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Habitat Use and Movement Patterns of the Viviparous Aquatic Snake, *Oocatochus rufodorsatus*, from Northeast Asia

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To determine the habitat usage and movement patterns of the viviparous aquatic snake *Oocatochus rufodorsatus* (formerly *Elaphe rufodorsata*), we radio-tracked 21 snakes on agricultural lands during two active seasons in 2007 and 2008. Male and female snakes stayed close to aquatic habitats such as paddy fields and agricultural ponds during both breeding and non-breeding periods, except when the snakes moved to dry terrestrial areas to hibernate in late fall. The use of different structural features in the habitat, such as ground, tree, underground, and water, varied depending on the air and water temperatures, female’s reproductive conditions, and the time of day. Male and female snakes moved about 17 m daily and postpartum females moved farther than antepartum females. The home ranges of males and females were 0.45 ha and 0.47 ha, respectively, and the year-round home range of this species was approximately 1.54 ha (95% fixed kernel). Thus, to conserve a population of *O. rufodorsatus* in our study area, areas including both aquatic and terrestrial habitats within a radius of 150 m from a core pond habitat must be preserved.

Key words: reptile, aquatic snake, conservation, radio-telemetry, home range, hibernation

INTRODUCTION

As in many other animal taxa, reptile populations are decreasing worldwide (Whitfield et al., 2007; Mullin and Seigel, 2009). Habitat alteration and destruction, exploitation by human beings, and climate change are considered responsible for such declines (Gibbons et al., 2000; Mullin and Seigel, 2009). In order to conserve and recover a reptile species, it is important to know the basic ecology of the species. Although such studies have been done for many terrestrial snakes (reviewed in Mullin and Seigel, 2009), relatively few studies have focused on aquatic or semi-aquatic snakes, and most of the extant research on these animals has been carried out on the genera *Nerodia* (Greene et al., 1994; Pattishall and Cundall, 2008), *Natrix* (Luiselli et al., 2007), and *Seminatrix* (Winne and Hopkins, 2006). Studies of Asian aquatic snakes are especially rare (Ji, 1995; Ji et al., 1997).

*Oocatochus rufodorsatus* (formerly *Elaphe rufodorsata*) is a viviparous aquatic snake that is distributed in the far eastern region of Russia, northeastern China, and Korea (Kang and Yoon, 1975; Helfenberger, 2001; Ananjeva et al., 2004; Zhao, 2006). This snake generally inhabits agricultural wetlands and ponds and forages for frogs, such as *Pelophylax nigromaculatus* and *Hyla japonica*, and freshwater fishes. Mating occurs in May and females give birth to 7–24 offspring between late July and early September (Kang and Yoon, 1975; Ji et al., 1997). Chinese studies have examined the sexual dimorphism, egg characteristics, and feeding patterns of the species (Ji, 1995; Ji et al., 1997). In Korea, because of the development of agricultural lands into residential areas and the modification of arable lands, many agricultural wetlands and ponds have been lost and the snake’s population has therefore decreased (Song, 2007). Nevertheless, because little is known about its basic characteristics and spatial ecology, developing effective conservation strategies for *O. rufodorsatus* are currently difficult. Understanding its use of habitats during breeding and non-breeding periods, its movement patterns, and its home range will allow us to determine which habitat areas, which components of habitats, and how large an area should be protected to conserve this species in the field (Semlitsch and Jensen, 2001; Camper, 2009). In this study, we radio-tracked 21 *O. rufodorsatus* snakes on agricultural lands in South Korea over two active seasons in 2007 and 2008 to obtain information about habitat usage and movement patterns of this species.

MATERIALS AND METHODS

Study area

The study was conducted in GangChon, Chuncheon, Kangwon, South Korea (in an approximately 540 m × 240 m area; Fig. 1A). The study area was comprised of agricultural fields surrounded by mountains. In the middle of the study area, there was a small
sons between 13 August and 6 November, 2007, and between 27 July and 29 October, 2008. We caught snakes by hand or with a snake-stick, verified their sex based on the presence of hemipenes in males and swollen abdominal cavity in females, measured their snout-vent length (SVL; ± 0.1 cm), and measured their body mass (± 0.1 g) with a field balance (ELT4001, Sartorius, USA). For individual identification, we then inserted a passive integrated tag (TX1411L, Biomark, USA) under the dorsal skin of each snake with a needle. If a female was pregnant, we determined the day of parturition and measured the female snake’s body mass again within 5 days of its parturition to compare body mass between males and postpartum females. In this study, the parturition day of a pregnant female was assumed to be the day on which we initially confirmed the laboring of the pregnant female.

