Herpetological Conservation and Biology 8(2):366−375.
Submitted: 16 January 2013; Accepted: 25 March 2013; Published: 15 September 2013.

Home Range and Movement Patterns of the Otton Frog: Integration of Year-round Radiotelemetry and Mark–recapture Methods

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***Abstract*.—For the effective conservation of frogs, knowledge about the movement patterns of the target species is essential. However, methods for tracking frogs, such as mark–recapture, spools of thread, and radiotelemetry all have their limitations. To compensate for the constraints of various methods, I combined radiotelemetry and mark-recapture to reveal the home range and movement patterns of an Endangered species, the Otton Frog (*Babina subaspera*). I tracked five individuals by radiotelemetry for up to 451 days. Additionally, I marked 316 individuals in 2010–2012. Radiotelemetry revealed that three females moved among different areas throughout a year (base area, breeding site, and overwintering site), while a male remained at the breeding site during the active season and then migrated to an overwintering area. The minimum convex polygon of the locations was 5,300–30,000 m^2. The migration distances from the base area to the breeding site and then to the overwintering area were 150 and 80–250 m, respectively, for females, and the distance from the breeding site to the overwintering area was 200 m for a male. These migration distances agree with the results of the mark-recapture study: more than 95% of the individuals were recaptured within 200 m of the tagging location during the active season. Distance between captures did not increase with time, indicating high site-fidelity in this species. The combination of the two different methods to track frogs proved successful and produced reliable information about the movements of this endangered frog, which will contribute greatly to its conservation.**

Key Words.—Amami Islands; amphibian; *Babina subaspera*; MCP; migration; site fidelity

Introduction

Amphibians are one of the most threatened groups of animals on the planet (Hof et al. 2011). Habitat degradation, climate change, and amphibian diseases have caused declines in many amphibian species worldwide (Alford and Richards 1999), showing the urgent need for appropriate conservation measures (Semlitsch 2000). To develop conservation strategies for endangered amphibian species, obtaining thorough ecological information about the target species is extremely important. For example, data pertaining to movement patterns and the home range of an amphibian species are needed to estimate the effects of habitat fragmentation or to create zones in protected areas (Pilliod et al. 2002; Baldwin et al. 2006).

Many attempts have been made to estimate the home ranges and movement patterns of amphibians using several methods, such as mark-recapture, spools of thread, and radiotelemetry. Mark-recapture has been a common method because it has low costs and individuals can be traced over long periods once they are successfully marked (Bellis 1965; Donnelly 1989; Driscoll 1997). However, the results are strongly influenced by the recapture rate, and determining multiple locations from a certain individual is difficult. Moreover, the observations are restricted to the survey area and survey period (frogs' active season). Spools of thread that unwind as the animal moves are effective for tracking animals continuously, but they are limited to short durations and distances (Sinsch 1988). Thus, a real possibility exists that estimates of home ranges based on only one of the above mentioned methods will lead to underestimates of their size, which is crucial for decision-making regarding their conservation measures.

Radiotelemetry allows the remote identification of animal locations and is currently the most widely used technique for tracking frogs (Wells 2007). However, transmitters are expensive and tracking large numbers of individuals within one project is difficult. In addition, the maximum weight of transmitters that can be attached to small frogs (the usual recommendation is that they weigh < 10% of the body weight; Richards et al. 1994) limits battery duration and therefore the tracking period, which can be less than two weeks (Fukuyama et al. 1988; Ra et al. 2008). Some studies have tried to combine data from different individuals that were tracked in different seasons to augment the short duration (Lamoureux and Madison 1999; Matthews and Pope 1999; Watson et al. 2003), but the "real" home range might not be equal to a simple addition of ranges based on short periods. Thus, to determine the "real" home range (i.e., the area that an individual frog needs throughout a year), researchers must replace transmitters before the battery life expires (Lamoureux and Madison 1999; Heemeyer and Lannoo 2012), which reduces the number of successfully tracked animals even further.

