

range = 17.0–28.7 mm; mean width = 11.6 mm, $s = 0.73$, range = 10.5–12.5 mm). The third specimen collected in January is poorly preserved (IB 65538, 648 mm SVL, 150 mm TL) and had five oviductal eggs (mean length = 15.8 mm, $s = 5.11$, range = 10.0–22.2 mm; mean width = 7.5 mm, $s = 0.9$, range = 7.7–9.0 mm), and four atresic eggs. These data show that in the rainy season (October–January) *L. atraventer* is reproductively active, but our data are insufficient to suggest a continuous reproductive cycle. Vitt (1983) obtained reproductive data for a few species of *Liophis*, including *L. viridis*, a relative of *L. atraventer* (Dixon 1987). He argues that *L. viridis* has an extended reproductive season and possible multiple clutches. Marques (1996) suggested that continuous reproduction is possibly conservative in the tribe Xenodontini, therefore additional data are needed to ascertain the reproductive cycle of *L. atraventer*.

Acknowledgments.—We thank Ivan Sazima and Paulo R. Manzani for kindly loaning the specimen from Museu de História Natural – Universidade Estadual de Campinas, and José P. Pombal Jr. and Luciana B. Nascimento for the identification of and information about the prey item. We are grateful to Otávio A. V. Marques, José P. Pombal Jr., and Ronaldo Fernandes for their comments on the manuscript. James R. Dixon and Robert A. Thomas critically reviewed the manuscript and made many helpful suggestions. Financial support was provided by the Conselho Nacional de Desenvolvimento Científico e Tecnológico (CNPq), Fundação de Amparo à Pesquisa do Estado de São Paulo (FAPESP), and Fundação Carlos Chagas Filho de Amparo à Pesquisa (FAPERJ).

LITERATURE CITED

- DIXON, J. R. 1987. Taxonomy and geographic variation of *Liophis typhlus* and related “green” species of South America (Serpentes: Colubridae). *Ann. Carnegie Mus.* 56:173–191.
- , 1989. A key and checklist of the Neotropical snake genus *Liophis* with country lists and maps. *Smithson. Herpetol. Info. Serv.* 79:1–40.
- , 2000. Ecuadorian, Peruvian, and Bolivian snakes of the *Liophis taeniurus* complex with description of two new species. *Copeia* 2000(2):482–490.
- , AND A. L. MARKEZICH. 1992. Taxonomy and geographic variation of *Liophis poecilogyrus* (Wied) from South America (Serpentes: Colubridae). *Texas J. Sci.* 44:131–166.
- , AND R. A. THOMAS. 1985. A new species of South American water snake (genus *Liophis*) from southeastern Brazil. *Herpetologica* 41(3):259–262.
- DONNELLY, M. A., AND C. W. MYERS. 1991. Herpetological results of the 1990 Venezuelan expedition to the summit of Cerro Guaiquinima, with new Tepui reptiles. *Am. Mus. Novitates* 3057:1–54.
- DOWLING, H. G. 1951. A proposed standard system of counting ventrals in snakes. *Brit. J. Herpetol.* 1(5):97–99.
- , AND J. M. SAVAGE. 1960. A guide to the snake hemipenis: a survey of basic structure and systematic characteristics. *Zoologica* 45:17–28.
- MARQUES, O. A. V. 1996. Biologia reprodutiva da cobra-coral *Erythrolamprus aesculapii* Linnaeus (Colubridae), no sudeste do Brasil. *Rev. Bras. Zool.* 13(3):747–753.
- , V. A. ETEROVIC, AND I. SAZIMA. 2001. Serpentes da Mata Atlântica. Guia ilustrado para a Serra do Mar. Holos Ed., Ribeirão Preto.
- MYERS, C. W., AND J. A. CAMPBELL. 1981. A new genus and species of colubrid snake from the Sierra Madre del Sur of Guerrero, Mexico. *Am. Mus. Novitates* 2708:1–20.
- PASSOS, P., AND D. S. FERNANDES. 2001. *Liophis atraventer*. Geographic distribution. *Herpetol. Rev.* 32:60.
- SHINE, R. 1980. Comparative ecology of three Australian snake species of

- the genus *Cacophis* (Serpentes: Elapidae). *Copeia* 1980(4):831–838.
- VITT, L. J. 1983. Ecology of an anuran-eating guild of terrestrial tropical snakes. *Herpetologica* 39(1):52–66.
- WILSON, R. F. 1941. The Wilson Colour Chart I & II. The British Colour Council. England.

