

# Monitoring free-living Japanese Bush Warblers (*Cettia diphone*) in a most highly radiocontaminated area of Fukushima Prefecture, Japan

Ken Ishida\*, Keitaro Tanoi and Tomoko M. Nakanishi

Agricultural and Life Sciences, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo, Japan

\*Corresponding author. Agricultural and Life Sciences, The University of Tokyo, Yayoi 1-1-1, Bunkyo-ku, Tokyo, Japan. Tel.: +81-3-58415499; Fax: +81-3-58410827. Email: ishiken@es.a.u-tokyo.ac.jp

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## ABSTRACT

The Fukushima–Daiichi Nuclear Power Plant (F1NPP) accident is an IAEA level 7 event, the same as that of Chernobyl, while the amount of radionuclides released is not comparable. Radioactivity attributed to the F1NPP accident was detected 250 km away from the F1NPP. Although we have not yet systematically studied the effect of radionuclides on the environment and wildlife, one of three Japanese Bush Warblers (*Cettia diphone*), captured in Akaugi district in August 2011, was observed to have a conspicuous lesion near the cloaca, which is rare in Japan. All of the birds' feathers were strongly contaminated. Further study is needed to determine the significance of this result. We emphasize the importance of continuing assessment of the effects of the F1NPP accident on wildlife.

**KEYWORDS:** Abukuma highland, Bush Warbler, microhabitat radiation heterogeneity, ecology, contingency

## INTRODUCTION

The total contamination of Fukushima–Daiichi Nuclear Power Plant (F1NPP) accident was about a tenth comparing to that of the Chernobyl accident, and a hundred times to that of the Windscale accident [1, 2]. Most of the radioactive materials dispersed to the Pacific Ocean by the dominant westerly wind occurring at the time of the explosions and release (vent). The rest was deposited mainly towards the northwest terrestrial area of about 1,000 km<sup>2</sup> from the F1NPP, on the highland of high biodiversity [2, 3] (Fig. 1). Ground contamination has been detected as far as 250 km southwest of the Chichibu mountain range. Vegetation, land use by man, terrain, distance and decontamination activities, are all factors related to the F1NPP accident that are expected to affect free-living wildlife such as aphids [4], butterflies [5], birds [6], and trees [7]. Exposure to free-living wildlife species is likely to be highly variable, depending on their ecology, behavior and by chance. Japanese Bush Warblers (*Cettia diphone*) found in the highest contamination district (Akaugi) had strong contamination on their feathers in 2011 [8]. We have been monitoring the radioactivity level of the environment and of Japanese Bush Warblers in the region.

## Study site and environment

The most contaminated area, with total radioactive Cesium fallout of >3000 kBq/m<sup>2</sup>, expands ~30 km to the northwest from the F1NPP through the northern part of the Abukuma mountains [3] (Fig. 1). The landscape consists of a mix of various types of forest, agricultural fields and small residential lands. There are various species of wildlife in the area, including Japanese Monkey (*Macaque fuscata*), Boar (*Sus scrofa*), Copper Pheasant (*Syrmaticus soemmerringii*), among many other species [8]. Forest covers ~70% (9750 km<sup>2</sup> [9]) of Fukushima Prefecture, and is thus the most dominant habitat within the area contaminated by the F1NPP accident. The forest and soil have been proved to steadily fix the radioactive <sup>134</sup>Cesium and <sup>137</sup>Cesium [2, 10].

## MATERIALS AND METHODS

Japanese Bush-Warblers were captured with a mist net in mid August 2011, and mid July and mid August 2012–2014. Birds were attracted to the net using audio recordings of their songs. The net sites were prepared (by removal of dense bush and grasses) at Akaugi (29.6–31.7 km northwest from F1NPP), Hiruzone (20.3 km NW), and