The Otton Frog (*Babina subaspera*) is an Endangered species that is endemic to the Amami Islands in southern Japan (Maeda and Matsui 1999). This frog has a high academic value because of its unique feature of a pseudothumb that has an appearance of "fifth finger" (Tokita and Iwai 2010; Iwai 2013), but it is now threatened due to habitat degradation and predation pressure from invasive predators (Watari et al. 2008). The Otton Frog is listed as an Endangered species in the IUCN Red List of Threatened Species (IUCN, Red List. 2011. IUCN Red List of Threatened Species Version 2012.2. Available from http://www.iucnredlist.org [Accessed 29 November 2012]), which indicates its high priority for conservation. Iwai and Shoda-Kagaya (2012) revealed that some populations of Otton Frog are genetically isolated, which means that conservation measures need to be based on the mobility of the species. However, no data about their home range, mobility, or site fidelity have been available despite the importance of this information in planning conservation measures.

In this study, I aimed to reveal the movement patterns and home range of the Otton Frog throughout a year. To compensate for the limitations of different techniques in tracking animals, I combined two different methods: radiotelemetry on a small number of individuals and mark–recapture with a larger number of animals. The results of the two methods were combined and the home ranges of individual adult Otton Frogs are presented.

Materials and Methods

Study area.—This study was conducted in the Sumiyo region of Amami-Oshima, which is located in Kagoshima Prefecture, southern Japan. Amami-Oshima is one of only two islands that the Otton Frog inhabits. The island is the largest (712 km^2) of the Amami Islands; it is mountainous and is covered with subtropical rain forests, with the highest peak at 694 m. The relative density of Otton Frogs in the Sumiyo region is known to be high on the island (Iwai and Watari 2006). I conducted the survey along a section of paved 4-m-wide road, 8.5 km in length, that connects small villages in the Sumiyo region located near the shore (Fig. 1). I started the survey along a road at 9 m above sea level (ASL), went up into the mountain, reaching 380 m ASL at the 6-km point, then headed down to 240 m ASL at the 8.5-km point, which I set as the endpoint. Except for the starting point, which was at the edge of a village, secondary forests were spread around the road and few human residences existed in the area (Fig. 1). Several streams traversed the road and small dams were constructed at the intersections; the pools created by the dams were used by Otton Frogs as breeding sites. Otton Frogs in the region bred from late April to early October (hereafter the "active season"), with a peak breeding season from June to August.

Radiotelemetry.—I tracked five Otton Frogs for varying durations from June 2010 to November 2011. I tracked the first female (N0) as a trial with a used transmitter from another study conducted in June 2010; the transmitter

