Chelonian Conservation and Biology, 1997, 2(4):494–499

Home Range of the Turtle, *Phrynops rufipes*, in an Isolated Reserve in Central Amazônia, Brazil

WILLIAM E. MAGNUSSON[1], ALDENIZA CARDOSO DE LIMA[1], VALDENISE LOPES DA COSTA[1], AND RICHARD C. VOGT[1,2]

[1]*Departamento de Ecologia, Instituto Nacional de Pesquisas da Amazônia, Caixa Postal 478, Manaus, Amazonas 69011-970 Brazil [Fax: 55-92-642-1838; E-mail: bill@inpa.gov.br];*
[2]*Instituto de Biologia, Universidad Nacional Autonoma de México, Apartado Postal 91, San Andres Tuxtla, Veracruz, 95700 México*

ABSTRACT. – ***Phrynops rufipes* is known from scattered localities throughout western Amazônia. We studied the species in small, closed-canopy streams in Reserva Florestal Adolpho Ducke, Amazonas, Brazil. A 15-year mark-recapture study indicates that most individuals have small (1–2 linear km of stream) home ranges within the reserve and that they remain in those home ranges over long periods. Individuals move between and among drainage basins within the reserve but there is no evidence that dispersal into surrounding agricultural and urban land will compromise the stability of the reserve population.**

KEY WORDS. – **Reptilia; Testudines; Chelidae; *Phrynops rufipes*; turtle; ecology; home range; movement; activity; Brazil**

For species which are limited by habitat availability in reserves, population size should be proportional to reserve size in reserves with fairly uniform habitat. However, although important, population size is not the only determinant of population viability (McCullough, 1996). If individuals migrate or disperse beyond the reserve and are there subject to increased mortality (e.g., Mattson et al., 1992), the initial population size on the reserve may erode quickly. This is especially important for long-lived animals with large or shifting home ranges (e.g., Congdon et al., 1993). In this paper, we investigate the potential effects of individual movements on the probability of persistence of an aquatic turtle population in an isolated reserve in central Amazônia, Brazil.

Based on the number of museum specimens, *Phrynops rufipes* (Fig. 1) has been described as one of the rarest of all turtles (Pritchard, 1979). It is restricted to closed-canopy rainforest streams and appears to be a trophic specialist, feeding on palm fruits throughout its range (Lamar and Medem, 1984; Lima et al., 1997). It is relatively fast growing; females probably attain sexual maturity at 6–10 years of age (Magnusson et al., 1997). The species has been recorded from few localities and Lamar and Medem (1984) considered it to be overhunted by indigenous people in some localities of eastern Colombia.

A population of this species occurs in Reserva Florestal Adolpho Ducke, Amazonas, Brazil (02°58'S, 59°56'W), where other ecological studies of this species have been undertaken (Lima et al., 1997; Magnusson, et al., 1997). The reserve is on the outskirts of Manaus and is in the process of being isolated from the surrounding forest by housing developments and agricultural activities (Fig. 2). Although near the city, the reserve is fairly large (ca. 100 km^2) and the headwaters of most of its streams are located within the reserve.

The goals of our study were to determine: 1) whether individuals have fixed home ranges, 2) whether those home ranges can be contained within the reserve, 3) whether interchange of individuals occurs between drainage basins within the reserve, and 4) whether the number of turtles in the reserve is likely to be sufficient to buffer the population against demographic and genetic stochasticity when the reserve becomes completely isolated.

METHODS

The study was undertaken in an area around a small stream, Igarapé Acará (Fig. 3), and one of its smaller tributaries (Fig. 4) near the center of the reserve (Fig. 5). The area has been described in detail by Magnusson and Lima (1991). Some study was also performed in a small stream, Igarapé Barro Branco, in an adjacent drainage basin close to the edge of the reserve.

