the Yamaguchi prefecture were conducted on an island (138 km²) where raccoon dog damage to tangerines is severe (Miyagawa, 1994).

7.3.5 Surveys/research conducted (Q.5)

Thirty-six prefectures (81.8%) assessed damage by wildlife using mainly municipalities' reports. A few prefectures investigated independently the causes of damage or the prevention methods that were used. Twenty-nine prefectures (65.9%) conducted ecological survey/research work on wildlife (mainly population distributions and density estimates) or entrusted the surveys to other organisations/institutions. In ecological surveys, nine mammalian species were reported, three of which were introduced (Figure 7.6). The number of species in ecological surveys ranged from zero to four per prefecture. Species causing agricultural or forest damage appeared to be the main target of the surveys. Two surveys on the black bear in Okayama and Hiroshima were probably done also for conservation reasons, because in those areas the populations are fragmented and have been declining (Environment Agency, 1992; Maita, 1998).

Figure 7.6 Species targeted by local ecological surveys.

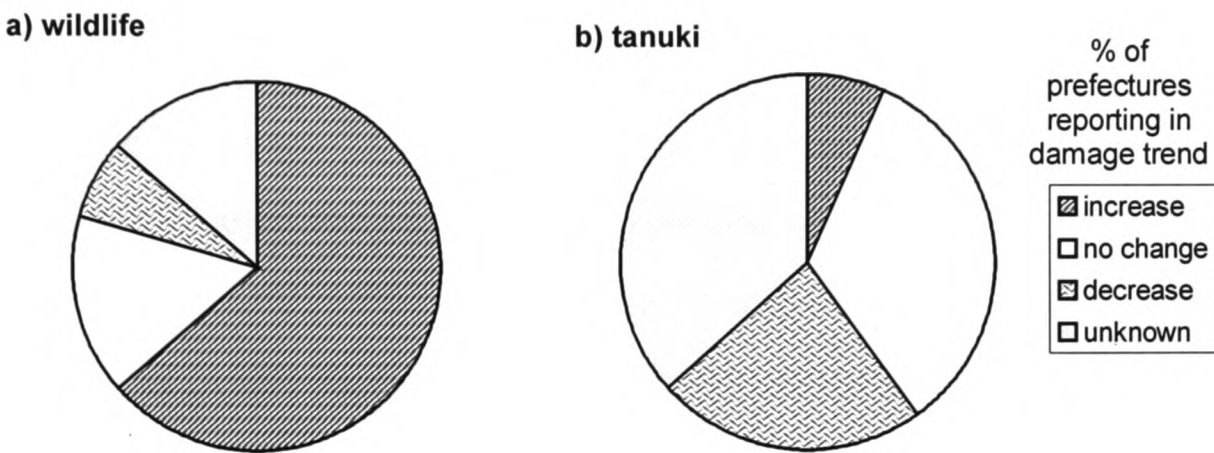


*introduced species

7.3.6 Trends in damage in the past 5 years (Q.6)

Twenty-eight prefectures (63.6%) responded that damage by wildlife had increased in the past 5 years; however, only two prefectures (4.5%) said that damage by the raccoon dog had increased (Figure 7.7).

Figure 7.7 Trends in agricultural damage by wildlife in general and the raccoon dog.



7.3.7 Compensation in the past 5 years (Q7)

Ten prefectures (22.7%) practised compensation/insurance programmes for wildlife damage. Three prefectures have considered developing such programmes but have not yet decided to implement them.

7.3.8 The relationships between ecological survey, damage trend, and compensation

The history of ecological surveying, i.e. conducted, not conducted, and unknown, was not independent of the trends for damage by wildlife, i.e. decreased, no change, increased, and unknown (Fisher's Exact test, $n = 44$, $p = 0.00398$; Table 7.2.). More prefectures than expected that reported increased or unchanged levels of damage conducted ecological surveys, while fewer than expected prefectures which reported decreased or unknown damage-trends conducted such surveys. In addition, fewer than expected prefectures which reported increased, unchanged or unknown damage trends did not conduct surveys.

Table 7.2 Contingency table for testing independence of the history of ecological survey and the trend of damage by wildlife reported by prefectures. (The upper number is frequency observed, and the lower number is frequency expected.)

Observed Expected	Damage trend			
	decreased	no change	increased	unknown
Ecological survey				
conducted	0 1.9773	7 4.6136	20 18.455	2 3.9545
did not conduct	1 0.6136	0 1.4318	4 5.7273	4 1.2273
unknown	2 0.4091	0 0.9545	4 3.8182	0 0.8182

The history of ecological surveying was not independent of the propensity for compensation programmes, i.e. yes, no, and unknown, (Fisher's Exact test, $n = 44$, $p = 0.00586$; Table 7.3.). More than expected prefectures which conducted ecological surveys had compensation programmes, while more than expected prefectures which did not conduct such a survey had less compensation. In addition, more prefectures than expected which did not know the history of ecological surveying also did not know about previous compensation programmes.

Table 7.3 Contingency table for testing independence of the history of ecological survey and the propensity for compensation programmes reported by prefectures. (The upper number is frequency observed, and the lower number is frequency expected.)

Observed Expected	Compensation		
	yes	no	unknown
Ecological survey			
conducted	8 6.5909	16 15.159	5 7.2500
did not conduct	1 2.0455	7 4.7045	1 2.2500
unknown	1 1.3636	0 3.1364	5 1.5000

The propensity for compensation programmes was independent from the trend of damage by wildlife (Fisher's Exact test, $n = 44$, $p = 0.202$; Table 7.4).

Table 7.4 Contingency table for testing independence of the propensity for compensation programmes and the trend of damage by wildlife reported by prefectures. (The upper number is frequency observed, and the lower number is frequency expected.)

Observed Expected	Damage trend			
	decreased	no change	increased	unknown
Compensation				
yes	0 0.6818	4 1.5909	5 6.3636	1 1.3636
no	1 1.5682	3 3.6591	15 14.636	4 3.1364
unknown	2 0.7500	0 1.7500	8 7.0000	1 1.5000

7.3.9 Case study (Q8)

Three prefectures reported specific damage cases. Iwate prefecture described projects on deer-damage prevention using netting (a prefectural project) and bear damage prevention by electric fencing (a National Treasury project). Hiroshima prefecture described projects on boar damage counter-measures by culling a population intensively and cutting grass in buffer zones. Miyazaki prefecture reported prevention by electric fencing against boar, macaque, and deer. Both prefectures reported that these were effective against wildlife damage.

7.3.10 Predicting raccoon dog damage

Discriminant analysis correctly classified 90.7% of 43 prefectures with regards to the presence or absence of raccoon dog damage. However, the proportion that was correct dropped to 65.1% during cross-validation. There were four prefectures that culled raccoon dogs despite reporting no raccoon dog damage (data from the Ministry of Environment). This discrepancy may have been the result of prophylactic control, i.e. attempting to reduce the population before damage occurred (in order to prevent it), or perhaps animals were routinely culled unnecessarily. Another possible explanation is that prefecture personnel made an error when answering the questionnaire. When classifying these four prefectures as having "damage present," the discriminant analysis correctly classified 95.3% of the prefectures, and the proportion correct was 72.1% in the cross-validation. In both cross-validations, most incorrect classifications occurred when absence of damage was coded as 'damage present.' The probability of grouping correctly by chance alone was 56.1%, i.e. $(29 \text{ present} \times 67.44\% + 14 \text{ absent} \times 32.56\%)/43 \text{ total}$, and 64.3%, i.e. $(33 \text{ present} \times 76.74\% + 10 \text{ absent} \times 23.26\%)/43 \text{ total}$, for analyses excluding and including the four prefectures with control-kills as damage present, respectively. The percentage correct in discriminant analysis was much higher than the probability of correct grouping by chance alone in both cases, suggesting its validity of the analysis. Mean profiles of prefectures in the latter analysis are shown in Table 7.5.

Table 7.5 Profiles of the prefectures for raccoon dog damage present and absent.

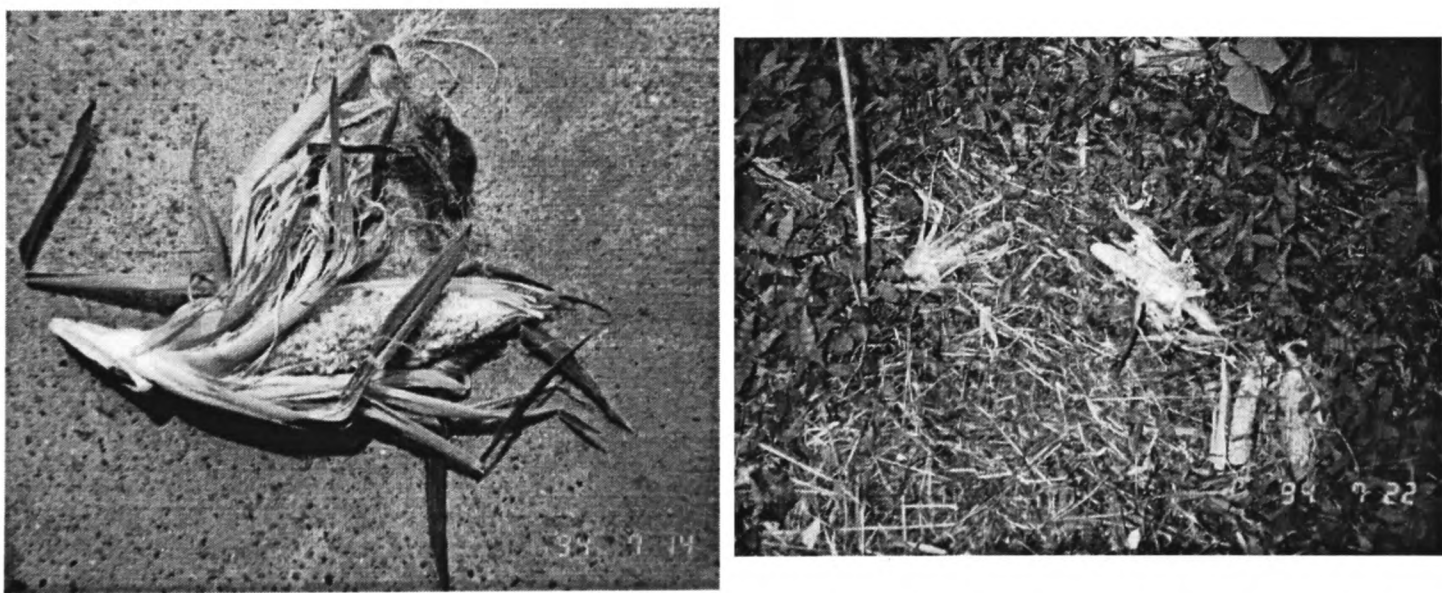
Variable	Prefectures with damage present	Prefectures with damage absent
% farm household	9.75 (0.83)	8.50 (1.60)
% small-scale farm	60.74 (2.21)	63.51 (5.32)
area (km ²)	7027 (539.0)	3822 (535.0)
human density (per km ²)	465 (114.0)	1369 (636.0)
% natural forest area	33.95 (1.87)	24.32 (3.95)
annual temperature (°C)	14.35 (0.34)	14.90 (0.42)
annual precipitation (mm)	1634 (74.40)	1497 (115.00)
% lowland area	15.31 (1.37)	20.58 (2.59)
hunting density (per 1000 km ²)	104.50 (17.60)	53.00 (13.00)

Data are shown as mean (SE); n = 33 for present and n = 10 for absent.

7.3.11 Examples of damage by the raccoon dog in the study area

During the raccoon dog studies I encountered four examples of damage by raccoon dogs, or specific interaction between raccoon dogs and farmers. In the first of these, evidence from radio-tracking and field signs strongly suggested that Echo, an adult female, and her offspring, had consumed maize in July 1994 (Figure 7.8). The family stayed in the bush near the field for nearly two weeks, consuming the crop. The owner, a dairy farmer, was sympathetic to the needs of the raccoon dogs, and tolerated the damage because the maize was for domestic consumption, rather than commercial gain. He put netting over the crop to protect against birds, mainly crows, but these were ineffective against raccoon dogs. I suggested that he tried using a guard dog and/or cleared the bush next the field to remove cover for the raccoon dogs.

Figure 7.8 Photographs of damaged maize by the raccoon dogs in the study area. Half-eaten maize in the field (left) and brought back to nearby bush and completely eaten (right).



In a second case, in 1997, I found raccoon dog footprints in a greenhouse from which grapes had been taken, during an investigation in response to a report by a local farmer. I was not able to identify the individual. Signs suggested that the raccoon dog had climbed between the greenhouse wall and the grape trees. This was a single incident, and was tolerated, because the greenhouse owner liked raccoon dogs.

The third case did not really constitute damage. In 1997, Poseidon, a yearling male, often visited a dairy farm to drink milk left out for pet cats; people enjoyed watching the raccoon dog. This appeared to be an amiable relationship between humans and wildlife. However, disease epidemic issues, such as scabies spreading in many parts of Japan, may make such a relationship problematic. Wild animals that are routinely fed by people may become more vulnerable to poaching or be more likely to consume crops than 'shy' animals.

The last case occurred during my absence from the study area, so I was unable to confirm the damage myself. In September, 1998, a dairy farmer illegally captured a pair of raccoon dogs. The farmer told the local authority that the raccoon dogs had killed his calf/calves, by eating their umbilical cord(s). He told local authority personnel that he killed a female and kept a male. After a month-long dispute between the authority, the farmer, local citizens and wildlife researchers (including myself), the male was released in February 1999, 25-km south of its home range in a protected forest located (Appendix III). No legal action was taken.

7.4 DISCUSSION

Farmers' despair over wildlife damage should not be confused with tolerance of a pest situation. Coping with wildlife damage is complicated by the many and varied interests which are involved, e.g. wildlife conservation, ecology, economy, politics, ethics, culture, emotion, and changes in agriculture and land use. Often, these have different and conflicting aims. Wagner *et al.* (1997) summarised three strategies for coping with wildlife damage: 1) managing wildlife and its habitat, 2) modifying human activities, and 3) increasing human tolerance of wildlife. Such strategies can be implemented to different degrees and in different combinations. In extreme cases, the first strategy could involve total extermination of wildlife in the area, and the second strategy could mean abandonment of farming. Of course, the most realistic strategy would probably involve a combined, less drastic, approach. Unfortunately, identifying the most effective combination is not easy. Furthermore, the third strategy (tolerance) is often completely overlooked.

7.4.1 General view of agricultural damage in Japan

Raccoon dog damage appeared to occur throughout Japan although the damage was minor except for two prefectures in Chugoku region. Similarity of occurrence suggests that species distribution affects damage by bear, serow, deer, and boar. Northern prefectures suffer from bear, serow and hare damage, whereas southern prefectures have damage caused by widely occurring species, such as the raccoon dog, macaque and hare. There was no clear nationwide trend in damaged agricultural products, partly because agricultural products are unique to prefectures.

Prefectures with raccoon dog damage were characterised by having a larger area, lower human density, higher percentage of natural forest, greater annual precipitation, lower percentage of lowland, and higher hunting density of the raccoon dog than those prefectures without damage. A percentage of farming households in population and ratio of small farms (excluding Hokkaido) probably do not influence damage occurrence.

7.4.2 Current problems in wildlife management for the prevention of damage

The local government's response to agricultural damage by wildlife varies greatly. The division in charge of this issue depends on the prefecture concerned. In some, wildlife damage is the responsibility of the agricultural administration, while in others, it is that of environmental conservation. The level of knowledge of personnel in charge also varies. According to the Network for Revising the Wildlife Protection Law (1999), only two prefectures (4.4 % of those responding to the questionnaire) had full-time personnel with ample knowledge of wildlife ecology and damage in charge of wildlife administration.

Farmers' attitudes toward wildlife damage also varied greatly. The four cases in the study area ranged from illegal killing to complete tolerance (without hostility against damaging animals). Although the level of economic loss may greatly affect farmers' attitudes, individual and regional differences in general attitudes toward wildlife cannot be ignored (Fukue, *et al.*, in preparation).

Claims for damages appear to be fairly subjective in that agricultural harvest is affected by climate, and the economy of the industry influences farmers' attitudes in reporting damage. In 1992, the Administrative Management Bureau in the Management and Co-ordination Agency advised the Ministry of Agriculture, Forestry and Fisheries that there were inappropriate reports with excessive figures, or failures of detecting damage (Lawyers' Association of Japan, 1999). No raccoon dog damage was reported to loquat fruits (*Eryobotrya japonica*) from 1994 to 1999 by the Chiba prefecture. However, one of the prefectural institutes, the Prefectural Southern Chiba Agricultural Training Institute for Youth (Kenritsu Naso-Nogyo-Seinen-Kenshusho) had previously (in 1994) asked me to talk about raccoon dog ecology because of significant raccoon dog damage to loquats in greenhouses in Chiba. Several loquat producers described this as a serious problem, which suggested that - prefectural governments may not be aware of damage even when it is considered serious by the farmers.

Confirming which wildlife species is responsible for damage is often difficult. Farmers can be biased, and this can interfere with making objective assessments. It is impossible for lay people to distinguish deer and serow from their tracks and droppings; people often confuse the raccoon dog with the badger or the common raccoon even when they trap the animals.

Furthermore, it is easier to confirm the species and sometimes individual(s) or group(s) that caused damage when the offending animal is a large, diurnal, boisterous, and/or group-foraging species than when it is a small, nocturnal, quiet, and/or solitary species. Identifying the correct target is essential for damage prevention especially when employing lethal methods.

Damage assessment is another difficult task. Under the current system in Japan, administrative authorities obtain descriptions of the damaged area, estimates of the amount of damage, and identifications of the damaging species from farmers. Objective methods of estimating damage need to be developed instead. Manuals can help improve the accuracy of farmers' estimate and species identification by providing keys, and explaining how to use sampling techniques, and take useful photographs for evidence. Local governments should be in a position to develop appropriate manuals for each agricultural product found in their area. This is feasible if they compile damage data and conduct investigations on damage processes.

Prophylactic wildlife culling is routinely conducted in many prefectures. The Network for Revising the *Wildlife Protection Law* (1999) found that most prefectures chose to do this because precedents has already been set and/or because local people request such action. Only one prefecture practised prophylactic controls on the basis of scientific risk assessments. The effectiveness of culling, whether prophylactic or in reaction to damage incidents, is not known. The current legal system does not oblige practitioners to investigate the effects of culling in order to request permission to proceed with new culling programmes (Lawyers' Association of Japan 1999). The questionnaire in this study showed that 70% of those prefectures that killed animals in an effort to control their pest activities were not aware of the likely impacts. Another problem in culling is disposal of animals. Incidents of lead poisoning in endangered birds of prey, e.g. the white-tailed eagle (*Haliaeetus albicilla* Linnaeus) and the Steller's sea-eagle (*H. pelagicus* Pallas) were reported in Hokkaido, due to these birds feeding on deer carcasses which had been shot and left in the field (Saitoh, 1998; Network of Eagle Lead-poisoning Problem, 1999). Gall-bladders of culled bears may be sold illegally (Environment Agency, 1999c). Live-trapped macaques are sold to research institutes for experiments (Environment Agency, 1999c; Cryanoski, 2000; Obara, 2000) and to underground pet dealers (K. Nagataki, personal communication).

