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Schools as Conservation Partners: Lessons Learned from over a Decade of Headstarting Turtles

Emilie R. Wilder[1,*], Cara L. McElroy[1], Matthew D. Kamm[1], John Berkholtz[1], and Bryan S. Windmiller[1]

Abstract - Headstarting is an increasingly common tool used by conservationists, especially with herpetofauna. However, attaining meaningful conservation results often entails headstarting large numbers of animals over many years, a significant investment of time, resources, and space. In order to share the burden of the work, and also enable community engagement in the project, we partner with local schools to raise the turtles in classrooms. Headstarting in schools also allows us to expose participating school children to local conservation concerns and give them an opportunity to make a difference in their communities. At the same time, a decentralized headstarting structure can present challenges, such as ensuring that protocols and standards are maintained, communicating with a large group of caretakers, and monitoring the health and growth of animals in different locations. Based on 14 year's experience in overseeing the raising of nearly 1000 hatchling *Emydoidea blandingii* (Blanding's Turtle) and *Glyptemys insculpta* (Wood Turtle) in classrooms, we present our key lessons learned and best practices for other organizations who may be contemplating similar collaborations with local schools.

Introduction

Headstarting is a chelonian-conservation intervention strategy that involves protecting animals at vulnerable life stages to increase their likelihood of survival in the wild (Burke 2015). Headstarting has been used since at least the 1970s, initially with sea turtles (Henderson 1978), and has been effectively used to increase individual turtle populations with low juvenile recruitment (Bougie et al. 2022, Carstairs et al. 2019, Golba et al. 2022, Regosin et al. 2017, Spencer et al. 2017, Thompson et al. 2020, Wijewardena et al. 2023). Despite debate over whether headstarting works and how to assess its utility at wider scales, this strategy is increasingly accepted (Bennett et al. 2017, Burke 2015), and more turtle-headstarting programs are initiated each year (Friends of Nachusa Grasslands 2020, Maryland Zoo 2022, Nashville Zoo 2021, The Nature Conservancy 2022).

Most headstarting programs employ trained professionals (such as animal keepers at zoos and aquariums, wildlife biologists at governmental agencies, or other trained individuals in NGOs and institutional settings) in centralized captive-rearing facilities. Relatively few turtle headstarting programs use a decentralized system in which turtles are raised by individual volunteers or school classrooms. Notable exceptions include the Massachusetts Division of Fisheries and Wildlife program to headstart *Pseudemys rubriventris* (Le Conte) (Northern Red-bellied Cooter; Regosin et al. 2017) as well as headstarting of *Malaclemys terrapin*

[1]Zoo New England, Boston, MA 02121. [*]Corresponding author - ewilder@zoonewengland.org.

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(Schoepff) (Diamondback Terrapin) in Maryland (Herlands et al. 2004). Headstarting under our model contrasts from these other school-based programs that occur in purpose-built or specialized settings, such as agricultural or technical schools (Green 2015). In this paper, we discuss a program in which regular K–12 schools have successfully headstarted turtles for conservation purposes. We show that, with appropriate protocols and oversight, school-based headstarting provides similar outcomes to more conventional headstarting programs in terms of survivorship and growth, while providing the following additional program benefits: increased headstarting capacity, reduced program costs, and greater community engagement with and support for turtle conservation.

History of the H.A.T.C.H. program and turtle headstarting at Zoo New England

We have been involved in Massachusetts turtle conservation efforts since 2003 with Grassroots Wildlife Conservation, Inc., and Zoo New England (ZNE). Over these past 2 decades, we have worked to conserve and restore local populations of *Emydoidea blandingii* (Holbrook) (Blanding's Turtle), *Glyptemys insculpta* (Le Conte) (Wood Turtle), *Terrapene carolina* (L.) (Eastern Box Turtle), and *Clemmys guttata* (Schneider) (Spotted Turtle) as well as urban populations of *Chelydra serpentina* (L.) (Common Snapping Turtle). Our comprehensive conservation-management strategies are site- and species-specific and include population surveys, modeling, nest protection, and habitat-restoration efforts, as well as headstarting where warranted and permitted. We have headstarted just over 1400 turtle hatchlings since 2003. In 2003 and 2004, we experimentally headstarted 26 Blanding's Turtle hatchlings, but headstarting began in earnest in 2007. Over the years, the great majority (86%) of the turtles that we have headstarted have been Blanding's Turtles, but we have also headstarted Wood Turtles (10%), Eastern Box Turtles (3%), and Spotted Turtles (1%).

In 2007 and 2008, headstarting took place at Zoo New England (Stoneham, MA) and the New England Aquarium (Boston, MA). Institutional capacity was limited, however, and following the model pioneered by the Massachusetts Division of Fisheries and Wildlife (MassWildlife) to headstart Northern Red-bellied Cooters (Regosin et al. 2017) in schools, B.S. Windmiller recruited 4 schools in 2009 near our original project site in Concord, MA, to assist with the headstarting. School participation grew by word of mouth or through outreach to school districts near project sites. To-date, we have worked with 61 individual schools in Massachusetts (36 elementary schools, 16 middle schools, and 9 high schools), with some of these schools being involved continuously since 2009. Our school-based headstarting effort is called H.A.T.C.H. (Hatchling and Turtle Conservation through Headstarting) and involves extensive teacher training, educational programming, and field trips for students, who release their turtles into the turtles' natal habitats and learn about the local environment. Our primary goal with the H.A.T.C.H. program is to help restore declining and threatened populations of turtles. Secondarily, we aim to involve the local community, especially school children, in our conservation program, increase awareness about the plight of turtles, and build a cadre of interested

citizens who care about local conservation and are empowered to make a difference in their communities. Below, we outline the program and consider the benefits and challenges of our highly collaborative approach, including comparing outcomes for turtles headstarted by schools, zoos and other institutions, and volunteers.