In the study area, Igarapé Acará is about 4 m wide and varies from about 20 cm to about 2 m in depth. The smaller tributary and Igarapé Barro Branco are both about 2.5 m wide and vary from about 10 cm to about 1 m deep. The water is usually crystal clear in the dry season (usually July – November) and transparent, but stained by brown organic acids, in the wet season (usually December – June).

Streams were mapped with a compass and surveyor's tape and marked with aluminum tags every 10 m. Distances presented in this paper are in linear km following the curves of the streams.

From 1981 to 1993 turtles were hand-collected by diving (day and night) but from 1984 onwards most captures were in single-entrance funnel traps baited with raw

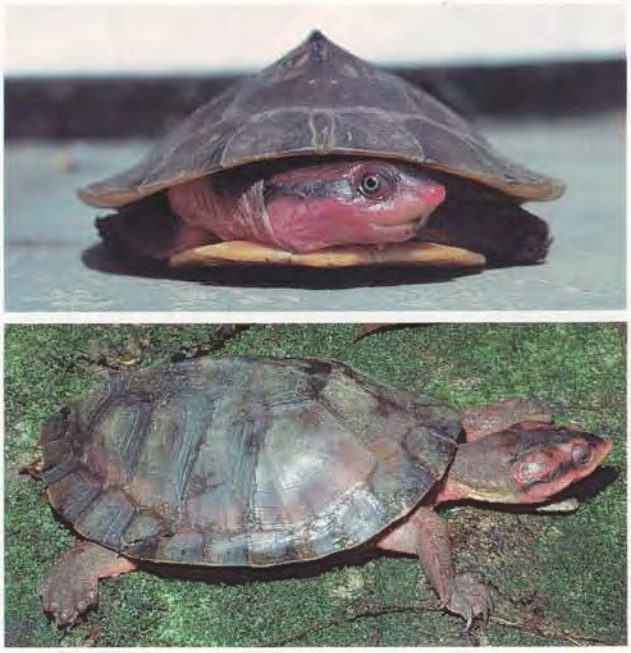

Figure 1. Adult *Phrynops rufipes* from different parts of its range. **Top:** Eastern Colombia (photo by R.A. Mittermeier). **Bottom:** Reserva Florestal Adolpho Ducke, Amazonas, Brazil (photo by W.E. Magnusson).

Figure 2. Landsat image of Reserva Florestal Adolpho Ducke, Amazonas, Brazil, in September 1995 (dark green area approximately within box), provided by the Instituto Nacional de Pesquisas Espaciais (INPE). The city of Manaus is shown in pink and white and agricultural areas in light green. The Rio Amazonas cuts the lower right corner of the photograph and the Rio Negro abuts the lower left corner. The southwest corner of the reserve is at the center of the picture. See Fig. 5 for detailed map of reserve.

chicken. Some traps were fitted with leads to form Fyke nets. We attempted to cover about 3 km in Igarapé Acará and 2 km in its tributary. Captures in the early years were sparse. From 1990 onwards we increased the capture effort, and although most study periods were of short duration (ca. 1 week), the capture and recapture rates were improved (Fig. 6). We generally placed one trap every 200 m of each stream and moved the traps ca. 100 m between study periods. Traps in Igarapé Barro Branco were placed at approximately 100 m intervals over 1 km in May 1994 and May 1995.

Captured animals were marked by drilling holes in the marginal scutes and the underlying bone. This did not appear to distress the animals and we recorded no regrowth sufficient to obliterate any mark. Turtles were sexed by external inspection. Males have a longer tail, a more posteriorly placed cloaca, and a concave plastron.

The size of the turtles was recorded as the straight-line length of the carapace (CL), measured in mm with Vernier calipers or a tape.

Four animals were followed by radiotelemetry for periods of 2 weeks to 14 months. The transmitters (Wildlife Materials, Inc., 165 mhz) were encased in a coating of surgical wax and dental acrylic, and were anchored to the

Figure 3 (top). Igarapé Acará in Reserva Florestal Adolpho Ducke, Amazonas, Brazil, where it flows through sandy sediments in the study area, showing shallow crystal clear water (dry season, August 1982).