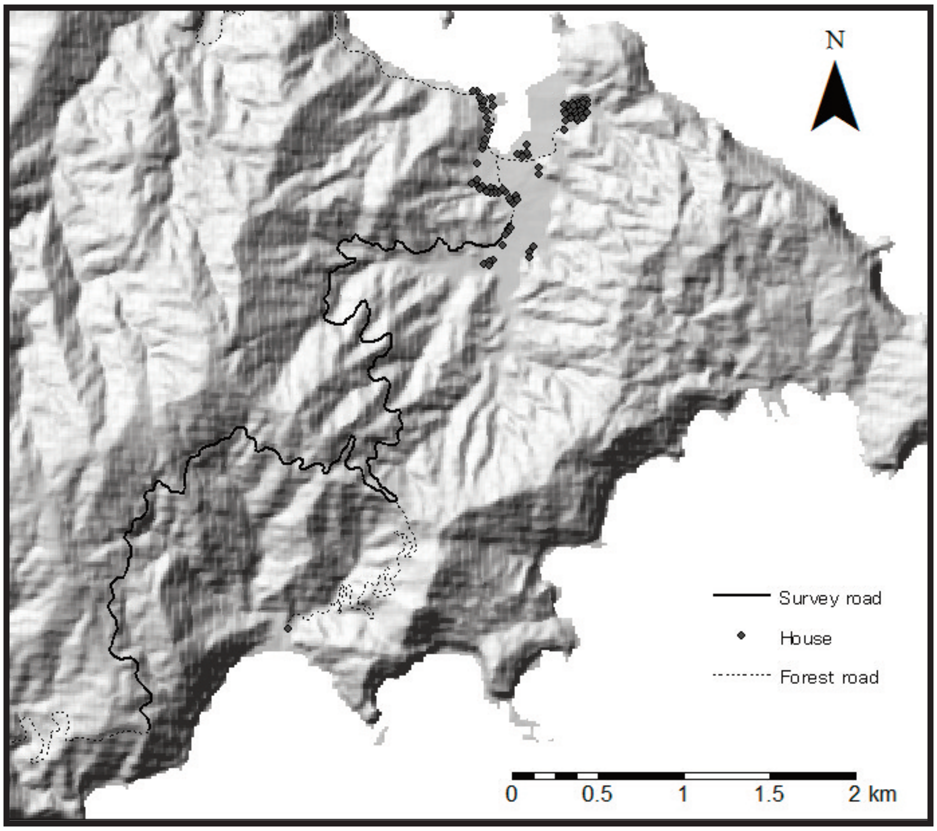

FIGURE 1. Map of the study area, Sumiyo region, Amami-Island, Japan. The bold line shows the survey road that was used for the mark-recapture study of Otton Frogs.

FIGURE 2. Otton Frog with a banded transmitter on its waist.

Table 1. Details of five individual Otton Frogs tracked using radiotelemetry in the Sumiyo region, Amami-Island, Japan.

ID	Sex	Weight (g)	Start date	Last location date	Duration (d)	# of locations	Longest distance	MCP (m2)
N0*	F	249	17 June 2010	7 September 2010	22	10	111.8	5,774.5
N1†	M	269	18 August 2010	12 November 2011	451	54	215.4	5,300.4
N2	M	261	18 August 2010	3 September 2010	16	2	-	-
N3	F	225	21 August 2010	9 April 2011	231	24	375.8	7,302.6
N4†	F	250	23 August 2010	12 November 2011	446	48	247.5	30,048.9

*Recaptured on 2 June 2012.
†Replaced transmitter on 9 April 2011.

battery had 1 mo of life left. Because the trial was successful, I fitted two males (N1, N2) and two females (N3, N4) with new transmitters (battery life 5–9 months; Holohil Systems Ltd., Carp, Ontario, Canada) in August 2010. I captured Otton Frogs along the survey road and banded transmitters to the waists of the frogs using a belt made of stainless steel balls or leather that passed through a tube attached to the transmitter (Matthews and Pope 1999; Fig. 2). I detected and followed radio signals using an FT-290 (Yaesu, Shinagawa, Tokyo, Japan) receiver and a handheld three-element Yagi antenna. I determined locations as often as possible (once every 1–4 days) during long survey periods on the island (August-October in 2010 and June-July in 2011) and one to three times during other visits (January, April, and November in 2011). At most of the locations, I could not obtain a visual confirmation of the individual because Otton Frogs were mostly hidden inside small holes, under rocks, between tree roots, or behind bushes, and I could only estimate the location by local triangulation (< 1 m). I recorded the locations using a global positioning system (GPS) receiver (Oregon 450; Garmin, Olathe, Kansas, USA) and noted the surrounding environmental conditions.

GPS data were plotted on maps using ArcGIS (ArcMap 10.0, ESRI, Redlands, California, USA). I calculated the size range for the minimum convex polygon (MCP) in ArcGIS for the four individuals whose locations were determined more than 10 times.

Mark–recapture.—Otton Frogs in the Sumiyo region were identified by toe-clipping during the active seasons from 2010 to 2012. Individuals were found and captured at night along the survey road or at breeding sites along the road. During initial captures, individuals were toe-clipped. When individuals were recaptured, their identification number was recorded. I recorded capture points using a GPS receiver and plotted them on maps using ArcGIS. I calculated linear distances between initial and successive capture points within an individual using ArcGIS.

Results

Radiotelemetry.—In total, I located five Otton Frogs multiple times using radiotelemetry (Table 1). Frogs N1 and N4 were recaptured in April 2011, and their transmitters were replaced. The transmitter on male N2 was found on the ground 16 days after attachment and was thus removed from further analysis.