Methods

Headstarting

Our goal with turtle headstarting is to augment the size of populations of rare turtles with which we work by increasing the probability that individual turtles survive from hatching to breeding age. We do this by protecting nests (both in situ and in ex situ incubators) and by accelerating the post-hatching growth rates of the turtles before release into their natal habitats. The headstarted juvenile turtles don't encounter predators until they are considerably larger in size and thus presumably better protected from predation than is the case with non-headstarted turtles of similar ages. In addition to accelerating their growth, our goal is also to minimize mortality and morbidity during the relatively brief captive phase of the turtles' lives. Our headstarting protocols are based on these goals and we have adjusted care protocols over the years to improve both survival and growth rates. Care protocols are adaptive, and we regularly revise care protocols, aquaria set-ups, diet, and other husbandry techniques based on observed turtle behavior or as we have learned what works. The methods and data described in this paper refer exclusively to our work with Blanding's and Wood Turtles unless otherwise noted. We have also successfully raised Spotted Turtles, Eastern Box Turtles, and Common Snapping Turtles in classrooms, so the collaborative school-based approach we use to headstart turtles can likely be applied to a wide variety of turtle species if their care needs can be met in a classroom setting.

Headstarting facilities. In this paper, we compare headstarting outcomes between 3 different "facility" types: schools (K–12 schools in Massachusetts participating in the H.A.T.C.H. program), institutions (including Franklin Park Zoo and the New England Aquarium in Boston, MA; Stone Zoo in Stoneham, MA; and various wildlife centers or other facilities with trained wildlife professionals), and volunteers (which include zoo staff and other individuals at their private residences).

Headstarting protocols. Hatchling turtles are obtained from protected nests at our field conservation sites or from nests protected by project partners. In rare cases ($n < 20$), hatchlings were found after emergence or sourced from salvaged eggs obtained from road-killed turtles. The number of turtles headstarted from a given nest or population is set by permits obtained under the Massachusetts Natural Heritage and Endangered Species Program and has varied by species and site over the years. Once hatchlings emerge (either from in situ nests or in ex situ incubators), the zoo or individual volunteers raise them for several weeks in a small number of centralized locations in groups of 15–20 turtles before the hatchlings are distributed to their "permanent" headstarting facility. During this time, caretakers maintain feeding and growth logs for the hatchlings, and an effort is made to deliver hatchlings to schools when they have begun eating commercial pellets regularly.

Once delivered to their permanent headstarting facility, the turtles are typically raised in pairs in 20-gallon long aquaria (or in larger aquaria or stock tanks at institutions) outfitted with a minimum of a submersible heater, water filter, UV light bulb on a timer, and a floating dock or other basking area. The submersible heater is set to 26.5 °C (80 °F) and the light is set to 12 hours on/12 hours off. Turtles are fed twice per day on school days in schools, and usually every day at institutions or with volunteers. During school vacations longer than a 3-day weekend, a teacher or volunteer will typically take turtles home to be cared for.

Each turtle is weighed and measured at hatching, and marked using a unique combination of marginal scute notches, allowing caretakers to individually identify each turtle in their care. Once these hatchlings are transferred to their headstarting location, headstarting supervisors become responsible for weighing and measuring the turtles at least once per month, on or near the first of the month. Data are logged onto a central online spreadsheet that is monitored by ZNE staff. When turtles are not growing at a steady rate, staff reach out to the headstarting facility to discuss concerns and adjust feeding techniques or food types until the turtle has regained normal growth. In some instances, the turtle is brought into our (or a partner's) veterinary facility for medical evaluation or treatment.

All headstarted turtles are kept in isolated facilities to prevent the introduction of pathogens and diseases to the wild. Within zoos, the turtles are housed in rooms that are quarantined from the rest of the collection, and keepers who work with the turtles do not work with any other reptiles or amphibians on the same day. Schools or private residences may have other pets on premises but cannot have the turtles in the same room as other ectothermic vertebrates or any aquatic animals. We do not test our headstarted turtles for pathogens prior to release. Given the strict isolation in which the headstarted turtles are kept from any possible vectors of disease novel to their populations, we believe that the risk of introducing harmful pathogens to the natal populations is very low (Jakob-Hoff et al. 2014). Additionally, pathogen screening would likely detect the presence of some pathogens that are ubiquitous within the turtles' natal populations and with which they were infected prior to collection from their nests (Allender et al. 2013, Carstairs et al. 2020). The detection of pathogens among the headstarted turtles that are already prevalent in their natal populations and that were acquired from the natal populations would not provide meaningful information relevant to decisions about their release.

School-specific headstarting protocols. Before delivery of the hatchlings, each new school, or new teacher at a returning school, receives an in-person training session on turtle-care protocols including instructions on feeding, tank maintenance, and safety considerations. At this time, ZNE staff members inspect the classroom and aquarium set-up to ensure that it meets our protocol standards, including confirming the absence of other prohibited animals in the classroom. Additionally, since 2018, all teachers must certify that their classes have watched a kid-friendly "How to Care for Your Turtles" video that details all the care protocols, after which the students sign a "Turtle Care Contract." At the time of delivery, schools headstarting turtles also receive an introductory classroom program presented by a

ZNE field biologist in which students learn about turtle conservation and their role in ZNE's turtle conservation efforts. This presentation specifically discourages the keeping of any turtles as pets and the importance of keeping wild turtles in the wild.

