Mixed infestation of sarcoptic and chorioptic mange mites in Japanese serow, *Capricornis crispus* Temminck, 1845 in Japan, with a description of *Chorioptes japonensis* sp. nov. (Acari: Psoropticidae)

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Abstract: Seven Japanese serows, *Capricornis crispus*, with clinical signs of mange were used for parasitological and histopathological examinations. Five of the seven animals examined were positive only for *Chorioptes* mites. On the other two animals, however, a mixed infestation with *Sarcoptes scabiei* and *Chorioptes* mites was observed. This *Chorioptes* mite was proposed as a new species, *Chorioptes japonensis* Takahashi et Nogami, sp. nov. Histopathologically, parakeratotic and hyperkeratotic crusts were observed in the epidermis, and many cross-sections of *S. scabiei* mites were also found in the focal thickened stratum corneum. *Chorioptes* mites were observed on all Japanese serows examined from 1975 to 1997. However, *S. scabiei* were only observed on the two animals examined in 1996 and 1997. Before then, *S. scabiei* were not observed.

INTRODUCTION

Sarcoptic mange caused by the burrowing mite, *Sarcoptes scabiei* (Linnaeus, 1858), in mammalian epidermis was reported in many wild and domestic animals as well as humans (Fain, 1968; Morner and Christensson, 1984; Pence et al., 1983; Alexander, 1984; Burgess, 1994; Yeruham et al., 1996). It has been recorded that *S. scabiei* often cause severe dermatosis in animals and human beings (Alexander, 1984; Burgess, 1994; Pence et al., 1983; Pence and Windberg, 1994; Yeruham et al., 1996; Takahashi et al., 2001 a, b).

However, *Chorioptes* mites are cosmopolitan, non-burrowing mites causing irritation and localized dermatosis in domestic and some wild herbivores (Sweatman, 1957, 1958; Yeruham et al., 1981, 1992, 1999; Heath et al., 1983; Heath, 1978a, b). In Japanese wild mammals, Ogata et al. (1977) reported the mites of genus *Chorioptes* from one Japanese serow, *Capricornis crispus* Temminck, 1845. At any rate, there is little definite information on the geographical distribution and epizootics of both sarcoptic and chorioptic mange mites among wild mammals in Japan.
In this paper, mixed infestation with *Sarcoptes* and *Chorioptes* mites in the Japanese serow with skin lesions will be revealed, which has not been previously reported. The results of parasitological and histopathological examinations are described.

**MATERIALS AND METHODS**

A total of seven Japanese serows were studied for parasitological and histopathological examinations. These were collected in the years 1975 to 1997 in Saitama, Nagano and Kanagawa prefectures in Japan. Data for all these specimens are shown in Table 1.

For the first time, the whole body surface of each Japanese serow was examined for the presence of any acarine ectoparasites. Thereafter, skin scrapings were taken from areas with clinical signs of mange. These skin scrapings were placed in 10% potassium hydroxide (KOH) solution for 2–6 hrs at room temperature, and were then mounted on glass slides for microscopic observation. The sarcoptic and chorioptic mites of each developmental stage (larva, nymph, female and male) were counted under a phase contrast microscope.

Two animals (Nos. 6 and 7), shown in Table 1, were examined histopathologically. Four and two skin samples (50 × 50 × 10 mm) of mange-like lesions were removed from animal No. 6 (jaw, abdomen, hind leg and chest) and No. 7 (thigh and chest), respectively. These specimens were fixed in 10% buffered formalin, embedded in paraffin, sectioned to 5 μm thickness, stained with hematoxylin and eosin, and examined microscopically. Each skin snip (5 × 5 × 5 mm) from three sites of the hyperkeratotic areas of each skin sample removed from the two animals was soaked in 10% KOH solution for mite-counting at each developmental stage.

*Chorioptes* mites collected from Japanese serows in the present study were identified according to the Fain's key (1975) and were compared with *C. bovis* (Hering, 1845) collected from sheep by Dr. Rosen in Israel. Essentially, the type host of *C. bovis* is cattle. However, this species was found throughout the world on many domestic livestock as well as on some zoo animals (Sweatman, 1958). Although we examined many specimens collected from cows at various areas in Japan, such as Kochi, Mie, Nagano and Gunma prefectures, all specimens were identified as *C. texanus*.

The outer setae of the opisthosomal lobes of male *Chorioptes* mites from different hosts were measured. The setal nomenclature follows that of Fain (1975). The systematic analysis was made by variance with four setae (ae, l4, d4, 13).

