Supplemental Information for the Pine Barrens Tree Frog

Biological Status Review Report

The following pages contain peer reviews received from selected peer reviewers, comments received during the public comment period, and the draft report that was reviewed before the final report was completed

March 31, 2011

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Peer review #1 from Patrick Gault

Comments on the Biological Status Review for the
Florida bog frog and pine barrens tree frog.

Respectfully submitted by Patrick Gault, 1 February 2011

I appreciate the opportunity to comment on these documents. My experience with both species is primarily based on field work assisting several graduate students studying the bog frog, along with, in the case of the pine barrens tree frog, personal observations and call counts with fellow biologist.

In brief, I agree the findings of the committee based upon the criteria set forth. I would encourage the FWC to encourage further study of the bog frog due to its uniqueness, relative small range, and the potential impacts of future changes in the mission of Eglin Air Force Base Reservation. Although this species is relatively common in its range, there is much more to be learned concerning its home use area and natural history.

Although there is little documented evidence showing a decline in the population of pine barrens tree frogs in the Florida range, I have witnessed the possible loss (based on the lack of calling males during breeding season) of at least two and possibly three historic sites since @ 1995. One site is located on the Eglin reservation, and two on or near power line r.o.w.s and subdivisions in Okaloosa County near Crestview. In all three cases, significant alteration to adjacent habitat could be involved. I appreciate the call for protection of this species from commercial trade and again would ask for further study of the Florida population to establish a baseline for the population and develop a clearer picture of the species future status.

As an aside, our facility is in the process of building an education/wildlife rehabilitation center that will include a series of native species zoos, as a former zoo herpetologist, I would welcome the opportunity to work with these species in a captive setting, primarily in an educational role to raise awareness of their existence, and the plight of amphibians worldwide, and also to study their biology and reproduction.

I thank you again for allowing me to have input on this important issue, please feel free to contact me if you have any further questions.

Sincerely,
Patrick Gault

Peer review #2 from Dr. Bruce Means

From: D. Bruce Means [mailto:means@bio.fsu.edu]
Sent: Tuesday, January 25, 2011 12:24 PM
To: Turner, Bill
Subject: Biol Status Rev of Pine Barrens Treefrog

Dear Bill,

I have completed my review of the Biological Status Review of the Pine Barrens Treefrog. Please see my comments in the attached letter.

Thank you,

--Bruce
D. Bruce Means, Ph. D.
President and Executive Director
Coastal Plains Institute and Land Conservancy
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22 January 2011

Bill.Turner@MyFWC.com
Biological Status Review
of the **Pine Barrens Treefrog**

Dear Bill,

I have reviewed the Biological Status Review of the Pine Barrens Treefrog and have the following comments.

1) Under Taxonomic Classification, you might consider adding: Florida populations differ slightly from populations in the Carolinas and New Jersey in the quality of their color pattern, mating call, and in some body measurements (Means and Longden 1976). In an electrophoresis study, slight genetic differences were found among the three enclaves, but deemed not sufficient for taxonomic distinction of the Florida populations (Karlin et al. 1982). Studies of mitochondrial and nuclear DNA are needed.

2) In Life History and Habitat Requirments, line 13 should read, "...suppression and increased evapotranspiration...."

3) Fix first sentence in Population Status and Trend: "...because of its relatively recent discovery."

4) In Quantitative Analyses, line 5 should read "...although running the model on potential habitat showed...."

5) Under Threats: "...a 26-year period..." should be hyphenated.

6) Under Threats, the paragraph should make a statement about the threats from human activities such as habitat alteration, fragmentation by roads, fields, etc., and development. The west Florida area is experiencing a huge expansion of human population inland from the coastline, and any *Hyla andersonii* populations remaining on private lands are suffering from the draining of bogs, expansion of pastureland, removal of pine forests, slash and loblolly pine plantations, and home construction.

The two new citations, if you choose to use them, are:

Means, D. B. and C. J. Longden. 1976. Aspects of the biology and zoogeography of the pine barrens treefrog (*Hyla andersonii*) in northern Florida. Herpetologica 32(2):117-130.

Karlin, A. A., D. B. Means, S. I. Guttman, and D. D. Lambright. 1982. Systematics and the status of *Hyla andersonii* (Anura: Hylidae) in Florida. Copeia 1982(1):175-178.

Otherwise, I think that the Biological Status Review of the Pine Barrens Treefrog was well done and I agree with its conclusions.

Very sincerely yours,

D. Bruce Means, Ph. D.
President and Executive Director

Peer review #3 from John Cely

From: John Cely
To: Imperiled
Subject: pine barrens treefrog review
Date: Monday, January 31, 2011 8:00:08 AM

To Whom It May Concern:

I have reviewed the information provided concerning the status and delisting of Hyla andersonii. I concur with the findings of the review committee. As a suggestion, however, I would include a brief narrative in the final draft, providing some context of why the species was listed in the first place. And I may have overlooked it but nowhere could I find in the review of what it's actual current status is in Florida.

Best regards,

John Cely
Wildlife Biologist (retired)
South Carolina Department of Natural Resources

Peer review #4 from Steve Bennett

From: Steve Bennett
To: Imperiled
Cc: Enge, Kevin
Subject: RE: Pine barrens treefrog Draft BSR Report
Date: Friday, January 28, 2011 2:09:56 PM
Attachments: Review of pine barrens treefrog report for FWC.doc

Sorry about the initial confusion … I hope this is of some use.

Steve
Stephen H. Bennett
Herpetologist
SCDNR

Review of pine barrens treefrog report for FWC

The pine barrens treefrog report is well written and thorough. I believe the report would be strengthened by including an estimate of the number of populations in Florida, if available, how many of these occur on protected lands, what type of "protected" lands and some information on the management afforded the species on these protected lands. The decision not to list seems to be based on the species "conservation potential" on managed lands, so any information that supported the conclusion would strengthen the report.

Some additional information you may use if you like:

Anderson S.C. is likely not the location where the first specimen was collected. This specimen was mailed to the Smithsonian from Anderson S.C. with no collection data. In fact there was no return address on the package and the only "data" the recipients had to go on was the Anderson S.C. postmark, so it was assumed to have been collected in that vicinity. Anderson is more than 100 miles from the nearest extant pbt population in S.C. and it's in the Piedmont. All of S.C's known pbt populations occur in the northern sandhills. To date no pbt specimens have been documented in the sandhills southwest of Columbia S.C.

In 2000, under permit from SCDNR, Riverbanks Zoo (Scott Pfaff, Curator of Herpetology) collected a number of pbt tadpoles from a historic population in S.C. Tadpoles were raised to metamorphosis then placed in an outdoor enclosure to determine age to reproduction and longevity, in a captive setting. Pine barrens treefrogs were sexually mature at 11 months of age and lived approximately 3-4 years (S. Pfaff unpublished data). This life history strategy, early reproduction and short life span (we're calling this a "simple" life history) coupled with the large reproductive output (number of eggs) indicates this species is limited more by habitat issues and has the capacity to recover in response to habitat management/restoration.

Peer review #5 from Jeff Beane

From: Beane, Jeff
To: Imperiled
Subject: RE: Pine barrens treefrog Draft BSR Report
Date: Monday, January 10, 2011 11:05:46 AM
Attachments: Pine Barrens Tree Frog Final Draft BSR 12-9-10.docx

I've reviewed the BSR draft for the Pine Barrens treefrog in FL, and I see no major problems with it. The analyses and interpretations of the available data, assumptions made, conclusions drawn, and recommendations made seem reasonable and straightforward. Only a few very minor comments/suggestions/corrections of typos, etc. on the attached.

Thanks for considering me as a reviewer!

jcb
Jeffrey C. Beane
Collections Manager for Herpetology
North Carolina State Museum of Natural Sciences
1626 Mail Service Center, Raleigh, NC 27699-1626 USA (postal address)
4301 Reedy Creek Road, Raleigh, NC 27607 USA (physical address for UPS, FedEx, DHL, etc.)

BIOLOGICAL STATUS REVIEW
of the
Pine Barrens Treefrog
(*Hyla andersonii*)

EXECUTIVE SUMMARY

The Florida Fish and Wildlife Conservation Commission (FWC) directed staff to evaluate all species listed as Endangered, Threatened, or Species of Special Concern as of 1 September 2010. Public information on the status of the Florida population of the pine barrens treefrog was sought from September 17 through November 1, 2010. A five-member biological review group (BRG) met on November 9-10, 2010. Group members were Bill Turner (FWC lead), Ryan Means (Coastal Plains Institute), Kelly Jones, Paul Moler (independent consultant), and John Himes (FWC) (Appendix 1). In accordance with rule 68A-27.0012 F.A.C, the BRG was charged with evaluating the biological status of the pine barrens treefrog using criteria included in definitions in 68A-1.004 and following protocols in the *Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0)* and *Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1).* Please visit http://myfwc.com/WILDLIFEHABITATS/imperiledSpp_listingprocess.htm to view the listing process rule and the criteria found in the definitions. The BRG concluded from the biological assessment that the pine barrens treefrog did not meet criteria for listing. Based on the BRG findings, literature review, and information received from the public and independent reviewers, staff recommends delisting this species.

Comment [N1]: I was always under the impression that the common name was in reference to the New Jersey Pine Barrens and thus should be capitalized ("Pine Barrens treefrog"). This actually may not be the case, (esp. since the type locality is SC), and I don't know if it really matters, but I've nearly always seen "Pine Barrens" capitalized in the name (it is also spelled that way on the FWC website).

This work was supported by a Conserve Wildlife Tag grant from the Wildlife Foundation of Florida.

BIOLOGICAL INFORMATION

Taxonomic Classification – The pine barrens treefrog (*Hyla andersonii* Baird, 1854) is a distinct species within a highly speciose genus. The specific epithet reflects the location where the first specimen was reportedly collected: Anderson, South Carolina.

Life History and Habitat Requirements – The life history characteristics and habitat requirements of the pine barrens treefrog have been summarized by Means and Moler (1978), Means in Moler (1992), and Means in Lannoo (2005). Breeding occurs in low pH (acidic, generally < 4.5) wetlands called seepage bogs. These bogs are created when rains saturate sands overlying an impermeable clay layer. Unable to pass through the clay, the rainwater moves laterally and seeps out on the nearby hillsides. Near the seepage, the vegetation consists mainly of herbs (herb bog), but downslope the bog is often dominated by woody plants (shrub bog). Herb bogs are characterized by sundews (*Drosera* spp.), pitcher plants (*Sarracenia spp.*), sedges, and grasses with extensive *Sphagnum* moss. Pine barrens treefrogs breed in shallow (usually < 10 inches), clear pools of water in the herb bogs. Adults forage in the shrub bogs, which contain black titi (*Cliftonia monophylla*), swamp titi (*Cyrilla racemiflora*), tall gallberry (*Ilex coriacea*), and sweet bay (*Magnolia virginiana). Means and Moler (1978) suspected that woody plant encroachment into herb bogs, often as a result of fire suppression, increased evapotranspiration,* *thus reducing seepage and making sites less suitable for the treefrogs. Disturbances that remove woody vegetation, such as power line rights-of-way, mimic historically fire-maintained seepage conditions (Means and Moler 1978).* Male pine barrens treefrogs call sporadically when seepage water fills breeding pools (Moler 1981). Pine barrens treefrogs have been heard calling as early as March and as late as the third week in September in Florida (Means 1992). Pine barrens treefrog choruses often have fewer than 10 calling males (Means and Moler 1978, Moler 1981). Tadpoles have been collected from May through August (Means 1992). Pine barrens treefrogs are known to forage up to 105 m from breeding sites (Means 2005). Egg masses contain between 800 and 1,000 eggs, which hatch in 3-4 days. If Florida populations have development times similar to New Jersey populations, the tadpoles would metamorphose in 50-75 days (Means 2005).

Population Status and Trend – The population status of the pine barrens treefrog in Florida is poorly understood because of its~~their~~ relatively recent discovery (Christman 1970). Populations are thought to have declined since pre-settlement times as a result of habitat degradation from fire suppression and other factors (Means and Moler 1978, Enge 2002, Means 2005).

Geographic Range and Distribution – Pine barrens treefrogs are found in three regions of the eastern U.S.: the Florida Panhandle and adjacent Alabama, the New Jersey Pine Barrens, and the Fall Line Sand Hills of the Carolinas (NC and SC) (Means 2005). Unknown in Florida until 1970 (Christman 1970), the species has now been recorded from 177 sites in Santa Rosa, Okaloosa, Walton, and Holmes counties (Endries et al. 2009), as well as from adjacent Escambia, Geneva, and Covington counties, Alabama (Moler 1981, Moler pers. commun. 2010).

Quantitative Analyses – Two PVA models have been calculated for pine barrens tree frogs in Florida (Endries et al. 2009). One of these models considered all potential habitat, while the other considered only potential habitat on managed lands. The predicted baseline growth rate for both models was 0.9979. The probability of extinction in the next 100 years under both of these demographic parameters was 0%, although the model run on all potential habitat showed a high probability of a decline (i.e., 54% probability of a 60% decline) (Endries et al. 2009).

BIOLOGICAL STATUS ASSESSMENT

Threats – Pine barrens treefrogs are adapted to low pH bogs. This habitat is a low nutrient ecosystem that is very sensitive to changes in water chemistry and flow (Means 2005, Bunnell and Ciraolo 2010). Bunnell and Ciraolo (2010) found that the pine barrens treefrog was also vulnerable to reduction in water depth at breeding sites from water table drawdowns. Pine barrens treefrogs are dependent on early successional fire-maintained bog habitat. Fire suppression allows woody plants to invade the bog habitat, increasing evapotranspiration and reducing seepage from the soil. The availability of seepage water is critical to pine barrens treefrog breeding habitat (Means and Moler 1978). Blackwater State Forest and Eglin Air Force Base (EAFB) make extensive use of prescribed fire, which should benefit local populations of pine barrens treefrogs (Printiss and Hipes 1999, U.S. Air Force 2010). Encroachment by invasive plants, particularly Chinese tallow tree (*Sapium sebiferum*), likewise degrades the bog habitat (Jackson 2004). Feral hogs (*Sus scrofa*) are present on EAFB and can damage treefrog habitat through their rooting. EAFB has a Feral Hog Management Plan for reducing the feral hog population (U.S. Air Force 2010). Global warming threatens pine barrens treefrogs through longer drought periods, more severe storms and floods, less available water, the effects of increasing temperatures, and sea level rise (Field et al. 2007). Severe droughts, like those predicted from climate change, have been implicated in declines of several amphibian species, including the southern leopard frog (*Lithobates sphenocephalus*~~a~~) in South Carolina during a 26-year period (Daszak et. al. 2005). Pathogens and parasites also threaten Florida bog frogs. A chytridiomycete fungus, *Batrachochytrium dendrobatidis* (chytrid), has been implicated as a cause of disease epidemics and subsequent population declines of amphibians in many parts of the world. Chytrid is not yet known to be responsible for any amphibian die-offs in the Southeast (Daszak et. al. 2005). Ranaviruses are likely a greater threat to amphibians than chytrid in North America (Gray et al. 2009b). Catastrophic die-offs of wild amphibian populations from ranaviruses have occurred in >30 states and 5 Canadian provinces (Green et al. 2002, Gray et al. 2009a). Although ranaviruses are pathogenic to both adult and larval amphibians, mortality rates tend to be higher for larvae (Gray et al. 2009a). A die-off of hundreds of ranid tadpoles in 2 ponds in Withlacoochee State Forest, Hernando County, FL, was apparently caused by an unnamed *Perkinsus*-like (or alveolate) microorganism (Davis et al. 2007, Rothermel et al. 2008). Pine barrens treefrogs and their larvae are probably preyed on by many creatures that hunt in their habitat. Bronze frogs (*Lithobates c. clamitans*), two-toed amphiumas (*Amphibuma means*), red salamanders (*Pseudotriton ruber*), banded pigmy sunfish (*Elassoma zonatum*), and turtles are all potential predators of larval pine barrens treefrogs. Banded water snakes (*Nerodia fasciata*) and common ribbon snakes (*Thamnophis sauritus*) feed on adults (Means 2005). Enge (2002) trapped mole kingsnakes (*Lampropeltis calligaster rhombomaculata*) in bogs within the Florida range of the pine barrens treefrog. Eastern mudsnakes (*Farancia a. abacura*), eastern gartersnakes (*Thamnophis s. sirtalis*) and cottonmouths (*Agkistrodon piscivorus*) are also possible predators of pine barrens tree frogs in Florida (Enge 2002).

Comment [N2]: This doesn't seem particularly relevant to me, as mole kingsnakes are not typically amphibian predators.

STATEWIDE POPULATION ASSESSMENT – Available data on the Florida pine barrens treefrog population were evaluated relative to each of the five criteria for state listing under Rule 68A-1.004 F.A.C. There are two steps in assessing the status of a regional population: (1) use FWC criteria for a preliminary categorization and (2) investigate whether conspecific populations outside the region may affect the risk of extinction within the region.

LISTING RECOMMENDATION

The pine barrens tree frog did not meet listing criteria, although it met some sub-criteria. The pine barrens treefrog has a sufficiently small extent of occurrence and area of occupancy to meet the first part of the Geographic Range Criterion, but it meets only one of the three other sub-criteria (b. continuing decline). The BRG thought that declines in habitat (b.) would continue, but that the species was not severely fragmented (a.) or subject to extreme fluctuations (c.). Staff recommends delisting the pine barrens treefrog based on the findings of the BRG and current biological information about the species. The BRG and staff recommend that protecting the pine barrens treefrog from commercial take be specified in the management plan, because both groups thought the species would be targeted for the pet trade.

SUMMARY OF THE INDEPENDENT REVIEW

To be included after the peer review.

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Biological Status Review Information Findings	
Species/taxon:	Pine Barrens Treefrog
Date:	Oct 26.2010
Assessors:	John Himes, Kelly Jones, Ryan Means, Paul Moler, Bill Turner
Generation length:	1 - 2 years

Criterion/Listing Measure	Data/Information	Data Type*	Criterion Met?	References
*Data Types - observed (O), estimated (E), inferred (I), suspected (S), or projected (P). Criterion met - yes (Y) or no (N).				
(A) Population Size Reduction, ANY of				
(a)1. An observed, estimated, inferred or suspected population size reduction of at least 50% over the last 10 years or 3 generations, whichever is longer, where the causes of the reduction are clearly reversible and understood and ceased[1]	There are no data to suggest a 50% decline in the last ten years.	S	N	Endries et al. 2009, Means 1992
(a)2. An observed, estimated, inferred or suspected population size reduction of at least 30% over the last 10 years or 3 generations, whichever is longer, where the reduction or its causes may not have ceased or may not be understood or may not be reversible[1]	There are no data to suggest a 30% decline in the last ten years.	S	N	Endries et al. 2009, Means 1992
(a)3. A population size reduction of at least 30% projected or suspected to be met within the next 10 years or 3 generations, whichever is longer (up to a maximum of 100 years) [1]	There are no data to suggest a 30% decline in the next ten years, but potential of collection for the pet trade should be addressed in the management plan by suggesting protective rules.	S	N	Endries et al. 2009, Means 1992
(a)4. An observed, estimated, inferred, projected or suspected population size reduction of at least 30% over any 10 year or 3 generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased or may not be understood or may not be reversible.[1]	There are no data to suggest a 30% decline in the next ten years.	S	N	
[1] based on (and specifying) any of the following: (a) direct observation; (b) an index of abundance appropriate to the taxon; (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat; (d) actual or potential levels of exploitation; (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors, or parasites.				
(B) Geographic Range, EITHER				
(b)1. Extent of occurrence < 20,000 km^2 (7,722 mi^2) OR	Using areas of counties of occurrence, estimate is 3862 mi^2.	E	Y	using GIS data Beth Stys pers. commun. 2010
(b)2. Area of occupancy < 2,000 km^2 (772 mi^2)	Area of occupancy estimated at 220 mi^2 from FWC habitat coverage.	E	Y	using GIS data Beth Stys pers. commun. 2010 and Endries et al. 2009
AND at least 2 of the following:				
a. Severely fragmented or exist in ≤ 10 locations	Estimated more than 10 locations from GIS, not severely fragmented.	E	N	Treated every site in a tributary as location using GIS

b. Continuing decline, observed, inferred, or projected in any of the following: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent, and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals	Continuing decline in habitat quality of plant succession due to ongoing fire suppression	I	Y	
c. Extreme fluctuations in any of the following: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals	Although most frog populations fluctuate, no extreme fluctuations are indicated in literature. Frog populations fluctuate naturally, but this was not considered extreme by the group.	I	N	
(C) Population Size and Trend				
Population size estimate to number fewer than 10,000 mature individuals AND EITHER	The group had great difficulty reaching a conclusion, but majority vote (3 to 2) was for more than 10,000 individuals.	E	N	Means 1992, Endries et al. 2009
(c)1. An estimated continuing decline of at least 10% in 10 years or 3 generations, whichever is longer (up to a maximum of 100 years in the future) OR	The group had great difficulty reaching a conclusion because of concerns over future habitat decline.	S	N	
(c)2. A continuing decline, observed, projected, or inferred in numbers of mature individuals AND at least one of the following:	Some continuing decline is probable from habitat loss.	I	Y	Endries et al. 2009
a. Population structure in the form of EITHER (i) No subpopulation estimated to contain more than 1,000 mature individuals; OR	Suspect that at least one sub-population (Yellow River) is greater than 1,000 individuals.	S	N	
(ii) All mature individuals are in one subpopulation		I	N	
b. Extreme fluctuations in number of mature individuals	Surveys indicate relative stability of calling males across years.	I	N	K. Jones pers. commun.
(D) Population Very Small or Restricted, EITHER				
(d)1. Population estimated to number fewer than 1,000 mature individuals; OR	The number of localities was stated as 177 in Endries et al. 2009. Means (1992) stated that most sites had fewer than 10 calling males. Assuming a 1:1 sex ratio, there would be about (20 x 177) 3,540 PBTFs	E	N	Endries et al. 2009
(d)2. Population with a very restricted area of occupancy (typically less than 20 km^2 [8 mi^2]) or number of locations (typically 5 or fewer) such that it is prone to the effects of human activities or stochastic events within a short time period in an uncertain future	Greater than 8 mi^2 (see above).	E	N	Endries et al. 2009
(E) Quantitative Analyses				

e1. Showing the probability of extinction in the wild is at least 10% within 100 years	A PVA model run on all potential habitats showed a high probability of a decline (i.e., 54% probability of a 60% decline over 100 years). Approximately 48% of the potential habitat was on managed lands, which resulted in a much smaller abundance than the model using all potential habitats. Given the reduced abundance on managed lands, an increased risk of a decline was evident (i.e., 94% probability of a 60% decline), but the risk of extinction remained 0%.	E	N	Means 1992, Endries et al. 2009

Initial Finding (Meets at least one of the criteria OR Does not meet any of the criteria)	Reason (which criteria are met)
Initial finding is that species does not meet criteria for listing.	
Is species/taxon endemic to Florida? (Y/N)	N

1	Species/taxon:	Pine Barrens Treefrog
2	**Biological Status Review Information** Date:	Oct 26.2010
3	Regional Assessment Assessors:	John Himes, Kelly Jones, Ryan Means
4		Paul Moler, Bill Turner
5		
6		
7		
8	Initial finding	
9		
10	2a. Is the species/taxon a non-breeding visitor? (Y/N/DK). If 2a is YES, go to line 18. If 2a is NO or DO NOT KNOW, go to line 11.	N
11	2b. Does the Florida population experience any significant immigration of propagules capable of reproducing in Florida? (Y/N/DK). If 2b is YES, go to line 12. If 2b is NO or DO NOT KNOW, go to line 17.	Y
12	2c. Is the immigration expected to decrease? (Y/N/DK). If 2c is YES or DO NOT KNOW, go to line 13. If 2c is NO go to line 16.	Do Not Know, although likely
13	2d. Is the regional population a sink? (Y/N/DK). If 2d is YES, go to line 14. If 2d is NO or DO NOT KNOW, go to line 15.	No
14	If 2d is YES - Upgrade from initial finding (more imperiled)	
15	If 2d is NO or DO NOT KNOW - No change from initial finding	No change
16	If 2c is NO or DO NOT KNOW- Downgrade from initial finding (less imperiled)	
17	If 2b is NO or DO NOT KNOW - No change from initial finding	
18	2e. Are the conditions outside Florida deteriorating? (Y/N/DK). If 2e is YES or DO NOT KNOW, go to line 24. If 2e is NO go to line 19.	
19	2f. Are the conditions within Florida deteriorating? (Y/N/DK). If 2f is YES or DO NOT KNOW, go to line 23. If 2f is NO, go to line 20.	
20	2g. Can the breeding population rescue the Florida population should it decline? (Y/N/DK). If 2g is YES, go to line 21. If 2g is NO or DO NOT KNOW, go to line 22.	
21	If 2g is YES - Downgrade from initial finding (less imperiled)	
22	If 2g is NO or DO NOT KNOW - No change from initial finding	
23	If 2f is YES or DO NOT KNOW - No change from initial finding	
24	If 2e is YES or DO NOT KNOW - No change from initial finding	
25		
26	Final finding	No change

APPENDIX 1. Biological s~~S~~tatus r~~R~~eview g~~G~~roup b~~B~~iographies.

