FINAL REPORT

Success Determination using Literature-Based Success Criteria (LBSC) Methodology for Wildlife Mitigations in New Jersey: Pine Barrens Treefrog (*Hyla andersonii*) and Northern Pine Snake (*Pituophis melanoleucus melanoleucus*) Mitigations as a Pilot (2006)

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Abstract:
Surveys were conducted at Pine Barrens treefrog (*Hyla andersonii*) and northern pine snake (*Pituophis m. melanoleucus*) mitigation sites in New Jersey to determine the relative success of these mitigations with respect to habitat functionality and species utilization. Parameters characteristic of natural habitats with healthy target species populations were gleaned from the literature and measured at each mitigation site. The success of each site was later evaluated using an adaptation of the Literature-based Success Criteria (LBSC) methodology developed by Short et al. (2000) for eelgrass, salt marsh and mud flat habitats. The LBCS methodology proved to be an incongruous evaluation method for animal species, given that animal species are mobile and presence, habitat use and population stability are key factors in determining success. Habitat attributes measured for the Pine Barrens treefrog mitigations were comparable to only three out of seven parameters (i.e. mean water depth – TF-1 mitigation site only: herbaceous vegetation composition, and woody vegetation composition) measured for natural sites. In addition, treefrogs were not observed to utilize either of these sites. Northern pine snake mitigation sites were comparable both in use and presence with regard to the reference sites (i.e. literature). However, comparison using the LBSC method was difficult to apply and reference data were lacking in some instances. Measurement of reference parameters and support from expert/literature resources may be more practical to aid in mitigating for a target species, with continued monitoring to ensure species presence, use and re-establishment of natural conditions, and attention to species-specific life history requirements.

Introduction:
New Jersey presently does not use a standardized universal method for assessing the success of wildlife mitigation projects. Monitoring of projects is limited, or in some cases does not occur and/or is not conducted over the long term. The performance history of wetland mitigation projects and other types of land use mitigation has been generally fair to poor, often due to the lack of consistent and/or reliable indices for assessment of success and failure, as well as evaluation feedback to improving mitigation construction design (Torok 2002). One common problem that often occurs while gauging success is inaccurately reporting the result as an administrative indicator (e.g. product output such as the number of plants seeded or planted, or organisms released, etc.) rather than the biological outcome of a mitigation (Wilkins et al. 2003). Many researchers agree (Wilkins et al. 2003, McCoy and Mushinsky 2002, Short et al. 2000, Fleishman et al. 2000, Zedler and Callaway 1999, Treweek and Thompson 1997, Brinson and Rheinhardt 1996) that there is no generally accepted method for evaluating and gauging the effectiveness of proposed mitigation measures.

Quality control of mitigations is becoming an increasingly popular issue, with both the regulatory community and designers realizing the importance of monitoring mitigation success (Wilkins et al. 2003, McCoy and Mushinsky 2002, NJDEP 2002, Zedler and Callaway 1999, Brinson and Rheinhardt 1996). For example, New Jersey conducted a survey on 90 wetland mitigation sites for the purpose of assessing whether the mitigation has achieved meeting its design criteria (NJDEP 2002). The NJDEP (2002) study also included the development of three study indicators (i.e. wetland area achieved, concurrence evaluation, and wetland mitigation quality assessment) to monitor performance of NJDEP’s wetland mitigation program. This study found that on average, only 48% of the study sites concurred with the project design, and would generally have the potential to function as natural wetlands through time. However, following this study, the Department (NJDEP) still recognizes that challenges exist within the current framework of the wetland monitoring program, and that changes to the current evaluation methodology must take place based on both results from present surveys and current evaluation techniques (L. Torok, Pers. Comm., NJDEP 2002).

Although a considerable amount of attention has been paid to wetland mitigations, mitigations designed specifically for wildlife habitat restoration are few (NJDEP 2005). Presently, private property owners/developers are not required to protect habitats suitable for threatened and endangered (T&E) animal species, and no requirements are in place for T&E plant species (L. Niles and B. Cartica, Pers. Comm.). Wildlife mitigations in the past have occurred through negotiation between Department programs as a precondition required for grant of permits (depending on the project). If new rules are proposed that require developers to meet new criteria, or specifically provide guidelines for characterizing habitat suitability, determining areas where activities will adversely modify habitat and characterizing the impact of proposed activities on habitat, along with detailed conservation measures, this could increase the number of wildlife mitigations in New Jersey. However, individual habitat conservation plans and regional habitat conservation agreements may provide an alternative to rules on a smaller or regional scale (D. Jenkins and M. Kaplan, Pers. Comm.).

This study is designed to evaluate the success of restored Pine Barrens treefrog (*Hyla andersonii*) and northern pine snake (*P. m. melanoleucus*) habitats completed under past land use mitigations using a combination of methods and comparison among them. The methodology includes using an adaptation of the LBSC methodology and species surveys. The LBSC methodology is designed to quantify habitat attributes through ranking based on field measurements, and can be adapted to varying sites of interest. Field measurements taken from natural reference sites (or found in the literature) of habitat characteristics best defining the requirements of the target organism, will be used as qualifiers for determining whether past wildlife mitigations can be deemed successful. Success will be defined in terms of percentages of habitat attributes found at the mitigation site as compared to natural conditions, as well as number of individual target species found on-site.

