DECREASING ROAD KILL OF *Pentalagus furnessi* WITH A WILDLIFE DETECTION SYSTEM THAT WARNS DRIVERS TO REDUCE VEHICLE SPEED

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Vehicular collisions with Amami rabbits (*Pentalagus furnessi*), an endemic species on Amami-Oshima Island, Kagoshima Prefecture, Japan, is a serious issue. One measure that can decrease the number of road kills is to reduce vehicle speed. We evaluated the effectiveness of a new Wildlife Detection System (WDS), which consists of a sign and light, compared to a passive warning sign only. To determine the effect of the combined sign and light on vehicle speed reduction, we recorded vehicle speeds in three experiments: control, sign only, and WDS. Vehicle speeds were significantly reduced in the sign only and WDS experiments. However, the lighting of the WDS facilitated the visibility of wildlife from a distance. Therefore, we believe that WDS is an effective method to prevent vehicular collisions with Amami rabbits.

**Key Words**: Amami rabbits, infrared sensor, speed reduction, warning sign

1. INTRODUCTION

Amami-Oshima Island, which has a subtropical climate, is located 380 km south of Kyusyu, Japan and belongs to the Nansei archipelago. The island has many regional endemic species, such as Amami rabbits (*Pentalagus furnessi*), Amami spiny rats (*Tokudaia osimensis*), and Ryukyu long-haired rats (*Diplothrix legata*), that are on the red list of endangered species of the International Union for Conservation of Nature¹ or the Ministry of the Environment².

Of these endemic species, Amami rabbits are found only on Amami-Oshima Island and the adjacent Tokunoshima Island³. The estimated population of this species on Amami-Oshima Island in 2003 was between 2,000 to 4,800, compared to that in the 1990s when it was estimated to have been between 2,600 to 6,200. The decline in the population can be attributed to land development, which lead to deforestation, and the introduction of Java mongooses (*Herpestes auropunctatus*) in 1979 to control venomous snake (*Trimeresurus flavoviridis*), that had spread throughout the island⁴,⁵.

Hiragi et al.⁶ reported that 20% of the deaths between 2007 and 2016 were caused by collisions with vehicles. Therefore, vehicular collision is the most serious threat to the preservation of the Amami rabbits, now that the population of Amami rabbits has started to recover with the extermination of Java mongooses⁷.

Amami-Oshima Island was designated a national park in 2017 because of its unique ecosystem composed of various endemic species, and a specific culture based on human and nature interactions⁸. In the future, if Amami-Oshima is registered on the World Natural Heritage List, the number of visitors will rapidly increase⁹,¹⁰. An increasing number of visitors will inevitably lead to a rise in traffic volume, which is a factor in road kills. Therefore, measures to prevent road kills is an urgent issue in the conservation of Amami rabbits and the island ecosystem.

Wildlife–vehicle collisions are related to vehicle speed; therefore, reducing speed decreases the number of road kills¹¹-¹³. Drivers ignore warning signs, which are generally used around the world,
because a sign is permanently at one site, and the display does not change (14), (15). Coulson (16) and Dique et al. (17) also reported that a warning sign has little effect on speed reduction. In fact, the number of road kills of Amami rabbits has not been reduced, although there are warning signs and signs written on the road surface in areas where collisions frequently happen. It is necessary that drivers are properly alerted and not ignore display changes. It has not become popular, although the system combined with animal detection and alert is effective in reducing road kills (15), (18).

In this paper, we evaluated the effectiveness of a new and convenient Wildlife Detection System (WDS) that warns drivers with a light and warning sign in real time when a mammal enters the road.

2. MATERIALS AND METHODS

(1) Study area

The study was conducted on R58, an old national road where Hiragi et al. (9) had found many cases of road kills of Amami rabbits in Amami City, Kagoshima Prefecture, Japan (28°16’ N, 129°25’ E; Fig. 1). The road is 5 m wide and runs through a mountainous area, going from 20 m to 350 m in elevation. We selected a 150 m long straight stretch to avoid speed changes due to a curve. The posted speed limit was 60 km/h on this road.

(2) Description of wildlife detection system

The WDS consists of an infrared sensor and a light that is triggered by the infrared sensor (Fig. 2). The sensor sits parallel to the road on the edge at a height of 30 cm (Fig. 3), so that it can detect middle-sized wildlife (Amami rabbits), if they enter the road from adjacent forests. The sensor’s maximum width and maximum distance are 4.48 m and 15.05 m, respectively. To alert drivers of the presence of Amami rabbits, a well-lit warning sign written in Japanese and English says, ‘Watch for Amami rabbits: Slow down’ is placed at a height of 80 cm so as to be easily seen by drivers (Fig. 4).

