Diamondback Terrapin *(Malaclemys terrapin)* Head-Starting Project in Southern New Jersey

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Abstract: *As part of a long-term research and conservation project on northern diamondback terrapins,* Malaclemys terrapin terrapin, *we recovered eggs from road-killed females during the 5 to 6 week nesting season every June and July since 1989. Round-the-clock patrols on roads crossing and adjacent to salt marshes on the Cape May Peninsula collected up to 900 eggs each season. The eggs were labeled by clutch, weighed and their lengths measured; they were incubated on moist, very coarse vermiculite in large plastic containers. We maintained the eggs under controlled temperatures, ranging from 26°C to 32°C, in the laboratory facilities at Richard Stockton College. Hatchlings emerged in 7 to 10 weeks. They were tagged and weighed and their carapace and plastron lengths measured. Hatchlings were then "head-started" in our special "terrapin farm" until the following summer when they were released into their salt marsh habitat. Our goal was to offset partially the severe mortality of adult terrapins resulting from road kills and from drowning in commercial crab traps. These efforts have provided data on the correlation of egg mass with initial hatchling mass and of incubation temperature with hatchling sex and growth. Initial hatchling mass and incubation temperature seemed to influence post-hatchling growth and development; however, other variables in our terrapin farm, such as tank position relative to heat vents and composition of tank occupants may also have been important. Egg mass varied in any given year. Initial hatchling mass, plastron length and carapace length also varied. Initial hatchling mass ranged between 4 g to 9 g. Higher initial mass was generally greater from larger eggs. Initial mass had the clearest effect on post-hatching growth for the 1996 cohort. Given these data, and in view of our objective of returning as many healthy hatchlings back to the local population as possible, we are working to maximize the birth size of hatchlings. A clear benefit of our project is increased public awareness of the negative impact of human activities on diamondback terrapins in New Jersey. The involvement of local groups in trying to prevent mature females from being killed on coastal roads may have a far greater conservation impact than our recovery and incubation of eggs and the head-starting of the hatchlings.*

For more than a century, populations of northern diamondback terrapins (*Malaclemys terrapin terrapin*) in New Jersey have been adversely affected by a variety of human activities, such as development of natural sand dune nesting sites (Montevicchi and Burger 1975), mortality on roads along or crossing salt marshes (Wood and Herlands 1997), harvest for terrapin stew (Carr 1952, Wood and Herlands 1997), and bycatch in commercial crab traps (Wood 1997). As a consequence of losing their natural nesting habitat along the New Jersey coast, female terrapins started to use road embankments to find alternate nest sites above high-tide levels and this, in turn, led to their crossing coastal roads in large numbers. Not surprisingly, this change in behavior resulted in hundreds of adult female terrapins killed on roads each summer during the nesting season in June and July (Wood and Herlands 1997). Since female terrapins do not reach sexual maturity until at least 7 to 8 years (Carr 1952, Roosenburg and Dunham 1997) and possibly attain ages of 25 years or more, the loss of these adult females inevitably represents a decrease in the reproductive potential of the populations in some Jersey shore areas.

To compensate partially for this loss, we began in 1989 to head-start a few hundred or more northern diamondback terrapin hatchlings in our rearing facility (the "terrapin farm") at Richard Stockton College. These

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hatchlings emerged from eggs recovered from road killed females during the five to six week nesting season every year. Round-the-clock patrols on roads crossing and adjacent to salt marshes on the Cape May Peninsula collected up to 900 potentially viable eggs each season. The eggs were then incubated in artificial nests under controlled temperatures, ranging from 26°C to 32°C, in the laboratory. Hatchlings emerged in 48 to 75 days. Terrapin hatchlings are small (carapace medial length between 2 cm and 3 cm) with soft, mostly unossified shells and they are thus the likely prey of a variety of birds, mammals, fish and crabs.

During the first year of this project, hatchlings were released to their salt marsh habitat in late August within a few weeks of their emergence from their eggs. These small terrapins were immediately snatched up by laughing gulls, so the remaining hatchlings were retrieved before further predation and maintained in a warm environment until the following June to give them a head start in growth and development before their release. Thus, our head-starting project began, with the goal of returning as many large hatchlings with hard, ossified shells as we can to help offset partially the severe mortality of adult terrapins from various sources (Wood 1997, Wood and Herlands 1997). Over the past decade, more than 2000 hatchlings have spent the first nine to ten months of their lives in our terrapin farm.

