Original article

Spatiotemporal Patterns of Endangered Species Roadkill : Iriomote Cat-Vehicle Collisions

Motohisa OSAKA[1) and Maki OKAMURA[2)

[1)] Department of Basic Science, School of Veterinary Medicine,
Nippon Veterinary and Life Science University, Musashino, Tokyo 180-8602, Japan
[2)] Iriomote Wildlife Conservation Center, Iriomote Ranger Office for Nature Conservation,
Ministry of the Environment, Komi, Taketomi, Okinawa 907-1432, Japan

Abstract

The aim was to propose techniques for analysis of spatiotemporal patterns of vehicle collisions with an endangered species. We examined Iriomote cat-vehicle collisions from 1978-2008 (n=46) along only a 50-km trunk road in the Iriomote island of Japan. The collisions obeyed a nonhomogeneous Poisson process with mean $\lambda(t)$ that increased with time t. Hence, the collisions turned out to be increasing steadily. To test for spatial distribution, the road was divided into 500 segments. We assumed a null hypothesis that each collision occurred with the same probability on each of the segments. We generated 1000 samples, each of which consisted of 46 randomly selected segments, and counted clusters of various sizes. We defined a cluster as collisions $\geq$ 4 (size 4) within 1 km. The results were 1.544/sample for size 4, 0.349/sample for size 5, 0.054/sample for size 6, and 0.008/sample for size 7. The real distribution had 1 cluster of size 4, 2 clusters of size 5 and 2 clusters of size 7 ($P<0.001$). In the almost all of these clusters, it have already paid for many effort to prevent cat-vehicle collision such as underpasses, elevated segments of the road and zebra zone, our findings suggest that it is reasonable statistically. Because the situation around the cat-vehicle collisions, such as road structure, traffic volume and habitat condition of the cat along the road, has been changed, we think also that it is necessary to examine further analysis using additional data to suggest the measurement against collision effectively.

Key words : collisions, endangered species, Iriomote cat

Bull. Nippon Vet. Life Sci. Univ., **61**, 51-59, 2012.

Iriomote cat-vehicle collisions are a serious problem for the conservation of wildlife in Japan. The Iriomote cats (*Prionailurus bengalensis ssp iriomotensis* ; *Iriomote-yamaneko* in Japanese) live exclusively on the Iriomote island at the southern end of the Japanese Ryukyu Archipelago, which are 200 km east of Taiwan. Initially, morphologically unique characteristics of the Iriomote cats suggested the discovery of a new species[3)]. The cat was declared a Special Natural Monument in 1977 by the Japan Government. Recently, the studies of DNA indicated that it is a subspecies of the leopard cat *Felis bengalensis*, which is widely distributed from Southeast Asia to East Asia[9)]. Various studies on ecology and behavior by fecal analysis, camera-trapping, and radio-tracking were conducted[6, 11, 13, 16-18, 21)]. Currently, it is estimated that there are barely 100 individuals left in the Iriomote cat population[20)]. The decline in population was considered to due to habitat loss from development and mortality from traffic accidents[5, 8, 14)]. Recently, it has been recognized that the population size, which had been stable until the late 1980s, tends to decrease on the basis of the first to fourth report of the Ministry of the Environment of Japan[10)]. *Prionailurus bengalensis ssp iriomotensis* is now listed as Critically Endangered (CR) in the Red List by IUCN[4)] because of its restricted habitat and less population size than 250. Similarly, it is listed as one of domestic rare animal-plant species and is conserved, according to a project of conservation and breeding by he Ministry of the Environment of Japan.

The spatiotemporal patterns of vehicle collisions with, for example, deer have been previously reported[15] but since the population size of an endangered species, such as the Iriomote cat, is very small, the annual frequency of wildlife-vehicle collisions is extremely low and the occurrences are sporadic. Hence, it is very difficult to conclude whether the number of collisions with endangered species are steadily increasing or decreasing, and new methods to analyze these data are needed. Our objective was to propose possible methods for analyzing the spatiotemporal distributions of collisions even though the number of collisions is extremely small. We applied these methods to analyze the data of vehicle collisions with Iriomote cats. First, we examined whether the temporal distribution of collisions could be described statistically, and whether the frequency of collision was steadily increasing. Second, we examined whether the spatial distribution had any characteristic pattern. If so, such findings would provide information vital for an effective strategy to decrease the number of collisions.

