Amphibia-Reptilia 29 (2008): 383-392

Home ranges and movements of the Chinese stripe-necked turtle (*Ocadia sinensis*) in the Keelung River, northern Taiwan

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Abstract. We investigated home ranges and movements of 13 adult *Ocadia sinensis* by radio-tracking in a narrow and disturbed riverine habitat of the Keelung River, northern Taiwan from January 2001 to April 2002. Our results indicated that individuals of this turtle were sedentary, with home range length averaging 703 m (range 170-1460 m). Home range length did not differ between the sexes. Movement patterns of radio-tracked turtles were highly variable, with no apparent seasonal patterns. The daily movement distances ranged from 5-245 m, equalling 0.3 to 47.1% of their home range length. Usually, *O. sinensis* moved into a new pool during flooding or after a longer period of low water level. This turtle was seldom relocated terrestrially, showing its highly aquatic nature. *Ocadia sinensis* used the riverine habitat unevenly, preferring the deep and slow-current pools and avoiding highly modified river sections. Our results raise conservation concern about loss of deeper, slow-current pools in many river management projects, which was important habitat for *O. sinensis* in their home ranges.

Keywords: home ranges, movements, radio-tracking, *Ocadia sinensis*, Taiwan.

Introduction

The Chinese stripe-necked turtle, *Ocadia sinensis*, is widely distributed in Taiwan, southeastern China (including Hainan), and northern Vietnam (Ernst and Barbour, 1989; Iverson, 1992). Recently populations of this turtle have been suffering from substantial declines throughout most of its geographical range (Zhao, 1998; Chen, Lin and Chang, 2000; Hendrie, 2000), presumably as a result of over-exploitation for the Chinese food market and habitat destruction. In Taiwan, this turtle is still relatively common in various aquatic habitats, including ponds, lakes, reservoirs, irrigation ditches, and rivers at low elevations (Mao, 1971; Ernst and Barbour, 1989). However, many Taiwanese populations are now thought to be declining as a result of physical changes of habitats, water pollution, and heavy exploitation for the pet trade and ritual release (Chen, Lin and Chang, 2000). Of these impacts, physical changes of the low-elevation aquatic habitats have been dramatic in the past few decades. This is especially true in the river systems because of the construction of flood control facilities. However, the influences of such habitat modifications on river-dwelling turtles, as well as other aquatic organisms, have not been carefully investigated. To develop effective conservation measures for turtles in such altered environments, we need a better understanding of their habitat requirements and movement patterns. This information is also essential for evaluating the effects of riverine habitat modification in each on-going development project. In the present study, we investigated the home ranges and movements of individual *O. sinensis* inhabiting in a disturbed river from northern Taiwan.

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Materials and methods

Study area

We conducted this study along a 2.5-km long section of the Keelung River (121°41′E, 25°06′N) in northern Taiwan (fig. 1). The river section was divided into several pools by shallow riffle areas. The water level of the study area is highly variable ranging 1.5 to 3 m in deep pools, with occasional flood after heavy rainfall (>8 m in water level). The annual precipitation recorded at the Wudu Gauging Station (121°40′49″E, 25°04′32″N), near the study area, varied from 2004 to 5160 mm during 1997-2002. There