(3) Speed measurements

To estimate the effect of a warning sign only or the WDS on speed reduction, we collected vehicle speeds in three experiments: control without a warning sign and WDS, warning sign only, and WDS. We recorded a vehicle’s speed when it passed a point approximately 20 m short of the sign and light (pre-sign), a point beside the sign (sign), and a point approximately 20 m from the sign and light (post-sign). Drivers could notice the sign board at the pre-sign point, but it was difficult to read the words clearly. As a result, we recorded the decelerated speed by drivers who noticed the light and sign board at the pre-sign point in the WDS experiment, while we recorded the speed before the deceleration at the point in the sign only experiment. Also, drivers could see the light of the WDS at a point approximately 50 m short of the sign. In each experiment a speed gun...
(Speed Star V; Bushnell, USA or ETEND LRS-1000; YUKON, USA) was used (Fig. 5). In the control and sign only, we recorded speeds at these points without a sign and light, and light, respectively. We also manipulated the light to collect sample in the WDS experiment. Our study was conducted during sunny or cloudy weather condition from April to November 2018. We studied approximately three hours from sunset. Traffic volume passing our study site was one to twenty vehicles during measurement time.

(4) Data analysis
We compared the speeds at each point in the three experiments. The difference between pre-sign and post-sign was examined using paired t-test in R ver. 3.4.2\(^{19}\) to understand the effectiveness of the WDS.

3. RESULTS
We collected 17 samples in the control, 21 samples in the sign only experiment, and 26 samples in the WDS experiment (Table 1).

Vehicles maintained a constant speed in the control (mean ± SD, pre-sign: 14.8 km/h ± 8.07 km/h, sign: 14.9 km/h ± 8.13 km/h, post-sign: 14.4 km/h ± 7.28 km/h). Each vehicle slightly reduced speed with a mean reduction of 0.35 km/h from the pre-sign to post-sign; however, it was not significantly different (t = 0.65, P > 0.05). On the other hand, the speed of the vehicles decreased during the passing (pre-sign: 17.4 km/h ± 7.93 km/h, sign: 14.1 km/h ± 6.28 km/h, post-sign: 14.1 km/h ± 5.91 km/h) in the sign experiment. There was significant difference between pre- and post-sign (t = 3.22, P < 0.05) with a reduced mean speed of 3.29 km/h. In the WDS experiment, the speed of the vehicles also decreased during the passing (pre-sign: 13.1 km/h ± 5.03 km/h, sign: 11.7 km/h ± 5.02 km/h, post-sign: 11.0 km/h ± 4.98 km/h). There was significant difference between pre- and post-sign (t = 2.40, P < 0.05) with a reduced mean speed of 2.08 km/h. Reduced speed was not significantly different between sign and WDS experiments (two sample t-test, t = 1.07, P > 0.05).

Overall, the speed in the WDS experiment (mean 11–13 km/h) was slower than that in the control (mean 14 km/h) and the sign only (mean 14–17 km/h).

In addition, we observed cases where drivers and passengers searched for mammals after seeing the sign and the light turned on.

4. DISCUSSION
Vehicle speed reduction is necessary to decrease road kills\(^{11,13,20,21}\). Our results showed that an alert sign with a light was effective in reducing vehicle speed from 2.1–3.3 km/h. We estimated that these speed reductions could decrease road kills by 6.5%–10.3% based on the formula used by Grace et al.\(^{15}\) who reported that road kills decrease by 5% with a vehicle speed reduction of 1.6 km/h. Our re-

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**Table 1** Study site on old national R58 in Amami-Oshima Island.

| Treatment  | n  | Pre-sign |  |  | Sign |  |  | Post-sign |  |
|------------|----|----------|---|---|------|---|---|----------|---|
|            |    | Mean     | SD | range | Mean | SD | range | Mean | SD | range |
| Control    | 17 | 14.76    | 8.32 | 5-38 | 14.94 | 8.38 | 5-38 | 14.41 | 7.50 | 5-36 |
| Only sign  | 21 | 17.38    | 8.13 | 6-37 | 14.14 | 14.14 | 5-31 | 14.10 | 6.06 | 5-30 |
| WDS        | 26 | 13.12    | 5.13 | 5-23 | 11.69 | 5.12 | 5-23 | 11.04 | 5.08 | 4-22 |

**Fig.4** Image of settlement of WDS (sign and light).

**Fig.5** Settlement of WDS (sign and light) and points of vehicle speed measurement.
sults showed that vehicles passed at low speed (from 14 to 17 km) in this study site; however, stopping distance would be shorter in WDS (0.59 m at 11.04 km) than control (1.02 m at 14.41 km) on dry concrete condition. Reduced speeds resulting from the use of warning sign and WDS were comparable. However, WDS could notify animal occurrences and induce speed reduction at an early point. Therefore, our study suggests that a WDS combined with a sign and light is a more effective way of preventing vehicular collisions with Amami rabbits.

In general, Amami rabbits are active in open areas such as forest roads\(^{22}\), resulting in this species frequently being observed on roads. Drivers at night will not reduce vehicle speed because the pelage of Amami rabbits is black and drivers are unable to see them in the dark. Therefore, it is necessary to improve the safety consciousness of drivers to prevent vehicular collisions with Amami rabbits in higher population areas. In this study, we showed that overall speeds were reduced more when a WDS was used with a well-lit warning sign as compared to the other two methods. We believe that drivers will see the alert with the light and reduce their speed far enough from the WDS to prevent a collision with the Amami rabbits, which makes this an effective means of reducing the number of road kills.

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