**Table 1.** Records of Japanese serow, *Capricornis crispus*, examined in this study.

<table>
<thead>
<tr>
<th>No.</th>
<th>Date</th>
<th>Locality</th>
<th>Condition</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>30 May 1975</td>
<td>Uematsu-cho, Kiso-gun, Nagano Pref.</td>
<td>Dead and emaciated with injuries to the body by the bite of an unidentified animal.</td>
</tr>
<tr>
<td>2</td>
<td>22 Jan. 1976</td>
<td>Kaminishijo, Shiojiri-shi, Nagano Pref.</td>
<td>Dead and emaciated</td>
</tr>
<tr>
<td>3</td>
<td>16 Mar. 1976</td>
<td>Kitaono, Shiojiri-shi, Nagano Pref.</td>
<td>Dead and emaciated</td>
</tr>
<tr>
<td>5</td>
<td>31 Aug. 1996</td>
<td>Mt. Tanzawa, Kanagawa Pref.</td>
<td>Weak. Death occurred after 2 days.</td>
</tr>
</tbody>
</table>
RESULTS

1. External Macroscopic Observations

In four Japanese serows (Nos. 1-4), shown in Table 1, mange-like lesions were mainly limited to the side of the tail root, hind part of the back, hind legs, and mouthpart, respectively. These lesions were small and hairless. More severe mange was observed in animal No. 5. The lesions had spread to the hind legs, root of the tail and lower part of the back and presented skin scales or crusts. The most severe mange was on animals Nos. 6 and 7 with clinical signs of sarcoptic or chorioptic mange covering the face and abdomen. On animal No. 6, the skin on the mouthpart, lateral abdomen, chest, tail root and lower back had become thickened, wrinkled and covered by crusts of dried serous exudate. On animal No. 7, most of the body surface was almost similar to that of No. 6. Depilated spots were also observed on the forelegs, hind legs, and thighs.

2. Identification

All the Sarcoptes mites isolated in this survey were identified as S. scabiei. The Chorioptes mites were classified as an unknown species according to the shape of a pair of opisthosomal lobes and the characterization of the five pairs of setae in adult males (Fig. 1). This Chorioptes sp. is very close to C. bovis. The differential diagnosis between Chorioptes sp. and C. bovis is based mainly on the shape of the spatular seta 14 located postero-medially on the opisthosomal lobes of the male (Figs. 2 and 3). The body size of the Chorioptes sp. adult male is wider than that of C. bovis (Figs. 4 and 5). Measurements of the three fine setae (ae, d4 and 13) and spatular seta 14 were confirmed on the Chorioptes sp. collected in the present study and compared with those of C. bovis from the sheep in Israel (Table 2).

![Fig. 1. Ventral view of opisthosomal lobes and setae (ae, 14, d4 and 13) of an adult male Chorioptes japonensis sp. nov. collected from Japanese serows, Capricornis crispus.](image)

Table 2. Comparative lengths of opisthosomal setae of Chorioptes bovis and Chorioptes japonensis sp. nov. in adult males.

<table>
<thead>
<tr>
<th>Species</th>
<th>n</th>
<th>ae</th>
<th>14</th>
<th>d4*</th>
<th>13</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chorioptes japonensis</td>
<td>10</td>
<td>199.5±10.98</td>
<td>111.0±8.99</td>
<td>84.8±8.93</td>
<td>63.0±4.68</td>
</tr>
<tr>
<td>Range</td>
<td>(175.0-212.5)</td>
<td>(100.0-130.0)</td>
<td>(75.0-100.0)</td>
<td>(55.0-70.0)</td>
<td></td>
</tr>
<tr>
<td>Chorioptes bovis</td>
<td>4</td>
<td>182.5±20.72</td>
<td>101.9±5.54</td>
<td>68.8±12.67</td>
<td>58.8±11.09</td>
</tr>
<tr>
<td>Range</td>
<td>(167.5-212.5)</td>
<td>(95.0-107.5)</td>
<td>(60.0-87.5)</td>
<td>(45.0-70.0)</td>
<td></td>
</tr>
</tbody>
</table>

* F_0>F(0.05)
Only the seta d4 is finer and significantly longer in *Choriopites* sp. than in *C. bovis* (84.8 \( \mu \)m vs. 68.8 \( \mu \)m). Based on the features of the spatular seta 14 and a minor difference in seta d4, we name *Choriopites* sp. as *C. japonensis* Takahashi et Nogami sp. nov. It is interesting to note that a few adult males of the *C. japonensis* sp. nov. were observed to have paired with female deutonymphs as in Fig. 7, and that ovigerous females were often encountered (Fig. 6).

