Temporal Changes in the Parasite Fauna of the Large Japanese Field Mouse *Apodemus speciosus* in the Radioactive Contaminated Zone of Fukushima

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ABSTRACT

We assessed the temporal changes in the parasite fauna of the large Japanese field mouse *Apodemus speciosus*, which served as a model to evaluate the biological effects of radioactive materials released upon the Fukushima Daiichi Nuclear Power Plant accident. Parasites were collected from 30 mice trapped before (1992) and after (2012 and 2014) the accident. Five species of parasites were identified; among these, *Heterakis spumosa* (Nematoda) was detected only before the accident and *Raillietina coreensis* (Cestoda) was detected only after the accident. This phenomenon may reflect accident-induced environmental changes affecting the abundance of paratenic and intermediate parasitic hosts. Regarding morphology, no malformations were observed in any of the isolated parasites.

Key words: *Apodemus speciosus*, Fukushima Daiichi Nuclear Power Plant, parasite fauna

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The Great East Japan Earthquake occurred at 14:46 JST on March 11, 2011. The resulting tsunami devastated the coast of Honshu. Consequently, the interruption in the power supply at the Fukushima Daiichi Nuclear Power Plant (FDNPP) disabled the reactor cooling systems. The resultant overheating compromised the reactor containment vessel, releasing a large amount of radioactive materials into the surrounding environment.

To evaluate the impact of radioactive materials on the local ecosystem, we assessed the temporal changes in the parasite fauna of the large Japanese field mouse, *Apodemus speciosus*. The species meet the criteria of reference animals for assessing the impact of radiation on wildlife as designated by the International Commission on Radiological Protection (ICRP) [1], and extensive information on its ecology, morphology, and parasite fauna is available. In addition, species that develop directly (egg infection) and species that develop indirectly (require intermediate or paratenic hosts) are known among parasites [2]. Thus, even though parasites are not designated as reference animals by the ICRP [1], temporal changes in the parasite fauna of *A. speciosus* before and after the accident might be one of the indicators of the effect of radiation on the various elements that make up the food web in the area contaminated with radioactive substances.

As the number of captured females was lesser than that of males and the reproduction status of female individuals varied (e.g. level of maturity, pregnancy or non-pregnancy, lactation or non-lactation), males with testicular descent were used to isolate parasites to minimize the effect of the reproductive cycle. In this study, 20 male mice (10 captured in 2012 and 10 in 2014) were used as specimens affected by radioactive materials. The capture site was in the area contaminated with

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Table 1 Internal parasites obtained from large Japanese field mice (*Apodemus speciosus*) captured within the radioactive contaminated zone of Fukushima. In each fraction, the numerator is the number of animals in which each parasite was detected, whereas the denominator is the number of examined field mice (10).

	1992 *1	2012	2014	Photographs
Cestoda				
Raillietina coreensis	0/10	6/10	3/10	Fig. 1 (1-3)
Nematoda				
Heligmonoides speciosus	7/10	10/10	5/10	Fig. 1 (4-7)
Syphacia frederici	8/10	1/10	2/10	Fig. 2 (1-3)
Rictularia cristata	2/10	1/10	1/10	Fig. 2 (4, 5)
Heterakis spumosa	6/10	0/10	0/10	

*1 Data for 1992 were obtained from Asakawa (1995).

radioactive substances called "difficult-to-return zone" located northwest of FDNPP in the Fukushima Prefecture. The mean ambient dose of gamma radiation at ground level was 16.7 μSv/h and 12.7 μSv/h in 2012 and 2014, respectively. Field mice were captured from August to November 2012 and from June to August 2014, after obtaining permission from the Fukushima Prefectural Office. Sherman-type live traps with sunflower seeds as bait were placed and observed the following day. Trapped field mice were handled in accordance with the guidelines of the Mammal Society of Japan to study wild mammals and the rules of the National Institute for Environmental Studies for the analysis and experimentation with environmental samples contaminated with radioactive materials.

Autopsies were performed after euthanizing mice with carbon dioxide. Gastrointestinal tracts were isolated, fixed in 70% ethanol solution, and examined under a stereoscopic microscope to visualize parasites. The isolated parasites were fixed in 70% ethanol and then observed for species identification under an optical microscope using lactophenol solution. Collected data on the presence and abundance of parasites were compared to information acquired from 10 mice captured at Otama Village in the same prefecture in 1992 and used as control [2] (Table 1).