Figure 4 (bottom). The main tributary of Igarapé Acará in the study area, showing very shallow, transparent water stained by brown organic acids (wet season, December 1988).

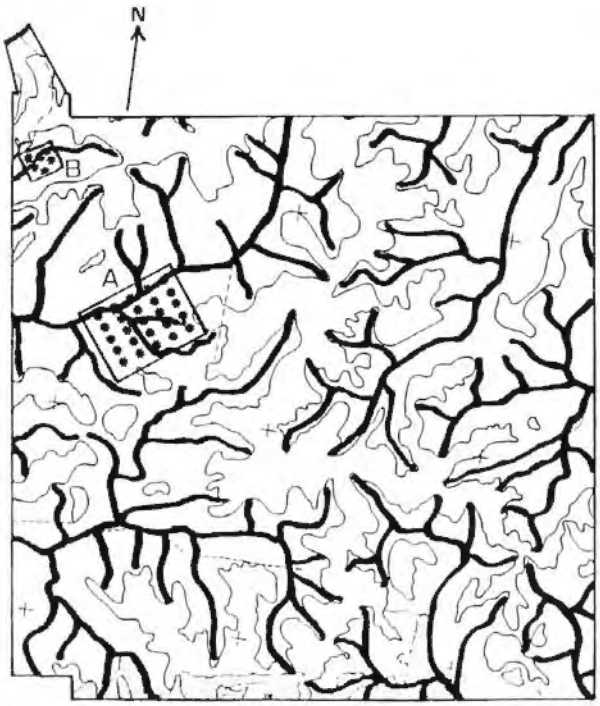

Figure 5. Map of Reserva Florestal Adolpho Ducke (see Fig. 2 for Landsat image). The reserve is ca. 10 km by 10 km in size. Thick lines represent watercourses. Fine lines represent the approximate limits of the plateau ridges that separate drainage basins. Shaded areas on the southern border indicate areas that were deforested before a fence was erected on the southern boundary in 1995. The approximate locations of the main study area (A) on Igarapé Acará (Fig. 3) and one of its tributaries (Fig. 4) and the secondary study area (B) on Igarapé Barro Branco are shown as stippled rectangles.

shell with dental acrylic through holes drilled in the marginal scutes. Turtles could generally be located at distances of up to 50 m and sometimes at greater than 100 m. We attribute the short detection range to the dense forest as similar transmitters have a range of about 1 km in open savannas.

RESULTS

Residence in the Study Area. — The rate of capture of unmarked turtles was generally constant over time, but increased after 1990 when we increased our capture effort (Fig. 6). We continued to recapture turtles marked early in the study, albeit at irregular and often long intervals. These data offer no evidence that the rate of loss of individual turtles from the study area approximated the rate of new captures and we believe that we have captured only a small proportion of the turtles resident in the area. Many turtles have been resident in the area for over a decade. The pattern of captures and recaptures was similar for males and females (Fig. 6).

A total of 43 males, 33 females, and 17 unsexed individuals were captured. However, other researchers removed 12 of those turtles from the center of our study area in February 1985. Ten of these were females, one a male, and one of unknown sex. Most were taken from the main stream and this loss complicated the analysis of distributions in relation to sex. Considering only males with recaptures, 9 were captured only in the main stream, 6 only in the tributary, and 3 were captured in both streams. Of the females with recaptures, 9 were captured only in the main stream, 2 only in the tributary, and 6 were captured in both streams. The relative proportions of captures in the three categories did not vary significantly between the sexes ($\chi^2_3 = 2.9$, $p = 0.23$), but two cells had expected values < 5 and the sample size is probably too small to detect small differences.