Materials

The Iriomote Ranger Office for Nature Conservation of the Ministry of Environment of Japan has collected information on Iriomote cat-vehicle collisions since 1978. Table 1 lists the dates when each of the Iriomote cats was found dead or injured. As of July 21 (2008), 46 cats (30 males and 16 females) were involved in vehicle collisions. Of them, 33 were adult cats (males $>$ 3 kg body weight ; females post-maternity), 5 were juveniles (males $<$ 3 kg ; females pre-maternity and older that 1 year), and 8 were kittens (males and females both $<$ 1 year old). Only one cat (No. 26) survived the collision, and the other 45 were found dead. The locations of the collisions are marked on a map of the island (Fig. 1).

Study Area

The island is 289.24 km^2 in area (24°20′N, 123°49′E), 130 km in circumference, and covered in broadleaf, evergreen, subtropical rainforest with dense mangroves along the estuaries. The interior of the island is mountainous with 3 mountains higher than 400 m above sea level (Fig. 1). The inland mountainous areas higher than 200 m above sea level are 104.29 km^2 in area. The lower areas than 200 m above sea level, excluding residential areas and farmland, were 173.61 km^2 in area, and residential areas and farmland were 11.34 km^2 in area. University of the Ryukyus[20] reported that the population density of the Iriomote cat of the inland mountainous areas was 0.12/km^2 and that of the lower areas was 0.56/km^2. Particularly, from the foot of mountain to the coastal side of the lower areas is considered to be suitable habitat for the cat, because of the variable forests containing wetlands and prey animals. Dietary habits of the Iriomote cats are rather variable, including mammals, birds, reptiles, frogs, and insects[7]. This is the reason why the population of the cat is dense in the lower areas. Only one

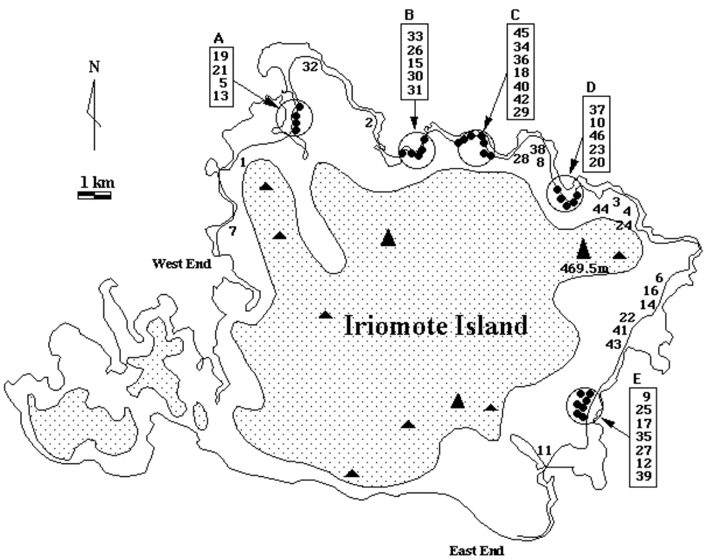

Fig. 1. Road map of Iriomote Island. Each number represents the order of witness dates of the collisions, according to the numbering in Table 1. Some shaded areas, which are higher than 200 m above sea level, are not preferable habitats. Three of the mountains are higher than 400 m above sea level, and the highest is 469.5 m. The diameter of all the circles is 1 km.

trunk road was constructed from the northwestern part to the southern one along the coastline in 1977, and the total length of it is about 50 km (Fig. 1). The first collision occurred in 1978. The Iriomote Ranger Office for Nature Conservation (Iriomote Wildlife Conservation Center) of the Ministry of the Environment of Japan has been collecting information on Iriomote cat-vehicle collisions since then. All the collisions occurred on this road. We analyzed these data on the collisions.

