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Evaluation of camera trap surveys for estimation of sika deer herd composition

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Abstract. Camera trap method has been developed for monitoring wildlife, however, most studies using camera trap depend on baited camera sites to attract target wildlife. This is likely to bias estimates of population structure. We evaluated the use of non-baited camera trap for the estimation of herd composition of sika deer (*Cervus nippon*). Camera trap showed a distinct seasonal pattern in sex ratios (males/100 female), which remained lowest between May and October but increased in November. Sex ratios were influenced by the number of observed males, because the ratios were positively correlated with the number of males but not females. The number of males increased in autumn during rutting season. Fawns/100 female ratios showed a distinct seasonal pattern. Highest and lowest fawns/100 female ratios were obtained in November and May, respectively. The decrease of fawns/100 female ratios in May comparing with that in November may be because of the overwinter mortality of fawns. Camera trap method is superior in term of continuously conduct in long-term, collect reasonable seasonal patterns, automatically record large numbers of sample sizes and useful in all weather conditions.

Key words: camera trap, fawn/100 female ratio, herd composition, sex ratio.

Herd composition, sex ratios and fawn/100 female ratios are the most important data for wildlife population management (McCullough 1994; Bender and Spencer 1999; Bender 2006; Curtis et al. 2009). For deer populations, vital statistics are commonly expressed as sex ratios and fawn/100 female ratios, and data on population structure are used for development of conservation schemes and management programs (Koenen et al. 2002; Swann et al. 2002; Roberts et al. 2006; Rutberg and Naugle 2008).

Herd composition counts are commonly used to estimate sex ratios, fawn/100 female ratios and fawns recruitment in deer populations (Woolley and Lindzey 1997; Rabe et al. 2002: Kaji et al. 2005). Many studies on herd composition counts focused to examine the precision, accuracy, and logical basis of this method. These methods, however, depended on experienced observers and was influenced by deer activity and habitat use (McCullough 1993; McCullough 1994; McCullough et al. 1994; Kaji et al. 2005).

To solve these problems, camera traps (CT) using infrared-triggered cameras have recently been employed in various wildlife habitats. Most studies on CT showed that CT could be of minimal disturbance in the environment; cost-effective in long-term studies; similarly effective in detecting nocturnal and diurnal species; and useful for unpredictable animal behaviors, such as alert behavior (Carthew and Slater 1991; Cutler and Swann 1999; Silveira et al. 2003). Although most studies on CT have used baited camera sites (Jacobson et al. 1997; Koerth et al. 1997; Koerth and Kroll 2000; Roberts et al. 2006; Curtis et al. 2009; Doughery and Bowman 2012; Weckerly and Foster 2010), which attracts target wildlife from other areas (Campbell et al. 2006; Watts et al. 2008). Mccoy et al. (2011) evaluated estimates of white-tailed deer (*Odocoileus virginianus*) herd composition using non-baited CT along deer trails, compared with baited CT, and revealed that baited CT generated biased herd composition. They showed the lack of feeder use

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by males and heavy use by fawns during the prerut and rut periods and suggested that interpretation of population structure during these periods may be biased.

We conducted monthly non-baited CT to establish sex ratios and fawn/100 female ratios of sika deer (*Cervus nippon*) on Nakanoshima Island in Hokkaido, Japan, where population trends and structures have been monitored by herd composition counts (HCC) since 1997. Previous research in this study area revealed that adult sex ratios and fawn/100 female ratios by HCC were unbiased during the rutting season (October–November), and fawn/100 female ratios in spring could be used to estimate recruitment if yearlings are counted as adults (Kaji et al. 2005). Based on patterns from previous research, we evaluated the use of non-baited CT in the estimation of herd composition.

Study area

We conducted this study on Nakanoshima Island in Lake Toya, southwestern Hokkaido, Japan (42°36'N, 140°51'E, Fig. 1). The island is composed of one main island (497.8 ha) and two adjacent small islets, Benten-Kannon Island (23.0 ha) and Manjyu Island (3.8 ha). Three sika deer (an adult male, a yearling female, and a pregnant female) were introduced onto this island for tourism in 1957, 1958, and 1965, respectively (Kaji et al. 1988). The island is located approximately 4 km from the opposite shore, so deer emigration and immigration has been negligible. On the island, predators are absent and hunting is prohibited because the island is a protected area located in Shikotsu-Toya national park. Under this protection, the deer population reached a peak of 273 deer (52.5 deer/km^2) in the winter of 1983–1984 (Kaji et al. 1988), and thereafter has shown repeated irruption (Kaji et al. 2006). We counted 236 deer (44.5 deer/km^2) in March 2011 and 277 deer (52.8 deer/km^2) in March 2012 on the island by drive counts. During 2003–2005 and 2009–2011, 307 deer were captured and equipped numbered ear-tag and collars. Sixty one marked female deer were observed in November 2011.

