Experimental Translocation of the Eastern Tiger Salamander in New Jersey: A Conservation Success Story

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Adult male Eastern Tiger Salamander

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to

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By

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Introduction

Amphibian declines has been an ongoing concern in the scientific community (Lannoo, 2005). Historically, the eastern tiger salamander's (*Ambystoma tigrinum*), range originally encompassed **8** different counties in southern New Jersey. In 2018, tiger salamanders are now restricted to only **3** southern New Jersey counties (e.g., Cape May, Cumberland and Salem). Within these three counties the remaining populations are known to successfully breed at approximately **13** suitable wetland locations. Currently, eastern tiger salamanders breed almost exclusively in human-made ponds that fill with ground water and rain water. These breeding sites are usually sand and gravel extraction borrow pits. Most of the known tiger salamander breeding ponds are on private property. However, suitability of borrow pits for salamander breeding is sometimes degraded from illegal dumping by homeowners, landscapers, and building contractors. Sometimes they dump industrial waste and chemical compounds into the burrow pits which not only pollutes the ground water, but eventually kills a host of amphibian and invertebrate species that traditionally breed there. Some burrow pits are used by breeding amphibians even if they are still being mined for sand and gravel.

Because of these ongoing disturbances that cause adverse environmental impacts to the amphibians and their breeding ponds, an experimental translocation and management plan was devised by the NJDEP's, Endangered and Nongame Species Program personal that was based upon recommendations from the late James D. Anderson of Rutgers University (1976), and Herpetological Associates, Inc. (1980). In order to mitigate these disturbances an experimental human made breeding pond was proposed at one or more NJDEP, Division of Fish and Wildlife Management Areas (WMA), in southern New Jersey.

The following best management practices or protocol was used and considered in the selection of the translocation sites (Anderson, 1976; Anderson, Galandak and Howthorne, 1978; Zappalorti and Johnson, 1980; Frier and Zappalorti, 1983):

1). The experimental breeding pond should only be constructed on permanently protected NJDEP state land.

2). The selected site should be at least 500-acres in size to provide enough buffer areas and terrestrial habitat for the adult salamander population.

3). The selected site should have suitable sandy, loamy soils for easy burrowing.

4). The recipient site should have a large tract of oak and pine forest that could be used as summer home range for the salamander population.

5). The proposed construction site for the experimental pond should have a clay or hardpan gravel soil horizon that would be capable of holding ground and rain water long enough (at least 4 to 5 months), to allow successful amphibian metamorphosis, and yet still serve as a vernal pond.

Figure 1. A male Tiger Salamander approaching its winter breeding pond in Cape May, New Jersey.

One of the most important factors of the experiment was to mimic a natural vernal pond, which was no easy task. The New York State Department of Environmental Conservation (NYS-DEC), has sponsored several management action plans for tiger salamander on Long Island, New York over the past 30-years. Actions that were implemented included: transplanting egg masses, establishing roadway crossings, creating artificial ponds, creating salamander preserves, conducting radio-telemetry studies, designating Class 1 wetlands, and establishing buffer zones (Levy 2001; NYS-DEC 2010a). Despite much of the occupied habitat occurring on various state and federal jurisdictions, none of the above management actions have been successful at halting the precipitous decline of the population at the statewide scale (Corser 2010).

Other salamander translocation efforts in Long Island, New York have used rubber pond liners with some success (NYS-DEC, 2010b), but over time the liners can crack or be punctured thus reducing there value by not holding enough water. Because of that potential problem, the NJDEP chose a different approach by seeking to build a vernal pond that had a natural clay or hardpan bottom (Anderson, 1976; Zappalorti and Johnson, 1980; Frier and Zappalorti, 1983). **Table 1**, lists all the amphibians species known to use vernal ponds in New Jersey.

Greenwood Forest WMA, in Ocean County was initially chosen for constructing an experimental amphibian breeding pond. An effort was made to select a site based upon soil types and forest types surrounding the proposed vernal pond. However, after the pond was constructed it was learned that the substrate was too porous and could not hold water long enough for successful amphibian metamorphosis. That site in Greenwood Forest WMA was abandoned and Higbee Beach WMA, in Cape May County was chosen, which is located at the southern tip of New Jersey. This Cape May site had all the structural habitat features listed above (Anderson, 1976; Zappalorti and Johnson, 1980; Frier and Zappalorti, 1983; Mitchell, Breisch and Buhlmann, 2006).

Breeding Habits and Natural History of Tiger Salamanders

Amphibians in general and tiger salamanders in particular are declining for a variety of reason (Pechmann et al., 1991). The eastern tiger salamander is a member of a group known as “mole salamanders.” They typically breed on rainy nights in winter form November through February in southern New Jersey. During rainstorms, migrating adults sometimes traverse snow or ice to reach the open water of their annual breeding pond. Some adult tigers may remain in the breeding pond for days or weeks until they successfully breed. The male tiger salamanders seek receptive females in the pond and swim around them waving their tails and rubbing against them. Fertilization is external. During the elaborate underwater courtship, adult female tiger salamanders pick up small, gelatinous spermatophore packets on their vent that were deposited by males (Hassinger, Anderson and Dalrymple, 1970; Anderson, Galandak and Howthorne, 1978).

Figure 2. A Tiger Salamander egg mass with approximately twenty developing larvae in individual round gelatinous cases.

Females lay and attach their egg clusters to aquatic vegetation, plant stems or sticks in the pond. An egg mass may contain 25 to 75 individual round eggs (average compliment is 50). The eggs take about two weeks to hatch depending upon water temperature and lack of ice on the pond surface. Back in 1989 at a Cape May borrow pond, HA has observed tiger salamander eggs hatching on New Year’s day (Zappalorti, personal observation).