The only remaining male, N1, was first found at a breeding site where several males and nests were observed, and it did not move much in

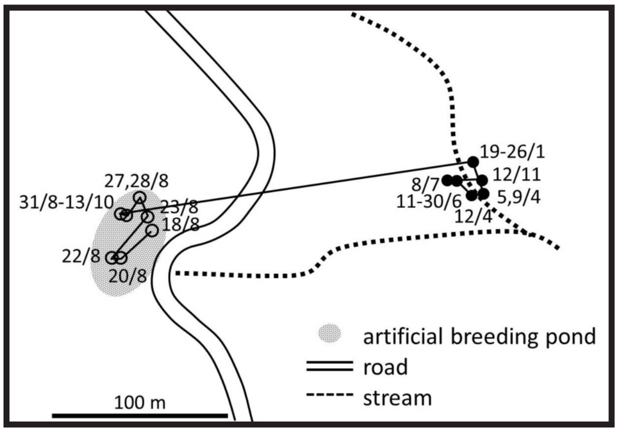

FIGURE 3. Movement of male Otton Frog N1. The open circles indicate locations in 2010 and filled circles represent locations in 2011. Dates (d/mo) for each location are beside each circle.

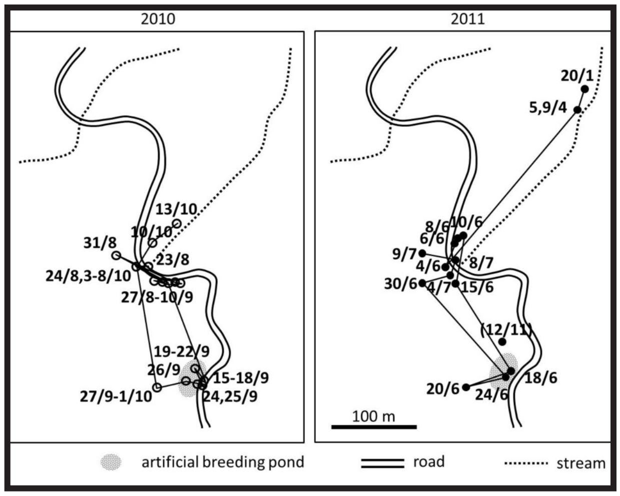

FIGURE 4. Movement of female Otton Frog N4 in 2010 (left) and 2011 (right). Dates (d/mo) for the locations are indicated beside each circle. The date in parenthesis (12/11 in 2011) shows when the transmitter was finally found on ground, not on the frog.

2010 (Fig. 3), always hiding in a hole behind a rock and calling. It spent the following winter 200 m downstream of the breeding site (Fig. 3) in a hole between rocks within 5 m of stream water.

The female that had the longest successful tracking period, N4, used three areas throughout the year (Fig. 4). One was a breeding site, where males were observed calling during the season; it spent one or two weeks there each year, possibly to lay eggs. Outside of the breeding weeks, N4 spent the time within a 100-m area that was approximately 150 m away from the breeding site (base area). At the base area, N4 was found inside small holes under rocks, between tree roots, or behind bushes. N4 used the same breeding site and base area in two successive years (Fig. 4). The third area used by N4 was during the winter and was 250 m downstream from the base area. There, N4 used a space between large rocks in a stream where the surface was wet but not under water.

Another female, N3, also used three areas; it spent a few days at the breeding site, returned to a base area that was 150 m downstream, stayed there (within 100 m) until the end of the active season, and moved 80 m farther downstream to a winter area where it stayed until the next spring (Fig. 5). During winter, N3's signal came from behind a huge rock in the stream where water was running over the rock, but it seemed not to be underwater behind the rock (Fig. 6).

The first trial with female N0 spanned only 3 weeks in the active season, but its movement pattern—a small area during the active season—was consistent with that of the other two females: it stayed within a 100-m area that included the breeding site (Fig. 7). In June 2012, this individual was recaptured in the same area where it was found in 2010 (Fig. 7).