Herpetological Review, 2003, 34(4), 320–323.
© 2003 by Society for the Study of Amphibians and Reptiles

Precision and Accuracy of Body-Size Measurements in a Constricting, Large-Bodied Snake (*Elaphe obsoleta*)

GABRIEL BLOUIN-DEMERS

Department of Biology, University of Ottawa, 150 Louis Pasteur
Ottawa, Ontario, K1N 6N5 Canada
e-mail: gblouin@uottawa.ca

Size measurements are used in a wide variety of snake studies. Obtaining the snout-to-vent length (SVL) of snakes is necessary to study systematics (e.g., Burbrink 2001), sexual size dimorphism (e.g., Madsen 1983; Shine 1989), growth (e.g., Macartney et al. 1990; Forsman 1993), or demography (e.g., Plummer 1985). The body of a conscious snake, however, is elastic and can stretch and contract, yielding variable measurements of SVL. Also, a recent report that Galápagos marine iguanas (*Amblyrhynchus cristatus*) can dramatically decrease in body size when food availability is low (Wikelski and Thom 2000) raises the possibility that reptiles can shrink. Quantifying the precision and accuracy of SVL measurements is important (1) to improve measurement methods for snakes, (2) to partition the observed variance around parameters obtained from SVL measurements (e.g., growth estimates) into variance associated with measurement error and variance associated with individual differences, and (3) to determine whether reported instances of snakes shrinking (Blouin-Demers et al. 2002; Madsen and Shine 2001) can be attributed to measurement error or to previously unsuspected instances of shrinkage. I am unaware, however, of any study that has quantified the error associated with SVL measurements of snakes. My general goal in this paper was to quantify both the precision and accuracy of SVL measurements in black ratsnakes (*Elaphe obsoleta*), a large constricting colubrid.

My first objective was to quantify the precision of SVL measurements of conscious *Elaphe obsoleta* obtained by a method commonly used in field studies and consisting in running a flexible measuring tape along the venter of a snake held horizontally by an assistant (described by Fitch 1987). Measurement error on SVL arises from the behavior of the animal when being measured (struggling) and from limitations intrinsic to the measuring method. Thus, my second objective was to determine what proportion of measurement error was due to the struggling of the snake and what proportion was due to the measurement method itself. Because black ratsnakes are large constricting colubrids, I expected they would be difficult to measure and I predicted that the struggling of the snake should account for a greater proportion of measurement error than the limitations of the measuring method. My third objective was to quantify the accuracy of SVL measurements on conscious *Elaphe obsoleta* obtained by the method described by

Fitch (1987). Lastly, I wanted to determine whether precision and accuracy of SVL measurements varied with the size of the snake being measured. Large snakes, with their strong musculature, might struggle more vigorously and be more difficult to measure. Thus, I predicted that the SVL measures of larger snakes should be less precise and less accurate than those of smaller snakes.

Materials and Methods

In May 2000, 20 wild-caught *Elaphe obsoleta* from the Queen's University Biological Station (40 km N of Kingston, Ontario; 44°34'N, 76°19'W, 200 m elevation) were measured three ways and subsequently returned to the wild. Individuals were selected spanning the size range of *Elaphe obsoleta*, with the caveat that individuals had to be large enough (> 500 mm SVL) to be intubated for anesthesia (see below). First, to determine the precision of SVL measurements, each snake was measured 10 times using the method of Fitch (1987). The snake was held behind the head and behind the cloaca by an assistant. With the snake suspended horizontally, the assistant gently stretched it until the snake tired and extended to full length, at which point a 2-m flexible measuring tape was run along its venter (Fitch 1987). In all cases, the snake was measured twice and the mean of the two measurements was recorded. Using this method (hereafter "Conscious – Tape"), the 20 snakes were measured every day for 10 days, assuming that growth over those 10 days was negligible. Second, to quantify the error associated with the behavior of the snakes when being measured, the snakes were measured again, but first rendered flaccid by isoflurane anesthesia (Blouin-Demers et al. 2000). To avoid anesthetizing the snakes repeatedly, all 10 pairs of measurements were taken during a single dose of anesthesia, but the snakes were coiled on a table between each pair of measurements (hereafter "Anesthetized – Tape"). Third, to quantify the error associated with running the flexible measuring tape along the venter of the snakes, the anesthetized snakes were also measured 10 times by laying them on a table along a 2-m metal ruler. These last 10 pairs of measurements were also taken under anesthesia, but the snakes were loosely coiled on a table between pairs of measurements (hereafter "Anesthetized – Ruler"). Thus, the 30 measurements for each snake (10 measurements by 3 methods) each represent the mean of two measurements. Data collection was blind: the numbers on the measuring device were covered and the measuring device was simply marked, after which an assistant recorded the number.