3. Description of Adult Male, *Choriopites japonensis* Takahashi et Nogami, sp. nov.

Body, including opisthosomal lobes, white in color, 324.0 \( \pm \) 6.75 long by 263.0 \( \pm \) 11.37 wide at the broadest point (mean \( \pm \) SD \( \mu \)m, \( n \) = 7), and also including the gnathosoma (from the tip of the gnathosoma to the distal end of the lobes) 350.5 \( \pm \) 4.47 long.

*Dorsum*

Propodosomal shield elongated and bell-shaped, bearing fine punctuations, and pointed posteriorly. Anterior portion narrower than posterior portion; length 81.0 \( \pm \) 2.24, width (max.) 37.5 \( \pm \) 1.61. Hysterosomal shield sclerotized, bearing fine punctuations as on propodosomal shield; length at medium line 102.5 \( \pm \) 1.74, width of anterior 122.5 \( \pm \) 1.77, middle and posterior portions 90.5 \( \pm \) 2.09 and 130.0 \( \pm \) 3.06, respectively. Opisthosomal lobe rectangular with straight borders, and anterior inside line of a pair lobes is rounded. Distance between right and left lobes; min. (posterior) 15.5 \( \pm \) 1.12, max. (middle) 27.5 \( \pm \) 1.62.

Dorsal setae of idiosome slender (mean \( \pm \) SD \( \mu \)m, \( n \) = 8); sc e and h particularly long; setae lengths as follows: sc i 31.1 \( \pm \) 1.34, sc e 178.8 \( \pm \) 3.23, h 187.5 \( \pm \) 3.54, i1 54.0 \( \pm \) 2.85, i2 46.6 \( \pm \) 1.39, d1 25.0 \( \pm \) 1.77, d2 36.5 \( \pm \) 1.37, d3 42.6 \( \pm \) 1.30, d5 110.8 \( \pm \) 7.86, i3, i4 and d4 as showed in Table 2.

*Venter*

Coxae I and II very close to each other and separated from Coxae III and IV which are close to each other. The genital organs situated at the level of Coxae III. Genital apparatus, little socket-like depressions flanked with a pair of fine setae and two pairs of hooks. A pair of large and distinct anal suckers situated at the base of the opisthosomal lobes, with an associated pair of short spine setae anterior to the suckers. One pair of ventral propodosomal setae longer (57.5 \( \pm \) 3.25) than two pairs of the ventral metapodosomal setae (34.2 \( \pm \) 2.65). Length of opisthosomal setae; ae 199.5 \( \pm \) 10.98, i5 200.0 \( \pm \) 11.12.

*Legs*

Legs I and II stouter than leg III, but leg IV very short and about 1/3 of the length of the leg III. The length of four segments from tarsus to femur of legs I–IV; 124.6 \( \pm \) 2.01, 128.0 \( \pm \) 2.09, 129.6 \( \pm \) 3.88, 42.5 \( \pm \) 1.77, respectively.

Lengths of tibiae I–IV: 29.6 \( \pm \) 1.88, 31.5 \( \pm \) 1.40, 32.0 \( \pm \) 2.09, 12.4 \( \pm \) 0.43, respectively. Lengths of tarsi I–IV; 36.3 \( \pm \) 1.37, 36.5 \( \pm \) 1.37, 36.3 \( \pm \) 1.42, 9.2 \( \pm \) 1.29, respectively.

All tarsi terminating in a claw and a short unsegmented caruncle. The caruncle of tarsus III longer than those of tarsi I and II. In addition, tarsus III bearing a rod-like structure. Caruncles on tarsi I–IV: 37.5 \( \pm \) 1.72, 37.5 \( \pm \) 1.62, 32.5 \( \pm \) 1.68, 12.5 \( \pm \) 1.13 long, respectively.

Type series. Holotype: \( \alpha \) (NSMT-Ac 11282), collected from Japanese serow, *Capricornis crispus*, 31–VIII–1996, Mt. Tanzawa, Kanagawa Pref. (Coll. S. Nogami). Paratypes: 3\( \alpha \), \( \alpha \) (NSMT-Ac 11283–11285), with the same data as above. These specimens will be deposited in the collection of the Department of Zoology, National Science Museum Tokyo, Japan.

*Etymology*

Referring specifically to the Japanese serow indigenous to Japan.

4. Number of *S. scabiei* and *C. japonensis*
Table 3. *Sarcoptes scabiei* and *Choriopotes japonensis* sp. nov. found in the epidermis of each of the seven
Japanese serow, *Capricornis crispus*.