For the radio-telemetry, we surgically implanted a BD-2 transmitter (1.8 g, 17 × 8.5 × 5.5 mm, Holohil Systems, Ltd., Canada) into the abdominal cavity of each snake following the Reinert and Cundall (1982) method. In this study, we only used snakes with body masses exceeding 30 g. Therefore, few males were suitable for implantation, which resulted in a lower number of radio-tracked males (five individuals) than females (16 individuals). All transmitters constituted less than 5% of the snake’s body mass (mean ± SE = 2.8 ± 0.2%, range: 1.2–4.4%). After implantation, the snakes underwent a recovery period of approximately one week in an individual plastic cage (60 cm long × 40 cm wide × 17 cm high). Because aquatic snakes often submerge themselves in water, we felt that a one-week recovery period was necessary to prevent injury to the implantation site. During this period, we injected the snakes with antimicrobial drugs (2.5 mg/kg body mass enrofloxacin, Dongbang Medical Co., Seoul) every 24 hr and anti-inflammatory drugs (0.1 mg/kg body mass flunixin, Korea Viel, Seoul) every 72 hr. When a snake was ascertained to have recovered from the surgery based on its activity level and skin condition at the implantation site, we released the snake to the location where it was caught and began radio-tracking the snake.

To follow transmitter signals, we used a TR-1000 receiver combined with a three-element Yagi antenna (Wildlife Materials, USA). We radio-tracked the snakes daily between 13 and 29 August, 2007, and between 27 July and 12 September, 2008. The time of day of each radio-tracking session was randomly selected from times between 0600 and 2200 hrs. During other periods, we checked the snakes’ locations once per 9.4 days (n = 59) because field researchers were not available for daily radio-tracking. When we detected a snake’s signal, we determined the coordinates of the snake using a hand-held GPS unit (Vista CX, Garmin, Taiwan), measured water temperatures using a thermometer (TES 1319A, TES, Taiwan), measured air temperatures and humidity (± 0.1%) using a 310 humidity temperature meter (CENTER, Taiwan), measured the temperature of the ground at the snakes’ location using a laser temperature meter (KOR 105, Korins Co., Ltd., Korea), and described the structural features used in the habitat. All temperatures in this study were measured with 0.1°C accuracy. In the early stages of the 2007 study, we measured the snakes’ traveled distances using a 50 m measuring tape and estim...
mated the distance using GPS coordinates plotted on a habitat map in Arc-View GIS (v. 3.2, ArcView GIS, ESRI Inc.). Because these methods did not produce different results, we collected only GPS coordinates of snake locations for the remainder of the study. If we did not directly observe a snake, we determined its approximate location using triangulation (Ra et al., 2008).

In the analyses, in order to delineate the outer boundaries of the aquatic habitats, ponds, and agricultural wetlands on a digital map of the study area, we collected coordinates using the track log function of the hand-held GPS unit by stopping every two meters along the boundaries. In the laboratory, we then plotted the coordinate data as well as data on snake locations on the digital map of the area in Arc-View GIS. The digital map contained contours, streams, crop fields, and roads, which were derived from the toposheets of the study area at a scale of 1:5,000. First, we counted the number of snake locations both in aquatic habitats and in dry habitats and determined the minimum distances between all snake locations and the nearest permanent ponds or wetlands. If the snake was located in a pond or wetland, the distance was taken to be 0 m. To compare proximities to the water bodies between males and females and between antepartum and postpartum females, we calculated each individual's mean distance from the ponds and wetlands throughout a given radio-tracking period.

To analyze the use of different structural features in the habitat depending on sex, female's reproductive condition, and the time of day, we classified the structural features into four types: ground, tree, underground, and water. The use of ground included the cases that snakes were being located on the ground in paddy fields, dried crop fields, mountain areas, and the grassy banks of the paddy fields, ponds, and wetlands. A snake was classified as being located in the trees when the body of the snake was completely above the ground, usually in a shrub or tree. The underground designation was used when we detected a signal from underneath the ground. A snake was classified as being located in water when the snake was on or under the water in ponds or wetlands (including snakes on water plants). For the analysis, we examined the use of different structural features for each sex and for antepartum and postpartum females. To draw a graph detailing the use of the features by the time of day, the data were grouped into three-hour blocks.