Methods:

Habitat characteristics identified as most favorable for the survival and proliferation of each species (as presented in the literature) was measured at mitigation sites designated for Pine Barrens treefrogs and northern pine snakes, respectively. Parameters quantified from each mitigation site was then compared to those calculated from natural reference sites (i.e. Pine Barrens treefrog – Hulmes et al. 1981, Freda and Morin 1984, Laidig et al. 2001; Northern pine snake – Zappalorti and Reinert 1984, Burger et al. 1988, Burger and Zappalorti 1989). Table 1 below summarizes the ecological parameters identified as important attributes of each species' natural habitat.

Table 1. Summary of critical habitat parameters and species life history traits for Pine Barrens treefrogs and northern pine snakes.

Species	Survey Period	Reference Sites	Key Habitat Features	Species Surveys
***Hyla andersonii* (Pine Barrens Treefrog)**	May – August (Breeding: May – July)	Literature: Laidig et al. 2001, Gove 1997	1) Water quality (i.e. pH) 2) Morphometry 3) Vegetation composition	1) No. of males calling 2) Breeding/Amplexus 3) Presence of egg masses and/or tadpoles
***Pituophis m. melanoleucus* (Northern Pine Snake)**	April – August (Nesting: June – July)	Literature: Zappalorti and Burger 1985, Burger and Zappalorti 1991, Pinelands Commission 1982	1) Pine-oak forest 2) Light intensity/temp. 3) Flat/dry substrates 4) % Vegetation cover 5) % Barren area	1) Presence 2) Breeding 3) Nesting sites 4) Hibernacula

The study (mitigation) sites sampled for both *H. andersonii* and *P. m. melanoleucus* are completed mitigations that were designed specifically for each species above. Unfortunately, some sites (e.g. TF-1 and TF-2) have experienced little monitoring since their completion (L. Torok, Pers. Comm.). In this study, new surveys of each mitigation site were initiated in March and April of 2006 (Pine Barrens treefrog and N. pine snake sites, respectively). General orientation surveys were conducted prior to field sampling; this was done in order to identify specific site features (e.g. ponds for *H. andersonii*, den identification for *P. m. melanoleucus*), field logistics/adjustment, and sampling preparation.

- <u>Pine Barrens Treefrog</u> (*H. andersonii*) - The field season for *H. andersonii* begins in April and runs through August, with peak male vocalizations heard from mid-May through July.

  A. History and Description of Mitigation Sites **– 2 Sites with 12 Ponds total** (4 & 8, respectively):

     1. Wetland/PB Treefrog Mitigation Project - Site **TF-1** (Burlington County): The TF-1 mitigation project (Figure 1), completed by a private consultant (1996), involved a wetland replacement (conversion of 10 acres of forested wetland/blueberry fields to cranberry bogs) with an effort to incorporate wildlife value and appeal. The ultimate objective of this mitigation was to attract *H. andersonii* to the shallow ponds established in a forested wetland that was adjacent to the wetland replaced. Four (4) small ponds (Ponds A – D, respectively) of varying depth, vegetation diversity, and vegetation density were constructed in an effort to lure treefrogs away from the cleared bog habitat. Surveys conducted by NJDEP and the consultant following project completion concluded that all of the ponds exhibited environmental criteria suitable for

treefrogs. However, several factors have affected the full evaluation of these ponds as a success. These include low annual numbers of treefrogs (i.e. males) with slight decline in use over the survey period (three years), failure of the ponds to dry allowing for fish invasions during flood events, and confirmation of breeding activity in only one of the survey years (i.e. 1996-1999) (Torok 2000, Gove 1997).

Figure 1. TF-1 mitigation site. Artificial ponds in forested wetland just over irrigation canal (open area beyond trees).

2. Wetland/PB Treefrog Mitigation Project - Site **TF-2** (Browns Mills, Burlington County): The objective of the TF-2 project was to create breeding ponds (Figure 2) for Pine Barrens treefrogs as a component of a property owner's mitigation plan for a cranberry bog expansion (approximately 10 acres). As with the TF-1 project (above example), eight (8) ponds (Ponds A – H) of varying depths were constructed in an attempt to define what type of pond habitat treefrogs favored. However, no treefrogs were observed to be using any of the ponds throughout the survey period (1996 through 1999) (L. Torok, Pers. Comm.). Apparent problems include insufficient depth to maintain ponded water long enough during the breeding season, and limited shrubby vegetation favored by treefrogs (Torok 2002, Dunne 2000). Adjacent wetlands were found to contain an abundance of *H. andersonii*, along with other annurans (L. Torok, Pers. Comm.; J. Bilinski, Pers. Observation 2006).

Figure 2. TF-2 mitigation site. View of Pond G facing east.

B. Water Chemistry and Morphometry – Specific conductance and temperature (YSI Model 33 Water Meter), water pH (litmus paper), and mean water depth were randomly sampled from each pond following the methods of Gove (1997) and Laidig et al. (2001). No water samples were taken from site TF-2 since all ponds (Ponds A – H) were without water throughout the survey period. Water data presented here are from the TF-1 mitigation site only. Three (3) samples were taken for each parameter where conditions permitted, and compared with natural site data obtained from the literature (Zappalorti and Johnson 1981, Freda and Morin 1984, Laidig et al.2001).

C. Vegetation Composition – An inventory of herbaceous and woody vegetation was conducted within and along the pond shorelines during site visits in March and May/June 2006. Percent composition of herbaceous and woody plants was measured using the line-transect method (May - June 2006). Randomly selected points were staked and vegetation types (i.e. herbaceous, woody, and sphagnum sp.) recorded according to method specifications (Brower et al.1990). Percent composition and frequency were calculated using the linear density index, following Brower et al. (1990) for each vegetation type.