Methods

Analysis of Temporal Distribution

We examined whether any characteristic patterns could be detected in the temporal distribution of the collisions. Figure 2 shows the annual frequencies of collisions. We plotted the date when each of the cats was found as a sequence of collisions on the time axis from 1 Jan 1978 (Fig. 3). We then assumed that the collisions occurred independently of each other, because the drivers are independent of each other. For example, even if two victims of the collision immediately after one collision were a mother and her child, it was considered that these collisions were independent of each other, because these victims suffered not from a single collision but from two collisions, which were caused by two different drivers. Probability p was defined as the probability of a collision within an arbitrary time unit. If the entire time of observation (31 years) was divided into n small time units such that the number of occurrences of the event is at most one, the data represents a binomial process $B(n, p)$, in which one collision occurred with probability p or no collision occurred with probability $1-p$. Then, if n becomes large and p small with $\lambda = np$ being held constant, it is well approximated by the Poisson process $P(\lambda)$. We examined whether or not an observed phenomenon could be considered as a Poisson process, assuming that the collisions obeyed a Poisson process $P(\lambda)$ with mean $\underset{\cdot}{\lambda}$= (46 collisions/31years) ≈ 1.48 collisions/year. The procedure was as follows : We first evaluated the parameter $\underset{\cdot}{\lambda}$ by counting the number of collisions for a sufficiently long preassigned observation time, assuming that the observed random process followed the Poisson probability law. Next, we obtained the waiting time W_n for a specified n-th occurrence of the collision, which is referred to as the time up to the specified n-th occurrence from $t=0$, which is 1 Jan 1978. Here, the waiting time W_n followed the gamma probability law with parameter n and $\underset{\cdot}{\lambda}$ from the theorem[12]. Hence, the random variable $2\lambda W_n$ had a χ^2distribution with $2n$ degrees of freedom. We then determined the values χ_1 and χ_2 of the χ^2distribution such that the interval (between χ_1 and χ_2) provided a confidence interval for the parameter $2\lambda W_n$ with confidence coefficient $1-\alpha$. That is,

$$\Pr\{\chi_1 < 2\lambda W_n < \chi_2\} = 1-\alpha. \quad (1)$$

Hence, the confidence interval for the parameter $\underset{\cdot}{\lambda}$ became :

$$\Pr\{\chi_1/2W_n < \lambda < \chi_2/2W_n\} = 1-\alpha. \quad (2)$$

Thus, if the observed value of the parameter $\underset{\cdot}{\lambda}$ fell within this interval, we concluded the collisions could be considered as a Poisson process. The significance level was taken as $P<0.05$ so that α was 0.05.

In the above methods, the parameter $\underset{\cdot}{\lambda}$ was considered

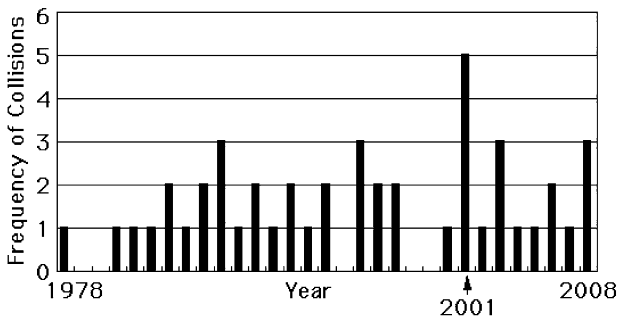

Fig. 2. Annual frequency of Iriomote cat-vehicle collisions.

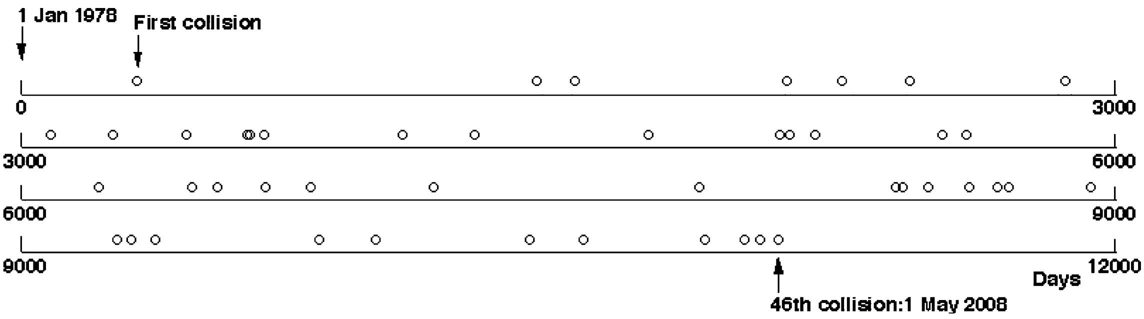

Fig. 3. Sequence of witness dates of the collisions. The origin of the time axis was defined as 1 Jan 1978.