Our efforts have also provided data that are useful for conservation efforts on this turtle population in southern New Jersey: egg size ranges during the nesting season; the effects of egg size, date of egg recovery within the nesting season, and incubation temperature on hatchling size and growth; and correlations between incubation conditions and sex determination. Preliminary analyses strongly suggested that initial hatchling mass is one of the best indicators for higher growth rate and development into a hard-shelled, healthy-looking hatchling. In addition, we have developed methods that increase the number of freshly hatched terrapins making a successful transition to the head-starting conditions. In view of our initial objective of returning as many healthy hatchlings back to the local population as possible, we attempted to maximize the birth size and health of our hatchlings. More recently, we have the potential to monitor the long-term fate of our released hatchlings by implanting small microchips under the loose skin anterior to their right hind limbs. Our goals now are also to evaluate restocking as a conservation tool and to identify various aspects of terrapin population biology.

Methods

We recovered eggs from road-killed females during the nesting season in June and July. Student research interns as well as community volunteers helped to monitor terrapin road kills along a 25 km network of roads crossing and adjacent to salt marshes and to retrieve potentially viable eggs (see Wood and Herlands 1997 for further details).

The recovered eggs were brought to Stockton College, where their mass (g) and length (mm) were recorded and they were labeled by pencil with a clutch number referring to their dead mother. The eggs were placed on a 5 cm bed of autoclaved, very coarse vermiculite (Schundler Company Horticulture vermiculite, grade 4) moistened with sterile water in 1:1 proportions by weight inside plastic containers that hold 25 to 30 eggs. The containers were covered to retain moisture. Additional sterile water was added as needed to keep the vermiculite slightly moist. At first the eggshells were pink and flexible, but viable eggs turned chalky white and became a bit harder within a week (Fig. 1a). Based on these criteria, about 50% to 60 % of the eggs were initially viable; however, rapid and persistent fungal infections often decreased the number of viable embryos. During the first two years, the eggs were incubated in the attic of a garage, which was chosen to provide an appropriate high temperature environment for producing females (Bull 1980, Auger 1989). A prolonged heat wave in early July 1990 overheated most of the eggs and resulted in a very low hatching rate (9 %, Wood and Herlands 1997). In subsequent years, eggs kept under constant temperature-controlled conditions in incubators increased hatching success (Table 1). We used a variety of incubators; our best hatching results have come with the use of tabletop Precision Scientific mechanical convection incubators (Model # 31534). Incubating temperatures ranged from 26°C to 32°C; our results showed that incubation at 30°C to 32°C consistently produced all females and incubation at 26°C to 27°C consistently produced all males (Herlands et al. 1993).

Depending on the incubation temperature, the embryos started pipping at 7 to 10 weeks of incubation. Higher temperatures reduced incubation times. When the hatchlings emerged from the eggs, they still displayed external remnants of their yolk sac; this external remnant interfered with their ability to swim (hatchlings from natural nests do not emerge from the nests until the yolk sac is resorbed). So we established a series of intermediate steps before the hatchlings were placed into tanks filled with water. First, they spent four to seven days in a five gallon fish tank filled with 7 cm of moist vermiculite until the yolk sac disappeared from their ventral plastron surface. Second, they spent a week in shallow water (about 2 to 3 cm deep) in a large plastic container. Finally, they were placed in a rearing tank in the head-starting facility.

We reared terrapins in a 4.8 m by 2.8 m room maintained at 25°C to 27°C year round. The room contained 16 modified sinks, 47.5 cm by 40 cm with a water depth of 8.75 cm. Each sink (or tank) had its own water supply outlet, drain, and brick under a 100 watt incandescent light for the animals to bask (Fig. 1b). Sinks were filled with brackish water, 12 ppt made from Fritz Super salt concentrate and trace elements and vitamins. Within three weeks of hatching, the turtles were fed daily with commercial food—TetraReptomin, Mazuri AquaMax fish food (LF size), Nasco Turtle Brittle—and once a week with cut up silversides (*Menidia menidia*). Each sink held 20 to 22 hatchlings, accommodating 320 to 350 terrapin hatchlings in all. By late September, all of our artificially incubated viable eggs had hatched.