7.4.3 Ecological factors influencing damage

By checking the locations of municipalities in the Hiroshima and Yamaguchi prefectures with significant raccoon dog damage, I found that most damage was reported on Islands, and that all but one municipality with extensive fruit damage were on islands (the exception was a small area facing the sea). Islands are a closed ecosystem and do not provide many alternative food sources. In addition, the warm, maritime climate in these areas may support high densities of the raccoon dog (Figure 1.3 and 1.4 in Chapter 1). These features may lead to extensive damage by raccoon dogs. On the island where most raccoon dog culling was conducted, the higher density of raccoon dogs there was blamed (amongst other reasons), on the removal of stray dogs through an extermination scheme (Miyagawa, 1994). Another factor might be that dispersal opportunities for the young are restricted in the insular environment (D. Harrison, personal communication). Juvenile dispersal coincides with maturation of some fruits. For example, tangerine fruits mature in the autumn (October to December), when the young become independent from parents and have a greater energy requirement (Korhonen, 1988). If potential dispersers remain in a small area, demand for food will increase.

In my study area, there was no record of mountain-type users, i.e. animals for which >50% of their home range consists of natural habitat types (details in Chapter 4), damaging agricultural products, despite their home ranges including cropped fields (Figure 4.3 in Chapter 4). In contrast, incidents of agricultural damage were reported within the home ranges of village-type users, i.e. animals with >50% of highly managed habitat type in their home range (detail in Chapter 4). If food preference and/or tolerance of humans are heritable characteristics or acquired via social learning from parents, management should focus on the village type. Feeding animals by humans, either intentionally or unintentionally, may result in increasing agricultural damage by making animals less wary of humans.

The crop most frequently mentioned in the questionnaire responses as being damaged, was maize (sweet-corn), followed by watermelon (Table 7.1). These may be preferred food items, and the edible parts mature in summer, when nursing adults and growing young require food more intensively than in other seasons. In summer, the feeding of nursing adults and young is usually concentrated in a small area. If a crop is readily available, such places can constitute their core feeding areas, as shown by the example of Echo. In addition,

acquired or inherited food preference might be important. I tried to feed tangerines to three individuals in captivity, but, none were consumed. Yuko Fukue (personal communication) had a similar experience with her captive animals. I also offered strawberries to one animal, but again, none were consumed. Neither fruit was common in the area. However, six prefectures reported strawberry damage, and six reported tangerine damage by the raccoon dog (Table 7.1). The tangerine is the most damaged product in Yamaguchi prefecture. It is possible that animals will only take these fruits at a particular time of year, when other resources are limiting, or that the behaviour of captive animals is not representative of that in the wild. Alternatively, the observation could be explained by acquired taste or varying taste among individuals. Variation in taste might open up the possibility of developing behavioural conditioning methods for the prevention of raccoon dog damage to certain crops.

7.4.4 Damage prevention

A wide variety of measures has been developed to prevent wildlife damage, and information is available for many species in the literature (e.g. Green *et al.*, 1994, coyote; Huxoll *et al.*, 1998, raccoon ; Lindzey ,1994, American badger; Maita, 1998, bears in Japan; Paul and Gipson, 1994, wolf; Phillips and Schmidt, 1994, red fox and grey fox). Here, I focus on the raccoon dog because no published information is available for this species. The summary of methods appears in Table 7.6. The raccoon dog has several features that make damage prevention difficult. First, they can squeeze through small openings, e.g. one of my captive animals (5.5 kg; 26.5 cm head circumference; >40 cm body circumference) escaped through 6 x 8 cm mesh. Second, they are also known to travel along gutters and underground pipes, making it difficult to detect their commonly used paths. Third, they can climb trees and fences if necessary. Fourth, they can dig underground, although their ability seems limited compared with the Japanese badger or the red fox. Fifth, they can swim and do not hesitate to enter water. Sixth, at least some individuals tolerate human presence, light, and/or noise, and thus would readily become habituated to frightening devices. They can be very cautious as well as bold, and so their reactions are difficult to predict. Seventh, they are mostly nocturnal, but not obligatorily so. Lastly, they are an opportunistic generalist. They eat most edible foods, although food preferences may differ among individuals or populations.

Table 7.6 Summary of non-lethal preventive measures for damage by the raccoon dog.

Methods	Examples	Effectiveness	Disadvantages
exclusion	● fence ● electric fence ● galvanised iron sheet ● barrier to climbing fruiting trees	● effective if built and maintained properly	● maintenance ● not cost effective for large areas ● habitat loss
frightening or repellent	● noise ● light ● scent/odour ● guard dog	● effective for a short period ● probably effective in combinations ● effective if engaged at the proper time	● habituation ● some are not suitable in residential areas ● some are not cost effective for large areas ● high cost for sophisticated devices, e.g. sensors
direct physical protection	● vinyl netting or strips on each fruit/crop	● unknown	● labour intensive
alternative food	● food provision ● habitat enrichment	● unknown	● may increase population density (although it is all right if they do not cause damage) ● cost
habitat modification	● clearing cover ● intercepting trails ● making rubbish unavailable	● probably effective, especially in combination with frightening method	● maintenance
relocation	● live-trapping and releasing	● not recommended	● If release point is close, the animal may come back ● if far enough, it may disturb resident individuals or ecosystem ● high mortality of released animals ● genetic and epidemic concerns

Home ranges of raccoon dogs often overlap greatly (Ikeda *et al.*, 1979; Yachimori, 1997), except between non-paired adults (Chapter 4). Identifying damaging individuals is usually difficult, and removing a few animals from an area may not decrease raccoon dog damage because other individuals may stay in the area, causing damage. Human perturbation may affect socio-spatial organisation in unpredicted ways (Tuytens, 1999). Furthermore, lethal control might be counter-productive if the target population responded by compensatory population growth (Helle and Kauhala, 1995) or high turnover rate (Tuytens and Macdonald, 1998). Culling operations are costly, and without information on demography and social aspects of the species, effectiveness of culling is questionable.

A combination of appropriate preventive methods may be more effective, and more cost-effective, than culling. It is important to record damage in detail in order to predict how the raccoon dog will approach the crop, what kind of damage to expect, and how long it will be before there is further damage.

7.4.5 Compensation

Wildlife is not owned by anyone under the *Civil Code* of Japan (Article 239; Wildlife Conservation Administration Study Group, 2000). Consequently the National government does not take any responsibility for wildlife damage, except for issuing permission for culling. The government, however, is considering establishing a nationwide compensation system after decreasing substantially the current population levels by culling (National Land and Environment Committee, 1999). Under the present plans, if culling fails to reduce actual damage levels, they will not proceed with compensation on a national basis. However, small-scale compensation provided by the Friendly Society (or Benefit Society) of Farmers with support from the National government, has been provided in some prefectures. The main purpose of the co-operative system is to provide compensation for natural disasters. This procedure requires farmers to pay subscriptions. There is a excess, i.e. compensation will be limited to claims for damage representing over 30% of the crop (Ministry of Agriculture, Forestry and Fisheries, 2001). In addition, some prefectures and municipalities provide subsidies for building fences. In North America, non-governmental organisations (NGOs) and private insurance companies may have compensation or insurance programmes for wildlife damage. Subsidies for non-lethal control and NGO participation have not been fully explored in

Japan. There is great potential in this area.

Compensation alone cannot solve problems. Several drawbacks have been identified: 1) budget constraints, 2) problems of making accurate damage assessment, 3) treating the symptom rather than the cause, 4) often not covering full value, and 5) potential fraud (Wagner *et al.* 1997). Therefore, compensation needs to be considered in the functional combinations with other preventive methods.

Wildlife problems cannot not be solved one-dimensionally within a scheme of linear relationships of conflicts, i.e. wildlife versus farmers, farmers versus the government, or the government versus wildlife. If we continue to leave these problems to farmers and governments, both wildlife and farmers will continue to suffer. Only when the whole of society participates in tackling wildlife problems will we achieve a satisfactory outcome. In order to realise this end, society needs to fully recognise and agree on the importance and value of wildlife.

7.4.6 Summary of recommendations

- to provide a budget to train professionals for wildlife damage problems
- to take a scientific approach to damage assessment and development of preventive measures
- to employ a wide range of subsidies for appropriate preventive measures
- to improve farm management
- to compensate for damage after all possible prevention has been taken with good farm management
- and to develop a single authority to create a unified system to carry out these recommendations.

CHAPTER 8

**IS WILDLIFE CONSERVATION
POSSIBLE IN JAPAN?**

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Summary

In this chapter, I consider the wider context of wildlife conservation in Japan, reviewing, in particular, the legal status of wildlife and describing socio-cultural aspects that influence wildlife and its conservation. The nature and implementation of possible policy changes in Japan are discussed. I conclude the chapter by using this information, together with results from my studies, to suggest preliminary conservation strategies for raccoon dogs in Japan.

Rivers and riverbanks are under jurisdiction of the Ministry of Land, Infrastructure and Transportation, whereas wildlife is usually managed by local governments.

This site used to be covered with dense scrub along the stream, where birds and small-to-medium sized mammals, including raccoon dogs, lived.



The sign says:
"GUN-HUNTING PROHIBITED AREA
CHIBA PREFECTURE"

Chapter 8 Is Wildlife Conservation Possible in Japan?

8.1 Effects of Japanese Society and Culture on Wildlife

8.1.1 Legal background

It has been perceived for many years by international communities that the Japanese Government has a lack of consideration for wildlife and their habitats. (e.g. Stewart-Smith, 1987; Danaher, 1999). The Government has responded to international criticism by declaring that wildlife is conserved by enforcing the *Wildlife Protection and Hunting Law* and the *Law for the Conservation of the Endangered Species of Wild Fauna and Flora* (Environment Agency, 1995a). In these sections I describe the legal background relating to wildlife law in Japan.

8.1.1.1 The *Wildlife Protection and Hunting Law* and the *Law for the Conservation of the Endangered Species of Wild Fauna and Flora*

According to Maruyama (1984) and Yamamura (1994), the *Wildlife Protection and Hunting Law 1918, 1963* (Appendix II) was enacted in order to protect human assets and industry, rather than to protect wildlife, although it prescribes hunting regulations. In general, this law has not functioned to prosecute poaching successfully (Maita, 1998; *Yomiuri Newspaper*, 1998a; *Asahi Newspaper*, 1999c; K. Tanaka, personal communication; Appendix III). The first and only sentence of confinement (4 months) was delivered in September 1999 to a crime to put mist nets routinely to catch rare wild birds, such as the dusky thrush (*Turdus naumanni* Temmnick) and the Siberian bluechat (*Tarsiger cyanurus* Pallas) (*Asahi Newspaper*, 1999d). The law states that a Minister of the Environment has the administrative authority for wildlife conservation and hunting regulations. However, prefectural (local) governments and municipal levels are responsible for administering conservation and the control of wildlife, such as giving permission for culling. Once damage, or risk of damage, to human assets is claimed, permission for culling can be issued without investigation. The following incidents illustrate the routine application of this. In March 1999, 15 raccoon dogs (*Nyctereutes procyonoides* Gray) that inhabited in an airport were killed for the safety of passengers, after collision incidents between the animals and aircraft (*Asahi Newspaper*, 1999a). Feeding by local people and passengers caused the problem by attracting raccoon dogs to the area, but non-lethal methods of control were not considered. In October 1998, when a black bear (*Selenarctos thibetanus* G. Cuvier) was found trapped illegally and injured in a snare, the authorities decided that, under

the law, the animal should be shot as a pest, because an injured bear is likely to attack people and because the consensus amongst local people would be not to release it (*Yomiuri Newspaper*, 1998a).

The law requires the investigating party to find physical evidence and/or a witness to prove that wildlife is captured illegally, unlike the *Protection of Badgers Act 1992* in the UK, which requires the investigated party to prove its innocence. Possessing a captured animal itself, dead or alive, a confession for capturing or killing wildlife without licence/permission, and tools for capturing animals cannot be considered as physical evidence for poaching under the *Wildlife Protection and Hunting Law* (*Asahi Newspaper*, 1999c; Appendix VII). Rather, illegally capturing wildlife creates an ownership for the person who captures it because wildlife is considered to be possessed by nobody, according to the Article 239 in the *Civil Code 1896, 1898* (Wildlife Conservation Administration Study Group, 2000). The primary investigating authorities are the local public service officials, not the police. Poaching is routinely overlooked. Furthermore, nine marine mammal species fall under the jurisdiction of the Ministry of Agriculture, Forestry and Fisheries, which means that they are excluded from the regulations of the criminal law. However, the penalty is more substantial for infringement of the *Fishing Law* than the *Wildlife Protection and Hunting Law* or the *Law for the Conservation of the Endangered Species of Wild Fauna and Flora*, indicating that human property is the priority.

8.1.1.2 International Trade

Exotic plants and animals have been imported under the supervision of the Ministry of International Trade and Industry, which pursues the economic growth that might accrue from the importation of exotics. The *Foreign Exchange and Foreign Trade Law* and the *Customs Tariff Law* control international trade. Although the Government acceded to CITES in 1980 (i.e. 7 years after international agreement as the 60th country), 13 species were held under the reservation, and six species of whale are still, in 2001, under the reservation. It took 14 years to withdraw the reservation of the hawksbill turtle (*Eretmochelys imbricata* Linnaeus) (used in industrial arts), and the Government recently started to seek opening international trade in the turtle with Cuba (TRAFFIC Japan, 2000).

It was 12 years after the CITES ratification by Japan that the *Law for the Conservation of the Endangered Species of Wild Fauna and Flora* (Appendix II) was promulgated as the

corresponding domestic law for species in Appendix I of CITES and the national endangered species. This law, however, treats parts and products of the endangered species rather vaguely, it may, for example, only applied to those which are "easily recognisable." The emphasis is on property rights (Article 3 and 6). Unscrupulous pet traders even use an infringement of the law to tempt enthusiastic customers to purchase exotics (e.g. *Asahi Newspaper*, 1999b). Furthermore, the Government does not seize most imported wildlife and pet animals (Yoshikawa, 1997). Quarantine is mandatory only for dogs and domesticated animals, and quarantine inspection for rabies has just started for the raccoon, fox, and skunk in 2000. According to *Yearbook of Animals' Quarantine* (Ministry of Agriculture, Forestry and Fisheries) cited by Yoshikawa (1997), the 'number' of personally imported mammals radically increased in 1992 by 15-fold from the previous year and decreased to less than a quarter in the following year, showing the uncontrolled 'pet boom.' People's craze for pets often resulted in animals being abandoned in the wild once their owners tired of them. It has been astonishing that Japan has not suffered outbreaks of rabies for decades (Ishida, 1994).

8.1.1.3 The Ramsar Convention

Japan joined the *Ramsar Convention* (the *Convention on Wetlands of International Importance Especially as Waterfowl Habitat*) in 1980 (i.e. 9 years after the international agreement), and under this convention 11 sites have been designated with the total area of 837.2 km², including 656.02 km² of Lake Biwa, the largest lake in Japan. In comparison with other countries this is a very small area: 11.6% of that designated by the UK and 13.3% of the average of 119 contracting parties (calculated from data from the Ramsar Convention Bureau, 2000).

All Ramsar sites were already designated as Wildlife Protection Areas and/or National Parks, therefore, legal protection has not increased significantly in these areas. Areas with development plans, such as Sanbanse, the Wajiro bay tidal flat, the Fujimae tideland, and the Isahaya bay tidal flat, were not considered as possible Ramsar sites, even though they were critically important for waterfowls and shorebirds, (Lawyers' Association of Japan, 1999). Isozaki (1999) pointed out that the Government has the responsibility to explain scientifically and logically the reasons why such important wetlands have not been designated as Ramsar sites or have been reclaimed, even though these wetlands were far above the Ramsar's criteria for designation.

8.1.1.4 The Convention on Biological Diversity

The *Convention on Biological Diversity* was ratified in 1993 (i.e. 1 year after international agreement). The Government, however, does not have any domestic laws corresponding to the Convention's precepts (Lawyers' Association of Japan, 1999). The Government stated that the existing legislation---such as the *Wildlife Protection and Hunting Law*, the *Law for the Conservation of the Endangered Species of Wild Fauna and Flora*, the *Aquatic Resources Protection Law*, and the *Law for the Protection of Cultural Property*---was sufficient to cover the Convention requirements (United Nations Department for Policy Co-ordination and Sustainable Development, 2000). This would not be true even if strict law enforcement had been undertaken, because the primary force behind large-scale habitat destruction, hence decreasing biological diversity, has been the Government itself with its public worksⁱ.

In 1997, more than 40% of the total expenditure on construction in Japan was for public works, and Japan has been called "the land of construction" (Kase, 1999). The general public have recently become less supportive of public works, but nonetheless, large construction companies, the politicians, and the bureaucrats have built up an "iron triangle" glued with hugely lucrative contracts, "votes for cash," and assurances of highly-paid positions after early retirement (Igarashi, 1999). Public works have resulted in increasing the debt as well as decreasing the Japanese biological diversity.

Japanese Official Development Assistanceⁱⁱ (ODA) to developing countries (mostly the ASEAN countries), the total amount of which has been the largest in the world since 1991 (Ministry of Foreign Affairs, 2000a), has functioned an export version of public works. Nature protection laws in developing countries are usually insufficient. Recently, the Organisation for Economic Co-operation and Development (OECD) and the World Commission on Environment and Development (WCED) have recommended environmental impact/risk assessments for ODA projects. Japan has become more conscious of environmental issues in ODA projects than before and, since 1996, has started to budget for an environmental section. Nonetheless, such 'environmental efforts' do not generally address biological diversity concerns. The Japanese government uses rhetoric of environmental protectionⁱⁱⁱ, making minimum institutional changes and classifying 'infrastructure development' under environmental ODA by adopting "sustainable development," which itself is ambiguously

^{i & ii} Notes are given at the end of the chapter.

defined by the United Nations Commission on Environment and Development (Potter, 1994).

8.2.1.5 The Government Policy for Wildlife

Thus, it appears that a systematic programme for wildlife and habitat protection exists only in the imagination of the administrative authorities (e.g. *National Strategy of Japan on Biological Diversity* by the Council of Ministers for Global Environment Conservation, 1995). A major difficulty is that most administrative personnel in charge of wildlife conservation and management do not have a background in ecology (even in science). For most people, including those in government policy, wildlife conservation means the protection of endangered (nearly extinct) species, and wildlife management means culling and thinning, if populations of species are thought to be too large and causing economic damage. For example, a relatively huge amount of money (e.g. 140 million yen in 2001, approximately £875,000; over a half of budget for wildlife conservation) has been spent on saving the Japanese crested ibis (*Nipponia nippon* Temminck), which had already become extinct in Japan in 1995 during the captive breeding programme which started in 1981. At the same time, over 10,000 Japanese macaques (*Macaca fuscata* Blyth) were removed in pest control programmes in 1998 alone, even though six local populations were designated as a Natural Monuments under the *Law for the Protection of Cultural Property*, some populations as threatened by the Ministry of Environment, and the species was listed as endangered in the *IUCN Red List of Threatened Animals* (1996)^{iv} (data from the Environment Agency). Through his examination of harvest records for last hundred years, Mano (1998) concluded that Japanese conservation policy has fostered aimless exploitation, leading to a series of protective measures in response to a drastic drop in harvests or harvest efficiency, followed by the resumption of reckless exploitation.