Headstarting duration. Most turtles (97%) are headstarted for <1 year, from hatching in the late-summer/fall through the following spring. The exact duration depends on the turtles' hatch and release date, but generally spans 8–11 months. Our target release weight, established in 2017 and based on evidence from Green et. al (2015), is ≥75 g; turtles who do not reach this threshold or that require medical observation before release may be "held back" for an additional year of headstarting (n = 43 [3%] over the course of our efforts so far).

Data analysis

Data considered. Data shown in Figure 1 pertain to hatchlings of all 4 turtle species of conservation concern that we have headstarted from 2007 through 2022 (n = 1395). All subsequent analyses only include data for headstarted Blanding's Turtles and Wood Turtles during the same period (n = 1335). These 2 species make up 96% of all our headstarted turtles; there are too few headstarted Spotted and Eastern Box Turtles in our sample to permit useful analysis. Additionally, for turtles that were headstarted for >1 year, we only consider the turtles' growth and survival in their first year of headstarting.

Comparative mortality analysis. We report simple mortality for the Blanding's Turtles and Wood Turtles (dead / # unique individuals headstarted) for an overview on survival in captivity. In order to eliminate bias due to differential headstarting durations, we have restricted the headstarting period to 1 November–1 May for our comparative mortality analysis. Turtles are generally all placed in their permanent headstarting facility by 1 November and are released after 1 May. We used chi-square tests to test our prediction that the mortality rate of turtles in schools was lower than or comparable to the mortality rate for turtles housed in other institutions or with volunteers via R package 'rcompanion' (Mangiafico 2023) in R v. 4.2.1 (R Foundation, Vienna, Austria).

Comparative growth analysis. Comparative growth analysis is based on 1 May mass. Since the turtles are typically released between mid-May and the end of June in the year following their hatching, 1 May is the last date the turtles can be directly compared in captivity. Because data are self-reported from caretakers, some data are missing, but we have 1 May weights for 92% of hatchlings. The 1 May weights of Wood Turtles were determined to be normally distributed and therefore were tested via a one-way ANOVA. However, the weights of Blanding's Turtles were not normally distributed according to the Shapiro–Wilk test of normality (Shapiro and Wilk 1965), so for those we tested the results via the non-parametric Kruskal–Wallis test (1952) followed by the Dunn test (1961) with a Bonferroni adjustment.

Results

Since 2007 we have headstarted 1395 turtle hatchlings, including 1195 Blanding's Turtles and 140 Wood Turtles, 42 Eastern Box Turtles, and 18 Spotted Turtles,

with the majority of these raised in schools (Fig. 1). Among Blanding's and Wood Turtles, 72% were raised in schools (n = 957), 21% in institutions (n = 278), and 7% with individual volunteers (n = 100). All but 43 (3%) of the Blanding's and Wood Turtles were raised less than a year (8–11 months). Of the 1335 unique Blanding's and Wood Turtles that were entered into the headstarting program, all but 74 (5.5%) survived to be released back to the wild.

Comparative mortality rates

During the 1 November–1 May headstarting period, schools had a lower rate of mortality (3.8%) compared to institutions (4.5%) or volunteers (5.1%), although the difference was not statistically significant (Table 1). A Pearson's chi-squared test of independence shows that there is no significant difference in the likelihood of a hatchling dying in captivity among the facilities (χ^2 = 0.74, df = 2, P = 0.69). There were an additional 20 deaths that occurred outside the 1 November–1 May headstarting period or in the second year of headstarting. Thirteen of these occurred prior to 1 November and 77% of those were ascribed to "failure to thrive"

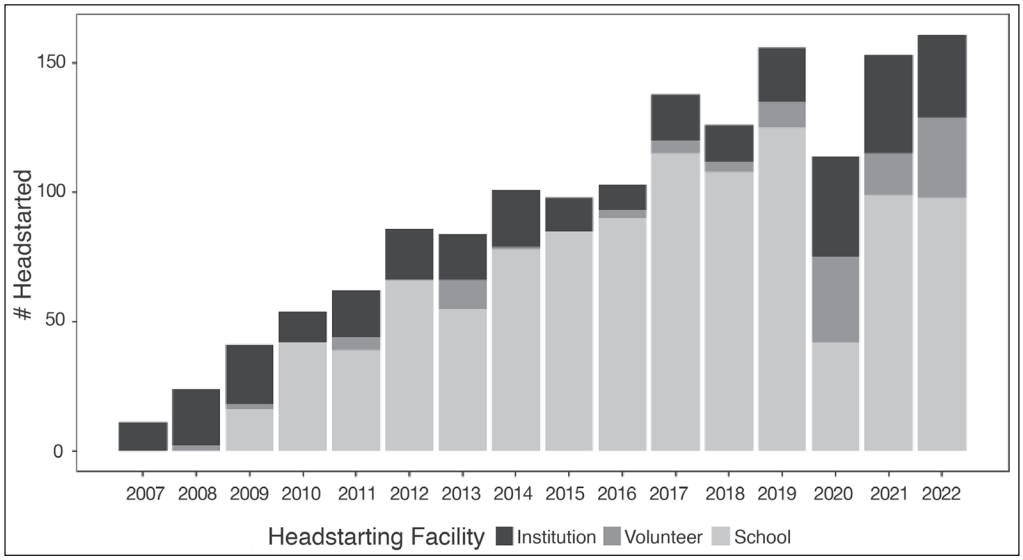

Figure 1. Number of turtles headstarted (all species) between 2007 and 2022. Year indicated is the hatch year, though turtles are headstarted into the following year. The 64 turtles (all species) that were headstarted into a second or third year are only counted in their first year. The number of turtles headstarted in schools decreased dramatically in 2020 due to the Covid-19 pandemic.