Dominant vegetation on the island includes deciduous broad-leaved trees (91.8%), coniferous plantations (6.3%) and open grassland (1.6%). In the deciduous forest, the major canopy species are oak (*Quercus crispula*), castor-aralia (*Kalopanax pictus*), magnolia (*Magnolia obvota*), painted maple (*Acer mono* Maxim. var. *glabrum*) and Japanese linden (*Tilia japonica*). Overgrazing by deer in grasslands has led to the replacement of taller palatable species with short grasses and unpalatable species including senecio (*Senecio cannabifolius*) and Japanese spurge (*Pachysandra terminalis*) (Kaji et al. 1991; Takahashi and Kaji 2001; Miyaki and Kaji 2004).

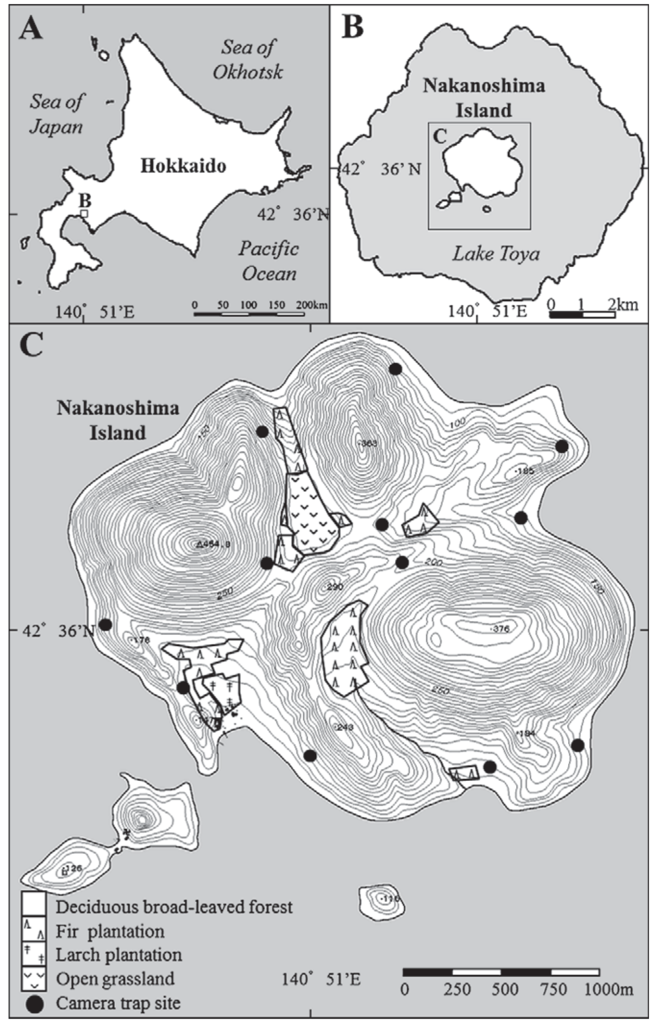

Fig. 1. Map of Nakanoshima Island, Lake Toya, Hokkaido, showing 12 camera trap sites.

Materials and methods

Camera trapping

We placed 12 camera trap stations and each station consisted of one infrared camera, model Moultrie Game Spy I-40 Infrared Flash Game Camera (Cabelas Inc., U.S.A.), strapped with trees approximately 1 m above ground. Cameras were oriented parallel to deer trails to attain maximum coverage of deer trails. Each sampling station was established following deer trails, signs and frequent observation of deer. We conducted surveys during August 2010–November 2011, but excluded between December 2010 and April 2011 because of the concentration of deer in wintering areas and to avoid the risk of equipment malfunction. SD cards and batteries were checked once per month.

