overall success of a control program using gas cartridges will depend on the proximity and extent of surrounding untreated woodchuck populations as well as the frequency and thoroughness with which burrows in the treatment area are monitored and fumigated.

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EFFECT OF MARKING TECHNIQUES ON GROWTH AND SURVIVORSHIP OF HATCHLING ALLIGATORS

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Marking techniques have been used widely in fishery and wildlife management to obtain information on migration, behavior, age validation, mortality, population size, and stocking success (Emery and Wydoski 1987). Marking of amphibians and reptiles is well documented (Pough 1970, Clark 1971, Ferner 1979) and has been used widely for crocodilians. Chabreck (1965) utilized toe and dorsal scute clipping for identifying individual American alligators (*Alligator mississippiensis*). Wild hatchling alligators were toe-clipped and scute-clipped by P. A. Wilkinson (unpubl. rep., S.C. Wildl. and Marine Res. Dep., Charleston, 1983), while Murphy (1977) scute-clipped adults and toe-clipped juveniles. Gorzula (1978) clipped ventral caudal scales on caiman (*Caiman crocodilus*) to identify previously captured animals. Similarly, Webb et al. (1989) used clipping of the dorsal tail scutes of Australian freshwater crocodiles (*Crocodylus johnstoni*) and saltwater crocodiles (*Crocodylus porosus*) to identify recaptured animals, and also clipped tail scutes to individually identify *C. porosus* hatched in captivity. Dispersal of hatchling *C. porosus* was monitored by the recapture of branded animals (Magnusson 1979). More recently, Kushlan and Mazzotti (1989) used a combination of scute-clipping and tagging to identify juvenile and adult American crocodiles (*C. acutus*).

Use of marking techniques in crocodilian research has been limited primarily to identification of specific individuals. Although most reports suggest that disfigurement of scale patterns is effective in this respect, none have documented the physical effects of marking on individual animals, particularly hatchlings. Correspondingly, no work has been done to determine if the age at marking affects growth or survivorship of hatchling crocodilians.

The lack of information regarding the effects of crocodilian marking techniques on growth and survival suggests that investigators have failed to recognize the potential impacts of marking on study animals or have considered the effects of marking to be nondetrimental. However, the possible effects of marking may have direct application to mark/recapture studies involving wild crocodilians, because one of the primary assumptions of recapture-generated population models is that marked animals have survival rates similar to unmarked animals (Manly 1971). Accordingly, biologists who mark crocodilians must assume that specific marking techniques do not result in differential growth or survivorship. Without evaluating these characteristics, studies or surveys that employ marking may be subject to biases associated with differential growth and survival rates of marked versus unmarked animals. The objectives of this study were to: (1) determine if the growth and survivorship of hatchling alligators are affected by the age at time of marking and (2) test the applicability of marking hatchling alligators with several techniques commonly used on amphibians and other reptiles.

METHODS

Age at Marking Effects

We selected 125 alligator hatchlings that were hatched from eggs collected in Charlotte County, Florida. The 125 hatchlings had a mean snout-vent length (SVL) of 15.9 (SD = 1.0 cm, range = 15.3–17.0) and mean mass of 103.5 (SD = 11.9 g, range = 85.0–123.0). Animals were randomly placed into 1 of 5 groups of 25 hatchlings each. We tagged each hatchling with a uniquely numbered #3 monel tag in the middle web of the right rear foot. One group was scute-clipped in November 1987: 1 dorsal tail scute was clipped on the single and double rows of scutes using a pair of fingernail clippers. Approximately 30 days after the treatment of group 1, we remeasured and weighed all 125 hatchlings and scute-clipped a second group of 25 previously unmarked hatchlings identically to group 1. We repeated this process for groups 3 and 4, approximately 60 and 90 days from the treatment of group 1, respectively. The fifth group was not marked and served as a control. We measured and weighed the 4 treatment groups and 1 control group at approximately 120, 150, and 180 days after the first group was scute-clipped. Scute-clipped and control animals were maintained in an enclosed, thermally regulated, 10-m diameter, circular, commercial grow-out facility in Charlotte County, Florida. We made daily observations to determine hatchling mortality.

Marking Techniques

We selected 125 hatchlings resulting from artificially incubated eggs collected from Orange Lake, Alachua County, Florida. Selected hatchlings had a mean SVL of 15.5 (SD = 0.90 cm, range = 13.5–17.5) and mean mass of 88.5 (SD = 17.4 g, range = 61.0–134.0). Because of the high variability in hatchling length and mass we blocked animals into treatment groups by sorting them into 5 groups of 25: the first group containing the 25 smallest, the second group containing 25 of the next largest hatchlings, etc. This procedure was repeated until all 125 hatchlings were assigned to 1 of 5 groups. After separation by size, we chose 5 hatchlings from each group such that each new group of 25 hatchlings contained a complement of small to large hatchlings. We tagged each hatchling with a #1 monel tag as described above.