<table>
<thead>
<tr>
<th></th>
<th><em>S. scabiei</em></th>
<th><em>Choriopotes japonensis</em></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>M</td>
</tr>
<tr>
<td>No. 1**</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 2</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 3</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Jaw</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Abdomen</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hind leg</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No. 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Thigh</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chest</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* On animals Nos. 6 and 7, the numbers of mites were counted in the epidermis (5×5×5 mm).
F, Female; M, Male; N, Nymph; L, Larva; DNF, Female deutonymph; DNM, Male deutonymph; PNF, Female protonymph; PNM, Male protonymph
** The Japanese serow no. examined is the same as shown in Table 1.

sp. nov. in each Japanese serow
All seven animals were found to be positive for *Choriopotes* mites. However, *S. scabiei* were only observed on animals Nos. 6 and 7. As shown in Table 3, many *S. scabiei* in every developmental stage were observed in both animals.

Concerning the number of *S. scabiei*, No. 6 was found to have 159.3, 75.1, 63.5 and 42.2 mites per 125 mm³ puncture of the skin on the jaw, abdomen, hind leg and chest, respectively. On animal No. 7, 51.9 mites on the thigh and 168.6 on the chest were counted.

Regarding the number of *C. japonensis* sp. nov. animal No. 6 was found to have 17.1 mites on the jaw, 10.7 on the abdomen and 5.0 on the hind leg. No mites were observed on the chest. Animal No. 7 harbored 47.9 and 28.3 mites on the thigh and chest, respectively. The density of *S. scabiei* was much higher than that of *C. japonensis* sp. nov. in every infested area of the two animals (Table 3).

The *Demodex* mite was not found at all on animals Nos. 1–7, mostly examined twenty or more years previously.

5. Histopathology
Histopathological observations were carried out for a total of seven skin samples from the mange-like lesions of animals Nos. 6 and 7. In each skin sample, parakeratotic and hyperkeratotic crusts were observed in the epidermis. Many *S. scabiei* of each developmental stage were found in the stratum corneum and the subcorneal layer. Usually, their mouthparts had reached the stratum granulosum or stratum spinosum (Fig. 8).

However, *Choriopotes* mites were not observed. The stratum corneum showed focal thickening due to the many burrows and galleries of *S. scabiei*, namely as the result of parakeratosis and hyperkeratosis. Neutrophils infiltrated into the dermal papillae with patchy edema. Coarse keratohyaline granules were observed in the stratum papillae.

**DISCUSSION**

The burrowing mite *S. scabiei* is a single species regardless of the difference in size and certain morphological characteristics,
Figs. 2–8. Fig. 2. The spatular seta $14$ (arrow head) on opisthosomal lobes of *Chorioptes japonensis* sp. nov. Fig. 3. The spatular seta $14$ (arrow head) on opisthosomal lobes of *Chorioptes bovis*. Fig. 4. Ventral view of adult male *Chorioptes japonensis* sp. nov. Fig. 5. Ventral view of adult male *Chorioptes bovis*. Fig. 6. Ventral view of ovigerous female *Chorioptes japonensis* sp. nov. containing an egg (arrow head). Fig. 7. Attachment pairs formed by the adult male (M) and female deutonymph (DN) of *Chorioptes japonensis* sp. nov. Fig. 8. Adult female of *S. scabiei* in a burrow, the mouthparts (arrow head) having reached the stratum granulosum in the epidermis. Bars: $50 \mu m$. 
or in the host species (Fain, 1968, 1978; Burgess, 1994). However, some consider that the *S. scabiei* mites infesting different hosts are a distinct species (Kutzer and Grunberg, 1967; Kutzer, 1970). In Japan, *S. scabiei* infestation has been observed in raccoon dogs, *Nyctereutes procyonoides* (Suzuki et al., 1981; Kozutsumi et al., 1988; Yachimori and Yamamoto, 1992; Yamamoto et al., 1998; Asakawa, 1998; Takahashi et al., 2001a, b); in Japanese serows (Anonymoust, 1996a, b; Baba et al., 1996) and in the red fox, *Vulpes vulpes* (Tsukada et al., 1999). Regarding other wild mammals, however, they were also observed in *Sus scrofa* in the Amami Islands (Honda, personal communication) and in Gunma Prefecture (Takahashi, unpublished data). From these observations, *S. scabiei* infestation may also be located in other wild mammals in Japan.

Regarding the non-burrowing *Choriopotes* mite, five species are proposed by Fain (1975); *C. bovis* (Hering, 1845), *C. texanus* (Hirst, 1924), *C. crewei* Lavoipierre, 1958, *C. mydaus* Fain, 1975 and *C. panda* Fain et Leclere, 1975. The *Choriopotes* mites collected in the present study did not accord with any species in the Fain’s key (1975), and were morphologically very close to *C. bovis*. However, these two species are clearly differentiated by the shape of a pair of opisthosomal lobes and the characteriziation of the spatular seta 14 located postero-medially on the opisthosomal lobes of the male. This species is thought to be specific to the Japanese serow indigenous to Japan.