Raccoon dogs, for example, are classified as a game species and can be culled with permission at any time of year. People often perceive raccoon dogs as either a 'pest' or a 'pet,' leading to populations either being culled or fed (Chapter 1). Raccoon dogs have suffered from a lack of consistent management plans and of habitat protection from human disturbance. In Japan, as well as in many countries, if the species is not considered to be endangered, populations are not monitored. I believe that managing sound populations of such species is crucial in relation to conserving biological diversity in unprotected areas. What is needed most

^{iii & iv} Notes are given at the end of the chapter.

in Japan may be a long-term, consistent scheme of wildlife monitoring for both common and endangered species, and a programme of conservation action based on the monitoring data.

8.1.2 People's perceptions of wildlife

Shintoism and Buddhism are the two major religions in Japan and have, along with Confucianism, greatly influenced people's values, lifestyles, and customs, and consequently their views on the natural world. The past and future development of conservation policy in Japan needs to be understood in the context of these influences. Some of the key elements are outlined in the following paragraphs.

Shintoism, with its worship of nature and cleanliness/purity, is the native religion of Japan, originating from myths and primitive animism. Mahayana Buddhism was introduced in Japan in the Sixth Century via Korea from India. Its main dogma is that life's suffering and pain is caused by desire or greed. Because Shintoism is a non-exclusive, polytheistic religion, the introduction of Buddhism took place without major conflict. They have become fused to great degree. The majority of people celebrate new-borns at Shinto shrines, have wedding ceremonies at Christian churches or Shinto shrines, and have funerals and keep graveyards at Buddhist temples. The religious ceremonies have become merely events, or blended more or less into daily and anniversary customs.

In spite of the frivolity in religious adherence, the influence of these religions on people's perspective on nature cannot be overlooked. Hunting has never been popular in Japan partly because of Buddhism's negative view of killing as evil doing. The concepts of "universal interconnectedness," "mutual interdependence," (Macy, 1991 cited by Schmithausen, 1997), cause-and-effect (*inga oho*), and mutability (*shogyo mujo*) in Buddhism are consistent with ecology and evolution. In Shintoism, large trees and high mountains can be subjects of worship and have been protected as sacred entities; animals themselves can be worshipped. For example, in Shintoism, the fox (*Vulpes vulpes* Linnaeus) has been sacred identity in the shrines of the deity of rice harvest (*inari*) throughout Japan, the Kasuga shrine, one of the most powerful and oldest shrines, deifies the deer (*Cervus nippon* Temminck), and the Mitumine shrine deifies the wolf (*Canis lupus* Linnaeus). Yet, Buddhism and Shintoism do not always work in favour of nature and wildlife. The term *kuyo* (*puja* in Sanskrit) is supposed to mean extended empathy to the deceased and to the loss of non-humans, including non-living

things, along with original meanings of "reverence," "paying homage," or "adoration" (Suzuki, 1938). However, it does not mean refraining killing or consuming, and it can work as an indulgence for these activities. For example, one of major excuses to hunt whales has been that "Japanese consume them efficiently with gratitude unlike the Westerners who kill them only for oil." Similarly, *jichinsai*, a ceremony to calm the *kami* (deities, gods or spirits in Shintoism) of the land before construction, has become a superficial routine or a method of escaping guilt (or avoiding curses) at most, rather than respecting the *kami*, i.e. nature. Buddhism shares anthropocentric viewpoints of the kind found in many other religions, assuming non-human beings as being inferior and allowing them to suffer more than humans (Schmithausen, 1997), even though Buddhism treats humans and non-humans equally through *rinne* (*samsara* in Sanskrit), transmigration of the soul or rebirth in another life form. Also, in Shintoism, the concept of *kami* acknowledges a superior aesthetic sense on the part of humans, which allows humans to feel awe in the presence of beauty. Therefore, *kami* does not always coincide with ecological and evolutionary significance.

The Japanese people's perception of nature has undergone some changes over centuries, especially after the Meiji Restoration (1868) because the Restoration started with denial of the past, including spiritual values, in order to accomplish the Westernisation. According to Umehara (1986), the ancient Japanese feared nature as an unpredictable and magical being that brought both harvest and disasters. The fear can be read in poems written in the Seventh Century. Animals also used to be subjects of fear; they were considered to be gods and later became either messengers from gods or similar identity to spectres, *mononoke* or *yokai* (Nakamura, 1990). Animals were not subordinate or inferior to humans. Nakamura (1984) found that connectivity between humans and animals and even sublimation from humans to animals in Japanese folklore, in which many stories are about transformation of animals to humans and humans to animals. By contrast, transformation of humans to animals usually means punishment or ordeals in Western fairy tales (Nakamura, 1984).

Basically, Japanese people do not clearly distinguish between man-made and natural things, nor between humans and nature, nor do they have a clear division of heaven or sky (*ten*), earth (*chi*), and human (*jin*) (Watanabe, 1974, 1995) although the order is always *ten chi jin*. For example, Japanese gardens are often complete with the background scenery, *shakkei*,

and some famous gardeners are known to perceive natural changes over decades into their original plans. Nature is rarely viewed as an object, a separate identity from humans. Empathy and assimilation of humans with natural phenomena and non-human living things can often be seen in Japanese traditional poems, *waka* and *haiku*, in which plants are often assumed to think and feel (Kamigaito, 1995; Watanabe, 1995).

Nature is also understood to be ever-changing. Buddhism and frequent natural disasters could have fostered this view, as Japan is known for typhoons, earthquakes, and tsunami. This view of nature may interfere with the progression in natural sciences, which are based on unchangeable substances in "uniformity of nature" to be analysed (Watanabe, 1995). In addition, the concept of 'ever-changing nature' can be adopted to justify extensive destruction caused by human activities. Japanese can easily accept environmental changes without distinguishing their causes, either by nature or human. The responsibility for artificial disasters is often disputed in court.

The lifestyle and quality of life of the Japanese also has changed drastically since World War II. The Gross Domestic Expenditure (GDE) per capita increased by 7.4 times from 1955 to 1997 (Figure A.4 in Appendix I). The post-war commitment to reconstruction was the result of a society facing a scarcity in materials and a solitary international position during the War and the immediate post-war era. A faith in the GDP and materialism seized people's hearts. Urbanisation was accelerated as depopulation in rural areas progressed; also, the secondary and tertiary industries prospered as the first industry declined (Figure A.3 in Appendix I). People today (1999) own, per 100 households, 127 passenger cars, 37 personal computers, 178 VCRs and 39 video cameras (Economic Planning Agency). The commercialisation of Japanese society is complete.

8.1.3 Wildlife conservation in Japan

The wildlife conservation effort by the Japanese government has occurred through the enactment of a series of conservation legislative measure (Appendix II) and the designation of protected areas (Table 8.1). There are 28 National Parks and 55 Quasi-National Parks in Japan. Three-quarters of nationally owned land in the National Parks is located in the National Forest, and the remaining areas in the National Parks are private land (Environment Agency, 1995a). Activities such as felling, mining, erecting buildings and reclamation are prohibited to

certain degrees depending upon specific zones in the National Parks. Five Wilderness Areas, where activities with adverse effects on ecosystems are prohibited, are located in the National Forests, and 10 Nature Conservation Areas, where some activities are permitted with regulations, are located in the National Forests and small privately-owned forests. The Ministry of Environment has established 3,767 Wildlife Protection Areas and 617 Wildlife Special Protection Areas, where hunting is prohibited, and permission from the Ministry are required for development activities, such as reclamation and erecting structures (Environment Agency, 1995a). Designations for a particular area often overlap. For example, a part of Yakushima Island is designated as the Kirishima-Yaku National Park, the Wilderness Area, the Site for World's Natural Heritage, and the Biosphere Reserves of UNESCO's MAB programme. It was not therefore possible to obtain total areas protected against development.

Table 8.1 Nature protected areas (km²) in Japan.

Number	Designation	Total area	Average area
28	National Park	20,482	731.5
55	Quasi-National Park	13,329	242.3
5	Wilderness Area	56	11.2
10	Nature Conservation Area	216	21.6
515	Prefectural Nature Conservation Area	73	0.1
3,767	Wildlife Protection Area	36,010	9.6
633	Wildlife Special Protection Area	2,960	4.7
24	Forest Biosphere Reserve	3,130	130.4
2	Forest Genetic Resources Reserve	110	55.0
336	Forestry Tree Genetic Resources Reserve	90	0.3
341	Plant Community Reserve	900	2.6
25	Specific Animal Habitat Reserve	120	4.8
30	Specific Geographical Feature Reserve	310	10.3
28	Local Symbol Forest Reserve	20	0.7
2	Natural Heritage	280	140.0
11	Ramsar Site	837	76.1
4	UNESCO Biosphere Reserve	1,160	290.0
0	Nature Habitat Conservation Area	proposed	

There are two types of national non-governmental organisations (NGOs) for conservation: those based and founded in Japan and those, such as the World Wide Fund for Nature Japan (WWF Japan), organised internationally. One of the former type is the Nature Conservation Society of Japan (NACS-J), founded in 1951. It grew out of the Oze Marsh Conservation Union, a voluntary group organised in 1949 to save the Oze Marsh from dam construction. NACS-J today works towards broad conservation objectives and funds scientific research necessary for conservation. The membership of such nature conservation NGOs are much smaller than in the UK (Table 8.2). However, numerous local groups with grass-root movements have been active. The activities of those groups are focused on local issues, such as the protection of local areas or focal species. For example, Kamoshika-no-kai (the Association of Serow), whose purpose is to foster co-existence of the Japanese serow (*Naemorhedus crispus* Temminck) and forestry, has been active for more than 20 years, providing labour to help protect plantations from browsing (Kamoshika-no-kai Kansai, 2001). Although such efforts do not solve basic problems of co-existence with wildlife, without them, the species might have been eliminated from the area by culling.

Table 8.2 Membership of conservation NGOs in Japan (125 million people) and the UK (58.8 million people)

Japan (1997)			UK (1998)		
NGO	member	in 10,000 people	NGO	member	in 10,000 people
Wild Bird Society of Japan	55,000	4.4	National Trust	2,557,000	435
WWF	50,000	4.0	RSPB	1,012,000	172
NACS-J	17,000	0.14	Wildlife Trust	320,000	54
Greenpeace	5,000	0.04	WWF	240,000	41
Friend of Earth	400	0.03	National Trust Scotland	228,000	39
Tsukinowa-no-kai	250	0.02	Woodland Trust	200,000	34
Kamoshika-no-kai Kansai*	200	0.02	Greenpeace	194,000	33
Tanuki Club	100	0.01	Ramblers Association	126,000	21
			Friend of Earth	114,000	19

*number of newsletter readers

8.1.4 Identifying problems

The difficulties faced in developing effective wildlife conservation measures in Japan are not necessarily unique, but the context is a challenging one. Japan has undergone rapid changes in both its physical and spiritual dimensions, has been exposed to both Eastern and Western cultures to a great degree, and has developed its economic power to reach a position of global influence.

The threats facing wildlife in Japan have arisen as a consequence of rapid economic

development as well as socio-cultural aspects. However, despite the small budget for wildlife conservation, opinion polls have clearly showed support for conservation and an interest in environmental issues (Prime Minister's Office, 1995a, 1995b). For example, recycling rates are much higher than those of the UK (e.g., 70.2% and 31% of aluminium cans and 77.3% and 12% of steel cans were recycled in 1996 in Japan and the UK, respectively). In addition, expenditure *per capita* for clean water and waste material processing is higher than in most of European countries (Economic Planning Agency, 2000). The majority of Japanese, however, have never been personally involved in wildlife conservation programmes, nor have they donated to them (Shin Joho Centre, 1993, 1997). Even environmental movements have concentrated on issues other than wildlife. The main Japanese concerns with regard to environmental issues are still restricted to pollution hazardous to humans, namely water pollution, air pollution, and disposal of waste materials. For example, the adverse effect of exogenous endocrine-disrupting chemicals (the so-called 'environmental hormones') on reproductive organs of freshwater fish was a major issue because of the risk to humans, rather than because of threats to the fish population or the aquatic ecosystem (Cryanoski, 2001). Even the Ministry of Environment lacks an interest in wildlife conservation. It conducted a risk assessment of dioxins in 1997 but completely ignored the effects on wildlife, which are probably more vulnerable to such pollution than humans. The legislation for regulation, even if it becomes effective, cannot protect wildlife under the Government's proposed scheme (Iwata, 1998).

Three particular misconceptions are common in Japan. The first relates to the view that plants represent nature. The result is that the conservation needs of animals are often overlooked. Many conservation activities in Japan focus only on plants. In extreme cases, planting exotic plants can be considered equivalent to nature conservation through the etymology of the word *ryokka*, 'making greenery.' Green Day, which was set on the birthday of the Showa Emperor, who was said to be concerned about the environment and to love nature, is now a holiday for nature and the environment. Planting ceremonies take place in many parts of Japan on that day. The second misconception is a belief that wildlife lives only in 'forests' (i.e. remote mountainous areas), while most people live in urban areas. Such a feeling makes it difficult for people to comprehend an idea of co-existence (e.g. *Yomiuri Newspaper*, 1993b).

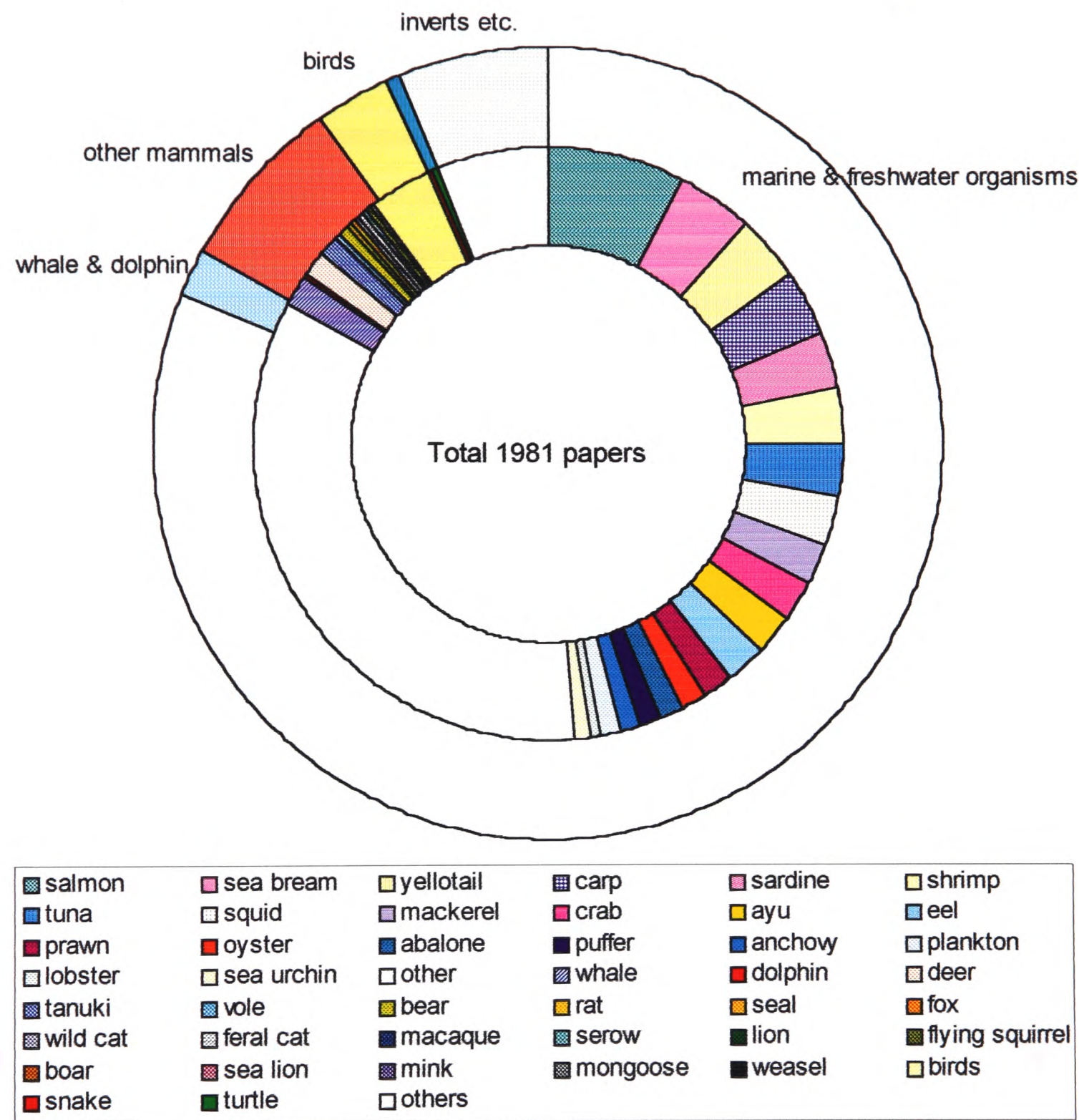
The third common misconception is based on the view that an animal is either a pest, to be controlled or killed, or is a pet, to be tamed or fed. This shows poor understanding of the concept of being wild, or having an ecological entity. Fukue *et al.* (in preparation) found that people (especially men) who resided in more rural areas, had a more negative view of wildlife, seeing them as enemies causing agricultural/forestry damage. People (especially women) who resided in urban areas showed more positive views, but preferred appealing species such as the squirrel or rabbit. Taming wildlife with food, so-called *eduke*, is a common practice among people who appreciate animals but who tend to be ignorant of wildlife ecology. On the other hand, people often release pet animals into the wild, without guilt or even with relief at not seeing death, convincing themselves that 'setting-free' is doing a favour to the animals, even when they are sick or juvenile.

Of major concern is the lack of understanding of ecological concepts on the part of the people and local governments, including the authorities that are responsible for wildlife conservation and management. Kellert (1991) pointed out that the Japanese had less sophisticated ecological and ethical views of wildlife than citizens in the USA and Germany, and the Japanese lacked the concept of 'habitat.' Although ecological movements in Japan have recently started to focus on environmental education, compulsory school and higher education have made only a minor contribution to conservation. Ecological and ethical views are not positively correlated to levels of education in Japan, as they are in the USA and Germany (Kellert, 1991). Children learn about environmental problems such as 'Minamata disease' in history class as a social issue. Ecology has been a neglected subject in science education from elementary to higher education. No Japanese universities hold a full curriculum of wildlife ecology or wildlife biology, which students can study as a major (A. Takayanagi, personal communication). Furthermore, local governments rarely employ wildlife experts in wildlife divisions (if they exist at all), and frequent personnel changes across divisions do not allow staff to gain experience (K. Uraguchi, personal communication).