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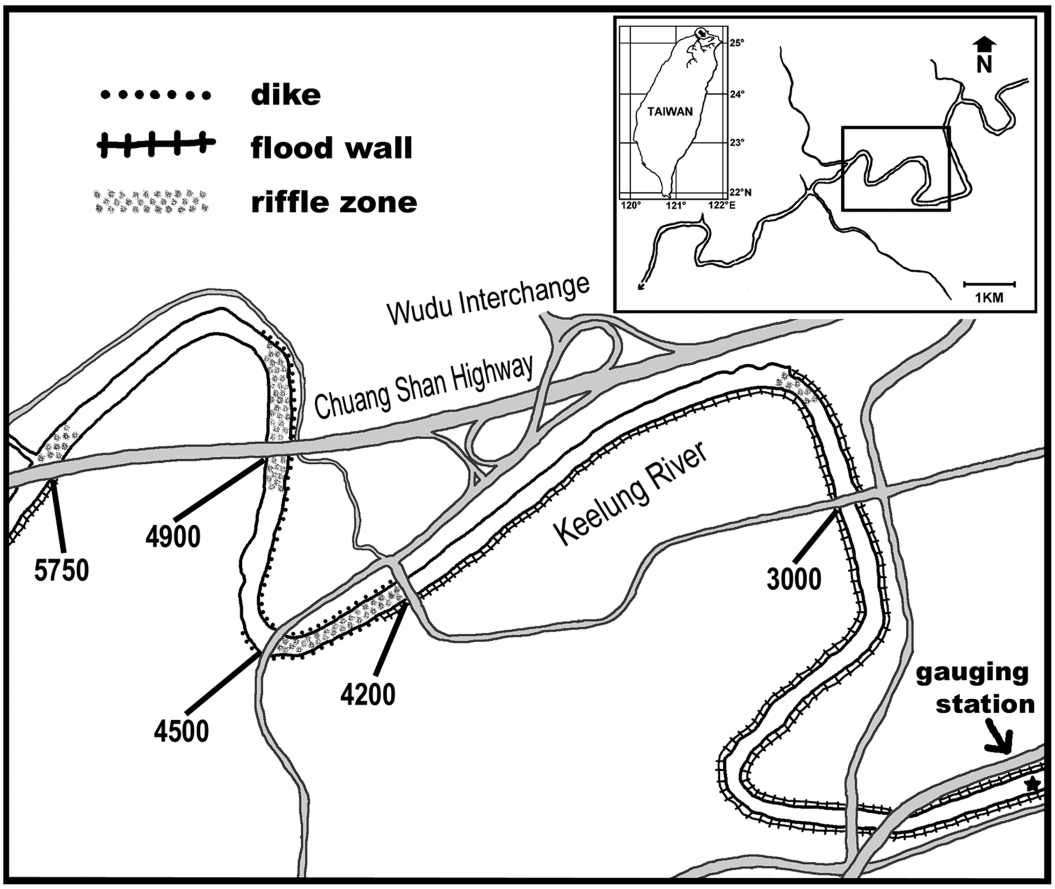

Figure 1. Outline of the middle Keelung River with location of the study site. The numbers indicate the distance marks placed along the banks during the flood control project.

were several days of occasionally high rainfall (300-500 mm) caused by typhoons. In October 1998, the suburban areas along the river were inundated by flood, leading to a large-scale flood control project for this and an adjacent portion of the river. In the course of the 2-year flood control project, the streambed and riparian habitats have been modified and greatly disturbed, mainly through the construction of rock dikes, cement flood walls and river channel dredging. Bamboo shrubs and high-stem trees were removed during the project, and the riparian vegetation was dominated by introduced *Brachiaria mutica* (Gramineae) and *Wedelia trilobata* (Compositae) (>50% of the total coverage), and some other herbaceous species. Since the riparian vegetation has been cleared periodically in the ongoing river management project, we did not incorporate data for the environmental characteristics into the present analyses.

Locally, *Ocadia sinensis* was abundant. This study was conducted in conjunction with a trapping program, which yielded a result of 567 different individuals captured (Chen, 2006). In the middle of September 2001, typhoon Nari caused flooding in the study area (fig. 2). We investigated the effects of this flood on the movements of *O. sinensis*.

Telemetry

From January 2001 to April 2002, we radio-tracked 16 adult turtles, of which four males and nine females were tracked longer than two months. Among the radio-tracked turtles, one male and two females were found dead during the study period for unknown reasons. Thus, data for 13 individuals were analysed. The 13 g, 150-151 MHz transmitters with 0.3 km maximum range of detection (model P2RLM-G3, AVM Instrument Co., California) were attached to the front lateral scutes of turtles with epoxy cement. Battery life span was about one year. Whip antennas of the transmitters were fastened around the lateral scutes with additional epoxy. We located the radio-tagged turtles using an AVM receiver (model LA 12-Q) and hand-held H-shaped antenna (150-154 MHz, Telonics, Arizona). We located radio-tagged turtles on two to four days monthly from January to August 2001 and less frequently from September 2001 to April 2002. To investigate the daily movement distance we obtained at least three relocations on a single day each month for some individuals. We made use of the distance markers placed at intervals of 25 metres on both banks by the River Management Office in the flood control project, and visually