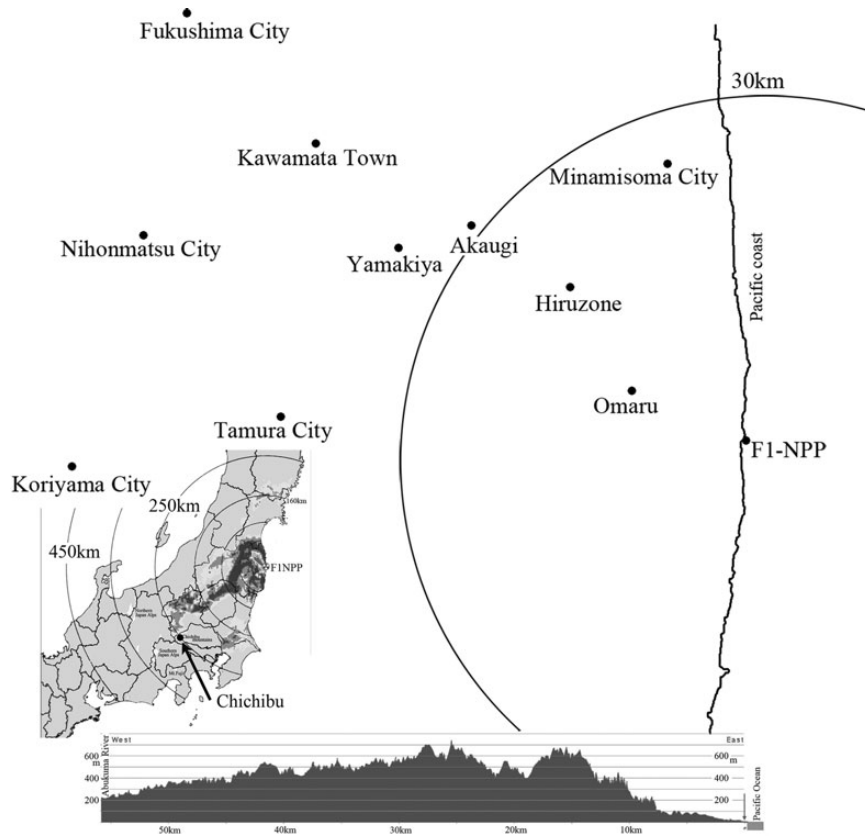


Fig. 1. Location of F1NPP, several cities, towns, and the main survey locations in Fukushima and Chichibu, Japan. The small map indicates the outline of detected radioactively contaminated areas resulting from the F1NPP accident [3]. The bottom figure shows the topography profile from F1NPP on the Pacific coast (right) to the west for ~55 km, close to Abukuma River (left). The altitude is magnified about five-fold on a relative scale.

Omaru (11.2 km NW), Namie Town, Fukushima Prefecture, Japan. Two or more rectrices (tail feathers) were removed from each individual for measurement of radioactive contaminants on the feathers. The feathers were placed in contact on a radio-autograph imaging plate (MS2025 Fuji Film) for three (2011) to seven (2013) days (~72–168 h) in a 5°C room. The imaging plate was subsequently read using FLA5000 (Fuji Film) at a resolution of 100  $\mu\text{m}$ . The feather sample dose rates were measured with a germanium semiconductor detector (GEM type, Seiko EG&G). The air dose rate at breast height around the netting sites was temporally measured with a portable survey meter (Hitachi-Aloka ICS-311), which indicates the value in  $\mu\text{Sv/h}$ .

Ten IC recorders (Olympus, DS-750) were placed around the area (the most western point is 20.6 km and the most northwestern point is 32.5 km from F1NPP, during late February or early March through September in 2012–2014. Natural sound was recorded with this equipment early every morning (starting at around sunrise) for 2–3 h. The recorded audio files were manually monitored with headphones, and recording dates and the period of the Japanese Bush Warbler songs and calls were determined. One-hundred glass dosimeter badges (Chiyoda Technol. Ltd, ES system: providing values in milliSievert) were placed in various microhabitats, including >15 cm below the ground, on the ground, and at different heights ranging up

to 12 m from the ground, at a number of locations (Kamitashiro, Yamakiya, Kawamata town and Tecchiro, Akaugi, Namie town) during a period extending from December 2012 to February 2013 (1200–1350 h).

## RESULTS AND DISCUSSION

### Radiation dose rates of microhabitats

The geography was a significant factor affecting the habitat and microhabitat contamination [3], and exposure of wildlife to radiation. Overall, the side of mountain peaks and ridges closest to the F1NPP received greater fall-out. Even structures like a hill or a rock affected the dose rates as measured *in situ*. For example, the ground measurement at the foot of a small hill facing away from the F1NPP, averaged 0.3  $\mu\text{Sv/h}$ , whereas the ground measurement at the hilltop, facing the F1NPP, averaged 4.0  $\mu\text{Sv/h}$ , in two-month continuous dose-rate observations using glass dosimeter badges in the Yamakiya district in 2013 (Fig. 2). The equivalent measurements varied from 12.4 to 30.1  $\mu\text{Sv/h}$  in the Tecchiro district.