Mark–recapture.—In total, 167 females, 145 males, and 4 juveniles were captured in three years (183 in 2010, 48 in 2011, and 85 in 2012), and 72 of them were recaptured (51 females and 21 males). Thirty-two frogs were recaptured once, 14 were caught two times, one frog was caught three times, one was caught four times, and one was caught five times. The range of distances between the initial capture point and each successive capture point was 2–567 m, with a median of 52 m ($n = 51$) for females and 0–182 m, with a median of 42 m ($n = 21$) for males. These values include multiple measurements for each frog, always representing the distance from the first capture to the new capture location. The

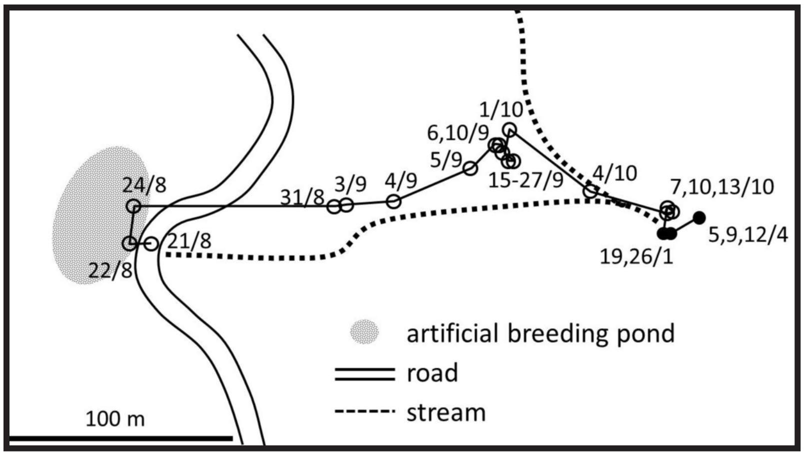

Figure 5. Movement of Otton Frog N3. Open circles indicate locations in 2010 and filled circles represent locations in 2011. Dates (d/mo) for each location are beside each circle.

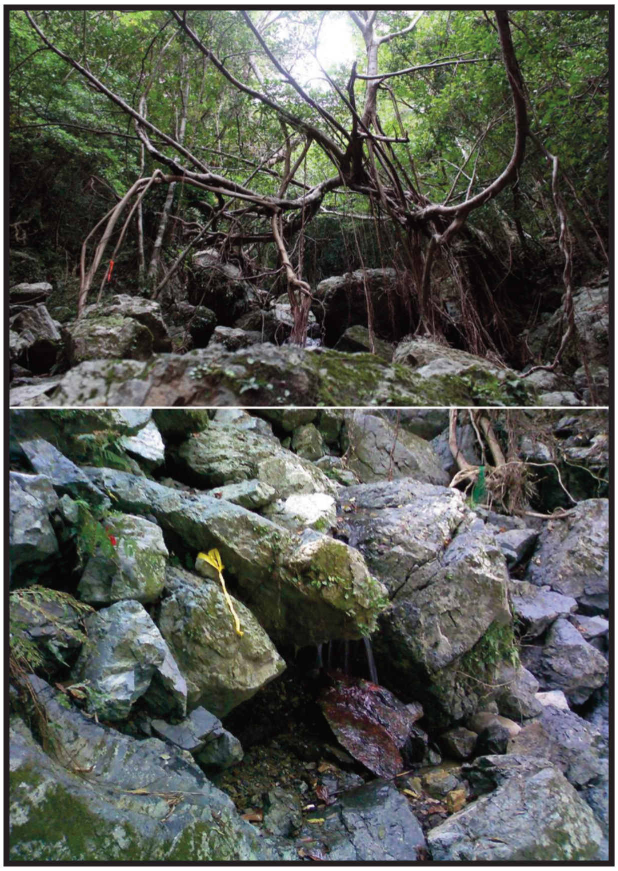

Figure 6. A picture of stream where N3 spent winter 2010/2011 (upper) and the rock behind which the signal was detected (lower) during that time.