Japan holds the second largest number of researchers and has the second largest expenditure on scientific research and development in the world (Organisation for Economic Co-operation and Development, 1998). However, the small national share of world totals for citations from scientific papers in ecology and the environment (1.9% in 1990-1994; the lowest

in 19 scientific fields) showed weakness in this field amongst the Japanese scientific community (Agency for Cultural Affairs, 1997). Ecological research, especially on native species, has never received major attention. A literature search in *Biological Abstracts* in the 1990s revealed that nearly 90% of papers searched using the key words 'Japan' and 'wildlife' concerned marine and freshwater organisms, which are economically important and likely to be found on the menu in restaurants and sushi bars (Figure 8.1). Papers on mammals comprised only 7.0% (if the papers on 'edible' marine mammals, e.g. whale and dolphin, were excluded, the figure dropped to 4.6%) and 3.4% on birds. In Japan, generally speaking, wildlife is only studied if endangered or causing economic damage.

Figure 8.1 Subjects in scientific papers on wildlife in Japan in the 1990s. Legend rows run from left to right, and correspond to a clockwise direction of the inner circle of subjects in the diagram.



The complicated administrative system responsible for wildlife conservation in Japan causes further difficulties. A number of government bodies are involved. For example, an issue relating to imported animals may be reviewed separately by the Ministry of International Trade and Industry, the Ministry of Agriculture, Forestry and Fisheries, and the Ministry of Health and Welfare. Wildlife damage to forests falls under the jurisdiction of the Forestry Agency as well as the Ministry of Environment and, if the species causing damage is a designated Natural Monument (such as the Japanese serow) the Agency for Cultural Affairs may also be involved. The inevitable consequences of such a system are delays in decision-making and action. Furthermore, political power struggles have thwarted the passage of conservation legislation. For example, in 1976 the Environment Agency prepared to legislate the *Environmental Impact Assessment Act*, but did not succeed because of objections from the Ministry of International Trade and Industry, the Ministry of Transport, and the Ministry of Construction, together with the financial world (Yamamura 1994). After failure in 1984, the law was finally passed in 1997, but with a rather incomplete structure.

The political power of NGOs in Japan is insignificant compared to their power in Western developed countries. There is no 'green' party represented in Government, nor any financial aid coming from supportive industries. Conservation NGOs are generally negatively viewed by the public, who are sceptical about contributing to conservation work. In addition, the numerous, but small, environmental organisations in Japan often lack communication and co-operation with each other and do not have significant funding or manpower.

A huge gap seems to exist between awareness and practice in wildlife conservation within the Government. The Government has published a variety of documents, such as the *National Action Plan for Agenda 21* and the *National Strategy of Japan on Biological Diversity*, that demonstrate awareness and knowledge. However, the same Government supports destructive public works, such as cutting off the Isahaya Bay's tidal flats (3,550 ha) from the sea, despite local and national protests (Lawyers' Association of Japan, 1999).

The same can be said for many Japanese. Most people eagerly agree with wildlife conservation but do not question their own lifestyle enough to act. The Japanese's notorious attitude of *honne-to-tatemae* (a separate use of private thoughts and public stance) allows them to ignore the discrepancy. For example, the international trade of wildlife products and

exotic pets is only realised if there is a demand by people. The one-off sale of 54 tons of ivory to Japan in 1999 increased prices of ivory as much as 50% after the approval of the sale in 1997 and probably encouraged poaching (Brecher, 1998; Pearce, 2000), despite the Ministry of Environment's explanation that the money will help the conservation of the African elephant (*Loxodonta africana*) (Environment Agency, 2000a). Most ivory in Japan is processed into luxury seals (*hanko*, name stamps). The private thought would be "I want to possess the luxury" whereas the public stance would be "We should protect elephants." The widespread mixture of pessimism and egocentric viewpoints prevents a concerted effort towards global or even local conservation.

Since the Meiji Era, the highest priority has always been on industrial growth; government policy and public attitudes in this regard have hardened during the post-war development. The inertia of rapid economic growth is still fostering a dream of unlimited, never-ending development, in the materialistic Japanese mind. Wildlife will struggle to survive and struggle also to maintain their independence from humans.

8.2 Some Solutions

The following is a summary of my recommendations for solving some of the problems facing wildlife conservation in Japan, outlined in the previous section. Some of the approaches may seem fundamental but, given the current situation in Japan, I believe that improvements in these basic areas are necessary.

8.2.1 Education and information disclosure

- strengthen natural science education, not through focusing on memorising or solving patterned problems, but stressing understanding logical thinking
- include ecology as an essential subject from elementary education, independent from the current general science, *rika*, in which devotes little time for ecological issues
- establish wildlife ecology and conservation curricula in universities and train professionals in the field
- establish a co-operative system among universities, institutions, national parks, NGOs, etc. with student assistantships/internships, financial aid, and logistic support
- encourage and support environmental education programmes by NGOs
- educate the public with regards to basic ecology and environmental ethics
- and disclose data to the public and provide easy access to data, including, for example, raw data from environmental impact assessments.

8.2.2 Scientific research

- foster training and employing of wildlife researchers
- conduct high quality scientific research, particularly on not only native species but also communities, and publish results/findings
- establish monitoring schemes based on scientific studies
- and support international research collaborations.

8.2.3 Government reform

- unit the authorities for nature conservation or develop a system that works efficiently and adequately

- employ professional wildlife biologists in both national and local governments
- and develop an efficient system of wildlife-law enforcement; for example, employ telephone hotlines to police and professional wardens.

8.2.4 NGOs

- communicate more efficiently with the general public to increase support
- establish a nationwide network system among NGOs
- strengthen monitoring of Government activities
- enhance international involvement on domestic issues
- and collate, share and utilise scientific data among NGOs.

8.2.5 Enactment of the Wildlife and Habitat Protection Law

- revise the current *Wildlife Protection and Hunting Law* to limit the law to hunting regulations with a recognition that hunting cannot regulate wildlife populations in Japan
- abandon the current status of wildlife as "items that are not owned by anyone" under an article 239 in the *Civil Code* and redefine wildlife as common property of a nation and the earth, in order not to create ownership on wildlife by poaching
- clarify the obligations of the national government. The Government has obligations to address issues relating to the global and national state of wildlife and its habitat, to communicate knowledge and information to the people, to develop conservation plans based on the scientific knowledge, to implement the plans, and to direct the local governments and the electorate.
- clarify the obligations of local government. Local governments have obligations to address issues relating to the state of wildlife and its habitat in their administrative jurisdiction in detail, to communicate knowledge and information to the public, and to administrate wildlife conservation appropriately and promptly.
- clarify the obligations of the people. The public has obligations to understand the importance of wildlife and its habitat, to monitor the government's policy on wildlife conservation, and to participate in wildlife conservation activities

- include biological diversity schemes as a corresponding domestic law with the *Convention on Biological Diversity*
- establish the Wildlife Agency in co-ordination with administering the law
- draw up conservation plans for habitat protection and restoration using a scientific approach
- consider an animal welfare and prohibit cruelty to wild animals
- create penalties equivalent to those for the infringement to personal property and public assets
- and enforce the law strictly.

8.3 Development of Conservation Strategies for Raccoon dogs in Japan

Having outlined the wider issues of wildlife conservation in Japan, I conclude this chapter by briefly reviewing my findings concerning the raccoon dog, as a basis for developing a conservation management plan for the species in Japan.

It is clear that Japan has a long way to go in terms of developing and broadening appropriate policy and practice relating to wildlife conservation. A general problem concerning wildlife conservation in Japan is a lack of habitat management and protection of common habitats, such as the wider countryside *satoyama*. This is despite continuous habitat loss, degradation and fragmentation. In Japan, protected areas are usually too small for medium to large sized mammalian species. For example, the average sizes of the Wildlife Protection Areas and the Wildlife Special Protection Areas are 9.6 km² and 4.7 km², respectively (Table 8.1). Considering the home-range size of >100 ha and the configurations within the study area (Chapter 4), this size of protected area would be inadequate for any more than a few families of raccoon dogs. Thus sympathetic management of wider countryside areas to make them more hospitable to wildlife is of key importance. This might involve, for example, increasing the amount of vegetative cover and optimising the configuration of habitat patches. Continuous cover is limited in the Japanese countryside, due to intensive land use and widespread road networks. Within this context, the protection of smaller, often linear, linkages of vegetation should form part of a management plan. For example, in the study area, riparian zones along streams appeared to provide important continuous vegetation cover for raccoon dogs, even though the areas of riparian strips were small (Saeki, 1995b; Chapter 3).

Results from radio-tracking raccoon dogs to determine habitat use suggested that two types of habitat users, mountain-type and village-type, existed in the study area. The raccoon dogs selected habitats at different scales and, although habitat preferences differed between the two types of habitat user at different scales, both types avoided Japanese cedar (*Cryptomeria japonica* D. Don) plantation. Plantations provided less food and a less heterogeneous habitat compared to herbaceous areas, secondary forest, rice fields, and cropland. The two types of raccoon dogs also displayed different movement patterns: movements of the mountain type were more complex than did those of the village-type raccoon dogs. These suggest that raccoon dogs are sensitive to habitat quality and heterogeneity.

Appropriate habitat restoration and management are therefore vital.

In Chapter 5, I found that badgers and raccoon dogs showed similar patterns of spatial use. Habitat management may be more cost-effective if it can benefit more than one species and this should be considered when developing conservation management plans. Preserving and restoring secondary forests and protecting den sites may be crucial for the co-existence of sympatric populations of raccoon dogs and badgers in Japan. Conservation of these species may also enhance local biological diversity, especially in *satoyama*.

Two particular issues are of considerable importance to raccoon dog conservation. The first of these, road-kills, are probably a major cause of mortality in raccoon dogs, and the estimated number of deaths from road accidents far exceeded the numbers due to legal harvest and culling. Although the overall impact of road-kills on raccoon dog populations is not clear, there is no evidence to suggest that road-deaths are causing a decline in raccoon dog populations. One possible reason for this is that raccoon dogs may have responded to the high mortality associated with road networks by increasing their reproduction rates (Helle and Kauhala, 1995).

Nonetheless, a range of measures might be employed to ameliorate the effects of the Japanese road-building programme on raccoon dogs, for welfare, conservation, and economic reasons. For example, allowing for animal movements by increasing the permeability of roads may help to prevent road-kills. However, the appropriate design of fences and under/overpasses will require sufficient knowledge of species ecology and their habitat use. Such data may also provide information on the high risk locations and times of road-kills; one cost effective preventive method might be to lower speed limits accordingly.

The second issue related to agricultural damage by raccoon dogs. The questionnaire survey results suggested that damage by raccoon dogs was not as severe as the levels of culling indicated. Nonetheless, raccoon dog damage was found to: 1) occur widely throughout Japan, but causing serious economic damage only within the islands of two prefectures and 2) occur on a wide variety of agricultural products. In order to reduce the potential conflicts between producers and raccoon dogs, site specific and product specific approaches may be required. It is very difficult to generalise on the nature of preventative measures, because of the wide range of site and crop types. However, they could include, for example, fencing valuable

crops or altering the habitat around a crop to make it less favourable for raccoon dogs. In some cases, compensation may be the only option. The standardised administration of culling and the poor law enforcement against wildlife crimes are a serious problem in Japan, not only for raccoon dogs but also for other wildlife species (Maita, 1998; Lawyers' Association of Japan, 1999; Appendix III). Development of preventive methods and public education are also important.

In summary, I propose the following as conservation strategies for raccoon dogs in Japan:

- identify habitat requirements for raccoon dogs (Figure 3.15 in Chapter 3)
- protect food patches, den sites, resting sites, and their connecting paths as a protecting unit
- increase the size of the Wildlife Protection Areas and Prefectural Nature Conservation Areas
- restore secondary forests that were replaced with Japanese cedar plantations
- preserve natural and semi-natural riparian vegetation and the continuity of such areas of vegetation
- build or modify bridges in such a way that raccoon dogs can pass underneath roads
- establish within local governments a system of monitoring of road-kills and link these systems nationwide
- and employ four recommendations in Appendix III section 2 for agricultural damage.

ⁱ For example, the Ministry of Construction alone spent 26,130 US billion (10^9) yen (approximately £163 US billion) for public works in 1999 (Ministry of Construction, 1999); the Ministry of Agriculture, Forestry and Fisheries has budgeted 220 US billion yen (approximately £13.8 US billion) for just one reclamation project at the Isahaya Bay (Lawyers' Association of Japan, 1999). As a result, both the national and local governments have accumulated huge deficits, i.e. a combined debt of over 600 trillion (10^{12}) yen (approximately £3.8 trillion), although the economy was affected by the pump-priming measures in the summer of 1999 like "a junkie who has just received a shot" (Igarashi, 1999).

ⁱⁱ Foreign governments receiving ODA funds then use that money to hire Japanese builders, through Japanese trading companies and consulting firms, for construction projects, such as roads, dams, and irrigation projects (Yamamura, 1994).

ⁱⁱⁱ The environmental component of the ODA focused on "improvements of residential environment (water supply and sewage systems, waste processing), and disaster prevention (through flood

prevention, etc.)" (Ministry of Foreign Affairs, 1997), and the budget for anti-pollution programmes was the largest part of the ODA's environmental efforts in 1998 (Ministry of Foreign Affairs, 2000b).

^{iv} The status of the Japanese macaque is under discussion and temporally Data Deficient in 2000 (IUCN 2000).



APPENDIX I

OVERVIEW OF THE CHANGES IN JAPAN

APPENDIX I Overview of the Changes in Japan

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1 Landscape

1.1 Forests

Forests on the Japanese Archipelago changed greatly as climate changed during the final period of last glacial age (25,000 - 15,000 years before the present (B.P.)); and boreal coniferous forest and temperate coniferous forest were two major cover types about 20,000 B.P. (Tsukada, 1984). Warm-temperate, evergreen broad-leaf forest started to expand northerly as temperature and humidity began to rise 13,000 B.P. and became a major cover type in south-western regions around 6,000 B.P. (Tsukada, 1984; Matsuoka and Miyoshi, 1998). Beech forest had started to form around 12,000 B.P. in many parts of Japan, and the Tohoku region, the northern part of the main island, became the centre of its range after 8,000 B.P. (Uchiyama, 1998). Japanese cedar forest also had increased with the change of climate, especially between 4,000 and 2,000 B.P. (Takahara, 1998).

Human influence on forests appeared at least 2,000 B.P. in Japan, increasing red pine (*Pinus densiflora* Sieb. et Zucc.) and herbaceous plants through slash-and-burn agricultural activities, while Japanese cedar was cut for timber (Sugita and Tsukada, 1983; Tsukada *et al.*, 1986). Human destruction of warm-temperate evergreen broad-leaf forest was apparent in many parts of south-western regions after 1,500 B.P. (Matsuoka and Miyoshi, 1998). Japanese Alder (*Alnus japonica* (Thunb.) Steud.) in wetlands rapidly disappeared, being replaced by rice fields after 1,400 B.P. (Miyoshi, 1988). Frequent transfers of the nation's capital during the Heian Period (Table A.1) consumed timber and forests at a high rate.

Construction of Buddhist temples, (e.g. Horyuji temple built in the early 8th Century) and Shinto shrines (e.g. Izumo Taisha) also created continuous demand for large logs, especially of the Japanese cypress (*Chamaecyparis obtusa* Endl. (Sieb. et Zucc.)). For example, more than 14,800 m³ of wood, including 84 pillars of >1 m in diameter and 30 m long, were used for just one building in Todaiji temple, which was originally built in the 8th century and destroyed in a war in 1180 (Nishioka and Kohara, 1978). At the time of rebuilding the temple in 1195, because timber resources were already limited in the Central Japan, enormous numbers of large logs were collected from the west end of Honshu (Nishioka and Kohara, 1978), starting the devastation of forests in Chugoku region (Tomiyaama, 1974). *Tatara*, a traditional iron smelting method from poor ore, required a huge amount of charcoal and consumed forests of *Quercus* spp, especially in Chugoku region, from 700 to 800 B.P. up to the Taisho Era (Table A.1) (Miyoshi, 1988; Toyohara, 1998). Rotational cutting and planting of softwood was adopted by the 17th century (Uchida, 1995). Wood became the primary material for building houses, furniture and ships and was used as fuel for ceramics, metallurgy, salt-making, and papermaking and to make charcoal, which has been a major energy source until recent years (1950s) (Toyohara, 1988, 1998; Uchida, 1995).

Table A.1 Timeline of Japanese history.

Year	Name of Period/Era
10,000 - 300 BC	Jomon Period
300 BC - AD 300	Yayoi Period
300 - 645	Kofun Period
645 - 710	Asuka Period
710 - 794	Nara Period
794 - 1185	Heian Period
1192 - 1333	Kamakura Period (Kamakura shogunate)
1333 - 1467	Muromachi Period (Ashikaga shogunate)
1568 - 1600	Azuchi-Momoyama Period
1603 - 1868	Edo Period (Tokugawa shogunate)
1868 - 1912	Meiji Era
1912 - 1926	Taisho Era
1926 - 1989	Showa Era
1989 - present	Heisei Era

Since the middle of the 17th century when the Tokugawa shogunate had established its ruling system, forests were managed by the shogunate or feudal clans, communities (villages), and individuals although a modern legal ownership had not been formed by this time (Funakoshi, 1981). Trespassing in the forests managed by the shogunate or feudal clans was forbidden, especially in the forests directly managed by the shogunate with words of "one tree, one head" (Funakoshi, 1981). Most forests were managed by the communities in this period;

and use of the forests was controlled with strict regulations, such as periods of use, tools, amounts of utilisation, and co-operational management of grass for compost (Funakoshi, 1981). Privately managed forests were limited to around houses and agricultural lands (Funakoshi, 1981).