Table 1. List of New Jersey Obligate and Facultative Vernal Pool Breeding Amphibians, their Threatened and Endangered Status, and Common Names.

Obligate Species	Scientific Name	Status
Easter tiger salamander	*Ambystoma tigrinum*	Endangered
Marbled salamander	*Ambystoma Opacum*	Special Concern
Spotted salamander	*Ambystoma maculatum*	Stable
Jefferson salamander	*Ambystoma jeffersonianum*	Special Concern
Blue-spotted salamander	*Ambystoma laterale*	Endangered
Eastern spadefoot toad	*Scaphiopus holbrookii*	Special Concern
Wood frog	*Lithobates sylvatica*	Stable
Facultative Species	**Scientific Name**	**Status**
Four-toed salamander	*Hemidactylium scutatum*	Stable
Long-tailed salamander	*Eurycea l. longicauda*	Threatened
Northern spring peeper	*Pseudacris crucifer*	Stable
New Jersey chorus frog	*Pseudacris triseriata kalmii*	Stable
Upland chorus frog	*Pseudacris triseriata ferarium*	Stable
Northern cricket frog	*Acris crepitans*	Special Concern
Northern gray treefrog	*Hyla versicolor*	Stable
Southern gray treefrog	*Hyla chrysoscelis*	Endangered
Pine Barrens treefrog	*Hyla andersonii*	Threatened
Carpenter frog	*Lithobates virgatipes*	Special Concern
Southern leopard frog	*Lithobates utricularia*	Stable
Pickerel frog	*Lithobates palustris*	Stable
Green frog	*Lithobates clamitans melanota*	Stable
Bullfrog	*Lithobates catesbeiana*	Stable
Fowlers toad	*Anaxyrus fowleri*	Stable

Tiger salamander larvae are voracious feeders which enables them to grow quickly (see **Figures 4** and **5**), and may become the top predator in the breeding pond. In a stomach content study conducted in Maryland, larval tiger salamanders preyed upon 1,259 identifiable food organisms found in 42 larvae (Lee, 2006). The larvae were feeding primarily on aquatic, bottom-dwelling insects and crustaceans. They occasionally eat the small tadpoles of spring peepers, chorus frogs and cricket frogs. They are not specialized feeders, but are more opportunistic with a variable prey base. Larval tiger salamanders feed on a variety of small aquatic life forms, such as fairy shrimp and other insect larvae. Some tiger salamander larvae may become cannibalistic and eat smaller members of the aquatic population in the breeding pond (Anderson, Galandak and Howthorne, 1978; Hassinger, Anderson and Dalrymple, 1970; Lee and Franz, 1974).

Figure 3. Notice the external gills developing on the larval salamanders.

After reproduction activities are completed, the adults migrate back to their terrestrial habitat and return to subterranean burrows in the surrounding coniferous or hardwood forests. Summer habitat may be near their breeding pond, but some individuals may migrate several hundred feet to upland burrows where they remain hidden in their tunnels until the fol1owing winter. After 4 or 5 months in the breeding pond, the larval tiger salamanders metamorphose into air breathing sub-adults (Noble and Brady, 1933; Bishop, 1947). Typically they migrate away from the breeding pond at night or on rainy days to their upland habitat where they seek and establish their summer burrow system (Hoffmann, 2003). However, they do not reach sexual maturity until they are 2 or 3-years of age, when they return to the same breeding pond from which they metamorphosed (Wilbur and Collins, 1973). Most mole salamanders have a strong fidelity to their natal breeding pond (Bishop, 1947; Lee, 1975). Tiger salamanders are capable of living from 13 to 25-years or more in their natural habitat.

