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Short communication

A technique for preventing wildlife intrusion via the intersection between drainage ditches and fences: Deer, macaque, raccoon dog, fox, and badger damage management

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ABSTRACT

Properly installed and maintained fences are effective for mitigating crop damage by mammals; however, drainage ditches intersect fences and reduce the fence effectiveness. Cattle gates and deer exclusion grates are developed for road crossings and the techniques are effective. This study aimed to develop techniques for enclosing the space between ditches and fences. Electrified lines are commonly used for preventing wildlife intrusion, but wildlife are often able to cross such fences; therefore, an electrified mesh was used. The electrified metal mesh was hung like a curtain. The technique was found to prevent over 98% of intrusion by wildlife. The effectiveness of the technique was high and this technique improves the fence effectiveness. This is the first study on reducing wildlife intrusions using ditches.

1. Introduction

Fences are often the most effective technique to reduce crop damage by mammals and many fences are developed by wildlife researchers, which include electric fences and net fences (e.g., metal or plastic net). Electric fences are used for medium-sized mammals such as pine marten *Martes martes* L., badger *Meles meles* L., and European rabbit *Oryctolagus cuniculus* L. (MacDonald and Balharry, 1999; McKillop and Wilson, 1999; Poole et al., 2002). For larger mammals, both electric fences and net fences are used (*Cervus* spp.: Fagerstone and Clay, 1997; Seamans and VerCauteren, 2006; Leblond et al., 2007; wild boar *Sus scrofa* L.: Hone and Atkinson, 1983; Asiatic black bear *Ursus thibetanus* G.: Huygens and Hayashi, 1999). Fences are effective for resolving damage by mammals, but in some cases, fences do not prevent damage effectively (Reidy et al., 2008). Geisser and Reyer (2004) verified the effect of lethal control, fencing, and feeding, and concluded that the effect of fencing is not always sufficient. Factors which reduce the effectiveness of fences are i) farmland is not enclosed by fences (Honda, 2005), ii) fences are not properly constructed (Conover, 2001; Karhu and Anderson, 2006), and iii) fences are not properly maintained (Conover, 2001; VerCauteren et al., 2006). Errors in construction such as mismatched fence types targeted mammal species, and poor maintenance often arose from human factors (Honda, 2007). Remaining unresolved factors which reduce the effectiveness of fences include the inability to achieve a farmland closure using a fence.

The fence effectiveness is high when fences completely enclose farmland (Fungo, 2011). If farmland is not enclosed completely, wildlife intrudes through openings in the fence. The simplest solution for forest wildlife is enclosing all forested areas or to completely enclose farmland using a fence. Enclosing farmland is relatively easy but the cost of fencing is high. Enclosing the forest by fence is difficult because ditches or roads intersect the fence. Cattle gates and deer exclusion grates are developed for road enclosings (Peterson et al., 2003); however, there are no effective techniques for the ditch problem. Fences are not suitable for enclosing ditches because fences can prevent water flow.

This study aims to develop a technique for enclosing ditches that intersect with fencing. Deer intrude by crawling under the fence when a gap at least 25 cm high exists (Hone and Atkinson, 1983; VerCauteren et al., 2006). A blockade ditch using net fencing obstructs water flow, and horizontal electrified lines become obstructed (e.g., branches and leaves) and overflow might occur. Some recently developed electric fences use electrified metal mesh rather than electrified lines. The electrified mesh is effective against both large and medium-sized mammals (Honda et al., 2009). The fine, electric metal mesh would be useful for enclosing ditches without preventing water flow because the fine mesh could be used as an electrical conductor. The electrified mesh which hangs from the upper side would move toward downstream and would not prevent water flow because it will not become obstructed by objects. The author hypothesized that electrified mesh (i.e., not line) is

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useful for enclosing ditches.

2. Methods

Study plots were Nirasaki (site A) and Hokuto (site B) city in Yamanashi Prefecture, central Japan. Both plots of fences were intersected by a ditch. Sika deer (*Cervus nippon* T.), Japanese macaque (*Macaca fuscata* G.), masked palm civet (*Paguma larvata* S.), raccoon dog (*Nyctereutes procyonoides* G.), red fox (*Vulpes Vulpes* L.), badger (*Meles anakuma* T.), and marten (*Martes melampus* W.) inhabit the areas around these plots. This study targeted all these species (large and medium-sized mammals). Japanese macaques did not inhabit site B. The fence of site A was constructed with metal net and electrified lines. The fence height was 2.3 m and four lines were installed at the top of the metal net for preventing macaque intrusion. The ditch width of sites A and B were 3.4 m and 0.6 m, respectively. The ditch depth of sites A and B were 0.8 m and 0.4 m, respectively.

A sensor video camera was set for counting the number of ditch passing species (GISupply, SG560P-8M). In each site, two cameras were used for checking both above and below the cross point (i.e., fence and ditch). The video camera had an infrared sensor and if a sensor detected a targeted species, the movie was recorded onto the SD card. In site A, video cameras were active both day and night; however, in site B, the camera was activated only at night (18:00 to 6:00). The Japanese macaque is diurnal and daytime recording was needed in site A. The time schedule for camera activation was the same as the previous study for testing the effectiveness of fencing (Honda et al., 2011). The observation period for both sites was shown in Table 1. From May 2015 to June 2018, long-term observation was conducted. The control duration was defined for the period when the electrified mesh was not installed. After the control period ended, the electrified mesh was installed and the periods were defined as “treatment”.