In 1869, forests that had been owned by the shogunate became national property, the original form of National Forests. During the Meiji Era (Table A.1) after the amendment of the Land Tax in 1873, large-scale sales of forests resulted in indiscriminate deforestation, and consequently resulted in flooding and damage to rice production (Funakoshi, 1981). Japanese chestnut trees had been cut continuously for railway sleepers since the middle of the Meiji Era (Tomiyama, 1974; Nakagawa, 1988). In 1897, the *Forest Law* was enacted, and the business administration by the government of the nationally owned forests had started (Funakoshi, 1981). Thirty percent of forest areas are national government-owned, mainly distributed in remote and high altitude areas (Statistics and Information Department, 1990). According to Shidei (1974), the National Forests went through three phases of change: 1) small-scale clear-cutting and afforestation after the wars with China and Russia, 2) selective cutting and natural renewals in the early Showa Era (around 1930; Table A.1), and 3) large-scale clear-cutting and afforestation after World War II to the 1960s (Figure A.1a). Under governmental direction, privately or publicly-owned forests underwent similar changes to the National Forests. Economic crises and natural disasters were partly responsible for deterioration of artificial forest. In addition, special felling for military use without afforestation started in 1937. Felling and afforestation of remote forests started in the early 1950s due to the increased timber demand as advanced machinery and forest roads developed (Figure A.1b) (Shidei, 1974). Extensive damage by a typhoon in 1954 brought in the use of chain saws and logging tractors to dispose of trees; and the use of heavy machinery, such as the harvester and processor, has drastically increased in the 1990s (Forestry Engineering Society of Japan, 2000). The government has maintained the policy of forest management, by promoting the construction of forest roads and the development of forestry machinery, along with workers' training programmes and production of brand-name timber, e.g. Kitayama cedar (*Cryptomeria japonica* var. with specific care), after a drastic drop of both cutting and afforestation since the 1970s (Minister of Agriculture, Forestry and Fisheries, 2000a; Figure A.1). It is apparent that

the independent profit policy of the National Forests resulted in rash forestry administration, such as the large-scale clear cutting after the 1930s (Tomiyaama, 1974). Only two species combined, the Japanese cedar and the Japanese cypress, comprised nearly 90% and 70% of afforested area in the National Forests and in publicly or privately owned forests, respectively in 1997 (Forestry Agency, 1998).

Figure A.1 Changes in (a) areas of cutting and (b) development of forest roads in National Forest and private land in Japan. (Data from the Forestry Agency and Funakoshi 1981)

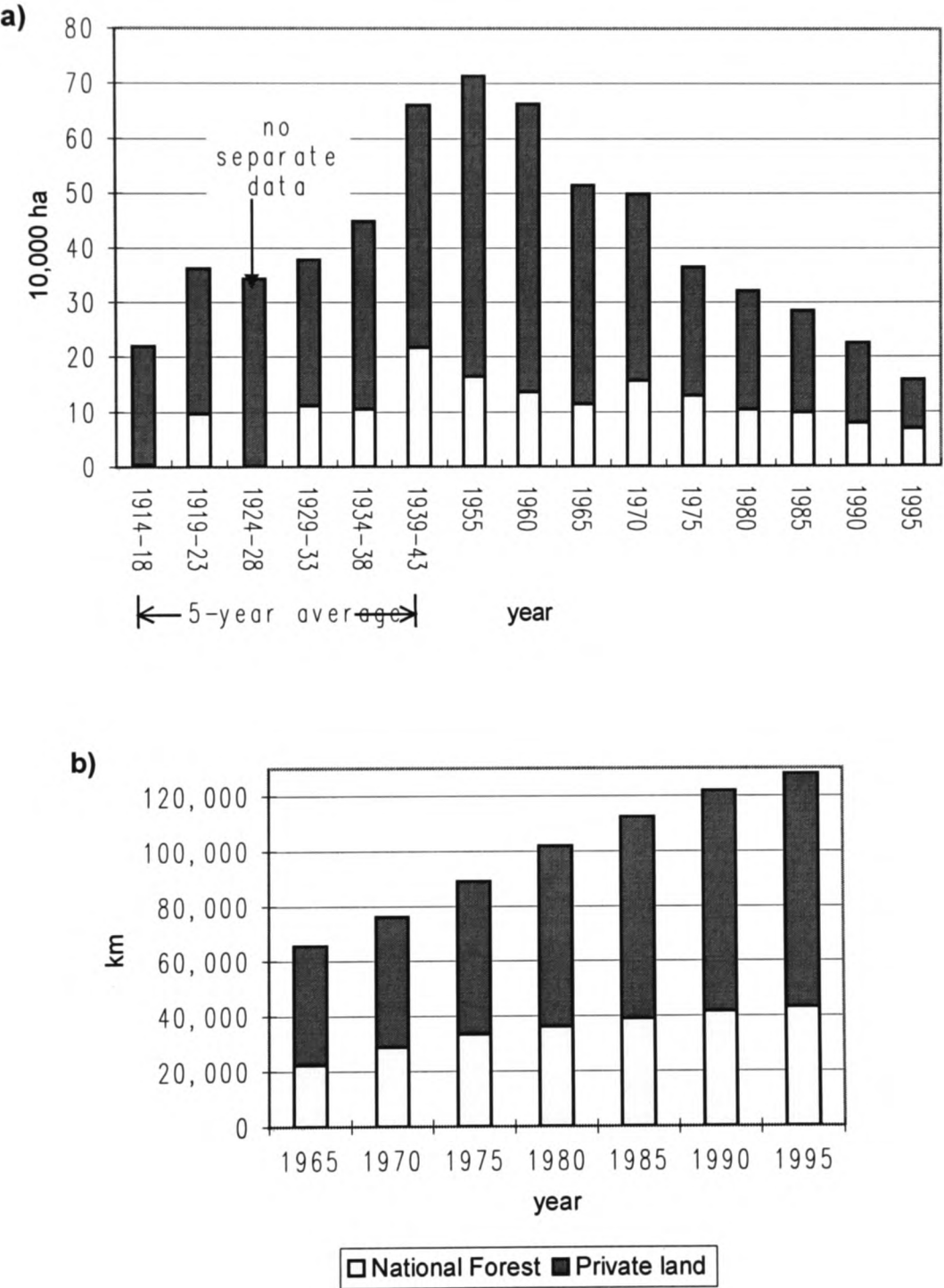
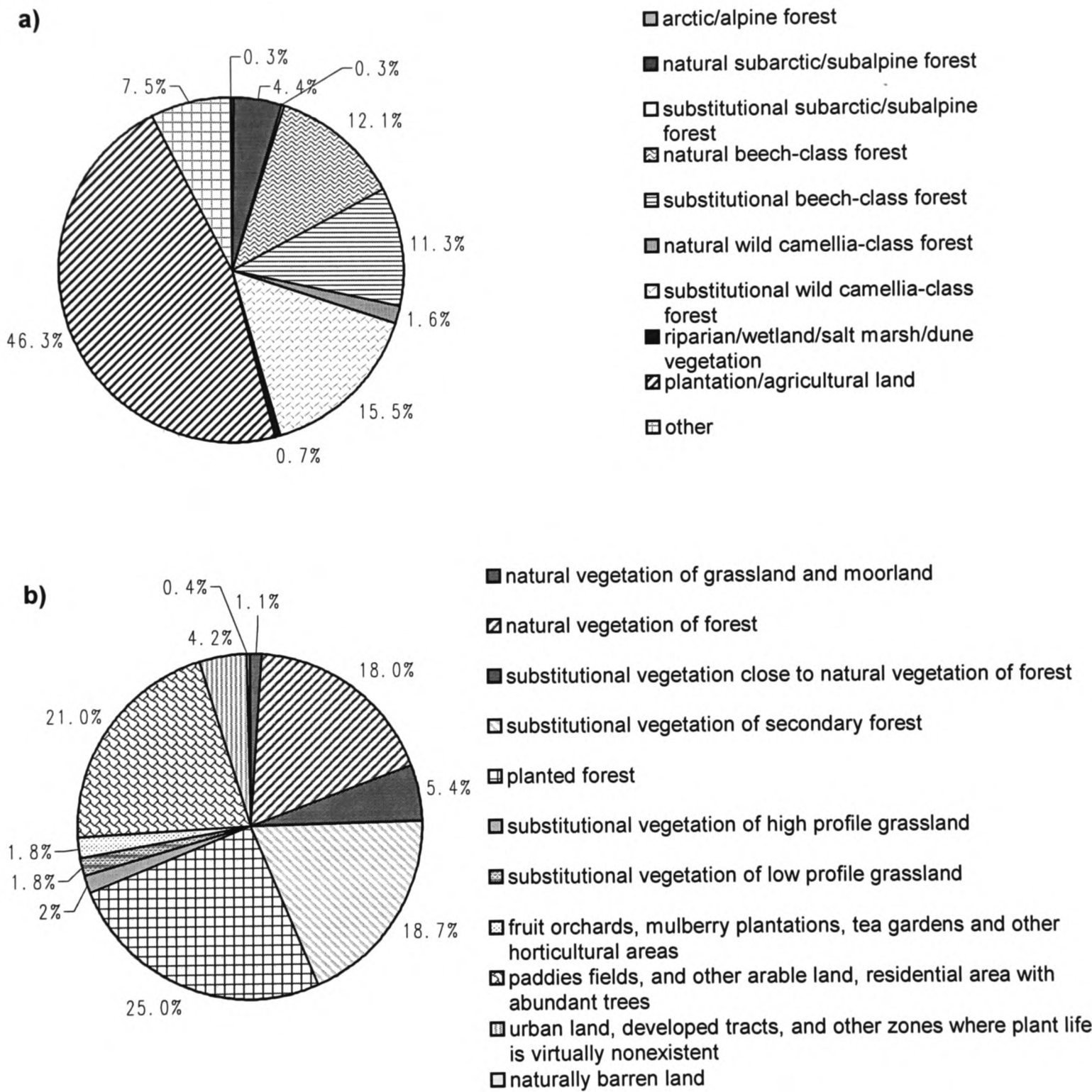


Figure A.2 shows current condition of vegetation in Japan. Plantation and agricultural land dominate in Japan. More substitutional vegetation, i.e. vegetation which has been substituted from natural vegetation and maintained by human activities, is present than natural vegetation which is <20%.

Figure A.2 Vegetational composition of Japan, (a) vegetation class and (b) naturalness of vegetation. (data from the Environment Agency 1988-1992)



Forests in Japan are still under threats of destruction and structural changes. Indirect effects by human activities cannot be estimated but probably are substantial. Because of steep slopes, torrential precipitation with typhoons, and/or seismic activity, erosion is a serious problem in many forested areas. Road construction, deforestation, and artificial plantation of softwood have increased the risk of erosion. The large-scale clear-cutting and afforestation of softwoods for decades have probably made forests more vulnerable to such natural disasters. Another example would be coppices of hardwoods, such as oak (*Quercus serrata* Thunb. and *Q. Acutissima* Carruth.) and pasania (*Castanopsis cuspidata* (Thunb.) Schottky) near human residences, which used to be a vital resource, producing charcoal as an energy source and compost for farmland. Most coppices have been lost to suburban development, being replaced by housing, roads, and golf courses. Bamboos, such as *Phyllostachys pubescens*, a species introduced from China in the 18th century, have recently invaded coppices in countryside, altering the forest structure (Forestry and Forest Products Research Institute, 1995; Torii and Isagi, 1997).

Destitution in domestic forestry also have adverse effects on artificial forests. In the 1990s, as the import of timber increased and forestry workers became older, more artificial forests were left unmanaged without proper thinning. The ratio of workers over 60 years old in forestry was three times that of other industries (National Forestry Union, 1997). The price of wood and logs has dropped since 1980, further discouraging the industry, and domestically produced wood comprised only 20.1% of wood consumption; in 1998 Japan, even with 76% covered by forest, being the largest timber importer in the world, imported 87 million m³ of wood (Forestry Agency, 1999a). There are little undergrowth and wildlife found in maturing artificial forests.

Natural processes have further destroyed the Japanese forests. Pine nematode (*Bursaphelenchus japonicus*) spread by the Japanese pine sawyer (*Monochamus alternatus*) has been a serious problem, especially in south-west parts of Japan (Kiyohara, 1989; Forestry Agency, 1998). About one million m³ of stand volume of pine were lost annually since the 1970s with a peak of 2.4 million m³ lost in 1979 (Forestry Agency, 2000). This long-term decrease of pine stands possibly has adverse effects on wildlife species which associate with pine forests. In addition, since the 1980s, over-browsing and/or bark-stripping by sika deer has become

severe in many places, such as Odaigahara (Akashi and Nakashizuka, 1999; Yokoyama *et al.*, 2001). Odaigahara is located at the southern limit of the Northern spruce's range, in the Nikko National Park (Tsujioka, 1999), one of the earliest National Parks (designated in 1934), and in the Eastern Hokkaido (Kaji, 1995; Uno, *et al.* 1998; Kaji *et al.*, 2000).

1.2 Agricultural Land

The earliest evidence of farming was found in the Jomon period (Table A.1), and rice production is believed to have been introduced in the late Jomon period (2,200 - 2,300 B.P.)(Higuchi, 1989; Sasaki, 1993); however, the remains of large rice fields with irrigation and storage buildings indicated that rice had become a staple food in the Yayoi period (Table A.1) (Uchida, 1995). Since then, rice has been the main agricultural product for more than 2000 years, and rice fields have been a major land use. The total area of rice fields, however, has constantly decreased for at least 30 years, currently comprising approximately only 5.2% of the total land of Japan (Ministry of Agriculture, Forestry and Fisheries, 1998).

While rice fields have decreased, the productivity of rice has risen (5.25 tonne/hectare in 1996; cf. about 1.7 tonne/hectare in 1880, Ministry of Agriculture, Forestry and Fisheries) because of advanced technology. Rice fields became drier, (i.e. shallower in water depth and drained earlier), due to use of heavy machinery, and irrigation channels became deeper, as artificial concrete structures with water pumps, replaced earth ditches. More than 80% of rice fields have been converted into the modern type in the last 30 years (Fujioka and Lane, 1997), and 99.1% of fields have been irrigated (Food and Agriculture Organisation, 2000). The average size of a field became larger, and the shapes became more regular in straight lines; thus the use of circumferential dykes decreased, down to 6% of cultivated area for rice in 1997 (calculated from data provided by the Ministry of Agriculture, Forestry and Fisheries). Methods of fertilisation also changed from compost made from fallen leaves in woods and grass cuttings, (i.e. the traditional *karishiki*), to fertiliser made from fish, bean cake and rapeseed cake to synthetic fertiliser (Funakoshi, 1981).

Earth dykes provide suitable habitat for small mammals and invertebrates, and earth ditches hold more fish and frogs than artificial gutters (Fujioka and Lane, 1997; Lane and Fujioka, 1998). In conjunction with water pollution by agricultural chemicals (pesticides and

herbicides) and eutrophication by synthetic fertiliser, the ecosystem of rice fields has altered greatly. Many species in rice field ecosystems have been lost through large amounts of agricultural chemical use and large-scale alteration of soil foundation in rice field (Kawano, 1998).

Agricultural fields other than those used for rice have also decreased in modern times. From 1970 to 1997, the area of ordinary upland fields decreased by 18.8% and land under permanent crops has decreased by 36.7% (Ministry of Agriculture, Forestry and Fisheries, 1999a).

1.3 Rivers and Lakes

In 1896, the *River Law* was enacted, and the Meiji government, with its absolute belief in technology, started building concrete embankments. Tomiyama (1974) pointed out that the employment of high water-level constructions, i.e. building continuous embankments, resulted in cutting off rivers from the earth and people, resulted in even greater floods and drought, leading to building dams, which later resulted in further forest destruction.

The Ministry of Land, Infrastructure and Transportation (the Ministry of Construction before February 2001) is the authority that manages the water systems. Since the Meiji Era, the main theme of management has been flood control, enhancing construction of dams, building concrete embankments, and dredging. The only law for regulating construction on rivers, the *River Law*, whose main purposes are protection and development of land through disaster prevention and functioning of running water, often favours the building artificial structures over the protection of aquatic and riparian ecosystems (Yamanura, 1994). As a result, by 1985, of 113 major rivers in Japan, only three were devoid of any obstruction, such as erosion control dams; 21.1% of total riverbank length has been modified artificially, and 28.7% of lakes had artificial shorelines (Environment Agency, 1997). Water pollution, acidification, and eutrophication have been problematic in many rivers and lakes; as has the introduction of non-native fish species, such as largemouth bass (*Micropterus salmoides* Lacepède) and aquatic weeds, such as *Elodea* and *Egeria* (Environment Agency, 2000a).

1.4 Coastal Areas

As an island nation, Japan has lengthy and varied coastlines (34,536 km, data from Coastal

Statistics, 1993 cited by Isobe). However, except for inaccessible precipices, a great part of the coast has been open to development. Tidal flats, mouths of rivers and shallow bays have been altered by extensive development and reclamation. For example, 7.5% of tidal flats (3,857 ha) were lost between 1978 and 1992, mostly to reclamation (Environment Agency, 1992). By the early 1990s, only 44.7% of the coastline was free from artificial structures on the four major islands (Environment Agency, 1992). Many mangrove forests, coral reefs, and seaweed beds have been lost around Japan by direct and indirect influences of human activities. For example, 3.2% (6,403 ha) of seaweed beds were lost between 1978 and 1992 (Environment Agency, 1992).

2 Wildlife

Land bridges, ice bridges, climate changes, and dispersal ability predetermined mammalian fauna on each island of Japan during the Quaternary Era (2 million to 10,000 B.P.) (Dobson, 1994; Kawamichi, 1996; Dobson and Kawamura, 1998). Larger mammals inhabited Japan during the Pleistocene (1.6 million to 10,000 B.P.), such as the Akashi elephant (*Stegodon akashiensis*) and arctic mammoth (*Mammuthus paramammonteus shigensis*) (early to middle Pleistocene), Kazusa deer (*Cervus kazusensis*) (early to late Pleistocene), Oriental elephant (*S. orientalis*), water buffalo (*Bubalus* sp.), and China rhinoceros (*Rhinoceros sinensis*) (middle Pleistocene), Naumann elephant (*Palaeoloxodon naumanni*) (middle to late Pleistocene), woolly mammoth (*M. primigenius*), red deer (*C. elaphus*), Nikitin serow (*Naemorhedus nikitini*), bison (*Bison priscus*), horse (*Equus* sp.), and moose (*Alces alces*) (late Pleistocene) (Kawamura *et al.* 1989). There are four extinct endemic carnivores: Tanaka bear (*Ursus tanakai*), Kuzuu weasel (*Mustela kuzuunensis*), Mukashi badger (*Meles mukasianakuma*), and Mukashi marten (*Martes ten*); and seven extinct non-endemic but native carnivores, such as Kuzuu badger (*Meles leucurus kuzuunensis*), caracal (*Felis caracal*), and leopard (*Panthera pardus*). (Kawamura *et al.*, 1989). The causes of extinction of these species are not clear although hunting pressure by prehistoric humans might have played a role in the extinction. The current situation of mammalian wildlife is described in Chapter 2.

3 Human demography and development

3.1 Human Demography

Human population size has been the most influential factor in nature destruction and wildlife exploitation throughout human history worldwide. In Japan, demographic change has undergone several phases, such as gradual increase in population during the prehistoric era, rapid increases after establishment of large-scale rice farming in the Yayoi era and during the first half of the Edo period, and a drastic shift after World War II by concentration in urban areas.

