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Home Range and Habitat Selection of the Endangered Euphrates Softshell Turtle *Rafetus euphraticus* in a Fragmented Habitat in Southwestern Iran

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Abstract. – We present information on movement patterns and habitat selection of the endangered Euphrates softshell turtle *Rafetus euphraticus* (Daudin 1802) from Karkheh Regulating Dam Lake in southwestern Iran. Twelve adult turtles were trapped, fitted with radio-tracking transmitters, and relocated 21 to 51 times between May 2011 and July 2012. The mean linear range size was 2.54 ± 0.83 km, the mean river channel area was 55.35 ± 17.98 ha, the mean minimum convex polygon (MCP) size was 47.49 ± 23.36 ha, and the mean 95% kernel density estimator (KDE 95%) measured 21.75 ± 9.44 ha with a core area (KDE 50%) of 5.74 ± 2.87 ha. Range overlap was generally high; on average, individual MCPs overlapped with those of 7.5 other turtles, individual KDEs with those of 7.3 other turtles, and core areas with those of 5.5 other turtles. Selection of habitat types was not proportional to availability. Study animals preferred shallow-water edge habitats covered with *Phragmites australis* over all other habitat types.

Key Words. – habitat selection; fixed kernel density estimator; minimum convex polygon; linear home range; radio-tracking; Khuzestan Province

The Euphrates softshell turtle, *Rafetus euphraticus* (Daudin 1802), is a highly aquatic and cryptic trionychid turtle found in the Euphrates and Tigris rivers and their tributaries in Turkey, Syria, Iraq, and Iran (Taşkavak and Atatür 1995, 1998; Ghaffari et al. 2008; Biricik and Turğa 2011). In Iran, the species is restricted to the Karoon, Karkheh, Dez, and Jarahi rivers and their tributaries as well as the Hawr-al-Azim marshlands in the southwestern part of the country (Ghaffari et al. 2008). Throughout its range *R. euphraticus* is severely threatened by ongoing habitat destruction and fragmentation caused by conflicts and wars in the past, by drainage to reclaim areas for agricultural purposes, and by an increasing number of dams (Taşkavak and Atatür 1995; Partow 2001; Ihlow et al. 2014). The species is also affected by water pollution through fertilizers and pesticides, oil, garbage, industrial chemicals, and incidental capture with fishing gear (Ghaffari et al. 2008). Populations have been reported to be declining in Turkey and Iran (Gramentz 1991; Taşkavak and Atatür 1995; Ghaffari et al. 2008; Biricik and Turğa 2011). In 1996, *R. euphraticus* was consequently listed as endangered on the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Biricik and Turğa 2011; IUCN 2013).

Impact assessments regarding habitat loss and drivers for population decline are currently lacking and are difficult to formulate without appropriate knowledge on the species' habitat requirements and movement ecology (Pittman and Dorcas 2009). So far the species has been studied almost exclusively in Turkey (Gramentz 1991; Taşkavak and Atatür 1995; Biricik and Turğa 2011). The present study reports the first data on movement patterns, home range sizes, habitat selection, and basking of the endangered species from a fragmented habitat in southwestern Iran.

METHODS

Study Area. — The Karkheh Regulating Dam Lake (KRDL) is situated in the northwestern part of Khuzestan Province in southwestern Iran (Fig. 1). It was part of the Karkheh River until the construction of the Pay-e-Pol Regulating and Diversion Dam, which separated it from the main river in 2009. The study area is bordered by the Karkheh Dam in the north and by the Pay-e-Pol Regulating and Diversion Dam in the south. The meandering lake measures 266.42 ha, is 101 to 658 m wide, and stretches10 km from north to south. The lake is generally deep (10–15 m) but also has shallow edges and several small islands. Tributaries and channels range from 30 to 67 m in width. The KRDL is spring-fed by numerous natural springs. The water level is regulated by dam gates and is highly variable. During the summer and autumn months, a few small temporary ditches exist in

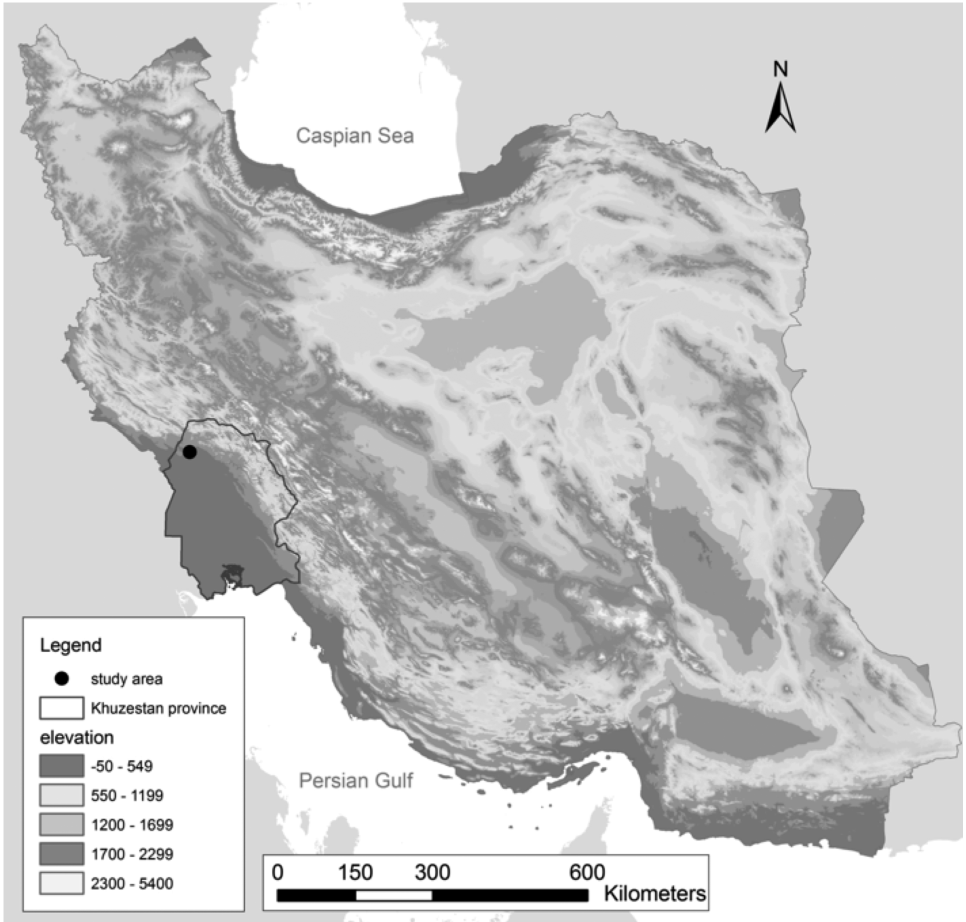

Figure 1. Topographic map of Iran, displaying the study area in Khuzestan Province as a black dot. Map designed using ArcGis 9.3. Elevation data: CGIAR SRTM (Jarvis et al. 2008).

close proximity to the northern edge of the lake that potentially serve as nurseries for *R. euphraticus* hatchlings. The rich submerged vegetation includes *Potamogeton pectinatus* and *Ceratophyllum demersum*. The lake is partly encompassed by a dense stand of *Phragmites australis*, which reaches 3 m in height. The surrounding area is mainly covered by shrubs including *Tamarix* spp. and *Prosopis farcta* and a few scattered trees, mainly *Populus euphratica* and *Ziziphus spina-christi* (Figs. 2 and 3). Several stretches of shoreline without any vegetation potentially serve as basking or nesting sites.