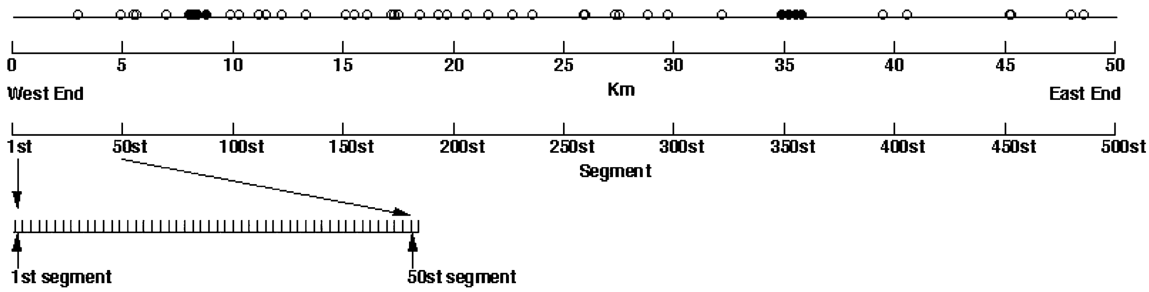

Fig. 4. One case of simulated distribution of collisions from 1000 simulations. The trunk road of 50 km in length is divided into 500 segments. For example, a part from the 1^{st} segment to 50^{th} segment is enlarged to be visible. Two clusters, each of which consists of 4 collisions within 10 segments, that is, 1 km, are marked in black.

to be constant for the duration of the 31 year observation time. Equation (2) suggested that the observed value of the parameter λ was variable within the 95%-confidence interval. Hence, we examined whether or not the collisions were an nonhomogeneous Poisson process with a parameter λ that was a function of time t, $\lambda(t)$. If $\lambda(t)$ increased with time t (year), this would indicate that the number of collisions was steadily increasing. $\lambda(t)$ was defined as the cumulative number of collisions until time t divided by time t. The points of $\lambda(W_n$; W_n, a waiting time for No. n (n＝2, 3, ⋯, 46) in Table 1, were fit to a logarithmic curve. Then, W_1 (corresponding to No. 1 in Table 1 [14 Nov 1978]) was excluded, because the date was very near 1 Jan 1978. The significance of the fit was evaluated by χ^2–test.

Analysis of Spatial Distribution

We examined whether the spatial distribution of the collisions had any characteristic pattern or not. There was only one main 50-km stretch of road with traffic, which ran along the coast of about three quarters of the island. Figure 1 shows that there appears to be some clusters among the 46 collisions, which are marked with circles. Hence, we examined whether these clusters appeared by chance or not. We defined a cluster as collisions ≥4 within 1 km, and represented a cluster consisting of n collisions as a cluster of size n. To clarify this issue, we did simulations in the following. The road was divided into 500 segments, each of which was 0.1 km in length (Fig. 4). These segments were numbered from 1 to 500. We assumed a null hypothesis that each collision occurred with the same probability on each of the segments so that 46 numbers were selected randomly from 1 to 500 by random number generators of computer software MATLAB®. Figure 4, for example, shows that one collision (marked in circle) occurs on each of 46 randomly selected segments, and that 2 clusters, which are both size 4 (marked in black), appear. We generated 1000 samples, each of which consisted of 46 randomly selected segments, and counted clusters of various sizes totally for those 1000 samples. We compared cluster distributions of 1000 samples with the cluster distribution of the real ones.

Results

Results on Temporal Distribution

Table 1 shows that the collisions of male cats are more than those of female ones. On a hypothesis that there was no difference in the frequency of the collisions between the male and female cats, the 95%-confidence interval of male collisions was [16.4, 29.7] so that the hypothesis was rejected and the collisions of male cats were significantly more than those of female ones [Male 30 ; Female 16]. Similarly, the number of the collisions of adult cats was significantly more than that of the collisions of young and very young ones [Adult 33 ; Young & Very Young 13]. From Fig. 2, it is unclear whether the annual frequency was increasing, although the frequency of the year of 2001 is the most of the data. Figure 3 shows that the witness dates are a random series in time.

For example, the waiting time W_{20} was 15.15 years. The random variable $2\lambda W_{20}$ had a χ^2distribution with 40 degrees of freedom. Then, equation (1) was as follows :

$P(24.4 < 2 \times 15.15 \times \lambda < 59.3) = 0.95.$

Hence, the confidence interval for the parameter λ became :

$0.81 < \lambda < 1.96.$

Thus, the observed value of the parameter $\lambda \approx 1.48$. fell within this interval. The waiting time W_{45} was 30.35 years. The random variable $2\lambda W_{45}$ had a χ^2distribution with 90 degrees of freedom. Then, equation (1) was as follows:

$P(65.6 < 2 \times 30.35 \times \lambda < 118.1) = 0.95.$

Table 1. Data of Iriomote cat-vehicle collisions (1978–2008). Each number is labeled on the road map (Fig. 1). In the column of Age, A is adult, J is juvenile, and K is kitten.

