

Present Status of Invasive Alien Raccoon and its Impact in Japan

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Abstract

Irresponsible breeding and release of pet raccoons (*Procyon lotor*) has caused their naturalization in Japan. The raccoons have already naturalized in 42 of Japan's 47 prefectures, and there has been a remarkable increase in agricultural (cattle breeding) and urban areas, where the raccoons can find food and hide easily. Their home range size varies widely according to the habitat, ranging from 35 ha in urban areas to 2,219 ha in forests (mean : 299.1 ha). The raccoon avoids energy loss in winter by semi-hibernation. It has opportunistic and omnivorous feeding habits, taking crops and fruit in agricultural areas and native species in forests. It also preys on indigenous species such as the Japanese crayfish (*Cambaroides japonicus*) and Ezo salamander (*Hynobius retardatus*). Reproductive observations have shown high productivity (reproductive rate : 66% in yearlings and 96% in adults, litter size : 3.6 in yearlings and 3.9 in adults) and a potentially rapid rate of population growth (0.20 to 0.25). Intensive eradication guided by biological data will be indispensable to controlling invasive alien raccoons.

Key words: impact, invasive alien raccoon, management, naturalization

1. Introduction

After the ratification of the 'Convention on Biological Diversity,' invasive alien species issues became a major concern in Japan. Invasive alien species are considered to be the one of the most important causes of extinction and decline of wild native species (Margin *et al.*, 1994; Williamson, 1999). In particular, invasive alien mammals are thought to have serious impacts on native ecosystems because of their high trophic level.

With Japan's spectacular economic growth, numerous species of mammals have been imported into Japan as pets. The number of alien mammals is on the increase with the increase of imported mammals, and over 30 species of mammals have thus far naturalized in Japan (The Committee on Mammal Conservation and Management, 1999).

Among these alien mammals of Japan, the raccoon (*Procyon lotor*) is a representative nuisance. The raccoon is very popular not only for its cute appearance but also its comical behaviors (Zaveloff, 2002). Its round, funny face with a bandit's mask across the eyes and a striped bushy tail create a humorous impression, and people find its habit of washing of food prior to

eating curious. It prefers waterfronts generally, but is well known to be highly adaptive to various environments owing to its omnivorous feeding habits (Sanderson, 1987).

This species came from North America. In addition to being introduced to Japan, it was introduced into the Caribbean islands in 1932 (Sherman, 1953), Germany in 1934 (Lever, 1985) and the Soviet Union in 1936 (Aliev & Sanderson, 1966), where it caused heavy damage to crops or native ecosystems.

In Japan, after the smash hit of the animated cartoon 'Rascal Raccoon' on TV in 1977, the raccoon became popular as pet animal and many raccoons were imported (Ikeda, 1999a). The raccoon, however, is fierce in nature, and comes to show its wildness as it grows up. It is thought that many raccoon breeders had troubles with their raccoons and abandoned them. The raccoon is also clever with its hands, and can escape from simple breeding cages easily. As a consequence of irresponsible abandonment and escapes from captivity, many raccoons have naturalized in various regions in Japan (Fig.1). Including temporal cases, the raccoon has already naturalized in 42 of Japan's 47 prefectures. The raccoon has so wide a food repertory that many native species are exposed to

the menace of raccoon predation.

This paper is a review of the spread of the invasive alien raccoon and its impact in Japan. We also attempt to compare its population trend data with those of the raccoon dog (*Nyctereutes procyonoides*) to point out the former's impact on native species specifically, and we attempt to develop effective countermeasures for its control.

2. History and Process of Naturalization of the Invasive Alien Raccoon in Japan.

The first naturalization of raccoons in Japan occurred in Inuyama City, Aichi Prefecture, in 1962 (Ando & Kajiura, 1985) (Fig.1). Some raccoons escaped from a zoo, then colonized Gifu Prefecture. In addition, a raccoon breeder abandoned over 40 raccoons in Kani City, Gifu Prefecture in 1982. Most of these raccoons were captured, but the remaining raccoons still continue to harm crops.