To examine the distances that the snakes traveled over the course of a day, we used only those instances in which radio-tracking location data were available over two sequential days. The distance was measured as the minimum distance between two sequential locations plotted on the digital habitat maps in ArcView GIS. To compare daily distances moved between males and females and between antepartum and postpartum females, we calculated the mean daily distance moved by each individual during a given radio-tracking period. To determine the correlation between daily distance and air temperature, water temperature, and humidity over a tracking period, we calculated the daily mean distance moved on a given day for all individuals radio-tracked on that particular day.

We also studied the winter migration of the snakes towards their hibernacula. We considered a snake to be moving toward a hibernaculum when it moved toward the mountains over dry habitats over more than two consecutive tracking periods in October or November. This method was chosen because snakes very rarely left the aquatic habitats during the breeding and non-breeding periods (see Results) and the battery life of the transmitters would not last through a hibernation period. In this study, the hibernation site of each snake was assumed to be its final location during the winter migration. In the data analysis, we calculated how far away snakes moved from the nearest boundary of an aquatic habitat.

The home range of each snake was estimated by both the minimum convex polygon (MCP) and fixed kernel density techniques using the animal movement extension for ArcView GIS. For the kernel method, we obtained fixed 50% and 95% estimations by applying the least squares cross-validation to choose smoothing parameters (Worton, 1989). We first estimated each individual's home range using snake location coordinates, including breeding, non-breeding, and winter migration periods (if available), and examined differences between the sexes and between the antepartum and postpartum periods in females. To compare home range sizes between antepartum and postpartum females, we used only the cases for which at least four data points were available in both the antepartum and postpartum periods. We also estimated a year-round home range by combining all snakes' locations (including winter hibernation sites) to determine a protection area for this species.

Statistical analysis

Because the SVL and body mass data of O. rufodorsatus were non-normal in distribution (Kolmogorov-Smirnov normality test, P < 0.05), we used the Mann-Whitney U-test to compare SVL and body mass between males and antepartum females and between males and postpartum females. To test for differences in the distance moved from aquatic boundaries between males and females and between antepartum and postpartum females, we used an independent samples t-test because the data were normal (Kolmogorov-Smirnov normality test, P > 0.05). To determine whether males and females or antepartum and postpartum females show differences in their use of different structural features in the habitat, we applied the chi-square test. In this analysis, we used the proportion data of four structural features used by males and antepartum and postpartum females instead of the actual number of observations because of different sample sizes between males (n = 5) and females (n = 16).

The result was significant, as a post-hoc test, we compared the use of each specific feature between males and females and between antepartum and postpartum females using the chi-square test. Differences in the use of the structural features in the habitat related to air, water, and ground temperature, time of day, and humidity were analyzed by the Kruskal-Wallis test because the data were non-normal (Kolmogorov-Smirnov normality test, P < 0.05). Daily distance moved and home range data were ascertained to be non-normal (Kolmogorov-Smirnov normality test, P < 0.05). Thus, to determine differences between the sexes and between antepartum and postpartum females with respect to the daily distance traveled, we applied the Mann Whitney-U test. Moreover, to determine correlations among distance and environmental factors, we used the Spearman correlation test. In addition, comparisons of home range sizes between males and females and between antepartum and postpartum females were carried out using the Mann Whitney-U test and the Wilcoxon signed rank test, respectively. All statistical analyses were conducted using SPSS (v. 17.0, SPSS Inc., Chicago, IL). Data are presented as mean ± standard error throughout the text.

RESULTS

We analyzed data from 21 snakes (16 females and five males) that were radio-tracked at least 9 times over 10 days. We located the snakes a total of 474 times (23 ± 3 times per snake, range: 9–48 times) over a total of 1070 study days (51 ± 6 days per snake, range: 14–95 days) in two active seasons. Out of the 474 detections, we directly observed individuals in 171 cases (36%) but could not observe the snakes in 303 cases (64%) as they were submerged in ponds or located in paddy fields. The proportions of direct and indirect observations did not differ between females and males (X² = 3.35, P = 0.067).