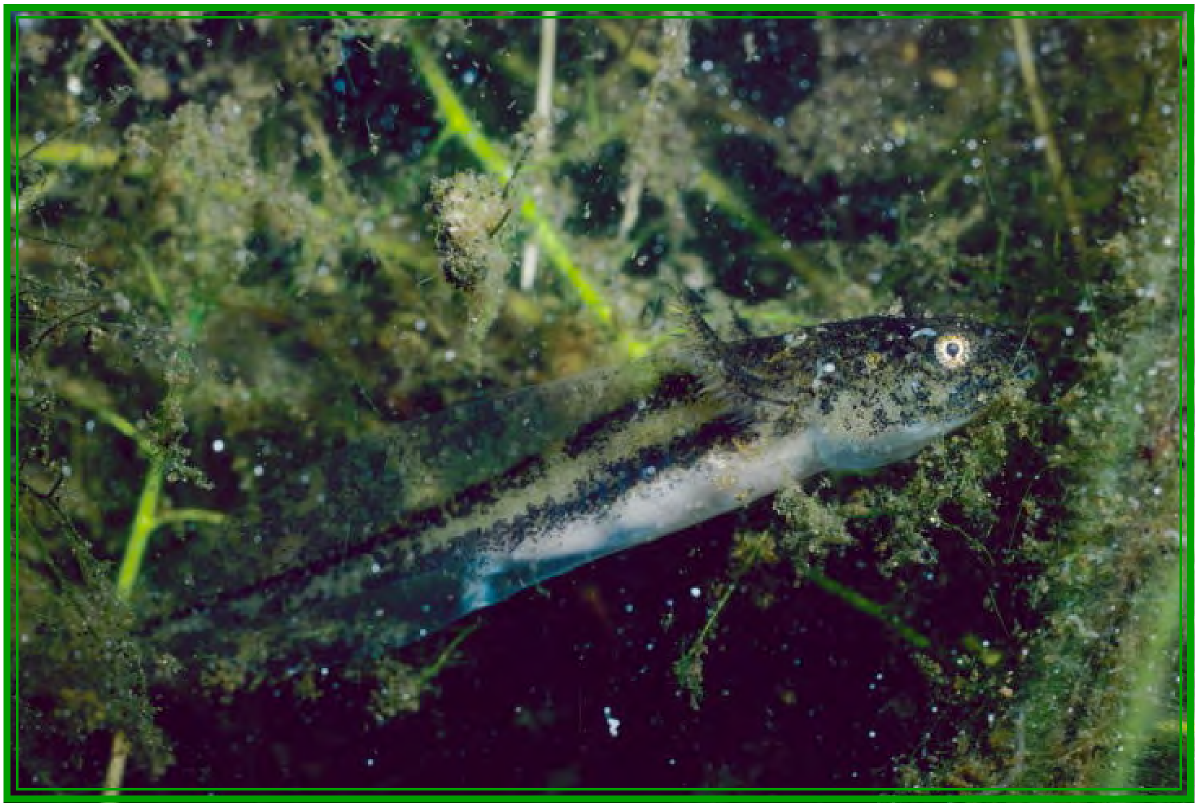

Figure 4. A larval Tiger Salamander about three weeks old. Notice the external gills and dorsal stripe.

Methods Used for the Experimental Translocation

In December 1981, an experimental tiger salamander breeding pond was excavated at Higbee Beach Wildlife Management Area following the design of Anderson (1976), and Herpetological Associates (Frier and Zappalorti, 1982). The pond measured 100-feet across by 300-feet long and had a gradual sloping bottom from its shallow edges of 6-inches to the center at 3-feet. The center of the pond also had a 2-feet wide 4-feet deep ditch that ran across its entire bottom, which was the deepest point. This was a safety trench in case the pond prematurely tried-up due to lack of rain. It would allow the larvae a reservoir of water to sustain them until metamorphosis (Zappalorti and Johnson, 1981). The construction of the breeding pond conformed to the dimensions recommended in the management plan (Frier and Zappalorti, 1982). After construction the pond was allowed to fill naturally with rain and ground water over winter. The midline ditch, designed to hold water in case of drought during the salamander's developmental period filled within 3-days after excavation, and the entire pond filled within 3-weeks afterwards with the help of seasonal rains. As designed, the pond dries up by late summer thus limiting predatory fish from becoming residents. It should be noted that there was about 500-acres of oak-pine forest and 35-acres of old field habitat surrounding the experimental pond which served as a buffer and summer foraging areas for the salamanders (Semlitsch and Bodie, 2003; Steen, et al., 2006).

Figure 5. A fully formed larval Tiger Salamander about two-months old. Notice the large gills and front and hind limbs.

In March 1982, approximately 20 tiger salamander egg masses (~1,000 eggs), were collected by dip net from unprotected privately owned ponds in Cape May and Cumberland Counties (**Figure 6**). These ponds were vulnerable to adverse impacts and pollution from illegal dumping. The eggs were transported in five-gallon buckets containing pond water (**Figure 7**). We also collected various aquatic vegetation that was planted in the recipient pond bottom along with some tree branches and stumps which would provide underwater shelter for the salamander larvae (Noble and Brady, 1933; Douglas and Monroe, 1981).

Additionally, we also collected the larvae of marbled salamanders (*Ambystoma opacum*), the string-like eggs of Fowler's toads (*Anaxyrus fowleri*), egg masses of leopard frogs (*Lithobates utricularia*), and tadpoles of New Jersey chorus frogs (*Pseudacris triseriata kalmii*) and spring peepers (*Pseudacris crucifer*). These amphibians were translocated to the experimental pond as well as a potential food source in the future. Extreme care was taken to avoid introducing fish predators into the experimental vernal pond. It should be noted that there was an existing freshwater pond within 600-feet from the experimental salamander breeding pond that had a sandy, clay bottom which gave us confidence that the selected site had the correct soil type (**Figure 6**).

Figure 6. The experimental tiger salamander breeding pond four months after its construction at Higbee Beach WMA. Bill Callaghan, of HA staff is placing egg masses along the edge of the pond.

Results of Translocation Efforts

Periodic monitoring (one or two week intervals), of the experimental breeding pond was done by visual surveys and dip-netting. After two weeks all the trans-located egg masses had hatched as evidenced by free swimming salamander larvae and tadpoles. Likewise, by the end of June and early July1982, the tiger salamander larvae had metamorphosed successfully. ENSP staff conducted field observations using a drift fence with pitfall traps around the experimental pond. These observations indicated that approximately 400 of the metamorphed tiger salamanders were caught in the pitfall buckets. They were marked by branding and released away from the drift fence. The juvenile salamanders migrated away from the breeding pond in June and July of 1982. As a follow-up to enhance the translocated population in February and March of 1983, another transfer of 20 tiger salamander egg masses (~1,000 eggs) was accomplished (**Figure 7**). Similar to the events of 1982, the eggs hatched and larvae metamorphosed by mid-July of 1983. Ongoing monitoring in the winter of 1984 resulted in observing adult individuals of the 1982 cohort who reached sexual maturity after two years living in underground burrows on the forest floor (**Figure 8**). These translocated tiger salamanders subsequently reached adulthood and returned to the artificial pond to breed as evidenced by the presence of 10 fertile egg masses observed during the winter of 1984 - 1985 by NJDEP staff (Dave Golden, ENSP, personal communication).