No.	Sex	Age	Witness Date
1	M	A	1978.11.14
2	M	K	1981.11.16
3	M	K	1982.2.26
4	M	A	1983.9.30
5	M	K	1984.2.29
6	M	A	1984.9.3
7	M	A	1985.11.4
8	F	J	1986.6.10
9	M	A	1986.11.25
10	F	A	1987.6.15
11	M	A	1987.11.28
12	M	A	1987.12.6
13	M	A	1988.1.14
14	M	A	1989.1.30
15	F	A	1989.8.14
16	M	A	1990.12.5
17	M	A	1991.11.29
18	M	J	1991.12.27
19	M	A	1992.3.5
20	M	A	1993.2.19
21	F	A	1993.4.25
22	M	A	1995.1.6
23	F	A	1995.9.17
24	M	K	1995.11.24
25	M	A	1996.4.6
26	M	K	1996.8.6
27	F	A	1997.7.9
28	M	K	1999.7.8
29	M	J	2000.12.29
30	F	J	2001.1.16
31	M	A	2001.3.27
32	M	A	2001.7.17
33	M	J	2001.10.3
34	F	A	2001.11.5
35	F	A	2002.6.17
36	F	A	2003.5.13
37	M	A	2003.6.22
38	F	A	2003.8.26
39	M	A	2004.11.17
40	F	A	2005.4.21
41	F	K	2006.6.19
42	F	K	2006.11.11
43	F	A	2007.10.12
44	M	A	2008.1.26
45	M	A	2008.3.11
46	F	A	2008.5.1

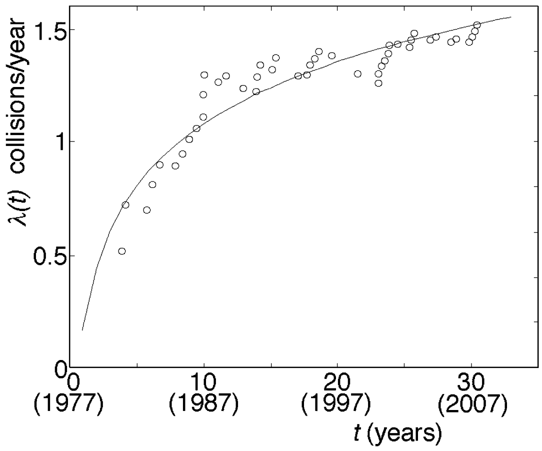

Fig. 5. Logarithmic curve fit to $\lambda(t)$ (marked by circles). Time t is the waiting time from 1 Jan 1978 to the witness of the respective collision. $\lambda(t)$ is the cumulative numbers of the collisions until time t divided by t.

Hence, the confidence interval for the parameter $\underset{\cdot}{\lambda}$ became

$1.08 < \underset{\cdot}{\lambda} < 1.95$.

As noted above for W_{20}, the observed value of the parameter $\lambda \approx 1.48$. fell within this interval ; this was also the result for all other W_n.

A plot of $\lambda(t)$ versus t is shown in Fig. 5. The points of $\lambda(W_n)$; W_n, a waiting time for No. n (n=2, 3, ⋯, 46) in Table 1, were fit to a logarithmic curve as follows :

$\lambda(t)=0.164+0.396\times log(t)$; log is natural logarithm (P=0.0001).

This equation indicated that $\lambda(t)$ was an increasing function with time t. This finding means that the yearly frequency of the cat-vehicle collisions is steadily increasing every year.

Results on Spatial Distribution

The results of 1000 samples were 1544 clusters of size 4 (1.544/sample), 349 clusters of size 5 (0.349/sample), 54 clusters of size 6 (0.054/sample), and 8 clusters of size 7 (0.008/sample). Particularly, any of these 8 clusters of size 7 did not appeared with another cluster in the same sample. These findings indicated that the probability of occurrence of cluster of size 7 was 0.008, and that the probability of simultaneous occurrence of 2 clusters of size 7 was less than 0.001. Figure 1 shows that 2 clusters of size 7, 2 clusters of size 5, and 1 cluster of size 4 appeared in the distribution of the real collisions. It indicated that the probability of occurrence of the real cluster distribution was much less than 0.001. Finally, the null hypothesis that each collision occurred with the same probability on each of the segments was rejected (P＜0.001).