The species and number of isolated parasites are shown in Table 1. Five species were identified; the parentheses following the scientific names encompass the family name followed by the predilection site: *Raillietina coreensis* (Davaineidae, small intestine), *Heligmonoides speciosus* (Heligmonellidae, small intestine), *Syphacia frederici* (Oxyuridae, cecum), *Heterakis speciosus* (Heterakidae, cecum), and *Rictularia cristata* (Rictulariidae, small intestine) (Fig. 1, 2). These five species are common throughout Japan [2]. Interestingly, although *H. speciosus*, *S. frederici*, and *R. cristata* were abundant both before and after the accident, *H. spumosa* and *R. coreensis* were detected only before or after the accident, respectively.

H. speciosus, and *S. frederici* have a direct development cycle; in contrast, *R. cristata* has an indirect development cycle that requires insects, such as beetles, as intermediate hosts [2]. The present result of the prevalence of the three nematodes was almost the same as that in other parts of Japan [2]; therefore, no effect related to the nuclear power plant accident for the three species have occurred during the survey period.

H. spumosa has a direct development cycle but may also use earthworms as paratenic hosts [2], whereas *R. coreensis* has an indirect development cycle that requires insects, such as ants, as intermediate hosts [3]. Thus, the disappearance of *H. spumosa* and the appearance of *R. coreensis* may reflect accident-induced environmental changes affecting the abundance of the respective hosts. Regarding earthworms, several reports describe the temporal changes in the concentration of radioactive material in tissues as well as the level of DNA damage [4, 5]. However, no information on changes in the species population after the accident is available. Thus, we are currently unable to verify a relation between the population of the paratenic hosts used by *H. spumosa* and its disappearance after the accident. Similarly, although there are reports on the concentrations of radioactive materials in the insect body and the relation between air doses and insect populations [5, 6], little to no information exists on