The next naturalization occurred in Eniwa City,

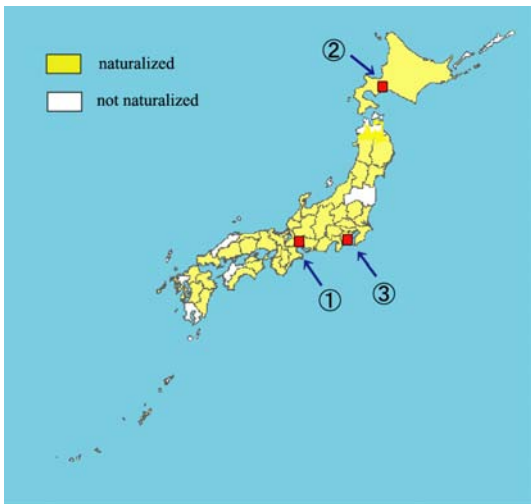


Fig. 1 Distribution of naturalized raccoons in Japan.

- : naturalized
- : not naturalized
- ① : Initial naturalized area
- ① in Inuyama City in 1962
- ② in Eniwa City in 1979
- ③ in Kamakura City in 1988

Hokkaido Prefecture, in 1979 (Ikeda, 1999a) (Fig.1). About ten raccoons escaped from a breeding cage and naturalized in a livestock farming area. Owing to multiple escapes and abandonment, the raccoon has spread throughout the west-central and eastern part of Hokkaido at present (Fig.2).

In Hokkaido, the raccoon naturalized in the livestock farming area initially (Fig.3). Figure 4 shows

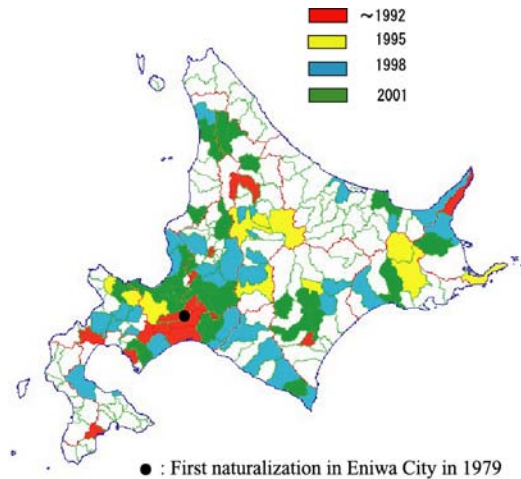


Fig. 2 Distribution of invasive alien raccoons in Hokkaido Prefecture.

Source: Natural Environment Division, Office of Environmental Affairs, Department of Environment and Lifestyle, Hokkaido Prefectural Government.



Fig. 3 Raccoon family roaming in a cowshed. (Photograph by the Raccoon Research Group)

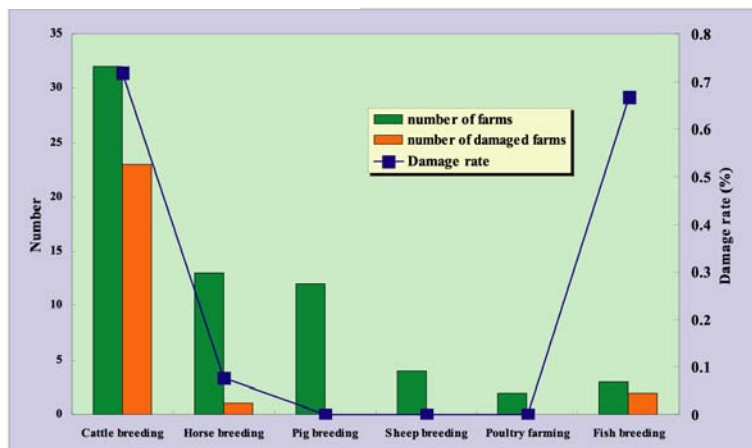


Fig. 4 Damage to livestock farms by invasive alien raccoons in Eniwa City in 1996.

damage to the livestock farms by raccoons. It is clear that the raccoons prefer cattle breeding farms and fish breeding farms to other livestock farms. At cattle breeding farms, the raccoons are likely to get plenty of corn, the raccoon's greatly preferred food, from the compound cattle feed throughout the year, and can find safe cover, such as lumps of dried pasture grass, for reproduction. As Giles (1940) and Tester (1953) highlighted the importance of corn in the diet of the raccoon, the raccoons roaming around the cattle breeding farm in Eniwa City also showed a high dependence on corn from the compound feed even after the harvest of corn in the field. In November, 80% of raccoon feces contained undigested corn (Yoshino, 1994). A fish breeding farm also made fish available for food, but was not suitable for reproduction. As a consequence, it seemed that the raccoons reproduced at the cattle breeding farm, then expanded their distribution mainly along the river.