Table 1. Mortality rates by facility type during the 1 November–1 May headstarting period.

Facility	# turtles	# deaths (1 Nov–1 May)	Mortality rate
School	954	36	3.8%
Institution	269	12	4.5%
Volunteer	99	5	5.1%
All	1322	53	4.0%

(deaths in which turtles present slow or no growth from hatching or show signs of birth defects and die at <25 g, which we attribute to congenital disease or defects). A breakdown of all deaths by proximal cause is provided in Supplemental File 1 (available online at http://www.eaglehill.us/NENAonline/suppl-files/n31-sp12-N2059cc-Wilder-s1, or for BioOne subscribers, at https://www.doi.org/10.1656/N2059cc.s1).

Comparative growth outcomes

By the end of the 8–11 month headstarting period, the average mass at release was 143.3 g for Blanding's Turtles and 233.8 g for Wood Turtles. Release dates have been anywhere from 12 to 115 days after 1 May, though, so to compare growth outcomes between headstarting facilities we use 1 May data (Table 2, Fig. 2). School-raised turtles were, on average, smaller on 1 May (Blanding's Turtles: mean ± SD = 112.9 ± 50.8 g, Wood Turtles: 191.0 ± 72.7 g) than those raised in other institutions (Blanding's Turtles: 129.2 ± 69.6 g, Wood Turtles: 206.9 ± 42.1g) or with volunteers (Blanding's Turtles: 163.9 ± 98.4 g, Wood Turtles: 227.8 ± 97.2 g). These differences were statistically significant for Blanding's Turtles (Kruskal–Wallis test: χ^2 = 40.02, df = 2, P <0.00001), but not for Wood Turtles (ANOVA: P value = 0.08).

Table 2. Mean turtle growth during headstarting by headstarting facility on 1 May the year after hatching and at release. Turtles raised for >1 year are excluded from the release column only because their release weight is not comparable to those raised <1 year. For turtles raised for 1 year, the release date was anywhere from 12 to 115 days after 1 May.

	Blanding's Turtles			Wood Turtles		
Headstarting facility	# turtles	1 May mass (mean ± SD; g)	Release mass (mean; g)	# turtles	1 May mass (mean ± SD; g)	Release mass (mean; g)
Schools	881	112.9 ± 50.8	133.3	76	191.0 ± 72.7	222.1
Institutions	240	129.2 ± 69.6	166.6	38	206.9 ± 42.1	231.4
Volunteers	74	163.9 ± 98.4	194.1	26	227.8 ± 97.2	271.5
All	1195	119.6	143.2	140	202.3	233.8

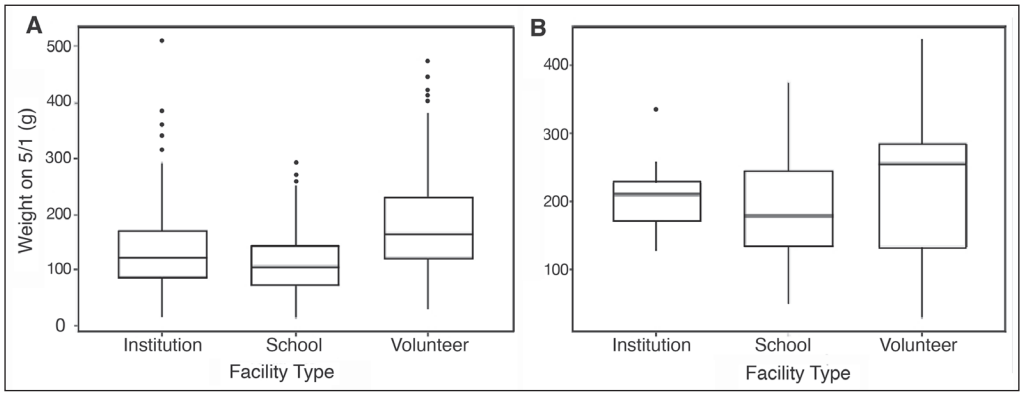

Figure 2. Mean turtle growth by 1 May for (A) Blanding's Turtles and (B) Wood Turtles for each facility type.

Discussion

Schools as a viable headstarting facility

We have encountered skepticism that schoolchildren can be trusted to raise threatened turtles, that they may not care for the turtles as well as trained professionals, or that raising turtles in a decentralized setting increases the risk of introducing non-native pathogens to wild turtle populations and makes it more difficult to assess turtle health or well-being.

Our data indicate that grade schools can in fact successfully and competently raise turtles, and their headstarting results (survival and growth rates) compare favorably with those at not only our other headstarting facilities but also with those in other headstarting programs.

Schools and turtle survival. In this study, we compared the mortality rate of turtles during the headstarting period between the different types of facilities. This analysis is presented primarily to demonstrate that the survival of turtles in schools was at least comparable to that of institutions and volunteers; however, we note that we did not set this study up as a formal experiment. Since our goal has been to minimize mortality and morbidity during headstarting, we have made individual decisions on the husbandry of the turtles that seek to maximize the welfare of the turtles. Despite concerns that students and teachers at schools would not be able to supply adequate care for turtle hatchlings, we observed marginally higher rates of survival for turtles headstarted in schools as compared to those raised by both individual volunteers and animal care institutions, although these differences were not statistically significant.