Sexual dimorphism and habitat use

We compared the SVLs and body masses of 23 male
and female snakes that were caught during our study period. Antepartum females had both longer SVL measurements (63.8 ± 2.3 cm, range: 50.2–85.3 cm) and heavier body masses (91.2 ± 7.4 g, range: 50.3–148.6 g) than males (46.5 ± 1.7 cm, range: 20.8–57.9 cm for SVL; 44.5 ± 1.9 g, range: 25.7–62.0 g for body mass; U = 43.00, P < 0.01 for SVL; U = 28.50, P < 0.01 for body mass). During our study, a total of 15 females gave birth. In 2007, ten females delivered offspring between 13 and 28 August, and in 2008, five females delivered between 16 August and 9 September. After parturition, females still demonstrated heavier body masses (62.5 ± 6.1 g, range: 37.1–112.3 g) than males (U = 106.00, P = 0.047).

During the breeding and non-breeding periods, most males and females were found near or in ponds or wetlands within aquatic habitats (447 locations, 94.3%; Fig. 1B). Their mean distance from a pond or a wetland was 10.3 ± 2.1 m (range: 1.6–36.6 m). This distance was not different between males (8.4 ± 3.8 m) and females (11.0 ± 2.5 m; t = 0.53, df = 19, P = 0.602). Females moved farther from pond or wetland boundaries after parturition (20.6 ± 4.8 m) than before parturition (5.9 ± 2.1 m; t = 3.59, df = 11, P = 0.04). In this analysis, we did not include three cases in which females were migrating for hibernation.

During breeding and non-breeding periods, *O. rufodorsatus* were found on the ground most frequently, followed by in water, tree, and underground features (Fig. 2A). Males and females exhibited different frequencies in the use of different structural features (X² = 12.41, P = 0.006). Females were more frequently found in trees (X² = 5.76, P = 0.016) and males were more frequently found underground (X² = 5.14, P = 0.023). Similarly, antepartum and postpartum females also differentially used the different structural features (X² = 10.75, P = 0.013; Fig. 2A). Specifically, antepartum females more often used trees than did postpartum females (X² = 5.83, P = 0.016). The preference for a specific structural feature in the habitat varied depending on air temperature (Kruskal-Wallis test, X² = 30.36, P < 0.001), water temperature (X² = 9.15, P = 0.027), ground temperature (X² = 16.07, P = 0.001), and time of day (X² = 13.90, P = 0.003; Fig. 2B). No differences in the use of the different structural features depending on humidity were found (X² = 4.51, P = 0.211).

Daily distance moved and winter hibernation

Air temperature was negatively related to the mean daily distances moved of both males (R = −0.36, n = 43, P = 0.018) and females (R = −0.42, n = 50, P = 0.002). Water temperature was also negatively correlated with the distance moved for females (R = −0.30, n = 47, P = 0.044), but not for males (P > 0.05). There were no significant relationships between distance and relative humidity for both males and females (P > 0.05 for both cases). The daily distances moved of males (16.1 ± 1.4 m, n = 92) and females (17.1 ± 1.1 m, n = 272) were not different (U = 12321.5, P = 0.827), while postpartum females (26.0 ± 2.9 m, n = 86) moved more than antepartum females (13.1 ± 0.7 m, n = 186; U = 5536.5, P < 0.01).

For winter hibernation, two males started migrating on 8 and 15 October, respectively, and three females started migrating on 16 and 24 October and on 11 November, respectively. The winter hibernation sites of five snakes were in dry terrestrial areas, 94.4 ± 169.8 m (range: 7.1–397.2 m) away from the nearest aquatic boundary and faced toward the south to southeast (Fig. 1B). After excluding one individual with a migration distance of 397 m, the mean distance of the four snakes from the aquatic boundary was 18.7 m (range: 7.1–41.4 m).

Home range

We estimated the home ranges of five males and 16 females. Home range was not correlated with SVL, body mass, or the number of radio-tracking locations obtained (P > 0.05 for all). Home ranges were not different between males and females (P > 0.05; Table 1). However, postpartum females had larger home ranges than antepartum females according to MCP (z = 2.85, P = 0.004), 50% kernel values (z = 2.85, P = 0.004), and 95% kernel values (z = 2.93, P = 0.003; Table 1). The sizes of a year-round home range used by both females and males, including the terrestrial hibernation sites of five snakes, were estimated by the three methods to be 16.15 ha (MCP), 0.16 ha (50% kernel),
and 1.54 ha (95% kernel; Table 1). When we excluded the hibernaculum datum of a F71 snake that migrated 397 m from aquatic habitats, the sizes of the year-round home range of 21 snakes were estimated by the three methods to be 7.8 ha (MCP), 0.14 ha (50% kernel), and 1.26 ha (95% kernel; Table 1).