Human population density is generally low, but the area is frequently used by local people for fishing, boating, hunting, and camping. Vertebrate species found in the KRDL include Caspian pond turtles (*Mauremys caspica siebenrocki*), various species of fish (including several species of the genus *Barbus*, *Cyprinus carpio*, *Cyprinion macrostomum*, *Glyptothorax kurdistanicus*, and *Glyptothorax silviae*), and several species of amphibians (e.g., *Pseudepidalea variabilis*, *Hyla savignyi*, and *Pelophylax ridibundus*). Numerous invertebrates, including abundant insect larvae, aquatic insects, and snail species, serve as potential prey for *Rafetus*.

Radiotelemetry and Data Collection. — Fourteen *R. euphraticus* were caught in a large submerged turtle trap. The trap design was developed based on local fishermen's experience and constructed of iron bars and chicken wire (Fig. 4). It was baited with approximately 400 g of fresh chicken intestines placed in bags made of chicken wire. Empty water-bottle buoys marked trap locations and facilitated retrieval. Although trapping in shallow water was more successful in previous studies in Turkey (Gramentz 1991), the trap was placed in a depth of 10 m to prevent it from being taken by local fishermen. The trap was checked every 8–12 hrs to prevent captured turtles from drowning (Kuchling 2003). Although *R. euphraticus* was reported to be mostly diurnal (Gramentz 1991; Taşkavak and Atatür 1995), trapping was unsuccessful during the daytime (between 1000 and 1700 hrs, $n = 6$ d). Thus, trapping was performed during the night between 2000 and 0800 hrs ($n = 13$ nights). The trap was placed in 13 different locations between 1 April and 31 May 2011 (Fig. 4). Fourteen *R. euphraticus* were caught, including 2 juveniles with straight-line carapace lengths (SCL) < 15 cm and 12 turtles with body sizes suitable for radio tracking (SCL > 29 cm).

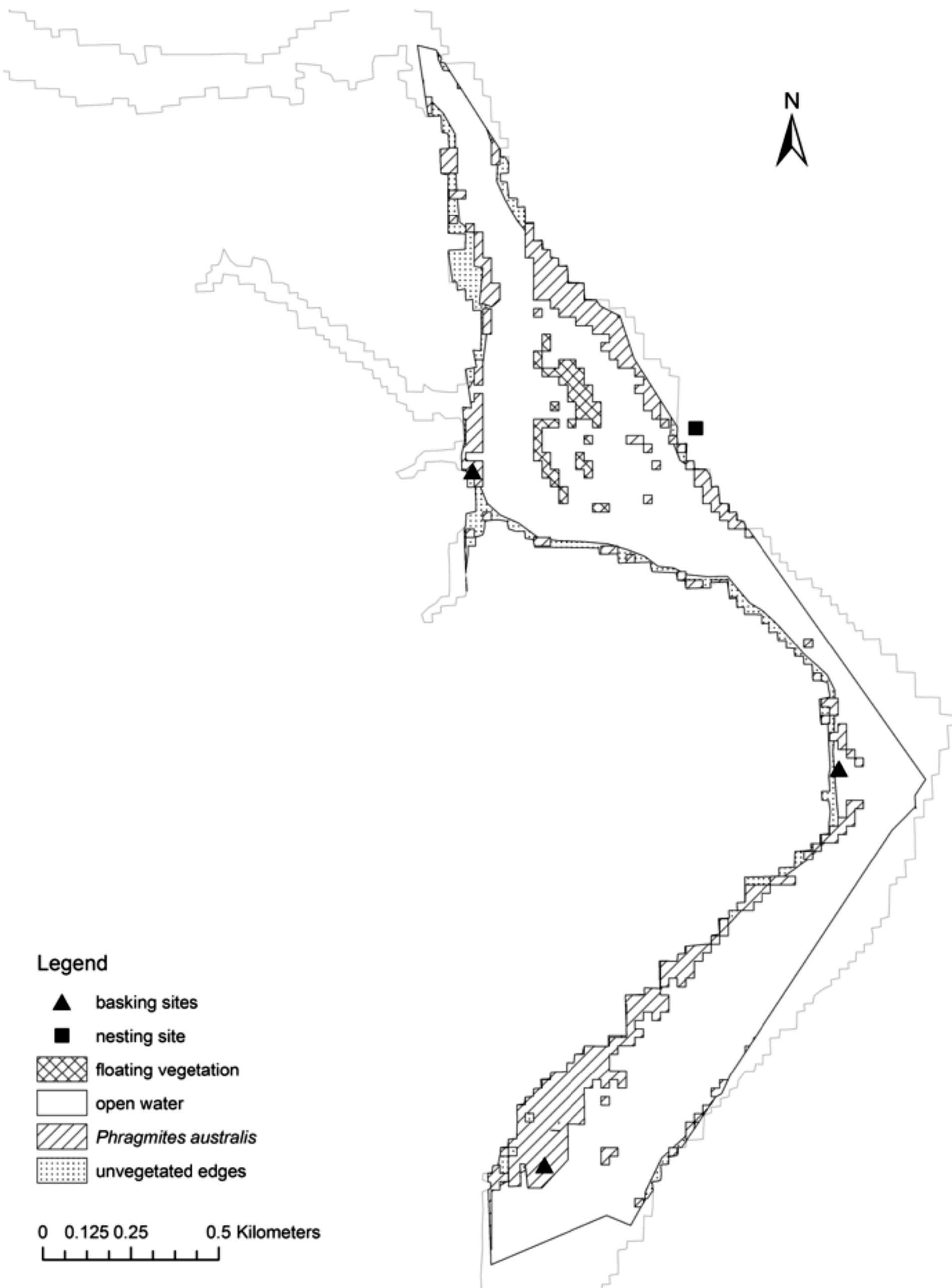

Figure 2. Map of the Karkheh Regulating Dam Lake highlighting the 4 major habitat types available at the study site.