Schools and turtle growth. Although school-raised turtles were, on average, smaller on 1 May than those raised in other facilities, we hypothesize this is largely due to unavoidable husbandry differences. School-raised turtles are fed almost 30% less due to missing feedings on weekends and 3-day holidays. Nonetheless, the school-raised turtles easily met or exceeded the sizes achieved by Blanding's and Wood Turtles headstarted in other programs. For example, compared to our average release weight of Blanding's Turtles raised at schools for 9 months (133.2 g), Starking-Szymanski et al. (2018) reported Blanding's Turtle release weights of 91–150 g after 18 months of headstarting, and Cann et al. (2021) noted average pre-release May weights of 123.6 g (2014 cohort) and 180.1 g (2015 cohort), also after almost 2 years of headstarting. For headstarted Wood Turtles, Mullin et al. (2023) reported mean release weights after 1 year of headstarting of 92.2–110.6 g depending on cohort year and 204.4 g after 2 years of headstarting, compared to our own 222.1 g at schools over just 9 months.

Individual volunteers raised the largest turtles (Blanding's Turtles with a mean 1 May weight of 163.9 g), but this is unsurprising since turtles raised by volunteers are generally fed more frequently (daily, instead of only on school or workdays) and receive more individualized care. For example, volunteers are more likely to experiment with different feeding regimens, food choices, and enclosure set-ups, catering to individual turtle preferences, while institutions and schools follow more rigid care protocols. The average release weight for volunteer and institution-raised

turtles is also larger because, on average, school-raised turtles are released earlier in the season (before school is out for the summer) compared to these other groups.

Is bigger better? While the goal of most headstarting programs is to help juvenile turtles avoid the high mortality rates experienced in the wild by accelerating their growth in captivity, more research should be done on the optimal duration of headstarting and ideal size at release. Our own research on the post-release survival of headstarted Blanding's Turtles suggests that larger turtles are surviving at higher rates (McElroy et al. 2024 [this issue]). Other researchers have also noted post-release survival benefits in larger turtles (see Green [2015] for Blanding's Turtles and Mullin et al. [2023] for Wood Turtles, as well as McGovern et al. [2020] for *Gopherus agassizii* (Cooper) [Mojave Desert Tortoises], Haskell et al. [1996] for Northern Red-bellied Cooters, and Tetzlaff et al. [2019] for Eastern Box Turtles). Mullin et al. (2023) described survival benefits for larger turtles raised for 2 years, but noted the tradeoffs required to raise turtles for longer periods. Therefore, raising turtles over a shorter period, but using protocols that allow for a higher growth rate as we do, can increase both headstarting efficiency and survival rates (Golba et al. 2022, McElroy et al. 2024, McGovern et al. 2020). Determining the magnitude of the survival benefit conferred by different release sizes within the same cohort and population is vital, but outside the scope of this paper.

Benefits of raising turtles in schools

We have shown that schools can be effective headstarting partners when given sufficient training and support, and that by partnering with schools we avoid the capacity tradeoffs described by Mullin et al. (2023). Beyond expanding capacity, however, working with schools provides additional benefits which we enumerate below.

Benefits for the schools. Our school-based H.A.T.C.H. program is popular with schools and classroom teachers (Faux 2018). We consistently have more interest from schools than openings in the program, and teachers note that students find the turtles enormously appealing and that the turtles help with cross-curricular connections and learning.

Animals in classroom settings are widespread nationwide, and there is ample evidence that having an animal in the classroom has positive outcomes for student learning and emotional well-being (Gee 2017, Ganzert and McCullough 2015). Turtles can be problematic classroom pets due to their long lifespans and changing space needs as they mature, but they are ideal for short-term headstarting: their care and maintenance are relatively straightforward, they require minimal space at a young life-stage, they do not pose any risk for students with allergies (however, see discussion below on the risks associated with *Salmonella* infection), and they enjoy widespread appeal compared to other reptiles. The timing of hatching in the Northeast (late summer–early fall) and the customary timing for releasing headstarted turtles (generally late spring–early summer) are well-suited to the academic calendar and eliminate one of the primary impediments to keeping animals in classrooms: what to do with the animals over summer vacation (Ganzert and McCullough 2015).

Benefits for the turtles. Raising turtles in schools has allowed us to achieve low stocking densities in captivity (generally 2 turtles per 20 gallon-long aquarium), despite raising over 100 turtles each year since 2014. Raising turtles in small groups/pairs also allows us (and the individual caretakers) to pay more attention to individual turtle needs and adjust husbandry protocols accordingly. Conspecific aggression and competition are minimized, and turtles that need specialized care can be easily isolated.

Benefits for the institution. Collaborating with schools can increase institutional capacity for turtle headstarting. Indeed, this was the original reason that motivated us to seek out schools as headstarting partners. In the first 2 years of our program, our total capacity at ZNE and the New England Aquarium was only 20 turtles. In recent years, we have raised as many as 100 turtles in schools alone. Moreover, since we charge many of our schools for in-class programming and field trips, headstarting turtles in schools has provided Zoo New England with a source of income that has helped fund the associated field work, including nest-protection efforts and post-release monitoring of the hatchlings. (Schools in low-income communities can apply for free or reduced-fee programming, which is offset through grants and donations).