Growth of individual hatchlings was followed by measuring carapace and plastron lengths (mm) and mass (g) at their emergence from eggs and once every four weeks. We measured the straight midline lengths of carapace and plastron of hatchlings with vernier calipers. We also observed each hatchling at emergence for carapace scute anomalies. Terrapins normally have a carapace pattern consisting of 5 central vertebral scutes, 4 right and 4 left costal scutes and 25 marginal scutes including a central anterior cervical scute. We noted the presence of extra or missing scutes.

Each June, large (carapace length of > 50 mm), hard-shelled hatchlings were returned with the help of local student groups (and with considerable media attention) to salt marshes near where the "mothers" were killed. Recently, we have tagged the hatchlings with 12 mm microchips (AVID 2023) placed under their skin in front of their right hind leg using an AVID MUSICC dispenser (AVID 3002); these marked terrapins can be identified easily with a hand-held scanner in the field. Because hatchling terrapins may imprint on their release point, the head-started juvenile terrapins were released at several different localities throughout the study area. This may prevent future clustering of nesting adults at a single former release site (Wood and Herlands 1997).

We used a Graph Pad Prism program to do statistical analyses: linear regression analysis between egg mass and initial hatchling mass, carapace and plastron lengths; and one-way ANOVA on egg mass, initial hatchling mass and carapace and plastron lengths from 1994, 1995, and 1996 cohorts.

Fig. 1a. Viable eggs in artificial nests.

Fig. 1b. Hatchlings basking on brick in tank.

Fig. 1c. New hatchling and a hatchling after six months in our head-starting facility.

Results

We have had consistent success with the hatching of recovered, artificially incubated terrapin eggs and with the survival of hatchlings in our rearing facility (Table 1). The hatching success rate ranged from 32% to 49.6% and the survival rate of hatchlings over the 9 to 10 month head-starting period ranged from 61% to 94.5%. Lower hatching success may have resulted from a number of factors: amount of fungal infection in the vermiculite-filled containers or in the incubator, improper functioning of the incubator, number of dehydrated eggs (constant incubation temperature over 30°C often increased dehydration), rotation of the recovered eggs once they were placed on moist vermiculite, or time of day eggs were retrieved. Eggs rotated accidentally after 24 hours of recovery almost never hatched and eggs

Table 1. Summary data from northern diamondback terrapin head-starting project, 1991–2000.

Year	Number of Eggs Incubated	Number of Hatchlings	% Hatching Success	No. Head-started & Released*	% Surviving Head-starting
1991–92	746	288	38.6	175	80
1992–93	734	235	32	144	61
1993–94	448	222	49.6	210	94.5
1994–95	399	157	39	162*	88
1995–96	250	113	45	157*	87
1996–97	897	406	45	341	76
1997–98	411	239	58	205	86
1998–99	890	294	33	257	87
1999–2000	791	340	43	312**	91.7**

*Additional hatchlings were often added to head-starting population from other sources.

**As of May 2000 and to be released in June 2000.

recovered at night or in the early morning hours were more likely to contain viable embryos. Post-natal mortality among hatchlings also varied for unknown reasons, but the number of deaths relatively soon after hatching decreased to almost zero with gradual transition from artificial nest to rearing tank. Most terrapin hatchlings grew larger, but a few did not during the 9 to 10 month period. What is clear is that hatchlings that grew and developed ossified shells were more likely to survive the entire head-starting period. In these hatchlings, growth from their initial size was often considerable with increased carapace lengths of 2.5 times or more (28 mm to > 70 mm) and increased mass of 8 to 10 times or more (6 g to > 50 g). Fig. 1c illustrates the difference in size between a few-weeks-old hatchling and a hatchling that has spent seven months in the head-starting facility.