Captured turtles were marked for individual identification using a notching system modified for softshell turtles (Plummer 2008). Morphometric characteristics of turtles were collected following Taşkavak and Atatür (1998) using digital calipers (202010, Vogel Germany GmbH & Co. KG, Kevelaer, Germany). Measurements were taken to the nearest 0.01 mm. The 12 turtles exceeding 29 cm SCL were taken to the Department of Environment in Dezful and fitted with radio-tracking transmitters (164 MHz; Al-2F, Holohil Systems Ltd., Caro Ontario, Canada) by professional veterinarians. After testing, transmitters were mounted on aluminum plates and attached with stainless steel wire (0.9-mm diameter) through 2 holes punched with a needle in the posterior margin of the turtles' carapace (Fig. 5). The wire was passed through a plastic button on the ventral plastral surface to prevent the transmitter from pulling out. The mean weight of the transmitter assembly totaled 35 g and therefore was less than 1.1% of the smallest turtle's body mass (BM; Table 1) and well below the 10% recommended maximum for reptiles (Anonymous 1987). All turtles tagged were released at their capture locations within 2 d of capture.

Fieldwork was carried out for 1 wk per month between May and October 2011, 2 d in January and March 2012, and for 1 wk per month between April and

Figure 3. Habitat of *R. euphraticus* at the Karkheh Regulating Dam Lake in Khuzestan Province, Iran. Left: shallow-water shorelines covered with *Phragmites australis*. Right: calm open water. Photographs by Hanyeh Ghaffari.

July 2012. During fieldwork, turtles were tracked daily between 0800 and 1800 hrs by boat using a hand-held receiver (TRX-1000S W, 164 MHZ, Wildlife Materials International Inc., Illinois, USA) and a 3 element folding Yagi antenna (Yagi 3 Element Folding Antenna, 164 MHZ, Wildlife Materials, Inc., Murphysboro, IL). Locations were recorded using a hand-held global positioning system unit (GPS map 78s, Garmin International Inc., Olathe, KS). At the end of the tracking study all radio-tracking transmitters were carefully removed from the turtles' shells.

Habitat Selection. — Based on remote sensing data (Indian Remote Sensing satellite image, 2007), we constructed a habitat map that subdivided the study area into 4 major habitat types to which turtle locations were assigned (Fig. 2): 1) shallow-water shorelines covered by *Phragmites australis* (20.22 ha, 17%); 2) shallow-water shorelines without any vegetation (7.3 ha, 6%); 3) floating vegetation and shallow vegetated areas inside the KRDL (2.89 ha, 2%); and 4) open, deep water (85.59 ha, 74%).

Data Analysis. — ArcGis 9.3 (ESRI, Redlands, CA) was used to measure linear range (LR) size as the straight-line distance between the most distant locations of each turtle (Sexton 1959; Pluto and Bellis 1988; Lue and Chen 1999). Because the species is highly aquatic, LRs crossing terrestrial areas were modified to represent the shortest distance in water (Carrière 2007).

Turtles' movements were analyzed using a river channel area (RCA) estimator, a minimum convex polygon estimator (100% MCP; Mohr 1947), and 95% and 50% fixed kernel density estimators (KDE). The RCA was determined by multiplying the aquatic LR length of each turtle by average river width (Plummer et al. 1997; Doody et al. 2002; Kay 2004; Souza et al. 2008).

The MCP connects the outermost relocation points, which yields a convex polygon that provides a maximum home range estimate but does not provide information on habitat use and selection (Kenward 2001; Row and Blouin-Demers 2006; Ryan et al. 2006). Furthermore, MCPs often include unused or unavailable habitats such as terrestrial habitats for highly aquatic species. To address this issue the terrestrial portion of each MCP was excluded based on satellite pictures (Indian Remote Sensing satellite map, resolution 24 m). An MCP is usually dependent on the number of fixes (Jenrich and Turner 1969). Due to several field constraints, equal numbers of fixes could not be gathered for turtles. Despite the disadvantages of the MCP method, it is the most frequently used approach to analyze animal movement (Powell 2000; Nilson et al. 2008) and therefore can facilitate comparisons of results with previous studies (Nilson et al. 2008). MCPs were calculated using ArcGis 9.3 and the Hawth's Analysis Tool extension (Beyer 2004).

The KDE provides a probability range around each location, giving areas used more frequently a higher value; it therefore provides information on habitat selection patterns by quantifying the intensity of use within an area (Row and Blouin-Demers 2006). Estimates of total home range (95% KDEs) and core areas (50% KDEs) were performed using ESRI ArcGis 9.3 and the Hawth's Analysis Tool extension. The smoothing parameter h was determined by least-square cross validation using Animal Space Use 1.3 (Horne and Garton 2009). To ensure comparability of KDEs, the mean smoothing parameter ($h = 50.22$) was used as recommended by Kenward (2001). Due to the turtles' highly aquatic lifestyle, the terrestrial portion was excluded from the resulting KDEs based on satellite pictures. In addition, interindividual overlap areas of MCPs, KDEs, and core areas were compared. One individual was excluded from the analysis due to an insufficient number of fixes ($n = 6$; minimum number of fixes required $= 20$).

The term ''home range'' was applied as defined by Kenward (2001) as ''an area repeatedly traversed by the study animal.'' An incremental area analysis was performed on MCP estimates of home range to assess whether home range size estimates reached asymptotes,