Benefits for conservation. Headstarting's impact on conservation outcomes is dependent upon context and the specific goals of a project (Bennett et al. 2017). It may not be appropriate for all species or in all situations and it is beyond the scope of this paper to prescribe headstarting as an intervention. However, as noted in our introduction, headstarting is an increasingly common tool used for turtle conservation and has been shown to be an efficacious tool for augmenting imperiled turtle populations (Bougie et al. 2022, Carstairs et al. 2019, Golba et al. 2022, Regosin et al. 2017, Spencer et al. 2017, Thompson et al. 2020, Wijewardena et al. 2023). Our own experience with headstarting Blanding's Turtles at a site in Concord, MA, has resulted in an at least quadrupling of that population over 2 decades (McElroy et al. 2024 [this issue]).

If headstarting has been identified as an appropriate intervention for a project, collaborating with nearby schools can provide additional conservation benefits, particularly by increasing the public's understanding of and support for local turtle conservation and possibly even wildlife conservation in general (Ardoin et al. 2020, Brewer 2001, McKinney 2002, Restall and Conrad 2015, Soga et al. 2016).

Common pitfalls of raising turtles in schools

While raising turtles in schools has many benefits and is an appealing strategy for increasing public engagement in a turtle conservation project, establishing a successful program requires a significant investment in staff time to train and support the schools and run the educational programming, and over the years we have identified a series of pitfalls that are likely to hinder the success of any school-based headstarting program.

Top-down approach. When establishing or expanding a school-based headstarting program, it is imperative to begin with a bottom-up approach involving

primary turtle caretakers (usually the classroom teachers) rather than a top-down approach (starting with administrators). For example, if a school principal likes the program and requires teachers to participate, the program may suffer. Disinterested teachers are less likely to take full advantage of having the animals in their classroom, and there will be poor student engagement in the program. At worst, animal care may suffer.

A top-down approach can also come in the form of an organizational directive to initiate a school-based headstarting program without buy-in from (or the capacity of) the rank-and-file staff. Many conservation groups are already understaffed and over-burdened, and taking on a school partnership is no simple endeavor. If the organization does not have adequate capacity to develop or sustain the program, the program is unlikely to succeed.

Too big, too fast. In order to build a sustainable program that fits within an organization's capacity limits, it is best to start small and begin working with just a few schools or even just a few committed teachers. Starting small will enable the organization to refine protocols and curricula and establish connections with key partners before expanding to a wider audience and working with larger numbers of turtles. Organizations should ensure that they have the capacity to communicate with all the schools, visit them regularly, and manage the care of all the animals being raised.

"Tail wagging the turtle." Our hope is that we have shown sufficient evidence that schools can be effective headstarting facilities and that this inspires other turtle headstarting programs to partner with schools. However, we caution organizations against putting educational goals or profit above the conservation management needs of the rare turtle populations that are the focus of the headstarting efforts. Turtle headstarting programs, whether conducted in schools or elsewhere, only make sense if they serve conservation management objectives, such as aiding in the recovery of declining populations of conservation concern or assisting in efforts to reintroduce rare turtles to areas from which they were extirpated (Green 2015).

Best practices for raising turtles in schools

Establish appropriate partnerships. Despite the benefits we describe of raising turtles in schools, a successful school-based headstarting program requires significant investment of resources and should be carefully considered. A successful program will start with a sound scientific basis for the program, which should involve on-going field studies that continuously evaluate the effectiveness of the headstarting effort on the target population (Bennett et al. 2017). Field studies may be carried out by the same organization running the school program, or by a committed partner. Additionally, veterinary expertise (ideally from veterinarians with extensive expertise with chelonian medicine and wildlife health) must be available in-house or through a partnering wildlife clinic or zoo hospital, in order to deal with inevitable turtle injuries or health concerns. The project will also need to include partnerships with regulatory authorities (federal, state, and local, as applicable) to ensure project compliance with all relevant wildlife laws.

Develop age-appropriate curricula. A successful program will incorporate age-appropriate educational curricula, ideally taught by trained educators with sufficient natural history knowledge and experience with the target species. The goal of the educational programming should be to both increase student engagement with the project, and also to ensure that participating students are learning ecologically accurate information. Our own H.A.T.C.H. in-class programming is always taught by people with prior field experience with the relevant species, creating a highly authentic program that allows students to "meet the scientists" and feel directly connected to the field program. While it certainly may be possible to partner with schools without providing them with associated curriculum, the impacts of such a partnership are then much more dependent on the effort and knowledge of the teacher(s) involved, increasing the likelihood that students could come away from the program with messages that are inaccurate or even detrimental. To minimize that risk, it is crucial to provide classroom teachers with enough background and understanding of the conservation program to allow everyone to be on the same page regarding the program. This approach minimizes mixed messages about some of the most vital takeaways from the program, including that turtles are not good pets or other information specific to your region or target species.

Mitigate the spread of disease. One of the primary concerns with headstarting turtles, particularly in non-institutional settings, is the risk of introducing or spreading disease to wild populations (Flanagan 2000, Seigel and Dodd 2000). However, disease risk can be largely eliminated if programs adhere to biological-control protocols mandating that wild-born turtles are returned to their native habitat without being exposed to sources of novel pathogens during their headstarting period (Jakob-Hoff et al. 2014). School-based headstarting programs should provide clear training to teachers on disease risk to the individual turtles, to the environment, as well as to the human caretakers. Guidelines on appropriate protocols to mitigate risk must be written clearly and provided to all caretakers. To protect the turtles, classrooms should be free of potential disease vectors, and program staff should visually inspect classrooms for compliance. Pre-release disease screening can also help protect wild populations, but it is crucial to also screen the wild population to determine which pathogens or viruses might be endemic (Allender et al. 2013, Carstairs et al. 2020). Post-release population monitoring is also vital for assessing changes in disease prevalence in the wild population.