Dr. John H. Himes received his Ph.D. from the University of Southern Mississippi, M.S. from Louisiana State Medical Center, and B.S. from the University of Mississippi. He is currently a regional biologist for FWC. He has published many papers on southeastern herpetofauna.

Kelly Jones received his M.S. in Biology from Ball State University. He is currently the project manager for the Virginia Polytechnic Institute and State University team working with red-cockaded woodpeckers, Florida bog frogs, reticulated flatwoods salamanders, and gopher tortoises on Eglin Air Force Base. He has short notes in press on distribution and natural history of native and exotic herpetofaunal species in the Florida panhandle.

Ryan C. Means received both his M.S. in Wildlife Ecology and Conservation (2001) and his B.S. in Zoology (1996) from the University of Florida. He is a wildlife ecologist with the Coastal Plains Institute in Tallahassee, FL. His research interests focus on ecology and conservation of ephemeral wetlands and associated amphibian fauna in the southeastern Coastal Plain. Ryan has many other interests, including wilderness exploration, archaeology, paleontology, and anything related to being in the outdoors.

Paul E. Moler received his M.S. in Zoology from the University of Florida in 1970 and his B.A. in Biology from Emory University in 1967. He retired in 2006 after working for 29 years as a herpetologist with FWC, including serving as administrator of the Reptile and Amphibian Subsection of the Wildlife Research Section. He has conducted research on the systematics, ecology, reproduction, genetics, and conservation biology of a variety of herpetofaunal species in Florida, with primary emphasis on the biology and management of endangered and threatened species. He served as Chair for the Florida Committee on Rare and Endangered Plants and Animals in 1992–94, Chair of the Committee on Amphibians and Reptiles since 1986, and editor of the 1992 volume on amphibians and reptiles. Paul has >90 publications on amphibians and reptiles.

William M. Turner received his B.S. from Erskine College and M.S. in Biology from the University of South Alabama. From 2003 to 2007, he was the Herpetological Coordinator for the Wyoming Game and Fish Department. In Wyoming, he conducted statewide surveys for amphibians and reptiles, focusing on emerging amphibian diseases and the impacts of resources development on native reptiles. Since 2007, he has been the Herp Taxa Coordinator for FWC in the Division of Habitat and Species Conservation. He has conducted research on native amphibians and reptiles in Florida, Alabama, and Wyoming that has resulted in several published papers and reports.

APPENDIX 2. Summary of public comments that were received 17 September–3 November 2010 regarding the proposed reclassification of the pine barrens treefrog.

Although he did not make a comment, John F. Bunnell, Chief Scientist of the Pinelands Commission, New Lisbon, NJ, submitted several publications during the commenting period for which we are thankful.

APPENDIX 4. Information and comments received from the independent reviewers.

Comment [N3]: Should this be Appendix 3, or is there going to be another appendix before this one?

Letters and emails received during the solicitation of information from the public period of September 17, 2010 through November 1, 2010

Email from John Bunnell

From: John Bunnell
To: Imperiled
Subject: information on Pine Barrens treefrogs
Date: Thursday, October 21, 2010 8:35:38 AM
Attachments: Laidig, K. J. et. al. 2001. Characteristics of selected Pine Barrens treefrog ponds in the New Jersey Pinelands Commission.pdf
Bunnell and Ciraolo. 2010. The potential impact of simulated ground-water withdrawals on the oviposition, larval development, and metamorphosis of pond-breeding frogs.pdf
Bunnell and Zampella. 1999. Acid water anuran pond communities along a regional forest to agro-urban ecotone.pdf

Florida FWC,

Attached are three documents that provide information regarding life history and habitat specifications, including vegetation, water-quality, pond bathymetry, and hydrologic conditions, associated with Pine Barrens treefrogs and their breeding habitats. I am sending this information in response to the news release below.

JB
John F. Bunnell
Chief Scientist
Pinelands Commission
PO Box 359
15 Springfield Road
New Lisbon, NJ 08064

CHARACTERISTICS OF SELECTED PINE BARRENS TREEFROG PONDS IN THE NEW JERSEY PINELANDS

KIM J. LAIDIG, ROBERT A. ZAMPELLA, JOHN F. BUNNELL,
CHARLES L. DOW, AND TANYA M. SULIKOWSKI

PINELANDS COMMISSION
LONG-TERM ENVIRONMENTAL-MONITORING PROGRAM

2001

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2001

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POND DESCRIPTIONS

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Introduction

This report presents data on the vegetation, anurans, water chemistry, and physical properties of selected natural and excavated Pinelands ponds that are known to support breeding populations of Pine Barrens treefrogs (*Hyla andersonii*). The 13 ponds (Figure 1, Table 1) were initially selected to study frog and toad adult and larval species composition relative to site-specific, local, and regional environmental variables (Bunnell and Zampella 1999). More recently, the vegetation structure, plant-species composition, and environmental attributes of these same ponds were examined (Zampella and Laidig 2001). The 13 ponds have been the subject of research and monitoring since 1996 and are part of the Pinelands Commission's network of long-term environmental-monitoring program sites. The purpose of this report is to characterize the habitat of known Pine Barrens treefrog breeding populations. The information presented here also provides a baseline data set against which future comparisons of selected biological and environmental attributes can be made.

Methods

Study Sites

The 13 ponds were assigned the names originally given by Bunnell and Zampella (1999). Nine of the 13 ponds are found in what appear to be naturally occurring depressions. These ponds are fairly representative of natural depressions found throughout the central Pinelands. The remaining four ponds (Chew, Hampton, Furnace, and Sphagnum) are found in excavated basins that were probably mined for fill material. County soil surveys indicate that all but one pond (Price) are associated with sandy soils of the Lakewood catena (Tedrow 1979). These soils include the Lakehurst (Haplaquodic Quartzipsamments), Atsion (Aeric Haplaquods), and Berryland (Typic Haplaquods) soil types. Price pond is associated with Fallsington (Typic Ochraquults) sandy-loam soils.

Environmental Characteristics

Data were collected for several morphometric, water quality, and landscape variables. In March 1998, a global positioning system (GPS) was used to delineate the shoreline of each pond. The delineations were completed in March because this month generally represents the period of greatest pond-surface area and water depth. Water depth was measured along four transects passing through the center of each pond and aligned with the major compass directions (N-S, E-W, NE-SW, and NW-SE). The ends of each transect were registered with the GPS. Within 2.5 m of the shoreline, water depth was measured every 0.5 m. All other water-level measurements were made at 2.5-m intervals. From April - September 1996, April - October 1997, and March - October 1998, monthly growing-season staff-gage readings were taken at a single point in each pond. Using the monthly staff-gage measurements in conjunction with the March 1998 point measurements, mean water level, surface-water area, and area of exposed substrate were calculated for each month. Shoreline-depth measurements were used to calculate mean shore slope. Mean slopes were based on the average 0.5 m interval slope for the first 2.5 m of each transect. Bathymetric maps were created for each pond using the GPS-registered water-level data and ARC/INFO software.

Specific conductance and pH were measured during each staff-gage monitoring round from March - June 1998, with an Orion model 122 conductivity meter and an Orion model 250A pH meter. Median pH and specific conductance values were calculated for this sampling period. Water samples were collected for laboratory analysis of total organic carbon (TOC) in June, July, and August 1998. All TOC water samples were collected at a depth of 10 cm at the center of each pond, transported to the lab on ice, and analyzed using a Dohrman DC-80 organic carbon analyzer. Since most ponds were dry in August, average TOC values were calculated using the June and July values ($n = 2$, except for Albertson and Price, where $n = 1$).

To characterize the landscape setting of the ponds, the dominant forest types were subjectively described within the four quarters of a circular buffer surrounding each site by walking around its perimeter and inspecting recent color-infrared photography. Forest types included Atlantic white cedar (*Chamaecyparis thyoides*) swamp, shrub wetlands, wet and dry pitch pine (*Pinus rigida*) lowlands, and upland pitch pine and oak (*Quercus* spp.) forest. Wet and dry pitch pine lowlands represent transitional vegetation types that grade from upland pitch pine forests to swamp forests (Roman et al. 1985, Zampella et al. 1992).

Vegetation Composition and Patch Structure

Comprehensive plant species lists were completed for each pond based on visits made throughout the

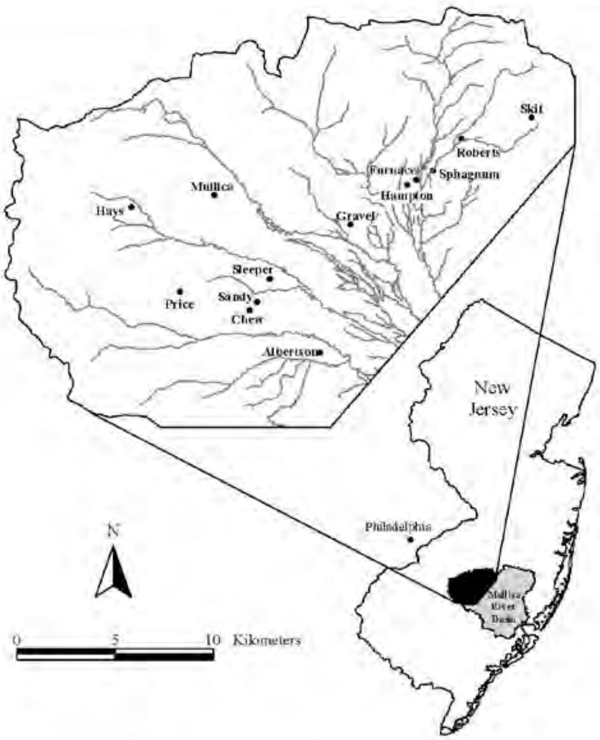

Figure 1. Location of thirteen Pine Barrens treefrog ponds in the Mullica River basin of the New Jersey Pinelands.

1998 growing season. The herbaceous-plant inventory was limited to the area within the pond shoreline. The woody-plant inventory included those found throughout the pond and within a two-meter band surrounding each pond. Taxonomic nomenclature follows Gleason and Cronquist (1991). Boundaries of tree-, shrub-, herbaceous, and *Sphagnum*-dominated patches within the margins of the 13 study ponds were delineated using the GPS. Each patch represented an area of homogenous plant cover ≥ 1 m². Tree and shrub patches were delineated in March and herbaceous patches were delineated in June. Herbaceous-patch boundaries were reviewed in September and, where necessary, new boundaries were delineated to reflect major changes in plant cover that occurred since the June survey. The Braun-Blanquet cover scale (Mueller-Dombois and Ellenberg 1974) was used to estimate cover of plant species within each patch. For each patch, only species with cover greater than 5% were tallied. All cover estimates were made in June and September. The large number of initial detailed-cover types was reduced by classifying and merging patches based on the dominant species present. For cases with more than one dominant species, trees species were considered before shrub species and shrub species were considered before herbaceous species. *Sphagnum* cover was always subordinate to vascular-species cover. Based on the dominant species present, fourteen cover types were derived. ArcView software and the GPS data were used to create cover-type maps and calculate pond and cover-type area for each pond.

Anuran Composition

Surveys of vocalizing, adult anurans were conducted from 1996-1999. Each year, nighttime (dusk to midnight) surveys were conducted at least once per month during the breeding season (late February/early March through June). Survey dates were chosen based on species-specific breeding phenology and weather conditions suitable for anuran vocalizations. The number of vocalizing adults for each species was estimated during a 5-minute period using a ranking scheme where 0 = none, 1 = 1, 2 = 2-5, 3 = 6-10, and 4 = >10 calling individuals.

Data Presentation

To facilitate comparisons between ponds, data on vegetation and anuran composition and environmental characterisitics of the ponds are presented in summary tables. The complete list of herbaceous and woody plant species found at the 13 ponds is presented in Table 2. Maximum calling ranks for anuran species and the number of years a species was heard at a pond are found in Table 3. Pond-water quality, pond morphometry, and vegetation cover-type data are presented in Table 4. Each pond description includes a map of the distribution, configuration, and percent cover of vegetation cover types, lists of the plant and anuran species present, a figure of pond bathymetry showing March 1998 hydrologic conditions, a hydrograph depicting monthly mean water depth for the 1996-1998 growing seasons, and water-quality and pond-morphometry summary statistics. The initial, detailed-cover estimates and the final cover-type designations for all pond-vegetation patches are listed in the Appendix.

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Acknowledgments

Joseph Arsenault and Ted Gordon identified several plant specimens. Dennis Gray performed total organic carbon analyses. This work was supported in part by the U.S. Environmental Protection Agency (Wetlands Protection-State Development Grant Program, Grant no. CD992051-01-0). Additional funds were provided by the National Park Service and the New Jersey Pinelands Commission. The views and conclusions contained in this document are those of the authors and should not be interpreted as representing the opinions or policies of the U. S. Government. Mention of trade names or commercial products does not constitute their endorsement by the U. S. Government.

Table 1. Selected Pine Barrens treefrog ponds in the New Jersey Pinelands. Latitude, longitude, and USGS 7.5 minute topographic quadrangle names are given in parentheses.

Site Name and Location
Albertson Pond
Hammonton Twp., Atlantic Co. (lat 39°41'10.44", long 74°44'22.75", Atsion quad). Eastern side of Route 206, between Great Swamp Branch and Albertson Brook.
Chew Pond
Waterford Twp., Camden Co. (lat 39°42'22.88", long 74°46'52.74", Hammonton quad). Northern side of Chew Road (Route 536), between Sandy Causeway Road and railroad.
Furnace Pond
Shamong Twp., Burlington Co. (lat 39°46'07.15", long 74°40'57.67", Indian Mills quad). Northern side of Hampton Road, near Hampton Furnace.
Gravel Pond
Shamong Twp., Burlington Co. (lat 39°44'49.13", long 74°43'15.80", Atsion quad). Northern side of Hampton Road, near excavated area between Route 206 and Stokes Road (Route 541).
Hampton Pond
Shamong Twp., Burlington Co. (lat 39°45'56.83', long 74°41'16.29", Indian Mills quad). Southern side of Hampton Road, between Deep Run tributary and Hampton Furnace.
Hays Pond
Waterford Twp., Camden Co. (lat 39°45'17.65", long 74°51'06.62", Medford Lakes quad). Southern side of sand road on southern side of Hays Mill Creek, west of Tremont Avenue.
Mullica Pond
Waterford Twp., Camden Co. (lat 39°45'39.37", long 74°48'09.27", Medford Lakes quad). South of Old Jackson-Atsion Road and west of the Mullica River.
Price Pond
Waterford Twp., Camden Co. (lat 39°42'51 74", long 74°49'20.20", Hammonton quad). South of Chew Road (Route 536), between Pestleton Road and Clark Branch.
Roberts Pond
Tabernacle Twp., Burlington Co. (lat 39°47'16.86', long 74°39'21.64", Indian Mills quad). Northern side of middle sand road between Skit and Roberts (Tom Roberts) Branches, upstream from Carranza Road.
Sandy Pond
Waterford Twp., Camden Co. (lat 39°42'35.35", long 74°46'36.80", Hammonton quad). Western side of Sandy Causeway Road, between Chew Road (Route 536) and railroad.
Skit Pond
Tabernacle Twp., Burlington Co. (lat 39°47'51.53", long 74°36'51.42", Chatsworth quad). South of Tabernacle-Chatsworth Road (Route 532), north of railroad, east of Skit Branch.
Sleeper Pond
Waterford Twp., Camden Co. (lat 39°43'16.89", long 74°46'09.29", Hammonton quad). North of Fleming Pike, east of Burnt House Road, south of Sleeper Branch.
Sphagnum Pond
Shamong Twp., Burlington Co. (lat 39°46'22.15", long 74°40'20.70", Indian Mills quad). Upstream from Hampton Road, adjacent to dike, on eastern side of Skit Branch.

Table 2. Plant species present (1998) at selected Pine Barrens treefrog ponds in the New Jersey Pinelands. Filled circles indicate a species was present at a pond. Nomenclature follows Gleason and Cronquist (1991) and Anderson (1989) for scientific and common names, respectively.

Scientific Name	Common Name	Ponds												
		Albertson	Chew	Furnace	Gravel	Hampton	Hays	Mullica	Price	Roberts	Sandy	Skit	Sleeper	Sphagnum
Herbaceous plants:														
Andropogon virginicus var. abbreviatus	bushy beard-grass	-	•	-	-	-	-	-	-	-	-	-	-	-
Aristida longespica	slender three-awn	-	•	-	-	-	-	-	-	-	-	-	-	-
Carex striata	Walter's sedge	•	-	-	•	-	-	•	•	-	•	•	•	-
Cladium mariscoides	twig-rush	-	-	-	-	-	-	-	-	-	-	-	-	•
Cyperus dentatus	toothed cyperus	-	•	-	-	-	-	-	-	-	-	-	-	•
Cyperus retrorsus	Pine Barrens cyperus	-	-	-	-	-	-	-	-	•	-	-	-	-
Decodon verticillatus	swamp loosestrife	-	-	-	•	-	•	•	-	-	-	-	-	-
Drosera filiformis	thread-leaved sundew	-	•	-	-	-	-	-	-	-	-	-	-	-
Drosera intermedia	spatulate-leaved sundew	•	•	•	-	•	-	-	-	•	-	•	-	•
Drosera rotundifolia	round-leaved sundew	-	-	-	-	-	-	-	-	•	-	-	-	-
Dulichium arundinaceum	Dulichium or three-way sedge	•	-	-	•	-	•	-	•	-	-	•	•	•
Eleocharis flavescens var. olivacea	green spike-rush	-	-	-	•	-	•	•	•	•	-	-	•	-
Eleocharis microcarpa	small-fruited spike-rush	-	•	•	-	•	-	•	•	-	-	-	-	-
Eleocharis robbinsii	Robbin's spike-rush	-	-	-	-	-	-	-	-	-	-	-	-	•
Eleocharis tenuis	slender spike-rush	-	-	•	-	•	-	-	-	-	-	-	-	-
Eleocharis tricostata	three-ribbed spike-rush	-	•	-	-	-	•	-	-	-	-	-	-	-
Eleocharis tuberculosa	tubercled spike-grass	-	-	-	-	-	-	-	-	-	-	-	-	•
Erianthus giganteus	plume-grass	-	-	-	-	•	-	-	-	-	-	-	-	-
Euthamia tenuifolia	slender-leaved goldenrod	-	•	-	-	-	-	-	-	-	-	-	-	-
Gratiola aurea	golden hedge hyssop	-	•	-	-	-	-	-	-	-	-	-	-	-
Hypericum canadense	Canada Saint John's-wort	-	•	-	-	-	-	-	-	-	-	-	-	-
Hypericum mutilum	dwarf Saint John's-wort	-	•	-	-	-	-	-	-	-	-	-	-	-
Juncus pelocarpus	brown-fruited rush	-	•	•	-	•	-	-	•	-	-	-	•	•
Lachnanthes caroliniana	redroot	-	-	-	-	-	-	-	-	-	•	-	-	•
Lycopodium appressum	southern bog clubmoss	-	•	-	-	•	-	-	-	-	-	-	-	-
Muhlenbergia torreyana	Torrey's dropseed	-	•	-	-	-	-	-	-	-	-	-	-	-
Nuphar variegata	bullhead lily	-	-	-	-	-	-	-	-	-	-	-	-	•
Nymphaea odorata	white water lily	-	-	-	-	-	-	-	-	-	-	-	•	•
Orontium aquaticum	golden club	-	-	-	-	-	-	-	-	-	-	-	-	•
Osmunda regalis	royal fern	-	•	-	-	-	-	-	-	-	-	-	-	-
Panicum longifolium	long-leaved panic-grass	-	•	•	-	-	-	-	•	-	-	-	-	-
Panicum spretum	Eaton's panic-grass	-	•	•	-	-	-	-	-	-	-	-	-	-
Panicum verrucosum	warty panic-grass	•	•	•	-	•	•	•	•	•	-	•	•	•
Panicum virgatum	switchgrass	-	-	-	-	•	-	-	-	-	-	-	-	-
Peltandra virginica	arrow arum	-	-	-	-	-	-	-	-	-	-	-	-	•
Proserpinaca pectinata	cut-leaved mermaid-weed	•	•	•	-	•	-	-	-	-	-	-	-	-
Rhexia virginica	Virginia meadow beauty	•	•	-	-	•	-	-	•	•	-	-	-	•
Rhynchospora alba	white beaked-rush	-	-	-	•	-	-	-	-	-	-	•	-	-
Rhynchospora capitellata	small-headed beaked-rush	-	•	-	-	-	-	-	-	-	-	-	-	-
Rhynchospora chalarocephala	loose-headed beaked-rush	-	•	-	-	-	-	-	-	-	-	-	-	-
Sarracenia purpurea	pitcher plant	-	-	-	•	-	-	-	-	-	-	-	-	-

Scientific Name	Common Name	Ponds												
		Alberson	Chew	Furnace	Gravel	Hampton	Hays	Mullica	Price	Roberts	Sandy	Skit	Sleeper	Sphagnum
Scirpus cyperinus	wool-grass	-	-	-	-	•	-	-	•	-	-	-	-	-
Scirpus subterminalis	water club-rush	-	-	-	-	-	-	-	-	-	-	-	-	•
Triadenum virginicum	marsh Saint John's-wort	-	-	•	-	-	-	•	•	-	-	-	-	•
Utricularia fibrosa	fibrous bladderwort	-	-	-	•	-	-	-	•	-	•	-	-	-
Utricularia geminiscapa	hidden-fruited bladderwort	•	•	-	-	-	-	-	•	-	-	-	•	-
Utricularia purpurea	purple bladderwort	-	-	-	-	-	-	-	-	-	-	-	-	•
Utricularia sp.	bladderwort species	-	-	•	-	-	•	-	-	-	-	-	-	-
Viola lanceolata	lance-leaved violet	-	•	-	-	-	-	-	-	-	-	-	-	-
Woodwardia virginica	Virginia chain fern	•	-	-	•	-	-	•	-	•	•	-	•	-
Xyris difformis	yellow-eyed grass	-	•	•	-	-	-	-	-	-	-	-	•	•
Xyris smalliana	Small's yellow-eyed grass	-	-	-	-	•	-	-	-	-	-	-	-	-
Woody plants:														
Acer rubrum	red maple	•	•	•	•	•	•	•	•	•	•	•	•	-
Amelanchier canadensis	oblongleaf juneberry	-	•	-	•	-	-	-	-	-	-	-	-	-
Aronia arbutifolia	red chokeberry	•	•	-	•	•	•	-	-	-	•	•	-	-
Betula populifolia	gray birch	-	•	-	•	-	-	-	-	-	-	-	-	-
Cephalanthus occidentalis	buttonbush	-	-	-	-	-	-	-	•	-	-	-	-	-
Chamaecyparis thyoides	Atlantic white cedar	-	-	-	•	-	-	-	-	•	•	-	-	•
Chamaedaphne calyculata	leatherleaf	•	•	•	•	•	•	•	•	•	•	-	•	•
Clethra alnifolia	sweet pepperbush	•	-	•	-	-	-	-	•	-	•	-	•	-
Comptonia peregrina	sweet fern	-	•	-	-	-	-	-	-	-	-	-	-	-
Eubotrys racemosa	fetterbush	•	•	•	•	•	•	-	•	•	•	•	•	•
Gaultheria procumbens	wintergreen	-	•	•	-	•	-	-	-	-	-	-	-	-
Gaylussacia baccata	black huckleberry	-	•	•	-	•	-	-	-	-	-	-	-	-
Gaylussacia dumosa	dwarf huckleberry	-	-	-	-	-	-	-	-	-	-	-	-	•
Gaylussacia frondosa	dangleberry	•	-	•	•	•	-	•	-	-	-	•	•	•
Hudsonia ericoides	golden heather	-	-	-	-	•	-	-	-	-	-	-	-	-
Ilex glabra	inkberry	-	•	•	-	•	-	-	-	-	-	-	•	-
Ilex opaca	American holly	-	-	•	•	-	-	-	-	-	-	-	-	-
Kalmia angustifolia	sheep laurel	•	•	•	•	•	-	•	•	•	•	•	•	•
Kalmia latifolia	mountain laurel	-	•	-	-	-	-	-	-	-	-	-	-	-
Leiophyllum buxifolium	sand myrtle	-	•	•	-	•	-	-	-	-	-	-	-	-
Lyonia mariana	staggerbush	•	•	•	-	•	•	•	•	-	-	-	•	-
Magnolia virginiana	sweet bay	-	-	-	•	-	-	-	-	-	-	-	-	-
Myrica pensylvanica	bayberry	-	-	•	-	•	-	-	-	-	-	-	-	-
Nyssa sylvatica	sour gum	•	•	•	-	•	•	-	-	-	-	-	•	-
Pinus rigida	pitch pine	•	•	•	•	•	•	•	•	•	•	•	•	-
Quercus ilicifolia	scrub oak	-	•	•	-	•	-	-	-	-	-	-	-	-
Quercus marilandica	black-jack oak	-	-	•	-	•	-	-	-	-	-	-	-	-
Rhododendron viscosum	swamp azalea	-	-	•	•	-	-	-	-	-	-	-	-	-
Sassafras albidum	sassafras	-	•	-	-	-	-	-	-	-	-	-	-	-
Smilax glauca	glaucous greenbrier	-	-	•	-	•	-	-	-	•	-	-	•	-
Smilax rotundifolia	common greenbrier	•	•	•	-	-	•	•	•	-	•	-	•	•
Toxicodendron radicans	poison ivy	-	-	-	-	-	-	•	-	-	-	-	-	-
Vaccinium corymbosum	highbush blueberry	•	•	•	•	•	•	•	•	•	•	•	•	•
Vaccinium macrocarpon	large cranberry	-	•	•	•	•	-	-	-	-	•	-	-	•

Table 3. Anuran species present (1996-1999) at selected Pine Barrens treefrog ponds in the New Jersey Pinelands. Maximum calling ranks for the period of record are listed. Calling ranks are as follows: 1 = 1, 2 = 2-5, 3 = 6-10, and 4 = >10 calling individuals. The number of years (maximum of four) that a species was heard at a pond is given in parentheses. Nomenclature follows Conant and Collins (1998).