D. Species Surveys – Nighttime surveys of male treefrog vocalizations were conducted at both mitigation sites during June and July of 2006. Selection of survey dates and times were based on breeding phenology and suitable weather conditions (Hulmes et al. 1981, Freda and Morin 1984, Gove 1997, and Laidig et al. 2001). Activity of males is most noticeable on nights (dusk until 12 a.m.) exceeding 70 degrees Fahrenheit and with high relative humidity (times either preceding or immediately following precipitation) (Hulmes et al. 1981, Laidig et al. 2001). Number of calling adult males (5-minute intervals) was estimated using the following ranking scheme after Laidig et al. (2001): 0 = none; 1,2 = 2-5; 3 = 6-10; and 4 = >10 calling individuals. In situations where no calling was initially heard on-site, pre-recorded vocalizations of treefrogs were played every 20 minutes for intervals of 2-3 minutes until callbacks were encountered.

E. Data Analysis – Measured habitat characteristics were compared to values presented in the literature. Reference site data was gleaned from Laidig et al. (2001) for 13 natural H. andersonii breeding ponds. An adaptation of the LBSC method (Short et al., 2000) was then applied to the data for comparison between mitigation site parameters versus reference sites. For comparison, Single Factor Analysis of Variance (ANOVA) was used to test for significance between ponds at all sites, and for significant differences between sites. Confidence intervals (95%) were calculated for each habitat criterion (reference site data) and used to identify whether mitigation site data fell in between these ranges.

- Northern Pine Snake (*P. m. melanoleucus*) – Key habitat parameters, as indicated by the literature (Zappalorti and Reinert 1984, Burger et al. 1988, Burger and Zappalorti 1989, D. Golden, Pers. Comm. 2006), were measured for *P. m. melanoleucus* in and around hibernacula located at each mitigation site. Species surveys were conducted at each den and for areas between dens, and areas with known pine snake concentration (R. Zappalorti, Pers. Comm.).

A. History and Description of Mitigation Sites – **2 Sites with 30 Dens total** (25 & 5, respectively):

1. Pine Snake Mitigation Project - Site **PS-1** (Ocean County): The PS-1 mitigation site (Figure 3) is located along an utilities right-of-way (formerly a railroad R.O.W.). The study area, approximately 3.5 miles in length, includes a number of residential developments and some mixed industrial use (Pinelands Commission 1982). In order to mitigate for impacts caused by residential development, increased infrastructure, and improvements to utilities (i.e. sewer and electric transmission lines), an environmental consulting firm (1985-1986) was contracted to create hibernacula along the R.O.W. The PS-1 site and surrounding area has been subject to intensive disturbance throughout its history. Due to the development pressure experienced in the 1980’s and 1990’s, and historically the former railroad, the area has been the focus of rigorous study. The PS-1 study site and adjacent area are rich in rare flora and fauna, specifically threatened and endangered reptiles and amphibians (e.g. Pine Barrens treefrogs, timber rattlesnakes, corn snakes, and pine snakes). Historically, mitigation activities at the site included hibernacula construction, snake mark/recapture, and snake relocation (R. Zappalorti, Pers. Comm.).

Figure 3. PS-1 mitigation site, view to south-west (Den 10 - bottom left corner, behind snow fencing).

2. Pine Snake Mitigation Project - **PS-2 (PS-2A and PS-2B, respectively)** (Ocean County.): A detailed history of the PS-2 study area is not available, however two study sites (PS-2A and PS-2B, both within 1 mile of each other) have experienced documented pine snake activity since the 1970's (R. Zappalorti, Pers. comm.). PS-2A (Figure 4) is a disturbed site comprised of various debris piles, including some large building foundations and concrete slabs. The northern portion of the site contains four (4) artificially constructed dens that are excavated every April since inception by NJDEP and the consultant (R. Zappalorti and D. Golden, Pers. Comm.). Given that these hibernacula are annually excavated, little vegetation other than herbaceous pioneers occupies the den mounds. PS-2B (east of PS-2A) contains one (1) den within a small thicket of pitch pine. Pine snake activity at this den has ceased in recent years, however snakes have been observed to nest in the vicinity (D. Golden, Pers. Comm.).

Figure 4. PS-2A mitigation site (View to southeast, Den 1 – center photo).

B. Vegetation Composition – Vegetation surveys were conducted for each hibernaculum and quantified using the line transect method (Brower et al. 1990). Randomly selected points were staked and vegetation types (i.e. herbaceous and woody) growing on and within 3 m of the hibernacula were recorded (Burger and Zappalorti 1989, Zappalorti and Reinert 1994). Percent vegetation composition was calculated using the linear density index for each vegetation type, in addition to estimation of percent vegetation coverage (Brower et al. 1990).

C. Canopy Coverage – Percent canopy cover was measured using a spherical densiometer (model C). Percent coverage was then estimated according to manufacturer instructions (Forest Densiometers and Forestry Suppliers, Inc.).

D. Species Surveys – The following information was recorded during each field visit: 1) presence/absence of snakes, 2) activity level in and around hibernacula, 3) general behavioral characteristics, and 4) potentially breeding behavior/nesting. Prior to hibernation (mid-October), snakes were located using a dog specially trained to locate pine snakes, "Bear". "Bear" is trained to track and locate both bobcats (*Lynx rufus*) and northern pine snakes by scent. On field visits in late September – early October, "Bear" was able to locate pine snakes and remnants (e.g. hatched shells, sheds, etc.) in or in the vicinity of hibernacula. The number of individuals (adult and neonates) at each hibernaculum was recorded, along with the type of activity observed at the time of sighting.