Logistic regression indicated that the probability of being recaptured increased with time since capture by about 70% per year (Table 1). This is expected if capture was proportional to effort and mortality and emigration were low. There was no significant effect of size at first capture on the probability of recapture and males were only about 17% as likely to be recaptured as females after consideration of the other variables. However, the confidence intervals on the odds ratios were large (Table 1).

The probability of recapture was greater on the periphery of the study area, increasing by about 7.5 times at 1 km from the center of the study area. However, the 95% confidence bounds were wide and the increase may only have been around 50% (Table 1).

Two marked individuals from Igarapé Acará were recaptured in a neighboring drainage basin (Igarapé Barro Branco) within the reserve. One, a female, had originally been captured as a juvenile (CL = 6.7 cm); the other, a male, had originally been captured as an adult (CL = 23.3 cm). The minimum overland distance between the points of capture and recapture was about 4 km (see Fig. 5). However, we believe it is most likely that the turtles followed the drainage pattern. By moving upstream and crossing the low plateau ridge between the two basins, the turtles would only have had to travel about 12 km. The ridge is ca. 90 m above

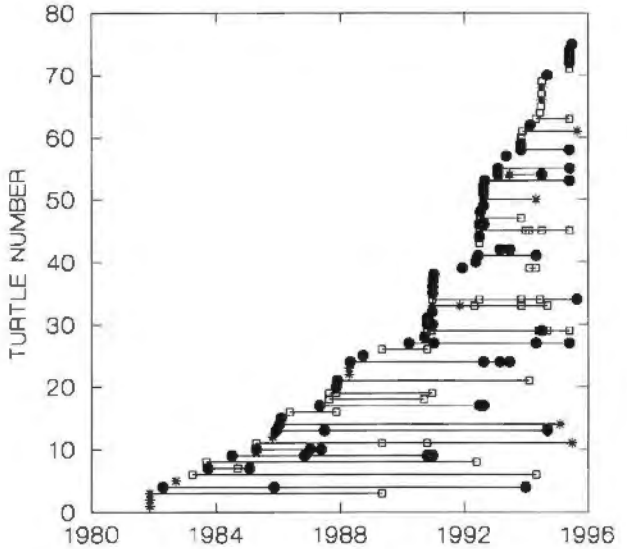

Figure 6. Dates of capture and recapture of individual turtles. Males – solid circles, females – open squares, animals of undetermined sex – asterisks.

Table 1. Summary of logistic regression relating probability of recapture (0,1) to distance from the center of the study area (Distance, km), time since capture (Time, years), carapace length (Size, cm), and sex (Sex, male = 2, female = 1). McFadden's rho-squared = 0.35, $\chi^2_4 = 27.5$, $p = 0.000$.

	Constant	Distance	Time	Size	Sex
Estimate	49.6	2.0	–0.53	0.01	–1.78
Standard Error	14.0	0.86	0.15	0.09	0.78
± – Ratio	3.54	2.36	3.45	0.13	–2.28
p	0.000	0.02	0.001	0.893	0.023
Odds Ratio	—	7.54	1.70	1.01	0.17
Upper 95% CI	—	40.50	2.29	1.21	0.78
Lower 95% CI	—	1.41	1.26	0.85	0.04

sea level and the vertical height between the sources of the streams and the ridge top is only about 10 m. If the turtles moved only within the stream, they would have had to travel downstream, the distance would have been more than 25 km, and they would have had to leave the reserve and enter relatively degraded riverine habitat.

Long-Term Movements. — Most turtles were recaptured within a few hundred meters of where they had been marked. For turtles captured four or more times over periods that included at least 6 calendar years (Fig. 7), apparent home ranges generally included 2 km or less of stream but captures were so sparse that any or all of those turtles may have also used areas outside the study area. Apparent sizes of home ranges were similar for males (1420, 1430, and 1790 linear m; mean, 1547 m) and females (520, 550, 1750, and 2030 linear m; mean, 1213 m). Home range overlap was high and the distribution of captures offers no evidence that the species is territorial.