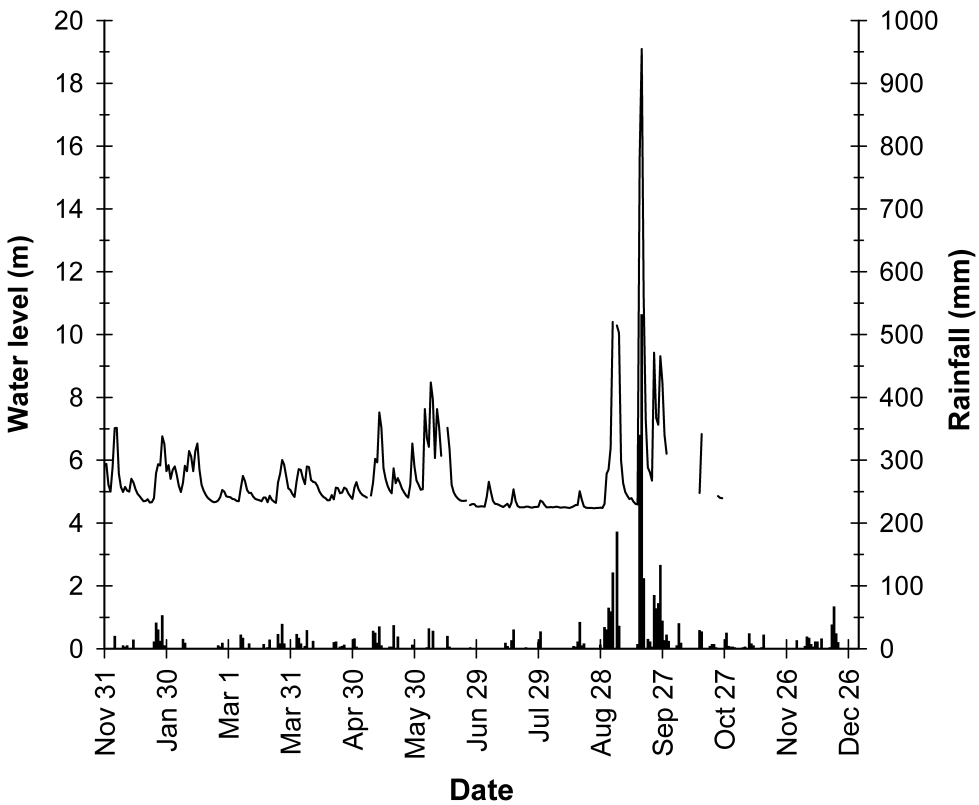

Figure 2. Water levels and precipitation during the study period at the Wudu Gauging Station near the study site in 2001. Water levels were the distance above sea level.

estimated location of each fix to the nearest five metres. Because the project covered most of the suitable riverine habitat of freshwater turtles in the middle and lower sections of the river, we cannot directly assess the impact of the flood control project on the turtles.

Estimation of home range

The channel of the Keelung River is rather narrow (only about 20-25 metres wide) and turtles used the river section unevenly. We thus regarded the length of maximum range of the movements by each turtle (henceforth referred to as the home range length) as an estimate of the individual home range following Pluto and Bellis (1988) and Plummer, Mills and Allen (1997). To decrease the noises from outliers, we used 95% of the home range length in the actual analyses.

Results

Table 1 summarizes the individual variation in number of relocations, home range length, and tracking period. Our data from radio-tracking indicated that this turtle was sedentary, with home range length averaging 703 m (range = 170-1460 m). Most of the relocations were confined to the aquatic areas and basking sites along the river. Home range overlap among individuals was high. We found no evidence of extensive terrestrial movements in *O. sinensis* by radio-tracking. Only one terrestrial fix was obtained under herbaceous bush on riverbank after flooding in September 2001. During our observation in 2001, two radio-tagged gravid females were found in the drift fence traps set on the sandy bar.