	Ponds												
Scientific Name/Common Name	Albertson	Chew	Furnace	Gravel	Hampton	Hays	Mullica	Price	Roberts	Sandy	Skit	Sleeper	Sphagnum
Acris crepitans crepitans northern cricket frog	-	-	-	-	-	1(1)	-	-	-	-	-	-	-
Bufo woodhousii fowleri Fowler's toad	-	1(1)	1(1)	-	1(1)	-	4(2)	1(1)	-	-	2(1)	-	-
Hyla andersonii Pine Barrens treefrog	2(4)	4(4)	3(3)	2(4)	4(4)	4(4)	4(4)	3(4)	3(3)	4(4)	4(3)	4(4)	4(4)
Hyla versicolor northern gray treefrog	-	2(2)	-	-	-	-	2(2)	1(2)	-	-	-	1(1)	-
Pseudacris crucifer crucifer northern spring peeper	3(1)	4(4)	4(4)	2(3)	4(4)	4(4)	4(4)	4(4)	2(2)	4(4)	4(4)	4(4)	4(4)
Pseudacris triseriata kalmi New Jersey chorus frog	-	4(4)	-	-	-	2(2)	-	-	-	2(1)	-	2(2)	-
Rana catesbeiana bullfrog	-	-	-	-	-	-	-	1(1)	-	-	-	-	-
Rana clamitans melanota green frog	1(1)	2(4)	2(1)	2(3)	2(3)	2(3)	1(2)	4(3)	1(1)	3(2)	2(1)	2(3)	2(4)
Rana sylvatica wood frog	4(1)	2(2)	2(1)	-	1(1)	2(1)	2(2)	4(3)	-	2(2)	-	1(1)	-
Rana utricularia southern leopard frog	4(2)	2(4)	2(3)	3(3)	3(4)	2(4)	2(3)	3(4)	-	4(4)	2(3)	4(4)	2(4)
Rana virgatipes carpenter frog	-	-	1(1)	3(4)	1(4)	-	1(1)	-	-	3(4)	1(3)	1(1)	2(4)
Total anuran species	5	8	7	5	7	7	8	8	3	7	6	8	5

Table 4. Attributes of selected Pine Barrens treefrog ponds in the New Jersey Pinelands. Refer to Methods for explanation of variables.

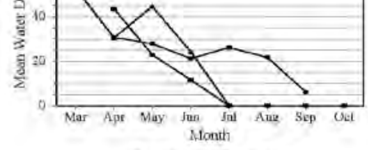
Attribute	Albertson	Chew	Furnace	Gravel	Hampton	Hays	Mullica	Price	Roberts	Sandy	Skit	Sleeper	Sphagnum
Water Quality (March-June 1998)													
median pH	4.0	4.5	4.4	3.9	4.6	3.9	3.8	4.0	3.8	3.9	3.8	4.0	4.3
med. specific conductance (µS/cm)	59	44	28	63	23	63	69	63	83	75	76	48	33
med. total organic carbon (mg/L)	34	8	10	38	11	36	31	27	41	25	53	30	4
Morphometry (March 1998)													
total pond area (m^2)	820	2148	153	2638	420	1536	5119	2426	412	7808	2973	3266	336
open water area (m^2)	387	2148	153	1574	420	616	2420	1776	168	5409	1166	2159	336
mean water depth (cm)	53	63	65	31	51	54	30	57	30	37	33	46	56
maximum water depth (cm)	66	124	81	56	79	94	55	115	55	55	62	75	88
mean shore slope (rise/run)	0.08	0.31	0.21	0.08	0.26	0.09	0.04	0.05	0.04	0.01	0.06	0.08	0.21
Vegetation (1998)													
herbaceous species richness	8	25	11	8	12	6	7	12	7	4	5	9	18
woody species richness	12	21	22	15	20	9	9	10	8	11	7	13	9
number of vegetation patches	21	4	5	19	8	11	39	32	5	14	14	13	9
number of vegetation cover-types	4	2	3	7	3	5	7	10	4	5	4	5	3
percentage of pond area of the following cover types													
Acer rubrum	38.3	-	-	-	-	-	1.3	12.0	-	0.8	-	4.8	-
Aquatic vegetation	-	-	-	-	-	-	-	-	-	-	-	-	69.2
Bare substrate	-	-	-	3.3	-	-	-	24.9	5.0	-	-	-	21.1
Carex striata	-	-	-	28.0	-	-	1.4	7.3	-	65.7	4.8	45.4	-
Chamaedaphne calyculata	21.4	-	-	45.5	-	4.6	48.6	33.8	1.1	35.0	-	30.2	-
Chamaecyparis thyoides	-	-	-	-	-	-	-	-	-	0.3	-	-	-
Decodon verticillatus	-	-	-	0.1	-	3.8	3.3	2.7	-	-	-	-	-
Dulichium arundinaceum	2.4	-	-	2.0		-	-	3.1	-		-	-	-
Emergent herb	-	96.8	62.6	-	84.5	-	-	-	-	-	-	17.0	-
Panicum verrucosum		-	-	-	-	8.5	-	8.0	-	-	9.6	-	-
Panicum longifolium/*P. virgatum*	-	3.2	4.3	-	8.9	-	-	2.5	-	-	-	-	-
Pinus rigida	-	-	-	0.2	-	-	3.1	-	-	-	-	-	-
Sphagnum sp.	37.9	-	35.1	20.9	6.6	27.8	40.5	5.7	34.7	-	24.6	2.6	9.7
Vaccinium corymbosum	-	-	-	-	-	55.4	0.8	0.1	59.2	0.1	60.9	-	-

POND DESCRIPTIONS

Albertson pond is a natural depression located between Great Swamp Branch and Albertson Brook, east of Route 206, in Hammonton Township, Atlantic County (Latitude 39°41'10.44" Longitude 74°44'22.75"). The surrounding vegetation communities consist of pine-oak upland and dry to wet pine lowlands. Vegetation toward the perimeter of the pond consists of patches dominated by leatherleaf or red maple with a leatherleaf understory. The open water portion of the pond supports floating *Sphagnum* species. Substrate exposed during the draw-down period of late summer supports patches of three-way sedge. Low numbers of Pine Barrens treefrogs are consistently detected at Albertson pond. Large choruses of wood frogs and leopard frogs are occasionally heard.

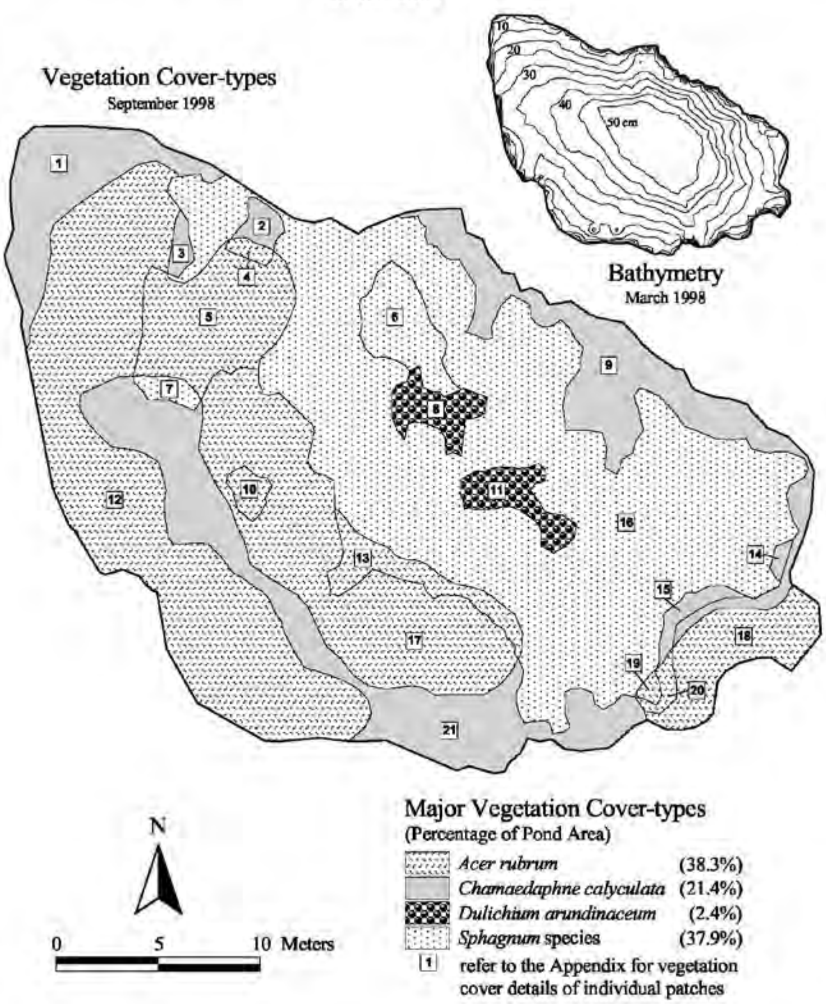
Plant species present in 1998
Herbaceous plants:
Carex striata
Drosera intermedia
Dulichium arundinaceum
Panicum verrucosum
Proserpinaca pectinata
Rhexia virginica
Utricularia geminiscapa
Woodwardia virginica
Woody plants:
Acer rubrum
Aronia arbutifolia
Chamaedaphne calyculata
Clethra alnifolia
Eubotrys racemosa
Gaylussacia frondosa
Kalmia angustifolia
Lyonia mariana
Nyssa sylvatica
Pinus rigida
Smilax rotundifolia
Vaccinium corymbosum

Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.0
med. specific conductance (μS/cm)	59
med. total organic carbon (mg/L)	34
Morphometry (March 1998)	
total pond area (m^2)	820
open water area (m^2)	387
mean water depth (cm)	53
maximum water depth (cm)	66
mean shore slope (rise/run)	0.08



Anuran species present in 1996-1999.	
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog

Albertson

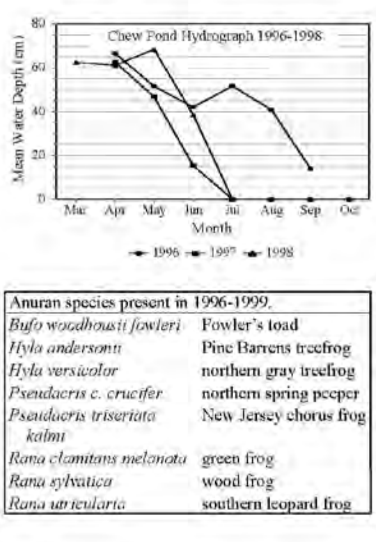


Vegetation Cover-types
September 1998
Bathymetry
March 1998
10
20
30
40
50 cm
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
N
0
5
10 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Acer rubrum (38.3%)
Chamaedaphne calyculata (21.4%)
Dulichium arundinaceum (2.4%)
Sphagnum species (37.9%)
refer to the Appendix for vegetation cover details of individual patches

Chew pond is an excavated basin located on the northern side of Chew Road, between Sandy Causeway Road and a railroad, in Waterford Township, Camden County (Latitude 39°42'22.88" Longitude 74°46'52.74"). The surrounding vegetation consists of pine-scrub oak upland. Chew pond lacks a perimeter shrub zone and exhibits steep shore slopes. This pond supports the highest plant-species richness of the 13 study ponds. Chew Pond supports high anuran-species richness, with Pine Barrens treefrogs, spring peepers, chorus frogs, wood frogs, and leopard frogs regularly detected.

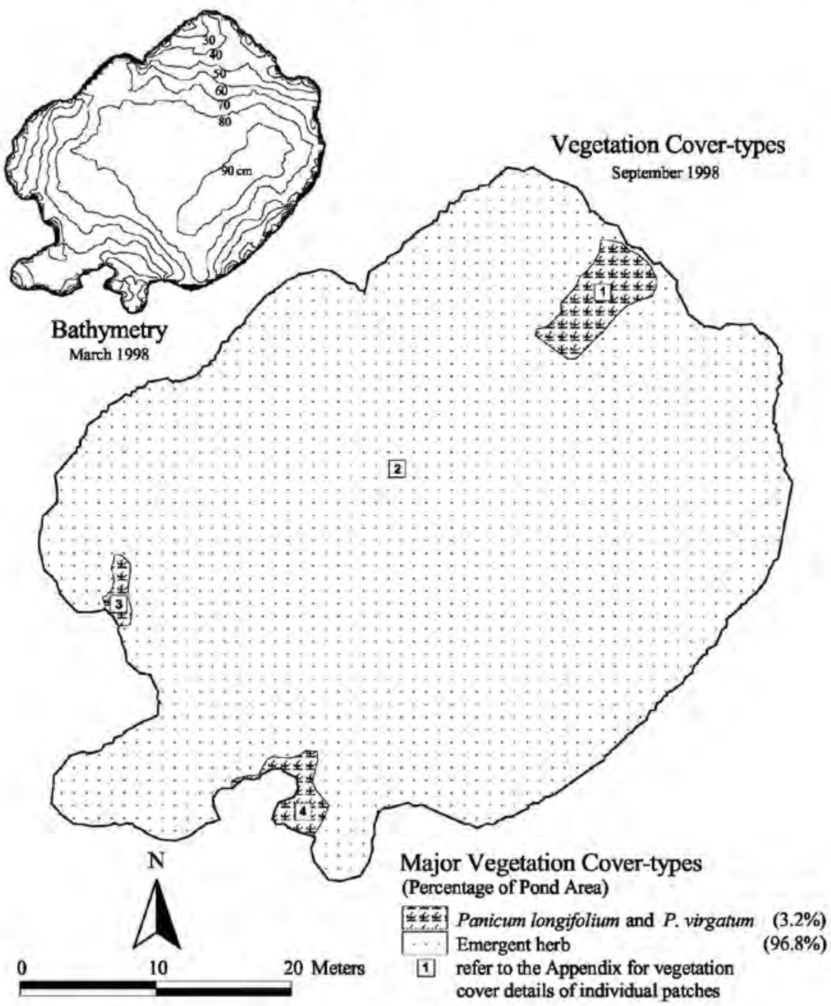
Plant species present in 1998
Herbaceous plants:
Andropogon virginicus var. abbreviatus
Aristida longespica
Cyperus dentatus
Drosera filiformis
Drosera intermedia
Eleocharis microcarpa
Eleocharis tricostata
Euthamia tenuifolia
Gratiola aurea
Hypericum canadense
Hypericum mutilum
Juncus pelocarpus
Lycopodium appressum
Muhlenbergia torreyana
Osmunda regalis
Panicum longifolium
Panicum spretum
Panicum verrucosum
Proserpinaca pectinata
Rhexia virginica
Rhynchospora capitellata
Rhynchospora chalarocephala
Utricularia geminiscapa
Viola lanceolata
Xyris difformis
Woody plants:
Acer rubrum
Amelanchier canadensis
Aronia arbutifolia
Betula populifolia
Chamaedaphne calyculata
Comptonia peregrina
Eubotrys racemosa
Gaultheria procumbens
Gaylussacia baccata
Ilex glabra
Kalmia angustifolia
Kalmia latifolia
Leiophyllum buxifolium
Lyonia mariana
Nyssa sylvatica
Pinus rigida
Quercus ilicifolia
Sassafras albidum
Smilax rotundifolia
Vaccinium corymbosum
Vaccinium macrocarpon

Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.5
med. specific conductance (µS/cm)	44
med. total organic carbon (mg/L)	8
Morphometry (March 1998)	
total pond area (m^2)	2148
open water area (m^2)	2148
mean water depth (cm)	63
maximum water depth (cm)	124
mean shore slope (rise/run)	0.31



Anuran species present in 1996-1999.	
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Hyla versicolor	northern gray treefrog
Pseudacris c. crucifer	northern spring peeper
Pseudacris triseriata kalmi	New Jersey chorus frog
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog

Chew

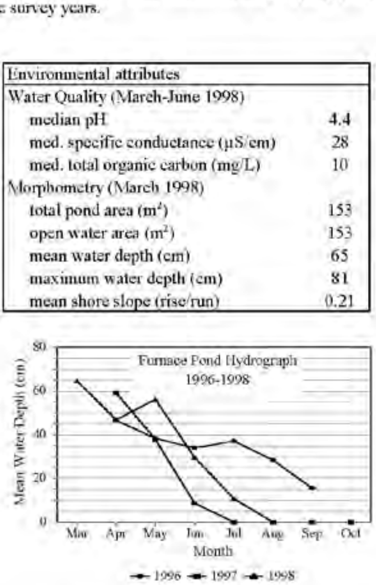


30
40
50
60
70
80
90 cm
Bathymetry
March 1998
Vegetation Cover-types
September 1998
1
2
3
4
N
0
10
20 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Panicum longifolium and P. virgatum (3.2%)
Emergent herb (96.8%)
refer to the Appendix for vegetation cover details of individual patches

Furnace pond is a small borrow pit located on the northern side of Hampton Road, near Hampton Furnace, in Shamong Township, Burlington County (Latitude 39°46'07.15" Longitude 74°40'57.67"). The pond is situated in a dry to wet pitch pine lowland. Scattered emergent, herbaceous plants dominate the flora. The cut banks and lack of perimeter shrub zone are typical features of an excavated basin. Pine Barrens treefrogs, spring peepers, and leopard frogs have been detected in three or more survey years.

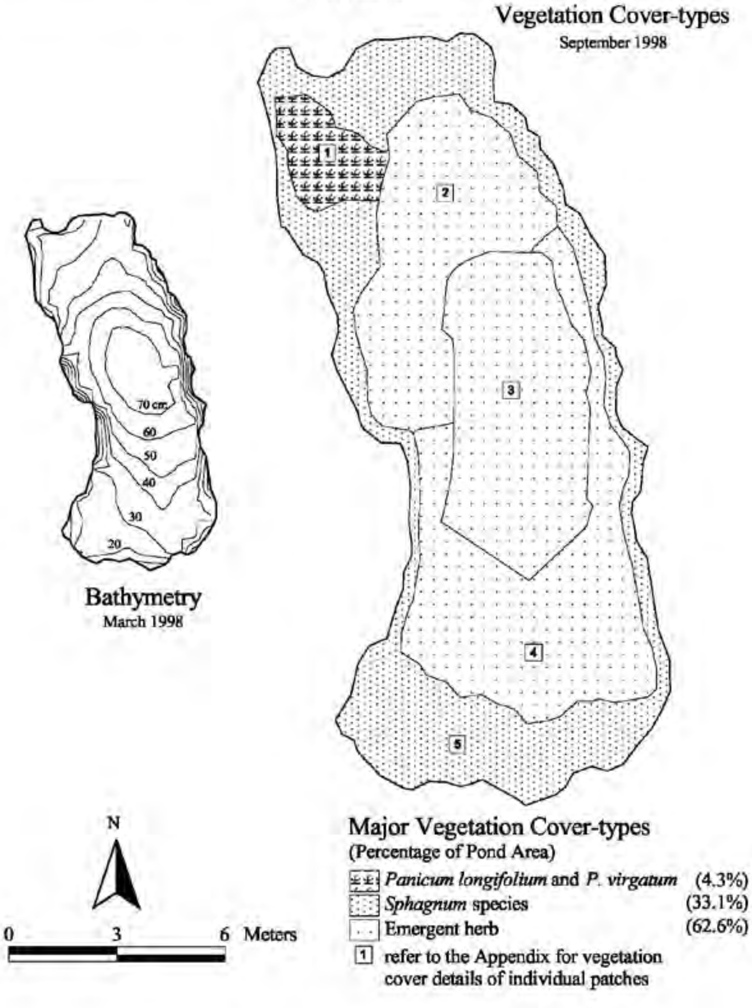
Plant species present in 1998
Herbaceous plants:
Drosera intermedia
Eleocharis microcarpa
Eleocharis tenuis
Juncus pelocarpus
Panicum longifolium
Panicum spretum
Panicum verrucosum
Proserpinaca pectinata
Triadenum virginicum
Utricularia sp.
Xyris difformis
Woody plants:
Acer rubrum
Chamaedaphne calyculata
Clethra alnifolia
Eubotrys racemosa
Gaultheria procumbens
Gaylussacia baccata
Gaylussacia frondosa
Ilex glabra
Ilex opaca
Kalmia angustifolia
Leiophyllum buxifolium
Lyonia mariana
Myrica pensylvanica
Nyssa sylvatica
Pinus rigida
Quercus ilicifolia
Quercus marilandica
Rhododendron viscosum
Smilax glauca
Smilax rotundifolia
Vaccinium corymbosum
Vaccinium macrocarpon

Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.4
med. specific conductance (µS/cm)	28
med. total organic carbon (mg/L)	10
Morphometry (March 1998)	
total pond area (m^2)	153
open water area (m^2)	153
mean water depth (cm)	65
maximum water depth (cm)	81
mean shore slope (rise/run)	0.21



Anuran species present in 1996-1999.	
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog

Furnace

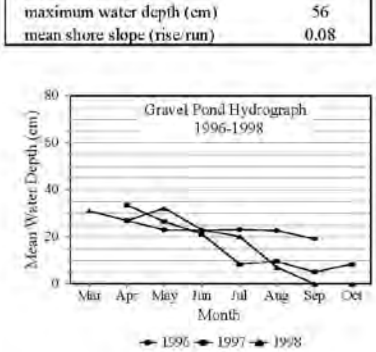


70 cm
60
50
40
30
20
Bathymetry
March 1998
Vegetation Cover-types
September 1998
1
2
3
4
5
N
0
3
6 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Panicum longifolium and P. virgatum (4.3%)
Sphagnum species (33.1%)
Emergent herb (62.6%)
1 refer to the Appendix for vegetation cover details of individual patches

Gravel pond is a natural depression located on the northern side of Hampton Road, between Route 206 and Stokes Road, in Shamong Township, Burlington County (Latitude 39°44'49.13" Longitude 74°43'15.80"). Gravel Pond is contained within a larger, circular wetland dominated by shrubs and scrub red maple. A portion of the pond is bordered by a pine-hardwood swamp. Leatherleaf dominates the outer vegetation zone and Walter's sedge dominates much of the rest of the pond. Each of the five anuran species listed below have been detected in at least three survey years, though not in large numbers.