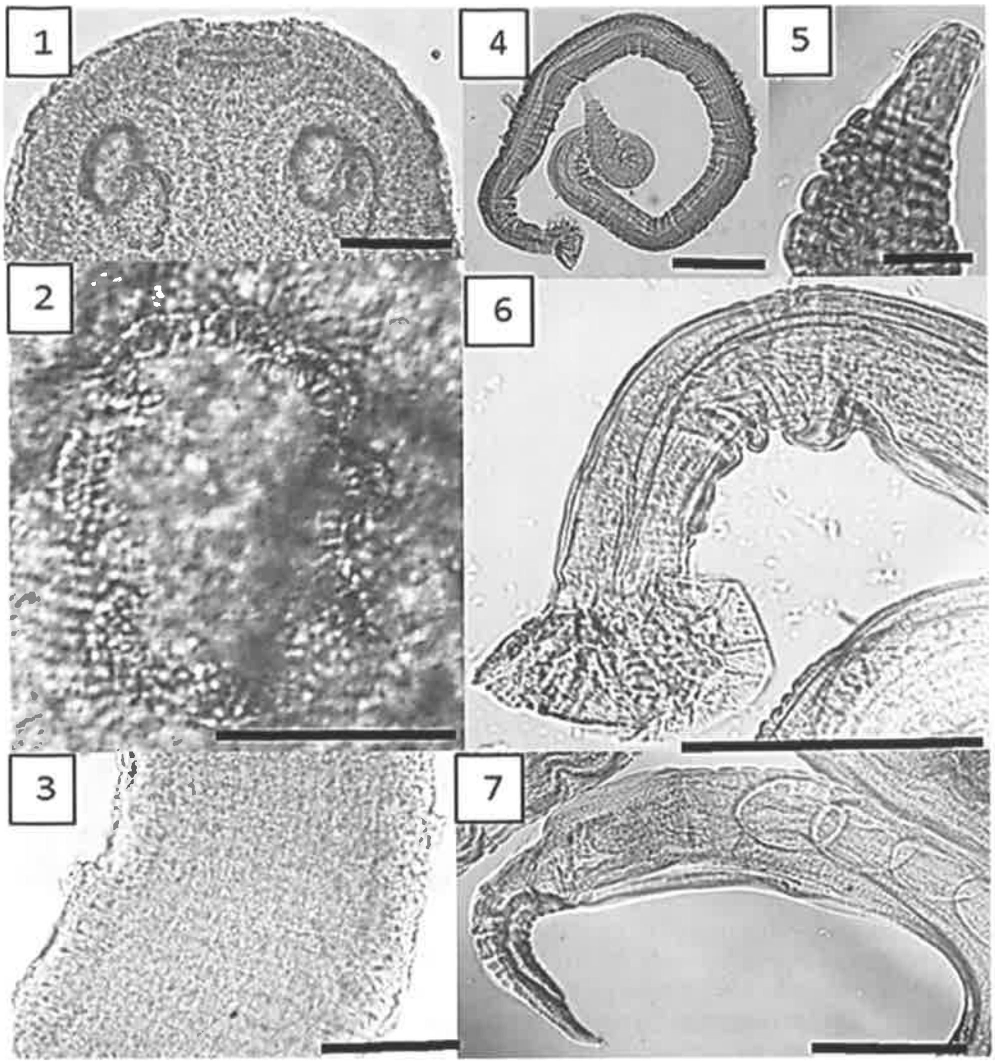

Fig. 1 Internal parasites obtained from large Japanese field mice (*Apodemus speciosus*) captured in the radioactive contaminated zone of Fukushima in 2012 and 2014 (1/2)

1-3: Scolex (1), suckers with minute spines (2), and mature segments (3) of *Raillietina coreensis*. The bars represent 100 μm in (1, 2) and 200 μm in (3).

4-6: Whole body (4), anterior extremity (5), and posterior extremity of male *Heligmonoides speciosus*. The bars represent 200 μm in (4), 20 μm in (5), and 100 μm in (6).

7: Posterior extremity of female *Heligmonoides speciosus*. The bar represents 100 μm.

the temporal changes in the species diversity of insects in the contaminated zone. Therefore, we cannot evaluate whether changes in the abundance of the intermediate host are indeed responsible for the appearance of *R. coreensis* in the area after the accident.

Although we speculated regarding the disappearance of *H. spumosa* and the appearance of *R. coreensis* after the accident, a conclusion should be achieved based on population data for the respective paratenic and/or intermediate hosts of both parasites. One strategy would be to confirm the presence of larvae in stored insect and earthworm samples. Moreover, an increase in the number of field mouse autopsies would give us a more accurate view of the changes in parasite abundance caused by the accident.

Morphological abnormalities have been reported in invertebrates such as the pale grass blue butterfly (*Zizeeria*