The third naturalization occurred in Kamakura City, in 1988 (Fig.1). The process of naturalization in Kamakura City was different from that in Hokkaido. The main cause of the naturalization was an escape from captivity, as with the other places, but the raccoon established its habitat in an urban area. There are many old wooden houses, Buddhist temples and Shinto shrines in Kamakura City, and these Japanese-style architectures have some air vents under the eaves and the floors. The raccoon invaded via these air vents and built nests under the roofs (Fig.5). In urban areas, the raccoon can access garbage easily, and catch carp and goldfish from ponds in gardens. The raccoon can also use drainpipes as safe travel paths that were used by the raccoon dog before the raccoon invasion. Urban areas are also available for the raccoon, so it is expanding its distribution. Figure 6 shows information on invasions by raccoons in Kamakura City in 2001. The raccoons have spread out all over the city at this moment.

In other areas where the raccoon has invaded, the main causes seem to be escapes and abandonment. From an ecological point of view, the raccoon can naturalize in all environments in Japan, but we must



Fig. 5 Raccoon invading a house.
(Photograph by the Raccoon Research Group)

pay special attention to agricultural and urban areas to prevent more multiplication of the raccoon.

3. Behavior of the Invasive Alien Raccoon in Japan.

Table 1 shows the home range size of the invasive alien raccoon in Japan determined by radio telemetry method. The home range size varies widely according to its habitat. The largest home range size was 2,219 ha in forested area, and the smallest was 35 ha in an urban area. The range size in urban areas (mean: 49.0 ha) was smaller than those in suburban and rural areas (mean: 358.0 ha) ($p < 0.01$, Mann-Whitney's U-test).

In forested areas of Hokkaido, the home range size of the invasive alien raccoon tended to diminish remarkably as the temperature dropped (Ikeda, 1993). The raccoon used only river sides for its paths in the snowfall season. It seemed that the raccoon had trouble walking in deep snow coverage according to our observations. In midwinter, the raccoon avoids energy loss by remaining motionless in the hollow of a tree or in a vacant house.

The raccoon is thought to have a polygamous or promiscuous mating system (Zevloff, 2002). The invasive alien raccoon in Japan also showed a polygamous mating system. The male raccoon tended to keep more than one female in its home range. The raccoon in Hokkaido mated from January through March, with a peak in February. In this breeding period, the male raccoon tended to come and go among a few females in its home range, while the female raccoons kept still in their dens.

These activities of the invasive alien raccoon in Japan are almost the same as its activities in its place of origin (Zevloff, 2002). It seems that the invasive

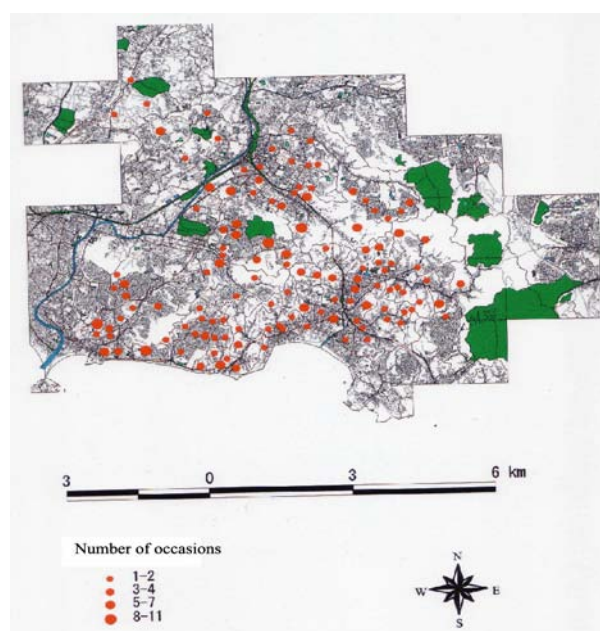


Fig. 6 Entry into houses or courtyards by invasive alien raccoons in Kamakura City in 2001.
Source: Kamakura City

alien raccoon can establish its niche in Japan easily. Furthermore, it has no natural enemies in Japan such as the bobcat (*Felis rufus*) or the coyote (*Canis latrans*). There is a danger that the invasive alien raccoon will continue to increase its numbers throughout the nation.