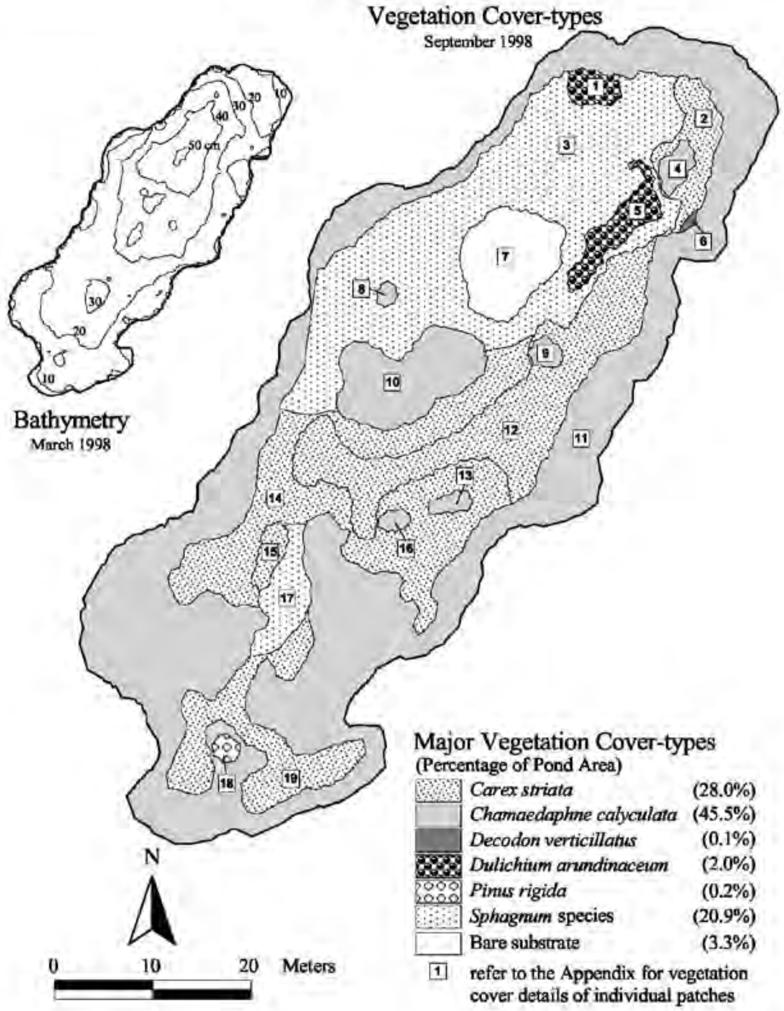
Plant species present in 1998
Herbaceous plants:
Carex striata
Decodon verticillatus
Dulichium arundinaceum
Eleocharis flavescens var. olivacea
Rhynchospora alba
Sarracenia purpurea
Utricularia fibrosa
Woodwardia virginica
Woody plants:
Acer rubrum
Amelanchier canadensis
Aronia arbutifolia
Betula populifolia
Chamaecyparis thyoides
Chamaedaphne calyculata
Eubotrys racemosa
Gaylussacia frondosa
Ilex opaca
Kalmia angustifolia
Magnolia virginiana
Pinus rigida
Rhododendron viscosum
Vaccinium corymbosum
Vaccinium macrocarpon

Environmental attributes	
Water Quality (March-June 1998)	
median pH	3.9
med. specific conductance	63
med. total organic carbon (mg/L)	38
Morphometry (March 1998)	
total pond area (m^2)	2638
open water area (m^2)	1574
mean water depth (cm)	31
maximum water depth (cm)	56
mean shore slope (rise/run)	0.08



Anuran species present in 1996-1999.	
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog

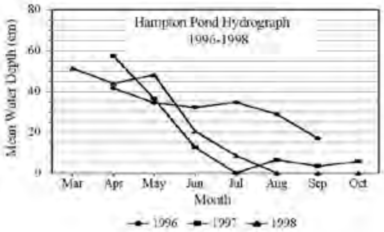
Gravel


Vegetation Cover-types
September 1998
Bathymetry
March 1998
50 cm
N
0 10 20 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Carex striata (28.0%)
Chamaedaphne calyculata (45.5%)
Decodon verticillatus (0.1%)
Dulichium arundinaceum (2.0%)
Pinus rigida (0.2%)
Sphagnum species (20.9%)
Bare substrate (3.3%)
1 refer to the Appendix for vegetation cover details of individual patches

Hampton pond is a small borrow pit located on the southern side of Hampton Road, between Deep Run tributary and Hampton Furnace, in Shamong Township, Burlington County (Latitude 39°45'56.83" Longitude 74°41'16.29"). The surrounding vegetation consists of dry to wet pine lowlands. This excavated basin has steep shore slopes and lacks a perimeter shrub zone. Emergent and wetland herbs dominate the plant community. Pine Barrens treefrogs, spring peepers, and leopard frogs are consistently heard at this pond.

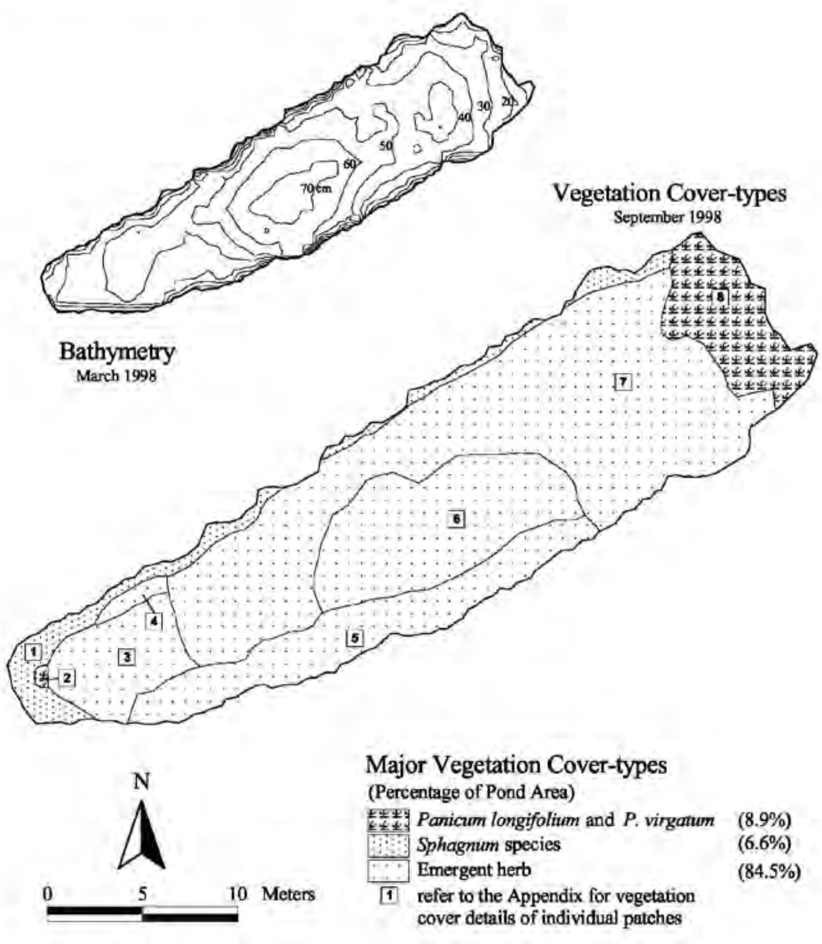
Plant species present in 1998
Herbaceous plants:
Drosera intermedia
Eleocharis microcarpa
Eleocharis tenuis
Erianthus giganteus
Juncus pelocarpus
Lycopodium appressum
Panicum verrucosum
Panicum virgatum
Proserpinaca pectinata
Rhexia virginica
Scirpus cyperinus
Xyris smalliana
Woody plants:
Acer rubrum
Aronia arbutifolia
Chamaedaphne calyculata
Eubotrys racemosa
Gaultheria procumbens
Gaylussacia baccata
Gaylussacia frondosa
Hudsonia ericoides
Ilex glabra
Kalmia angustifolia
Leiophyllum buxifolium
Lyonia mariana
Myrica pensylvanica
Nyssa sylvatica
Pinus rigida
Quercus ilicifolia
Quercus marilandica
Smilax glauca
Vaccinium corymbosum
Vaccinium macrocarpon

Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.6
med. specific conductance (µS/cm)	23
med. total organic carbon (mg/L)	11
Morphometry (March 1998)	
total pond area (m^2)	420
open water area (m^2)	420
mean water depth (cm)	51
maximum water depth (cm)	79
mean shore slope (rise/run)	0.26



Anuran species present in 1996-1999.	
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog

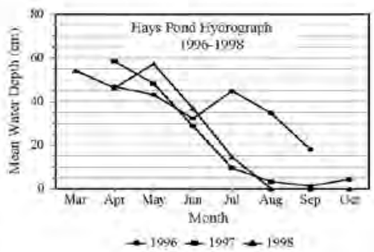
Hampton


70 cm
60
50
40
30
20
Bathymetry
March 1998
Vegetation Cover-types
September 1998
1
2
3
4
5
6
7
8
N
0
5
10 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Panicum longifolium and P. virgatum (8.9%)
Sphagnum species (6.6%)
Emergent herb (84.5%)
1 refer to the Appendix for vegetation cover details of individual patches

Hays pond is a natural depression located near a sand road on the southern side of Hays Mill Creek, west of Tremont Avenue, in Waterford Township, Camden County (Latitude 39°45'17.65" Longitude 74°51'06.62"). The pond is surrounded by pine-oak upland and wet pine lowland. A broad shrub zone dominated by highbush blueberry is present along the perimeter. Substrate exposed during the draw-down period of late summer supports significant areas of warty panic-grass. Pine Barrens treefrogs, spring peepers, and leopard frogs are regularly detected here. Hays pond is the only site where cricket frogs were encountered.

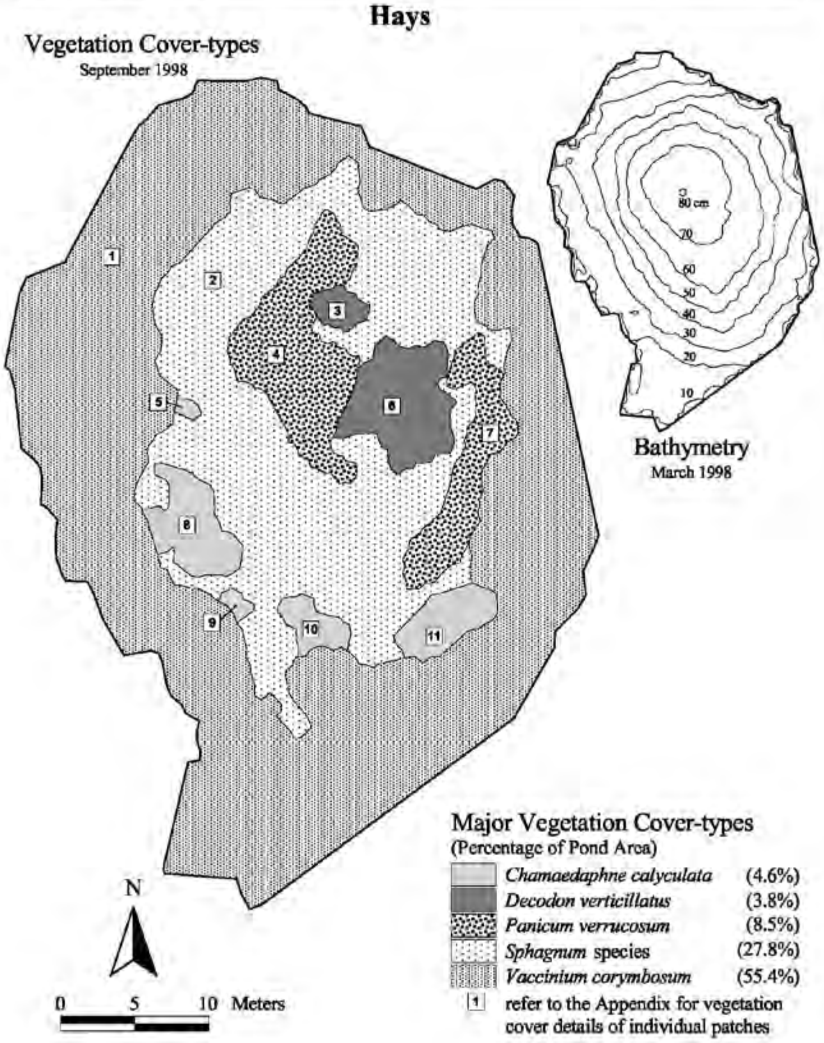
Plant species present in 1998
Herbaceous plants:
Decodon verticillatus
Dulichium arundinaceum
Eleocharis flavescens var. olivacea
Eleocharis tricostata
Panicum verrucosum
Utricularia sp.
Woody plants:
Acer rubrum
Aronia arbutifolia
Chamaedaphne calyculata
Eubotrys racemosa
Lyonia mariana
Nyssa sylvatica
Pinus rigida
Smilax rotundifolia
Vaccinium corymbosum

Environmental attributes	
Water Quality (March-June 1998)	
median pH	3.9
med. specific conductance (μS/cm)	63
med. total organic carbon (mg/L)	36
Morphometry (March 1998)	
total pond area (m^2)	1536
open water area (m^2)	616
mean water depth (cm)	54
maximum water depth (cm)	94
mean shore slope (rise/run)	0.09



Anuran species present in 1996-1999.	
Acris crepitans crepitans	northern cricket frog
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Pseudacris triseriata kalmi	New Jersey chorus frog
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog

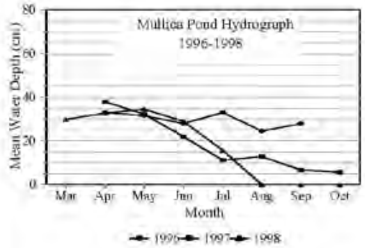
Hays


Vegetation Cover-types
September 1998
1
2
3
4
5
6
7
8
9
10
11
80 cm
70
60
50
40
30
20
10
Bathymetry
March 1998
Major Vegetation Cover-types
(Percentage of Pond Area)
Chamaedaphne calyculata (4.6%)
Decodon verticillatus (3.8%)
Panicum verrucosum (8.5%)
Sphagnum species (27.8%)
Vaccinium corymbosum (55.4%)
1 refer to the Appendix for vegetation cover details of individual patches
N
0 5 10 Meters

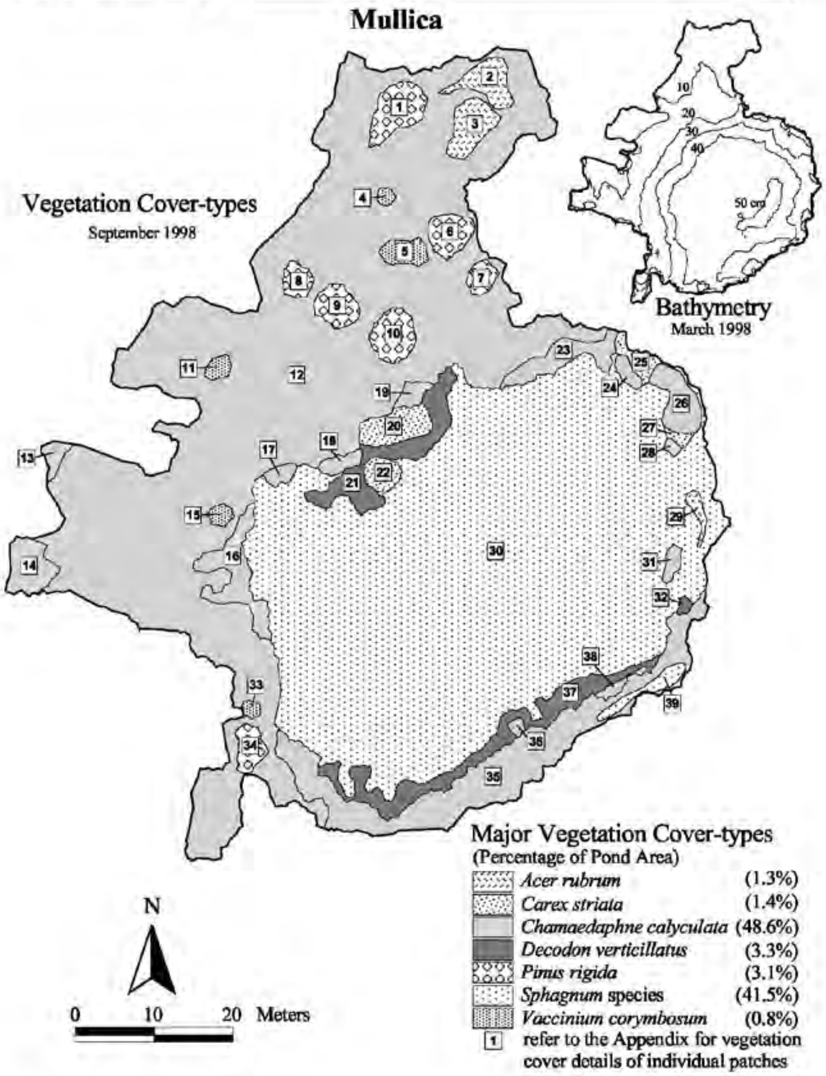
Mullica pond is a natural depression located south of Old Jackson-Atsion Road and west of the Mullica River, in Waterford Township, Camden County (Latitude 39°45'39.37" Longitude 74°48'09.27"). Most of the pond is surrounded by wet pine lowland. A narrow to very broad zone of leatherleaf dominates the pond perimeter. Swamp loosestrife occurs in two narrow areas between the leatherleaf and open water zones. Mullica pond supports high anuran-species richness, with Pine Barrens treefrogs and spring peepers evident each of the survey years.

Plant species present in 1998
Herbaceous plants:
Carex striata
Decodon verticillatus
Eleocharis flavescens var. olivacea
Eleocharis microcarpa
Panicum verrucosum
Triadenum virginicum
Woodwardia virginica
Woody plants:
Acer rubrum
Chamaedaphne calyculata
Gaylussacia frondosa
Kalmia angustifolia
Lyonia mariana
Pinus rigida
Smilax rotundifolia
Toxicodendron radicans
Vaccinium corymbosum

Environmental attributes	
Water Quality (March-June 1998)	
median pH	3.8
med. specific conductance (µS/cm)	69
med. total organic carbon (mg/L)	31
Morphometry (March 1998)	
total pond area (m^2)	5119
open water area (m^2)	2420
mean water depth (cm)	30
maximum water depth (cm)	55
mean shore slope (rise/run)	0.04



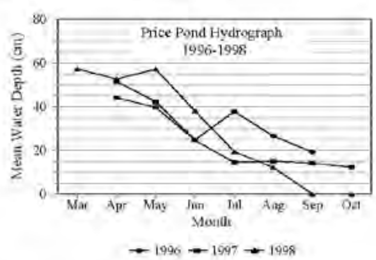
Anuran species present in 1996-1999.	
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Hyla versicolor	northern gray treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog


Mullica
Vegetation Cover-types
September 1998
Bathymetry
March 1998
10
20
30
40
50 cm
Major Vegetation Cover-types
(Percentage of Pond Area)
Acer rubrum (1.3%)
Carex striata (1.4%)
Chamaedaphne calyculata (48.6%)
Decodon verticillatus (3.3%)
Pinus rigida (3.1%)
Sphagnum species (41.5%)
Vaccinium corymbosum (0.8%)
1 refer to the Appendix for vegetation cover details of individual patches
N
0 10 20 Meters

Price pond is a natural depression located south of Chew Road, between Pestleton Road and Clark Branch, in Waterford Township, Camden County (Latitude 39°42'51.74" Longitude 74°49'20.20"). This pond is surrounded by oak, oak-pine, and pine-oak uplands. Price pond supports the highest vegetation cover-type richness of the 13 ponds studied. Distinct vegetation zonation occurs especially along the eastern pond perimeter where leatherleaf, Walter's sedge, and warty panic-grass zones are clearly evident. Price pond also exhibits high anuran-species richness and is noted for large choruses of spring peepers, green frogs, and wood frogs. Pine Barrens treefrogs and leopard frogs are also consistently detected here. Price pond is the only site where bullfrogs were encountered.

Plant species present in 1998
Herbaceous plants:
Carex striata
Dulichium arundinaceum
Eleocharis flavescens var. olivacea
Eleocharis microcarpa
Juncus pelocarpus
Panicum longifolium
Panicum verrucosum
Rhexia virginica
Scirpus cyperinus
Triadenum virginicum
Utricularia fibrosa
Utricularia geminiscapa
Woody plants:
Acer rubrum
Cephalanthus occidentalis
Chamaedaphne calyculata
Clethra alnifolia
Eubotrys racemosa
Kalmia angustifolia
Lyonia mariana
Pinus rigida
Smilax rotundifolia
Vaccinium corymbosum

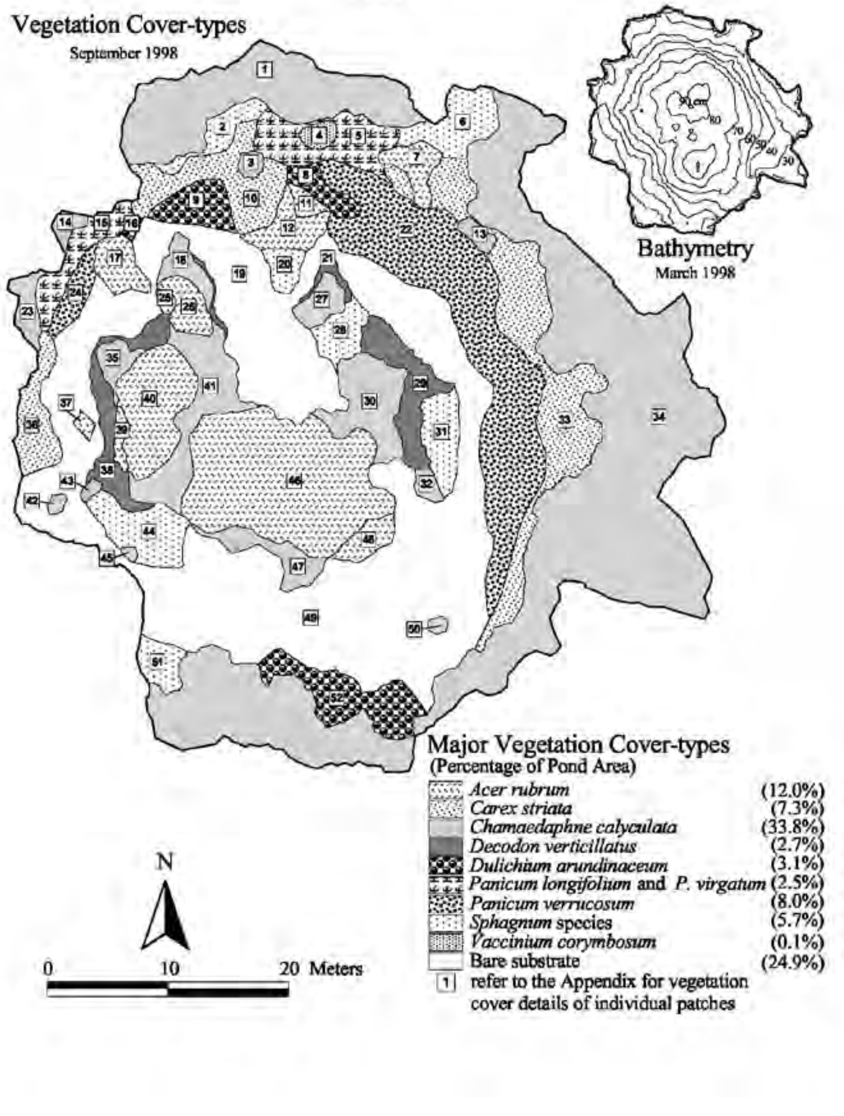
Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.0
med. specific conductance (µS/cm)	63
med. total organic carbon (mg/L)	27
Morphometry (March 1998)	
total pond area (m^2)	2426
open water area (m^2)	1776
mean water depth (cm)	57
maximum water depth (cm)	115
mean shore slope (rise/run)	0.05



Anuran species present in 1996-1999.	
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Hyla versicolor	northern gray treefrog
Pseudacris c. crucifer	northern spring peeper
Rana catesbeiana	bullfrog
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog

Pine Barrens Treefrog Ponds 25

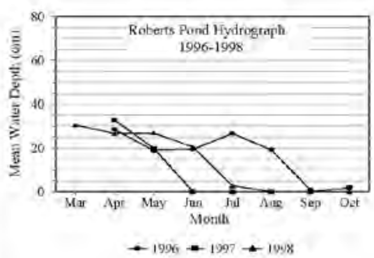
Price



Roberts pond is a natural depression located on the northern side of a sand road between Skit and Roberts (Tom Roberts) Branches, upstream from Carranza Road, in Tabernacle Township, Burlington County (Latitude 39°47'16.86" Longitude 74°39'21.64"). Atlantic white cedar, pine lowland, and pine-scrub oak upland surround this pond. The Roberts pond perimeter supports a shrub zone dominated by highbush blueberry and scattered leatherleaf. This pond is characterized by low plant-species richness and the lowest anuran-species richness (three) of the 13 ponds.