Four groups were randomly selected for marking in December 1987 with either freeze branding, web-hole punching, scute-clipping, or toe-clipping. The fifth group was unmarked and served as a control. We applied freeze branding to the distal 1 cm of tail by submersion into an ethyl alcohol/dry ice slurry for approximately 20 seconds. In addition, the right rear foot pad was branded by pressing the foot onto a supercooled aluminum strip. Web-hole punching was accomplished by marking the outer web of the right rear foot using a leather punch, resulting in a circular 2-mm diameter hole. We toe-clipped animals using a pair of surgical scissors. The outer toe of the right rear foot was removed at the junction of the web and digit. We conducted scute-clipping as previously described.

We measured and weighed all 125 hatchlings at approximately 30-day intervals for 150 days. We maintained animals in covered, outdoor, 0.7- × 1.5-m grow-out pens at the Florida Game and Fresh Water Fish Commission's Wildlife Research Laboratory, Gainesville. We provided artificial heat by 250-watt incandescent heat lamps during periods of ambient air temperature < 10 C.

Analysis

The time-of-marking and marking technique studies represented completely randomized and randomized block designs, respectively, with repeated measures on each individual. We used a 1-way analysis of variance with repeated measures model to test the effect of treatment (age or technique) on SVL and mass (SAS Inst. Inc. 1985). Initial analysis of monthly means indicated a relationship between means and variances of the growth parameters. To stabilize variance, we conducted natural-log transformations for weight and power transformations with coefficients of -1.0 for SVL (Box et al. 1978). We used Dunnett's test to determine differences between control and treatment groups (Steel and Torrie 1980).

RESULTS AND DISCUSSION

Our data indicated that the age of marking or the marking techniques we tested have no effect on growth or survivorship of hatchling alligators. We found that age at which hatchlings were scute-clipped did not affect SVL or mass at any measurement interval ($F < 2.03$; $P > 0.05$). Further, neither SVL nor mass was different ($F < 2.47$; $P > 0.05$) for the control or treatment groups at each measurement interval. At the second measurement interval, however, the control group differed in mass from the group that was to be marked at the fourth measurement interval ($F = 3.01$; 4,115 df; $P = 0.02$). Because neither of these groups had been treated by the second measurement interval or had received different husbandry care, the difference in mass may only be explained by variability in growth of juvenile alligators. No mortality was reported for any of the treatment or control groups during the 6-month study; consequently, no analysis of survivorship was performed.

Similarly, we found no differences in the effects of the 4 marking techniques on SVL ($F = 0.52$; 4,100 df; $P = 1.00$) or mass ($F = 0.58$; 4,100 df; $P = 1.00$). Only 1 mortality was recorded in the control group during the 5-month study period, precluding a need for survivorship analysis.

These data indicate that the age at which hatchling alligators are marked or the type of marks used does not affect the growth or survivorship of hatchlings reared in captivity. Although limited to captive alligator hatchlings, we believe these results are also applicable to wild hatchling crocodilians. Furthermore, we believe that juvenile and adult crocodilians would not be affected by any of the marking techniques we tested or by the age at which they were marked, because hatchlings are presumed to be more susceptible to stress from handling and marking than older age classes. As a result, our findings substantiate the apparent consensus among available literature that effects of marking are not an important consideration.

Of the 4 marking methods studied, scute-clipping appeared to be the best marking technique with respect to ease of application and identification of many individuals. Subsequent examination of 56 of the animals 30 months after marking, however, indicated that clipped-scutes could only be readily identified on approximately 7% of the marked animals. Poor retention of marks may be a result of inadequate tissue removal at the time of marking and accelerated growth of alligators maintained in environmentally controlled conditions. Web-hole punched and toe-clipped animals remained identifiable throughout this study and retained marks for approximately 30 months. However, partial closure of the web-hole was noted on several individuals. These techniques would likely be appropriate for short-term research purposes, except that they are commonly mimicked by natural mutilations of the feet due to conspecific aggression and predatory attempts. Freeze-branding provides permanent marking by discoloring skin pigment, but in our study many animals sustained loss of digits and extreme distal portions of their tails. Freeze-branding for less than 20 seconds may provide satisfactory marks without resulting in severe tissue damage, but this technique was difficult to apply in the field, and would likely be inappropriate when large numbers of crocodilians had to be marked.

The length of time a mark remains with an animal is an important consideration in determining its effectiveness. Gorzula (1978) found that ventral caudal scute-clipping remained visible for at least 26 months in wild *C. crocodilus*. Although our data suggest that juvenile and adult crocodilians can be marked at any age or with the marking techniques we tested without affecting growth or survivorship, additional work should be conducted to determine retention times and the long-term applicability of marking techniques to research and management.

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