Short-Term Movements. — One male and three females were followed by radiotelemetry for periods of two weeks to six months. The female that was followed for two weeks was monitored on 6 different days and used an area of about 460 m close to where she was captured two years later (Fig. 8 – diamonds).

A female monitored on 18 different days during two months (Fig. 8 – triangles) used 1330 m of stream, with most activity in a stretch 460 m long. Another female monitored on 7 days during 5 months (Fig. 8 – pentagons), used about 365 m of the main stream, including the site where she was recaptured three years later.

The only radio-equipped male was followed for separate periods of 5 months (20 locations) and 6 months (10 locations) during a 14-month period (Fig. 8 – squares and circles, respectively). The centers of activity were different, but the two areas overlapped almost completely.

Turtles frequently remained at, or returned to, the same site over many consecutive days. One animal (Fig. 8 – diamonds) was monitored hourly from 1140 hrs on day 1 to 2000 hrs on day 2. It did not move until between 1600 and 1700 hrs on day 2 when it moved upstream 46 m. By 2000 hrs it had moved a further 23 m upstream and at 0700 hrs on day 3 it was a further 32 m upstream. The male (Fig. 8 – squares) did not move during 24 hours of hourly monitoring. Generally, the variance in movement between days was high, turtles remaining in a limited area for long periods and then moving up to a kilometer in a single night.

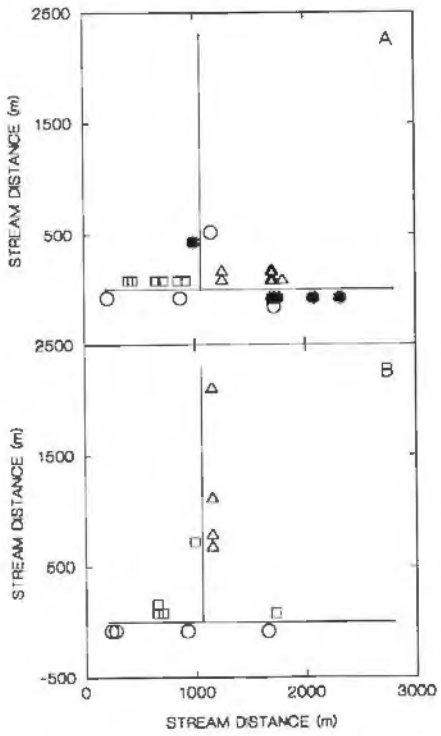

Figure 7. Sites of capture and recapture for individual (different symbols) female (A) and male (B) turtles that spanned at least 6 calendar years. Streams are represented as straight lines for clarity of presentation. Igarapé Acará is represented by the horizontal line, its tributary by the vertical line.

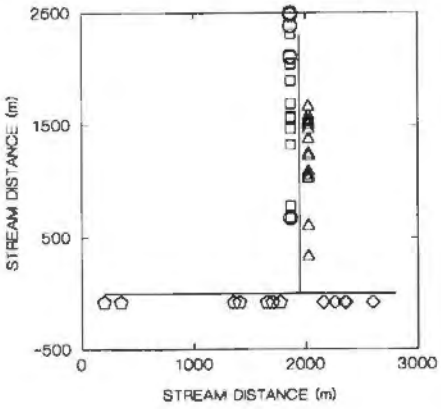

Figure 8. Locations of individual turtles determined in short-term studies by radiotelemetry. Different symbols represent different turtles, execept for the circles and squares which represent different study periods for the same animal. Streams are represented as straight lines for clarity of presentation. Igarapé Acará is represented by the horizontal line, its tributary by the vertical line.

The areas used over short-term periods of 0.5 to 14 months (Fig. 8) were of similar size to those used for periods of over 5 years (Fig. 7). Together, these results indicate small (1–2 linear km) and fixed home ranges for the majority of the population.