Figure 7. A 5-gallon bucket containing 10 tiger salamander egg masses along with some aquatic vegetation. The eggs were collected at unprotected breeding sites and transported the same day to the experimental breeding pond in Cape May.

Figure 8. A female Tiger Salamander leaving the pond after breeding.

Follow-up Monitoring to Measure Success

Periodic follow-up winter egg-count surveys were conducted by HA and Endangered and Nongame Species Program personal. Monitoring during the 1990's era, and again between 2000 - 2005 has shown the continued presence of eggs and/or larval of tiger salamanders in this artificially created breeding pond. One unforseen problem that has gradually occurred over the years was the invasion of the plant *Phragmites australis*. Although the *Phragmites* has choked the open water in the pond, it has not deterred the salamanders from returning and breeding in it.

Biologists with the NJDEP and HA have monitored the use of this pond by tiger salamanders over the past 36-years. Every time a winter egg-count survey was conducted, egg masses, salamander larvae, and/or adult tiger salamanders have been seen in the pond. Adult females now attach their egg masses to the stems of the *Phragmites*. This experiment has been especially rewarding because over the years the trans-located salamanders continue to breed, lay eggs, and metamorphose. Ongoing observations have shown that a population of tiger salamanders has been established at Higbee Beach WMA. More important, it demonstrates the value of this conservation management technique. This method could work with other members of the "mole salamander" family (*Ambystoma spp*.). Likewise, rare frog species could also benefit from experimental translocation to suitable ponds by carefully moving their egg masses to a recipient vernal pond site.

Figure 9. A front view of a larval Tiger Salamander. Notice the large external gills.

Importance of Breeding Pond Buffers and Terrestrial Habitat

Many studies have been conducted on the appropriate size of protective buffer zones around salamander breeding ponds (Semlitsch, 1998). Semlitsch and Bodie (2003), summarized the results of 40 papers describing the biologically relevant core habitats that surround amphibian breeding ponds. They concluded that the size of the core upland or terrestrial habitat required to protect adult salamanders and other frogs and toads was a radius of 521 to 951-feet from the breeding pond. Additionally, a protective buffer of 150-feet should be added to ensure that there is enough terrestrial habitat available for the long-term protection of the amphibian populations (Scott, et. al., 2013).

In New Jersey, the wetland protection law requires only a 150-feet buffer if rare species are present. However, the New Jersey Pinelands Commission has expanded buffer zones to 300-feet at known areas that have endangered or threatened wildlife species using the wetland habitat. The best management practices are to protect large inter-connected wildlife corridors between seasonal wetlands and upland forests (e.g., containing vernal ponds). If paved roads are near amphibian breeding ponds or pass through the upland habitat, barriers and under road tunnels should be considered to keep salamanders, frogs and toads off the roads (Woltz, et. al., 2008). Every year, hundreds of amphibians are killed by passing motor vehicles as they attempt to migrate across paved or gravel roads to their ancestral breeding ponds (Pechmann, et. al., 1991; Clevenger, et. al., 2001).

Figure 10. A pair of Tiger Salamanders migrating towards their breeding pond.

Summary and Recommendations

One potential problem that was unforseen and not thought of back in 1981 when this conservation project was designed and planned, is the possibility of sea level raise in lower Cape May County. In the future, portions of Higbee Beach WMA may suffer from salt water intrusion, thus making the breeding pond and surrounding forested habitat unsuitable for tiger salamanders and other wildlife. Actions should be taken to establish tiger salamander "assurance colonies" from the Higbee Beach population.

To that end, HA recommends that the NJDEP select other WMA's within the historic known range of the tiger salamander in New Jersey (e.g., Atlantic, Burlington, or Ocean Counties), and replicate this experiment. In other words, find suitable natural vernal ponds which currently lack tiger salamanders and initiate a conservation program by trans-locating egg masses to selected sites for repatriation. If suitable vernal ponds cannot be found, then the NJDEP should create some ponds following the protocol cited above in this report. Since the Higbee Beach WMA tiger salamander translocation was successful in the past, if the same protocol was used again then there is a high probability that it could be repeated (Anderson, 1976).

Every effort should be made to establish several tiger salamander "assurance colonies" on NJDEP Wildlife Management Areas. HA is ready, willing and able to assist with this experimental conservation program should the Endangered and Nongame Species Program and Bureau of Land Management (NJDEP), decide to implement a tiger salamander repatriation project within its known historic range in New Jersey.

Figure 11. An adult female Eastern Tiger Salamander migrating towards its breeding pond.

Literature Cited, Vernal Pool References and Tiger Salamander Bibliography

Allison, L. J., P. E. Brunkow, and J. P. Collins. 1994. Opportunistic breeding after summer rains by Arizona tiger salamanders. Great Basin Nat. 54:376-379.

Anderson, J.D. 1976. The status of the tiger salamander (*Ambystoma tigrinum*), blue spotted salamander (*Ambystoma laterale*), Tremblay's salamander (*Ambystoma tremblayi*), gray treefrog complex (*Hyla versicolor and Hyla chrysoscelis*), Pine Barrens treefrog (*Hyla andersonii*), and bog turtle (*Clemmys [Glyptemys] muhlenbergii*) in New Jersey. Special unpublished report to the Endangered and Nongame Species Program, NJDEP. Pp 67.

Anderson, J.D., J. Galandak, and K. Howthorne. 1978. A report on the status of endangered reptiles and amphibians of New Jersey. Bulletin of the New Jersey Academy of Science. Volume 23, No. One, Pp 23-33.