The measure of precision was the coefficient of variation (CV; Zar 1999). Ideally, the SVL measurement obtained on a conscious snake would be identical to that obtained by measuring the snake when anesthetized (Fitch 1987). In the present study, however, the snakes were measured anesthetized using two different methods. Snakes stretched considerably when anesthetized and suspended in the air (see Results). Consequently, I considered that the "true" SVL of black ratsnakes was the mean of the 10 values obtained by the Anesthetized-Ruler method. Thus, the measure of accuracy for a particular

method was the mean of the absolute values of the deviations of the SVL values from the "true" SVL, expressed as a percentage of the "true" SVL.

Repeated measure ANOVA (one within design) or paired t-test were used to analyze the precision and accuracy of each measurement method, and linear regression was used to determine whether precision or accuracy of measurements varied with SVL. The data were screened for violations of the assumptions of normality and homogeneity of variance using box plots and Shapiro-Wilk tests. All analyses were conducted on JMP Version 3.2 (Statistical Analysis Systems 1997) and SPSS Version 6.1 (Statistical Package for the Social Sciences 1995) on a Macintosh desktop computer. Means are reported \pm 1 standard error.

Results

The three measurement methods differed in precision as measured by their CVs ($r^2 = 0.85$, repeated measures ANOVA $F_{(2,18)} = 103.42$, $P < 0.001$). Tukey post-hoc tests indicated that the three methods differed from one another. Measuring snakes by laying them along a ruler when they were anesthetized was the most precise method, followed by measuring them with a flexible tape when they were anesthetized, and then by measuring them with a flexible tape when they were conscious (Table 1). Nevertheless, measuring conscious snakes was surprisingly precise, with an average CV of $1.10 \pm 0.10\%$ and a maximum value of 2.16%. The calculation of CV involves the deviation of each measurement from the mean. The mean of the absolute values of those deviations gives a direct estimate of measurement error. The mean of the absolute values of the deviations from the mean SVL of the conscious snakes was 8.14 mm, or 0.82% of the mean SVL.

Assuming that measurement error is random and thus has a symmetrical distribution centered on the mean (my data do not suggest otherwise), the mean measurement error around a growth estimate based on two SVL measurements would be twice the measurement error of SVL ($2 \times 0.82\% = 1.64\%$) half of the time. If errors are random, errors on two SVL measurements should be in opposite direction half of the time (and thus cumulative) and in the same direction the other half of the time (and thus noncumulative). During the active season, the average growth rate for a 1000-mm *Elaphe obsoleta* in Ontario is 0.4 mm/day (Blouin-Demers et al. 2002). Thus, when the errors are cumulative (i.e., 1.64% measurement error) it would take an average of 41 days of activity before growth of a 1000-mm individual becomes detectable using Fitch's (1987) measurement method.

TABLE 1. Precision (CV), accuracy (absolute values of deviations of SVL), and mean SVL for 20 black ratsnakes measured by three methods. Tape refers to measuring snakes by running a measuring tape along their body while snakes are held horizontally. Ruler refers to measuring snakes by laying them on a table along a metal ruler.

Method	CV (%)			Deviations (%)			SVL (mm)	
	Mean	SE	Max	Mean	SE	Max	Mean	SE
Conscious – Tape	1.10	0.10	2.16	1.39	0.19	2.80	1046.7	62.1
Anesthetized – Tape	0.62	0.04	0.98	3.41	0.34	5.82	1075.1	66.6
Anesthetized – Ruler	0.16	0.02	0.40	—	—	—	1036.3	61.7

The Anesthetized – Tape method was 44% more precise than the Conscious – Tape method (Table 1), indicating that, on average, 44% of the imprecision when measuring conscious snakes was attributable to their activity (i.e., struggling). A further 42% increase in precision was achieved by the Anesthetized – Ruler method (Table 1). This result did not support my prediction that a greater proportion of measurement error would be attributed to the behavior of the snake when being measured, than to limitations of the measuring method.