### Warblers

In mid August 2011, an adult male Japanese Bush Warbler was captured at Tsushima district, where the air dose rate measured directly at breast height was 5–10  $\mu\text{Sv/h}$ . Three other adult males were captured



Fig. 2. Landscape and representative microhabitat dose rates at Kamitashiro, Yamakiya, Kawamata town, ~29 km northwest of the F1NPP. The aerial dose rates were measured with glass dosimeter badges (type ES, Chiyoda Technol. Ltd, Tokyo). This photo was taken using a motor paraglider, at several hundred meters above the ground (Bizworks Corp. Inc., Niiza). Typical dose measurement results and microhabitats are indicated in the picture: for example, the minimum and maximum values on the ground, and those close to the average value in air and in several types of forest, agricultural and water environments.

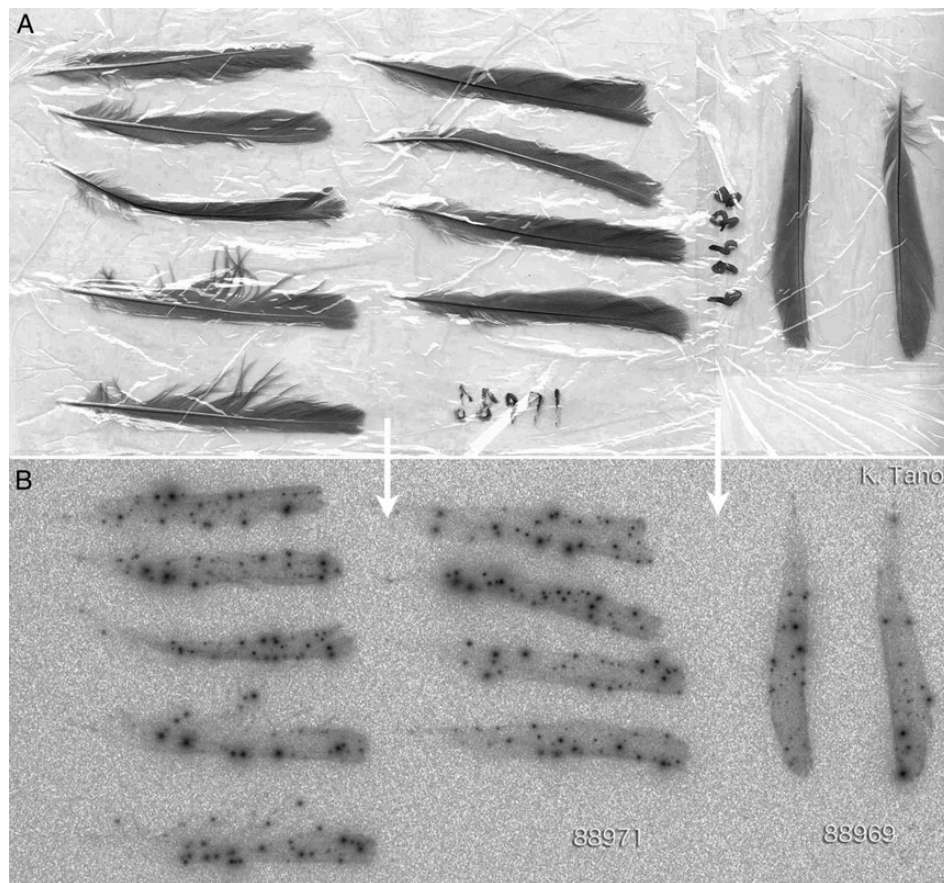


Fig. 3. A male Japanese Bush Warbler (left) and the lesion observed around the upper tail coverts on a male captured at Akaugi on 11 August 2011 [8].

in the Akaugi district, where the air dose rates were 20–30  $\mu\text{Sv/h}$  (Fig. 3) [8]. The radioactivity of  $^{134}\text{Cs}$  and  $^{137}\text{Cs}$  was estimated to be above 3000  $\text{kBq/m}^2$  at Akaugi and above 1000  $\text{kBq/m}^2$  at Tsumima (where the birds were captured) [3]. The contamination of tail feathers (rectrices) collected from the three warblers from Akaugi were rated as high (Fig. 4, Bird 1, 1.2 Bq of  $^{134}\text{Cs}$  and 1.8 Bq of  $^{137}\text{Cs}$  for 0.015 g feathers; Bird 2, 2.5 Bq of  $^{134}\text{Cs}$  and 3.6 Bq of  $^{137}\text{Cs}$  for 0.026 g feathers; Bird 3, 12.5 Bq of  $^{134}\text{Cs}$ , 17.3 Bq of  $^{137}\text{Cs}$  and 1.4 Bq of  $^{110\text{m}}\text{Ag}$  for 0.056 g feathers) [8]; these measurements were determined with a germanium semiconductor detector at the University of Tokyo. The total feather dose rates were calculated as 117–557 Bq/g for the three birds. The radioactive material on the feather was strongly fixed, and most of it could not be removed by washing with