Estimation of home range

The home range lengths of radio-tracked *O. sinensis* averaged 853 ± 454 m (range = 410-1410 m, $n = 4$) in males, and 636 ± 443 m (range = 170-1460 m, $n = 9$) in females. There was no significant sex-specific difference in home range length (t-test, 95% home range length: $t = 0.8851$, $P = 0.3950$). Home

Table 1. The numbers of relocations (n), home range length estimates, and tracking periods of *Ocadia sinensis* from a northern Taiwan population.

Turtle code	CL (mm)	n	100% home range length (m)	95% home range length (m)	Tracking periods
Males					
M001	175.5	85	1460	1410	2001/01/04-2001/12/26
M004	185.7	28	1250	1025	2001/01/06-2001/10/26
M011	162.1	44	440	410	2001/02/18-2001/07/11
M026	176.3	14	760	565	2001/08/02-2001/11/14
Females					
F005	259.9	27	815	440	2001/01/06-2001/04/20
F008	229.1	19	805	775	2001/02/06-2001/04/13
F028	188.1	49	425	170	2001/02/22-2001/07/24
F029	234.3	33	1075	750	2001/02/22-2001/06/15
F050	221.3	28	1530	1460	2001/02/22-2001/09/06
F060	210.4	73	1445	1165	2001/02/22-2001/12/26
F412	229.7	29	610	420	2001/07/11-2002/02/07
F417	225.8	14	210	195	2001/07/11-2001/11/14
F422	251.8	34	420	350	2001/07/16-2002/04/24

range length was not significantly correlated with either carapace length (ANCOVA, $F_{1,11} = 0.0143$, $P = 0.9069$), number of relocations ($F_{1,11} = 2.9060$, $P = 0.1163$), or tracking period ($F_{1,11} = 4.2429$, $P = 0.0639$).

Movement patterns

Most radio-tracked turtles were rather sedentary, remaining within a short section of the river over long periods. For example, two females (F028 and F422) stayed in less than 400 m home range length for more than three months (fig. 3). Other individuals (M001 and F060) showed larger forays, moving among temporary pools during long periods of low water level, or during the flooding after typhoon Nari in 2001 (turtles subsequently returned upstream when water level dropped and current velocity decreased) (fig. 3). The movement patterns were highly variable among individuals and showed no apparent seasonal trends.

The total distance of daily movement in *O. sinensis* ranged from five to 245 m, with average distance from 20 to 108 m in males and from 6 to 88 m in females (table 2). Although the movement distances were highly variable among individuals, the difference of average distance between sexes was not statistically significant ($t = 0.5596$, $P = 0.5870$). *Ocadia sinensis* tended to stay in a limited area, usually within the same pool, for long periods and then to move slightly upstream or downstream in short periods. The daily movement distances of radio-tagged turtles equalled 0.3 to 47.1% of their home range length.

Activity centres and habitat use

The pooled relocations of all radio-tracked individuals were concentrated in two major sections, located at roughly 3300-4150 m and 4450-4650 m according to the distance marks along the river banks (fig. 4). These areas were relatively deep (1.5-2.0 m), slow-moving pools. Turtles used the areas with more natural riparian vegetation and less modified habitat in the flood control project. Most of the relocations were restricted to one side of the river without flood control facilities or with deeper water, usually on the erosion side of the river. The frequency of relocations was low in the highly modified section of the river, such as the sections of 2800-3200 m and 4200-4400 m where there were cement flood walls or rock dikes on both banks (fig. 1). The turtles used the habitat unevenly and they had one to three activity centres in general (fig. 5).