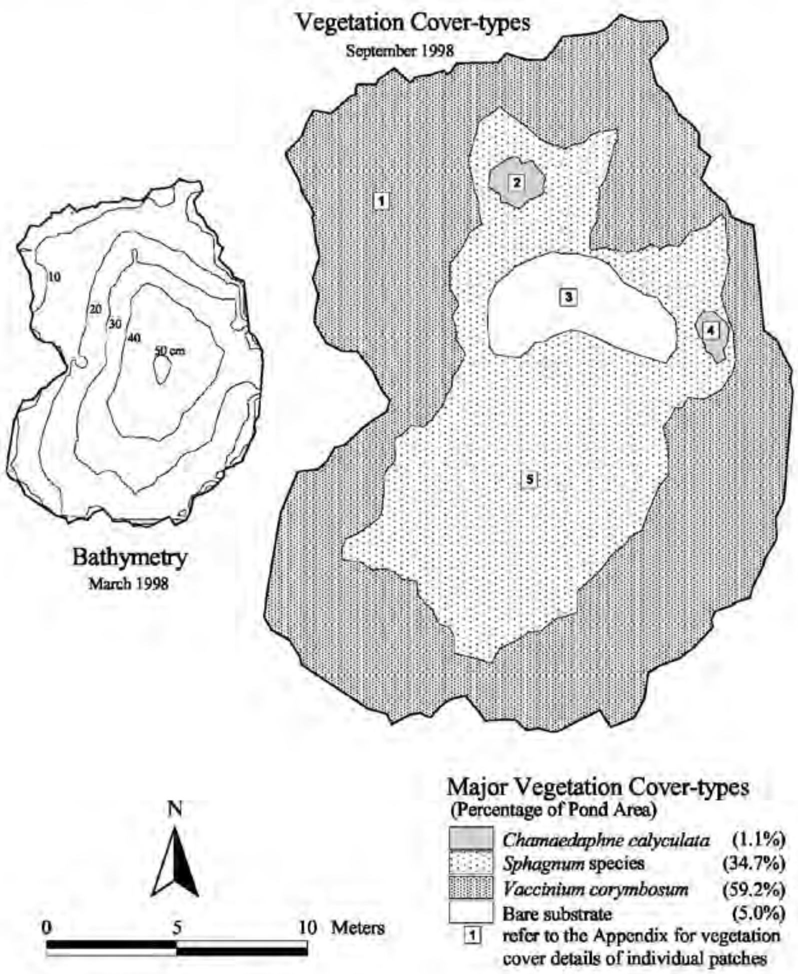
Plant species present in 1998
Herbaceous plants:
Cyperus retrorsus
Drosera intermedia
Drosera rotundifolia
Eleocharis flavescens var. olivacea
Panicum verrucosum
Rhexia virginica
Woodwardia virginica
Woody plants:
Acer rubrum
Chamaecyparis thyoides
Chamaedaphne calyculata
Eubotrys racemosa
Kalmia angustifolia
Pinus rigida
Smilax glauca
Vaccinium corymbosum

Environmental attributes	
Water Quality (March-June 1998)	
median pH	3.8
med. specific conductance (µS/cm)	83
med. total organic carbon (mg/L)	41
Morphometry (March 1998)	
total pond area (m^2)	412
open water area (m^2)	168
mean water depth (cm)	30
maximum water depth (cm)	55
mean shore slope (rise/run)	0.04



Anuran species present in 1996-1999.	
Hyla andersonii	Pine Barrens treefrog
Pseudacris c.crucifer	northern spring peeper
Rana clamitans melanota	green frog

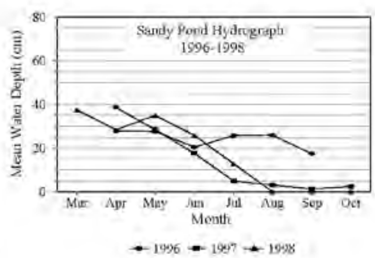
Roberts


Vegetation Cover-types
September 1998
1
2
3
4
5
10
20
30
40
50 cm
Bathymetry
March 1998
N
0
5
10 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Chamaedaphne calyculata (1.1%)
Sphagnum species (34.7%)
Vaccinium corymbosum (59.2%)
Bare substrate (5.0%)
1 refer to the Appendix for vegetation cover details of individual patches

Sandy pond is a natural depression located on the western side of Sandy Causeway Road, between Chew Road and a railroad, in Waterford Township, Camden County (Latitude 39°42'35.35" Longitude 74°46'36.80"). Adjacent vegetation communities consist of pine and pine-scrub oak uplands, dry pine lowland, and wet pine lowland with Atlantic white cedar. A distinct zone of leatherleaf encircles the entire pond. Walter's sedge dominates most of the rest of the pond. Sandy pond supports high anuran-species richness with large numbers of Pine Barrens treefrogs, spring peepers, and leopard frogs.

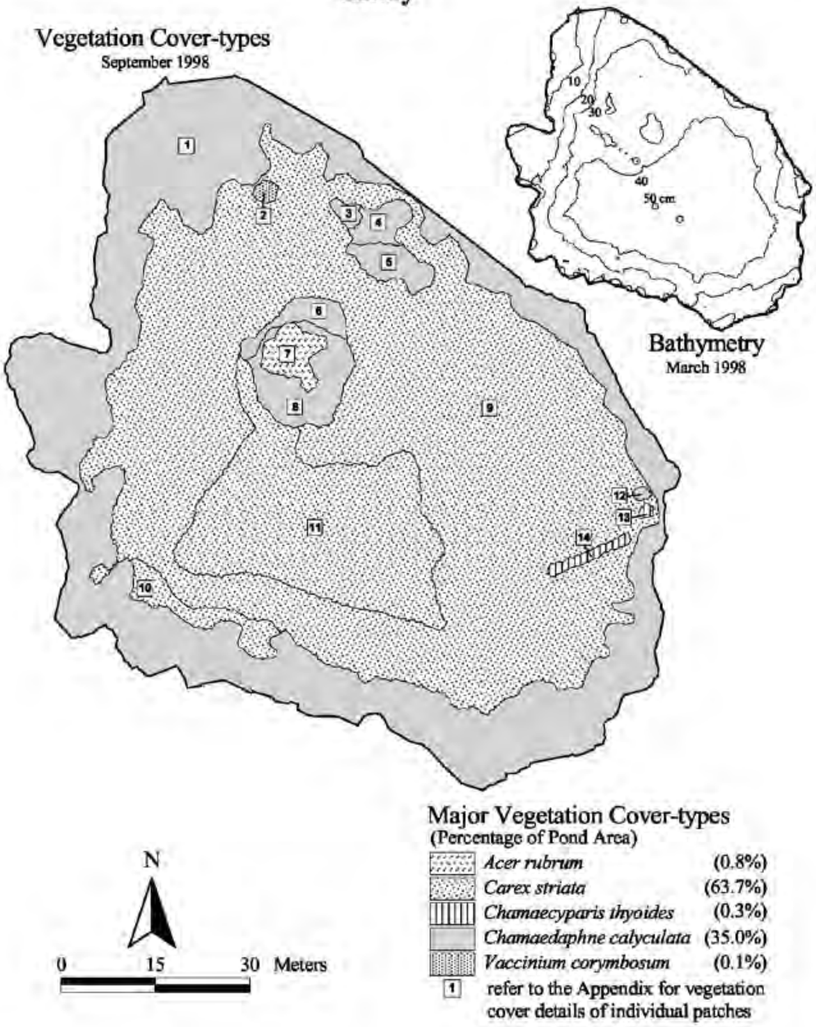
Plant species present in 1998
Herbaceous plants:
Carex striata
Lachnanthes caroliniana
Utricularia fibrosa
Woodwardia virginica
Woody plants:
Acer rubrum
Aronia arbutifolia
Chamaecyparis thyoides
Chamaedaphne calyculata
Clethra alnifolia
Eubotrys racemosa
Kalmia angustifolia
Pinus rigida
Smilax rotundifolia
Vaccinium corymbosum
Vaccinium macrocarpon

Environmental attributes	
Water Quality (March-June 1998)	
median pH	3.9
med. specific conductance (µS/cm)	75
med. total organic carbon (mg/L)	25
Morphometry (March 1998)	
total pond area (m^2)	7808
open water area (m^2)	5409
mean water depth (cm)	37
maximum water depth (cm)	55
mean shore slope (rise/run)	0.01



Anuran species present in 1996-1999.	
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Pseudacris triseriata kalmi	New Jersey chorus frog
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog

Sandy

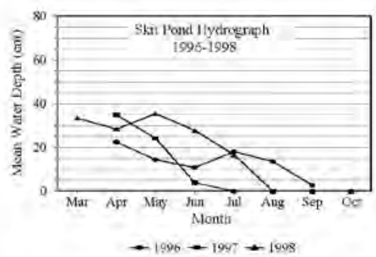

Vegetation Cover-types
September 1998
Bathymetry
March 1998
10
20
30
40
50 cm
1
2
3
4
5
6
7
8
9
10
11
12
13
14
N
0
15
30 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Acer rubrum (0.8%)
Carex striata (63.7%)
Chamaecyparis thyoides (0.3%)
Chamaedaphne calyculata (35.0%)
Vaccinium corymbosum (0.1%)
refer to the Appendix for vegetation cover details of individual patches

Skit pond is a natural depression located south of Tabernacle-Chatsworth Road, north of a railroad, and east of Skit Branch, in Tabernacle Township, Burlington County (Latitude 39°47'51.53" Longitude 74°36'51.42"). Skit pond is surrounded primarily by pine-scrub oak upland. A highbush blueberry zone forms the perimeter of the pond. Patches of Walter's sedge and warty panic-grass occur in the non-woody portion of the pond. Skit pond has the lowest plant-species richness of the 13 ponds. Skit pond supports large numbers of Pine Barrens treefrogs and spring peepers.

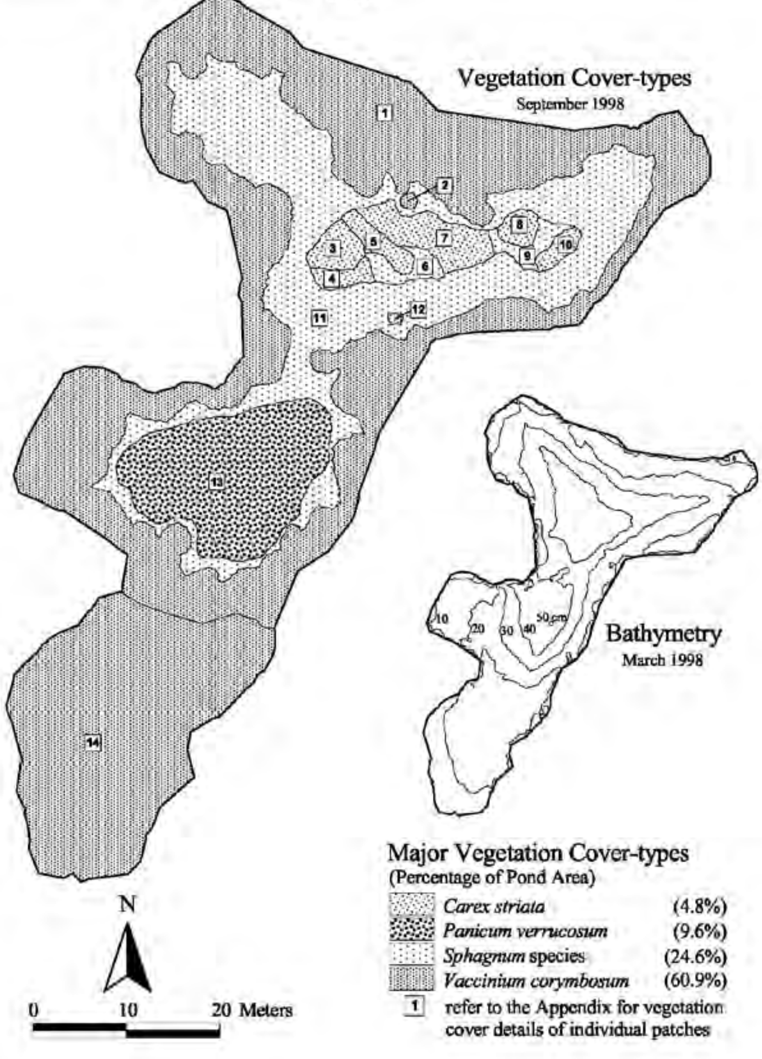
Plant species present in 1998
Herbaceous plants:
Carex striata
Drosera intermedia
Dulichium arundinaceum
Panicum verrucosum
Rhynchospora alba
Woody plants:
Acer rubrum
Aronia arbutifolia
Eubotrys racemosa
Gaylussacia frondosa
Kalmia angustifolia
Pinus rigida
Vaccinium corymbosum

Environmental attributes	
Water Quality (March-June 1998)	
median pH	3.8
med. specific conductance (µS/cm)	76
med. total organic carbon (mg/L)	53
Morphometry (March 1998)	
total pond area (m^2)	2973
open water area (m^2)	1166
mean water depth (cm)	33
maximum water depth (cm)	62
mean shore slope (rise/run)	0.06

Anuran species present in 1996-1999.	
Bufo woodhousii fowleri	Fowler's toad
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog



Skit


Vegetation Cover-types
September 1998
1
2
3
4
5
6
7
8
9
10
11
12
13
14
10
20
30
40
50 cm
Bathymetry
March 1998
Major Vegetation Cover-types
(Percentage of Pond Area)
Carex striata (4.8%)
Panicum verrucosum (9.6%)
Sphagnum species (24.6%)
Vaccinium corymbosum (60.9%)
1 refer to the Appendix for vegetation cover details of individual patches
N
0 10 20 Meters

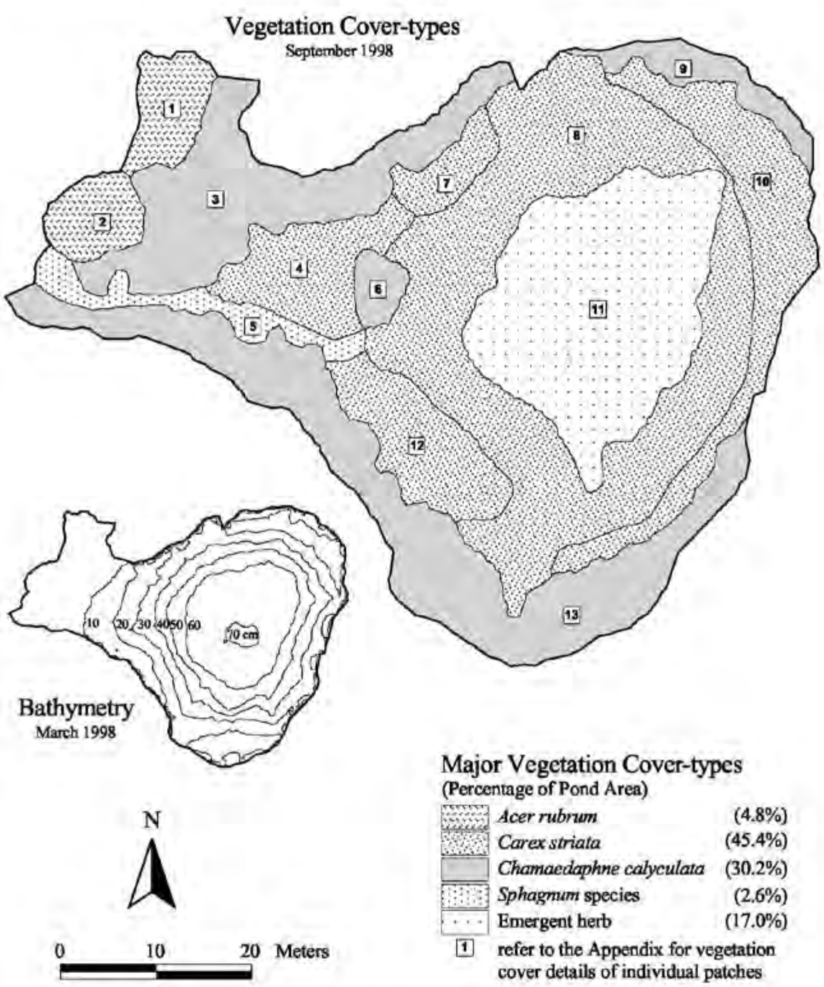
Sleeper pond is a natural depression located north of Fleming Pike, east of Burnt House Road, and south of Sleeper Branch, in Waterford Township, Camden County (Latitude 39°43'16.89" Longitude 74°46'09.29"). The surrounding vegetation consists of dry pine lowland. Distinct vegetation zones of leatherleaf and Walter's sedge are present. Sleeper pond exhibits high anuran-species richness, supporting large numbers of Pine Barrens treefrogs, spring peepers, and leopard frogs.

Plant species present in 1998
Herbaceous plants:
Carex striata
Dulichium arundinaceum
Eleocharis flavescens var. olivacea
Juncus pelocarpus
Nymphaea odorata
Panicum verrucosum
Utricularia geminiscapa
Woodwardia virginica
Xyris difformis
Woody plants:
Acer rubrum
Chamaedaphne calyculata
Clethra alnifolia
Eubotrys racemosa
Gaylussacia frondosa
Ilex glabra
Kalmia angustifolia
Lyonia mariana
Nyssa sylvatica
Pinus rigida
Smilax glauca
Smilax rotundifolia
Vaccinium corymbosum

Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.0
med. specific conductance (µS/cm)	48
med. total organic carbon (mg/L)	30
Morphometry (March 1998)	
total pond area (m^2)	3266
open water area (m^2)	2159
mean water depth (cm)	46
maximum water depth (cm)	75

Anuran species present in 1996-1999.	
Hyla andersonii	Pine Barrens treefrog
Hyla versicolor	northern gray treefrog
Pseudacris c. crucifer	northern spring peeper
Pseudacris triseriata kalmi	New Jersey chorus frog
Rana clamitans melanota	green frog
Rana sylvatica	wood frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog

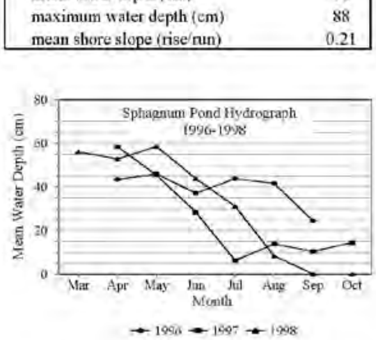
Sleeper


Vegetation Cover-types
September 1998
1
2
3
4
5
6
7
8
9
10
11
12
13
10
20
30
40
50
60
70 cm
Bathymetry
March 1998
N
0
10
20 Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Acer rubrum (4.8%)
Carex striata (45.4%)
Chamaedaphne calyculata (30.2%)
Sphagnum species (2.6%)
Emergent herb (17.0%)
1 refer to the Appendix for vegetation cover details of individual patches

Sphagnum pond is an excavated basin located upstream from Hampton Road, adjacent to a dike, and on the eastern side of Skit Branch, in Shamong Township, Burlington County (Latitude 39°46'22.15" Longitude 74°40'20.70"). Pine-scrub oak upland borders the pond to the southeast and southwest. A narrow band of Atlantic white cedar separates the pond from Skit Branch to the northwest and the dike to the northeast. The pond supports a high percentage cover of submerged, floating *Sphagnum* species and several aquatic and emergent plant species. No shrub zone is present at this excavated pond. Sphagnum pond supports large numbers of Pine Barrens treefrogs and spring peepers, and lesser numbers of carpenter frogs, green frogs, and leopard frogs.

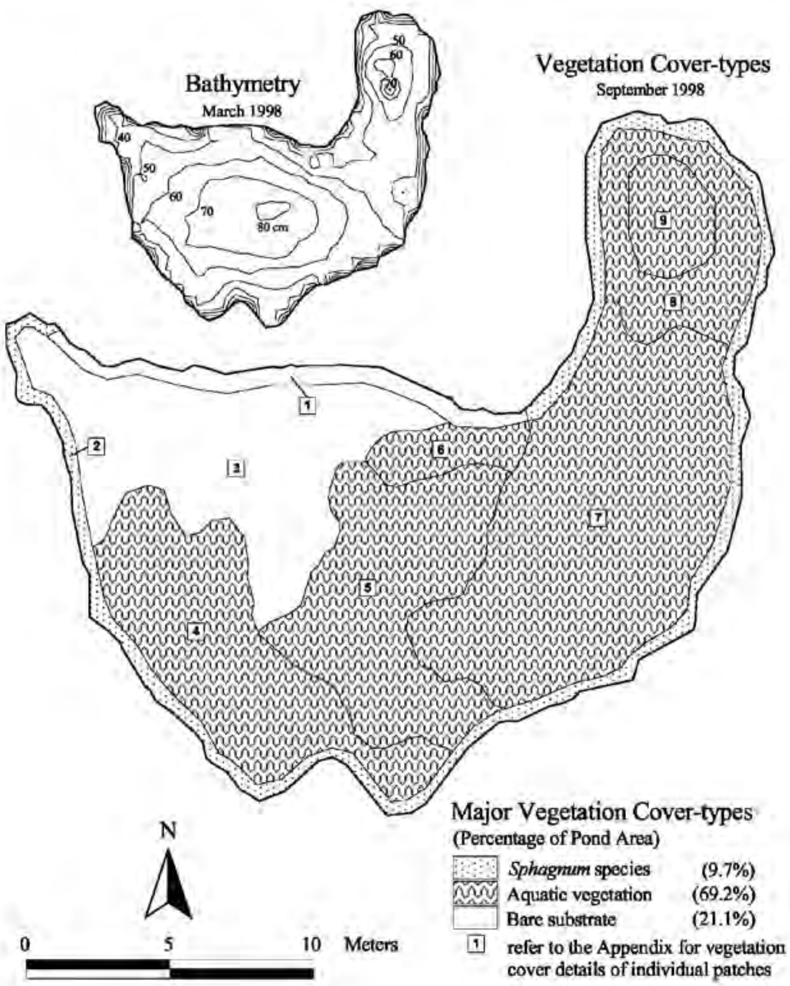
Plant species present in 1998
Herbaceous plants:
Cladium mariscoides
Cyperus dentatus
Drosera intermedia
Dulichium arundinaceum
Eleocharis robbinsii
Eleocharis tuberculosa
Juncus pelocarpus
Lachnanthes caroliniana
Nuphar variegata
Nymphaea odorata
Orontium aquaticum
Panicum verrucosum
Peltandra virginica
Rhexia virginica
Scirpus subterminalis
Triadenum virginicum
Utricularia purpurea
Xyris difformis
Woody plants:
Chamaecyparis thyoides
Chamaedaphne calyculata
Eubotrys racemosa
Gaylussacia dumosa
Gaylussacia frondosa
Kalmia angustifolia
Smilax rotundifolia
Vaccinium corymbosum
Vaccinium macrocarpon

Environmental attributes	
Water Quality (March-June 1998)	
median pH	4.3
med. specific conductance (µS/cm)	33
med. total organic carbon (mg/L)	4
Morphometry (March 1998)	
total pond area (m^2)	336
open water area (m^2)	336
mean water depth (cm)	56
maximum water depth (cm)	88
mean shore slope (rise/run)	0.21



Anuran species present in 1996-1999.	
Hyla andersonii	Pine Barrens treefrog
Pseudacris c. crucifer	northern spring peeper
Rana clamitans melanota	green frog
Rana utricularia	southern leopard frog
Rana virgatipes	carpenter frog

Sphagnum


Bathymetry
March 1998
40
50
60
70
80 cm
Vegetation Cover-types
September 1998
1
2
3
4
5
6
7
8
9
N
0
5
10
Meters
Major Vegetation Cover-types
(Percentage of Pond Area)
Sphagnum species (9.7%)
Aquatic vegetation (69.2%)
Bare substrate (21.1%)
refer to the Appendix for vegetation cover details of individual patches

APPENDIX

Appendix. Vegetation cover-type designations, initial detailed-cover estimates, and patch size for vegetation patches in selected Pine Barrens Treefrog ponds in the New Jersey Pinelands. Patch numbers correspond with those on vegetation cover-type maps. Numerical values included in the initial detailed-cover estimates are from the Braun-Blanquet cover scale, where 2 = 5-25%, 3 = 25-50%, 4 = 50-75%, and 5 = > 75%. The four-letter cover codes are as follows: ACER=Acer rubrum, BARE=bare substrate, CAST=Carex striata, CHCA=Chamaedaphne calyculata, CHTH=Chamaecyparis thyoides, CLMA=Cladium mariscoides, DALG=dry algal mat, DEVE=Decodon verticillatus, DUAR=Dulichium arundinaceum, ELMI=Eleocharis microcarpa, ELRO=Eleocharis robbinsii, ERGI=Erianthus gigantea, HERB=emergent herb, JUPE=Juncus pelocarpus, KAAN=Kalmia angustifolia, NYOD=Nymphaea odorata, PALO=Panicum longifolium, PAVE=Panicum verrucosum, PAVI=Panicum virgatum, PIRI=Pinus rigida, PRPE=Proserpinica pectinata, REVI=Rhexia virginica, SCCY=Scirpus cyperinus, SCSU=Scirpus subterminalis, SMRO=Smilax rotundifolia, SPHG=Sphagnum spp., STWA=standing water, TRVI=Triadenum virginicum, VACO=Vaccinium corymbosum, VAMA=Vaccinium macrocarpon, WOVI=Woodwardia virginica, XYRI=Xyris difformis or X. smalliana.

Patch #	Cover Type	Initial Detailed-Cover Estimate	Area (m^2)
Albertson			
1	*Chamaedaphne calyculata*	CHCA5/SPHG5	34.1
2	*Chamaedaphne calyculata*	CHCA5/SMRO2/SPHG5	3.6
3	*Chamaedaphne calyculata*	CHCA5/SPHG5	2.6
4	*Acer rubrum*	ACER5/CHCA5/SMRO2/SPHG5	1.8
5	*Acer rubrum*	ACER5/SPHG5	37.3
6	*Sphagnum*	SPHG5/REVI2	16.2
7	*Sphagnum*	SPHG5	3.3
8	*Dulichium arundinaceum*	DUAR4/SPHG5	9.4
9	*Chamaedaphne calyculata*	CHCA5/SPHG5	55.7
10	*Acer rubrum*	ACER5/CAST2/ SPHG5	3.6
11	*Dulichium arundinaceum*	DUAR4/SPHG5	10.3
12	*Acer rubrum*	ACER5/CHCA5/SPHG5	143.5
13	*Acer rubrum*	ACER5/SPHG5	12.8
14	*Chamaedaphne calyculata*	CHCA2/WOVI2/SPHG5	1.1
15	*Chamaedaphne calyculata*	CHCA5/WOVI2/SPHG5	4.0
16	*Sphagnum*	SPHG5	291.4
17	*Acer rubrum*	ACER5/CHCA5/SPHG5	86.3
18	*Acer rubrum*	ACER5/CHCA5/SPHG5	25.1
19	*Acer rubrum*	ACER5/SPHG5	1.2
20	*Acer rubrum*	ACER5/CHCA5/WOVI2/SPHG5	2.4
21	*Chamaedaphne calyculata*	CHCA5/SPHG5	74.9
Chew			
1	*Panicum longifolium and P. virgatum*	PAVI4/DALG5	41.2
2	Emergent herb	HERB2/DALG5	2080.4
3	*Panicum longifolium and P. virgatum*	PAVI4/DALG5	8.0
4	*Panicum longifolium and P. virgatum*	PAVI4/VAMA2/DALG5	18.6
Gravel			
1	*Dulichium arundinaceum*	DUAR4/SPHG5	16.8
2	*Carex striata*	CAST2/SPHG5	47.9
3	*Sphagnum*	SPHG5	508.4
4	*Chamaedaphne calyculata*	CHCA5/CAST2/SPHG5	12.6
5	*Dulichium arundinaceum*	DUAR3/SPHG5	35.6
6	*Decodon verticillatus*	DEVE2/SPHG5	1.8
7	Bare substrate	BARE5	87.7

Appendix. Continued.