Another disease concern, particularly in classroom settings with young children, is the risk of *Salmonella* infection (Harris et al. 2010). Some recent *Salmonella* outbreaks have been linked to pet turtles, though patients are usually very young, with the median patient age of 3 years-old in a Centers for Disease Control and Prevention report (CDC 2007). To mitigate the risk of *Salmonella* infection in classrooms, teachers and students are warned about the risk and are instructed to wash their hands after handling turtles. Handwashing (and particularly the use of hand sanitizer) has become routine in classrooms, and even though we have had over 20,000 students participate in the H.A.T.C.H. program, we have never had a reported incident of turtle-associated salmonellosis.

Conclusion

Our own experience shows that headstarting can have a significant impact on declining turtle populations, with our longest-running program headstarting Blanding's Turtles contributing to a four- to sixfold increase in the population at our main study site over 2 decades (McElroy et al. 2024 [this issue]). However, successful population augmentation through headstarting usually requires headstarting large numbers of turtles over many years (Golba et al. 2022, McElroy et al. 2024 [this issue], Regosin et al. 2017), and one of the primary limiting factors cited for raising larger numbers of turtles is institutional capacity (Mullin et al. 2023). Working with schools has the potential to greatly increase institutional headstarting capacity while concurrently raising awareness for turtle conservation and building community support for other long-term interventions, such as habitat restoration and protection, that are essential for safeguarding the turtle populations we hold dear.

Our current headstarting manual and school resources are available upon request. Contact hatch@zoonewengland.org.

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Literature Cited

Allender, M.C., M.A. Mitchell, D. McRuer, S. Christian, and J. Byrd. 2013. Prevalence, clinical signs, and natural history characteristics of frog virus 3-like infections in Eastern Box Turtles (*Terrapene carolina carolina*). Herpetological Conservation and Biology 8:308–320.

Ardoin, N.M., A.W. Bowers, and E. Gaillard. 2020. Environmental education outcomes for conservation: A systematic review. Biological Conservation 241:1-13.

Bennett, A.M., J. Steiner, S. Carstairs, A. Gielens, and C.M. Davy. 2017. A question of scale: Replication and the effective evaluation of conservation interventions. Facets 2:892–909.

Bougie, T.A., M.Z. Peery, C.N. Lapin, J.E. Woodford, and J.N. Pauli. 2022. Not all management is equal: A comparison of methods to increase Wood Turtle population viability. Wildlife Management 86(5):e22234.

Brewer, C. 2001. Cultivating conservation literacy: "Trickle-down" education is not enough. Conservation Biology 15:1203–1205.

Burke, R.L. 2015. Head-starting turtles: Learning from experience. Herpetological Conservation and Biology 10:299–308.

Cann, A.A., R.R. Weber, L.A. Harden, D. Thompson, J. Nadolski, J. Mattes, A. Karwowska, S. Shahjahan, and J.R. Milanovich. 2021. Physiological health and survival of captive-reared and released juvenile Blanding's Turtles. Physiological and Biochemical Zoology 94:411–428.

Carstairs, S., J.E. Paterson, K.L. Jager, D. Gasbarrini, A.B. Mui, and C.M. Davy. 2019. Population reinforcement accelerates subadult recruitment rates in an endangered freshwater turtle. Animal Conservation 22:589–599.

Carstairs, S., C.J. Kyle, and S.T. Vilaça. 2020. High prevalence of subclinical frog virus 3 infection in freshwater turtles of Ontario, Canada. Virology 543:76–83.

Centers for Disease Control and Prevention (CDC). 2007. Turtle-associated salmonellosis in humans: United States, 2006–2007. Morbidity and Mortality Weekly Report 56:649–652.

Dunn, O.J. 1961. Multiple comparisons among means. Journal of the American Statistical Association. 56(293):52–64

Faux, R. 2018. Zoo New England Blanding's Turtle education project: interim report. Davis Square Research Associates, Cambridge, MA. 14pp.

Flanagan, J. 2000. Disease and health considerations. Pp. 85–95, *In* Klemens, M.W. (Ed.). Turtle Conservation. Smithsonian Institution Press, Washington, DC. 334 pp.

Friends of Nachusa Grasslands. 2020. Head-starting hatchlings: A collaborative effort to protect endangered Blanding's Turtles. Available online at https://www.nachusagrasslands.org/nachusa-blog/head-starting-hatchlings-a-collaborative-effort-to-protect-endangered-blandings-turtles. Accessed 24 August 2023.

Ganzert, R.R. and A. McCullough. 2015. Pets in the classroom study: Phase I findings report. American Humane Society Association, Washington, DC. 39 pp..

Gee, N.R. J.A. Griffin, P. McCardle. 2017. Human-animal interaction research in school settings: current knowledge and future directions. AERA Open 3:1–9.

Golba, C.K., G.A. Glowacki, and R.B. King. 2022. Growth and survival of wild and head-started Blanding's Turtles (*Emydoidea blandingii*). Ichthyology and Herpetology 110:378–387.

Green, J.M. 2015. Effectiveness of head-starting as a management tool for establishing a viable population of Blanding's Turtles. M.Sc. Thesis. University of Georgia, Athens, GA. 122 pp.

Harris, J.R., K.P. Neil, C.B. Behravesh, M.J. Sotir, and F.J. Angulo. 2010. Recent multistate outbreaks of human Salmonella infections acquired from turtles: A continuing public health challenge. Clinical Infectious Diseases 50:554–559.

Haskell, A. T.E. Graham, C.R. Griffin, and J.B. Hestbeck. 1996. Size-related survival of headstarted Redbelly Turtles (*Pseudemys rubriventris*) in Massachusetts. Journal of Herpetology 30:524–527.