4. Reproductive Characteristics of the Invasive Alien Raccoon

Table 2 shows the pregnancy rate and mean litter size of invasive alien raccoons in west-central Hokkaido by analysis of placental scars or fetuses in the uterus (Asano *et al.*, 2003). Juveniles (that year's litters) were distinguished from yearlings and adults (over 2 years of age) by examining tooth eruption and root foramina closure of the canines. The invasive alien raccoon showed very high productivity. The

mean pregnancy rate was 66% in yearlings and 96% in Adults. Litter sizes ranged from 1 to 7 and averaged 3.6 in yearlings and 3.9 in Adults. These reproductive characteristics are almost the same or slightly higher than those reported in North America (Ritke, 1990; Stuewer, 1943; Fritzell *et al.*, 1985). The rate of population growth in west-central Hokkaido was estimated to range from 0.20 to 0.25 without harvest mortality (Asano *et al.*, 2003). Based on these data, it is clear that without relevant measures to control the raccoon, it is capable of population expansion.

5. Feeding Habits of the Invasive Alien Raccoon

The invasive alien raccoon shows opportunistic and omnivorous feeding habits in response to its habitat environment. In general, the raccoon takes animal

Table 1 Home range size of invasive alien raccoons in Japan determined by radio telemetry method

Each home range size shown is the maximum size in each period. We attached collar transmitters (Type 8C by ATS Inc., weight:120 g) to raccoons, and plotted locations by triangulation method with a 3-element Yagi antenna (YA-23L) and mobile receiver (Yaesu FT290mkII).

Home range size (ha)	Sex	Period	Study area	Habitat type
2219	Male	Jun.1992-Jan.1993	Eniwa	Forest
509	Male	Sep.1993-Oct.1994	Eniwa	Forest
417	Male	Sep.1993-Oct.1994	Eniwa	Forest
152	Male	Sep.1993-Oct.1994	Eniwa	Suburban
184	Male	Sep.1993-Oct.1994	Eniwa	Suburban
144	Male	Mar.2000-May 2000	Nopporo	Forest park surrounded by residences
77	Male	Apr.2000-May 2000	Nopporo	Forest park surrounded by residences
40	Male	Sep.2000-Oct.2000	Kamakura	Urban
47	Male	Sep.2000-Oct.2000	Kamakura	Urban
648	Female	Sep.1993-Oct.1994	Eniwa	Forest
313	Female	Jun.1992-Jan.1993	Eniwa	Forest
310	Female	Sep.1993-Oct.1994	Eniwa	Forest
278	Female	Sep.1993-Oct.1994	Eniwa	Forest
207	Female	Sep.1993-Oct.1994	Eniwa	Forest
195	Female	Sep.1993-Oct.1994	Eniwa	Forest
138	Female	Nov.1999-May 2000	Nopporo	Forest park surrounded by residences
114	Female	Nov.1999-May 2000	Nopporo	Forest park surrounded by residences
100	Female	Sep.1993-Oct.1994	Eniwa	Suburban
81	Female	Sep.1993-Oct.1994	Eniwa	Suburban
74	Female	Sep.2000-Oct.2000	Kamakura	Urban
35	Female	Sep.2000-Oct.2000	Kamakura	Urban

Table 2 Age-related pregnancy rate and mean litter size of invasive alien raccoons collected in west-central Hokkaido in 1999-2000. (Asano *et al.*, 2003)

Age(years)	N	Pregnancies		Mean litter size (\pm SD)
		N	%	
0	69	0	0	
1	71	47	66	3.6 \pm 1.3
2	43	41	95	3.7 \pm 1.2
3	27	25	93	4.1 \pm 1.2
4	18	18	100	3.7 \pm 1.5
\geq 5	14	14	100	3.8 \pm 1.3
Total	242	145	84	3.8 \pm 1.3

fat in summer and vegetable fat in autumn in preparation for semi-hibernation in winter.