Discussion

The number of the collisions of male cats was twice as many as that of the female ones. The reason was presumed to be that males occupy broader ranges in peripheral habitats than females (males : 2.1 to 4.7 km^2, females : 0.95 to 1.55 km^2)[22]. The number of the collisions of adult cats was twice and a half as many as that of the young and very young ones. The reason was considered to be that home ranges of adult cats are broader than those of young and very young ones.

Results from the statistical analysis indicated that the collisions obeyed a Poisson process $P(\lambda)$ with parameter $\lambda \approx 1.48$ collisions/year ; the observed value of the parameter λ fell within the 95%-confidence interval. Since the parameter λ was within the 95%-confidence interval, it indicated that the collisions followed a Poisson process from a statistical point of view, although it is possible that λ was variable within that interval. The finding that the cat-vehicle collisions followed a Poisson process is consistent with that the traffic accidents are considered in general to follow a Poisson process[1]. In a Poisson process the parameter λ equals the expectation of that process. Hence, we examined whether λ increased with time t to predict if the collisions were steadily increasing. Although the frequency distribution of collisions did not show a clear increasing trend (Fig. 2), the fit curve for $\lambda(t)$ was an increasing curve indicating that the number of the collisions was steadily increasing. In summary, we found that : 1) the temporal distribution of the collisions obeyed a Poisson process ; and 2) the Poisson process was nonhomogeneous with the parameter $\lambda(t)$, which increased with time t. This indicates that : 1) an arbitrary two collisions are presumed to occur independently of each other, which can be justified by the observations that arbitrary drivers who cause a collision are independent of each other, and the cat is solitary ; and 2), the collisions are steadily increasing. The sharply increase of the collisions from 1978 to 1987 (Fig. 5), which is fitted by the logarithmic curve, may be due to an insufficient strategy for the prevention of the collisions and/or an insufficient caution of the cat against vehicles, because the trunk road was just constructed in 1977. Figure 5 also shows that the real data are approximately below the fitting curve after 1997. It may be due to an effectiveness of the projection of the road improvement as 'Eco-road' starting in 1995 or/and the reduction of the cat by the road. The female resident Iriomote cat at the roadside is estimated to have reduced after 1997 because of collision and destroying of the habitat[20]. No female places tend to make resident and transient males less, so that cat-vehicle collisions may reduced after 1997.

The findings from the spatial distribution show that the real collisions did not occur uniformly with the same probability on the segments of the road. In other words, it indicates that the probability of occurrence of those collisions depended on the segments of the road. Hence, the areas marked by the circles in Fig. 1 were considered to be those where the collisions were likely to occur. These 5 circles were labeled A, B, C, D, and E in order from the west to the east (Fig. 1). In the last 30 years the structure of roads, the environment around the roads, the traffic volume, and the habitat of the cat had been changed drastically[20]. In spite of such a drastic change, the cat has been frequently encountered on the road within the 5 circles when these conditions have rarely changed from 2001 (Okamura's private communication). Hence, it is considered that the cat was still at high risk within those circles. Each of the areas of A, B, C, D and E had various risk factors, such as the wetlands suitable for the cat around it ; the easy access for the cat on the road without hindrance ; the easy road structure for the car to speed up and/or the poor visibility due to many curves, where it might be difficult for both the driver and the cat to find each other. One of the reasons why the collisions occurred frequently within area E was considered to be that the ridges and wetlands were alternately along the road, which was unique in the island. Iriomote cat liked particularly such a mosaic-like environment[2]. The second reason was presumed to be that the cat could cross the road easily without hindrance to enter the suitable wetlands of the both sides of the road. The third was that the cat got accustomed to taking prey animals killed by the car on the road[10]. Additionally, there were so many curves.