Recovered Egg and Hatchling Parameters—The mass and length of the retrieved eggs were fairly consistent across a nesting season. Egg mass ranged from 5 g to 13 g and egg length ranged from 29 cm to 36 mm. Mean egg parameters for three typical years are given in Table 2. Egg mass differs significantly between years (ANOVA, $F_{2, 1800} = 5.81$, $p<0.01$). Clutch size is typically in the range of 8 to 12 eggs, but can be as small as 5 and as large as 23. We consistently saw a linear correlation between egg mass and initial hatchling mass: the heavier the egg, the heavier the hatchling (see Fig 2; linear regression analysis on the 1996 data yielded $F_{1, 388} = 1216$; $r^2 = 0.7590$, $p< 0.0001$). Carapace and plastron lengths were also significantly correlated with egg mass ($F_{1, 392} = 372.8$, $r^2 = 0.4487$, $p<0.0001$ and $F_{1, 392} = 43.90$, $r^2 = 0.1012$, $p < 0.0001$, respectively).

Table 2. Typical egg and hatchling data.

z	1994	1995	1996
Mean egg mass (g)	7.5 ± 1.17	7.56 ± 1.27	7.3 ± 1.25
Mean egg length (mm)	NA	NA	32.2 ± 2.0
Mean hatchling mass (g)	6.48 ± .88	6.24 ±1.09	6.3 ± .93
Mean carapace length (mm)	28.8 ± 4.8	27.8 ± 2.1	27.8 ± 1.6
Mean plastron length (mm)	25.4 ± 4.7	24.7 ± 1.7	24.7 ± 3.5

Initial hatchling measurements also varied; mass ranged from 4 g to 9 g, carapace length ranged from 24 mm to 32 mm, and plastron lengths ranged from 19 mm to 27 mm. The average initial size of hatchlings based on mass, carapace length and plastron length for three typical years is shown in Table 2. Hatchling mass and carapace lengths statistically differed between these years shown ($F_{2, 705} = 3.04$, $p = 0.049$ and $F_{2, 737} = 7.96$, $p < 0.001$, respectively). There was clearly a considerable range in these parameters each year; these parameters also varied for hatchlings from natural nests at Reeds Beach along the Delaware Bay shore of New Jersey's Cape May Peninsula (Wood and Herlands unpubl. data).

For the 1996–1997 cohort, we followed the weight gain of individual hatchlings. We found that hatchlings with an initial mass of less than 6 g grew more slowly (0.04 g/day) than hatchlings with an initial mass of 6 g or more (0.12 g/day) for the first six months in our rearing facility.

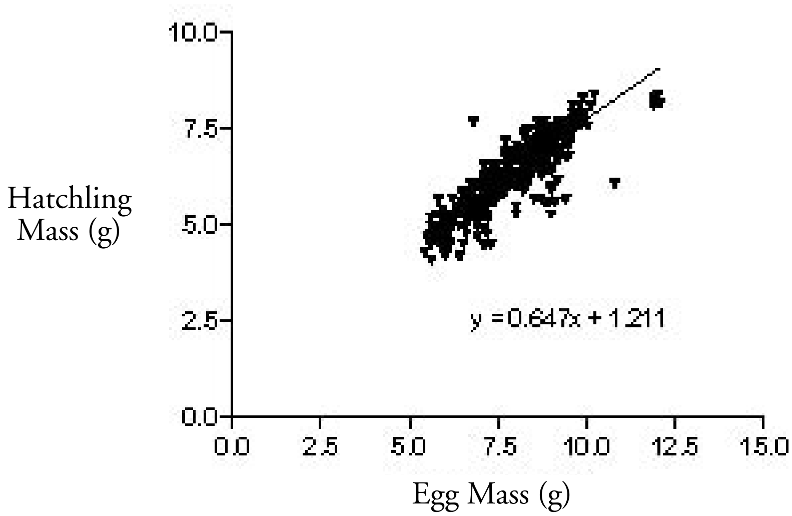

Fig. 2. The relationship between egg mass and initial hatchling mass in 1996. Linear regression analysis showed a significant relationship, $p<0.0001$ ($r^2 = 0.759$).

Effects of Rearing Conditions on Hatchlings—The survival of a reared hatchling depended on its ability to adapt to a continuous warm environment, stay active, feed and grow. We identified a number of factors that may have affected the extent of growth of hatchlings in our facility: initial hatchling mass, hatching date, location of tank in head-starting facility, type of food and frequency of feeding, and relative size of other hatchlings in same tank. Until this past year, most of the post-natal mortality (about over 80 %) occurred within four months after hatching when the hatchling had used up its internal stored yolk; the dead hatchlings were almost always soft-shelled and had the same carapace length as they had at hatching, but weighed less. Usually, other hatchlings in the same rearing tank did grow. In 1999, we started feeding the hatchlings

Table 3. Carapace scute anomalies.