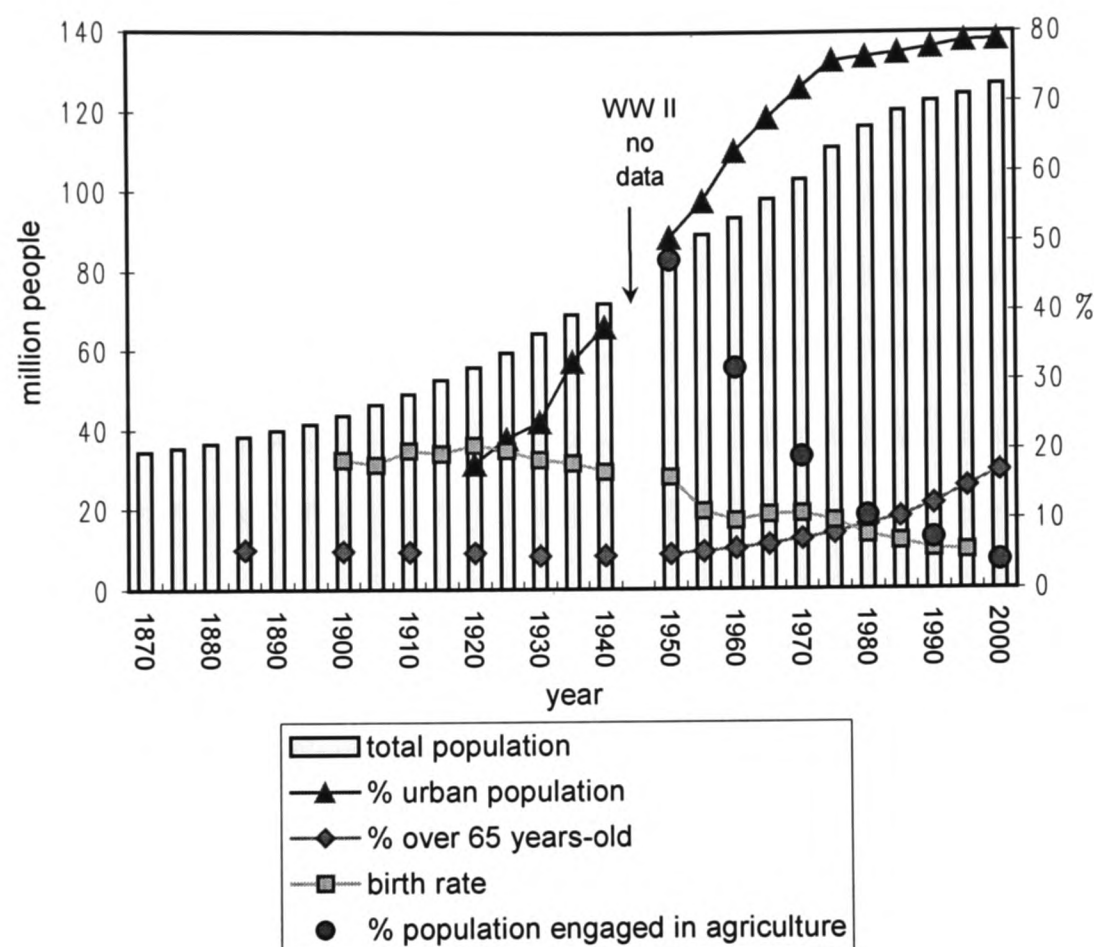
Humans started to inhabit in the Japanese Islands during the glacial epochs, before 600,000 B.P. in the Palaeolithic period (Kito, 2000). According to an estimation by Kito (1983, 2000), the prehistoric population in Japan slowly increased from 20,100 in the early Jomon Period (8,100 B.P.) to 0.6 million in the Yayoi Period (1,800 B.P.). Population density was significantly higher in eastern Japan than the western part during the Jomon Period, whereas human population increased at a greater rate in western Japan during the Yayoi Period, probably because of the introduction of large-scale rice production along with climate changes and immigration from Eurasian Continent (Sasaki, 1993; Kito, 2000). The population exceeded 5.5 million in the 8th Century and 12 million in the 16th Century.

The population increased remarkably in the first half of the Edo Period (Table A.1) from about 15 million to the level of 30 million, according to the first nationwide population census in 1721 (Dolan and Worden, 1994; Uchida, 1995). About 80% of the total population were engaged in agriculture, mostly producing rice, which was the economic basis of this period (Uchida, 1995). The population growth in the second half of the Edo Period stopped due to natural disasters and famines (Kito, 2000).

Over the last 100 years the total population of Japan has gradually increased (to 126.5 million in 1998) while the birth rate has decreased to less than one-third of that 100 years ago (9.6% in 1998)(Ministry of Health and Welfare, 2000). The most obvious changes appeared to be the increase of urban population to nearly 80% of the total population and the drastic drop in the population engaging in agriculture from approximately 40% to 5% of the total population during the last 50 years of the 20th century (Food and Agriculture Organisation of

the United Union, 2000) (Figure A.3). Despite the recent slow population growth in Japan (Figure A.3), the density of 337/km² in 1995 was the fourth in the world; overall habitable density was 1,044.5/km², showing further concentration of human population density (data from the Population Census, 1995). The National Institute of Population and Social Security Research (1997) predicted the total population would decrease after 2007.

Figure A.3 Demographic changes in Japan from 1879 to 2000.



3.2 Industrial and Economic Development

Prehistoric development in Japan can be traced through archaeological finds of hand-axes, flake tools, blades, and microliths throughout Japan. The shapes of these tools show there were already cultural differences between western and eastern parts of Japan before 6000 or 6500 B.P. (Sasaki, 1993). Diverse food items in the remains and increasing village-size indicate a rich environment that supported higher human density in Japan than in Europe during the Stone Age (Higuchi, 1989). Human density was especially high in the middle eastern part of Japan estimated at over 5 people/km² from (Kito, 2000). Hunting and gathering remained the predominant lifestyle during the Jomon Period. The remains of more than 30 species of terrestrial mammals, 15 species of marine mammals, 18 species of birds, 50

species of fish, large numbers of shellfish, and acorns were found in shell mounds and at other human site from the Jomon Period (Higuchi, 1989).

Large-scale irrigation for rice production resulted in a population increase that was, in turn, required for the high level of rice production during the Yayoi Period. Large villages were built mostly in the western part of Japan in this period. Transition was completed from the hunting-gathering life style to large settled agrarian communities with rice production.

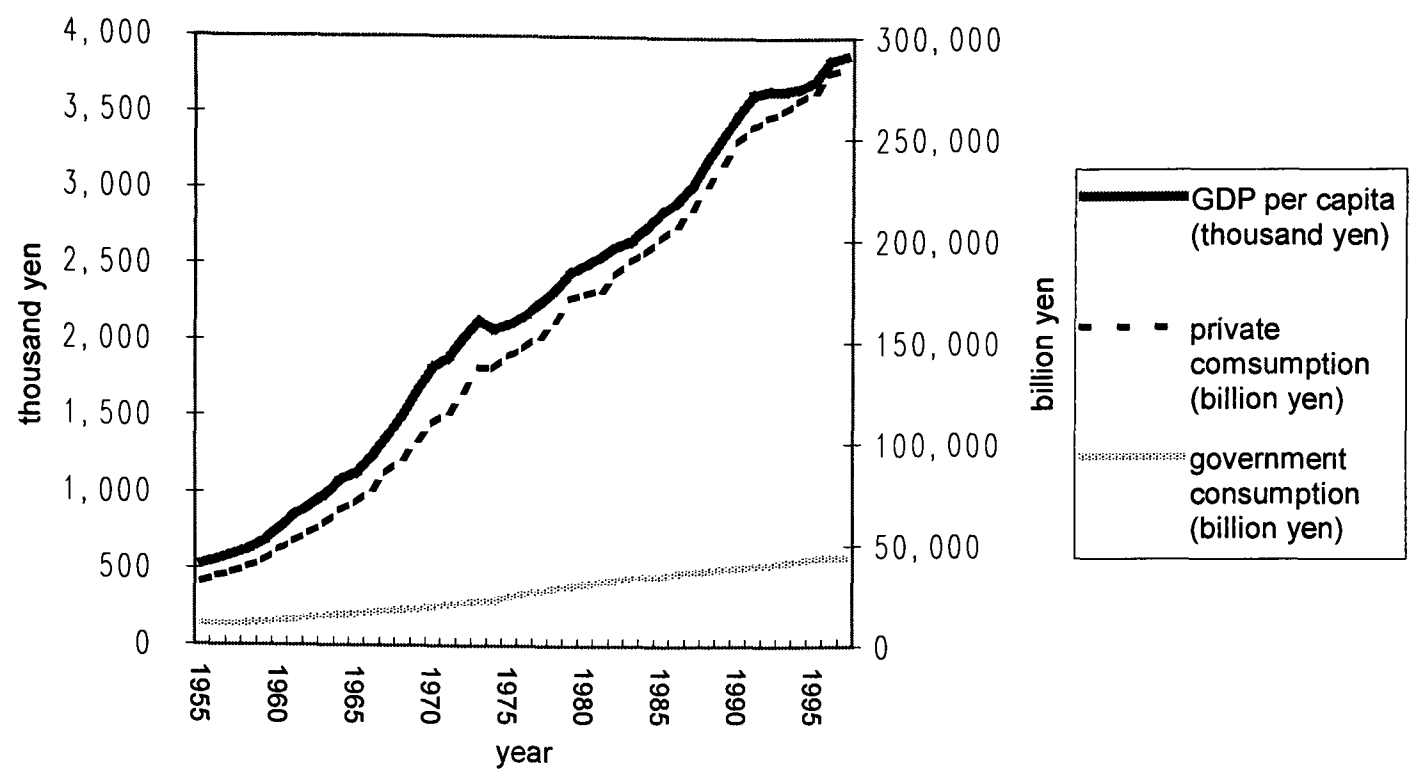
Japan's first capital city was built in 694 during the Asuka Period (Table A.1), leading to the first centralised dynasty in the Nara Period (Table A.1) followed by the Heian Period. State ownership of land and yearly taxes were adopted from the Chinese Empire, and a 3.9-km grid system of land started in these periods. Centralisation can be seen in a construction of the Daibutsu, a large Buddha's image cast in the 740s from 500 tonnes of copper, 8.5 tonnes of tin, 440 kg of gold, and 2.5 tonnes of mercury (Fujino, 1991). Diverse division of labour in technology (e.g. woodcutter, charcoal burner, blacksmith, carpenter, etc.) was apparent in the Muromachi Period (Table A.1) (Uchida, 1995). Rice-farmers supported the entire nation, providing food and a self-sufficient economy during the Edo Period (Uchida, 1995). The total production of rice rose greatly from 2.59 million tonnes in 1598 to 3.61 million tonnes in 1697, but only increased slowly to 4.26 million tonnes in 1830 during the late Edo Period (Kito, 2000).

After the Edo Period, which lasted more than 250 years under isolation as the shogunate's policy of closing the nation with an exception of small international trade, the Meiji Era abolished the closed country policy and brought about modernisation in politics and industry as the government set the clear goal of catching up with industrialisation in Western countries. The first telegraph line in 1869 and the first railroad in 1872 were symbols of modern technology; the first constitution in 1876 was a form of Western political system modelled on the German Constitution (although it declared extensive power to the emperor); and the establishment of the Bank of Japan in 1882 formed the financial base and a modern currency system. Light industries, such as the textile industry, were the most important secondary industries and constituted Japan's staple exports until the 1920s; and heavy industries, such as steel, started to prosper at the turn of the 20th Century. Japan had taken Taiwan from China after the Sino-Japanese War (1894 - 1895) and South Sakhalin from Russia after the Russo-Japanese War (1904 - 1905), setting a basis of expansionism and exploitation outside

of Japan and even creating a myth which Japan always wins. Japanese industries enjoyed an economic boom during World War I (1914 - 1918) and grew rapidly. It was the first time that the contribution to the national economy of industrial output exceeded that of agricultural yields. Plutocracies called *zaibatsu* began to dominate industry as heavy industries grew. They supported the government policy that sought raw materials and markets overseas, especially in Manchuria. Political upheaval and an economic depression took the government into military expansionism and increasing military expenditure as the Diet's, the Japan's main legislative body, influence declined and the power of the military clique increased; thus the country was led into the Pacific War in 1941. World War II (1942 - 1945) devastated Japan, destroying most major cities, radically altering people's lives and beliefs, and undermining the national economy.

Japan accomplished a remarkable economic recovery after World War II. Gross domestic product (GDP) per capita increased more than 7-fold from 1955 to 1997 while the government consumption increased 4.3 times and private consumption increased 9.3 times (Figure A.4). The economic development has been supported by the enactment of a series of developmental laws and economic plans (Appendix II). Prime Ministers followed a governmental long-term policy characterised by an exclusive focus on economic growth. This focus inspired people to pursue unlimited, thus unsustainable development, following approaches such as those outlined in the 'Income-Doubling Plan' in the 1960s (proposed by PM Hayato Ikeda) and the 'Japanese Islands Reconstruction theory' in the 1970s (invented by PM Kakuei Tanaka). One result was a reckless resort boom in the 1980s (led by PM Yasuhiro Nakasone) with the *Resort Arrangement Law 1987*. The spending of large amounts of tax money for public works under the 'Pump-priming Measures' in the late 1990s (directed by PM Keizo Obuchi) also contributed to the development. There were oil crises in 1973 and 1978, interrupting economic growth, and the economy of Japan was stagnant after the bubble burst in 1990, the worst and longest economic crisis after World War II. Yet Japan's GDP remained the second largest in the world after the USA in 1998.

Figure A.4 Economic development in Japan from 1955 to 1997.



Industrial development of Japan has its long history over centuries although people usually think of only the post-war development. Also, drastic changes in land management administrations and policies at the Meiji Restoration affected greatly the state of environment in Japan. Protection of industries and economic development are still two priorities among the Japanese people and the Government.

APPENDIX II

HISTORY OF JAPANESE LEGISLATION CONCERNING DEVELOPMENT AND CONSERVATION

APPENDIX II History of Japanese Legislation concerning Development and Conservation

year	Law	International and domestic events
1868		Meiji Restoration
1873	Hunting Regulations	
1894		Sino-Japanese War (-1895)
1895	Hunting Law	
1896	River Law	
1897	Forest Law (except Okinawa and Hokkaido) Erosion Prevention Law	
1901	Revision of Hunting Law	
1904		Russo-Japanese War (-1905)
1907	Revision of the Forest Law	
1909	Law for Standing Trees	
1914		World War I (-1918)
1918	Hunting Law (3rd revision)	
1919	Law for the Protection of Historic and Scenic Natural Monuments Cultivation Aid Law	
1921	Public Waters Reclamation Law	
1923		Great Kanto Earthquake: 130,000 deaths
1928		IOPN establishment
1931	National Park Law	
1934		Wild Bird Society of Japan establishment
1939	Revision of the Forest Law	
1941		Pacific War
1942		World War II (-1945)
1945	Forest Resources Preparation Law	
1946		International Convention for the Regulation of Whaling
1948	Agricultural Chemical Regulation Law	IUPN establishment
1949	Revision of the National Park Law Fisheries Law	
1950	Law for the Protection of Cultural Properties Revision of Hunting Law National Land Development Law Hokkaido Development Law	International Convention for the Protection of Birds Korean War (-1953)
1951	Revision of the Forest Law Harbour Law Fisheries Resources Protection Law	International Plant Protection Convention NACS-J establishment
1952	Agricultural Land Law Road Law Law to Promote Electric Source Development	International Convention for the High Seas Fisheries of the North Pacific Ocean
1953	Solitary Island Promotion Law	
1954	Special Measures Law to Encourage Development on Amami Archipelago	
1955	Japan Housing Public Corporation Law	
1956	City Park Law Seacoast Law Japan Highway Public Corporation Law	IUCN establishment
1957	Natural Park Law Revision of the Forest Law Law to Promote Development in Tohoku Region Specific Multipurpose Dam Law	
1958	Water Quality Conservation Law Sewerage Law Factory Effluent Control Law Landslide Prevention Law Revision of Hunting Law	
1959	Law to Promote Development in Kyushu Region Tokyo Metropolitan Area Arrangement Law Forest Development Public Corporation Law (revision: forest roads in remote areas)	WCED establishment

1960	Waste Material Law Law to Promote Development in Hokuriku Region Law to Promote Development in Chugoku Region Law to Promote Development in Shikoku Region Urgent Measures Law for Management of Water and Mountain Basic Agriculture Law	
1961	Water Resources Development Promotion Law Urgent Measures Law for Bay Arrangement Provisional Measures Law for Promotion in Coal Production Areas Law to Promote Industrial Development in Under-developed Area	WWF International establishment
1962	Smoke Control Law Law for Protection of Trees for Maintaining Scenic Beauty in Cities Law to Promote Construction of New Industrial Cities Special Measures Law for Countermeasures in Heavy Snow Areas Law for Special Measures on National Budget for Total Arrangement of Public Facility in Remote Areas Law to Promote New Industrial Cities Nationwide Total Development Plan	International Convention for the Prevention of Pollution of the Sea by Oil
1963	Wildlife Protection and Hunting Law Kinki Region Arrangement Law	
1964	Law to Promote Industrial Arrangement Special Areas Provisional Measures Law for Road Arrangement in Industrial Development in Remote Areas Revision of the River Law	Tokyo Olympic joining to OECD
1965	Japan Environment Corporation Establishment Law Mountain Village Promotion Law Forest Development Public Corporation Law (revision: Super Forest Roads)	
1966	Law for Protection of the Suburb Green Land in Tokyo Metropolitan Area Law for Preservation of Ancient Cities Development Arrangement Law in Chubu Region	
1967	Basic Law of Pollution Countermeasure Law for Prevention of Troubles by Aircraft Noise near Public Airports Law for the Development of Conservation Areas in Kinki Region	
1968	Air Pollution Control Law Noise Control Law Urban Planning Law	
1969	Law for Compensation in Health Damage by Pollution Special Measures Law for Restoration on Ogasawara Islands New Nationwide Total Development Plan	International Convention on Civil Liability for Oil Pollution Damage