E. Data – Measures of habitat characteristics were compared to data presented in the literature (Zappalorti and Reinert 1984, Burger et al. 1988, Burger and Zappalorti 1989).

An adaptation of the LBSC method was performed for data parameters recorded at the above sites. For comparison, Single Factor Analysis of Variance (ANOVA) was used to test for significance between ponds at all sites, and for significant differences between sites. Where appropriate, confidence intervals (95%) were applied to each habitat criterion using the above, and used to identify target intervals for the mitigation site habitat criteria.

- LBSC Methodology:
  The following methodology was used for the evaluation of habitat criteria:

  A. Measurement of Key Habitat Variables (adaptation of Short et. al., 2000 methodology):

     1. Choosing Restored Sites/Reference Sites and Target Species: Pine Barrens Treefrog and Northern Pine Snake – Use existing Land use/wildlife mitigation projects implemented in New Jersey as examples of restored sites. Areas of naturally occurring treefrog, pine snake, and bog turtle populations can be used as reference sites for comparison and assessment of candidate indicators of core habitat (literature can be used as substitute if data are present).

     2. Choose candidate indicators (CI's) – Candidate indicators were chosen based on the recommendations of ENSP biologists and those found in the literature. CI's are measurable representatives of functions and values of a habitat containing target species and are used to quantitatively evaluate a restoration project. The CI's are prioritized to rank the relative importance of each function, or key habitat variable. Examples of key habitat variables may include (1) Canopy Structure, (2) Water quality, (3) Vegetation composition, (4) Suitable nesting sites/substrates, and (5) Prey abundance, etc.

     3. Measure CI's at selected reference sites – This involves quantitative measurement of the above for each reference site (i.e. field measurements). Attention must be placed on site-specific characteristics, seasonal dynamics, life cycle, etc., so as to establish the background conditions on which the success criteria (SC) will eventually be based. If adequately presented in the literature, field measurements are not required. As mentioned above, parameters reported in the literature were used for this project. However, consultation of established methodology for particular habitat/species in the literature should be completed.

     4. Rank the CI's – Create a table with CI's compiled with mean, standard deviation (SD), and coefficient of variation (CV = SD/mean). The CV's are used to rank the CI's (In general, the lower the CV, the higher the rank).

     5. Selection of CI's as qualifying indicators – Qualifying indicators represent the top ranked CI's (those with lowest CV's). The CI's are compiled, and then compared with data gleaned from the restoration/mitigation project to calculate success criteria (SC) for functions of the restored habitats.

6. Calculate SC for each qualifying indicator – Qualifying indicators (from step 5) are used to compare the monitoring data from the restoration site to a mathematically derived representation of the reference site. The SC can then be calculated as follows:

$$SC = 100^* \frac{(\text{Mean of all reference sites} - 1\ \text{S.D.})}{(\text{Mean of reference sites})}$$

   where "1 S.D." is defined as one standard deviation. Depending on the function/value used as the qualifying indicator, the percentage of its distribution and importance within the habitat or the presence of target species will determine its importance as a SC unit.

7. Determine time frame of assessment – Time frame is important in knowing the time needed for the establishment of the important functions used as qualifying indicators. Depending on the species or habitat, the time needed to accurately assess the SC may take anywhere from one growing season to 5-10 years. This needs to be established for each mitigation project, however the given study will only assess success during a snapshot rather than an extended monitoring period.

8. Calculate the success ratio (SR) for each indicator – The SR is the measure of how successful each restoration site is compared with the selected reference site for the functional characteristics being evaluated. SR is calculated as follows:

$$SR = 100^* \frac{(\text{Mean of one restoration site})}{(\text{Mean of reference sites})}$$

   When the SR for a given indicator equals or exceeds the SC, the restoration is deemed successful. As the restored habitat develops, further application of the SC will indicate if reference conditions are achieved. Knowledge of suitable parameters is necessary for this assessment, since in some instances (e.g. pH) values in excess of the SC (20% or greater) may also disqualify the success of a parameter for a given site (Short et al. 2000).

9. Apply success ratio – Short et. al. (2000) recommend that at least three (3) reference sites be included in the sampling plan in order to avoid inadequate sample sizes. The goal for the SR's (as in species richness, if a qualifying indicator) is show achievement of success at all sites.

B. Confidence Intervals (95% confidence) – Habitat parameters measured from mitigation sites were compared to reference site data using a 95% confidence interval ($\alpha = 0.05$). Mitigation site parameters falling within the range of the confidence interval are accepted as meeting the standard for a given habitat criterion. Confidence intervals are calculated using data provided in the literature, and follow general methods of biostatistical analyses (Brower et al. 1990, Zar 1996).

<u>Results and Discussion</u>:

- <u>Pine Barrens Treefrog</u>:
  Water measurements from the TF-1 mitigation site (Ponds A – D) were taken in late May 2006. Mitigation ponds at the TF-2 site did not maintain significant amounts of water during the breeding season, and therefore could not be sampled (Ponds D and H being an exception; however water depth was negligible – ≤ 2-3 cm). Hulmes et al. (1981) reported that pH values measured for numerous *H. andersonii* breeding ponds fell within the range of 3.8 to 5.5 (mean pH = 4.3). Water pH samples taken from site TF-1 differed significantly (mean = 5.5, $P < 0.001$) when compared to reference ponds (mean = 4.1) (Table 2). Treefrogs (Figure 5) were absent from all four ponds during the survey period; only Fowler's toads (*Bufo woodhousei fowleri*), carpenter frogs (*Rana virgatipes*), southern leopard frogs (*R. utricularia*), and green frogs (*R. clamitans melanota*) were observed using the mitigation ponds. A large wetland complex loosely connected to and approximately 0.25 miles southeast of the mitigation site was used extensively by *H. andersonii*. Success ratios (Table 3) for the TF-1 mitigation site exceeded the SC for pH by at least 40%, well above the acceptable range of 20% (Table 3). The higher than optimal pH may be one factor that explains treefrog absence from this site. Pine Barrens treefrogs are well adapted for successful reproduction and development in acidic waters, and are the most tolerant species to low pH (Hulmes et al. 1981, Freda and Morin 1984). In ponds with pH of 4.5 or greater, competition from other amphibian species can become a limiting factor (Hulmes et al. 1981, Zappalorti and Johnson 1981, Frieda and Morin 1984). Species such as bullfrogs (*R. catesbeiana*) and fish (e.g. sunfish) can be voracious predators of *H. andersonii* tadpoles.