	% of terrapins with carapace scute anomalies	% of terrapins with carapace scute anomalies excluding those with only a split cervical scute
A. Versus Incubation Temperature		
Temp of Incubation °C		
32	53.6 (110)*	44.5 (110)
31	54.2 (28)	50 (28)
30	44.8 (395)	29.3 (395)
28	40.8 (421)	15.9 (421)
27	28.7 (223)	20.1 (223)
26	37.6 (216)	19.9 (216)
B. In Natural Populations		
Hatchlings Recovered from Reeds Beach in New Jersey		
1997 (9/29–9/30)	71 (73)	17.8 (73)
1999 (8/24)	53.6 (25)	25 (25)
2000 (5/9)	47.7 (151)	31 (151)
Adults from Cape May Populations		
Females	22.9 (341)	14.1 (341)
Males	23 (65)	7.7 (65)

*total number of terrapins in sample is indicated within parentheses within three weeks of hatching rather than waiting six weeks. This change was followed by a marked decrease in mortality at four months and might explain the relatively high percentage of surviving hatchlings in the 1999–2000 cohort (Table 1). Hatchlings from eggs retrieved early in the nesting season grew bigger than hatchlings from eggs retrieved at the end. Although the data varied year to year, for the 1999–2000 cohort, early-emerging hatchlings grew to an average carapace length of 110 mm, whereas late-emerging hatchlings grew to an average carapace length of 57.2 mm. This difference may reflect a longer period for growth for the early hatchlings. For most years, no deaths occurred during the rearing period among this group of hatchlings. Moreover, our impressions were that small hatchlings did better in general when they were grouped with other similar sized hatchlings and when they were moved to slightly warmer water tanks (from 23.3°C to 25.5°C).

Hatchling Carapace Scute Anomalies—One of our early and consistent observations concerned the possible association between embryonic incubation temperature and supernumerary carapace scutes (Table 3). We focused on carapace scute anomalies because they are far more frequent than plastron scute anomalies. Terrapins normally have a carapace pattern consisting of 5 central vertebral scutes, 4 right and 4 left costal scutes and 25 marginal scutes including a central anterior cervical one. The most common scute anomaly was a medial subdivision of the unpaired cervical scute in both the natural population and in our head-started population; the next most common scute anomalies were extra scutes resulting from subdivisions of the 4th and 5th vertebrals. Hatchlings from eggs incubated at 30°C to 32°C had a higher percentage of individuals with supernumerary scutes than hatchlings from eggs incubated at lower temperatures. This difference was more pronounced when subdivisions of the cervical scute were not considered. A higher percentage of adult females compared to adult males in the local population also showed supernumerary vertebral and costal scutes. Road-killed female carapaces were examined whenever possible for scute abnormalities; we never found a connection between a dead female's carapace scute pattern abnormalities and her hatchlings' scute pattern.

Discussion

Head-starting involves rearing turtle hatchlings in captivity until they reach a size that will ensure the survival of substantial numbers of them after release into wild populations. Head-starting activities have typically served one of two purposes: (1) to bolster populations, such as the giant tortoises on the Galapagos Islands (Merlen 1999), and (2) to establish new nesting sites for threatened and endangered species, such as the Kemp's Ridley (Frazer 1994, Mortimer 1995). Even though there have been a number of well-funded and well-publicized head-starting programs with sea turtles, we are aware that head-starting as a conservation tool is controversial and questions remain whether it is a cost effective method for bolstering a declining population (Frazer 1992,1994; Dodd and Seigel 1991). On the other hand, Burke (1991) concluded that repatriation, relocation and translocation techniques should be considered as an option in any conservation program; furthermore, Merlen (1999, pg.39) claimed that the breeding and repatriation program for Galapagos tortoises has aided a half dozen populations and that "the success of breeding the Espanola race shows that a population can be brought back from the brink of extinction." Our project differed from most head-starting programs because we raised and repatriated juveniles primarily from eggs recovered from road-killed females and so we returned to the wild 200 to 300 terrapins each year which would otherwise never have existed. These efforts represented an attempt to compensate partially for the loss of terrapins due to human activities in southern New Jersey: killing females attempting to find nests on coastal roads (Wood and Herlands 1997), drowning of both adults and juveniles in commercial crab traps (Wood 1997), and the destruction of natural sand dune nesting sites by coastal development. We do not know yet the extent to which our efforts have helped offset the above losses from the local populations because we have only been able to track a few of the released terrapins in the past year. Our success at replenishing the terrapin population can only be partial at best because, in a typical year, 400 to 600 adult females are killed on roads within or adjacent to our study area (Wood and Herlands 1997).