1970	Pollution Dispute Management Law Water Pollution Control Law Marine Pollution Control Law Law for Burden on Industry of Pollution Prevention Waste Management and Public Cleaning Law Ordinance on Nature Conservation in Hokkaido Urgent Measures Law to Manage Depopulation Areas Law for the Construction of the Tsukuba Research Institute City Law for Special Measures on National Budget for the New Tokyo International Airport	EXSPO '70 (Osaka)
1971	Environment Agency Establishment Law Bad Smell Control Law Law for Preventing Agricultural Soil Pollution (Cd) Marine Fisheries Development Promotion Law Special Measures Law to Promote Development in Okinawa Law to Promote Industrial Introduction in Agricultural Village Areas Revision of Wildlife Protection and Hunting Law	WWF-J establishment Ramsar Convention
1972	Nature Conservation Law Migratory Bird Treaty with USA Law for Regulating the Transfer of Designated Bird Species Special Measures Law for Total Development in Lake Biwa Law to Promote Industry Replacement	UNEP establishment London Dumping Convention Convention for the Protection of the World Cultural and Natural Heritage
1973	City Green Zone Conservation Law Law for Regulations in Tests and Production of Chemical Substances Migratory Bird Treaty with Russia Provisional Measures Law for Seto Inland Sea Environmental Protection Special Measures Law for Water Resources Area	CITES International Convention for the Prevention of Pollution from Ships
1974	Migratory Bird Treaty with Australia Productive Green Land Law National Land Use Planning Law Urban Re-development Law Law for Living Environment Arrangement around Power Stations Revision of the Forest Law	Nature Conservation Constitution
1976	Vibration Control Law Ordinance on Environmental Impact Assessment in Kawasaki-city	
1977	<u>Third Nationwide Total Development Plan</u>	
1978	Revision of Wildlife Protection and Hunting Law Revision of the Forest Law Environmental Protection Special Measures Law for Aircraft Noise near Specific Airport	
1979	Revision of Wildlife Protection and Hunting Law	Bonn Convention
1980	Washington Convention (CITES) Ramsar Convention London Dumping Convention Migratory Bird Treaty with China Ordinance on Environmental Impact Assessment in Hokkaido Ordinance on Environmental Impact Assessment in Tokyo and Kanagawa	World's Strategies of Nature Conservation
1982		Nairobi Declaration World Chapter for Nature UN Convention on the Law of the Sea Benelux Convention on Nature Conservation and Landscape Protection IWC adopting a moratorium on whaling

1983	Marpol Convention Law Concerning Special Measures for Conservation of the Environment of the Seto Inland Sea Septic tank Law Dismissal of Law for Environmental Impact Assessment Revision of Wildlife Protection and Hunting Law	International Tropical Timber Agreement (ITTA)
1984	Clean Lake Law	
1985	Peninsula Promotion Law	Vienna Convention for Ozone Layer Protection ASEAN Agreement on Conservation of Nature and Natural Resources
1986		Convention for the Protection of the Natural Resources and Environment of the South Pacific Region
1987	Resort Arrangement Law Law for Construction Promotion of the Kansai Cultural Academic Research City Fourth Nationwide Total Development Plan	Montreal Protocol for Ozone Layer Protection
1988	Vienna Convention for Ozone Layer Protection Law for Ozone Layer Protection by Regulation of Specific Substances Revision of Wildlife Protection and Hunting Law Stopping commercial whaling and starting scientific whaling	
1989	Montreal Protocol for Ozone Layer Protection Revision of Wildlife Protection and Hunting Law	Basel Convention
1990	Revision of Wildlife Protection and Hunting Law	1st Earth Day
1991	Law to Promote the Use of Recycled Materials Revision of Wildlife Protection and Hunting Law Revision of River Law (Alleviation)	New Strategies for Nature Conservation
1992	NGO Convention Law for the Conservation of Endangered Species of Wild Fauna and Flora Law for Reduction of Total Automobile's NO ₂ Osaka Bay-area Law	Rio Declaration NGO Earth Constitution Convention of Biological Diversity Agenda 21 UN Framework Convention on Climate Change
1993	Convention of Biological Diversity Convention for the Protection of the World Cultural and Natural Heritage Basic Environment Law Law on Interim Measures to Promote Business Activities Relating to the Use of Recycled Materials and the Rationalisation of Energy Usage, etc Revision of Wildlife Protection and Hunting Law	
1994	Basic Environmental Plan Revision of Wildlife Protection and Hunting Law	UN Convention to Combat Desertification Criteria and Indicators for Conservation and Sustainable Management of Temperate and Boreal Forests
1995	Revision of Wildlife Protection and Hunting Law Law to Promote the Collection and Remerchandising of Preseparated Container Packaging	Great Hanshin-Awaji Earthquake: 6,000 deaths; 40,000 injured
1996	Law concerning Conservation and Management of Marine Living Resources	
1997	Environmental Impact Assessment Law Revision of River Law Revision of Wildlife Protection and Hunting Law	Kyoto protocol establishment of the World Commission on Dams
1998	Non Profit Organisation Act Revision of Wildlife Protection and Hunting Law	

1999	Revision of Seacoast Law Ministry of Environment Establishment Law Law to Promote Improvement of Management for Releasing Particular Chemicals into Environment Law for Special Measures to Dioxins Revision of Wildlife Protection and Hunting Law	
2000	Basic Law to Form Recycling Society Revision of Wildlife Protection and Hunting Law	
2001	The Environment Agency upgraded to the Ministry of Environment	

Conservation laws in green and developmental laws in red in principle; but conservation laws can work against conservation. Also many laws work in both ways (e.g. the Forest Law and the Urban Planning Law).

Purposes of the *Wildlife Protection and Hunting Law, 1918*

Article 1 (Purposes)

This Law is aimed at contributing to the conservation and propagation of wild birds and animals through conducting conservation projects and proper hunting management, to improving the environment of human life and to the promotion of agriculture, forestry and fisheries by culling pest birds and animals and creating a safe environment.

Purposes of the *Law for the Conservation of Endangered Species of Wild Fauna and Flora, 1992*

Article 1 (Purposes)

This Law, recognising that wild fauna and flora are an indispensable element of the whole life of human beings, not only as an important constituent of the ecosystems, but also as that of the natural environment as a whole, aims to conserve the natural environment by protecting endangered species of wild fauna and flora and contributing towards the maintenance of wholesome and cultured living of the people in the present and in the future.

APPENDIX III
AN EXAMPLE OF 'WILDLIFE-CONSERVATION'
ADMINISTRATION IN JAPAN

**APPENDIX III An Example of 'Wildlife-Conservation' Administration
in Japan**
(from the Tanuki Club's homepage)

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1. Course of the Incident

19 January, 1999

I returned to my study area, Chiba Prefecture in Japan for 4 weeks, to clean up the field station. Then I heard that a dairy farmer had trapped a raccoon dog (tanuki), which was the tanuki I had radio-tracked until the failure of its transmitter. I also heard that the farmer was feeding him with crows killed with lead shots. I reported this incident to the local authorities and asked for an investigation.

25 January, 1999

An official from the local office of the Forestry division went to see the farmer. She found that the farmer had trapped a pair last September just after I left for Oxford for a term, had killed the female (possibly by beating) and had kept the male. I was told that a chief clerk of the office planned to talk to the farmer on February 3rd.

4 February, 1999

I called the local office of the Forestry division again and found out that nothing had been done yet. The chief clerk had gone to the dairy farm, didn't see the farmer, and so returned. Since I felt that nothing was going to happen with the local office, I called the higher authorities, the Chiba Prefectural Government, to see what they had to say about this. However, there was nobody available who could answer my questions. I left my message and the telephone number of my friend, Yuko Fukue, who is also a tanuki researcher at Tokyo University of Agriculture and Technology for further correspondence. I made these calls from the airport just before I took a flight back to the UK.

10 February, 1999

Ms. Fukue called the Prefecture because there had been no response from them. She told them that the Tanuki Club was preparing a letter to the Prefecture. They promised to send a report to her on 12th.

12 February, 1999

Ms. Fukue received a report on the correspondence from the Nature Conservation Division, Environmental Department, Chiba Prefecture.

15 February, 1999

The official finally succeeded in "persuading" the farmer to release the tanuki. But the farmer insisted that he did not want the tanuki near his place. He said the tanukis killed his calves by eating the umbilical cords. The tanuki was released far away from his original home range in a different habitat. The prefectural authorities never enforced any kinds of laws; they made no issue of his killing the female nor the method of capturing. Methods for preventing damage to his livestock have never been discussed with the farmer.

23 February, 1999

The Tanuki Club received a final report of the release and photographs of the tanuki from the Nature Conservation Division, Environmental Department, Chiba Prefecture.

26 March, 1999

Two members of the Tanuki Club and one local citizen visited the Prefectural Office in Chiba-city and submitted the letters from the Tanuki Club and from wildlife scientists in Wildlife Conservation Research Unit (WildCRU), University of Oxford.

The *Wildlife Protection and Hunting Law* states that anyone who wants to hunt or capture game species (29 avian and 18 mammalian species) requires permission and/or licences. Only game species are allowed to be taken within the period of hunting season, i.e. November 15th to February 15th (except for 24 species of rodents, 18 species of insectivores and 9 species of marine mammals, which are excluded from the regulations). Thirty-eight avian and 21 mammalian species are subjects for control-kills at any time of year with permission from a local government governor or a mayor/village head of public offices. In order to capture wildlife for scientific research you need to have a permission from the Ministry of Environment of Japan; you may be allowed to capture non-game species and/or outside of the hunting season. Tanuki is a game species. The authorities explained to us that keeping wild animals is illegal but cannot be considered as evidence of poaching. So, the legal restriction is in practice unenforceable. Also, a confession of capturing wildlife without a licence and during the non-hunting season is not sufficient to prove the illegality of poaching. Instead, they suggested the farmer that he apply for a damage claim to kill wildlife legally (*yugai-choju-kujo sinsei*). The primary investigating authorities for this law are local public officials, not police. Therefore, there is effectively no restriction on poaching. In other words, 'poaching' can be legal in Japan because the law works mostly as the *Human Protection and Hunting Wildlife Law*.

2. Letter to the Prefecture from the Tanuki Club (original in Japanese)

Midori Saeki (Representative), Yuko Fukue, and Atsushi Takayanagi
Tanuki Club
March 26, 1999

Director
Environmental Department
Chiba Prefecture

Re: Letter of complaint on the incident of illegal trapping and captivity of tanukis in Mutsuzawa-machi.

Illegal trapping and captivity of tanuki(s) came to light in Mutsuzawa-machi, Chosei-gun, Chiba Prefecture on January 19, 1999. The incident ended as one tanuki was released in the Uchiura Prefectural Forest on February 15 thanks to the effort of your department. We have found, in investigating the incident, that the Chiba Prefecture acted in ways that seem inconsistent with wildlife conservation and the enforcement of the *Wildlife Protection and Hunting Law*. We would like to submit this letter of complaint to try to prevent similar incidents in the future.

Let us point out the following:

First, it took a long time to address the problem since we reported the incident. It took five days to get through to you. We reported the incident on January 19 (your report erroneously states that we reported the incident on the 21st), and your response came on January 25. Five days seems too long to tackle a criminal act. The trapper was feeding a tanuki with a crow that had lead bullets in his body, which could have caused lead poisoning. In addition, the trapper may have killed the tanuki. When a citizen reports a criminal incident, the authorities are supposed to take action immediately. The tardiness of your actions shows a lack of seriousness in enforcing these laws.

Second, although an authority received information of possibly one more tanuki trapped in addition to the one released in the woods later, he failed to confirm the fact. We doubt if he made an effort to find out the facts.

Third, your report mentions only control-kills. Damage prevention caused by wildlife wasn't mentioned at all. It is important to prevent damages by wildlife, and you ought to take a lead on educating local municipalities on damage prevention.

Fourth, you ignored requests by experts to become involved and simply released a tanuki in the woods. We, tanuki researchers, were willing to give advice and help on the treatment of the tanuki. Many other prefectures have been cooperating with wildlife specialists to preserve other mammals. We would like to see the Chiba Prefecture do the same.

Let us suggest improvements as follows:

1. In order to prevent similar incidents in the future, it is important to educate not only farmers engaging agriculture and forestry, but the general public what to do when damages are made by wildlife. "Kenmin Dayori," or prefecture newsletters, municipal newsletters and lectures

provide good opportunities to educate people.

2. When an incident like this happens, it is necessary to have policies to deal with it immediately and appropriately. If a similar incident ever happens, a person in charge can follow an incident manual to take prompt action so that it won't take almost one month to release one tanuki, as happened this time. It is important to establish a system for exchanging information with other offices and wildlife specialists and to train personnel.

3. You need to make sure that the current system functions as it is supposed to. Damages should be detected immediately, all facts (period, time, scale, process of damage) should be obtained accurately, and countermeasures should be taken promptly, so that unnecessary waiting for both the damage sufferer and the wildlife can be minimized. Monitoring accurate damage data and educating municipalities and individuals make it possible to prevent damage by wildlife. It is no longer good enough for the administrators of wildlife to give permission to destroy wildlife who cause damage.

4. It is necessary to create a system to accumulate scientific and ecological information from researchers or individuals in the field. Future wildlife conservation administration and management has to be based on scientific and ecological perspectives. Administration and management need to view the problems comprehensively. In order to establish long term and thorough measures to prevent damage by wildlife. It will be essential to obtain scientists' recommendations which are the result of scientific research. For example, the accumulation of data quantifying the damage evaluation is useful to determine the standard of controlled kills and is necessary for creating policies of damage prevention and compensation programs.

As for this tanuki incident, since the Tanuki Club owns the most extensive database on tanukis in the world, it was a shame that your administration did not to use it. For example, we had confirmed the damage in the corn field and the grape damage in the green house by tanukis in the same area of this incident. Also, we had confirmed that the degree of the damages caused by the tanuki was tolerable to the farmers. Let us point out that there has been no scientific report which states that any generalist omnivores like tanukis causes a decrease in wild bird populations. There has been no trace of wild bird consumption by tanukis in the food habitat study in the area.

We understand that there are problems which cannot be solved by the Chiba Prefecture alone. Japan is unfortunately not an advanced nation in the area of wildlife. We obtained comments on the incident and your reaction from the wildlife scientists of Wildlife Conservation Research Unit to which our representative of the Tanuki Club, Midori Saeki, belongs. Those scientists are actively working on wildlife conservation in the world (over twenty countries). Attached please find a letter from them which was written by Dr. Paul Johnson and signed by researchers at Oxford University. We hope that the letter will make you aware of a global viewpoint on wildlife conservation.

Our Tanuki Club is a group of people who love the natural world of the Chiba Prefecture, and we are working actively to be a bridge of communication between scientists/researchers and the general public. Our purpose in this letter is not merely to pass on complaints or criticism to your administration and management, but something more constructive: to create a better understanding of wildlife conservation. We would like to cooperate with you to improve wildlife management. We are hoping this letter will be helpful to your future policies on wildlife conservation.

(signatures of members of the Tanuki Club)

3. Letter to the Prefecture from wildlife researchers in WildCRU

Dear Governor,

We are writing to you in concern with the incident described to us by our colleague, Midori Saeki, in which one of her study animals was killed, and another moved.

We wish to express our concern that, though this was illegal, no appropriate action against the culprit has been taken by the authorities. This pair of animals had been tracked for some time, and were a vital part of the study. As well as the damage caused to this research, in which Midori has invested a huge amount of effort, we believe this incident raises wider issues.

Conflicts between the interest of research and the actions of farmers arise all over the world. However, in our experience it is only in poor third-world countries that actions outside the law are routinely tolerated. The failure to enforce the law in incidents such as this can only foster the impression that wildlife issues are not taken seriously in Japan, and that future incidents will be similarly treated. If true, we believe this would greatly damage the reputation of Japan among wildlife scientists.

We are confident that you will be able to assure that this is not the case, and there has been some unusual complication related to this particular incident, that we may not be aware of.

We look forward to hearing from you,

yours faithfully,

(24 signatures of wildlife scientists from 11 countries: Australia, Belgium, Canada, Chile, Germany, Iceland, Italy, Japan, Namibia, UK, and Zimbabwe)

4. Response to Tanuki Club from Chiba Prefecture (original in Japanese)

Wildlife Management and Counter-measures Section
Nature Conservation Division
Environmental Department
Chiba Prefectural Government
27 April, 1999

Dear Ms Saeki,

In the fresh green season we congratulate your still more success.

We are grateful to your cooperation with our administration of wildlife conservation.

We, Wildlife Management and Counter-measures Section in Nature Conservation Division, are conducting our administration based on the *Wildlife Protection and Hunting Law* and executing the establishment of wildlife protection areas, a rescue project of injured or sick wildlife, designation of bird-loving model schools, an operation of a wild bird observation facility in Gyotoku, and license/registration/control of hunting as well as management and counter-measures for wild macaque and deer.

We are working seriously with a point of view of law and conservation for administrative affairs every day. We also have collaboration with researchers of the Chiba Central Museum and others and conservation groups.

Also, we have been enlightening the idea of wildlife conservation to the general public in the prefecture with co-operation from civil volunteers by the rescue project of injured or sick wildlife, designation of bird-loving model schools and so on.

We have received a letter of complaint from the Tanuki Club and comments from the researchers in Oxford University about the incident regarding tanuki in Mutsuzawa on 26 March, 1999.

Regarding to the points about immediate correspondence and the illegal action in the letter, we have intended our best effort within the framework of laws, but also understand that we had points for reflection.

We will examine and utilize the letter and the comments for our administration in wildlife conservation in future.

We are asking for your cooperation to our administration in wildlife conservation as well as valuable comments from now on.

Sincerely yours,
(no signature)

5. Letter to the Prefecture from a British citizen

Mr. Takeshi Numata
The Governor
Chiba Prefecture
Japan
23 February, 1999

Dear Mr. Numata,

Tanuki dogs

I understand that a request has recently been made to your office to investigate the trapping of two tanuki, a male and female. After the animals were trapped last autumn, the female is reported to have been killed, and the male later released in an area far from his home range. I am writing to ask you to ensure that this incident is fully investigated through laws against poaching. Tanuki have a special importance as a species unique to Japan and still living in the wild, whose survival is a matter of international concern.

In view of this concern, I am sure you will appreciate the seriousness of even one incident threatening the welfare of tanuki, and urge you to ensure that appropriate legal action is taken. If laws for the protection of wildlife are to be effective, they need strict enforcement on every occasion of abuse.

Could you kindly let me know what measures are being taken?

Yours sincerely,

(signature)
Mrs. Nina Weaver

6. Response to the British citizen from Chiba Prefecture

25 March, 1999

Dear Mrs. Weaver,

Thank you for your valuable comments regarding the trapping of Tanuki dogs. Upon the request by Ms. S, a Tanuki Researcher, on January 21st 1999, we conducted an investigation concerning this case. We are pleased to inform you as to the results of the investigation and the measures taken by Chiba Prefecture which are as follows;

Ms. S reported to us that milk producer Mr. M captured Tanuki dogs and had been keeping them illegally, and asked us to investigate the case and to make him release the Tanuki. Upon her request, a person in charge was sent to the house of Mr. M in order to investigate the fact. We confirmed that Mr. M had captured one Tanuki dog and been keeping it without permission. The explanation given by Mr. M was that Tanuki had killed his calf, and aiming to prevent a second accident, he had been keeping it on his property.

According to the Japanese "Law of Wildlife Conservation and Hunting", it is permitted to capture Tanuki during the hunting season with a hunter's license. Furthermore, at times out with the hunting season, the Governor can give permission to capture Tanuki, if there is serious damage to agricultural business. Since the capture of Tanuki by Mr. M is contrary to this law, the Prefecture made him release the Tanuki immediately and warned him against catching Tanuki without permission.

We understand that wild animals are to be returned to nature, they should be released where they were captured. However in this case, this could lead to further damage to Mr. M's calves, and the Tanuki was released on February 15th 1999 in the best conserved area inhabited by wild Tanuki.

We wish for your further endeavor and success in wildlife conservation.