  Differences in mean pond depth were not significant between site TF-1 and the reference sites (SR's for Ponds B – D were within the 20% of the SC); however, maximum depth was significantly less (46.5 cm, $P = 0.02$) for the mitigation site ponds. Mean specific conductance measured at TF-1 was comparable to values reported by Laidig et al. (2001) (66.7 vs. 55.9 µS/cm), and did not differ significantly. Specific conductance is related to pH, thus it can be expected that the values observed at the mitigation site are higher than for reference sites.

  Comparisons of vegetation composition yielded no significant differences between mitigation sites and between vegetation types (i.e. herbaceous, woody, and Sphagnum sp.), although some significant differences were observed at each mitigation site among ponds. In general, herbaceous vegetation was more abundant at both mitigation sites than either woody vegetation or Sphagnum sp. coverage. Herbaceous coverage at TF-1 was dominated by bull sedge (*Carex bullata*) and white water lily (*Nymphaea odorata*). Dominant woody species at this site included trident red maple (*Acer rubrum* var. *trilobum*), Atlantic white cedar (*Chamaecyparis thyoides*), and highbush blueberry (*Vaccinium corymbosum*). Similar percent coverage for vegetation type was observed by Laidig et al. (2001), and also Hulmes et al. (1981); however, herbaceous species composition differed between sites. The TF-2 mitigation site was unique with respect to species, although significant differences for vegetation type were not detected when compared with either reference sites or TF-1. Species richness was greater at TF-2, which was comprised of wetland obligates and facultative obligates (majority), in addition to a few upland species.

Table 2. Mean values for habitat features measured at *H. andersonii* mitigation sites: TF-1 and TF-2.

Habitat Parameter[a]	**Reference Sites (n = 13)**	**TF-1 (n = 4)**	**TF-2[b] (n = 8)**
Mean pH	4.1 (± 0.3, 0.1)	5.5 (± 0.16, 0.0)	---
Calling rank (0 = none, 1 = 1,2, 2 = 2-5, 3 = 6-10, 4 = >10)	3.5 (± 0. 8, 0.2)	0	0
Mean water depth (cm)	46.6 (± 12.9, 0.3)	41.5 (± 8.3, 0.2)	---
Maximum water depth (cm)	77.3 (± 23.0, 0.3)	46.5 (± 9.9, 0.2)	---
Mean specific conductance (µS/cm)	55.9 (± 19.2, 0.3)	66.7 (± 11.0, 0.2)	---
Woody veg. composition (%)	38.5 (± 27.9, 0.7)	22.4 (± 4.9, 0.2)	35.9 (± 13.1, 0.4)
Sphagnum sp. composition (%)	19.3 (± 15.4, 0.8)	33.8 (± 17.7, 0.5)	19.3 (± 10.3, 0.5)
Herbaceous veg. composition (%)	41.8 (± 36.3, 0.9)	43.9 (± 20.3, 0.5)	46.9 (± 14.8, 0.3)

[a] – Habitat parameter data expressed as "mean (± 1 S.D.,C.V.)"; C.V.'s ranked from lowest to highest.
[b] – "---" represents no data available for water morphometry and chemistry parameters.

Table 3. Success Criteria (SC) and Success Ratios (SR)[a] calculated for *H. andersonii* data from the TF-1 and TF-2 mitigation sites compared to reference site (REF) data. Underlined values represent SR's that are within ± 20 percent (%) of the calculated SC for each given parameter.

	REF	**TF-1**				**TF-2[b]**							
Parameter	**(SC)***	**A**	**B**	**C**	**D**	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Mean pH	**93.1**	135.2	135.2	130.2	140.1								
Calling rank (0 = none, 1 = 1,2, 2 = 2-5, 3 = 6-10, 4 = >10)	**77.6**	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Mean water depth (cm)	**72.4**	66.1	84.1	105.1	100.8								
Maximum water depth (cm)	**70.3**	42.7	59.5	72.4	66.0								
Mean specific conductance (µS/cm)	**65.7**	95.3	143.1	116.2	122.1								
Herbaceous vegetation composition (%)	**13.2**	150.9	50.3	78.1	140.5	75.4	89.0	108.5	163.9	87.1	82.7	128.6	161.4
Woody vegetation composition (%)	**28.1**	39.1	61.5	67.1	62.4	83.8	138.5	81.5	81.0	103.4	120.7	104.4	26.2
Sphagnum sp. composition (%)	**20.6**	112.2	284.8	213.4	88.0	172.4	46.5	118.7	0.0	121.1	95.9	128.8	115.5

* - Reference site SC used for comparison to mitigation sites (TF-1 and TF-2)
[a] - SR = 100*(Mean of one restoration site)/(Mean of ref sites)
[b] – TF-2 ponds without water for entire *H. andersonii* breeding season.