Austin, N.E. and J.P. Bogart. 1982. Erythrocyte area and ploidy determination in the salamanders of the *Ambystoma jeffersonianum* complex. Copeia 1982(2):485-488.

Bishop, S.C. 1923. Notes on the herpetology of Albany County, New York. Copeia 118:64-68.

Bishop, S.C. 1941. The salamanders of New York. New York State Mus. Bull. 324:1-365.

Bishop, S.C. 1947. Handbook of Salamanders. Comstock Publishing Co., Inc., Ithaca, New York. 555 p.

Bogart, J.P. 1982. Ploidy and genetic diversity in Ontario salamanders of the *Ambystoma jeffersonianum* complex revealed through electrophoretic examination of larvae. Can. J. Zool. 60:848-855.

Brooks, R.T., Hayashi, M., 2002. Depth–area–volume and hydroperiod relationships of ephemeral (vernal) forest pools in southern New England. Wetlands 22 (2), 247–255.

Brodie, E.D., Jr. 1977. Salamander anti-predator postures. Copeia 1977:523-535.

Burne, M.R., 2001. Massachusetts aerial photo survey of potential vernal pools. Natural Heritage and Endangered Species Program, Massachusetts Department of Fisheries and Wildlife, Westborough, MA.

Calhoun, Aram. 2010. Vernal Pool Directional Buffer Guidance. Available at http://www.nae.usace.army.mil/reg/Permits/VPDirectionalBufferGuidance.pdf

Calhoun, A. J. K. and M. W. Klemens. 2002. Best development practices: Conserving pool-breeding amphibians in residential and commercial developments in the northeastern United States. MCA Technical Paper No. 5, Metropolitan Conservation Alliance, Wildlife Conservation Society, Bronx, New York. Available at http://www.nae.usace.army.mil/reg/Links/BestDevelopmentPractices-ConservingPool-breedingAmph.pdf

Calhoun, A.J.K., Walls, T.E., Stockwell, S.S., McCollough, M., 2003. Evaluating vernal pools as a basis for conservation strategies: a Maine case study. Wetlands 23 (1), 70–81.

Church, S. A., J. M. Kraus, J. C. Mitchell, D. R. Church, and D. R. Taylor. 2003. Evidence for multiple Pleistocene refugia in the post-glacial expansion of the eastern tiger salamander, *Ambystoma tigrinum tigrinum*. Evolution 57:372-383.

Clevenger, A. P., M. McIvor, D. McIvor, B. Chruszcz, and K. Gunson. 2001. Tiger salamander, *Ambystoma tigrinum*, movements and mortality on the Trans-Canada Highway in southwestern Alberta. Canadian Field-Naturalist 115:199-204.

Collins, J. P., J. B. Mitton, and B. A. Pierce. 1980. *Ambystoma tigrinum*: a multi-species conglomerate? Copeia 1980:938-941.

Collins, J. P., T. R. Jones, and H. J. Berna. 1988. Conserving genetically distinctive populations: the case of the Huachuca tiger salamander (*Ambystoma tigrinum stebbinsi* - Lowe). Pages 45-53 in Szaro, R.C., et al., technical coordinators. Management of amphibians, reptiles, and small mammals in North America. USDA For. Serv., Gen. Tech. Rep. RM-166.

Collins, J.T., R. Conant, J.E. Huheey, J.L. Knight, E.M. Rundquist and H.M. Smith. 1982. Standard Common and Current Scientific Names for North American Amphibians and Reptiles, 2nd ed. Society for the Study of Amphibians and Reptiles. Herpetological Circular No. 12. 28 pp.

Conant, R. and J.T. Collins. 1991. A Field Guide to Reptiles and Amphibians of Eastern/Central North America. Houghton Mifflin Co., Boston. 450 p. + 48 Pps.

Corser, Jeffrey D. 2010. Eastern tiger salamander (*Ambystoma tigrinum tigrinum*). In: Chaloux, Andrea, Jesse W. Jaycox, Jeffrey D. Corser, Matthew D. Schlesinger, Hollie Y. Shaw, Elizabeth M. Spencer. Surveying for New York's high-priority reptiles and amphibians: implications for standardized protocols. Final report. New York Natural Heritage Program. New York State Department of Environmental Conservation. Albany, NY. 2 volumes. 261 pp. plus appendices. p. 25-29.

Crouch, W.B. and P.W.C. Paton. 2000. Using egg-mass counts to monitor wood frog populations. Wildlife Society Bulletin 28:895-901.

Cryan, John F. 1984. The status of the eastern tiger salamander (*Ambystoma tigrinum tigrinum*) on Long Island, New York. Unpublished report to New York State Department of Environmental Conservation, Endangered Species Unit.

Douglas, M.E. and B.L. Monroe, Jr. 1981. A comparative study of topographical orientation in *Ambystoma* (Amphibia: Caudata). Copeia 1981(2):460-463.

Downs, F. L. 1978. Unisexual *Ambystoma* from the Bass Islands of Lake Erie. Occasional Papers Museum Zoology. University of Michigan (685):1-36.

Dunn, E.R. 1917. The breeding habits of the salamander, *Ambystoma opacum* (Gravenhorst). Copeia 1917(43):40-43.

Fernandez, P. J., Jr., and J. P. Collins. 1988. Effect of environment and ontogeny on color pattern variation in Arizona tiger salamanders (*Ambystoma tigrinum nebulosum* - Hallowell). Copeia 198:928-938.