Additional benefits of our project are increased public awareness of the plight of this state-protected turtle in New Jersey and the involvement of local groups in our efforts. We have received superb media coverage of our terrapin releases, which routinely have included school children. We have had a number of community volunteers who do road patrols. School groups and local public works departments have made and set up terrapin crossing signs warning drivers to watch out for terrapins during the nesting season. A number of school groups also raised money to help us defray the costs of rearing hatchlings for nine to ten months.

All of this is important because conservation is not simply an academic exercise. Without public awareness, concern, and involvement, necessary political conservation measures will not occur. Successful conservation programs often hinge on efforts to save charismatic megavertebrates, such as tigers, pandas, and whales. Turtles can serve the same function because of their almost universal appeal to people all over the world. Our experience is that people respond to the plight of turtles in much the same way as they do to the appeals for saving the large vertebrates. The economic and social changes that have made southern New Jersey a year-round tourist location are likely to expand in the coming years and that reality makes increased public awareness and our efforts to get commercial crabbers to use turtle excluders (Wood 1997) all the more important. Furthermore, the saving of any mature female – which has the capacity to lay more than a thousand eggs over her lifetime – would have substantial conservation impact on the local population.

We have hatched terrapins from eggs retrieved from road kills and successfully reared many of the hatchlings. We would, however, like to maximize the number of hatchlings that grow large enough to be released because larger size at release may also be important for survival in the wild; a study on head-started Red-bellied turtles (*Pseudemys rubriventris*) released back into the wild in Massachusetts (Haskell et al. 1996) reported that larger size at release did correlate with higher survival rates after three years. We found that initial hatchling mass was an important indicator of hatchling growth and survival in our terrapin farm. Our data showed that initial hatchling mass correlated significantly with egg mass; Roosenburg and Kelley (1996) also found a correlation between mass of eggs and hatchlings from natural nests along the Patuxent River drainage of the Chesapeake Bay in Maryland.

Is there any other way we might increase hatchling mass? Our experiments with incubating eggs from road kills confirmed the findings of others (Bull 1980, Auger 1989) that diamondback terrapins have temperature-dependent sex determination (Herlands et al. 1993); others have made similar findings (Jeyasuria et al.1994, Roosenburg and Kelly 1996). Even though higher incubation temperatures produce females and lead to higher growth rates of hatchlings (Roosenburg and Kelly 1996), we chose to limit constant incubation temperature to no more than 30°C because we found increased dehydration of eggs and subsequent loss of these embryos from incubation in temperatures over 30°C. On the other hand, studies on snapping turtles (Packard et al.1987, Packard et al. 1998) suggested that the availability of water during the prenatal period is critical for healthy and larger hatchlings. Our experience has been that increased water in the artificial nests led to increased fungal infection and loss of embryos. Keeping new hatchlings in moist vermiculite for four to seven days until the external yolk sac remnant disappeared might compensate for a slightly drier incubation environment. We also plan to vary the amount of sterile water added to the vermiculite in the artificial nests to see whether doing so does increase hatchling mass and can be accomplished without increasing fungal growth. Our results from the 1999–2000 hatchling cohort suggested that an earlier start to feeding the hatchlings resulted in greater growth too.