Patch #	Cover Type	Initial Detailed-Cover Estimate	Area (m^2)
8	*Chamaedaphne calyculata*	CHCA5/CAST2/SPHG5	4.0
9	*Chamaedaphne calyculata*	CHCA5/VACO3/CAST2/SPHG5	8.1
10	*Chamaedaphne calyculata*	CHCA5/SPHG5	104.0
11	*Chamaedaphne calyculata*	CHCA5/SPHG5	1057.4
12	*Carex striata*	CAST3/SPHG5	240.9
13	*Chamaedaphne calyculata*	CHCA5/CAST2/SPHG5	7.5
14	*Carex striata*	CAST2/SPHG5	309.9
15	*Carex striata*	CAST3/SPHG5	14.6
16	*Chamaedaphne calyculata*	CHCA5/VACO2/CAST2/ SPHG5	5.6
17	*Sphagnum*	SPHG5	42.8
18	*Pinus rigida*	PIRI5/CHCA5/KAAN2/CAST2/ SPHG5	6.1
19	*Carex striata*	CAST2/SPHG5	125.9
Furnace			
1	*Panicum longifolium* and *P. virgatum*	PALO3/SPHG2/BARE4	6.5
2	Emergent herb	JUPE3/PALO2/PRPE2/TRVI2/SPHG2	28.5
3	Emergent herb	JUPE3/ BARE4	30.4
4	Emergent herb	JUPE3/PRPE2/TRVI2/SPHG2/BARE4	36.5
5	*Sphagnum*	SPHG5	50.5
Hays			
1	*Vaccinium corymbosum*	VACO5	850.6
2	*Sphagnum*	SPHG5	426.6
3	*Decodon verticillatus*	DEVE3/PAVE2/SPHG5	8.6
4	*Panicum verrucosum*	PAVE3/SPHG2/BARE4	83.0
5	*Chamaedaphne calyculata*	CHCA4/SPHG5	1.9
6	*Decodon verticillatus*	DEVE3/PAVE2/SPHG5	50.5
7	*Panicum verrucosum*	PAVE3/SPHG2/BARE4	46.9
8	*Chamaedaphne calyculata*	CHCA3/SPHG5	31.1
9	*Chamaedaphne calyculata*	CHCA3/SPHG5	3.0
10	*Chamaedaphne calyculata*	CHCA5/SPHG5	12.2
11	*Chamaedaphne calyculata*	CHCA5/SPHG5	22.1
Hampton			
1	*Sphagnum*	SPHG5	27.9
2	*Panicum longifolium* and *P. virgatum*	PAVI5/VAMA3	0.7
3	Emergent herb	JUPE3/XYRI3/BARE4	31.0
4	Emergent herb	ELMI5/PRPE3/JUPE2	3.5
5	Emergent herb	ELMI5/JUPE2/PRPE2/XYRI2	54.4
6	Emergent herb	ELMI3/XYRI3/JUPE2/BARE3	69.9
7	Emergent herb	ERGI3/JUPE2/PRPE2/XYRI2/BARE4	196.4
8	*Panicum longifolium* and *P. virgatum*	PAVI4/VAMA3/SPHG5	36.6
Mullica			
1	*Pinus rigida*	PIRI4/VACO4/CHCA5/SPHG2	36.8
2	*Acer rubrum*	ACER4/PIRI4/VACO2/CHCA5/SPHG4	28.6
3	*Acer rubrum*	ACER2/VACO5/CHCA3/SPHG5	31.4
4	*Vaccinium corymbosum*	VACO5/CHCA5/SPHG2	4.2
5	*Vaccinium corymbosum*	VACO5/CHCA5/SPHG2	16.7
6	*Pinus rigida*	PIRI5/CHCA5/SPHG5	24.6
7	*Pinus rigida*	PIRI5/CHCA5/SPHG5	12.7
8	*Pinus rigida*	PIRI5/VACO5/CHCA5/SPHG3	13.6

Appendix. Continued.

Patch #	Cover Type	Initial Detailed-Cover Estimate	Area (m^2)
9	*Pinus rigida*	PIRI5/CHCA5/SPHG4	23.2
10	*Pinus rigida*	PIRI5/VACO3/CHCA5/SPHG3	30.2
11	*Vaccinium corymbosum*	VACO5/CHCA4/SPHG2	7.9
12	*Chamaedaphne calyculata*	CHCA5/SPHG5	2014.6
13	*Chamaedaphne calyculata*	CHCA5/WOVI2/SPHG5	10.2
14	*Chamaedaphne calyculata*	CHCA5/WOVI2/SPHG5	34.5
15	*Vaccinium corymbosum*	VACO5/CHCA2/SPHG3	6.8
16	*Chamaedaphne calyculata*	CHCA5/DEVE2/SPHG5	54.0
17	*Chamaedaphne calyculata*	CHCA5/DEVE3/SPHG5	8.1
18	*Chamaedaphne calyculata*	CHCA4/DEVE4/SPHG5	10.4
19	*Chamaedaphne calyculata*	CHCA5/DEVE2/SPHG5	10.1
20	*Carex striata*	CAST5/DEVE2/SPHG5	34.4
21	*Decodon verticillatus*	DEVE2/SPHG5	70.2
22	*Carex striata*	CAST5/SPHG5	16.3
23	*Chamaedaphne calyculata*	CHCA5/DEVE2/SPHG5	38.9
24	*Chamaedaphne calyculata*	CHCA5/CAST2/DEVE2/SPHG5	8.1
25	*Carex striata*	CAST3/DEVE2/SPHG5	15.1
26	*Chamaedaphne calyculata*	CHCA5/CAST2/DEVE2/SPHG5	34.3
27	*Carex striata*	CAST3/SPHG5	4.6
28	*Chamaedaphne calyculata*	CHCA5/DEVE2/SPHG5	3.1
29	*Acer rubrum*	ACER3/CHCA2/DEVE4/SPHG5	7.4
30	*Sphagnum*	SPHG5	2109.4
31	*Chamaedaphne calyculata*	CHCA3/DEVE3/SPHG5	7.6
32	*Decodon verticillatus*	DEVE3/SPHG5	3.1
33	*Vaccinium corymbosum*	VACO5/CHCA3/SPHG5	4.3
34	*Pinus rigida*	PIRI4/VACO5/CHCA3/SPHG5	17.7
35	*Chamaedaphne calyculata*	CHCA5/SPHG5/DEVE2	243.6
36	*Chamaedaphne calyculata*	CHCA3/DEVE3/CAST3/SPHG5	3.4
37	*Decodon verticillatus*	DEVE2/SPHG5	97.1
38	*Chamaedaphne calyculata*	CHCA5/DEVE5/SPHG5	6.1
39	*Sphagnum*	SPHG5	16.1
Price			
1	*Chamaedaphne calyculata*	CHCA4/CAST2/SPHG5	117.9
2	*Sphagnum*	SPHG5	14.3
3	*Chamaedaphne calyculata*	CHCA5/SPHG5	3.9
4	*Vaccinium corymbosum*	VACO5/SPHG5	5.4
5	*Panicum longifolium* and *P. virgatum*	PALO5/CAST3/DUAR3	37.7
6	*Sphagnum*	SPHG5	28.0
7	*Acer rubrum*	ACER4/CHCA4/CAST2/SPHG5	14.0
8	*Dulichium arundinaceum*	DUAR3/CAST2/SPHG3/BARE3	12.0
9	*Dulichium arundinaceum*	DUAR4/SPHG5	20.1
10	*Carex striata*	CAST5/SPHG5	37.3
11	*Acer rubrum*	ACER2/DUAR3/CAST2/SPHG3/BARE3	4.9
12	*Acer rubrum*	ACER2/SPHG5	17.8
13	*Chamaedaphne calyculata*	CHCA5/CAST3/SPHG5	4.9
14	*Chamaedaphne calyculata*	CHCA4/CAST2/SPHG5	5.3
15	*Panicum longifolium* and *P. virgatum*	PALO5/SPHG5	22.5
16	*Dulichium arundinaceum*	DUAR5	2.2

Appendix. Continued.

Patch #	Cover Type	Initial Detailed-Cover Estimate	Area (m²)
17	*Acer rubrum*	ACER4/CHCA5/CAST3/SPHG5	15.4
18	*Chamaedaphne calyculata*	CHCA5/SPHG5	11.4
19	*Decodon verticillatus*	DEVE2/SCCY2/SPHG5	2.2
20	*Sphagnum*	SPHG5/SCCY3	9.4
21	*Decodon verticillatus*	DEVE4/SPHG5	4.4
22	*Panicum verrucosum*	PAVE2/BARE5	180.9
23	*Chamaedaphne calyculata*	CHCA4/CAST2/SPHG5	10.8
24	*Panicum verrucosum*	PAVE3/SPHG5	12.7
25	*Acer rubrum*	ACER5	2.2
26	*Acer rubrum*	ACER5/CHCA5/SPHG5	13.7
27	*Chamaedaphne calyculata*	CHCA5/DEVE2/SPHG5	11.7
28	*Sphagnum*	SPHG5	15.8
29	*Decodon verticillatus*	DEVE3/SPHG5	31.7
30	*Chamaedaphne calyculata*	CHCA5/SPHG5	39.0
31	*Sphagnum*	SPHG5	21.6
32	*Chamaedaphne calyculata*	CHCA5/SPHG5	4.7
33	*Carex striata*	CAST4/SPHG5	114.5
34	*Chamaedaphne calyculata*	CHCA4/CAST2/SPHG5	526.4
35	*Chamaedaphne calyculata*	CHCA5/SPHG5	9.3
36	*Carex striata*	CAST4/SPHG5	25.7
37	*Acer rubrum*	ACER4/CHCA5/SPHG5	2.3
38	*Decodon verticillatus*	DEVE2/SPHG5	28.1
39	*Acer rubrum*	ACER5/DEVE2/SPHG5	4.5
40	*Acer rubrum*	ACER5/CHCA5/SPHG5	49.7
41	*Chamaedaphne calyculata*	CHCA5/SPHG5	48.8
42	*Chamaedaphne calyculata*	CHCA5/CAST2/SPHG5	2.0
43	*Chamaedaphne calyculata*	CHCA5/SPHG5	2.0
44	*Sphagnum*	SPHG5	31.0
45	*Chamaedaphne calyculata*	CHCA5/SPHG5	1.2
46	*Acer rubrum*	ACER5/CHCA5/SPHG5	154.8
47	*Chamaedaphne calyculata*	CHCA5/SPHG5	18.1
48	*Acer rubrum*	ACER5/STWA5	11.2
49	Bare substrate	BARE5	604.7
50	*Chamaedaphne calyculata*	CHCA5/SPHG3	1.9
51	*Sphagnum*	SPHG5	13.1
52	*Dulichium arundinaceum*	DUAR2/SPHG5	40.8
Sandy			
1	*Chamaedaphne calyculata*	CHCA5/SPHG5	2398.3
2	*Vaccinium corymbosum*	VACO5/CAST4/SPHG5	10.8
3	*Chamaedaphne calyculata*	CHCA5/SPHG5	14.9
4	*Chamaedaphne calyculata*	CHCA4/WOVI5/SPHG5	48.2
5	*Chamaedaphne calyculata*	CHCA5/SPHG5	64.4
6	*Chamaedaphne calyculata*	CHCA5/SPHG5	57.3
7	*Acer rubrum*	ACER3/CHCA5/VACO3/WOVI5/SPHG5	65.1
8	*Chamaedaphne calyculata*	CHCA4/WOVI5/SPHG5	145.5
9	*Carex striata*	CAST4/SPHG5	4000.5
10	*Carex striata*	CAST3/SPHG5	94.1
11	*Carex striata*	CAST3/SPHG5	877.9
12	*Chamaedaphne calyculata*	CHCA5/SPHG5	4.7

Appendix. Continued.

Patch #	Cover Type	Initial Detailed-Cover Estimate	Area (m^2)
13	*Chamaecyparis thyoides*	CHTH3/CHCA5/VACO2/CAST2/SPHG5	3.8
14	*Chamaecyparis thyoides*	CHTH4/CHCA5/CAST2/SPHG5	22.1
Skit			
1	*Vaccinium corymbosum*	VACO5	1222.8
2	*Vaccinium corymbosum*	VACO5/SPHG5	2.7
3	*Carex striata*	CAST3/SPHG5	24.5
4	*Carex striata*	CAST2/SPHG5	14.3
5	*Carex striata*	CAST2/SPHG5	20.2
6	*Sphagnum*	SPHG5	19.7
7	*Carex striata*	CAST4/SPHG5	57.7
8	*Carex striata*	CAST3/SPHG5	14.4
9	*Sphagnum*	SPHG5	18.9
10	*Carex striata*	CAST3/SPHG5	12.3
11	*Sphagnum*	SPHG5	694.0
12	*Vaccinium corymbosum*	VACO5/SPHG5	1.8
13	*Panicum verrucosum*	PAVE2/SPHG5	285.2
14	*Vaccinium corymbosum*	VACO4/KAAN2/SPHG4	584.4
Sleeper			
1	*Acer rubrum*	ACER2/CHCA5/VACO3/SPHG5	82.6
2	*Acer rubrum*	ACER4/PIRI3/CHCA5/SPHG2	74.0
3	*Chamaedaphne calyculata*	CHCA5/SPHG5	352.3
4	*Carex striata*	CAST4/SPHG5	153.2
5	*Sphagnum*	SPHG5	85.1
6	*Chamaedaphne calyculata*	CHCA5/SPHG5	35.1
7	*Carex striata*	CAST2/SPHG5	58.9
8	*Carex striata*	CAST3/SPHG5	834.6
9	*Chamaedaphne calyculata*	CHCA5/SMRO2/SPHG5	75.8
10	*Carex striata*	CAST2/SPHG5	275.8
11	Emergent herb	HERB2/JUPE2/SPHG5	555.0
12	*Carex striata*	CAST4/SPHG5	161.5
13	*Chamaedaphne calyculata*	CHCA5/SPHG5	522.2
Sphagnum			
1	Bare substrate	BARE5	10.3
2	*Sphagnum*	SPHG5	32.5
3	Bare substrate	BARE5/SPHG2	60.7
4	Aquatic vegetation	NYOD2/SPHG5	50.0
5	Aquatic vegetation	SCSU5/ELRO2/NYOD2	49.0
6	Aquatic vegetation	SCSU5/ELRO2/CLMA2	8.5
7	Aquatic vegetation	SCSU5/ELRO4	90.5
8	Aquatic vegetation	NYOD2/SCSU2/BARE4	23.8
9	Aquatic vegetation	NYOD2/SCSU2/STWA5	10.7
Roberts			
1	*Vaccinium corymbosum*	VACO5/CHCA5/WOVI5/SPHG5	244.2
2	*Chamaedaphne calyculata*	CHCA5/SPHG5	2.9
3	Bare substrate	BARE4/REVI2	20.6
4	*Chamaedaphne calyculata*	CHCA5/SPHG5	1.7
5	*Sphagnum*	SPHG5	143.0

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ORIGINAL PAPER

The potential impact of simulated ground-water withdrawals on the oviposition, larval development, and metamorphosis of pond-breeding frogs

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Abstract Wetland hydroperiod is a key factor for the reproductive success of pond-breeding amphibians. Ground-water withdrawals may cause intermittent ponds to dry prematurely, potentially affecting amphibian development. In three intermittent ponds, we monitored hydrology and tracked oviposition, larval development, and metamorphosis for three frog species that represented a range of breeding phenologies. The three species were the southern leopard frog (*Lithobates sphenocephalus*), spring peeper (*Pseudacris crucifer*), and Pine Barrens treefrog (*Hyla andersonii*). We simulated ground-water withdrawals by subtracting from 5 to 50 cm (in 5-cm increments) from the measured water-depth values at the ponds over a short-term (2-year) period and a long-term (10-year) period to estimate the potential impact of hydroperiod alterations on frog development. Short-term simulations indicated that 5 and 10 cm water-depth reductions would have resulted in little or no impact to hydroperiod or larval development and metamorphosis of any of the species. Noticeable impacts were estimated to occur for reductions ≥15 cm. Long-term simulations showed that impacts to the appearance of the first premetamorphs and metamorphs would have occurred at reductions ≥10 cm and impacts to initial egg deposition would have occurred at reductions ≥20 cm. For all simulations, successively greater reductions would have caused increasing impacts that varied by species and pond, with the 50-cm reductions shortening hydroperiods enough to practically eliminate the possibility of larval development and metamorphosis for all three species. Compared to the spring peeper and southern leopard frog, the estimated impacts of the simulations on the various life stages were the greatest for the Pine Barrens treefrog.

Keywords Anuran-larval development · Coastal-plain ponds · Ground-water withdrawals · New Jersey Pinelands · Pond hydroperiod · Simulation

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Introduction

Wetland hydroperiod, defined here as the length of time when standing water is present, is a key factor that directly shapes the community composition and reproductive success of pond-breeding amphibians. The timing and duration of wetland flooding must coincide with amphibian-breeding biology for successful oviposition, hatching, larval development, and metamorphosis to occur (Paton and Crouch 2002). Long-term studies in natural ponds (Pechmann et al. 1989; Semlitsch et al. 1996) and experimental manipulations in artificial ponds (Rowe and Dunson 1995; Ryan 2007; Ryan and Winne 2001) have shown that early pond drying can result in fewer amphibian species metamorphosing, reduced metamorphic success for individual species, or complete larval mortality.

Shallow depression wetlands are a common feature throughout the New Jersey Pinelands, which is a 379,827-ha coastal-plain region located in the southern portion of the state (Fig. 1). Often embedded in a forested matrix, these coastal-plain wetlands typically support open-water with herbaceous and shrub communities and sometimes dry one or two times per year (Zampella and Laidig 2003). Although salamanders and fish are largely absent, up to nine species of anurans may utilize these intermittent wetlands as breeding ponds (Bunnell and Zampella 1999; Zampella and Bunnell 2000).

Seasonal water-depth fluctuations in Pinelands ponds reflect those for pitch pine forest water tables, suggesting that pond-water levels mirror regional ground-water patterns (Zampella et al. 2001a; Zampella and Laidig 2003). Ground-water-level changes due to human-induced hydrologic alterations, such as water withdrawals to serve development and agriculture, may cause intermittent ponds to dry prematurely, potentially affecting the larval development and metamorphosis of pond-breeding anurans. Both the tight connection between ground-water and pond-water levels (Lide et al. 1995; McHorney and Neill 2007) and reductions in pond-water levels from nearby ground-water pumping (McHorney and Neill 2007) have been shown for coastal-plain ponds in other regions.

The goal of our study was to assess the potential effects of ground-water withdrawals on the larval development and metamorphosis of pond-breeding anurans. We monitored hydrology and tracked oviposition, larval development, and metamorphosis for three frog species in three intermittent Pinelands ponds. We applied simulated water-depth reductions to the measured hydroperiods of the three ponds over a short-term (2-year) period and a long-term (10-year) period to estimate the potential impact of hydroperiod alterations on the oviposition, larval development, and metamorphosis of each species and to determine the relative vulnerability of each species to hydrologic stress. This study was part of the Kirkwood–Cohansey Project (Pinelands Commission 2003), a larger research effort designed to evaluate the potential effects of ground-water withdrawals on aquatic and wetland communities associated with the Kirkwood–Cohansey aquifer, the primary water-table aquifer in the Pinelands (Rhodehamel 1979a, b; Zapecza 1989).

Methods

Study ponds

We chose three excavated ponds (Chew, Hampton, and Furnace) for the study. All three ponds are associated with the Kirkwood–Cohansey aquifer system and are located on state land in the northwestern portion of the Mullica River watershed (Fig. 1). The three ponds were part of earlier studies of anuran composition (Bunnell and Zampella 1999) and functional equivalency (Zampella and Laidig 2003) of 10 natural and four excavated ponds.

We selected Chew, Hampton, and Furnace from the group of 14 ponds because these three ponds supported similar anuran assemblages and displayed hydrologic regimes comparable to natural Pinelands ponds, but lacked the thick shrub border, dense *Sphagnum*, and extremely dark water (Bunnell and Zampella 1999; Zampella and Laidig 2003) that makes sampling anuran larvae difficult in natural ponds of the region. Based on bathymetric maps and monthly water-depth measurements for April–September 1996, April–October 1997, and March–October 1998, mean pond depth was 63 cm for Chew, 51 cm for Hampton, and 65 cm for Furnace (Laidig et al. 2001; Zampella and Laidig 2003). Chew was the largest of the three ponds (2,148 m^2) and was embedded in a pine-scrub oak upland matrix, whereas Hampton (420 m^2) and Furnace (153 m^2) were smaller and were located in dry to wet pitch pine lowlands (Laidig et al. 2001; Zampella and Laidig 2003). Chew was located about 10 km from Hampton (Fig. 1). Furnace and Hampton were 515 m apart. All three ponds were acidic (median pH of Hampton = 4.69, Furnace = 4.49, and Chew = 4.39, Bunnell and Zampella 1999).

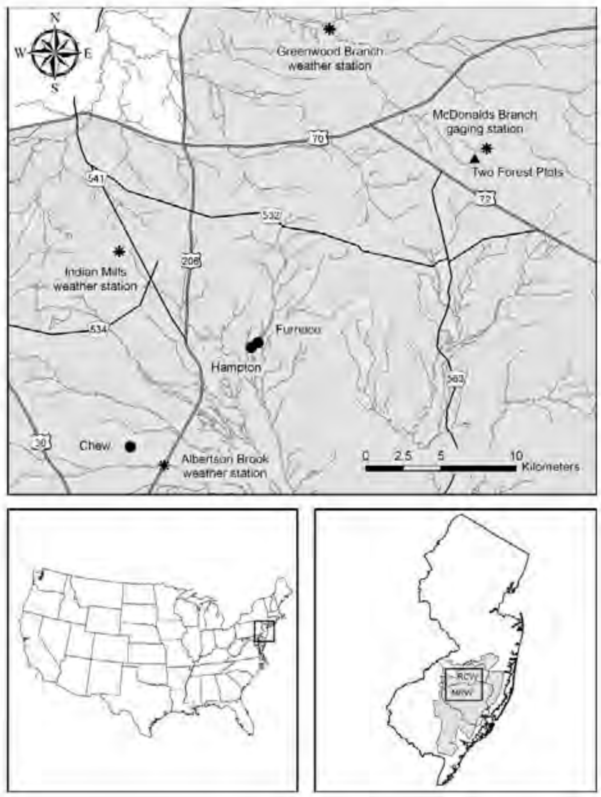

Fig. 1 Location of three intermittent ponds (*dots*), three weather stations and one stream-gaging station (*stars*), and two forest plots (*triangle*) in the Mullica River and Rancocas Creek watersheds in the New Jersey Pinelands, USA (*shaded area*)

Anuran sampling

We sampled breeding adult anurans at the three ponds from 1996 to 2006 by completing monthly nighttime-vocalization surveys from March through June ($N = 4$) of each year. All anurans calling in a 5-min period were identified. Vocalization surveys were used to document which species were attempting to breed at the ponds each year.

In addition to vocalization surveys, we sampled anuran eggs, larvae, and metamorphs in the three ponds in 2005 and 2006. We sampled larvae using 1-m sweeps with a 38 × 38-cm dip net (4.8-mm mesh size). During each sampling event, we completed 30 dip-net sweeps in Hampton and Furnace and, because of its larger size, 70 dip-net sweeps in Chew. Although we reduced the number of dip-net sweeps per visit when a drop in water depth decreased the volume of water in the pond, the mean (±1 SD) number of sweeps per visit for the 2005 and 2006 seasons was 30 ± 0.0 for Hampton, 29 ± 4 for Furnace, and 63 ± 17 for Chew. In 2005, sampling frequency was biweekly (every other week) from April 14 to May 31 and weekly from June 1 to August 31 ($N = 17$). In 2006, sampling frequency was weekly from March 31 to October 13, 2006 ($N = 28$). Larvae in advanced stages of metamorphosis that were encountered near the edge of water were also captured. The presence of anuran eggs of each species was recorded during larval-sampling events.

Anuran larvae were identified to species using Altig (1970) and staged according to Gosner (1960). We refer to developmental stages 25–38 as larvae, stages 39–41 as pre-metamorphs, and stages 42–46 as metamorphs. A 10× hand lens was used to examine limb development to determine larval stage in the field. All larvae were returned to the pond. Taxonomic nomenclature follows Crother (2008).