French, H.M., Demitroff, M., 2001. Cold-climate origin of the enclosed depressions and wetlands (‘spungs’) of the Pine Barrens, southern New Jersey, USA. Permafrost and Periglacial Processes 12, 337–350.

Gehlbach, F.R. 1967. *Ambystoma tigrinum*. Catalogue of American Amphibians and Reptiles. 52:1-4.

Geraghty, C., and R. Willey. 1992. Current habitat status of, and anthropogenic impacts on the tiger salamander, *Ambystoma tigrinum nebulosum*. Abstract, 6th Annual Meeting of the Society for Conservation Biology, p. 61.

Gibbs, J.P., 1993. Importance of small wetlands for the persistence of local populations of wetland-associated animals. Wetlands 12 (1), 25–31.

Gibbs, J.P., 1998. Amphibian movements in response to forest edges, roads, and streambeds in southern New England. Journal of Wildlife Management 62 (2), 584–589.

Gibbs, J.P., A.R. Breisch, P.K. Ducey, G. Johnson, J.L. Behler, and R.C. Bothner. 2007. The amphibians and reptiles of New York State. Oxford University Press, NY.

Gilhen, J. 1974. Distribution, natural history, and morphology of the blue-spotted salamanders, *Ambystoma laterale* and *A. tremblayi* in Nova Scotia. Nova Scotia Museum Curatorial Report No. 22:1-38.

Hassinger, D.D., J.D. Anderson, and G.H. Dalrymple. 1970. The early life history and ecology of *Ambystoma tigrinum* and *Ambystoma opacum* in New Jersey. Amer. Mid. Nat. 84:474-495.

Harte, J., and E. Hoffman. 1989. Possible effects of acidic deposition on a Rocky Mountain population of the tiger salamander *Ambystoma tigrinum*. Conservation Biology 3:149-158.

Hoffmann, K. E. 2003. Tiger salamander (*Ambystoma tigrinum tigrinum*) emergence in natural and man-made ponds.

Hulse, A. C., C. J. McCoy, and E. Censky. 2001. Amphibians and reptiles of Pennsylvania and the Northeast. Comstock Publishing Associates, Cornell University Press, Ithaca. 419 pp.

Hulmes, D., P. Hulmes, and R. Zappalorti. 1981. Notes on the ecology and distribution of the Pine Barrens treefrog, *Hyla andersonii*, in New Jersey. Bull. New York Herp. Soc., 17(1).

Irschick, D. J., and H. B. Shaffer. 1997. The polytypic species revisited: morphological differentiation among tiger salamanders (*Ambystoma tigrinum*) (Amphibia: Caudata). Herpetologica 53:30-49.

Jones, T. R., A. G. Kluge, and A. J. Wolf. 1993. When theories and methodologies clash: a phylogenetic reanalysis of the North American *Ambystomatid* salamanders (Caudata: Ambystomatidae). Systematic Biology 42:92-102.

Jones, T. R., E. J. Routman, D. J. Begun, and J. P. Collins. 1995. Ancestry of an isolated subspecies of salamander, *Ambystoma tigrinum stebbinsi* Lowe: the evolutionary significance of hybridization. Molecular Phylogenetics and Evolution 4:194-202.

Jones, T. R., and J. P. Collins. 1992. Analysis of a hybrid zone between subspecies of the tiger salamander (*Ambystoma tigrinum*) in central New Mexico. J. Evol. Biol. 5:375-402.

Jones, T.R., Collins, J.P., Kocher, T.D. and Mitton, J.B. 1988. Systematic status and distribution of *Ambystoma tigrinum stebbinsi* Lowe (Amphibia: Caudata). Copeia. 1988:621-635.

Kallaji, Michael. 1992. In search of the eastern tiger salamander. New York State Department of Environmental Conservation Bureau of Wildlife Newsletter. December 1992.

Kenney, L.P., Burne, M.R., 2003. Salamanders, Frogs and Turtles of New Jersey's Vernal Pools. NJDEP Division of Fish and Wildlife, Trenton, NJ, p. 54.

Kling, H. M. 2001. Emergent tiger salamander (*Ambystoma tigrinum tigrinum*) use of cover-boards at Brookhaven National Laboratory. Upton, New York. U.S. Department of Energy-Office of Science, Energy Research Undergraduate Laboratory Fellowship program. University of Georgia.

Lannoo, M. (*editor*). 2005. Amphibian declines: the conservation status of United States species. University of California Press, Berkeley. xxi + 1094 pp.

Lathrop, R.G., 2004. Measuring Land Use Change in New Jersey: Land Use Update To Year 2000, CRSSA Publication # 17-2004-1, Center for remote Sensing and Spatial Analysis. Rutgers University, New Brunswick, NJ, p. 32.

Lee, D. S. 1975. *Ambystoma*'s February march: The breeding migration of the tiger salamander. Atlantic Naturalist 30(4):164-171.

Lee, D. S. 2006. Those Rare and Endangered State-listed Species: who's minding the store? Bulletin of the Chicago Herp. Society. 41(12):217-224.

Lee, D. S., and R. Franz. 1974. Comments on the feeding behavior of larval tiger salamanders, *Ambystoma tigrinum*. Bulletin of the Maryland Herp. Soc. 10(4):105-107.

Levy, J. R. 2001. Analysis of the Long Island habitat of the eastern tiger salamander (*Ambystoma tigrinum*) using a geographic information system. M.S. Thesis, University at Albany, State University of New York, Albany, NY.

Madison, D. M. 1998. Habitat-contingent reproductive behaviour in radio-implanted salamanders: a model and test. Animal Behaviour 55:1203-1210.