### DISCUSSION

#### Sexual dimorphism and habitat use

Female *O. rufodorsatus* had larger SVLs and heavier body masses than males. This is consistent with results from a previous study (Ji et al., 1997), and has been reported for several other aquatic snakes, such as *Acrochordus arafurae, N. sipedon,* and *Helicops leopardinus* (Shine, 1986; Weatherhead et al., 1995; Ávila et al., 2006). For snakes, sexual dimorphism, in which the female of the species is generally larger than the male, could be useful in that a larger abdominal cavity can allow for more eggs and offspring (Rivas and Burghardt, 2001). Additionally, this may constitute an ecological adaptation to prevent feeding competition with males (Shine, 1986). Because *O. rufodorsatus* males and females inhabit relatively small common areas, it is more plausible that the former explanation (efficient reproduction) pertains to this sexual dimorphism (Ji et al., 1997).

*Oocatochus rufodorsatus* in our study were located in aquatic habitats in more than 94% of cases, and most snakes did not travel more than 20 m from ponds or wetlands. Such frequent use of aquatic areas has been reported for several aquatic snakes, such as *N. harteri paucimacula* (Whiting et al., 1997), *N. rhombifer,* and *N. erythrogaster* (Keck, 1998). The distribution of snakes in a habitat is largely determined by the distribution of their prey (King and Duvall, 1990). For *N. harteri paucimacula,* a transition in prey types was closely related to changes in the use of habitats (Greene et al., 1994). Although we do not know the exact composition of *O. rufodorsatus‘*s diet in Korea, foraging frogs and aquatic fishes (Kang and Yoon, 1975) may have contributed to the snakes’ frequent use of aquatic environments. In addition, although it has been known that thermal requirements also affect the distribution of snakes in a habitat (Blouin-Demers and Weatherhead, 2001), related aspects were not specifically questioned in this study.

*Oocatochus rufodorsatus* were frequently found in water in addition to on the ground in the habitat. Water surface and water plants floating on the water were often used by aquatic snakes as basking sites, because such sites are fully open (Robertson and Weatherhead, 1992; Burger and Jeitner, 2004). In addition, such sites are relatively safe from predation as the snakes can quickly submerge underwater (Shine, 1980; Gregory et al., 1999; Winne and Hopkins, 2006). These factors might mainly contribute to the present finding. In special, antepartum females were found more often in trees than postpartum females, which may be helpful for developing fetuses (Graves and Duvall, 1995). Trees in a habitat provide good basking locations, particularly after rain, because air convection is active among tree branches at these times (Tiebout and Cary, 1987). Our results show that although *O. rufodorsatus* were most often found on the ground, the species may also use various other structural features in habitats, depending on the sex, physical conditions such as pregnancy, and the time of day.

#### Daily distance moved and winter hibernation

In aquatic snakes, it is known that air and water temperature affect individual movements (Tiebout and Cary, 1987; Scribner and Weatherhead, 1995). This is consistent with our current results that show air and water temperature were negatively related to the moved distance of *O. rufodorsatus*. In addition to the temperature, other factors such as the time of a season and reproductive status of females could also affect the moved distance of snakes (Lin et al., 2008; Camper and Chick, 2010). Nevertheless, we did not specifically address such factors in this analysis, because the activity period of snakes was not exactly overlapped between the years, but we combined the data for both years in the analysis.

In this study, male *O. rufodorsatus* moved approximately 16 m per day and did not differ from females (17 m). This distance is relatively short compared to the 53.3 m and 25.6 m daily movements of *N. erythrogaster neglecta* and *N. sipedon sipedon,* respectively (Roe et al., 2004), and the 48.8 m and 49.3 m daily movements of male and female *N. sipedon,* respectively (Roth et al., 2006). The shorter distance moved by this species may be attributable to the relatively small areas used by both male and female *O. rufodorsatus.* Postpartum females moved approximately twice as far as antepartum females. Most snakes (e.g., *Thamnophis sauritus;* Bell et al., 2007) show increased feeding and movement after parturition or laying eggs, probably to compensate for the energy used in reproduction (Shine, 1985). As amphibians are more often found in cultivated fields than in permanent ponds (Snodgrass et al., 2000) and postpartum females used paddy fields more often than antepartum females did, postpartum *O. rufodorsatus* may also increase their amphibian consumption to recoup energy used in reproduction.