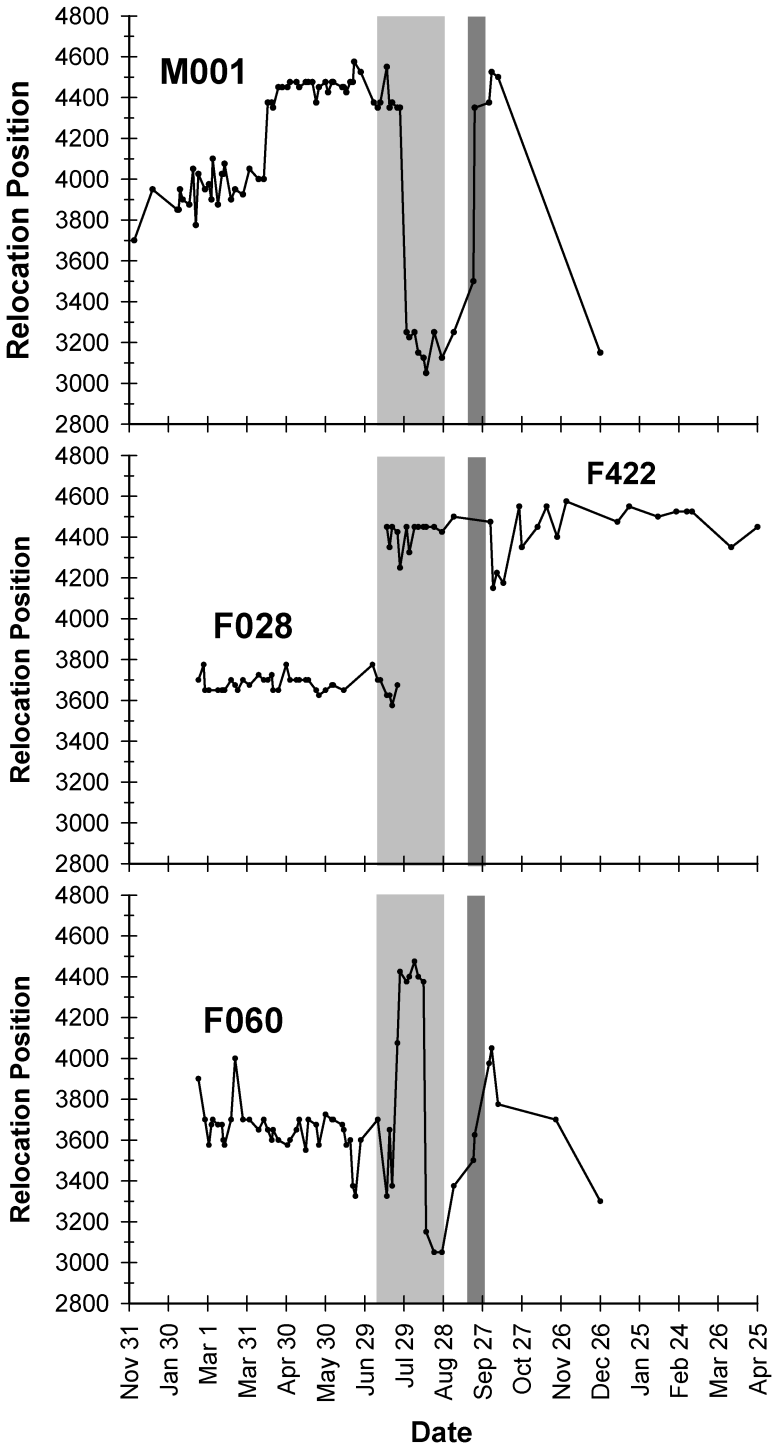

Figure 3. Sequential movements of selected individuals of *Ocadia sinensis*. Each dot represents a point location. Light grey bars represent periods of low water, the dark grey bars represent periods of high water. The numbers of relocation position shown on *y* axis were estimated using the distance marks placed along the banks during the flood control project.

Table 2. The daily movement distance (m) of selected individuals of *Ocadia sinensis* from a northern Taiwan population.