Madison, D. M., and L. Farrand, III. 1998. Habitat use during breeding and emigration in radio-implanted tiger salamanders, *Ambystoma tigrinum*. Copeia 1998:402-410.

Madison, D. and V. R. Titus. 2006. Progress report for New York State Department of Environmental Conservation: Tiger salamander upland habitat requirements. Project MOU # AM 05513.

Madison, D. and V. R. Titus. 2009. Final report for New York State Department of Environmental Conservation: Tiger salamander upland habitat requirements. Project MOU # AM 05513.

Minton, S.A., Jr. 1972. Salamanders of the *Ambystoma jeffersonianum* complex in Indiana. Indiana Acad. Sci. Indianapolis, Indiana. 346 p.

Mitchell, J.C., A.R. Breisch, and K.A. Buhlmann. 2006. Habitat management guidelines for amphibians and reptiles of the northeastern United States. Partners in Amphibian and Reptile Conservation, Technical Publication HMG-3, Montgomery, Alabama. 108 pp.

New York State Department of Environmental Conservation. 1985. Checklist of the amphibians, reptiles, birds, and mammals of New York State, including their protective status. Nongame Unit. Wildlife Resources Center. Delmar, NY.

New York State Department of Environmental Conservation. 2005. Comprehensive Wildlife Conservation Strategy Planning Database. New York State Department of Environmental Conservation. Albany, NY.

New York State Department of Environmental Conservation. 2010. Eastern tiger salamander fact sheet. Available http://www.dec.ny.gov/animals/7143.html. (Data accessed November, 2010)

New York State Department of Environmental Conservation. 2010. Guidance for land cover set aside for conservation of the eastern tiger salamander. October 26, 2010.

Noble, G.K. and M.K. Brady. 1933. Observations on the life history of the marbled salamander, *Ambystoma opacum* Gravenhorst. Zoologica 11:89-132.

Pawlak, E.M., 1998. Remote sensing and vernal pools. Our Hidden Wetland: The Proceedings of a Symposium on Vernal Pools in Connecticut. p. 20–21.

Pechmann, J.H.K., D.E. Scott, R.D. Semlitsch, J.P. Caldwell, L J. Vitt, and J.W. Gibbons. 1991. Declining amphibian populations: the problem of separating human impacts from natural fluctuations. Science 253:892-895.

Petranka, J.W. 1998. Salamanders of the United States and Canada. Smithsonian Institution Press, Washington, D.C., 587pp.

Pfingsten, R.A. and F.L. Downs, eds. 1989. Salamanders of Ohio. Ohio Biol. Surv. Bull. New Series Vol.7 No. 2 xx + 315 p. + 29 Pps.

Preisser, E.L., Kefer, J.Y., Lawrence, J.D., 2000. Vernal pool conservation in Connecticut: an assessment and recommendations. Environmental Management 26 (5), 503–513.

Robichaud, B., Buell, M.F., 1983. Vegetation of New Jersey. Rutgers University Press, New Brunswick, NJ.

Robinson, D.A., 2003. From drought to deluge. New Jersey Flows: New Jersey Water Research Institute 4 (2), 3.

Schlauch, F.C. 1981. Report on the status of the eastern tiger salamander, *Ambystoma tigrinum tigrinum*, in the state of New York. Report to Endangered Species Unit, New York State Department of Environmental Conservation. Delmar, NY. 55 pp.

Scott, D. E., M. J. Komoroski, D. A. Croshaw, and P. M. Dixon. 2013. Terrestrial distribution of pond-breeding salamanders around an isolated wetland. The Ecological Society of America - Ecology, 94(11), 2013, pp. 2537–2546.

Semlitsch, R. D. 1983. Structure and dynamics of two breeding populations of the eastern tiger salamander, *Ambystoma tigrinum*. Copeia 1983:608-616.

Semlitsch, R.D. 1998. Biological delineation of terrestrial buffer zones for pond-breeding salamanders. Conservation Biology. Volume 12, No. 5 (October 1998), pp 1113-1119.

Semlitsch, R.D., Bodie, J.R., 1998. Are small, isolated wetlands expendable? Conservation Biology 12 (5), 1129–1133.

Semlitsch, R.D., Bodie, J.R., 2003. Biological criteria for buffer zones around wetlands and riparian habitats for amphibians and reptiles. Conservation Biology 17 (5), 1219–1228.

Smith, H.M., R. T. Zappalorti, A.R. Briesch, and D.L. McKinley. 1995. The Type Locality of the Frog *Acris crepitans.* Herpetological Review 26(t):14.

Snodgrass, J.W., Komoroski, M.J., Bryan Jr., A.L., Burger, J., 2000. Relationships among isolated wetland size, hydroperiod, and amphibian species richness: implications for wetland regulations. Conservation Biology 14 (2), 414–419.

Steen, D. A., L. L. Smith, G.J. Miller, and S. C. Sterrett. 2006. Post-breeding terrestrial movements of *Ambystoma tigrinum* (eastern tiger salamanders). Southeastern Naturalist 5(2):285-288.

Stine, C. J., J. A. Fowler, and R. S. Simmons. 1954. Occurrence of the eastern tiger salamander, *Ambystoma tigrinum tigrinum* (Green), in Maryland, with notes on its life history. Annals, Carnegie Museum 33(7):145-152.

Stone, J., 1992. Vernal pools in Massachusetts: Aerial photographic identification, biological and physiographic characteristics, and state certification criteria. MS Thesis, University of Massachusetts, Amherst, MA.

Strong, L.L., Cowardin, L.M., 1995. Improving prairie pond counts with aerial video and global positioning systems. Journal of Wildlife Management 59 (4), 708–719.