Treefrogs (Figure 5) were not observed utilizing either mitigation site as mentioned above. Present conditions at each site suggest that each is in varying stages of mid to late succession.

This may be problematic for treefrogs, which prefer breeding sites dominated by early successional vegetation (Hulmes et al. 1981, Zappalorti and Johnson 1981). Although vegetation composition seemed favorable for all ponds (i.e. Ponds A – D) at TF-1, areas surrounding each pond were dominated by dense woody vegetation, as well as mature trees that shade the ponds for portions of the day (Figure 6). Freda and Morin (1984) reported that *H. andersonii* called infrequently from streams and backwater areas; large choruses were always observed from areas of open canopy, early successional vegetation, and waters of low pH. The TF-2 site is situated in open woodland composed of short shrub/herbaceous cover (e.g. lowbush blueberry – *V. pallidum*, leatherleaf – *Chamaedaphne calyculata*, fetterbush – *Leucothoe racemosa*, sedges and grasses, false reindeer lichen – *Cladonia subtenius*, etc.) and a closed canopy of pine and oak. Additionally, ponds are not deep enough to maintain water for extended periods, and barely reach the water table (L. Torok, Pers. Comm.). Withdraw of water for cranberry irrigation appeared to affect water levels in the adjacent wetlands to the south (observed during 2-3 week periods without rain in June 2006), which further compounds water scarcity onsite.

Figure 5. Adult Pine Barrens treefrog – *Hyla andersonii* (Photo by R. Grant; Source – NJDEP-DFW: www.nj.gov/dep/fgw/ensp/).

Figure 6. TF-1 mitigation site (Pond A) showing typical vegetation coverage throughout and surrounding pond area.

Species surveys were conducted at the TF-1 and TF-2 mitigation sites beginning on June 5th and continuing through July 13th, 2006. Although *H. andersonii* were absent from all mitigation ponds, both sites had an abundance of treefrogs located in adjacent wetlands. Due to cool temperatures experienced in late May until mid-June, treefrogs did not begin calling until June 23rd in chorus (1-2 individual calls were encountered sporadically at TF-1 as early as June 16th). Both mitigation sites were abundant in other anuran species, especially TF-2. The latter was heavily utilized by Fowler's toads (juveniles found en mass throughout the survey period), along with northern gray treefrogs (*H. versicolor*), and New Jersey chorus frogs (*Pseudacris triseriata kalmi*) and northern spring peepers (*H. crucifer*) (the last two species observed on the initial May 4th field visit). While a given habitat may appear to have all of the characteristics suitable for a species, it may not be present due to local extinction, geographical isolation, or other physical, chemical, or ecological variables (Hulmes et al. 1981, Freda and Morin 1984). Overall, the TF-1 and TF-2 mitigations were not successful based on both qualitative (i.e. empirically, no treefrog activity/breeding observed) and quantitative (i.e. LBSC - SR's not consistent with and beyond ranges established from reference site data; treefrogs absent from ponds) evaluation.

- Northern Pine Snake:
  Reference site comparisons to mitigation sites (i.e. PS-1 and PS-2, respectively) were difficult given that the reported habitat parameters presented limited summaries of sample data or the parameter was presented in tabular form as a list of individual components (e.g. plant species). For example, tables listing individual plant species data were grouped by type (i.e. woody or herbaceous) and averaged to obtain a value for "percent [woody or herbaceous] vegetation composition", requiring tedious extrapolation and combination to synchronize habitat parameters (mitigation sites) with the literature values. For that reason,

descriptive statistics were relied on heavily for assessment and interpretation. Confidence intervals for mitigation site habitat parameters were calculated and compared with means reported for each reference site parameter (Table 4). The above circumstances illustrate the need for measuring the same parameters on the reference sites, as opposed to reliance on data from the literature. Habitat parameters for mitigation sites with estimated confidence intervals ($\alpha = 0.05$) are presented below.

Table 4. Confidence intervals ($\alpha = 0.05$, Student's t-statistic) and mean percentage data for habitat features calculated for pine snake mitigation sites PS-1 and PS-2 compared with reference site data (NA = not available).

	Mean ± t_{sx} (95% confidence)					
Parameter	**PS-1 (n = 25)**	**PS-2 (n = 5)**	**Reference Sites**	**[a]SC_{Ref}**	**[b]SR_{PS-1}**	**[b]SR_{PS-2}**
Presence/Absence[c] (0 = absent, 1 = present)	**1 (14)**	**1 (4)**	---	---	---	---
Herbaceous vegetation composition (%)	**43.0 ± 11.3**	**24.2 ± 18.3**	41.0	NA	95.3%	169.4%
Woody vegetation composition (%)	**57.0 ± 11.3**	**12.2 ± 9.2**	59.0	NA	103.6%	485.1%
Open ground (%)	**58.2 ± 9.7**	**63.6 ± 36.2**	55.0	NA	94.6%	86.4%
Canopy cover (%)	**47.1 ± 14.7**	**38.3 ± 31.4**	NA	NA	NA	NA

[a] - S.D. information (used for SC calculation) not available from literature for reference sites

[b] - SR = Total for site (i.e. all den data combined): 100*(Mean of ref sites)/(Mean of mitigation sites)

[c] Present (1) - Number of hibernacula with snake activity observed shown in parentheses