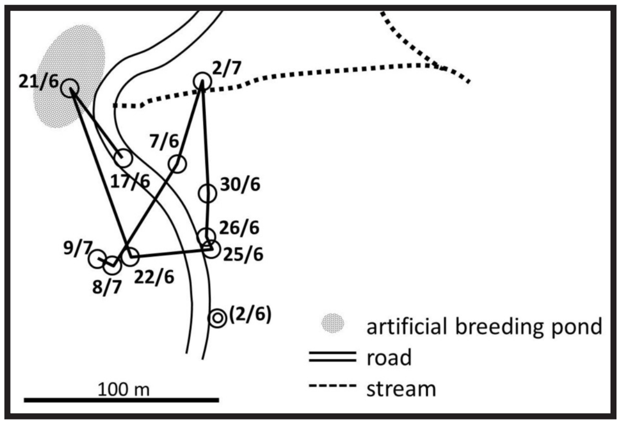

Figure 7. Movement of female Otton Frog N0. Open circles indicate locations in 2010 and double circle represents recapture location in June 2012. Dates (d/mo) for each location are beside each circle.

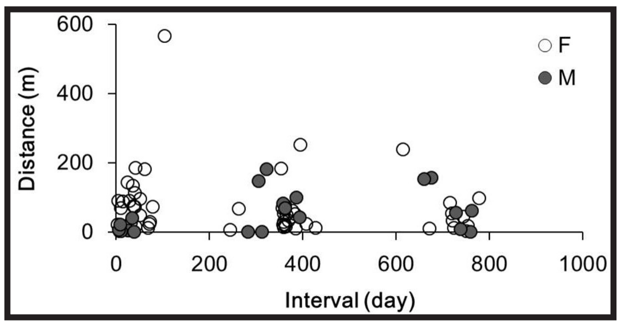

Figure 8. The relationship between capture interval (d) and the linear distances (m) moved between the initial and successive capture points within individuals in mark-recapture study.

frogs did not move very much; all of the individuals, except for three females, were recaptured within 200 m of their previous capture location, even after two years (Fig. 8). The distance moved did not increase with the capture interval (linear regression; $r = 0.03$, $P = 0.23$ for females, $r = 0.11$, $P = 0.14$ for males). All four males captured once at a breeding site were recaptured at the same site after 38, 283, 312, and 759 days, which suggests that they use the same site every year.

Discussion

I successfully tracked individuals for more than one year. The home range estimates (MCPs from the radiotelemetry data) throughout all seasons was 5,300–30,000 m^2 for adult Otton Frogs. No outlier points were identified that may have unduly inflated the MCP for each frog. This range included different movement patterns among seasons and between sexes, but was fairly fixed, with individuals moving less than 400 m within a period of more than one year. The mark-recapture results showed that individuals were mostly recaptured within 200 m of the initial capture point, even with long intervening periods (> 700 d). The distance did not increase with the capture interval, suggesting that Otton Frogs have high site-fidelity using fixed areas over several years. Although the number of tracked individuals was not large and thus we need caution in interpretation, the data from radiotelemetry and that of mark-recaptures were consistent, showing that the results were reliable.

Studies on frog home ranges have generally reported smaller home range values: 45.3 m^2 (MCP) for *Rana capito* (Blihovde 2006); 714 m^2 (95% adaptive kernel) for *Rana chosenica* (Ra et al. 2008); and 52.8–5336.2 m^2 (90% adaptive kernel) for *Rana muscosa* (Matthews and Pope 1999). These smaller values might have been because of their short tracking periods of at most 118 days for Blihovde (2006), a mean of 6.4 days for Ra et al. (2008), and one month for Matthews and Pope (1999), meaning that they examined home ranges within limited seasons. Watson et al. (2003) showed that *Rana pretiosa* had smaller MCPs of 0.2–0.9 ha if tracked only during one of each season (breeding, dry, and wet seasons) while it had much larger MCP of 2.6 ha if tracked throughout those seasons. Matthews and Pope (1999) showed that frogs tracked in September had larger home ranges (5,336.2 m^2) than in August (385 m^2) or October (52.8 m^2). Thus, frogs use various-sized areas in different seasons. If I used data collected only during the breeding season (May-September), I would have concluded that the home range of the Otton Frog was 428–8,179 m^2, which is 8–43% of the range used throughout the entire year; however, it would have been close to previously reported values. One must be aware that frog home ranges should be determined from data collected in all seasons, or otherwise the results can be misleading and the estimated home range could be less than half the size of the "true" range.