Turtle code	Daily movement distance (m)		*n*	% of home range length	
	Mean	Range		Mean	Range
Males					
M001	57	10-235	7	4.1	0.7-16.7
M004	108	25-245	3	3.7	2.4-31.7
M011	38	15-55	5	9.3	3.7-12.2
M026	20	15-25	2	3.5	2.7-4.4
Females					
F005	15	5-25	3	3.4	1.1-10.2
F008	93	10-175	2	23.9	1.3-22.6
F028	46	15-80	5	27.0	8.8-47.1
F029	6	5-10	4	0.8	0.7-1.3
F050	59	5-110	5	4.0	0.3-7.5
F060	34	10-125	7	2.9	0.9-10.7
F412	18	5-35	4	4.2	1.2-8.3
F417	43	20-65	2	21.8	10.3-33.3
F422	88	70-105	2	25.0	20.0-30.0

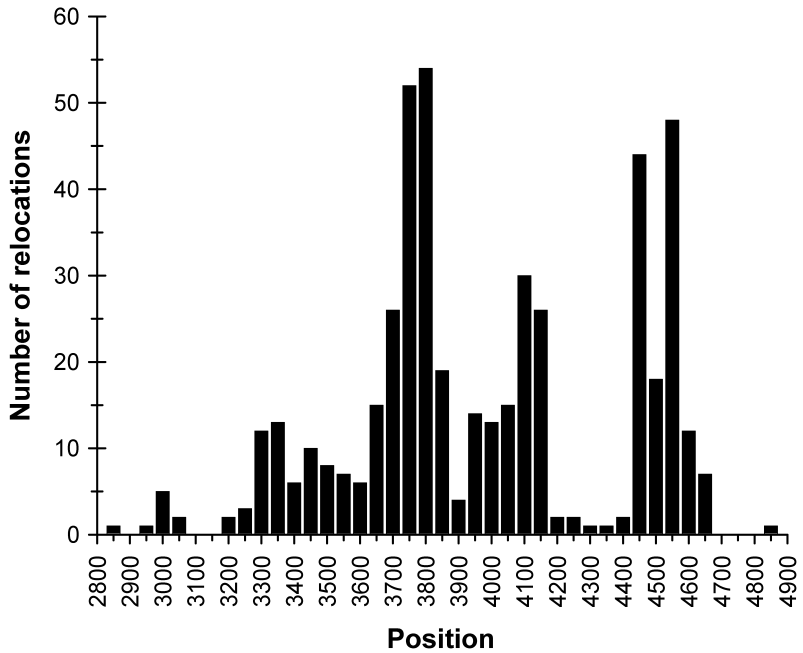

Figure 4. The distribution patterns of the pooled relocations of the radio-tracked *Ocadia sinensis* from 2001 to 2002 in the Keelung River. Each bar represents a 50 m stretch of the river. The numbers of relocation position shown on *x* axis (in metres) were estimated using the distance marks on the banks.

Discussion

Home range and movements

The home ranges of aquatic turtles are usually affected by various biological and environmental factors, including body size (Schubauer, Gibbons and Spotila, 1990), sex (Morreale, Gibbons and Congdon, 1984; Schubauer, Gibbons and Spotila, 1990), reproductive condition (Morreale, Gibbons and Congdon, 1984), sea-