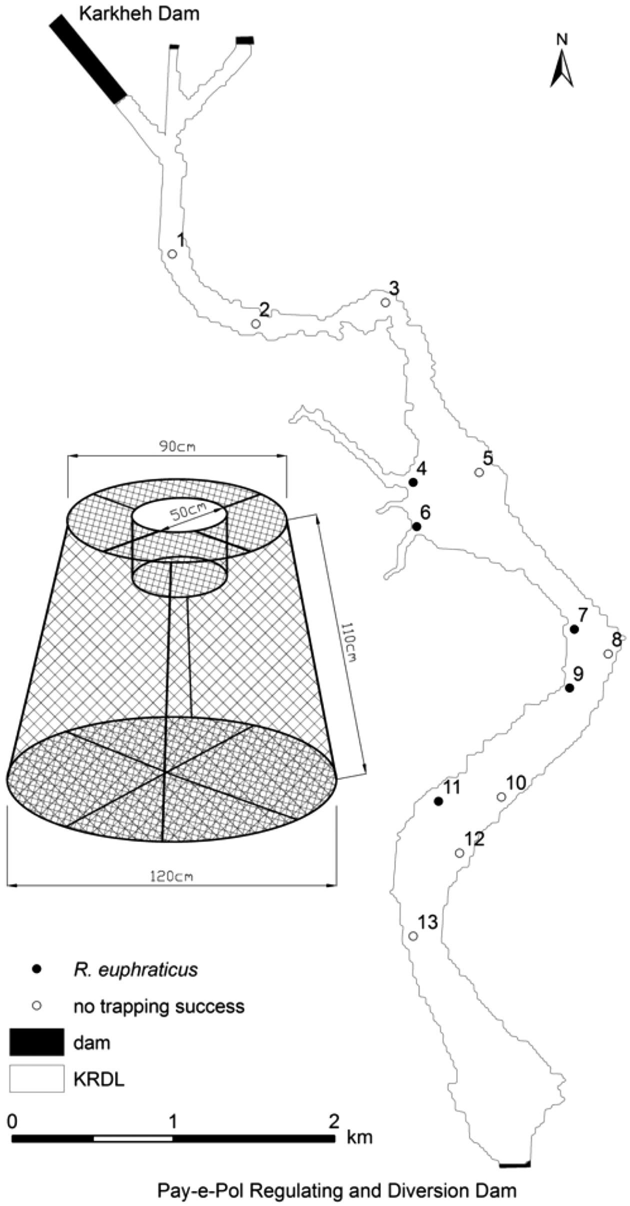

Figure 4. Industrial drawing of turtle trap construction as well as a map of the Karkheh Regulating Dam Lake indicating trapping locations.

using a randomized resampling approach with 10 iterations in the packages ''adehabitat'' (Calenge 2006), ''maptools'' (Bivand and Lewin-Koh 2013), and ''fields'' (Furrer et al. 2013) for Cran R (R Development Core Team 2012) as described by Harris et al. (1990) and Kernohan et al. (2001). In order to investigate whether turtles performed nomadic movements or exhibited site fidelity, the radio-tracking data sets were compared with computer-simulated distribution models (Munger 1984; Spencer et al. 1990; Turchin 1998; Schwarzkopf and Alford 2002). ''Random walk models'' (RWMs) were performed for each turtle using ''turning angles'' and ''distances between successive fixes'' from real radio-tracking data using a bootstrapping approach with 100 iterations using the above packages for Cran R (Turchin 1998). A total of 100 RWMs were generated for each turtle's kernel density estimate home range and core area and compared with real observed movement. Animals are deemed to be exhibiting site fidelity when observed distributions of real individuals are significantly smaller than computer-simulated RWMs (Munger 1984; Spencer et al. 1990).

Range overlap for each turtle was determined as the percentage of its total home range that overlapped ranges of other turtles (Geffen and Mendelssohn 1988). The analysis was performed using the ''adehabitat'' package for Cran R (Calenge 2006).

Data were checked for normality using a Kolmogorov-Smirnov test and $\log_{10}$-transformed prior to statistical analysis with SPSS 14.0 (SPSS Inc., Chicago, IL). Significance was determined at $\alpha = 0.05$. The relationship of range size and body size was determined using a Spearman's rank correlation test. Potential habitat selection was determined using a χ^2 goodness-of-fit test (Neu et al. 1974; Manly et al. 2002; Ryan et al. 2006). Confidence intervals were determined using a Bonferroni z-test (Neu et al. 1974; Ryan et al. 2006). Range estimates tend to increase with number of fixes, which may lead to a bias if sample sizes obtained are variable among study animals (White and Garrott 1990). As sample size in this study was highly variable, a linear regression analysis of MCP sizes on number of fixes was performed to analyze the data set for a potential bias due to sample size (Dreslik et al. 2003). Means are reported as $\pm$ 1 standard deviation (SD).

RESULTS

Turtle Trapping. — Trapping was successful in 5 of 13 trapping locations (38.5%), all along the western shore (Fig. 4). The highest numbers of *R. euphraticus* were caught in locations 6 and 9 ($n = 3$ each). Successful trapping locations were less than 20 m from densely vegetated water edges (habitat type 1). Two successful trapping locations (4 and 6) were situated at the entrance of side channels. Sixty percent of the study animals were caught within their subsequently defined 95% KDE range, 20% were caught in close proximity (5–20 m) to their subsequently defined 95% KDE range, and only 20% were caught at greater distances. Thirty percent of the study animals were caught within their core areas, 20% were caught in close proximity (5–20 m), and 50% were caught more than 20 m from their core areas.

Home Range Size. — Due to transmitter failure in 4 cases, movement was analyzed for a total of 8 turtles. Except for occasional basking, movement was exclusively aquatic (96%; $n = 254$ total number of fixes).

Incremental area analysis curves for turtles' MCPs revealed that 22 fixes were required to capture 90% of the study animals' home range size, suggesting the study period was sufficient to obtain home range size estimates (Fig. 6). Comparison of observed movements and results gained by the simulated RWMs revealed turtles' observed

Figure 5. *Rafetus euphraticus* with a very-high-frequency radio-tracking transmitter attached to its posterior carapace. Photograph by Hanyeh Ghaffari.

movement patterns to be significantly smaller than random walk estimates, suggesting that turtles exhibited site fidelity (Table 2).

Mean LR size was 2.54 ± 0.83 km SD and ranged from 0.80 to 3.41 km with a coefficient of variation (CV) of 33% (Fig. 7). Mean RCA was 55.35 ± 17.98 ha SD and ranged from 17.38 to 71.24 ha (CV = 32%). There was no statistically significant relationship of LR/RCA size with either SCL or BM (LR/RCA with SCL: $r_s = -0.517$, $p = 0.15$, $n = 9$; LR/RCA with BM: $r_s = -0.143$, $p = 0.76$, $n = 7$). Sizes of MCPs varied greatly among individuals (range 13.17–87.16 ha, CV = 49%) with a mean size of 47.49 ± 23.36 ha SD (Fig. 7). There was no significant relationship of MCP size with body size (MCP and SCL: $r_s = -0.429$, $p = 0.29$, $n = 8$; MCP and BM: $r_s = -0.486$, $p = 0.33$, $n = 6$).

The number of fixes was highly variable among individuals (range 20–51) and a linear regression analysis between range size estimates and the number of fixes obtained revealed a statistically significant bias ($r^2 = 0.564$, $p = 0.032$, $n = 8$). The turtles' mean total KDE size was 21.75 ± 11.23 ha SD while individual 95% KDEs ranged from 9.04 to 39.51 ha (Fig. 8). While there was no relationship between SCL and 95% KDE size ($r_s = -0.595$, $p = 0.12$, $n = 8$), 95% KDE size was significantly related to BM ($r_s = -0.886$, $p = 0.019$, $n = 8$). Mean core area was 5.74 ± 2.87 ha SD (range 2.59–9.91 ha; Fig. 8) and was significantly negatively related to both SCL and BM (50% KDE and SCL: $r_s = -0.714$, $p = 0.047$, $n = 8$; 50% KDE and BM: $r_s = -0.943$, $p = 0.005$, $n = 6$).

Home Range Overlap. — The MCP of each turtle overlapped with MCPs of 6–8 other turtles (mean =

Table 1. Summary of turtles' body size and home range by minimum convex polygon (MCP), 95% and 50% kernel density estimator (KDE) core areas, linear range (LR), and river channel area (RCA).