For hibernation, *O. rufodorsatus* traveled about 18.7 m from the nearest aquatic habitat (after an outlier with a value of 397 m was removed from analyses) to dry terrestrial areas. The hibernation sites all faced the south or southeast. It is known that aquatic snakes hibernate both in terrestrial areas and in water. In previous studies, *N. sipedon sipedon,* *N. erythrogaster neglecta,* and *N. rhombifer* hibernated in terrestrial areas approximately 24.4 m, 53.5 m, and 18.7 m away from aquatic areas, respectively (Michot, 1981; Roe et al., 2003). Conversely, *T. sauritus* may hibernate in water (Bell et al., 2007). Our result suggests that *O. rufodorsatus*

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**Table 1.** Home ranges (ha) of *Oocatochus rufodorsatus* depending on sex and female’s reproductive conditions. Year-round home ranges were estimated using both male and female data. MCP (Minimum convex polygon).

<table>
<thead>
<tr>
<th>Estimator</th>
<th>Male (n = 5)</th>
<th>Female (n = 16)</th>
<th>Female (n = 11)</th>
<th>Year-round (n = 21)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Antepartum</td>
<td>Postpartum</td>
<td>Antepartum</td>
<td>Postpartum</td>
</tr>
<tr>
<td><strong>MCP</strong></td>
<td>0.27 ± 0.10</td>
<td>0.3 ± 0.06</td>
<td>0.07 ± 0.02</td>
<td>0.20 ± 0.05</td>
</tr>
<tr>
<td><strong>Kernel 50%</strong></td>
<td>0.10 ± 0.04</td>
<td>0.08 ± 0.02</td>
<td>0.03 ± 0.01</td>
<td>0.11 ± 0.02</td>
</tr>
<tr>
<td><strong>Kernel 95%</strong></td>
<td>0.45 ± 0.16</td>
<td>0.47 ± 0.09</td>
<td>0.16 ± 0.04</td>
<td>0.60 ± 0.13</td>
</tr>
</tbody>
</table>
hibernate in dry terrestrial areas near aquatic habitats.

**Home range and conservation**

The home ranges of male and female *O. rufodorsatus* were similar, at 0.45 ha and 0.47 ha for 95% kernel, respectively. The year-round home range for this species was estimated as 1.54 ha (95% kernel). These home range sizes are comparable to that of *N. sipedon*, a species that has been intensively studied in various areas, although the average length of adult *N. sipedon* is longer: approximately 135 cm, as compared to 60–70 cm in *O. rufodorsatus*. In this species, body size was positively correlated with the home range size of females, but not of males (Roth et al., 2006). Roe et al. (2004) reported the sizes of the male and female home ranges of this species to be 6.9 ha and 3.1 ha (95% kernel), respectively, and Roth and Greene (2006) reported home range sizes of 2.92 ha for males and 2.72 ha for females. In a recent study, *N. sipedon* used a smaller 0.12 ha home range (95% kernel) in an urban area (Pattishall and Cundall, 2008), demonstrating that the size of home ranges used by a species can vary depending on habitat. In this study, postpartum females used a larger home range than antepartum females, suggesting that increased daily movements and increased usage of paddy fields in postpartum females might be responsible for the enlarged home range.

Previous studies have revealed the importance of aquatic and terrestrial buffer zones (Semlitsch and Jensen, 2001; Gibbons, 2003; Camper, 2009) and efficient connectivities between aquatic wetlands (Attum et al., 2008) to conserve aquatic or semi-aquatic amphibians and reptiles. Our results demonstrate that although *O. rufodorsatus* generally use aquatic habitats during breeding and non-breeding periods, they also use terrestrial areas during winter hibernation. Therefore, to conserve this species in typical, traditional agricultural lands in Korea, core pond or wetland habitats as well as terrestrial hibernation habitats should be protected. In our study area, conservation areas should be round with a radius of approximately 150 m around a core pond habitat. This is similar to the core habitat size suggested by Semlitsch and Jensen (2001) to conserve semi-aquatic reptiles. Additional studies of adjusted agricultural lands (following the removal of ponds or other wetlands) are necessary because such conditions could lead to species decline.

**ACKNOWLEDGMENTS**

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