The mean SVL of snakes obtained by the three methods differed from one another ($r^2 = 0.64$, repeated measures ANOVA $F_{(2,18)} = 32.65$, $P < 0.001$). Tukey post-hoc tests indicated that SVL values did not differ between Conscious – Tape and Anesthetized – Ruler methods, but the Anesthetized – Tape method yielded SVL values greater than the other two methods (Table 1). Based on the absolute values of the deviations from the “true” SVL, measuring snakes with the tape was less accurate when snakes were anesthetized than when they were conscious (paired $t_{(19)} = 5.77$, $P < 0.001$). These results were due to the anesthetized snakes stretching when they were measured with the tape.

Contrary to my prediction, precision of the Conscious – Tape method increased significantly with increasing SVL ($r^2 = 0.27$, $F_{(1,18)} = 6.57$, $P = 0.019$, Fig. 1). Precision was not significantly related to SVL ($F_{(1,18)} = 0.86$, $P = 0.366$) when snakes were anesthetized and measured with the tape (Fig. 1). Precision decreased significantly with increasing SVL ($r^2 = 0.22$, $F_{(1,18)} = 5.16$, $P = 0.036$) when snakes were anesthetized and measured with the ruler (Fig. 1). This last relationship, however, appears to be driven by one large snake with a high CV (Fig. 1). Excluding this data point from the analysis made the relationship non-significant ($F_{(1,17)} = 3.06$, $P = 0.099$). Contrary to my prediction that SVL measurements on larger snakes should be less accurate than those on smaller snakes, accuracy was not related to SVL for conscious snakes ($F_{(1,18)} = 1.04$, $P = 0.307$). Accuracy was, however, strongly related to SVL for anesthetized snakes ($r^2 = 0.79$, $F_{(1,18)} = 67.23$, $P < 0.001$). Larger snakes stretched proportionally more than smaller snakes when measured anesthetized and their SVL was thus overestimated to a greater extent (Fig. 2).

Discussion

I found that SVL measurements of conscious snakes were both precise and accurate (mean error $\approx 1\%$) and that the proportions of measurement error attributable to the behavior of the animal and to the measuring method itself were approximately equal. Precision of measurements increased with increasing SVL for conscious snakes. Accuracy of measurements on anesthetized snakes with tape, however, decreased with increasing SVL.

Contrary to my prediction, SVL measurements on a large-bodied constrictor such as *Elaphe obsoleta* were surprisingly precise. After an initial struggle when first grasped, ratsnakes in this study usually calmed down within 1–2 min. This resulted in (1) my ability to make precise measurements, and (2) the behavior of the snakes when measured accounting for approximately the same proportion of measurement error as limitations of the measurement method itself.

One unexpected result was that the precision of measurements increased with increasing SVL for conscious snakes measured with

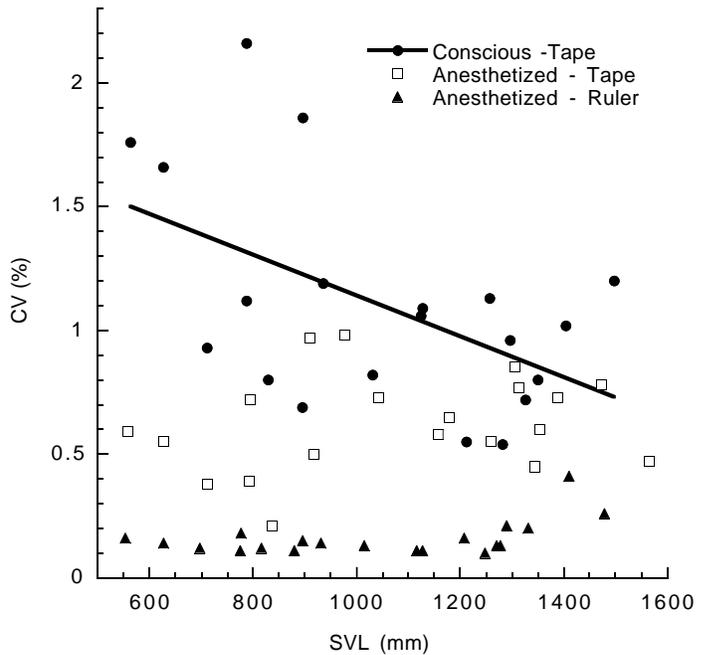


FIG. 1. Precision of SVL measurements (measured by the coefficient of variation expressed as a percentage) as a function of mean SVL for 20 black ratsnakes measured by three methods.