Yours sincerely,

(signature)
Shohei Naito
Director General
Nature Conservation Division
Environmental Department
Chiba Prefectural Government

APPENDIX IV
COMMON AND SCIENTIFIC NAMES OF WILDLIFE

APPENDIX IV Common and Scientific Names of Wildlife

Species of mammal and bird.

Common name	Scientific name
Japanese white-toothed shrew	<i>Crocidura dsinesumi</i>
greater Japanese shrew-mole	<i>Urotrichus talpoides</i>
small Japanese mole	<i>Mogera minor</i>
European hedgehog*	<i>Erinaceus europaeus</i>
horseshoe bat	<i>Rhinolophus ferrumequinum</i>
least horseshoe bat	<i>Rhinolophus cornutus</i>
Japanese large-footed bat	<i>Myotis macrodactylus</i>
Eastern bent-winged bat	<i>Miniopterus fuliginosus</i>
Japanese pipistrelle	<i>Pipistrellus abramus</i>
Japanese macaque	<i>Macaca fuscata</i>
Japanese field vole	<i>Microtus montebelli</i>
large Japanese field mouse	<i>Apodemus speciosus</i>
small Japanese field mouse	<i>Apodemus argenteus</i>
harvest mouse	<i>Micromys minutus</i>
Norway rat*	<i>Rattus norvegicus</i>
roof rat*	<i>Rattus rattus</i>
house mouse*	<i>Mus musculus</i>
Siberian chipmunk	<i>Tamias sibiricus lineatus</i>
Japanese squirrel	<i>Sciurus lis</i>
Taiwanese squirrel*	<i>Callosciurus caniceps taiwanensis</i>
Japanese giant flying squirrel	<i>Petaurista leucogenys</i>
rabbit*	<i>Oryctolagus cuniculus</i>
Amami rabbit	<i>Pentalagus fumessi</i>
Japanese hare	<i>Lepus brachyurus</i>
mountain hare	<i>Lepus timidus ainu</i>
coypu*	<i>Myocastor coypus</i>
capybara*	<i>Hydrochoerus hydrochaeris</i>
muskrat*	<i>Ondatra zibethicus</i>
Japanese serow	<i>Naemorhedus crispus</i>
sika deer	<i>Cervus nippon</i>
wild boar	<i>Sus Scrofa</i>
Iriomote cat	<i>Felis iriomotensis</i>
Tsushima leopard cat	<i>Felis bengalensis euptilura</i>
domestic cat	<i>Felis catus</i>
raccoon dog	<i>Nyctereutes procyonoides</i>
red fox	<i>Vulpes vulpes japonica, V. v. schrencki</i>
domestic dog	<i>Canis lupus familiaris</i>
Japanese wolf	<i>Canis lupus hattai, C. l. hodophilax</i>
Japanese weasel	<i>Mustela itatsi</i>
Siberian weasel*	<i>Mustela sibirica coreana</i>
ermine	<i>Mustela erminea</i>
least weasel	<i>Mustela nivalis</i>
ferret*	<i>Mustela putorius fuso</i>
American mink*	<i>Mustela vison</i>
Japanese marten	<i>Martes melampus melampus, M. m. tsuensis</i>
sable	<i>Martes zibellina</i>
river otter	<i>Lutra nippon</i>
Japanese badger	<i>Meles meles anakuma</i>
common raccoon*	<i>Procyon lotor</i>
masked palm civet*	<i>Paguma larvata</i>
Javanese mongoose*	<i>Herpestes javanicus</i>
Asiatic black bear	<i>Selenarctos thibetanus</i>
brown bear	<i>Ursus arctos</i>
oral owl	<i>Strix uralensis</i>
Northern goshawk	<i>Accipiter gentilis</i>
black kite	<i>Milvus migrans</i>
grey-faced buzzard-eagle	<i>Butastur indicus</i>
jungle crow	<i>Corvus macrorhynchos</i>
carion crow	<i>Corvus corone</i>
dusky thrush	<i>Turdus naumanni</i>
Siberian bluechat	<i>Tarsiger cyanurus</i>
Japanese crested ibis	<i>Nipponia nippon</i>
white-tailed eagle	<i>Haliaeetus albicilla</i>
Steller's sea-eagle	<i>Haliaeetus pelagicus</i>

Appendix IV continued.

Species of fish and amphibian in the study area.

Family	Common name	Scientific name
fish		
ANGUILLDAE	freshwater eel	<i>Anguilla japonica</i>
CYPRINIDAE	[motsugo]	<i>Pseudorasbora parva</i>
	[tamoroko]	<i>Gnathoropogon elongatus</i>
	carp	<i>Cyprinus carpio</i>
	silver crucian	<i>Carassius auratus langsdorfii</i>
	gold crucian	<i>C. a. auratus</i>
	gengoro crusian	<i>C. a. suvieri</i>
	bitterling*	<i>Rhodeus ocellatus</i>
COBITIDIDAE	loach	<i>Misgurnus anguillicaudatus</i>
ORYZIIDAE	medaka	<i>Oryzais latipes</i>
MUGILIDAE	grey mullet	<i>Mugil cephalus cephalus</i>
GOBIIDAE	goby	<i>Rhinogobius brunneus</i>
CENTRACHIDAE	bluegill*	<i>Lepomis macrochirus</i>
amphibian		
SALAMANDRIDAE	Tokyo salamander	<i>Hynobius tokyoensis</i>
BUFONIDAE	Eastern-Japanese common toad	<i>Bufo japonica formosus</i>
HYLIDAE	Japanese tree frog	<i>Hyla japonica</i>
RANIDAE	Japanese brown frog	<i>Rana japonica</i>
	Mountain brown frog	<i>Rana omativentris</i>
	wrinkled frog	<i>Rana rugosa</i>
	Tokyo daruma pond frog	<i>Rana porosa porosa</i>
	American bull frog*	<i>Rana catesbeiana</i>
	Schlegel's green tree frog	<i>Rhacophorus schlegeli</i>

'Mouse' that was reported to cause crop damage may include voles, rats, and field mice and house mouse.
*introduced in Japan.

Mammalian species inhabit in the study area are shown in **bold** (data from Tanabe, 1999; Chiba Prefecture 1996a, 1996b; M. Saeki, personal observation).



APPENDIX V

BODY MEASUREMENTS

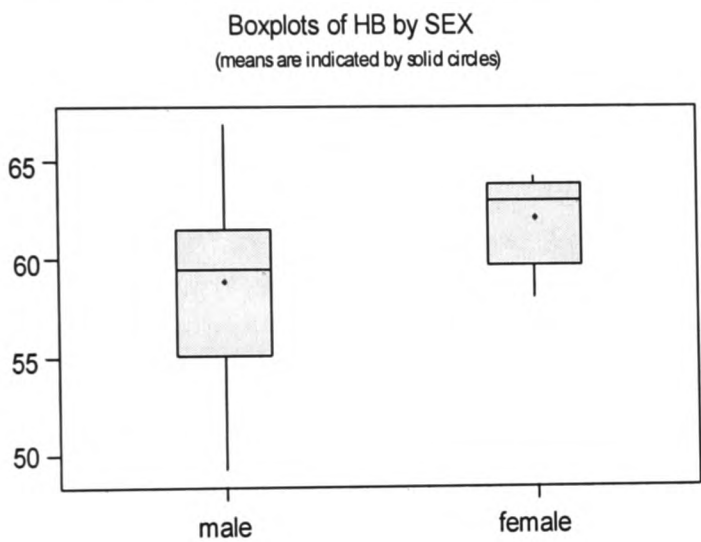
Appendix V Body Measurements of the Raccoon dogs

MO	YR	HB	T	HF	E	WT	SEX	AGE	road-kill	ID	fate/remark
8	93	53.0	17.0	10.5	4.3	5.00	1	3	yes	-	
8	93	58.0	19.5	10.9	4.3	3.95	2	3		A	killed by dog in Sept. '93
9	93	52.0	14.0	9.7	3.8	1.70	2	1		-	
9	93	52.5	18.0	10.5	3.5	2.00	2	1		-	
9	93	56.5	20.5	12.0	4.3	4.90	1	3		B	battery died in Dec. '95
10	93	60.5	16.0	10.8	4.0	5.20	1	3	yes	-	
10	93	54.0	22.0	11.0	4.5	3.60	1	1		C	
11	93	-	-	-	-	4.00	1	3	yes	C	
11	93	59.1	18.7	11.0	4.2	4.20	2	1		D	battery died in Dec. '95
2	94	63.5	16.5	11.2	3.7	4.85	2	3		E	
4	94	61.0	18.8	11.8	3.8	4.20	2	2		F	lost signal
4	94	57.5	20.0	10.2	3.8	4.10	2	2		G	killed by dog in June '94
7	94	55.0	20.0	12.0	4.4	5.65	1	3		H	collar drop
10	94	57.7	15.8	12.3	5.1	5.05	1	3		I	traffic accident in Jan. '95
11	94	56.1	18.7	10.8	4.0	3.85	1	1		J	
11	94	63.5	16.8	11.5	4.8	6.25	1	3		K	lost signal
12	94	64.2	-	10.4	3.7	5.40	2	3	yes	-	
1	95	59.7	17.7	10.5	4.2	4.40	1	3	yes	-	
1	95	-	-	-	-	5.55	1	3		I	in captivity/escape in Feb. '95
4	95	65.4	17.5	11.9	4.1	5.20	2	2		L	killed by dog in July '95
4	95	66.2	18.9	12.4	5.5	5.15	1	3		M	killed by dog in May '95
8	95	49.2	22.0	11.2	4.0	4.10	1	3		N	
9	95	32.1	16.8	-	3.6	2.15	1	1	yes	-	
9	95	-	-	-	-	4.40	1	3		N	recapture
9	95	36.1	16.4	10.6	3.8	2.50	1	1		O	
9	95	-	-	-	-	2.50	1	1		Ta	injury (attacked by dog in trap)
10	95	-	-	10.9	-	4.90	1	3	yes	-	
11	95	-	-	-	-	3.35	1	1		O	in captivity/road-killed in May '96
11	95	56.0	16.5	10.6	4.3	3.00	1	1		Ta	in captivity/escape in Jan. '96
4	96	61.4	14.9	11.1	3.6	5.85	2	3	yes	-	pregnant/4fetus(85g)
6	96	-	-	-	-	4.95	2	3	yes	-	
6	96	63.0	17.6	10.2	4.2	4.80	2	3	yes	E	lactation
8	96	55.2	15.6	9.7	3.7	3.70	1	-	yes	-	
8	96	-	-	-	-	5.20	1	3	yes	-	
9	96	-	17.4	11.0	3.0	3.05	2	-	yes	-	
11	96	58.5	17.2	11.5	3.5	3.40	1	-	yes	-	lost paws
1	97	61.5	20.5	10.6	4.0	4.50	1	2		P	
2	97	50.7	18.1	10.5	4.2	3.70	1	2		Q	collar drop
3	97	-	-	-	-	4.30	1	3	yes	J	
3	97	59.5	20.5	11.1	4.1	4.55	1	3		N	
4	97	57.0	19.0	10.8	4.2	4.10	1	2		P	recapture
8	97	53.1	16.3	10.0	3.9	2.60	2	1	yes	-	
9	97	59.2	16.2	10.6	3.9	3.40	2	-	yes	-	
9	97	59.1	16.3	11.5	4.1	4.00	1	3	yes	-	
9	97	51.8	19.5	11.2	4.3	3.30	2	1	yes	-	
1	98	66.9	19.6	11.7	-	6.05	1	3		R	illegally trapped in Sept. '98*
2	98	60.0	17.2	11.6	4.2	5.00	1	3	yes	-	
2	98	61.5	23.0	11.0	4.2	5.15	1	3		N	recapture
3	98	65.9	19.3	11.2	4.1	3.70	1	2		S	
4	98	62.5	19.5	10.5	4.3	2.70	1	2		T	illegally trapped/injury
4	98	63.2	20.5	10.9	4.8	5.00	2	2		U	
6	98	-	-	-	-	4.00	1	3		T	released
8	98	54.8	21.7	11.6	4.4	4.00	1	3	yes	-	
8	98	-	-	-	-	1.95	2	1	yes	-	

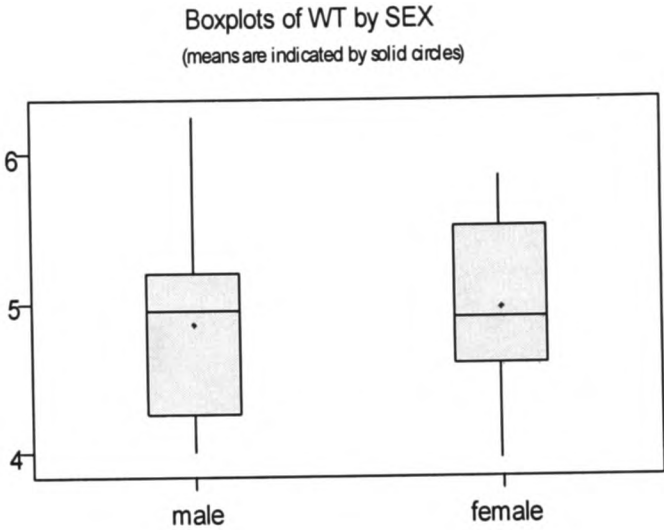
APPENDIX V continued.

mean					
category	HB	T	HF	E	WT
all	57.5 (43)	18.3 (43)	11.0 (44)	4.1 (43)	4.10 (55)
male juvenile	46.9 (5)	18.1 (5)	10.8 (4)	4.0 (5)	2.99 (7)
male yearling	59.5 (5)	19.3 (5)	10.7 (5)	4.2 (5)	3.74 (5)
male adult	58.9 (15)	18.9 (15)	11.4 (16)	4.4 (14)	4.86 (22)
female juvenile	53.7 (5)	17.3 (5)	10.5 (5)	3.9 (5)	2.63 (6)
female yearling	61.8 (4)	19.2 (4)	11.2 (4)	4.1 (5)	4.63 (4)
female adult	62.0 (5)	17.1 (4)	10.8 (5)	3.9 (5)	4.97 (6)

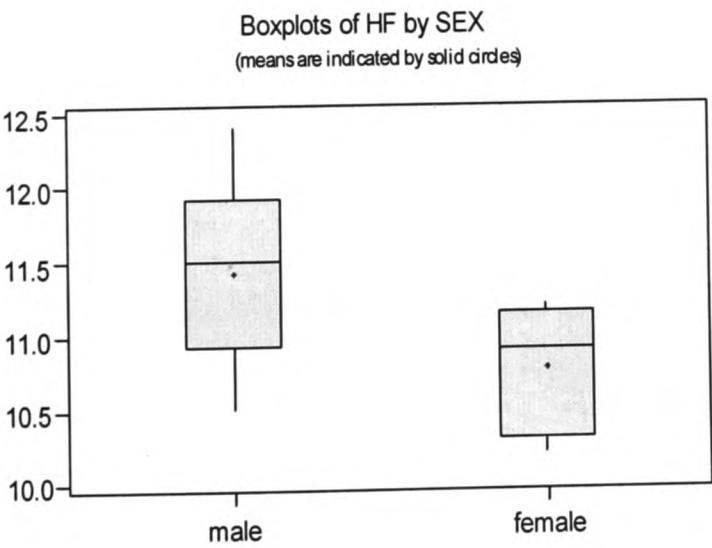
HB = head and body length (cm), T = tail length (cm), HF = left hind-foot length (cm), E = left ear length (cm), WT = body weight (kg), sex: 1 = male; 2 = female, age: 1 = juvenile; 2 = yearling; 3 = adult, sample size in parentheses. HB was measured along the body, and T does not include hairs on the tip. Animals with ID were captured by M. Saeki for radio-tracking in this study; only the initial is shown, and alphabetical order is the order of capturing, excluding the juveniles that were released only with ear-tags. All animals were from the study area.
*released in March 1999 by the authorities.



T= -1.90, DF= 13, P=0.080



T= -0.38, DF= 8, P=0.72



T= 2.65, DF= 9, P=0.026

APPENDIX VI
QUESTIONNAIRE TO PREFECTURES

APPENDIX VI Questionnaire to Prefectures

The following is a questionnaire used in this study (original in Japanese).

prefectural no.

Questionnaire on Agricultural Damage by the Raccoon Dog and other Mammals

Please answer as many questions as you can. Mark a circle in appropriate cells or X if you do not know the answer.

1. Have you received complaints/reports of agricultural damage caused by wildlife in the last 5 years?

Yes	No
-----	----

2. If you answered 'Yes' above, what kind of agricultural damage (include crops, poultry, dairy, fish), and by what kind of wildlife? (e.g. tangerines by macaque; chicken by red fox)

--

3. In case of damage by raccoon dogs:

Please describe the damage. Include these details as much as you can.

Year	Month	Name of crop	Number of incidents	Name of city, town or village	Estimated damage (yen)	Damaged area (unit)

If the space is not enough, please use the back of this page.

4. Counter-measures (for the raccoon dog, badger, fox, masked palm civet, mink and raccoon only): Please mark as many as appropriate, and specify the repellent/other method, if you can.

	Practised in the past (yes/no)	Planning
Control killing		
Fencing		
Repellent ()		
Relocation after trapping		
Other ()		

a. About the practised method(s) above (e.g. the trapping method, the number of trapped animals and fencing features):

1st Method

Counter-measure in detail						
year				cost		
how effective	very	somewhat	not effective	opposite effect	unknown	

2nd Method

Counter-measure in detail						
year				cost		
how effective	very	somewhat	not effective	opposite effect	unknown	

3rd Method

Counter-measure in detail						
year				cost		
how effective	very	somewhat	not effective	opposite effect	unknown	

If you have more than three cases, please use the back of this page.

5. About wildlife-related survey/research activities in the last 5 years:

a. Has your prefecture conducted (or commissioned to a private organisation) a survey/research on agricultural damage by wildlife?

Yes	No	Don't know
-----	----	------------

If you answered 'Yes' above, what kind of survey/research (crop and wildlife) was it?

b. Has your prefecture conducted (or commissioned to a private organisation) survey/research on wildlife ecology?

Yes	No	Don't know
-----	----	------------

If you answered 'Yes' above, what kind of survey/research were they?

6. About the trend in agricultural damage by mammalian wildlife in the last 5 years:

The damage by mammalian wildlife has

increased	not changed	decreased	unknown
-----------	-------------	-----------	---------

The damage by raccoon dogs has

increased	not changed	decreased	unknown
-----------	-------------	-----------	---------

7. About compensation/insurance systems:

a. Have any compensation/insurance systems been in effect for damage in the last 5 years?

Yes	No	Don't know
-----	----	------------

If you answered 'Yes' above, what kind of system was it?

b. If you answered 'No' above, have any compensation/insurance systems been considered?

Yes	No
-----	----

8. Case study: If there are any particular cases of agricultural damage by wildlife and/or innovative counter-measures in your prefecture, please describe.

Thank you for your co-operation.

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