ethanol or soapy water in the ultrasonic cleaner [8]. Feather contamination rates had decreased by 80% (to about a fifth) in August 2012, with further decreases in frequency (some individuals had no detectable radiocontamination by 2013) compared with those collected in 2011 [8]. Japanese Bush Warblers immigrate to this district in late March, as determined by automatic sound recording using IC recorders in 2012–2014. Usually a male stays in its territory at one location till late summer, and continues to sing and call for the entire day. Mid-August was during the annual molting season for the male warblers. The feathers collected, which grew the year before, were expected to have remained in a highly contaminated condition for five months. The total external dose for humans was roughly estimated as 50 mSv in the Akaugi district ( $= 20 \mu\text{Sv/h} \times 24 \times 150 \text{ h}$ ). We need to determine





**Fig. 4.** Radio images of contaminated rectrices of two male Japanese Bush Warblers captured at Akaugi on 11 and 12 August 2011. Strong spots indicate higher contamination on the feathers.

the conversion rate for small birds based on this value to estimate the radiation effects on the birds. One of the three birds captured in Akaugi in 2011 had a conspicuous lesion (that looked like an avian poxvirus lesion) near its cloaca; it was not likely to have been a tumor, but more likely was an abscess or a dilatation of cutaneous glands; histological examination was not performed [8]. Similar lesions had been observed on two males of the same bird species at Wakayama Prefecture, western Japan, in summer 2006 (Kumashiro *et al.*, unpublished data). This kind of observation is rare in wild birds in Japan, and the probability is currently under research. The observation rate in Fukushima (1 in 3) is significantly higher than that in Chichibu mountains during 1989–2013 (0 in 224 adult Japanese Bush Warblers captured by the first author,  $Z = 8.64$ ,  $P = 0.013$ , Exact test – Mann–Whitney U test). It will be necessary to accumulate further comparable data related to this type of lesion.

#### The relevance of monitoring wildlife in the contaminated areas for radiation risk assessment

Monitoring of free-living wildlife in their natural habitat in the highly contaminated area of the F1NPP accident may have three benefits. First, this may provide helpful information about the real consequences of radioactive contamination in the environment. Wildlife are exposed directly to contaminated radioactive materials in their

natural habitats. We assume that the effects of radiation do not independently affect an organism in the contaminated area of the F1NPP accident. The effects can depend simultaneously on the other environmental stresses on each individual. The behavior of each individual could also change its exposure rate, often by chance, because dose rates vary greatly among the microhabitats. Second, the results from studies of wildlife populations may play a role in influencing when and where people decide to return to the homes from which they evacuated immediately following the F1NPP accident. Wild animals are exposed directly to the environment and may not have any speculation to avoid the radioactive contamination and its influences. We can assume that better conditions for the wildlife, especially vertebrates, should indicate better conditions for human beings, with safety redundancy. A number of species of wildlife, such as warblers, can be indicator species for such speculations. Third, there is huge variety among wildlife and in life histories in relation to the environment, intra- and interspecific interactions, etc. We can learn about the various characteristics of radioactivity affecting the organisms in the natural environment. This information has the potential to provide better understanding for future generation of people about ways to deal with radioactivity in the world, which we cannot afford to miss. This also means we should study radiation activities, the process and pattern of radiation through organisms in the ecosystem, and how to preserve the biodiversity and the ecosystem services. However, we do

not yet know very well enough which wildlife species and how to observe the free-livings. We can search many kinds, according to our own experiences and skills at F1NPP accident. The ICRP [11] has listed several wild organisms as candidate reference animals, such as deer, rats, ducks, frogs, bees and earthworms. They also described their standards as provisional ones, and stated that it will be valuable to select other organisms for our references, as the nature of each individual place is unique. Fortunately, we commenced observations in the early stages following the F1NPP accident.

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