Success Ratio's calculated for habitat parameter means from the PS-1 mitigation site fell within ranges (within ± 5.5%) reported for reference sites (Zappalorti and Reinert 1984, Burger et al. 1988, Burger and Zappalorti 1989). In contrast, habitat parameter SR's calculated for PS-2 (2A & 2B) varied widely (see Table 4). Large differences in percentages of herbaceous vs. woody vegetation composition between hibernacula were observed for both sites (e.g. herbaceous and woody composition ranging from 100% to 0%, respectively). Although male pine snakes show a preference for woody vegetation (Burger and Zappalorti 1989), this does not affect winter or summer use of hibernacula by either sex (Zappalorti and Burger 1985, Burger and Zappalorti 1988, 1989, Zappalorti and Reinert 1994). On average, PS-1 hibernacula had a higher occurrence of woody vegetation than estimated for PS-2 dens (56.96% vs. 12.16%, respectively), however site conditions and degrees of disturbance were strong determining factors (e.g. ORV activity, vandalism, etc.). For example, due to frequent excavation, Dens 1-4 at PS-2A were sparsely vegetated (mean open ground = 63.63%). Consequently, vegetation coverage was limited to pioneering species such as annual grasses, herbaceous species, and a few tree saplings. Zappalorti and Burger (1985) examined the effects and importance of disturbance on habitat selection by pine snakes. They noted that pine snakes exhibit great preference for human-disturbed sites, especially those with open soils and low cover. Therefore, conservation efforts for *P. m. melanoleucus* have focused on maintaining areas in an early successional stage with associated cover and debris (Burger and Zappalorti 1988, Zappalorti and Reinert 1994, R. Zappalorti, Pers. Comm.).

Canopy cover was not significantly related to vegetation composition on most hibernacula, but rather to nearby (within 5 m) trees and cover. In some instances (PS-1: Dens 17, 19 through 25), shading was due to larger trees (trees $\geq$ 15 cm dbh) growing next to or on the hibernaculum. As with vegetation, mean canopy cover on either mitigation site ranged from 100% to 0%, depending on the hibernaculum location (Mean canopy cover = 47.21%). An example of vegetation coverage typically found on hibernacula is shown in Figure 7.

Pine snake sites and individual hibernacula were surveyed during the period of June 12th through October 19th, 2006. Since *P. m. melanoleucus* exhibits high site fidelity with respect to hibernacula and nesting suitability (Burger et al. 1988, Burger and Zappalorti 1986, 1988, 1989, and 1991, Zappalorti and Reinert 1994), surveys concentrated on dens and areas in between the dens. The period of late September through October is considered the most critical time for observation, since snakes would be returning to the hibernacula for over-wintering (Zappalorti and Reinert 1994, D. Golden, Pers. Comm.). Verification of pine snake presence or absence was concluded by visual observation of individual snakes, evidence such as shed skins, and/or eggshells. “Bear”, the pine snake tracking dog (Figure 8), contributed greatly to this process, proving invaluable to this study. Individual snakes (Figure 9) were observed using or in the vicinity of 14 out of 25 dens at PS-1 (Table 5). This is consistent with observations reported by Zappalorti and Reinert (1994) for the same site (17 out of 25 in 1989) (also R. Zappalorti, Pers. Comm.). Since hibernacula were not excavated or individual snakes tracked, estimates of whether the population is increasing, decreasing, or stable cannot be presently made. Three (3) hatchlings were observed at Dens 2 and 3 (2 and 1, respectively), which lends evidence that breeding activity and successful reproduction is still occurring on site. *Pituophis m. melanoleucus* eggshells and nest cavities (as well as those of the endangered corn snake – *Elaphe guttata*) were also found on separate occasions on different field visits.

Although pine snakes were not found during PS-2A and PS-2B site visits, their presence (PS-2A) was verified by NJDEP-DFW staff following Den excavations in April 2006 (D. Golden and R. Zappalorti, Pers. Comm.). In the course of this study, concerns were raised after discoveries made during an August 2006 field visit, where Dens 1- 3 at PS-2A were found to be vandalized (Figure 10). Fortunately, NJDEP-DFW and DPF staff quickly repaired all damaged hibernacula without evident detriment to any wildlife (D. Golden, Pers. Comm.). Damage to den entrances could cause nesting female snakes and/or hatchlings to become trapped, and/or could severely impair over-wintering opportunities (Burger et al. 1988). Pine snakes were absent from Den 5 at the PS-2B site, although one adult was spotted nearby in April 2006. Northern pine snakes prefer open habitats with open canopy and loose, dry substrates (Zappalorti et al. 1983, Burger et al. 1988, Burger and Zappalorti, 1986, 1988, 1989, and 1991). Den 5 deviates greatly from this description, but is surrounded by substrates (i.e. Lakehurst sand) favored for nesting (D. Golden and R. Zappalorti, Pers. Comm.). The hibernaculum mound is covered by a dense stand of pitch pine (*Pinus rigida*) and miscellaneous debris, which may cause obstructions above (e.g. blockage to den entrances) and below ground (e.g. infiltration by roots). Shading may also play a significant role in the lack of snake activity at this den.

Table 5. Observations of northern pine snakes present/absent in or in the vicinity of hibernacula prior to hibernation (October 2006): PS-1 and PS-2 (2A & 2B) mitigation sites.

