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SHORT COMMUNICATION

Ectoparasites of the Pallas squirrel, *Callosciurus erythraeus*, introduced to Japan

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Abstract. The squirrel *Callosciurus erythraeus* (Pallas) (Rodentia: Sciuridae) was intentionally introduced to Japan in 1935 and has become established throughout much of the country. Although they live mainly in forests, Pallas squirrels come into gardens and are frequently fed by people or kept as pets, so their ectoparasites could be of potential medical as well as veterinary importance. During 2001–2003 we conducted the first ectoparasite survey of Pallas squirrels in Japan. From 105 *C. erythraeus* captured in Kamakura District of Kanagawa Prefecture on Honshu Island, three types of ectoparasite were found: 52 specimens of the sucking louse *Neohaematopinus callosciuri* Johnson (Anoplura: Haematopinidae), 26 fleas *Ceratophyllus* (*Monopsyllus*) *anisus* Rothschild (Siphonaptera: Ceratophyllidae) and four nymphs of the tick *Haemaphysalis flava* Neumann (Acari: Ixodidae) on 22, 13 and one squirrels, respectively. Evidently in Japan *C. erythraeus* carries relatively few ectoparasite species; this may be a contributory factor to their invasive success. Further investigations are needed to assess risks of zoonotic transmission of plague or murine typhus by *C. anisus*, of louse-borne typhus by *N. callosciuri* and of tularaemia and especially Japanese spotted fever (*Rickettsia japonica*) by *H. flava*.

Key words. *Callosciurus erythraeus*, *Ceratophyllus anisus*, *Haemaphysalis flava*, *Neohaematopinus callosciuri*, ectoparasites, fleas, introduced species, lice, squirrels, ticks, Honshu, Kamakura, Kanagawa, Japan.

The Pallas squirrel, *Callosciurus erythraeus*, is widespread across south-eastern Asia from Bhutan and eastern India to The Malayan archipelago, Indochina, southern China and Taiwan (Corbet & Hill, 1992). In 1935, 40 individuals of *C. erythraeus* from Formosa* (Taiwan) were introduced to Izuoshima Island ~100 km south of Tokyo (Setoguchi, 1990). As they thrived, some were transferred to other localities in Japan and kept as pets, quickly becoming more widespread through escapes, possibly including other subspecies introductions. In the Honshu island (the main island of Japan) *C. erythraeus* is now established in 16 prefectures, particularly Kanagawa and Wakayama, and on Ohshima Island (Kobayashi, 1987).

The diet of *C. erythraeus* includes various leaves, fruit, seeds and insects in their usual forest habitats and orchards. Their habit of burying seeds and nuts is regarded as important for regeneration. As they also inhabit gardens and areas close to human habitations, people sometimes feed them, and Pallas squirrels make good pets. Thus any ectoparasites of *C. erythraeus* might engender medical risks in

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*When the Pallas squirrel was originally introduced to Japan from Taiwan it was called the Formosan squirrel, but that subspecies *Callosciurus erythraeus thaiwanensis* (Bonhote, 1901) is now regarded as synonymous with the more widespread *C. e. flavimanus* Geoffroy, 1831 (Corbet & Hill, 1992), also called belly banded or red-bellied squirrel.

addition to their possible veterinary importance. The tick, *Haemogamasus kitanoi* (Asanuma) (Acari; Laelapidae) (Allred, 1969) and the flea *Medwayella robinsoni* (Rothschild) (Siphonaptera: Pygiopsyllidae) (Traub, 1972), were reported from Pallas squirrels in Taiwan and Malayan peninsula, respectively, but vector-borne pathogens of Pallas squirrels are still unknown in their native habitats. Therefore, we conducted a preliminary survey of *C. erythraeus* ectoparasites in Japan.

During the autumn and spring months from October 2001 to April 2003, Pallas squirrels were sampled in gardens of Kamakura district (35°21′ N, 139°30′ E) of Kanagawa Prefecture. After live-trapping by wildlife management staff of the local government, the squirrels were euthanized with Nembutal in plastic bags (so that removed ectoparasites were caught in the bag) and the carcasses placed on a white tray and brushed. Ectoparasites were retrieved with forceps immediately after detection and stored in 70% ethanol. Specimens were cleared in potassium hydroxide and slide-mounted in Bioleit medium (Okenshoji Co Ltd, Tokyo) for microscopic examination and taxonomic identification by means of standard keys (Sasa, 1965; Shiraki, 1981; Traub *et al*., 1983; Takada, 1990).

From 105 squirrels examined, three species of ectoparasites were obtained (Table 1): the tick *Haemaphysalis flava* (four nymphs from one squirrel), the flea *Ceratophyllus* (*Monopsyllus*) *anisus* (26 fleas from 13 positive squirrels) and the sucking louse *Neohaematopinus callosciuri* (52 lice from 22 positive squirrels).