Management Implications

The trunk road was constructed in 1977, and the first collision occurred in 1978. Thereafter, there were more tourists visiting the island and more immigrants year by year[19,20] so that collisions occurred almost every year. Hence, the Iriomote Wildlife Conservation Center continued public relations to prevent traffic accidents involving the cat. However, the number of collisions did not decrease. The administration of Okinawa prefecture projected the road improvement as 'Eco-road' in 1995, which would mitigate negative effects on wildlife, in cooperation with the Iriomote Wildlife Conservation Center. However, such a project including the installation of underpasses and the improvement of gutters beside could not decrease collisions. Finally, the examination committee consisting of the Administrative Division of Okinawa Prefecture, the Iriomote Wildlife Conservation Center, and the specialists, was formed to deal with the problem in 2003. The results from the spatial distribution indicated that the collisions were likely to occur in the areas marked by the circles of Fig. 1. Except area A, which was not included in 'Eco-road', many efforts were thereafter made to prevent cat-vehicle collision such as many underpasses and "zebra zones", in which vibration calls attention to drivers while driving on the zone, in areas B, C, and D. It was planned that more underpasses and one elevated segment of the road would be installed in area E. Some defaults of the underpasses, which often became out of sight by grasses or submerged, were pointed out by the examination of 'Eco-road'. And then, some counter measures were worked out in areas B and D. Since area C was not adequate for the installation of underpasses because of the landform of it, "zebra zone" were paved, and signs saying 'Attention to Cats' were installed. However, it was considered that only the installation of more underpasses would not prevent collisions, because it was witnessed that cats took preys killed by cars on the road. The Administrative Division of Okinawa decided the construction of seven elevated segments of the road, which were considered to be more effective for the cat to keep away from the road than the underpasses[14]. It was planed that one of the elevated segments would be installed in area E. From the cost versus effectiveness point of view, it is important to call attention to the problem of cat-vehicle collisions by various methods. Sixteen of "zebra zone" and 43 of signs saying Attention to Cats and 12 of movable signboards were installed until 2008. Ninety-four underpasses and gutters were installed along the 30-km segment of the road. The defects of them were improved at the next 20-km segment plan[14] so that the gutters keep wildlife away. The Iriomote Wildlife Conservation Center has been conducting a campaign for preventing collisions to visitors as well as residents twice a year. The findings of the clusters has raised an important issue that any compound risk factors in the clusters would be made clear and the measures against the respective factors would be taken. Because the situation around the cat-vehicle collisions, such as road structure, traffic volume and habitat condition of the cat along the road, has been changed, it is also necessary to examine further analysis using additional data. In addition, it is important to let the drivers know more about the critically endangered Iriomote cat by various enlightening campaign. Iriomote Wildlife Conservation Center and all the companies of rent-a-car in the island launched the project entitled "Declaration of Safety Driving for Wildlife" since 2010 to appeal to drivers for spontaneous corporation.

References

1) Djauhari, M.A. (2002). Stochastic pattern of traffic accidents in Bandung city. IATSS Research **26**, 85–91.

2) FORESTRY AGENCY OF JAPAN, BRANCH OF KUMAMOTO. (1995). Reports on the second conservational study on the Iriomote cat and its habitat (1994) : 192. [In Japanese.]

3) Imaizumi, Y. (1967). A new genus and species of cat from Iriomote, Ryukyu islands. J. Mammalogical Society Jp **3**, 74–107.

4) INTERNATIONAL UNION FOR CONSERVATION OF NATURE AND NATURAL RESOURCES [IUCN]. (2009). IUCN Red List of Threatened Species homepage. <http://www.iucnredlist.org/apps/redlist/details/18151/0>. Accessed 12 Jan 2010.

5) Izawa, M. and Doi, T. (1991). Status of conservation and management of two cat species of Felidae in Japan. Honyurui Kagaku [Mammalian Science] **31**, 15–22 (In Japanese with English abstract).

6) Izawa, M. and doi, T. (1994). Fexibilty of the social system of feral cat, *Felis catus*. Animal Societies Individuals . Interaction and Organization (Physiology and Ecology Japan Vol. 29) (Jarman, P.J. and Rossiter, A. eds.). Kyoto University Press, Kyoto, pp. 237–247.

7) Izawa, M., Sakaguchi, N. and Doi, T. (2000). Recent conservation programs for the Iriomote cat *Felis iriomotensis*. Tropics **10**, 79–85.

8) Izawa, M., Doi, T., Nakanishi, N. and Teranishi, A. (2009). Ecology and conservation of two endangered subspecies of the leopard cat (*Prionailurus bengalensis*) on Japanese islands. Biol. conserv. **142**, 1884–1890.

9) Masuda, R., Yoshida, M.C., Shinyashiki, F. and Bando, G. (1994). Molecular phylogenetic status of the Iriomote cat *Felis iriomotensis*, inferred from mitochondrial DNA sequence analysis. Zoolog. Sci. **11**, 597–604.

10) MINISTRY OF THE ENVIRONMENT & FORESTRY AGENCY OF JAPAN. (2008). Reports on the forth study for conservation and breeding of the Iriomote cat. <http://www.env.go.jp/press/press.php?serial=10060>. Accessed 1 Aug 2012.