Jacobson et al. (1997) suggested that adequate camera density for population estimates of white-tailed deer was 64 ha/camera, and for estimates of sika deer density in Maryland, cameras were set at approximately 65 ha/ camera (Doughery and Bowman 2012). In this study, we set 12 camera traps at a higher density of 42 ha/camera, which we predict is sufficient for herd composition counts. We set the cameras' photographic mode to capture three photos per 13 seconds with a 5-min interval between consecutive groups of photos according to the function of the type of used camera. However, marked individuals rested in front of camera sites for < 50 minutes. Thus, following Watts et al. (2008), we excluded all photographs of deer, including marked and unmarked deer, within a < 1-hour period to minimize double counts.

Herd composition analysis

We collected data on the number of deer photographed, as well as sex and age class. Photographed deer were classified into four sex-age classes: males, females, fawns, and unknown individuals. Males and females are including yearling and older age classes, because sometime yearling could not be differentiated reliably from adults. Unknown individuals were determined when we could not firmly identify the sex and age classes. We calculated monthly number of deer photographed, sex ratios (males/100 female), and fawn/100 female ratios. We estimated 95% confidence intervals by the delta method (Manly et al. 1993) from following the formula:

$$\frac{M}{F} \pm 2\mathrm{SE}\left(\frac{M}{F}\right) =$$

$$\frac{M}{F} \pm 2\left(\left[\frac{M}{F}\right]^2 \left[\left\{\frac{\mathrm{Var}(M)}{M^2}\right\} + \left\{\frac{\mathrm{Var}(F)}{F^2}\right\} - 2\left\{\frac{\mathrm{Cov}(M,F)}{M \times F}\right\}\right]\right)^{1/2}$$

M and F are the number of males and females photographed, respectively, and var(M) and var(F) are the variance for M and F, respectively, and cov(M, F) is the covariance between males and females.

We used R-2.13.1 for all statistical analysis. For sex ratios and fawn/100 female ratios, we tested the correlation between sex ratios and the number of males or females. We tested for normality using Pearson or Spearman correlation test.

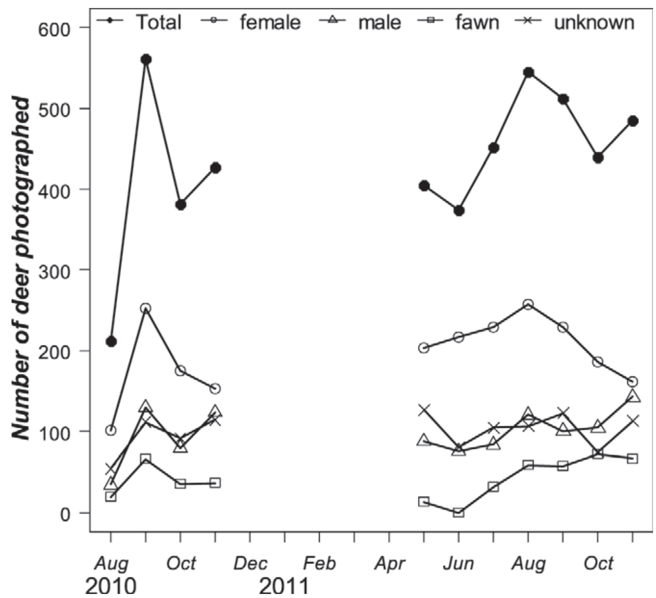

Fig. 2. The number of deer photographed in total, and sex and age composition by month for camera traps (CT) on Nakanoshima Island, Japan, during August 2010–November 2011.

Results

Number of deer photographed

During the sampling period of 4,032 camera trap-days (12 camera × 336 days), we counted 4,809 deer (female = 2,170, male = 1,087, fawn = 461, unknown = 1,105) in 4,046 distinct photographs. The monthly number of deer photographed varied from 212 to 561, and peaked in September 2010 and August 2011 (Fig. 2).

Mean monthly number of males (99 ± 31, $n = 11$) was lower than the number of females (197 ± 47, $n = 11$). The mean monthly number of females showed a distinct seasonal pattern, peaking in August or September then declining until November (Fig. 2). However, the mean monthly number of males did not show a distinct seasonal pattern, but increased from October to November in both years reaching to nearly the same levels as females in November (Fig. 2). Few fawns were photographed in June, but the number increased as the season progressed. The percentage of unknown deer was 22.7%.