We recognize that both our egg incubation and head-starting conditions differed substantially from what occurs in the terrapin's natural salt marsh habitat. Vermiculite has routinely served as substrate for incubating eggs (see Roosenburg and Kelly 1996, Merlen 1999). Other turtle egg breeding programs (Merlen 1999) also incubate eggs on top of the vermiculite. Perhaps we need to investigate whether we could reduce dehydration of eggs if we partially bury the eggs in the vermiculite; doing so, however, would impede monitoring for fungal infections and our experience has shown that rampant infections can destroy all the embryos in the same artificial nest (Herlands unpubl. data). Our choice of incubation temperatures determined the sex ratios of released juveniles; most years we have raised and released more females and this bias reflected our aim to replace females lost on area roads during the nesting season. We believe that this bias is appropriate because the loss of these mature females represents a critical loss to the reproductive potential of local populations. Moreover, our head-starting facility has kept the hatchlings at a warm temperature and thus active during a six month period when they would normally hibernate and not eat or grow. Their constant activity and eating means that they reached the size of 2 to 3 year olds when we released them the following June. Because young, small hatchlings represent the most vulnerable life stages for aquatic turtles (Frazer 1994), the relatively larger size of our released juvenile terrapins may give them a greater chance at survival. The ability to track released juveniles in the coming years should tell us how well they succeed in returning to a normal feeding schedule and a slower growth rate.

As Carr (1952) has noted, feeding over the winter months may accelerate the maturation of females. We have some evidence (unpublished data) suggesting that local terrapin populations are declining rapidly. Such populations may experience loss of genetic diversity due to a population bottleneck effect. An accelerated maturation of released female hatchlings, even if only a few should survive, may potentially offset this loss in genetic diversity.

In addition to the growth and survival of terrapin hatchlings, we needed to limit possible problems induced by our incubation and rearing conditions, so that we could release healthy terrapins back into their salt marsh habitat. Crowded rearing tanks certainly provide another departure from normal habitat conditions. Under these conditions, external injuries have occurred with increasing frequency as the hatchlings grew. We isolated any hatchling with external injuries (tail bites or eye scratches) or with abnormal swimming behavior. These measures have usually led to the return to seemingly healthy individuals. Finally, we have initiated a study to determine if our head-started terrapins have acquired any bacterial or parasite infections not already present in the wild population. Preliminary tests showed no evidence of parasites in our head-started terrapins (R. Werner pers. comm.).

One possible problem stemming from constant, high incubation temperatures has been the development of supernumerary carapace scutes. The carapace in diamondback terrapins is attached to the vertebrae and ribs and its development during the prenatal period can have profound effects on body shape (Alibardi and Thompson 1999). We have seen a higher proportion of scute anomalies in hatchlings incubated at higher temperatures as well as in adult females in the local wild population. Shell abnormalities themselves are not rare in turtles (Carr 1952, Zangerl and Johnson 1957), but some anomalies in our hatchlings are associated with twisted body morphologies and we have chosen not to release these individuals. It may be that insufficient hydration during incubation (Lynn and Ullrich 1950) produced supernumerary scute formation. Our finding that hatchlings from eggs incubated at higher constant temperatures and females (presumably produced at higher nesting temperatures) in the wild population have higher numbers of scute anomalies is consistent with this correlation. We plan to investigate whether increasing the moisture level during incubation also leads to a decrease in the number of supernumerary vertebral scutes. Our project also has provided us with large numbers of related terrapin hatchlings. We are beginning to investigate a number of developmental and genetic questions that this opportunity provides.

Addendum: After the submission of this paper, we have identified a few of our released juveniles caught accidentally in seining nets. These terrapins looked healthy and were feeding on grass shrimp. A paper by Seigel and Dodd (Manipulation of Turtle Populations for Conservation: Halfway Technologies or Viable Options?), appeared in 2000 in *Turtle Conservation,* edited by Michael W. Klemens, Smithsonian Institution Press, Washington, D.C.; pp. 218–238, reconfirming their criticism of head-starting as a conservation tool.

Acknowledgments

This project depends on the contributions of a large number of volunteers over the past decade. We particularly want to thank all the college and high school research interns at the Wetlands Institute and community volunteers for their dedicated work on road patrols at all times of day and night and Ruthann Flannagan for the Reeds Beach sample of natural hatchlings. We especially appreciate the care of the hatchlings in the terrapin farm provided by John Rokita and his student assistants; their nurturing care has been most important for the success of this project. We thank our colleagues, Stan Hales, Matthew Landau, and Linda Smith, for their assistance with editing and statistical analyses. We are also most grateful for the sustained and long-term support from Richard Stockton College and the Wetlands Institute.

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