11) Nakanishi, N., Okamura, M., Watanabe, S., Izawa, M. and Doi, T. (2005). The effect of habitat on home range size in the Iriomote cat *Prionailurus bengalensis iriomotensis*. Mammal Study **30**, 1–10.

12) OCHI, M.K. (1990). Applied probability & stochastic processes in engineering and physical sciences. A Wiley-Interscience Publication, New York.
13) OKAMURA, M., DOI, T., SAKAGUCHI, N. and IZAWA, M. (2000). Annual reproductive cycle of the Iriomote cat *Felis iriomotensis*. Mammal Study **25**, 75–85.
14) OKAMURA, M., IZAWA, M., DOI, T., TAMAYOSE, R., MAEMURA, O., TAKARA, H., OHASHI, S., OHASHI, F. and OSHIRO, M. (2008). The traffic accidents and its countermeasure of the Iriomote cat, *Prionailurus bengalensis iriomotensis*. Proceedings of workshop on wildlife and transportation. Wildlife Conservation Society. pp. 9–10. Tokyo. (In Japanese).
15) RAMAKRISHNAN, U., DAUGHERTY, L., PELKEY, N.W. and WILLIAMS, S.C. (2006). Effects of gender and season on spatial and temporal patterns of deer-vehicle collisions. Proceedings of the 2005 International Conference on Ecology and Transportation. Center for Transportation and the Environment (IRWIN, C.L., GARRETT, P. and MCDERMOTT, K.P. eds.) North Carolina State University, Raleigh, NC, pp. 478–488.
16) SAKAGUCHI, N. (1994). Ecological aspects and social system of the Iriomote cat, *Felis Iriomotensis* (Carnivore ; Felidae). Thesis, Kyushu University, Fukuoka, Japan.
17) SAKAGUCHI, N. and ONO, Y. (1994). Seasonal change in the food habits of the Iriomote cat *Felis iriomotensis*. Ecolog. Res. **9**, 167–174.
18) SCHMIDT, K., NAKANISHI, N., OKAMURA, M., DOI, T. and IZAWA, M. (2003). Movements and use of home range in the Iriomote cat (*Prionailurus bengalensis iriomotensis*). J. Zoology, London **261**, 273–283.
19) TAKETOMI TOWN. (2011). Reports on the population. http://www.town.taketomi.lg.jp/fckeditor/town/tikubetu_jinkoudoutai_rekinen.pdf. Accessed 15 August 2011. [In Japanese.]
20) UNIVERSITY OF THE RYUKYUS. (2008). Reports on the fourth conservational study on the Iriomote cat and its habitat. ＜http://www.env.go.jp/press/press.php?serial=10060＞. Accessed 12 Jan 2010. [In Japanese.]
21) WATANABE, S., NAKANISHI, N. and IZAWA, M. (2003). Habitat and prey resource overlap between the Iriomote cat *Prionailurus iriomotensis* and introduced feral cat *Felis catus* based on assessment of scat content and distribution. Mammal Study **28**, 47–56.
22) WOZENCRAFT, W.C. (2005) Mammal Species of the World (WILSON, D.E. and REEDER, D.M. eds.) 3rd ed, Johns Hopkins University Press, New York. pp. 543.

絶滅危惧種の交通事故の時間・空間パターン：イリオモテヤマネコの交通事故

大坂元久[1]・岡村麻生[2]

[1] 日本獣医生命科学大学獣医学部

[2] 環境省西表野生生物保護センター（西表自然保護官事務所）

要　約　我々は1978年から2008年までに西表島の唯一の主幹道路50 kmで発生したイリオモテヤマネコの交通事故46例を検討した。事故は年間平均発生率が時間とともに増加する不均一ポアソン分布に従っていた。事故の好発箇所の有無を検討するために道路を500の区画に均等に分割した。コンピュータシミュレーションで事故が発生する場所として500区画から重複を許してランダムに46区画選ぶというということを1000回試行し，クラスターの個数を集計した。クラスターとは1 km内に4回（サイズ4）以上の事故が遍在している領域と定義した。サイズ5，サイズ7の出現率はそれぞれ0.349，0.008であったが，実際のデータではいずれも2回であった（P＜0.001）ことから，これらの箇所を事故の好発箇所と特定できた。以上より，事故が徐々に増加していることから有効な対策はクラスターとなっている事故の好発箇所を重点的にイリオモテヤマネコが近づけないように整備することであることが示唆された。

キーワード：絶滅危惧種，交通事故，イリオモテヤマネコ

日獣生大研報 **61**，51-59，2012.