In agricultural areas of Hokkaido, the raccoon damages crops and fruits such as corn, melons, watermelons, strawberries, paddy rice, soybeans, potatoes, beets, oats, and so on in summer and autumn. It eats livestock feed, feed grain and pasture grasses, too. The total amount of agricultural damage amounts to 30,000,000 yen every year. The raccoon eats crops and fruit only in the harvest season, excluding dried corn in compound cattle feed which is available throughout the year. The raccoon takes beetles and hornets (*Vespa flaviceps*) in summer and autumn (Murayama, 1991; Yoshino, 1994; Nakamura, 1994). Research in Nopporo Forest Park surrounded by agricultural and residential areas in Hokkaido showed that bower actinidia (*Actinidia arguta*) and arthropods occurred in 90% of raccoon scats in autumn (Yutani, 1999).

In forests, the raccoon preyed on various native species. So far we have recorded their predation on small mammals such as the gray red-backed vole (*Clethrionomys rufocanus bedfordiae*), snakes, frogs, dragonflies, damselflies, bees, butterflies, cicadas, shrimp, shellfish, wild vines and Japanese yew (*Taxus cuspidata*) by dissection of raccoons trapped during a nuisance control harvest.

6. Impacts of the Invasive Alien Raccoon

Besides damage to crops, the raccoon also poses a threat of spreading infectious diseases. The raccoon can transmit raccoon roundworm (*Baylisascaris procyonis*) infection (Miyashita, 1993). Raccoon roundworm has not been detected in naturalized raccoons yet, but we should be concerned about this infection because it has been detected in a raccoon in captivity. Furthermore, raccoons transmit rabies. It is feared that rabies could spread throughout the nation carried by raccoons if the disease should invade Japan (Ikeda, 1999a).

As for the impacts on native ecosystems, competition with some native species is likely occurring. Resource competition with the raccoon dog and the red fox (*Vulpes vulpes*) turned these animals out into unfavorable habitats (Ikeda, 1999a). In Nopporo Forest Park, the raccoon occupied the peripheral parts of the park where animals could access crops easily, so the raccoon dog was pushed deeper into the forest (Fig.7). In this area, the number of the raccoon dogs increased after an active harvest of the raccoon, but decreased again as the number of raccoons recovered (Fig.8). Another example of a raccoon impact is a take-over of a hollow tree from an owl for a breeding nest, which disrupted the owl's reproduction (Fig.9).

In addition to resource competition, direct predation on valuable native species is another serious problem posed by the invasive alien raccoon. An investigation by digestive tract analysis made it clear

that the raccoon preys on the Japanese crayfish (*Cambaroides japonicus*) (Hori & Matoba, 2001), and it is likely that the raccoon preys on the Ezo salamander (*Hynobius retardatus*) and some species of frogs

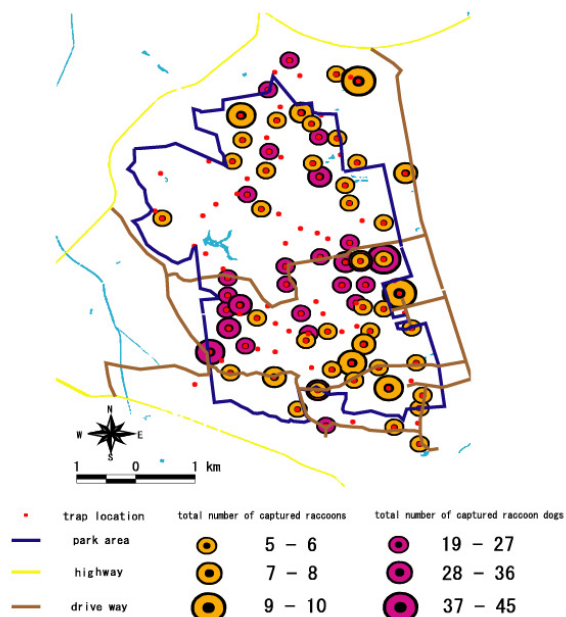


Fig. 7 Main sites of captures of raccoons and raccoon dogs in Nopporo Forest Park.