Focal species

Nine anuran species have been heard calling from Chew, Hampton, and Furnace (Table 1). We focused on three species, the spring peeper (*Pseudacris crucifer*), Pine Barrens treefrog (*Hyla andersonii*), and southern leopard frog (*Lithobates sphenocephalus*), because they commonly breed in Pinelands ponds (Bunnell and Zampella 1999; Zampella and Bunnell 2000) and each exhibits a different breeding

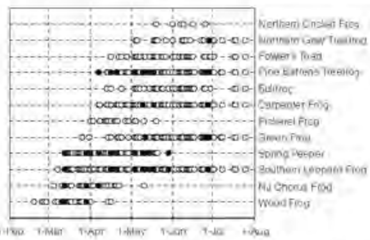

Fig. 2 Breeding phenology of Pinelands anurans. *Filled circles* indicate that a species was heard during vocalization surveys conducted at three Pinelands ponds in 2005 and 2006. *Open circles* indicate that a species was heard during surveys completed at 227 Mullica River watershed sites in 1993 and 1996–1999. See Zampella et al. (2001b) for details regarding Mullica River watershed surveys

phenology (Fig. 2). The southern leopard frog and spring peeper are among the first species to begin breeding each year, but the southern leopard frog continues to breed well after the spring peeper stops. In contrast, the Pine Barrens treefrog, which is a species of conservation concern in New Jersey, South Carolina, Florida, and Alabama, is a relatively late-breeding frog. The varied breeding phenology of these three species allowed us to determine the

Table 1 The percentage of the total number of years in which each of nine anuran species was heard vocalizing at three Pinelands ponds

Species	2005–2006 Survey period			1996–2004 Survey period		
	Chew	Hampton	Furnace	Chew	Hampton	Furnace
Pine Barrens treefrog (*Hyla andersonii*)*	100 ab	100 ab	100 ab	100	100	89
Spring peeper (*Pseudacris crucifer*)*	100 ab	100 ab	100 ab	100	89	100
Southern leopard frog (*Lithobates sphenocephalus*)*	100 ab	100 ab	100 ab	100	100	89
Green frog (*Lithobates clamitans*)	100 ab	50	50 ab	78	78	33
Carpenter frog (*Lithobates virgatipes*)	–	100 ab	50 b	–	67	22
New Jersey chorus frog (*Pseudacris kalmi*)	100	–	–	100	–	–
Wood frog (*Lithobates sylvaticus*)	100	–	50	33	11	11
Northern gray treefrog (*Hyla versicolor*)	50	–	–	44	11	11
Fowler's toad (*Anaxyrus fowleri*)	–	–	–	22	22	11
Mean (±1 SD) hydroperiod (days)	308 ± 58	290 ± 76	290 ± 76	261 ± 74	253 ± 78	270 ± 83

The three focal species are indicated with *asterisks*. Letters indicate the year in which larvae were present for that species during 2005 (a) and 2006 (b). Mean hydroperiod for both survey periods is based on monthly water-depth measurements. The year 2000 was excluded due to incomplete water-depth data relative vulnerability of each to potential changes in pond hydroperiod.

Pond hydrology

From 1996 to 2006, we measured water depth monthly at the three ponds with a staff gage located in the deepest part of each pond. In addition to these monthly readings, we measured water depth at each pond weekly or biweekly during each larval-sampling event in 2005 and 2006. Using the weekly/biweekly and monthly measurements, we determined the hydroperiod of each pond as the number of days when standing water was present from January 1 to the date of first drying.

To determine whether water-depth fluctuations were similar among the three ponds, we used Spearman rank correlation to relate water depth among ponds on the individual sample dates in 2005 and 2006. To assess the relationship between pond hydroperiod and precipitation in 2005 and 2006, we obtained daily precipitation data from the National Oceanic and Atmospheric Administration (http://www.ncdc.noaa.gov/oa/climate/) for the Indian Mills, NJ weather station and from the U. S. Geological Survey (http://waterdata.usgs.gov/nj/nwis/) for the Albertson Brook near Hammonton, NJ and the Greenwood Branch at New Lisbon, NJ stations (Fig. 1). We averaged daily precipitation values from the three weather stations, summed the mean values between sampling events, and compared precipitation amounts with pond hydrographs graphically.

Many Pinelands ponds, including the three study ponds, are embedded in an upland pine-oak or pitch pine lowland forest matrix (Zampella and Laidig 2003). To evaluate the relationship between water-level fluctuations in ponds and forests of the region, we used Spearman rank correlation to relate the water depths of each of the three ponds to the water depths of shallow wells installed in a pitch pine lowland and a pine-oak upland forest plot. The two adjacent forest plots were 19 km from Hampton and Furnace and 30 km from Chew (Fig. 1). Water-level values from three wells in each forest plot were averaged for a single monthly value for each plot. The water-level data were a subset of the data used in Zampella et al. (2001a). Although pond and well water levels were both collected monthly during the 1996–2006 period, we excluded dates when the ponds were dry or frozen and dates when the pond and well measurements were more than 2 days apart. This resulted in 49, 50, and 51 dates (Furnace, Chew, and Hampton, respectively) for relating water levels of the three ponds to those for each forest plot.

Climatic conditions

We obtained long-term stream-discharge and precipitation data from nearby stations to assess climatic conditions during the 1996–2006 study period. Daily stream-discharge data were obtained from the U. S. Geological Survey for the McDonalds Branch at Brendan T. Byrne State Forest gaging station (Fig. 1). The McDonalds Branch station represents a minimally impacted hydrologic-benchmark site (Mast and Turk 1999). Daily precipitation data were acquired for the Indian Mills, Albertson Brook near Hammonton, and the Greenwood Branch at New Lisbon stations (Fig. 1). To determine whether overall climatic conditions were similar during each year of the 1996–2006 study period, we compared total monthly precipitation values and mean monthly stream-discharge values between years using Kruskall–Wallis ANOVA tests. Post hoc comparisons were completed using multiple comparisons of mean ranks (Siegel and Casetllan Jr 1988).

Short-term simulations

To simulate the potential impact of ground-water withdrawals on pond hydroperiod over a short-term (2-year) period, we created 10 water-depth-reduction scenarios by subtracting from 5 to 50 cm (in 5-cm increments) from each weekly or biweekly water-depth value measured at the three study ponds in 2005 and 2006. For each pond and year, we determined the date of initial pond drying based on actual water-depth measurements and for the 10 water-depth-reduction scenarios. Drying dates were used to determine pond hydroperiods. We determined which scenarios would have induced pond drying prior to the earliest egg-deposition date for each focal species at a pond. We also calculated the percentage of the total number of larvae, pre-metamorphs, and metamorphs that would have occurred on the drying dates for each focal species present at a pond.

Long-term simulations

To simulate the potential impact of ground-water withdrawals on pond hydroperiod over a long-term (10-year) period, we subtracted from 5 to 50 cm (in 5-cm increments) from each monthly water-depth value measured at the three ponds from 1996 to 1999 and 2001 to 2006. We excluded 2000 because water-depth measurements were missing for June, July, and August of that year. The date of initial drying was determined for each pond in each year based on actual water-depth measurements and for the 10 water-depth-reduction scenarios. For each scenario, we determined the percentage of the 10 years that each pond dried prior to the earliest date in which eggs were found during the 2-year period and prior to the date in which we first observed pre-metamorphs and metamorphs for each focal species at a pond during the 2-year period.

We also applied the long-term-hydroperiod reductions to southern leopard frog metamorph production. This analysis was limited to leopard frogs because metamorph sample size was the greatest for this species. Because the window of metamorphosis for leopard frogs varied somewhat among ponds and between 2005 and 2006, we chose the year with the longest metamorphic window for each pond and calculated the percentage of the total number of metamorphs collected on each sample date. We used linear interpolation to estimate the percentage values for individual dates between sample dates, which resulted in a continuous timeline of cumulative metamorph production for the leopard frog at each pond. Using the drying dates from each reduction scenario and the metamorph-production timelines, we estimated the percentage of leopard frog metamorphs produced at each pond during each of the 10 years.

Some pond water-depth values were missing from the long-term record for the months of October–March due to factors such as staff-gage vandalism and frozen-pond conditions. Missing water-depth values did not affect the results of the long-term analyses because none of the reduction scenarios induced pond drying as early as March and the frog data that were applied to the long-term period were collected during the months of March–August of 2005 and 2006, which brackets the earliest and latest dates for oviposition, pre-metamorphs, and metamorphs for all three species.

Results

Pond hydrology

Water-depth fluctuations were strongly correlated among ponds during the 2005–2006 period, with fluctuations most similar between Hampton and Furnace (Hampton vs. Furnace, $r = 0.95$, Hampton vs. Chew, $r = 0.82$, Chew vs. Furnace, $r = 0.80$, $n = 45$ and $P < 0.001$ for all three ponds). Water-depth fluctuations at each of the three ponds were strongly related to water-depth fluctuations in the pitch pine lowland forest plot ($r = 0.85$ and $P < 0.001$ for all three ponds) and the pine-oak upland forest plot ($r = 0.83$ for Furnace, $r = 0.84$ for Hampton and Chew, $P < 0.001$ for all three ponds).

Water depth at the three ponds varied with precipitation (Fig. 3). In 2005, Hampton and Furnace dried in early August, partially refilled, and dried again in early September (Fig. 3). Chew also dried in early September. All three ponds remained dry until early October 2005. In 2006, Chew dried in late August, whereas Hampton and Furnace came close to drying, but did not dry.

In both years, the hydroperiod for Hampton and Furnace was about the same when based on weekly/biweekly versus monthly water-depth values (both ponds were 216 vs. 215 days in 2005 and 365 vs. 365 days in 2006). For Chew, the hydroperiod using the weekly/biweekly and monthly values was identical in 2005 (250 days), but was much shorter in 2006 when using the weekly/biweekly values (236 days) compared to the monthly values (365 days). Based on monthly water-depth measurements, the mean hydroperiod for each of the three ponds was greater in the 2005–2006 period compared to the 1996–2004 period (Table 1).

Climatic conditions

There was no overall difference in total monthly precipitation between years from 1996 to 2004 (ANOVA, $P = 0.270$). There was a difference in mean monthly stream discharge between years from 1996 to 2004 (ANOVA, $P < 0.001$). Mean monthly discharge for 2002 was lower than that for 1996 ($P < 0.001$), 1998 ($P = 0.012$), 2003 ($P = 0.005$), 2004 ($P < 0.001$), 2005 ($P = 0.003$), and 2006 ($P = 0.022$). No other pair wise comparisons were

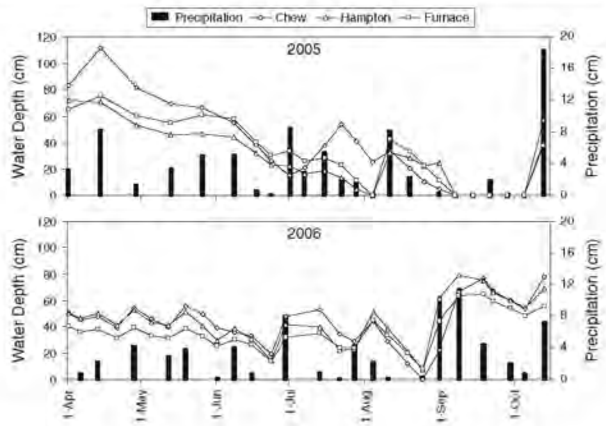

Fig. 3 Hydrographs for three Pinelands ponds in 2005 and 2006. Mean daily precipitation values from three weather stations were summed between pond water depth dates

Table 2 Dates in which eggs were found for three frog species in three Pinelands ponds in 2005 and 2006

Year	Pond	Spring peeper	Pine Barrens treefrog	Southern leopard frog
2005	Chew	–	–	4/14
	Hampton	4/29	–	4/14, 8/11
	Furnace	–	–	8/11, 8/19
2006	Chew	4/28, 5/5	6/1	3/31, 4/21, 5/19, 7/27, 8/10, 8/31, 9/22
	Hampton	4/6, 4/13, 5/5	–	3/31, 4/6, 4/13, 4/21
	Furnace	4/13, 4/28	–	4/6, 4/13, 6/1, 8/31

different, indicating that climatic conditions in 2005 and 2006 were similar to conditions for all but one of the other 8 years.

Breeding and oviposition

We heard eight frog species calling at the three ponds in 2005 and 2006 (Table 1). With the exception of the Fowler's toad, anuran species heard during the 2005–2006 survey period were the same as those heard at the ponds during the 1996–2004 survey period (Table 1). In 2005 and 2006, species were heard calling on dates that corresponded to their documented breeding phenology for the region (Fig. 2).

During 2005 and 2006, eggs were found only for the three focal species (spring peeper, southern leopard frog, and Pine Barrens treefrog). The southern leopard frog deposited eggs first, followed by the spring peeper, and then the Pine Barrens treefrog (Table 2). Southern leopard frog egg masses were found in all three ponds in both years and during a greater number of sampling dates in each year (3 dates in 2005, 10 dates in 2006) compared to the spring peeper (1 date in 2005, 4 dates in 2006) and Pine Barrens treefrog (1 date in 2006). Early season leopard frog egg masses were absent only from Furnace in 2005. Late-season leopard frog egg masses were usually found when a pond partially refilled after it either dried or came close to drying.

Larval development

We collected and staged 4,545 larvae, pre-metamorphs, and metamorphs from the three ponds in 2005 and 2006. Five species were represented, including the carpenter frog (224 individuals), spring peeper (290), green frog (478), Pine Barrens treefrog (1,251), and southern leopard frog (2,302). We found carpenter frog larvae in Hampton in 2005 and Hampton and Furnace in 2006 and green frog larvae in Chew and Furnace in both years (Table 1). Carpenter frog and green frog larvae appeared in ponds relatively late in the season (late July for both years) and neither species was able to complete larval development prior to pond drying. Carpenter frog larvae were observed at developmental stage 28 in 2005 and stages 25–33 in 2006. Green frog larvae were found at stages 25–27 in 2005 and stages 25–40 in 2006.

Spring peeper, Pine Barrens treefrog, and southern leopard frog larvae were present in all three ponds in 2005 and 2006. The abundance of larvae and pre-metamorphs varied widely among the three focal species and three ponds (Table 3).

Based on size and developmental stage, almost all of the southern leopard frog larvae captured in Furnace in 2005 and a few of the leopard frog larvae collected from Hampton in 2005 hatched during the previous year and spent the winter of 2004/2005 in the ponds. Leopard frogs did not overwinter in Chew in the 2004/2005 season or in any pond in the 2005/2006 season. Spring peepers and Pine Barrens treefrogs did not overwinter in any pond during the study.

Table 3 Number of larvae, pre-metamorphs, and metamorphs collected for three frog species from three Pinelands ponds in 2005 and 2006

Species	2005			2006		
	Chew	Hampton	Furnace	Chew	Hampton	Furnace
Spring peeper						
Larvae	70	18	27	31	51	58
Pre-mets.	10	–	2	–	7	11
Mets.	4	–	–	–	–	1
Pine Barrens treefrog						
Larvae	337	20	100	312	86	159
Pre-mets.	77	6	24	49	16	22
Mets.	29	1	–	11	–	2
Southern leopard frog						
Larvae	220	221	204	143	426	708
Pre-mets.	61	25	54	2	47	43
Mets.	29	16	54	2	21	26

Unlike the spring peeper, low numbers of Pine Barrens treefrog and southern leopard frog larvae were often present during the sampling event prior to a pond drying. Almost all of the larvae present during sampling events after a pond dried and partly refilled were from the southern leopard frog, although some Pine Barrens treefrog larvae were occasionally present. This indicated that both of these species were capable of breeding relatively late in the season.

Metamorphosis

In each year, spring peeper metamorphs were found in one pond, Pine Barrens treefrog metamorphs at two ponds, and southern leopard metamorphs at all three ponds. Similar to the larvae and pre-metamorphs, the number of metamorphs collected also varied among species and ponds (Table 3).

With three exceptions, metamorphosis for the three focal species began on June 23 of each year. The exceptions were southern leopard frog (June 17) and Pine Barrens treefrog (July 15) in Hampton in 2005 and Pine Barrens treefrog (July 13) in Furnace in 2006. With one exception, metamorph production for the focal species appeared to stop from two to six sampling events (13–41 days, mean ± 1 SD of 20 ± 11 days) prior to a pond drying. The exception was Chew in 2006, where we collected metamorphs during the sampling event prior to the pond drying.

Short-term simulations

The first two water-depth-reduction scenarios (5 and 10 cm reductions) would have resulted in little or no change to the hydroperiods of the three ponds in 2005 and Chew in 2006 (Fig. 4). For Hampton and Furnace in 2006, the first reduction scenario would not have caused either pond to dry and the second scenario would have resulted in both ponds drying at 237 days (August 24, Fig. 4). This was the same hydroperiod for Chew in 2006 based on actual water-depth measurements and from the first two scenarios.

The first two reduction scenarios would have also resulted in little or no impact to the percentages of larvae, pre-metamorphs, or metamorphs that occurred for the three focal species (Fig. 5). In contrast, some of the larger water-depth reductions would have shortened pond hydroperiods in both years to the point where relatively few or no larvae and pre-metamorphic larvae were present and metamorph production had not yet begun. The 45 and 50-cm scenarios in 2005 would have induced pond drying sometime between mid-May and mid-June and the 35, 40, 45, and 50-cm scenarios in 2006 indicated that the ponds would have dried between early April and early June (Fig. 4). None of the ponds was estimated to produce metamorphs for any species under these six scenarios.

Simulated pond drying would have affected initial oviposition only in 2006. The greatest effects were observed for Chew, where the 40, 45, and 50-cm scenarios would have resulted in pond drying prior to the date of first oviposition for the spring peeper and Pine Barrens treefrog. As mentioned previously, Pine Barrens treefrog eggs were observed on only one date (Table 2). The 50-cm scenarios would have induced pond drying prior to the date of first oviposition for all ponds in which spring peeper eggs were observed. For the southern leopard frog, the 50-cm scenarios would have caused Furnace to dry prior to the date of first oviposition and would have induced Chew and Hampton to dry 1 day after the date of first oviposition. Overall, the effects of simulated water-depth reductions on hydroperiod, oviposition, larval development, and metamorphosis were estimated to be greater in 2006 compared to 2005 probably because ponds started out with less water in 2006 (Fig. 3).

Long-term simulations

Over the 10-year period, pond hydroperiod (drying date) based on the actual water-depth measurements ranged from 190 days (July 8) to 365 days (i.e., not drying at all). The 5- and 10-cm reduction scenarios would have had no effect on pond hydroperiod during 8 and 5 of the 10 years, respectively, whereas the 50-cm reductions would have resulted in hydroperiods that ranged from 96 days (April 5) in 2006 to 239 days (August 26) in 1996.

None of the ponds would have dried prior to the date of initial egg deposition for any species based on the actual water-depth measurements and for the first three reduction scenarios (Fig. 5). Effects on initial spring peeper and Pine Barrens treefrog oviposition were estimated to occur for reductions of $\geq$20 cm. For Pine Barrens treefrog oviposition, which only occurred on one date at Chew (Table 2), the 50-cm reduction scenario would have caused Chew to dry prior to the date of first egg deposition during 5 of the 10 years (Fig. 5). For the spring peeper, the 50-cm scenario would have caused Hampton, Furnace, and Chew to dry prior to first oviposition during 1, 2, and 3 of the 10 years, respectively. The simulations showed the greatest estimated impact on the first

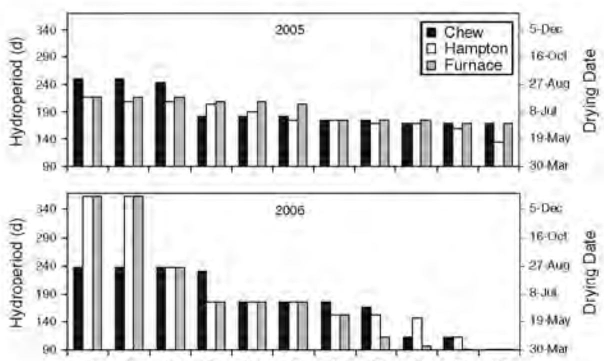

Fig. 4 Hydroperiods for three Pinelands ponds in 2005 and 2006 for the actual water-depth measurements and for water depths reduced by 5–50 cm

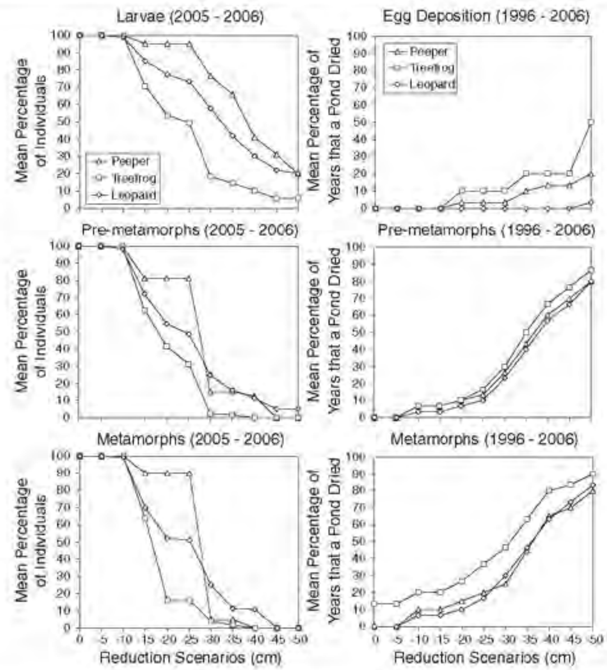

Fig. 5 Mean percentage of individual larvae, pre-metamorphs, and metamorphs that occurred on drying dates for 2005–2006 (*left panel*) and mean percentage of years from 1996 to 2006 in which three Pinelands ponds dried prior to the date of initial egg deposition and appearance of the first pre-metamorphs and metamorphs (*right panel*) for the actual water depth measurements and for water depths reduced by 5–50 cm

date of oviposition for the Pine Barrens treefrog compared to the spring peeper. Simulated pond drying was estimated to have little effect on the first date of oviposition for the southern leopard frog (Fig. 5).

With one exception, based on the actual water-depth measurements, none of the ponds would have dried prior to the appearance of the first pre-metamorphs and metamorphs for any of the three focal species (Fig. 5). The exception was that Hampton and Furnace would have dried before the first Pine Barrens treefrog metamorphs in 2001 and 2004. On average, estimated impacts to the date of the first pre-metamorphs and metamorphs began at reductions of 10–15 cm and increased more sharply for reductions ≥20 cm. The 50-cm scenarios would have resulted in the ponds drying prior to the first pre-metamorphs and metamorphs during 80–90% of the years.

Although the differences were not dramatic, the reduction scenarios showed the greatest average impact for pre-metamorphs and metamorphs of the Pine Barrens treefrog compared to the spring peeper and southern leopard frog (Fig. 5). The lack of major differences among species for the estimated impact of hydroperiod reductions on pre-metamorphs and metamorphs was due to the similarity in the timing of metamorphosis among species and ponds.

The separate analysis on southern leopard frog metamorph production showed that long-term mean metamorph production for this species decreased with each successive water-depth-reduction scenario (Fig. 6). For each scenario, variation in long-term mean metamorph production within and among

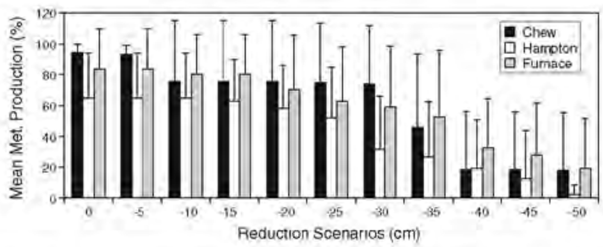

Fig. 6 Long-term mean (1 SD) metamorph production for southern leopard frogs for three Pinelands ponds for the actual water-depth measurements and water depths reduced by 5–50 cm. Means represent an average of 10 annual values from 1996 to 2006. The year 2000 was excluded due to incomplete hydroperiod data

ponds was due to different annual hydroperiods for each pond over the 10-year period and the different pond-specific leopard frog metamorph-production timelines used. Declines in long-term metamorph production for the leopard frog were more pronounced for reductions of ≥30 cm, especially for Hampton, which was estimated to produce very few metamorphs for the 50-cm reductions. Hampton displayed the lowest mean metamorph production for almost every scenario because it was slightly shallower than Furnace and Chew.

Discussion

Our results show how water-depth reductions that may result from ground-water withdrawals have the potential to reduce pond hydroperiods and lead to impacts on the various life stages of frogs. For the long-term analysis, the actual and reduced hydroperiods were determined from monthly water-depth measurements, but ponds may have actually dried at some point between those monthly readings, which would have resulted in a shorter hydroperiod. Inflated hydroperiods derived from monthly readings would result in overestimated metamorph production and underestimated impacts to the first date of encountering eggs, pre-metamorphs, and metamorphs. This indicates that our long-term results are likely somewhat conservative. Compared to the long-term analysis, the results of the short-term simulations were probably more accurate due to the use of hydroperiods derived from biweekly/weekly water-depth values and because we estimated impacts during the period when we actually collected the frog life-stage data.