			Home range sizes				
ID	Mass (kg)	SCL[a] (cm)	MCP (ha)	95% KDE (ha)	50% KDE (ha)	LR (km)	RCA (ha)
1	4.60	29.50	87.16	39.51	9.91	3.27	71.24
2	3.20	53.00	38.37	12.74	2.59	2.85	62.05
3	10.10	48.30	60.70	21.05	4.76	2.57	55.87
4	—	31.00	75.36	31.81	8.57	3.41	74.34
5	12.80	35.50	39.77	25.21	7.09	2.96	64.34
6	8.00	55.00	39.08	16.19	4.44	3.02	65.66
7	3.45	35.00	13.17	9.04	3.67	1.40	30.43
8	—	33.00	—	—	—	2.61	56.85
9	14.00	38.00	26.30	18.46	4.89	0.80	17.38

[a] SCL, straight-line carapace length.

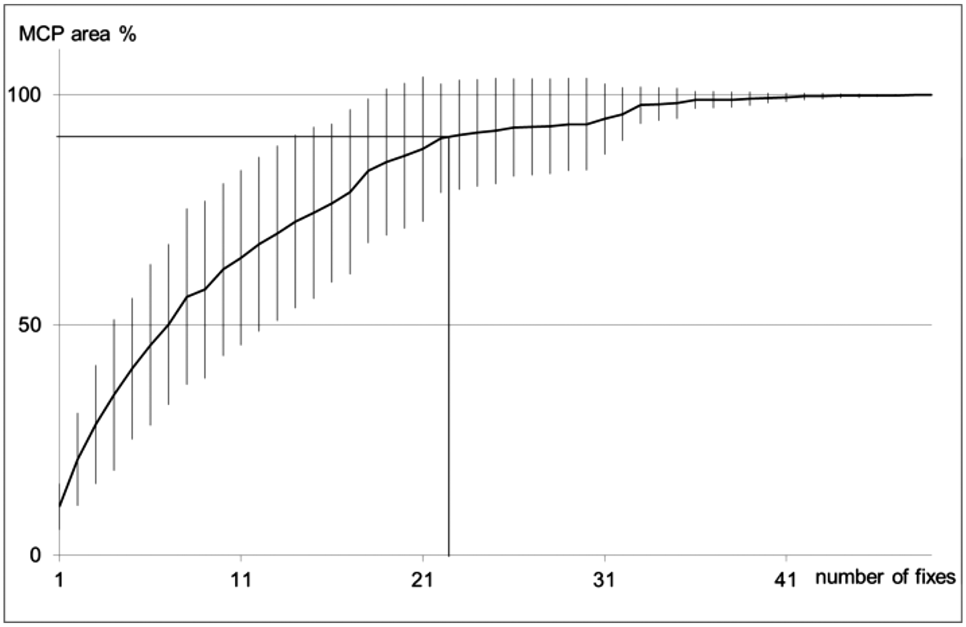

Figure 6. The incremental area analysis plot illustrates that 22 fixes were needed to capture 90% of a study animal's minimum convex polygon (MCP) home range size (horizontal bar). Vertical bars represent ranges of mean MCP area.

7.5 ± 0.71 SD, $n = 8$; Table 3). The mean area of MCP overlap varied among individuals between 10.99 ± 3.92 ha SD (range 2.74–13.46 ha, $n = 6$) and 32.47 ± 16.66 ha SD (range 5.08–61.05 ha, $n = 8$).

Total KDEs overlapped with 5–7 other turtles (mean = 6.31 ± 0.78 ha SD, $n = 8$) with mean overlap areas ranging from 4.75 ± 2.52 ha SD to 10.04 ± 4.25 ha SD among individuals (Table 3). Core areas overlapped with 4–7 core areas of other study animals (mean = 5.50 ± 1.22 SD; $n = 8$).

Habitat Selection. — Due to low sample sizes in some habitats, habitat data from individual turtles were pooled for analysis. Selection of habitat types was not proportional to availability ($\chi^2_3 = 2623$, $p < 0.0001$). Bonferroni confidence intervals (95%) showed proportion of use for habitat type 1 (vegetated shorelines) was greater than the expected proportion of use, whereas the proportions of use for habitat types 3 (floating vegetation) and 4 (open, deep water) were below expected proportions of use (Table 4). Analysis of habitat selection of individual turtles was not possible due to insufficient numbers of observations (< 5 observations) in several habitat type categories.

Basking and Nesting Habits. — *Rafetus euphraticus* was observed basking along vegetated shorelines (35%), atop halms of *Phragmites australis* (30%), and on floating trunks of fallen trees within dense foliage (20%). In addition, turtles were observed to bask partially submerged on gravel along the shoreline (14%) and fully exposed on the muddy shoreline approximately 1 m from the water's edge (1%). During basking, an individual's head and limbs were often extended, as described by Gramentz (1991). One female was observed nesting on the east shore by a local fisherman in 2011 but we could not find nests despite intensive searching.

Table 2. Range size estimates performed using kernel density estimators (KDEs, including the terrestrial portion) in comparison with range sizes obtained from simulated random walk models. Results indicate *Rafetus euphraticus* possess home ranges, rather than exhibiting a nomadic movement pattern.

ID	95% KDE obs. (ha)	CI 95%[a]	*s*[b]	50% KDE obs. (ha)	CI 95%	*s*[b]
1	26.26	47.7–101.49	−	7.11	13.2–14.5	−
2	37.91	30.3–33.0	+	8.93	7.4–8.1	+
3	25.05	29.0–32.3	−	5.23	5.9–6.7	−
4	43.58	45.8–49.9	−	10.27	10.6–11.5	−
5	15.16	24.2–27.6	−	2.70	6.4–7.2	−
6	21.14	23.2–25.6	−	4.99	6.0–6.7	−
7	9.38	17.9–20.3	−	3.67	4.7–5.4	−
9	18.36	37.2–40.2	−	4.82	10.0–10.9	−

[a] CI 95%=95% confidence interval.
[b] Significant alteration of observed range size used and random walk model results. − = site fidelity; 0 = random movement; + = observed movement exceeds random walk predictions.