The electrified stainless mesh (ESM) is shown in Fig. 1. Stainless mosquito screen (1.39 mm mesh) was used as metal mesh and punched stainless steel (ss) metal (thickness: 1 mm, height 200 mm) was additionally set on the low side of the mesh because stainless mesh flaps in the wind and a weight was needed. The metal pipe can be used as a weight for the ESM, but this study used punched ss metal because the cut surface of punched ss metal has an edge which helps to electrify animals compared to the rounded surface of the pipe. The rounded surface of the pipe has been suggested to inhibit electrification through fur (Hone and Atkinson, 1983; MacDonald and Balharry, 1999). For binding the punched metal and stainless mesh, the author used a banding band (i.e., zip ties) through the punched hole. Punched ss metal was set on the downstream side. The distance from the bottom of the ditch to the ESM was 100 mm. The ESM was fixed onto a metal pipe and electrified by fence energizer (LACME, Secure35). Power voltage was kept over 9000 V. Voltage was determined at least twice a week using a circuit tester (SPEEDRITE, Digital voltmeter). Whether animals got shocked or not was evaluated by observing muscle contraction. If animals jumped up, ran from ESM, or charged ESM immediately after touching, the animals were also defined as shocked.

Statistical analysis was conducted using software R3.5.0 (R Core Team, 2018) and the function of the generalized linear model (GLM) with Poisson distribution. The target variable was the total number of animals that passed during control and treatment and the explaining variable was a dummy variable with values of one (ESM was set) or zero (ESM was not set). Because observed periods of control and treatment differ, offset was used in GLM. The offset term was log (observed days). This is an analysis of count data from before-after control-treatment studies. The replicate was the site (Table 1).

Table 1
The observation period for each site.

	site A	site B
control	May 14, 2015–June 13, 2016	Sep.18, 2015–April 11, 2017
treatment	Aug. 8, 2016–June 30, 2018	April 12, 2017–June 30, 2018

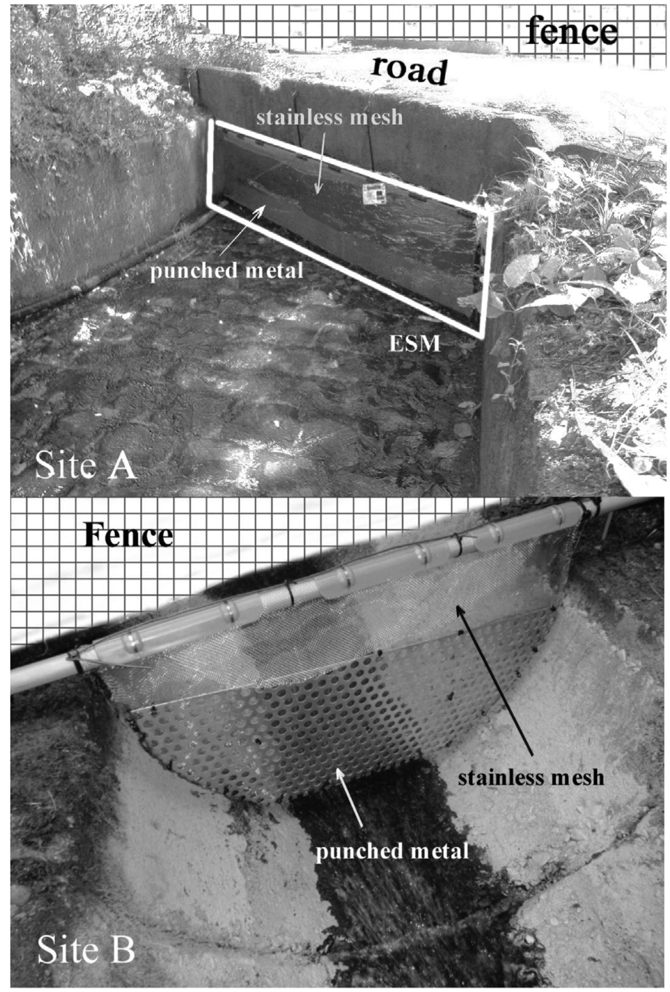

Fig. 1. Electrified stainless mesh (ESM) device for preventing animals from passing through ditch under the fence. The ESM at sites A and B differed in size. The fence at site A was installed along the road. The fence and ditch cross each other and ESM was hung from the bridge; therefore, animals could walk along the fence but animals must go through the ditch to cross the fence. The ESM at site A was not hung directly from the fence because of ESM maintenance from the road. The ESM at site B was hung directly below the metal fence. The photographs in the figures were edited because the fence was hardly visible.

3. Results and discussion

During the control periods for site A and B, the total number of sika deer, Japanese macaques, masked palm civets, raccoon dogs, red foxes, badgers and Japanese martens that passed through the ditch was 599, 276, 334, 535, 128, 44 and 4, respectively. During the treatment period, sika deer, Japanese macaque, masked palm civet and marten passed the ditch for 8, 7, 2, 3 times. Raccoon dog, red fox, and badger never passed ESM. Table 2 shows these data as passed number per 100 days and estimated p-value. The number of animals that passed during the treatment period was small (< 2 per 100 days), which indicated that the ESM was effective for resolving human-wildlife conflicts. Eight sika deer passed the ESM, but all of the deer that passed got an electric shock and charged the ESM. Seven macaques passed the ESM and got shocked. These macaques passed the side (i.e., between the vertical concrete wall and the ESM) or the lower side (i.e., between the water surface and the ESM) of the ESM. Two electrified masked palm civet