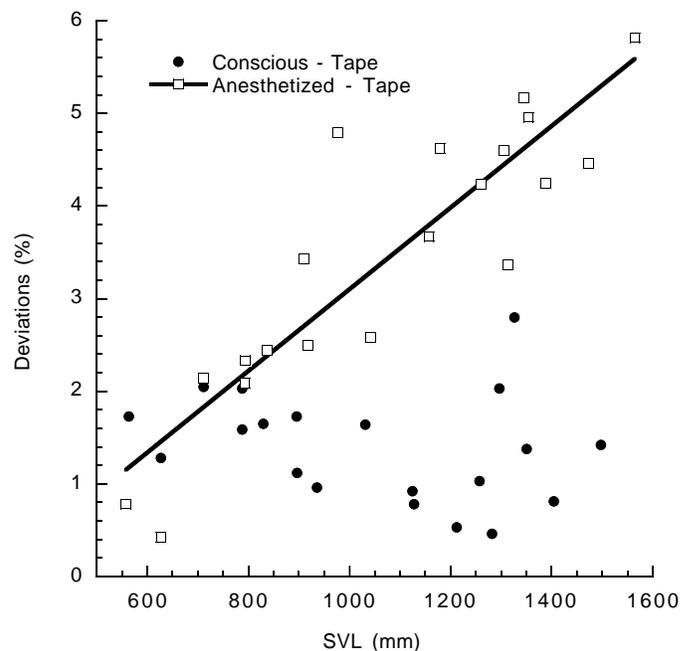


FIG. 2. Accuracy of SVL measurements (measured by the mean deviation of the SVL measurements from the “true” SVL expressed as a percentage) as a function of mean SVL for 20 black ratsnakes measured by two methods.

tape. Precision did not vary with SVL for anesthetized snakes measured with tape, suggesting that the behavior of the snakes when being measured causes the difference in precision between large and small snakes. Thus, it appears that larger snakes, which tend to be more placid, are easier to measure than are smaller snakes because larger snakes provide more precise measures. Accuracy

did not vary with SVL for conscious snakes. However, measuring anesthetized snakes with tape tended to slightly overestimate their SVL, and this problem was more severe for larger snakes.

Because SVL measurements in conscious snakes are both precise and accurate, it should be possible to detect instances of shrinkage (Madsen and Shine 2001; Wikelski and Thom 2000) if they do occur in snakes. Based on the small magnitude and low frequency of negative growth estimates in this population (Blouin-Demers et al. 2002), it seems unlikely that shrinkage occurs. Individual cases of apparent shrinkage were thus likely due to measurement error.

In summary, my data suggest that the best way to measure the SVL of snakes is by anesthetizing them and laying them next to a ruler. If this method is not practical, measuring them conscious with a flexible tape (Fitch 1987) is a reasonable alternative.

Acknowledgments.—The protocols for this experiment were approved by the Carleton University Animal Care Committee (Protocol B97-1). I am grateful to H. McCracken and C. Verreault for their able help with data collection. P. Weatherhead, R. Espinoza, and two anonymous reviewers provided comments that improved this manuscript. Logistical support for my work was provided by the Queen's University Biological Station. This research was supported by NSERC postgraduate scholarships to the author and an NSERC research grant to P. Weatherhead.