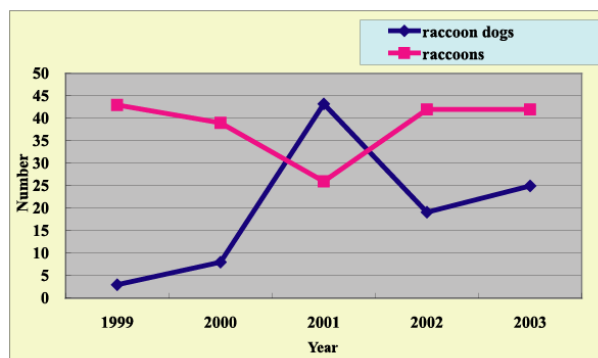


Fig. 8 Fluctuation in number of captured raccoons and estimated population of raccoon dogs in Nopporo Forest Park.



Fig. 9 Raccoon taking over an owl's nest for breeding. (Photograph by T. Ikeda)

judging from the shape of leftover carcasses (Ikeda, 2002).

Raccoon predation on birds and eggs is common in North America (Zaveloff, 2002). In Nopporo Forest Park, some raccoons attacked a reproductive colony of grey herons (*Ardea cinerea*), which subsequently abandoned their breeding grounds in 1997 (Ikeda, 1999b; Ikeda, 2000).

7. Present Measures against the Invasive Alien Raccoon in Japan

Nuisance control harvests of the invasive alien raccoon were conducted in various places in Japan, but they amounted to no more than a bandage measure, because the decrease in damage to crops reduced the victims' desire to catch the invasive alien raccoon.

The Hokkaido government made a municipal by-law to put raccoon breeders under obligation for registration starting 2001 (Ono, 2002). Under this municipal bylaw, raccoon breeders must notify the governor of their possession of raccoons. This measure seemed to be effective at stop irresponsible releases, preventing new naturalization of the raccoon.

The Hokkaido government formulated basic guidelines for the control of the invasive alien raccoon, and set eradication from the wild as its goal in 2003. The Hokkaido government also started a scientific action plan toward eradication of the raccoon. This plan was intended to eradicate the invasive alien raccoon in the course of ten years, but faced difficulty due to lack of budget.

Other prefectures continue to conduct nuisance control harvests continually. They are expected to switch from nuisance control harvesting to scientific control programs based on ecological population data to eliminate the impacts on native ecosystems.

8. Toward Creation of Effective Management Measures

Due to its excellent adaptability to various environments and its lack of natural enemies in Japan, the invasive alien raccoon has increased in number and caused serious damage to native ecosystems and human economy.

The invasive alien raccoon shows high reproductive power and a potentially rapid rate of population growth, thus we certainly will be unable to control the raccoon if we resort only to nuisance control harvesting. Unfortunately, public awareness of invasive alien raccoon issues is low, except in some prefectures where damage from raccoons is serious. It must be noted that educational efforts will be needed regarding invasive alien raccoon issues, especially their irreversible impacts on native ecosystems.

As for methods of control, intensive extermination under scientific control programs on the basis of adaptive management rather than nuisance control harvests,

will be indispensable to controlling the invasive alien raccoon. It will be necessary to collect detailed population data and reproductive parameters in cooperation with prefectural governments. These data should then be used to estimate a culling rate that can reduce or even eradicate the population.

The Invasive Alien Species Act will be enforced in 2005. We hope that scientific raccoon control programs will start in many parts of the country.

Acknowledgements

We would like to acknowledge the contributions of the Raccoon Research Group members, Dr. Norio Ohtaishi, Dr. Masatsugu Suzuki, Laboratory of Wildlife Biology (Graduate School of Veterinary Medicine, Hokkaido University) member, Dr. Mitsuhiko Asakawa, members of the Department of Veterinary Parasitology (Rakuno Gakuen University) and the Research Group of Regional Sciences (Graduate School of Letters, Hokkaido University). Great appreciation is extended to the Natural Environment Division (Department of Environment and Lifestyle, Hokkaido Prefectural Government) and Kamakura City. Our study was supported in part by a grant from the Ministry of the Environment as part of the Global Environment Research Programme.

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(Received 28 December 2004, Accepted 31 December 2004)