*Choriopotes bovis* and *C. texanus* were recorded in various wild and domestic herbivores, each having widespread geographical distribution (Rosen et al., 1989; Yeruham et al., 1991, 1992; Faccini and Massard, 1976; Kadulski, 1996). However, the extent of the distribution of *C. bovis* in Japan has not yet been confirmed, despite our many investigations. These two species are considered to be the only valid species in the mites of genus *Choriopotes* (Sweatman, 1957). This concept is also supported by the analysis of the second internal transcribed spacer of the rRNA gene in fourteen *Choriopotes* isolates from cattle, horse, sheep and llama (Essig et al., 1999). The other three species were collected from a single host species, namely from an antelope (Lavoipierre, 1958, 1959), a badger (Fain, 1975) and giant pandas (Fain and Leclere, 1975; Wang et al., 1985), respectively.

The skin lesions of animals Nos. 6 and 7 showed more severe dermatosis than those of animals Nos. 1–5 and the numbers of *S. scabiei* were more abundant than that of *C. japoniet* sp. nov.

Hyperkeratotic or crusted mange observed in the present study is considered to be similar to that of the severe sarcoptic mange reported in red foxes (Morner and Christensson, 1984; Morner, 1992; Bornstein et al., 1995) and raccoon dogs (Yamamoto et al., 1998; Takahashi et al., 2001a, b). The condition is characterized by the development of hyperkeratotic and parakeratotic crusts which may be loose or dense, thickened, adherent and either scaly or flaky (Burgess, 1994). The densities of *S. scabiei* were lower in the present study than in previously reported cases of raccoon dogs per 125 mm² puncture of the skin (Yamamoto et al., 1998; Takahashi et al., 2001a, b).

Epidemics of sarcoptic mange among wild mammals have spread in the past 20 years or so in Japan, within such species as the raccoon dog (Suzuki et al., 1981 Takahashi et al., 2001a, b; Yamamoto et al., 1998), while epidemics among the Japanese serow have been noticed increasingly in the last five years (Anonymous, 1996 a, b; Baba et al., 1996) and in red fox recently (Tsukada et al., 1999). The factors leading to the increase in mange incidence are not yet understood. However, high levels of destruction of the habitats and environments of these animals cause so much stress in most cases that immunity may be decreased, causing heavy-type sarcoptic mange resulting from hyper-infestation.
Chorioptic mites are considered to be a permanent skin inhabitant (Reddy et al., 1992; Cremers, 1985; Heath et al., 1983). These mites have chewing chelicerae and feed on the epidermal debris (Sweatman, 1957), causing irritation (Crawford et al., 1970; Heath, 1978a, b; Heath et al., 1983; Yeruham et al., 1981, 1992), impaired fertility, reduced testicular size and seminal tubule degeneration associated with the chorioptic mange of the scrotum of rams (Crawford et al., 1970; Rhodes, 1975, 1976; Heath 1978a, b). In particular, the lesions caused by Chorioptes japonensis sp. nov. were considered to be a result of an allergic reaction in hypersensitive animals to the secretions and excretions of these mites (Matthysse and Marshall, 1963; Yeruham et al., 1999).

This chorioptic mange condition is almost similar to that of the sarcoptic mange but usually, sarcoptic mange involves more severe dermatosis than chorioptic mange in the infested animals. Also, chorioptic mange is considered to have the same allergic irritant condition resulting from the burrowing mite S. scabiei in mammalian epidermis (Burgess, 1994) including human beings, with delayed hypersensitivity playing the principal role (Orkin, 1975).

It has been suggested that sarcoptic mange may play a role in the reduction of wild canid population (Knowles, 1914; Pryor, 1956; Trainer and Hale, 1969; Stone et al., 1972; Tsukada et al., 1999; Yamamoto et al., 1998, Takahashi et al., 2001a, b). However, some investigators consider that mange was not a significant factor in the reduction of the numbers of wild canid populations, such as the coyote and red fox (Storm et al., 1976; Pence et al., 1983; Pence and Windberg, 1994). More extensive studies of pathogenic viruses, bacteria, protozoan and helminthic parasites of the Japanese serow, inclusive of those becoming virulent, are necessary to evaluate due effects of sarcoptic and/or chorioptic mange on the fluctuations of wild populations of this serow.

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