If the home ranges were estimated from mark-recapture data from individuals that were recaptured more than three times during the two years (n = 3), the estimates would be 571.3 m^2 (4 points in 384 days), 693.6 m^2 (5 points in 754 days), and 520.7 m^2 (6 points in 721 days). These values were much smaller than the MCPs that were estimated from the telemetry data. Bellis (1965) also found a small MCP of 64.5 m^2 for *Rana sylvatica* from recapture data from 17 individuals that were caught more than five times during the summer (June-September). These small MCP values would be expected because mark-recapture studies can only be conducted during the active season in certain areas. Thus, the mark-recapture method itself has a high chance of underestimating frog home ranges, just as in radiotelemetry over short periods.

Female N4 showed high site-fidelity. This individual came back to the same base area and migrated to the same breeding site in the second year. Female N0, which was only tracked during the summer in 2010, was recaptured in 2012 in the same base area (Fig. 7), which also suggests that females use the same base area among years. Although the high site-fidelity was only from two individuals in the radiotelemetry data, this pattern was supported by the multiple mark-recapture results. The distance from the first point of capture to recapture points did not increase with the time interval between captures, and they often occurred within 50 m. Also, males captured at the breeding site were recaptured at the same site one or two years later. High breeding site-fidelity in frogs is common (Wells 2007) and many frog species return to the same site year after year (Kusano et al. 1999; Matthews and Preisler 2010; Heemeyer and Lannoo 2012). The high site-fidelity sometimes has a negative effect on the frog population when the site becomes no longer suitable for them (Matthews and Preisler 2010). Thus, for the conservation of Otton Frogs, it is important to remember that the frogs will not be able to change their habitat easily and that we should not expect them to find better place and move to once their habitat has been degraded.

I found Otton Frogs used artificial ponds as breeding sites. Otton Frogs naturally use small, pooling areas of streams (i.e., swamp-like portions on gentle slopes). The pooling occurs as a consequence of the topographic nature, and thus, the swamp remains for years. The artificial ponds that Otton Frogs use as breeding sites, however, are located in areas where still water does not occur naturally (e.g., mid-flow in streams) thus, this condition could easily change. In recent years I have found that some of these artificial breeding sites were buried by sediment deposition. Considering the high site-fidelity of Otton Frogs, artificial breeding sites that do not last long may have negative effects on this species as an "ecological trap" (Battin 2004) by first attracting frogs and then disappearing. It seems common for Otton Frogs to use artificial ponds, as I observed them doing so in many other areas on Amami Island. It will be needed to carefully examine the effectiveness of these artificial ponds as breeding sites for the conservation of the Otton Frog.

In this study, the home ranges and movement patterns of the Otton Frog were determined by radiotelemetry and the results were supported by data from a mark-recapture study. Although the number of individuals tracked through a year was not large, the consistency of results from radiotelemetry and mark-recapture imply the information is reliable. This information will be valuable for determining conservation measures for this Endangered species. Further studies on the effects of artificial water bodies on frog movements and on the dispersal of juveniles would help create even better conservation strategies.

Acknowledgments.—I thank Yumiko Nagai and Shohei Oumi for their help in the field. I also thank Shintaro Abe, Kikuko Nogami, Takao Nogami, Shigekazu Yamashita, and the people in Ichi village for their support. The civil engineering and construction division of Sumiyo region helped maintain access to the study area. This study was carried out under permits no. 53 and no. 80 from the Kagoshima education commission and was financially supported by the JSPS Research Fellowship and Research Fund.

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Noriko Iwai is an assistant professor at the University of Tokyo. She is interested in ecology of amphibians, especially frogs and tadpoles. Dr. Iwai received her Ph.D. from the University of Tokyo, Japan. Her Ph.D. study investigated the role of tadpoles as a nutrient regenerator in aquatic ecosystems. Dr. Iwai also has worked on conservation of Endangered frog species, especially in Amami Island on their ecology, behavior, population genetics, and evolution. (Photographed by Kayo Fukuda)