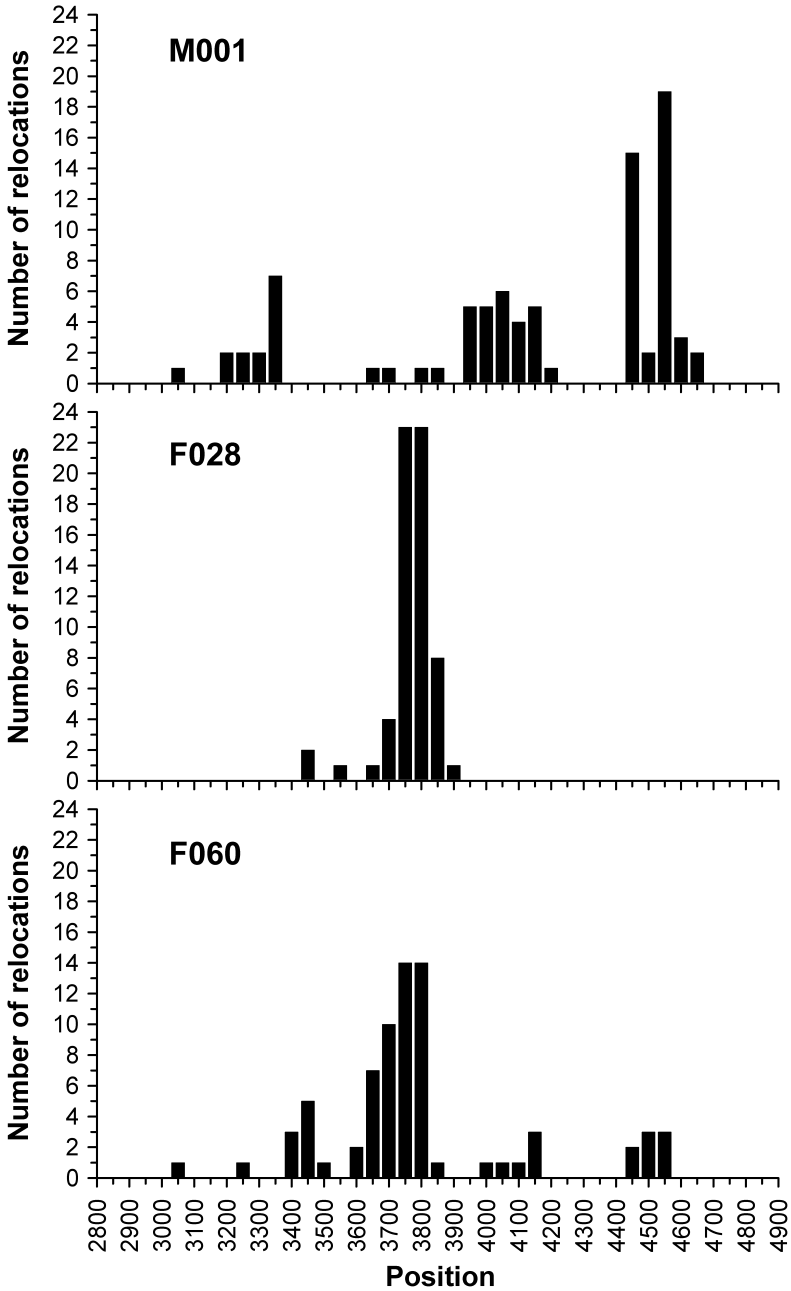

Figure 5. The distribution patterns of the relocations of the three *Ocadia sinensis* (male: M001; female: F028, F060) obtained from the Keelung River. The numbers of relocation position shown on x axis (in metres) were estimated using the distance marks on the banks.

sonal activity (Jones, 1996), water body size (Plummer, Mills and Allen, 1997), and habitat productivity (Brown, Bishop and Brooks, 1994). However, the relationship is highly variable, and the trends are usually species-specific. In the results of radio-tracking for *O. sinensis* based on limited sample size, we found no significant correlations between home range length and sex, body size, or length of tracking period, although there was pronounced sexual size di-

morphism and differential food habits between sexes in this turtle (Chen and Lue, 1998, 1999). Our estimate of home range size can be underrepresentative due to small sample size and duration of tracking. Long-distance movements and extensively terrestrial excursions were usually found in long-term studies of aquatic turtles (Burke, Greene and Gibbons, 1995).

The spatial distribution of aquatic turtles may reflect in part the availability of suitable habitats and food resources (Galbraith, Chandler and Brooks, 1987; Schubauer, Gibbons and Spotila, 1990; Jones, 1996; Goodman and Stewart, 2000; Lindeman, 2003). Some turtles may prefer slow-moving riverine habitat and avoid aquatic areas with high water velocity (Plummer, 1977; Jones, 1996; Bodie and Semlitsch, 2000). The movements of aquatic turtles can be restricted to deeper pools, with the boundaries of the home range defined distinct change of habitat type (Plummer, Mills and Allen, 1997). In our study, turtles were rarely relocated near riffle zones, but were concentrated in deeper sections with low flow rates. Most daily movements of *O. sinensis* were constricted to one single pool, and long distance excursion or terrestrial movements were occurred rarely. The home range length of *O. sinensis* might be affected by the size and connectivity of suitable habitats. Long distance nesting excursions of gravid females were commonly found in aquatic turtles (Obbard and Brooks, 1980; Joyal, McCollough and Hunter, 2001). In our studies, female *O. sinensis* usually nest on the sandbars along the riverbanks (Chen and Lue, 1998). This may explain partly for the rareness of long distance movements for this turtle in the Keelung River.