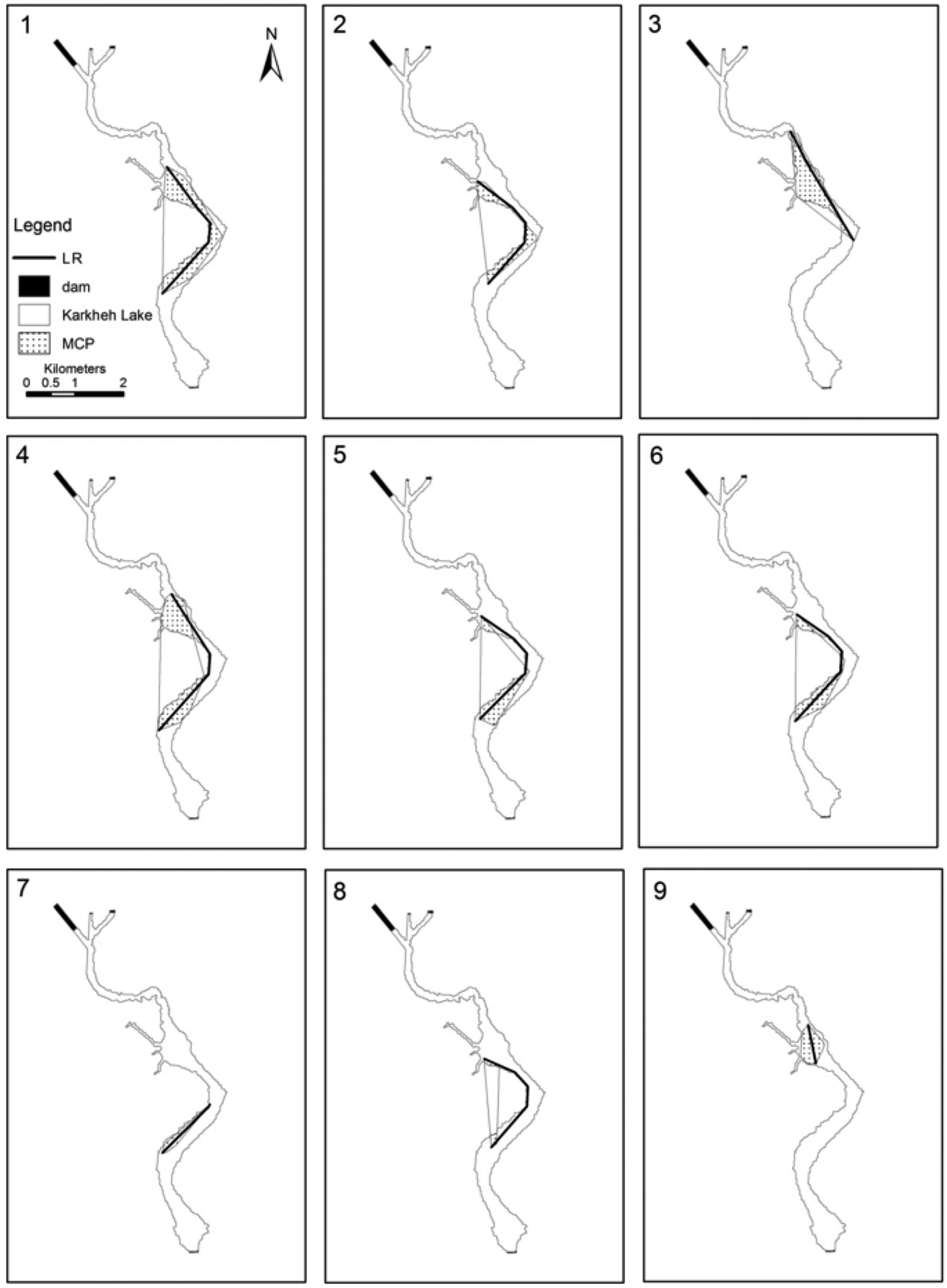

Figure 7. Map of the study area showing the turtles' linear range (LR) and minimum convex polygon (MCP) home range. Map designed using ArcGis 9.3.

DISCUSSION

LR Size. — The only previously reported LR estimates for trionychid turtles include the American species *Apalone mutica* (0.7 km in a small river; Plummer and Shirer 1975) and *Apalone spinifera* (1.5 km in a small stream, Plummer et al. 1997; 11.1 km in a large river, Galois et al. 2002). Differences in sample sizes, study period, species, and habitat type hamper a direct comparison among studies.

Home Range Sizes. — The use of different analytical methods complicates comparison of results obtained in this study with those of previous studies. The MCP estimator is heavily influenced by outlying locations and therefore may incorporate areas that have never been used by the animal and as a consequence, often overestimates range size (Powell 2000; Kenward 2001). According to Borger et al. (2006), MCPs are subject to unpredictable bias. Nilson et al. (2008) also questioned the ecological value of the MCP. Nevertheless, the MCP is commonly used to perform home range estimates and to facilitate inter- and intraspecific comparison of different studies.

The KDE is currently the most widely used approach for home range estimates and habitat selection analysis