LITERATURE CITED

- BLOUIN-DEMERS, G., K. A. PRIOR, AND P. J. WEATHERHEAD. 2002. Comparative demography of black rat snakes (*Elaphe obsoleta*) in Ontario and Maryland. *J. Zool.* 256:1–10.
- , P. J. WEATHERHEAD, C. M. SHILTON, C. E. PARENT, AND G. P. BROWN. 2000. Use of inhalant anesthetics in three snake species. *Contemp. Herpetol.* 2000:4.
- BURBRINK, F. T. 2001. Systematics of the eastern ratsnake complex (*Elaphe obsoleta*). *Herpetol. Monogr.* 15:1–53.
- FITCH, H. S. 1987. Collecting and life-history techniques. In R. A. Seigel, J. T. Collins, and S. S. Novak (eds.), *Snakes: Ecology and Evolutionary Biology*, pp. 143–164. MacMillan Publishing, New York.
- FORSMAN, A. 1993. Growth rate in different colour morphs of the adder, *Vipera berus*, in relation to yearly weather variation. *Oikos* 66:279–285.
- MACARTNEY, J. M., P. T. GREGORY, AND M. B. CHARLAND. 1990. Growth and sexual maturity of the western rattlesnake, *Crotalus viridis*, in British Columbia. *Copeia* 1990:528–542.
- MADSEN, T. 1983. Growth rates, maturation and sexual size dimorphism in a population of grass snakes, *Natrix natrix*, in southern Sweden. *Oikos* 40:277–282.
- , AND R. SHINE. 2001. Do snakes shrink? *Oikos* 92:187–188.
- PLUMMER, M. V. 1985. Demography of green snakes (*Opheodrys aestivus*). *Herpetologica* 41:373–381.
- SHINE, R. 1989. Ecological causes for the evolution of sexual dimorphism: a review of the evidence. *Q. Rev. Biol.* 64:419–464.
- STATISTICAL ANALYSIS SYSTEMS INC. 1997. *JMP Statistics and Graphics Guide*. Statistical Analysis Systems, Cary, North Carolina.
- STATISTICAL PACKAGE FOR THE SOCIAL SCIENCES INC. 1995. *Advanced statistics*. Statistical Package for the Social Sciences, Chicago, Illinois.
- WIKELSKI, M., AND C. THOM. 2000. Marine iguanas shrink to survive El Niño. *Nature* 403:37–38.
- ZAR, J. H. 1999. *Biostatistical Analysis*. 4th ed. Prentice-Hall, Englewood Cliffs, New Jersey.

Multiple Recaptures of a Hybrid Hawksbill-Loggerhead Turtle in the Ten Thousand Islands, Southwest Florida

W. N. WITZELL

National Marine Fisheries Service, Southeast Fisheries Science Center
75 Virginia Beach Drive, Miami, Florida 33149, USA
e-mail: Wayne.Witzell@noaa.gov

and

JEFFREY R. SCHMID

The Conservancy of Southwest Florida
1450 Merrihue Drive, Naples, Florida, 34102, USA

The Miami Laboratory of the National Marine Fisheries Service (NMFS) conducted a study to determine the distribution and abundance of immature sea turtles in the nearshore waters of southwest Florida. Standard mark-recapture techniques were used as described in Eckert et al. (1999), and tissue samples were taken from green, loggerhead, and hawksbill turtles for genetic analysis.

The NMFS turtle survey documented the presence of immature Kemp's ridley (*Lepidochelys kempi*), loggerhead (*Caretta caretta*), and green (*Chelonia mydas*) sea turtles in the coastal waters of southwest Florida, in order of decreasing abundance. One turtle, originally identified as an immature hawksbill (*Eretmochelys imbricata*), was captured on 15 October 1998. Hawksbill turtles are considered a tropical species more commonly found in coral reef habitats (Meylan 1992; Witzell 1983), and it seemed unusual that this turtle was caught in the turbid waters of the Ten Thousand Islands in southwest Florida. The turtle's shape, scale pattern, and color were not readily distinguishable from a "normal" hawksbill. However, nuclear DNA analysis demonstrated that this animal was, in fact, a hawksbill-loggerhead hybrid, a rare phenomenon previously documented (Bowen and Karl 1997; Karl et al. 1995). Researchers from the University of South Florida in Tampa, Florida analyzed tissue samples from the turtle. Maternally inherited mtDNA was used to resolve maternal parent. The control region sequence from the mitochondrial DNA matched *Caretta caretta* haplotype A, indicating that the maternal parent was a loggerhead. Restriction digests of three nuclear DNA loci (CM-12A, CM-28, CM-14A) were performed using restriction enzymes *Rsa I*, *Bst NI*, and *Dra I*, respectively. Together, these three digests indicate the turtle is a post-first generation (F1) hy-

TABLE 1. Capture dates and recorded sizes of an immature hybrid hawksbill turtle recaptured in the Ten Thousand Islands, southwest Florida.

Date (m/d/y)	MSCL ¹	Weight (kg)	Days Free
10/15/98	52.2	20.8	0
07/05/99	54.5	—	263
08/02/99	—	—	296
11/16/99	59.5	25.8	418
09/04/00	64.6	—	711

¹Medial straight carapace length (notch-to-notch).