DISCUSSION

The home range of *Phrynops rufipes* is within the range reported for other aquatic chelonians (Schubauer et al., 1990; Kramer, 1995; Morales-Verdeja and Vogt, 1997). However, to our knowledge, it is the only species of closed-canopy tropical-forest aquatic turtle that has been studied in detail. A linear range of 1–2 km in streams that are only 2.5–4 m wide indicates an effective home range of only 0.4–0.8 ha. The small home range of *P. rufipes* is probably facilitated by its diet of palm fruits. Palms are common along the banks of these streams and some species fruit throughout the year (Lima et al., 1997). Terborgh (1986) considered palms to be keystone species for neotropical frugivores.

The distribution of captures offers no evidence of territorial behavior and up to 6 individuals have been caught together in the same trap. These aggregations included several males and females at the same time. Presumably, either the species has some social behavior or individuals aggregate at food resources.

Initially, we hoped to be able to estimate biomass and density of the turtle population. However, the sizes of home ranges were large in relation to the study area and recaptures were more common on the periphery of the study area. That may have occurred because our camp was on the bank of the stream near the center of the study area and turtles avoided areas of highest human activity, or it may have reflected natural variation in some unknown habitat characteristic. In any case, it prevented density estimates based on any simple model of home-range overlap. Assuming that the effective sampling area was about one half a home range (ca. 1 km) more of stream than we trapped on each extremity of the study area, a minimum biomass estimate based on captured animals would be 20.5 kg/ha of stream. This is within the broad range expected for an aquatic turtle (Iverson, 1982) but much less than the 364 kg/ha reported by Morales-Verdeja and Vogt (1997) for the neoptropical turtle, *Kinosternon leucostomum*, in shoreline habitat. There are insufficient published studies to evaluate the effects of habitat type on home ranges of turtles, but one species (*Pseudemys nelsoni*) has much smaller home ranges in springs than in lake habitats (Kramer, 1995). However, our data are sufficient to indicate that the species is abundant in the reserve. We sampled only about 3.5% of the total kilometers of streams in the reserve, most of which have characteristics similar to the streams in our study area, so the population in the reserve may contain at least 2500 individuals.

We did not sample other drainage basins, but the capture rate of *P. rufipes* in Igarapé Barro Branco appeared to be at least as high as in Igarapé Acará and all drainage basins contain similar closed-canopy, first, second, and third order streams.

The probability of recapture did not vary with animal size, so we assume that juveniles use a permanent home range from an early age. However, the probability of recapture was significantly lower for males. We do not know whether this represents a behavioral difference or if mortality rates are higher for males.

We interpret the recaptures of two individuals in the adjacent drainage basin as indicating that turtles can cross the ridges between drainage basins. However, we cannot discount the possibility that these individuals traversed tens of km of degraded riverine habitat outside the reserve to enter the second drainage basin. In either case, it appears that individuals in the five major drainage basins in the reserve would not be totally isolated from each other. While this rate of movement should be sufficient to avoid extinction within basins due to demographic or genetic stochasticity, the fixed home ranges of the majority of the population, in both the short and the long term, suggest that most of the population in the reserve would not disperse into the surrounding urban and agricultural areas.

The results of our study bode well for the persistence of *P. rufipes* in Reserva Florestal Adolpho Ducke. They also indicate that the species may be more abundant than previously thought. The habitat in the reserve is similar to that which occurs over a large part of Amazônia. The relative lack of distribution records for this species may simply reflect the lack of research in closed-canopy rainforest streams in Amazônia. Another large reptile which inhabits such streams, *Paleosuchus trigonatus*, once thought to be vulnerable to extinction (Honegger, 1979), is probably the highest biomass large predator in the Amazon rainforest (Magnusson and Lima, 1991). If *P. rufipes* is as abundant throughout its range as it is in the only areas where it has been studied in detail (here and in eastern Colombia), rather than being one of the rarest turtles (Pritchard, 1979), it may be one of the Amazon's more abundant turtles. The small transparent streams that *P. rufipes* inhabits are deceptive in that they harbor many large reptiles that exhibit cryptic behavior. More studies of undisturbed Amazon systems are necessary so that we can more fully understand the threats these species face and focus attention on those species that are truly endangered and subject to near term extirpation or extinction.