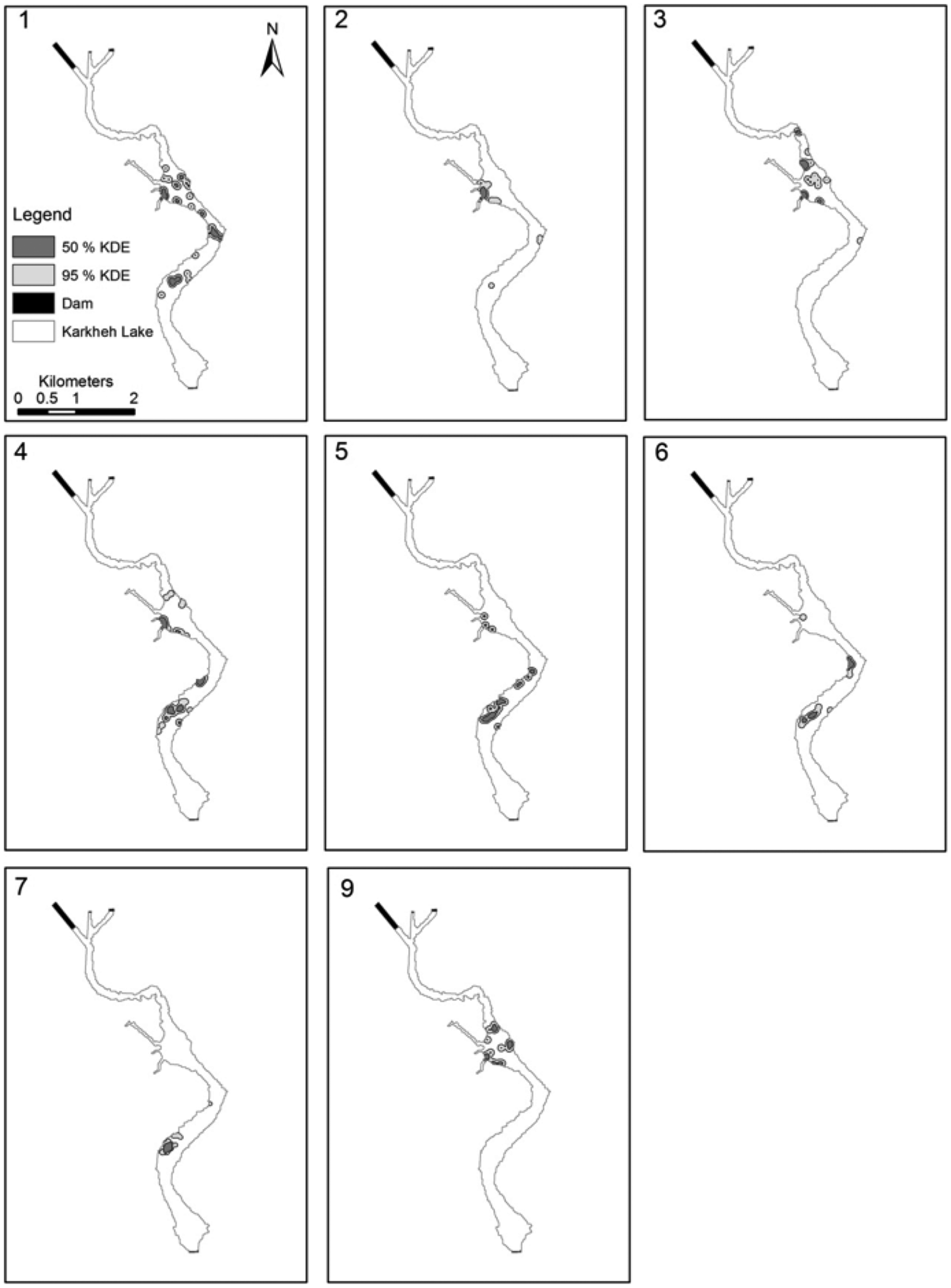

Figure 8. Map of the study area showing the turtles' 95% and 50% KDE home ranges. Individual no. 8 was excluded from the analysis due to an insufficient number of fixes ($n = 6$; minimum number of fixes required = 20). Map designed using ArcGis 9.3.

(Worton 1995; Seaman and Powell 1996; Seaman et al. 1999). However, the kernel technique may not accurately estimate home range sizes for reptiles as the frequent multiple use of locations by an ectotherm leads to autocorrelation (Row and Blouin-Demers 2006). Home range size is generally known to depend on the study animal's body size (Harestad and Bunnell 1979), which previous studies confirmed for several reptile species, including aquatic chelonians (Schubauer et al. 1990; Plummer et al. 1997; Perry and Garland 2002; Carrière 2007). Despite the low sample size for *R. euphraticus*, the KDE method revealed statistically significant relationships of home range sizes with BM and SCL, whereas these relationships could not be demonstrated using the MCP method. Whereas range size may depend on habitat quality and resource availability, range shape and location may reflect resource distribution and abundance (Bury 1979; Harestad and Bunnell 1979; Savitz et al. 1983; Ims 1987; Macartney et al. 1988; Brown et al. 1994; Kenward 2001; Kjellander et al. 2004). Compared with studies conducted in relatively undisturbed areas, Galois et al. (2002) suggested that range size might increase with increasing habitat fragmentation and modification, as in this study.

Table 3. Overlap of movement areas of 8 *Rafetus euphraticus*, given as percentage of the total range of the individuals listed in the left column (see Table 1 for definition of abbreviations).

MCP

ID	1	2	3	4	5	6	7	9
1		42.92	49.44	70.04	41.94	45.66	15.44	26.74
2	97.51		40.62	74.21	58.06	64.31	25.44	23.12
3	70.99	25.67		60.66	7.12	11.00	0.00	43.59
4	81.01	37.78	48.86		47.58	44.88	17.66	34.76
5	91.93	56.01	10.87	90.16		88.40	33.52	8.93
6	100.00	63.14	17.09	86.55	89.97		34.20	11.73
7	100.00	74.11	0.00	100.00	100.00	100.00		0.00
9	88.59	33.72	100.00	99.60	13.50	17.43	0.00	

95% KDE

ID	1	2	3	4	5	6	7	9
1		21.17	38.48	42.86	25.81	24.16	7.11	31.37
2	65.64		100.00	53.49	43.71	18.54	6.87	48.11
3	54.40	25.26		31.89	7.31	0.00	0.00	50.08
4	53.23	21.43	61.26		50.77	26.83	20.08	25.51
5	40.46	22.10	6.10	64.08		44.33	30.66	30.66
6	58.95	14.59	0.00	52.71	69.00		36.66	1.26
7	31.11	9.69	0.00	70.70	85.54	65.70		0.00
9	67.14	33.21	100.00	43.96	17.61	1.11	0.00	

50% KDE

ID	1	2	3	4	5	6	7	9
1		19.30	15.60	40.45	14.88	17.70	2.60	15.23
2	73.88		43.76	80.17	8.83	0.00	0.00	37.32
3	32.48	23.79		28.20	3.39	0.00	0.00	23.72
4	46.76	24.21	15.66		20.32	8.80	11.18	15.53
5	20.79	3.22	2.27	24.57		30.85	30.25	2.83
6	39.47	0.00	0.00	16.98	49.24		29.14	0.00
7	7.01	0.00	0.00	26.10	58.40	35.24		0.00
9	30.85	19.75	23.09	27.23	4.11	0.00	0.00	

The only areal ranges reported for a trionychid turtle are those for *A. spinifera* in a small stream (11.6 ha; Plummer et al. 1997) and a large river (2424 ha; Galois et al. 2002). The mean river channel area (55.35 ha) as well as the slightly smaller mean MCP 100% home range (47.49 ha) for *R. euphraticus* in a much wider lake is comparable to the 95% MCP reported by Galois et al. (2002). Correlation of habitat size and range size in freshwater turtles has previously been reported (Plummer et al. 1997).

Plummer and Shirer (1975) and Galois et al. (2002) reported females' ranges to be significantly larger than those of males or subadults in *A. mutica* and *A. spinifera*. As we were unable to determine sex or reproductive condition of turtles, their possible effects on range size in *R. euphraticus* is unknown.

The data collection intervals in our study were highly variable with several fixes obtained in a single day and gaps of several weeks between subsequent field trips. Since we required at least 20 fixes to calculate a home range, we included all fixes in the analysis. Because this inclusion likely resulted in an autocorrelated data set and biased home range estimates (White and Garrott 1990), results should be treated with caution.

Home Range Overlap. — As with *R. euphraticus*, home ranges are known to overlap among individuals of *A. mutica* and *A. spinifera* (Plummer and Shirer 1975; Plummer et al. 1997). As a possible indicator of intraspecific aggression in *R. euphraticus*, bite marks along the posterior carapace edges have been reported by Gramentz (1991) and along the lateral and caudal carapace edges by Taşkavak and Atatür (1995). Bite marks were present in both sexes and different size and age classes (Gramentz 1991; Taşkavak and Atatür 1995). Bite marks commonly occur on the posterior edge of the carapace of male *A. mutica* and *A. spinifera* and are related to courtship aggression by females (Plummer 1977b; M.V. Plummer, *pers. obs.*). We found few bite marks along the lateral carapace edge of adult *R. euphraticus* in our study, suggesting either lower levels of aggression or lower population density. Trapping success in the present study was low in comparison with studies of *R. euphraticus* in Turkey (Taşkavak et al., in press), also suggesting either low population density or a reluctance to enter traps.