Henderson, G.E. 1978. Proceedings of the Florida and interregional conference on sea turtles, 24–25 July 1976, Jensen Beach, Florida. Florida Department of Natural Resources, Marine Research Laboratory, Ste Petersburg, FL. 33 pp.

Herlands, R., R. Wood, J. Pritchard, H. Clapp, and N. Le Furge. 2004. Diamondback Terrapin (*Malaclemys terrapin*) head-starting project in southern New Jersey. Pp. 13–21, *In* C.W. Swarth, W. Roosenburg, and E. Kiviat (Eds.). Conservation and Ecology of Turtles of the Mid-Atlantic: A Symposum. Bibliomania, Salt Lake City, UT. 132 pp.

Jakob-Hoff R.M., MacDiarmid S.C., Lees C., Miller P.S., Travis D., and Kock R. 2014. Manual of procedures for wildlife disease risk analysis. World Organization for Animal Health, Paris, France. 160 pp.

Kruskal, W.H., and W.A.Wallis. 1952. Use of ranks in one-criterion variance analysis. Journal of American Statistics Association. 47:583–621.

Mangiafico, S.S. 2023. rcompanion: Functions to support extension education program evaluation. Version 2.4.30. Rutgers Cooperative Extension. New Brunswick, New Jersey. Available onlint at https://CRAN.R-project.org/package=rcompanion.

Maryland Zoo. 2022. Maryland Zoo is raising, or "headstarting", Wood Turtles to release into the wild. Available online at https://www.marylandzoo.org/news-and-updates/2022/11/maryland-zoo-is-raising-or-headstarting-wood-turtles-to-release-into-the-wild. Accessed 24 August 2023.

McElroy, C.L., B. Windmiller, J. Berkholtz, E.R. Wilder, J.F. Welch, K.T. Shoemaker, and M.D. Kamm. 2024. Recovery of a Blanding's Turtle population through nest protection and headstarting. Northeast Naturalist 31(Special Issue 12):E25–E42.

McGovern, P.A., K.A. Buhlmann, B.D. Todd, C.T. Moore, J.M. Peaden, J. Hepinstall-Cymerman, J.A. Daly, and T.D. Tuberville. 2020. The effect of size on postrelease survival of head-started Mojave Desert Tortoises. Journal of Fish and Wildlife Management 11:494–506.

McKinney M.L. 2002. Urbanization, biodiversity, and conservation. BioScience 52:883–890.

Mullin, D.I., R.C. White, J.L. Mullen, A.M. Lentini, R.J. Brooks, and J.D. Litzgus. 2023. Headstarting turtles to larger body sizes for multiple years increases survivorship but with diminishing returns. Journal of Wildlife Management 87:1–16.

Nashville Zoo. 2021. Releasing Alligator Snapping Turtles. Available online at https://www.nashvillezoo.org/our-blog/posts/releasing-alligator-snapping-turtles. Accessed 24 August 2023.

Regosin, J.V., M.T. Jones, L.L. Willey, N. Gualco, H.P. Roberts, and P.R. Sievert. 2017. Status of the Northern Red-bellied Cooter in Massachusetts. Final Report to the U.S. Fish and Wildlife Service, 106pp.

Restall, B., and E. Conrad. 2015. A literature review of connectedness to nature and its potential for environmental management 159:264–278.

Seigel, R.A., and C.K. Dodd Jr. 2000. Manipulation of turtle populations for conservation: halfway technologies or viable options? Pp. 218-238, *In* M.W. Klemens (Ed.). Turtle Conservation. Smithsonian Institution Press, Washington, DC. 334 pp.

Shapiro, S.S. and M.B. Wilk. 1965. An analysis of variance test for normality (complete samples.) Biometrika 52(3-4):591–611.

Soga, M., K.J. Gaston, Y. Yamaura, K. Kurisu, and K. Hanaki. 2016. Both direct and vicarious experiences of nature affect children's willingness to conserve biodiversity. International Journal of Environmental Research and Public Health 13:529–540.

Spencer, R.J., J.U. Van Dyke, and M.B. Thompson. 2017. Critically evaluating best-management practices for preventing freshwater turtle extinctions. Conservation Biology 31:1340–1349.

Starking-Szymanski, M.D., T. Yoder-Nowak, G. Rybarczyk, and H.A. Dawson. 2018. Movement and habitat use of headstarted Blanding's Turtles in Michigan. Journal of Wildlife Management 82:1516–1527.

Tetzlaff, S.J., J.H. Sperry, B.A. Kingsbury, and B.A. DeGregorio. 2019. Captive-rearing duration may be more important than environmental enrichment for enhancing turtle head-starting success. Global Ecology and Conservation 20:1-11.

The Nature Conservancy. 2022. A collaborative approach to restore Bog Turtle populations. Available online at https://www.nature.org/en-us/newsroom/bog-turtle-head-start-north-carolina. Accessed 24 August 2023.

Thompson, D., G. Glowacki, D. Ludwig, R. Reklau, A.R. Kuhns, C.K. Golba, R. King. 2020. Benefits of head-starting for Blanding's Turtle size distributions and recruitment. Wildlife Society Bulletin 44:57–67.

Wickham, H. 2016. Ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag, NY.
Wijewardena, T., M.G. Keevil, N.E. Mandrak, A.M. Lentini, J.D. Litzgus. 2023. Evaluation of headstarting as a conservation tool to recover Blanding's Turtles (*Emydoidea blandingii*) in a highly fragmented urban landscape. PLoS ONE 18:1–19.