Sex ratios and fawn/100 female ratios

Sex ratios (males/100 female) showed clear seasonal changes (Fig. 3). Between May and October, monthly sex ratios remained lowest, but increased from October to November. Sex ratios were positively correlated with the number of males photographed ($r = 0.75$, $n = 11$, $P < 0.01$), but not with the number of females photographed

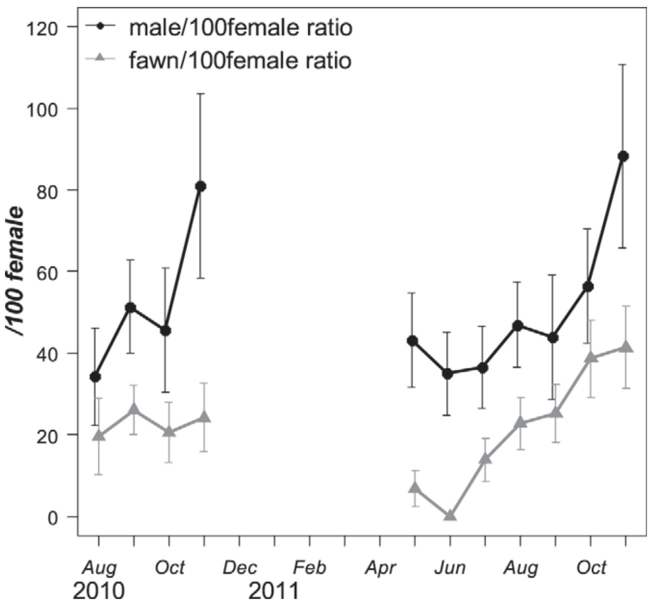

Fig. 3. Sex ratios (males/100 female) and fawns/100 female, 95% confidence intervals for camera traps (CT) on Nakanoshima Island, Hokkaido, Japan, during August 2010–November 2011.

($r = –0.269$, $n = 11$, $P = 0.42$).

Fawn/100 female ratios showed clear seasonal changes. The ratios remained highest between September and November, and then declined until June (Fig. 3).

Discussion

Sex ratios (males/100 female) showed a distinct seasonal pattern, and monthly sex ratios peaked in November. This pattern was consistent with a previous study on HCC, which peaked in October (Kaji et al. 2005). Sex ratios were positively correlated with the number of males but not females. This was also consistent with the findings of a previous study on HCC, and the highest sex ratios were obtained during rutting season (Kaji et al. 2005). Rutting season appeared to be a suitable time to derive reasonable sex ratios for sika deer because of increased male observation rates, which were extremely low except during the rutting season (Kaji et al. 2005). McCullough et al. (1994) also suggested that the mating season is a more suitable time to derive reasonable sex ratios for black-tailed deer (*Odocoileus hemionus columbianus*). Number of observed females decreased from August–September to October–November in 2010 and 2011 (Fig. 2). This pattern was consistent with the previous study (Kaji et al. 2005). This might be the effect of rutting males behavior on females during rutting season, when adult males vary their range for rutting behavior (Nagata 2005). In 1999 and 2000, sex ratios by HCC reached the peak in late October (1999: October 19–25, 2000: October 18–22) with 91.8 males/100 females and 102.2 males/100 females (Kaji et al. 2005), while the sex ratios by CT in late October in this study were 58.2 males/100 females and 67.0 males/100 females in 2010 and 2011, respectively. The sex ratios reached the peak in November with 81.1 males/100 females and 88.3 males/100 females in 2010 and 2011, respectively. These two weeks differences of the peak might be reflecting inactive males in October, which probably due to delay rutting season in these years. Further study is required to confirm a relationship between sex ratios and rutting behavior.

Monthly fawn/100 female ratios in a previous study (Kaji et al. 2005) showed that the ratios were lowest in spring and early summer, reflecting calving season (June–July in this study area). This monthly trend was confirmed by CT in this study. We could photograph more fawns in November than in June–September, and the decrease of fawn/100 female ratios in May comparing with that in November may be because of overwinter mortality of fawns.

In this study, a month camera trap period resulted in relatively narrow range of 95% confidence intervals which suggested reasonable results. CT could automatically record large numbers of sample sizes during the study period and could be used in all weather conditions. CT could also continuously conduct in long-term and collect reasonable seasonal patterns for sex ratios and fawn/100 female ratios.

Number of unknown deer from CT might result in biased sex ratios. To minimize this difference, setting two cameras, one on either side of the trail might be useful to reduce number of unknown deer. Further studies, moreover, are required to test the effects of identification in sex and age classes. In this study, finally, our results showed the decrease of the number of observed females in rutting season and suggested male activity in rutting season varied between 1999–2000 and 2010–2011. Further study is required to confirm a relationship between sex ratios and rutting behavior.

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