The home range of turtles may also be affected by the distribution of food resources in the habitat. Turtles usually aggregate in areas with more food (Magnusson et al., 1997). Adult *O. sinensis* feed mainly on leaves of herbaceous plants, aquatic snails, terrestrial and aquatic insects and oligochaeta (earthworm and sewage worm) in the Keelung River (Chen and Lue, 1999). As the primary productivity in the study area was high, enhanced by the nutritional discharge from the nearby industrial park and resident areas (Chen and Lue, 1998), the home range size of *O. sinensis* may not be limited by the supply of food resources in the environments.

The movements of *O. sinensis* in our study usually were confined to one to three deeper pools. Most of the radio-tracked turtles stayed in one pool throughout the tracking period, and only a few individuals moved from one pool to another during the periods of high water or after long periods of low water (fig. 3). During the periods of extremely low water, the shallow river sections may have been unsuitable for *O. sinensis*. Turtles may move and search for deeper pools as refuges. Although the water depth in most river sections in the study area was less than 50 cm in June 2001, *O. sinensis* could seemingly still make upstream or downstream movements in searching for suitable habitat. In a previous study, movements between pools were also recorded rarely in the Keelung River, based on the results of a mark-recapture study (Chen and Lue, 1998).

In the present study, some radio-tagged turtles showed downstream movements during high water after typhoon, but most turtles moved upstream thereafter. Nevertheless, some individuals stayed in the same pool throughout the tracking period. Some lotic turtles have been reported to move downstream during periods of heavy rain and high water (Gibbons, Greene and Congdon, 1990; Plummer, Mills and Allen, 1997). Turtles that made this downstream movement might be influenced by the unidirectional water flow (Pluto and Bellis, 1988; Gibbons, Greene and Congdon, 1990; Doody, Young and Georges, 2002).

Conservation implications for river management projects

Home ranges of turtles may vary over time in response to natural and human-induced habitat changes (Reese and Welsch, 1998; Milam

and Melvin, 2001). The characteristics of the riverine habitats may change greatly within a short distance or a short period after dramatic events. Under natural conditions, the environment may become unsuitable to turtles due to stochastic events. Turtles may leave in search for a better environment or remain in the habitat in quiescent state to confront the environmental extremes (Gibbons, Greene and Congdon, 1990). Our results indicate that *O. sinensis* avoided river sections with degraded habitat, instead using the limited suitable habitat in the river. However, long distance movements were not found.

Habitat modification and anthropologic disturbance may cause turtles to clump in specific suitable habitat (Galois et al., 2002). The distribution of *O. sinensis* was restricted to the limit deeper sections of the Keelung River after the flood control project. Our findings raise conservation concern about loss of deeper, slow-current pools in many river management projects, which was important habitat for *O. sinensis* in their home ranges, and it is especially true as refuges during low water season. Therefore, we suggest that the preservation of critical habitats of aquatic fauna, such as deeper, slow-current pools for *O. sinensis* in the Keelung River, should be considered in the river regulation projects.

Acknowledgements. We thank H. Ota, L. Luiselli and two anonymous reviewers for providing valuable comments on the early drafts of this manuscript. We sincerely appreciate the following individuals who assisted in fieldwork and support for this study: W.-C. Yu, M.-L. Chang, S.-L. Liu and some other kindly residents near the study site. This study was financially supported by the National Science Council and Council of Agriculture, Republic of China [Grants to T.-H. Chen: NSC-89-2621-Z-396-003, NSC-90-2313-B-396-004 and COA-90-AST-1.3.3-F-R1(12)].

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Received: January 28, 2007. Accepted: March 16, 2008.