Habitat Selection. — In Turkey and Iran, *R. euphraticus* generally inhabits calm and shallow rivers, preferring tributaries and the shallow backwaters of main river channels and seasonal ponds and wetlands. Habitat preferences may differ between adults and juveniles (Gramentz 1991; Taşkavak and Atatür 1995, 1998; Ghaffari et al. 2008; Taşkavak et al., in press). Adults preferred tributaries with access to deeper water (up to 2 m), whereas juveniles preferred puddles (10–15 cm

Table 4. Habitat selection of *Rafetus euphraticus*.

Habitat type	True proportion of observations (p_i)	Proportion of habitat (p_{io})	CI 95% (p_i)[a]	*sp*[b]	True no. of observations	Expected no. of observations
1	0.84	0.063	$0.78 \leq p_i \leq 0.89$	+	214	16
2	0.04	0.023	$0.01 \leq p_i \leq 0.07$	ns	11	6
3	0.06	0.173	$0.02 \leq p_i \leq 0.1$	−	16	44
4	0.05	0.740	$0.01 \leq p_i \leq 0.08$	−	13	187
Total					254	254

[a] 95% confidence interval of area under an expected selection hypothesis.
[b] Significant preference for habitat type: + = significantly higher than expected; − = significantly below expected; ns = not significant.

deep) with higher water temperatures and abundant potential prey (Gramentz 1991; Taşkavak and Atatür 1995). Our results show that *R. euphraticus* favored vegetated shorelines over open deep water in concordance with the previous studies in Turkey. While vegetated shorelines are essential for nesting (Ghaffari et al. 2013), vegetated edges may serve as refuge in disturbed habitats such as reservoir lakes. Therefore the presence of such vegetated shorelines is considered an important feature, providing retreats for the endangered species, especially in disturbed habitats. The preference for shoreline habitat may be related to the higher water temperatures at the edges or activity levels. For example, foraging individuals might select areas of higher food abundance (plant material, insect larvae, crustaceans, mollusks, amphibians, and fish) within the dense *Phragmites australis* stands along the lakes edges compared to deep open water, whereas inactive individuals might select areas based on suitability of retreat sites (Siebenrock 1913; Taşkavak and Atatür 1998). We had difficulties determining the activity level of animals in dense vegetation as they were easily disturbed when approached. Additional research needs to be done to clarify this issue.

Although the results of statistical analysis generally agreed with observations of habitat selection made, avoidance of habitat type 3 (floating vegetation) does not. The distribution and abundance of vegetation at the KRDL is known to be highly variable among seasons and years. The satellite images used were taken in 2007 and vegetation cover likely has changed since dam construction. In addition, habitat selection analysis procedure requires that temporal spacing between observations is free from autocorrelation (Byers and Steinhorst 1984), which unfortunately was not the case in this study. Gramentz (1991) suggested habitat use and selection might vary seasonally in *R. euphraticus*. Unfortunately, data spanning all seasons in this study were few, especially for the winter. Likewise, although sexual differences in habitat selection in softshell turtles are known (Plummer 1977a), no comparable data for *R. euphraticus* were collected.

Basking Habits. — Basking of individuals or groups of up to 10 *R. euphraticus* was observed by Griehl (1981). In concordance with Gramentz (1991), basking was frequently observed close to the water's edge, mostly on the muddy shore but also on grass or stone. Turtles in this study tended to bask in more hidden places such as vegetated shorelines, floating tree trunks, and floating vegetation, which may be related to frequent disturbance by fishermen.

Conservation Status. — Recent regulations of rivers for flood control and hydroelectric power have severely altered environmental conditions (Partow 2001). Water level fluctuation and decreasing temperatures have been reported to cause the depletion of food items and induce changes in aquatic and riverine vegetation that strongly affect freshwater turtle populations (Dodd 1990; Gramentz 1993; Taşkavak and Atatür 1995, 1998). Severe population decline as a response to dam constructions on the Euphrates River was reported by Gramentz (1993) and Taşkavak and Atatür (1998). Channelization and dam construction were also found to heavily fragment remnant populations of *R. euphraticus* (Ihlow et al. 2014). Currently *R. euphraticus* is threatened by the construction of several additional dams across its range, which will cause further habitat fragmentation and loss and may even increase the probability of local extinction (Gramentz 1991). In addition, the species is affected by water pollution through pesticides, fertilizers, oil, garbage, and industrial chemicals (Ghaffari et al. 2008). Turtles are frequently caught accidentally on baited hooks or entangle themselves in fishing nets (Ghaffari et al. 2008). Despite fishing being prohibited in April and May in Khuzestan Province, people were observed fishing throughout the year, sometimes even using illegal electrofishing (H. Ghaffari, *pers. obs.*). Because turtles are wrongly believed to be detrimental to fish populations, they are often killed by fishermen (Ghaffari et al. 2008).

As the endangered species' survival may soon become critical, knowledge of its ecology is desperately needed to prepare a conservation management plan for the species. To successfully sustain viable populations, hunting, fishing, and pollution need to be reduced to a minimum while patrolling needs to be initiated. Considering our results on range sizes and habitat selection, future conservation efforts should focus on large but shallow interconnected wetlands and rivers with side channels and backwaters. Regarding the increasing modification of natural rivers, artificial habitats considered suitable for *R. euphraticus* should provide unvegetated water edges as well as retreat sites covered with vegetation. To prevent further fragmentation of populations through dams, future dam constructions should be equipped with passes for turtles and other aquatic species to facilitate emigration (Ihlow et al. 2014).

To establish successful conservation management, we consider capacity-building and education of the native populations to be highly important. A program to protect the Euphrates softshell turtle populations in Khuzestan Province was carried out by the Pars Herpetologists Institute from 2009 to 2012 through a partnership program with the Global Environment Facility funded by the Small Grants Programme of the United Nations Development Programme. The project focused on education and raising awareness and highlighting the necessity of conservation measures to protect and conserve the Euphrates softshell turtle. This project already has proven successful and induced a significant behavioral change among the local population, providing confidence for future projects. The establishment of the introduced softshell turtle species *Pelodiscus sinensis*, abandoned from the pet trade, may become another threat for the species in the near future. Although *R. euphraticus* is not consumed by native

Iranians, Chinese employees of the National Iranian Oil Company catch the species for human consumption, especially in the Hawr-al-Azim wetland and along the border with Iraq.

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