Acknowledgments

Many individuals helped capture turtles but special mention is due to Peter Harlow, Jean-Marc Hero, Albertina Lima, Morgan Janson, and Peter Cohen. Financial support was provided by grants from the Brazilian Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq) to VLdC (Iniciação Científica), ACdL (Aperfeiçoamento), and WEM (Pesquisa and Auxílio a Pesquisa). Bruce Nelson provided the base map and obtained the Landsat image provided by INPE.

LITERATURE CITED

CONGDON, J.D., DUNHAM, A.E., AND VAN LOBEN SELS, R.C. 1993. Delayed sexual maturity and demographics of Blanding's turtles (*Emydoidea blandingii*): implications for conservation and man-

agement of long-lived organisms. Conserv. Biol. 7(4):826-833.

HONEGGER, R.E. 1979. Red Data Book. Volume 3: Amphibia and Reptilia. Morges, Switzerland: IUCN.

IVERSON, J.B. 1982. Biomass in turtle populations: a neglected subject. Oecologia 55:69-76.

KRAMER, M. 1995. Home range of the Florida red-bellied turtle (*Pseudemys nelsoni*) in a Florida spring run. Copeia 1995(4):883-890.

LAMAR, W.W., AND MEDEM, F. 1984. Notes on the chelid turtle *Phrynops rufipes* in Colombia (Reptilia: Testudines: Chelidae). Salamandra 18:305-321.

LIMA, A.C. DE, MAGNUSSON, W.E., AND COSTA, V.L. DA. 1997. Diet of the turtle *Phrynops rufipes* in central Amazonia. Copeia 1997:216-219.

MAGNUSSON, W.E. AND LIMA, A.P. 1991. The ecology of a cryptic predator, *Paleosuchus trigonatus*, in a tropical rainforest. J. Herpetol. 25:41-48.

MAGNUSSON, W.E., LIMA, A.C. DE, COSTA, V.L. DA, AND LIMA, O.P. DE. 1997. Growth of the turtle, *Phrynops rufipes*, in central Amazônia, Brazil. Chelonian Conservation and Biology 2(4):576-581.

MATTSON, D.J., BLANCHARD, B.M., AND KNIGHT, R.R. 1992. Yellowstone grizzly bear mortality, human habituation, and whitebark pine seed crops. J. Wildl. Manag. 53:432-442.

MORALES-VERDEJA, S.A., AND VOGT, R.C. 1997. Terrestrial movements in relation to aestivation and the annual reproductive cycle of *Kinosternon leucostomum*. Copeia 1997:123-130.

MCCULLOUGH, D.R. 1996. Spatially structured populations and harvest theory. J. Wildl. Manag. 60:1-9.

PRITCHARD, P.C.H. 1979. Encyclopedia of Turtles. Neptune, NJ: TFH Publ., 895 pp.

SCHUBAUER, J.P., GIBBONS, J.W., AND SPOTILA, J.R. 1990. Home range and movement patterns of slider turtles inhabiting Par Pond. In: Gibbons, J.W. (Ed.). Life History and Ecology of the Slider Turtle. Washington: Smithsonian Inst. Press, pp. 223-232.

TERBORGH, J. 1986. Community aspects of frugivory in tropical forests. In: Estrada, A., and Fleming, T.H. (Eds.). Frugivores and Seed Dispersal. Dordrecht: W. Junk, pp. 371-384.

Received: 18 July 1996
Reviewed: 1 August 1997
Revised and Accepted: 10 September 1997