Study Site	Den ID	Present (+)/Absent (-)	Observation (A = Adult, H = Hatchling, S = Shed Skin, D = Dog – "Bear")	Comments
PS-1	1	+	H (1)	
	2	+	S,H (2)	
	3	-		
	4	+	A (1)	
	5	-		Hognose snake on access road
	6	+	S,D	Sheds of pine snake & other species around Den 6
	7	+	A (1)	Adult corn snake under board
	8	-		
	9	-		Hatched corn snake eggs on south side of den
	10	+	D	
	11	+	D	
	12	+	A (1), S	
	13	+	S,D	
	14	+	D	
	15	-		
	16	-		
	17	-		
	18	+	S,D	
	19	-		
	20	+	D	
	21	-		
	22	-		
	23	+	S,D	
	24	-		
	25	+	S,D	
PS-2A	1	+	R. Zappalorti/J. Burger (April 2006)	Dens 1-4 excavated by J. Burger (NJDEP-DFW) in April 2006; Pine snakes found in all dens
	2	+	R. Zappalorti/J. Burger (April 2006)	
	3	+	R. Zappalorti/J. Burger (April 2006)	
	4	+	R. Zappalorti/J. Burger (April 2006)	
PS-2B	5	-	R. Zappalorti/J. Burger (April 2006)	No signs of snake activity

Figure 7. Typical hibernaculum vegetation coverage with entrance featured (Den 2, PS-1 mitigation site).

Figure 8. "Bear", dog trained to track northern pine snakes (*Pituophis m. melanoleucus*) and bobcats (*Lynx rufus*).

Figure 9. Adult pine snake in vicinity of Den 7, PS-1 mitigation site.

Figure 10. Photos taken at PS-2A (Den 1 – left photo, Den 2 – right photo) showing a vandalized hibernacula with destroyed entrance pipes (August 2006). Dens were repaired later by NJDEP staff, with no detriment to snakes.

Taken as a whole, PS-1 and PS-2A based on empirical evidence of snake presence, utilization of hibernacula (i.e. verification by NJDEP-DFW, "Bear", and personal observation) and successful reproduction (i.e. presence of eggshells and hatchlings). Quantitatively, both mitigation sites include habitat parameters that proportionally resemble those observed for reference sites (i.e. substrate – Lakehurst and Lakewood sands, higher percentage of open ground, vegetation representative of natural *P. m. melanoleucus* habitat). Using the LBSC method comparison, PS-1 appears to closely emulate reference conditions. PS-2 (2A) site conditions vary greatly compared to natural sites (see Table 4), however snakes continue to utilize hibernacula and site regardless (D. Golden and R. Zappalorti, Pers. Comm.).

- The LBSC Methodology for Evaluating Success:
  The consensus for using the LBSC methodology as a tool for success evaluation, as found by this study, is that it is limited to geographically, short-ranging species and seems more suited for plants than for animals. Applying the LBSC method was problematic, and it is difficult to gauge the degree of accuracy in the results. For example, maximum water depth for the TF-1 treefrog mitigation site differed significantly from the reference sites (Table 2). However, SR's calculated for this site indicated that these values were within the acceptable range of the SC for the maximum water depth parameter (Table 3). This result may suggest that a minimum depth value may be required. Similarly for the PS-2A site, SR's calculated for each habitat attribute differed considerably from the calculated SC's, especially the SC estimated for woody vegetation composition (Table 4). Yet, this site was found empirically to have pine snakes successfully using the site and hibernacula since monitoring began 25+ years ago (R. Zappalorti and D. Golden, Pers. Comm.).

Summary and Conclusions:
Although the temptation exists for applying a 'catch-all' method to assessing wildlife mitigation success, variation in species' requirements and life history necessitates novel methodologies and survey procedures unique to each particular species. Four main conclusions/suggestions can be drawn from the results observed in this study:

1. The literature should be thoroughly reviewed for selecting habitat parameters and life history traits to be measured for a target species. In as much, both reference and mitigation sites should be measured directly. In this way, variation and sampling error may be minimized, as well as sample sizes appropriately chosen.
2. Multiple parameters are important for evaluating the successful colonization, utilization, and reproductive capacity of a species, and how a restored/mitigation site effectively recreates these conditions. Measuring only one or two parameters may not produce an accurate indication of success. For example in this study, the TF-1 treefrog mitigation site parameters closely resembled a successfully functioning *H. andersonii*-breeding habitat, however the absence of treefrogs suggests otherwise.
3. Measurement of habitat parameters must be species-specific. The LBSC methodology, as illustrated by this study, cannot be effectively applied universally, but with focus on each individual species and its unique requirements. Confidence intervals and/or other statistical analyses must be applied to test for significance, and for ranges by which the means should be bound.
4. Utilization of the LBSC methodology is most appropriate for species (i.e. animals) with small home ranges and/or those geographically isolated (e.g. pond, hillside, along a utility R.O.W., etc.). This method is especially appropriate for plant species (i.e. for which it was originally developed).

The discrepancies between the calculated SR's and common biostatistics further illustrate the problems associated with the LBSC methodology. Specifically, SC's and SR's calculated for certain parameters may be falsely labeled as an unimportant ecological factor (i.e. disqualifying candidate indicator) for species success, showing widely fluctuating percentages (greater than ± 20 percent) and/or high variation (large CV's). Since reference sites were not measured directly, some of these discrepancies may be due to sampling error and missing data. Coupling of other methods, such as the application of confidence intervals to habitat parameters, aids in bridging gaps created by obscure LBSC results. Moreover, applying other statistical methods can be helpful simply for the purpose of comparison. Although the LBSC method is a time effective way for evaluating general mitigation success, data gleaned from the literature should be interpreted with caution, and limited to finding critical habitat parameters. The critical or qualifying parameters selected for a given species should be physically measured at the chosen reference sites. In this way, parameters measured at the mitigation sites will be the same, as well as measured in a similar fashion and analyzed with the appropriate statistical methods.

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