Tiner Jr., R.W., 1990. Use of high-altitude aerial photography for inventorying forested wetlands in the United States. Forest Ecology and Management 33/34, 593–604.

Tiner Jr., R.W., 1995. Wetlands of New Jersey. National Wetland Inventory. US Fish and Wildlife Service, Newton Corner, MA, p. 117.

Thompson, E.L., J.E. Gates, and G.J. Taylor. 1980. Distribution and breeding habitat selection of the Jefferson salamander, *Ambystoma jeffersonianum*, in Maryland. J. Herpetol. 14(2):113-120.

Uzzell, T.M., Jr. 1964. Relations of the diploid and triploid species of the *Ambystoma jeffersonianum* complex (Amphibia: Caudata). Copeia 1964(2):257-300.

Uzzell, T.M., Jr. 1967. *Ambystoma laterale*. Cat. Amer. Amphibians Rept.:48.1-48.2.

Woltz, H. W., J. P. Gibbs, and P. K. Ducey. 2008. Road crossing structures for amphibians and reptiles: Informing design through behavioral analysis. Biological Conservation, Volume 141, Issue 11, Pages 2745-2750.

Wilbur, H.M. 1977. Propagule size, number, and dispersion pattern in *Ambystoma* and *Asclepias*. Amer. Nat. 111(977):43-68.

Wilbur, H.M. and J.P. Collins. 1973. Ecological aspects of amphibian metamorphosis. Science 183:1305-1314.

Williams, P.K. 1973. Seasonal movements and population dynamics of four sympatric mole salamanders, genus *Ambystoma*. Ph.D. Dissert. Indiana Univ. Bloomington, Indiana.

Whiteman, H. H., R. D. Howard and K. A. Whitten. 1995. Effects of pH on embryo tolerance and adult behavior in the tiger salamander, *Ambystoma tigrinum tigrinum*. Canadian J. Zoology 73:1529-1537.

Zappalorti, R. T. 1978-79. An updated progress report on the distribution and locality records of New Jersey's endangered and threatened reptiles and amphibians. For NJDEP, E&NSP, Vol. 10, Herpetological Associates, Inc., Parts 1, 2, 3, 4. pp. 198.

Zappalorti, R.T. 1995. Vernal pond breeders. In, Living Resources of the Delaware Estuary. L.E. Dove and R.M. Nyman (*eds*.). The Delaware Estuary Program. Pp. 321-330.

Zappalorti, R. T. and J. Bockowski. 1965. The northern cricket frog (*Acris crepitans*) on Staten Island, New York. Bulletin of the New York Herpetological Society. Vol 25.

Zappalorti, R. T. and D. Hulmes. 1980. A Preliminary Ecological Study of the Southern Gray Treefrog, *Hyla chrysoscelis*, Cope (Amphibia, Anura, Hylidae) in Southern New Jersey. Unpublished report submitted to the NJDEP. HA File No. 80.09, p. 25.

Zappalorti R. T. and E. W. Johnson. 1981. Proposed management plans for endangered and threatened amphibians and reptiles in New Jersey. Unpublished report submitted to the NJDEP, HA File No. 81.12, pp. 12-15.

Zappalorti, R. T. and E. W. Johnson. 1982. An Updated Progress Report on the Distribution and Locality Records of Endangered and Threatened Amphibians in New Jersey. Submitted to NJDEP, Endangered and Nongame Species Project. (Unpublished and classified information). Pp. 181.

Zappalorti, R. T. and S. A. Sykes. 1999. Northern Cricket Frog (*Acris crepitans*) Surveys, Habitat Evaluations, and a Review of the Proposed Apple Greens East 9 Hole Golf Course, Lloyd Township, Ulster County, New York. HA File No. 99.24. Submitted September 1, 1999, to Alec Diachishin and Associates, P.C., Consulting Engineers and Land Surveyors, Napanoch, New York 12458. By Herpetological Associates, Inc.

Zappalorti, R. T. and D. Hulmes. 1980. A preliminary Ecological Study of the Southern Gray Treefrog (*Hyla chrysoscelis,* Cope) in Southern New Jersey. Unpublished report submitted to the NJDEP, HA File No. 80.09, Pp. 25.

Zappalorti, R.T. and G. L. Rocco. 1994. A 5-year monitoring study and a translocation, repatriation, and conservation project with the tiger salamander (*Ambystoma tigrinum*) in southern New Jersey. Wildlife Rehabilitation 12:201-218.

Zappalorti, R. T., P. R. Metcalf and M. E. Torocco. 1995. Marbled Salamander (*Ambystoma opacum*) Studies in the Vicinity of the Proposed Landfill Site in Douglas, Massachusetts, and a Proposed Mitigation Plan. HA Report No. 94.11-B. Prepared for Vincent Barletta, Douglas Environmental Associates, Inc., P.O. Box 226, Roslindale, MA. 02131. Pp. 44.

Zappalorti, R. T., D. W. Schneider, and M. P. McCort. 2003. Breeding Pool Habitat Evaluation, Presence or Absence Survey for Wildlife Species, and Mitigation Plans for the Proposed Vernon Retail Development (Wal-Mart Store), in Vernon, Connecticut. Unpublished report submitted to *BSC Group, Inc*., 200 Glastonbury Blvd. - Suite 305, Glastonbury, Connecticut 06033. HA File No. CT2003.43.

Zedler, P.H. 2003. Vernal pools and the concept of “isolated wetlands.” Wetlands 23 (3), 597–607.

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Figure 12. Tiger Salamander.