This survey found infestations of only three types of ectoparasite on Pallas squirrels in a typical habitat of Kanagawa Prefecture in Japan. Whereas the tick and flea species collected in this survey are fairly common on other hosts throughout much of Japan and Taiwan, the louse *N. callosciuri* had not been found in Japan until our survey. The flea *Ceratophyllus anisus* occurs in Japan, Korea, Taiwan and the People's Republic of China, infesting cats and rodents (Shiraki, 1981; Sakaguti, 1962). However, no *C. anisus* has been reported from squirrels in Japan. The tick *H. flava* is distributed throughout Japan and Taiwan: the nymphs infest many small and medium-sized mammals and birds; the adults infest domesticated pets (e.g. dogs and cats), livestock (e.g. horses and cows) and wild animals such as racoons, deer and rodents, but *H. flava* has not been found previously on squirrels. A few cases of human infestation have also been reported (Takada, 1990). The louse *N. callosciuri* is widespread across much of south-east Asia to Borneo and Taiwan (Durden, 1991; Durden & Musser, 1994). In Japan, it has only been found on Pallas squirrels. Elsewhere *N. callosciuri* infests this and other squirrels, mainly of the genus *Callosciurus*, as well as *Lariscus insignis* (Cuvier) and *Sundasciurus tenuis* (Horsfield), with an uncertain record from the slow loris, *Nycticebus coucang* (Boddaert) (Primates: Lorisidae).

Japan has three endemic species of squirrel: *Sciurus lis* (Temminc), *S. vulgaris orientis* (Thomas) and *Tamias sibiricus lineatusthere* (Siebold), of which only *S. lis* shares the characteristic habitats of *C. erythraeus*. However, nothing is known about ectoparasites of *S. lis*.

Surveys of squirrels in other parts of the world have reported multiple species of fleas, lice and ticks infesting particular squirrel host species (Sonenshine *et al*., 1978; Patrick & Wilson, 1995; Pung *et al*., 2000), whereas we found only single species of each ectoparasite group on *C. erythraeus*. Durden & Musser (1994) listed four species of Anoplura from *C. erythraeus*. The limited ectoparasite fauna of *C. erythraeus* found in our survey could be attributed to the small number and conditions of Pallas squirrels at the time of their introduction to Japan, as small population subsets reduce the probability of parasites being introduced along with a host species (Torchin *et al*., 2003; Wilson & Durden, 2003). Thus, the results of our survey would seem to support the hypothesis that introduced populations have fewer parasites, but we cannot draw firm conclusions on this point because there is insufficient information on the natural ectoparasite fauna on Pallas squirrels in their native ranges.

Although *N. callosciuri* has not yet been tested for vector competence, other species of *Neohaematopinus* on flying squirrels in the U.S.A. are known to transmit enzootic *Rickettsia prowazekii*, the aetiological agent of human epidemic louse-borne typhus (Sonenshine *et al*., 1978; Duma *et al*., 1981; Reynolds *et al*., 2003).

Both the other ectoparasites we found on *C. erythraeus* are competent vectors of zoonotic pathogens. The squirrel flea *Ceratophyllus* (*Monopsyllus*) *anisus* can transmit *Yersinia pestis*, which causes human plague (Shiraki, 1981), and *Rickettsia typhi*, which causes murine typhus (Azad, 1990). The hard tick *Haemaphysalis flava* often bites humans and transmits *Rickettsia japonica* causing Japanese spotted fever (Uchida *et al*., 1995; Parola & Raoult, 2001; Fournier *et al*., 2002) as well as *Francisella tularensis* causing tularemia (Sasa, 1965). It remains to be seen whether Pallas squirrels serve as reservoirs of these infections in Japan or elsewhere. If not, their lack of such pathogens and paucity of ectoparasites might have contributed to their healthy proliferation and dispersal in Japan.

Inevitably, invasive species carry infections from their native habitats into new environments, although many parasites are lost along the way (Torchin *et al*., 2003).

Table 1. Ectoparasites recovered from 105 Pallas squirrels, *Callosciurus erythraeus*, captured in Kamakura district of Kangawa Prefecture, Japan, October 2001–April 2003

Ectoparasite	No. infested	Prevalence (%)	Total no. collected	Intensity Mean ± SD (range)
Acari: *Haemaphysalis flava*	1	1.0	4 nymphs	4
Anoplura: *Neohaematopinus callosciuri*	22	21.0	52	2.4 ± 1.5 (1–7)
Siphonaptera: *Ceratophyllus anisus*	13	12.4	26 (16♂, 10♀)	2.0 ± 1.6 (1–7)

Because the numbers of invasives per country are increasing due to upsurge of modern transportation and other reasons (http://www.iucn.org/pareport/species_invasives.htm), there are increasing risks of introducing vector-borne diseases via their hosts and ectoparasites. Furthermore, keeping Pallas squirrels as pets increases the risk of their ectoparasites transmitting zoonotic pathogens to humans. Whereas ground squirrels are major reservoirs of plague in many parts of the world (WHO, 1999), tree squirrels are less involved, presumably because their fleas are less likely to transmit for circumstantial reasons. There is a surprising lack of information about squirrel pathogens in south-east Asia and Japan, so more investigations are needed – with particular attention to the question of whether invasive species, such as the Pallas squirrel, engender more or less zoonotic risks than arise from congeneric endemic hosts.

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