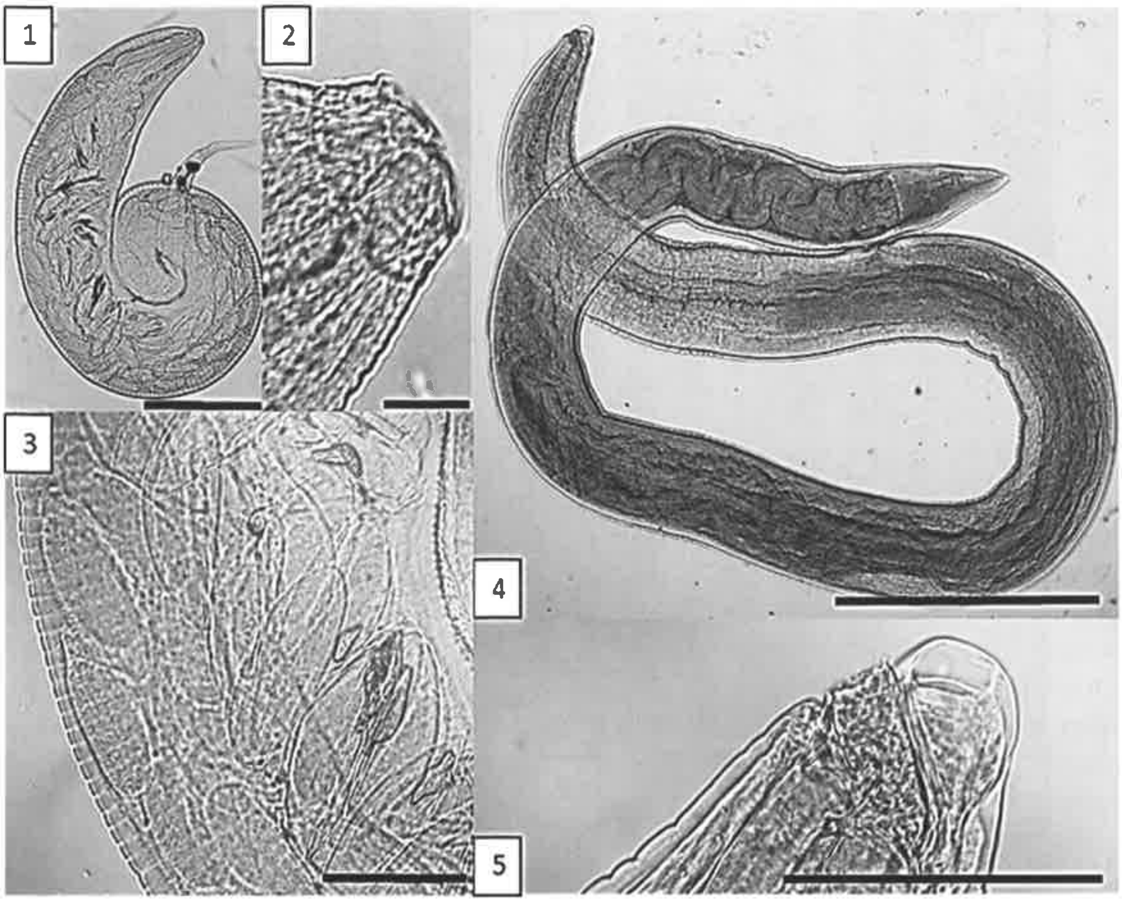

Fig. 2 Internal parasites obtained from large Japanese field mice (*Apodemus speciosus*) captured in the radioactive contaminated zone of Fukushima in 2012 and 2014 (2/2)

1-3: Whole body of mature female (1), anterior extremity of female (2), and eggs in uterus (3) of mature female *Syphacia frederici*. The bars represent 200 μm in (1), 50 μm in (2), and 100 μm in (3).

4, 5: Whole body (4) and anterior extremity (5) of immature female *Rictularia cristata*. The bars represent 1 mm in (4) and 100 μm in (5).

maha) and gall-forming aphids (*Tetraneura* spp.) that were captured in areas contaminated with radioactive substances [7, 8]. Morphological abnormalities might occur in parasites; therefore, morphological observation using an optical microscope was conducted to evaluate abnormalities in isolated parasites. The results showed no individual with morphological abnormalities. The expected total daily dose in the field mouse capture site was 0.547 mGy/day and 0.302 mGy/day in 2012 and 2014, respectively [9]. As the collected parasites were probably exposed to similar daily doses during their development, the lack of malformations suggests that the estimated doses are unable to cause developmental abnormalities in the isolated species. Interestingly, this result differs from the phenomenon observed in other invertebrates such as the pale grass blue butterfly and gall-forming aphids [7, 8]. Thus, further studies on parasites may provide insight into how differences in developmental processes among invertebrates are linked to the differential resistance to radiation during development.

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研究短報　寄生虫学

福島県帰還困難区域に分布するアカネズミ *Apodemus speciosus* の寄生虫相の経時的変化

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要　約

福島第一原子力発電所の事故で放出された放射性物質による環境影響を評価する一環で，アカネズミの寄生虫相の時間的変化を評価した。事故前後に捕獲した合計 30 匹のアカネズミから寄生虫の分離を試み，5 種の寄生虫を得た。線虫 1 種は事故前，条虫 1 種は事故後にのみ確認された。これは，事故による環境変化が待機宿主，中間宿主の個体数に影響を与えたことによる現象かもしれない。形態観察の結果，奇形は観察されなかった。

キーワード：*Apodemus speciosus*，福島第一原子力発電所，寄生虫相　　　　── *日本野生動物医学会誌 26(1)：1-5, 2021*

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