Water-depth reductions that resulted in pond drying prior to the date of the initial appearance of pre-metamorphs, metamorphs, and eggs were striking because of the consequences of the total lack of recruitment for those scenarios. Our analysis did not incorporate the cumulative effects of water-depth reductions or reduced or failed recruitment in successive years. While the threshold at which persistently low metamorph production would cause a species to decline at any particular pond is not known, the combined effect of low metamorphic success, reduced larval development, and the lack of water for oviposition would magnify the probability of decline or even extirpation at a pond. Although long-term hydroperiod reductions may be particularly detrimental to relatively short-lived frog species due to the cumulative effect of reduced juvenile recruitment each year and the relatively few number of times that a short-lived species may be capable of breeding (Berven 1990), pond-breeding amphibian populations appear fairly resilient to the effects of multiple years of low metamorphic success due to short (≤100 days) hydroperiods (Semlitsch et al. 1996) and even several years of no water from prolonged droughts (Gibbons et al. 2006).

Our analysis did not include the possibility of acceleration of larval development in response to pond drying (Denver 1997). While acceleration has been shown for several amphibian species, acceleration often results in fewer individuals reaching metamorphosis (Parris 2000; Ryan and Winne 2001; Ryan 2007) and individuals that metamorphose are usually smaller (Crump 1989; Denver et al. 1998; Ryan and Winne 2001), which may (Berven 1990) or may not (Boone 2005) affect juvenile survival. Increased larval density as a pond dries may even extend larval period and delay metamorphosis (Leips et al. 2000). Although we found no studies on acceleration for the spring peeper or Pine Barrens treefrog, acceleration in southern leopard frogs can range from 2 days (Parris 2000) to 15 days (Ryan and Winne 2001). Although it is possible that some focal-species larvae could accelerate development, acceleration values for frogs are relatively short and our results showed that relatively few or no pre-metamorphic larvae were present and ready to metamorphose when a pond was estimated to dry.

Early breeding and oviposition may provide an advantage for the spring peeper and southern leopard frog over the Pine Barrens treefrog. For the spring peeper, the relatively low abundance of larvae, pre-metamorphs, and especially metamorphs at the study ponds during 2005 and 2006 suggested that peepers may constitute a relatively minor component of total annual metamorph production for Pinelands ponds. The spring peeper constituted a relatively small proportion of the number of metamorphs collected from a coastal plain pond in South Carolina (Gibbons et al. 2006) and seven woodland vernal pools in Rhode Island (Paton and Crouch 2002). Unlike the spring peeper, the propensity for the southern leopard frog to deposit egg masses very early and periodically throughout the season and the ability of the larvae to overwinter in a pond likely contributed to its relatively high larval, pre-metamorph, and metamorph abundance at the ponds. Southern leopard frogs have been observed to be a dominant component of the metamorphs that emerged from a South Carolina coastal plain pond (Gibbons et al. 2006).

Like our study, late-season oviposition by the southern leopard frog has been observed in several other regions of the United States (Wright and Wright 1949; Martof et al. 1980; Caldwell 1986) and, similar to what we noted, appears to be related to precipitation events (McCallum et al. 2004). Late-season breeding for the southern leopard frog and the Pine Barrens treefrog may provide an opportunity for both species to exploit ponds that dry and refill late in the season, which would reduce or eliminate aquatic predators and competitors (Morin et al. 1990; Semlitsch et al. 1996). Late-season breeding is more likely to benefit the leopard frog because of the ability of the larvae to overwinter. In any case, premature pond drying associated with ground-water pumping may eliminate the possibility of larvae overwintering for any species. The lack of early season leopard frog egg masses in Furnace in 2005 may have been due to the presence of large leopard frog larvae that overwintered from the previous season because they can prey upon freshly deposited anuran eggs and recent hatchlings (Faragher and Jaeger 1998).

Our findings that the Pine Barrens treefrog was the most vulnerable to water-depth reductions and the spring peeper the least vulnerable must be interpreted with some caution because peeper and treefrog pre-metamorphs and metamorphs were not found in all ponds and sample size was low at some ponds. Despite small sample sizes, the trends were similar to those with larger sample sizes. The single date of June 1 in which we observed treefrog eggs seemed a little late for this species because treefrogs typically begin vocalizing in mid- to late-April (Fig. 2) and have been observed in amplexus and depositing eggs in late-April/early May (JFB, personal observation). Nonetheless, the June 1 date falls between the mid-May and mid-June breeding pulses reported for Pinelands ponds in Morin et al. (1990) and the estimated impacts of water-level reductions on oviposition would have been similar even if we used an early May egg-deposition date.

The lack of complete larval development for the carpenter frog and green frog indicated that these two species require a longer hydroperiod than the three focal species. Both species can be heard vocalizing from temporary and permanent-water habitats in the Pinelands (Zampella and Bunnell 2000; Bunnell and Zampella 2008) and elsewhere (Werner and McPeek 1994; Werner et al. 1995; Otto et al. 2007). Although both species can develop and metamorphose if eggs are deposited early enough in the year, they typically spend one winter as larvae and metamorphose the following season (Martof 1956; Standaert 1967). In our study, larvae of both species were still developing in Furnace in mid-October 2006, which indicated that larvae probably overwintered into 2007. Ground-water withdrawals that cause early pond drying every year would likely eliminate these species because of their long larval periods, which is particularly important for the carpenter frog because of its conservation status in New Jersey, Delaware, Maryland, and Virginia.

Although adults were heard calling, the absence of eggs and larvae for the New Jersey chorus frog, northern gray treefrog, and wood frog may be due to the low pH of the ponds. Although these non-Pinelands species can occasionally be heard calling from Pinelands ponds (Zampella and Bunnell 2000), the environmental resistance associated with the low pH of Pinelands wetlands may prevent acid-sensitive non-native species from reproducing successfully (Gosner and Black 1957; Bunnell and Zampella 1999, 2008).

Management applications

The strong relationships for water levels among the ponds and between the ponds and distant forest plots emphasized the linkage between ground-water and pond-water levels and indicated that hydrologic patterns for ponds and forests were similar across the region. Zampella et al. (2001a) found that ground-water levels in Pinelands forest plots mirrored reference-forest sites regardless of whether they were proximate or distant. Like Carolina Bays, which are also found in coastal-plain soils, Pinelands ponds appear to represent a "surface expression of the water table" (Lide et al. 1995). Variations in pond-water levels reflect ground water, which, in the highly permeable sand and gravel sediments of the region, are responding directly to precipitation (Rhodehamel 1979a).

The impact of long-term hydrologic alterations on anurans may become increasingly important in the future due to increased ground-water withdrawals in human-dominated regions and greater variability in future weather patterns predicted in climate-change models (IPCC 2001; Hulme et al. 2002). Our results can be used to assess the potential impacts of ground-water withdrawals on the various life stages of pond-breeding frogs. Although different measures were used for the short-term and long-term simulations, the results of all simulations indicated that impacts would generally begin to occur at water-depth reductions of 10–15 cm. For all simulations, successively greater reductions would have caused increasing impacts that varied by species and pond, with the 50-cm reductions shortening pond hydroperiods enough to practically eliminate the possibility of larval development and metamorphosis for all three species.

Our results can be used in conjunction with watershed-wide hydrologic models that were developed as part of the larger Kirkwood–Cohansey Project (Pinelands Commission 2003). These models will be used to estimate the potential effects of ground-water pumping on various hydrologic and ecological attributes of Pinelands wetlands and to help determine the optimum location, depth, and pumping rate for water-supply wells. Some of the general well-siting criteria determined from the Kirkwood–Cohansey project may also be applicable to other coastal-plain regions.

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Acid Water Anuran Pond Communities Along a Regional Forest to Agro-Urban Ecotone

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We related the distributions of adult and larval anurans to 14 environmental variables in 14 acid water ponds located within drainage areas that displayed a range of agricultural and developed land use cover in the New Jersey Pinelands (Pine Barrens). Species were classified as those restricted to the Pinelands (Pine Barrens species: *Hyla andersonii* and *Rana virgatipes*), those with a wide-ranging distribution in southern New Jersey (wide-ranging species: *Pseudacris crucifer crucifer*, *Bufo fowleri*, *Rana sphenocephala utricularius*, and *Rana clamitans melanota*), and those normally unable to enter the Pinelands except in habitats disturbed by human activities (border-entrant species: *Hyla versicolor*, *Pseudacris kalmi*, *Acris crepitans crepitans*, and *Rana sylvatica*). The frequency of occurrence of Pine Barrens and wide-ranging species was greater than that of any border-entrant species. Detrended correspondence analysis revealed an adult community gradient associated with geographic position where border-entrant species were heard only at ponds located along the transition between forested and disturbed landscapes. Principal component analysis revealed a primary environmental gradient of increasing pH and emergent herbaceous vegetation cover and decreasing specific conductance and floating vegetation cover and contrasted natural and artificial (borrow pits) pond types. Floating vegetation cover and specific conductance were lower and pH was higher in artificial versus natural ponds. Larval recruitment occurred for all species except the four border entrants and *B. fowleri*. Larval species richness was directly related to emergent herbaceous vegetation cover and inversely related to specific conductance. Our results suggest that landscape patterns influence the distribution of adult anurans, whereas pond chemistry may limit recruitment.

POND water pH has a major influence on the distribution and abundance of anurans (Pierce, 1985; Freda, 1986). Acid waters are lethal to many anuran species (Beebee and Griffin, 1977; Saber and Dunson, 1978; Karns, 1992), affecting embryonic and larval development and survival (Freda and Dunson, 1985; Freda et al., 1991; Freda and Taylor, 1992). Gosner and Black (1957) were the first to demonstrate the effect of low pH on embryonic development and suggested that interspecific differences in pH tolerance limited the distribution of anurans. Their frequently cited and widely applied paper focused on species found in and adjacent to the New Jersey Pinelands (Pine Barrens).

In the Pinelands region, streams and ponds unaffected by upland land uses are characterized by acid waters that are low in dissolved solids and often dark colored (Freda and Dunson, 1986; Morgan and Good, 1988; Zampella, 1994). Native Pinelands anurans, such as *Hyla andersonii* and *Rana virgatipes*, are tolerant of these harsh conditions (Gosner and Black, 1957; Freda and Dunson, 1986), whereas anurans whose natural distribution is outside the Pinelands may reproduce within the region only in areas that have been altered by human activity (Gosner and Black, 1957; Conant, 1962, 1979). Although biotic interactions can influence anuran community organization (Morin, 1983; Woodward, 1983; Wilbur, 1987), it is doubtful that biological resistance from native Pinelands anurans could prevent invasion by these nonnative species. For example, results from studies in artificial ponds indicate that *H. andersonii* may be a poor competitor (Morin et al., 1988, 1990; Pehek, 1995).

Although species' boundaries may fluctuate naturally over time (MacArthur, 1972), range changes may be accelerated in human-dominated regions (Lodge, 1993). Because elevated pH is associated with waters modified by agricultural and developed land use activities (Morgan and Good, 1988; Zampella, 1994), disturbed landscapes may offer less environmental resistance (Baltz and Moyle, 1993; Moyle and Light, 1996) to anuran species that are normally unable to tolerate the extreme acidity of typical Pinelands ponds. Altered landscapes may also serve as a source for the spread and establishment of nonnative species into relatively undisturbed areas (Forman, 1995). The composition of anuran communities occurring along the

Fig. 1. Location of 14 study ponds along the northwestern boundary of the Mullica River drainage basin in the New Jersey Pinelands. Shaded areas represent altered land (agricultural and developed land uses).

transition from forested landscapes to agricultural and urban landscapes (forest to agro-urban ecotone) can offer insight into the dynamics of species invasions.

We studied ponds within Pinelands drainage areas that displayed a range of agricultural and developed land uses (Fig. 1). Proximity to altered landscapes varied among these ponds. In this paper, we address two related questions. First, do adult anuran assemblages vary in relation to site-specific conditions and local and regional landscape characteristics? Second, what site-specific, local, or regional factors are associated with larval recruitment in these assemblages?

Materials and Methods

Study sites and species surveys.—We chose 14 ponds within publicly owned forest lands along the northwestern boundary of the 1473 km^2 Mullica River basin (Fig. 1). Each site was assigned a name. The nine westernmost ponds were in drainages with a high percentage of developed and agricultural land use, whereas the five other ponds were within relatively undisturbed drainages along the northern boundary of the study area. Ten ponds were natural, and four ponds (Chew, Sphagnum, Furnace, and Hampton) were shallow borrow pits (i.e., small areas excavated for fill). These small excavations are a common feature throughout the Pinelands.

To inventory vocalizing adults, we conducted eight surveys for each pond, except for Furnace pond ($n = 7$), between dusk and midnight from 13 March to 24 July 1996. We chose survey nights based on breeding phenology and optimal weather conditions, and stopped a survey if it became too cold or windy. The mean ($\pm$ SD) number of days between visits to a particular pond was less in the March through April period (11.9 ± 3.7 days) compared to the May through July period (18.4 ± 6.2 days) to ensure that we heard species with early, short breeding periods. Using a ranking system, where $0 =$ none calling, $1 = 1$ calling, $2 = 2$–5 calling, $3 = 6$–10 calling, and $4 = > 10$ calling individuals, we estimated the number of vocalizing adults of each species heard during a 5-min period.

We used Conant's (1979) classification to characterize the distribution of anurans as either Pine Barrens, wide ranging, or border entrant (Appendix 1). These classes indicate differences in geographic affinity. Within New Jersey, species classified as Pine Barrens species are restricted to the Pinelands area, whereas wide-ranging species are widely distributed across the southern portion of New Jersey, including the Pinelands. Species normally unable to enter the Pinelands except in human-altered habitats are classified as border entrants. Border-entrant species are widely distributed outside the Pinelands in southern New Jersey. We refer to Pine Barrens and wide-ranging species as characteristic Pinelands species. Common and scientific names throughout this paper conform to Collins (1997). The nomenclature that we used may differ from that of other sources (e.g., Conant and Collins, 1998).

On four separate occasions from May through August, we thoroughly sampled all microhabitats throughout each pond for larvae with a 45 × 23 cm, 2-mm mesh nylon dipnet. With one exception (Hays), we also sampled ponds that had > 10% open water using a 4 mm mesh nylon seine. Sampling duration for each visit ranged from approximately 0.5 h for small ponds to 2.0 h for large ponds. Although we did not intensively search for eggs, we noted the presence and condition of all egg masses that we encountered. We used Altig (1970) to identify larvae. Voucher specimens are housed at Pinelands Commission headquarters.

We used the presence of larvae or metamorphosing individuals (≥ stage 25, Gosner, 1960) as an indication of recruitment and refer to both as larvae. We calculated the percentage of recruitment for each species as [(number of ponds with larvae of a species/number of ponds with adults of that species) × 100].

Environmental variables.—We included 14 environmental variables in our analysis. Site-specific attributes were median pH, median specific conductance, water color, pond area, water depth range, and percentages of floating vegetation, emergent herbaceous vegetation, emergent woody vegetation, open water, shrub cover, and tree cover. Local and regional environmental variables were the percentage of adjacent altered land and latitude and longitude, respectively.

All environmental variables, except pond area, were measured in 1996. We measured pond area in March of 1998 by walking along the shrub/tree-water interface with a global positioning system. March is generally a period of high water in the Pinelands. We measured water depth at the center of each pond on five separate occasions from May to September. In mid-September, we characterized the habitat structure within each pond by visually estimating the percentage cover of floating vegetation (algae, *Nymphaea odorata*, *Sphagnum* spp., and *Utricularia* spp.), emergent herbaceous vegetation (*Dulichium arundinaceum* and various *Carex*, *Juncus*, *Panicum*, and *Scirpus* species), emergent woody vegetation (*Acer rubrum*, *Chamaedaphne calyculata*, *Cephalanthus occidentalis*, and *Decodon verticillatus*), and open water. We also visually estimated the percentage of shrub (*C. occidentalis*, *C. calyculata*, *Clethra alnifolia*, *Eubotrys racemosa*, *Gaylussacia* spp., *Kalmia angustifolia*, and *Vaccinium corymbosum*) and tree (*A. rubrum*, *Chamaecyparis thyoides*, *Nyssa sylvatica*, and *Pinus rigida*) cover within a 1-m band along the shrub/tree-water interface. We completed monthly specific conductance and pH field measurements from April through August and subjectively ranked pond water color as clear (1), intermediate (2), or dark (3). We measured specific conductance and pH with an Orion model 122 conductance meter and an Orion model 250A pH meter with a Ross combination electrode.

We used 1991 aerial photography (1:12,000 scale) and a point intercept method to estimate the percentage of forest land (upland and wetland), upland agriculture, blueberry agriculture, and developed (residential) land cover within a 500-m radius of each pond. We combined agricultural and developed land cover types into a percentage altered land for each 78.5-ha circular area. We also registered the geographic position of each pond with a global positioning system.

Data analysis.—We used detrended correspondence analysis (DCA; Hill, 1979a; Hill and Gauch, 1980) to produce an ordination of species and sites based on adult presence/absence data. With the same data, we classified species and sites using TWINSPAN (Hill, 1979b). DCA and TWINSPAN were performed using DECORANA and TWINSPAN programs (Microcomputer Power, Ithaca, NY, 1987, unpubl.). Default options were used for both analyses.

To reduce the list of site-specific environmental factors and identify the major sources of variation in these data, we performed a centered-standardized principal component analysis (PCA) using ORDIFLEX (Microcomputer Power, Ithaca, NY, 1977, unpubl.) and 10 site-specific variables. Because PCA is a mathematical rather than statistical technique, no assumption is made regarding the distribution of the original variables (Chatfield and Collins, 1980). However, the results may be more meaningful if the data are assumed to be multivariate normal. Prior to analysis, we logarithmically transformed specific conductance, pond area, and water depth range and arcsine transformed the percentages of floating vegetation, emergent herbaceous vegetation, emergent woody vegetation, open water, shrub cover, and tree cover to better approximate a normal distribution (Zar, 1984). We did not transform pH. Because water color was ranked data, we excluded it from the PCA.

We used Spearman rank correlation to determine whether adult community attributes or larval recruitment varied in relation to site-specific, local, or regional environmental factors. We evaluated the relationship between four community attributes and seven environmental factors. The four community attributes were the first and second DCA axes based on adult presence/absence data and adult and larval species richness. The seven environmental factors were latitude, longitude, percentage adjacent altered land, and four site-specific variables (pH, specific conductance, floating vegetation cover, and emergent herbaceous vegetation cover). We selected the four site-specific variables based on the results of the PCA. We also correlated the first DCA axis with the percentage of border-entrant species vocalizing for each pond.

TWINSPAN is a relatively objective method of producing site classes (groups of ponds) based on species data. To directly compare biological and environmental attributes among ponds defined by the first two TWINSPAN site classes, we used the Mann-Whitney test to evaluate differences in adult and larval species richness and the seven environmental variables (latitude, longitude, percentage adjacent altered land, pH, specific conductance, floating vegetation cover, and emergent herbaceous vegetation cover) between these two classes. To determine whether a particular species was associated with one TWINSPAN group or the other, we used 2 × 2 contingency table analysis and the Fisher exact test to compare the occurrence of each species of adult between the two site classes.

We compared environmental factors between ponds with border-entrant species and ponds without these species to determine whether the presence of these species may be due to differences in site-specific, local, or regional environmental attributes. We used the Mann-Whitney test to test for differences in the seven environmental variables (latitude, longitude, percentage adjacent altered land, pH, specific conductance, floating vegetation cover, and emergent herbaceous vegetation cover) between these two community types.

To compare biological and environmental attributes of artificial (borrow pits) and natural ponds, we used the Mann-Whitney test to test for differences in adult and larval species richness and the seven environmental variables (latitude, longitude, percentage adjacent altered land, pH, specific conductance, floating vegetation cover, and emergent herbaceous vegetation cover) between these two pond types. To investigate whether any particular species of adult was associated with either pond type, we used 2 × 2 contingency table analysis and the Fisher exact test to compare the occurrence of each species of adult between both pond types. We also used 2 × 2 contingency table analysis and the Fisher exact test to compare the occurrence of each species of larvae between pond types.

We applied the sequential Bonferroni significance level adjustment within sets of related Spearman rank correlations, Mann-Whitney tests, and Fisher exact tests (Rice, 1989). We report the initial *P*-values, give the number of tests pooled for adjustment, and indicate which results are significant at the Bonferroni adjusted levels in the tables of statistical results. The alpha level for all tests was 0.05. All Mann-Whitney and Fisher exact tests were two-tailed tests. Statistical analyses were completed using Statistica for Windows (Statsoft, Inc., Tulsa, OK, 1994, unpubl.).

RESULTS

Species inventory.—We heard a total of 10 species vocalizing during the night surveys. These included the two Pine Barrens species, four wide-ranging species, and four border-entrant species (Appendix 1). The number of species heard per pond ranged from two to seven. The frequency of occurrence of all six characteristic Pinelands species was greater than that of any border entrant. Wesickaman was the only pond where Pine Barrens species were not heard. Pine Barrens treefrog (*Hyla andersonii*), northern spring peeper (*Pseudacris crucifer crucifer*), and green frog (*Rana clamitans melanota*) were the most widely distributed species, occurring at 13 of the 14 ponds. Based on the number of calling individuals, Pine Barrens treefrog and spring peeper were also the most abundant species. Where heard, the maximum calling rank for both species ranged from 2 (2–5 individuals) to 4 (> 10 individuals). Southern leopard frog (*Rana sphenocephala utricularius*) was also widely distributed. Carpenter frog (*Rana virgatipes*) and Fowler's toad (*Bufo fowleri*) were the least abundant and least frequently encountered of the characteristic Pinelands species. Border-entrant species included wood frog (*Rana sylvatica*), gray treefrog (*Hyla versicolor*), New Jersey chorus frog (*Pseudacris kalmi*), and northern cricket frog (*Acris crepitans crepitans*). None of these species was heard at more than four sites. Where heard, the maximum calling rank for border-entrant species ranged from 1 (1 individual) to 3 (6–10 individuals). We excluded northern cricket frog from the ordination and classification analyses because it was heard only at one pond on one occasion.

Larvae were collected in 11 of the 14 ponds (Appendix 1). Five larval species were found, including the two Pine Barrens species and three of the four wide-ranging species. Of these five species, southern leopard frog and Pine Barrens treefrog had the highest percentage recruitment at 80% and 62%, respectively, whereas spring peeper had the lowest at 23%. The percentage recruitment for carpenter frog and green frog was 29% and 38%, respectively. We found no Fowler's toad larvae or larvae for any of the four border-entrant species. Larvae of a species never occurred in the absence of an adult record. We found Fowler's toad eggs in Mullica, and wood frog egg masses in Sandy, Hays, Sleeper, and Albertson. Water color was intermediate to dark in these five ponds (Appendix 2). Albertson was the only pond where we found eggs for a species that we did not hear during our vocalization surveys. Although the

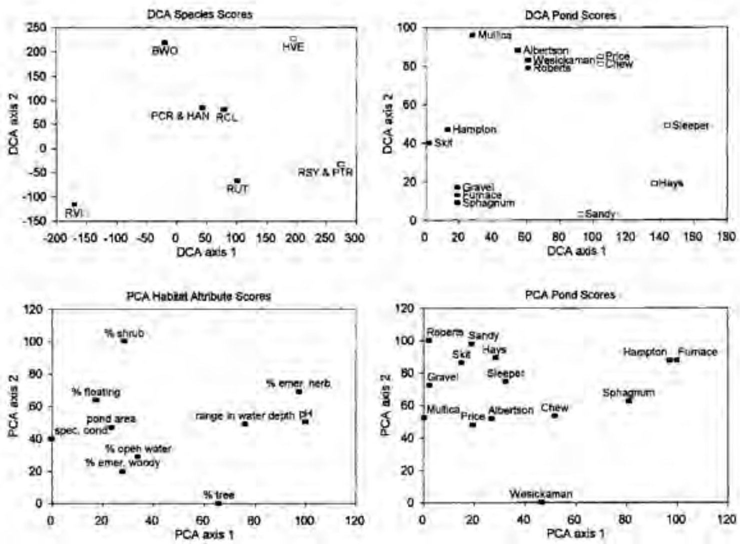

Fig. 2. Species and pond score DCA diagrams and habitat attribute and pond score PCA diagrams. The DCA was based on adult presence/absence data. The two TWINSPAN species and site classes for adult data are shown on the DCA diagrams. The PCA was based on 10 site-specific environmental variables. Refer to Table 1 for species name abbreviations.

Fowler's toad eggs and the majority of the wood frog eggs did not develop, wood frog eggs from Sandy contained numerous embryos curled inside their membranes. All of the wood frog masses were stained brown, rubbery in texture, and covered with a fungus.

DCA ordination.—The first DCA axis (eigenvalue = 0.219) of the species ordination and the TWINSPAN classification separated border-entrant species from the characteristic Pinelands species (Fig. 2). All three border entrants are located to the right of the six characteristic Pinelands species in the species score diagram. Along the second DCA axis (eigenvalue = 0.055) of the species ordination, gray treefrog and Fowler's toad were contrasted with carpenter frog and southern leopard frog (Fig. 2).

The first DCA axis of the site ordination and the TWINSPAN classification separated five ponds (Price, Chew, Sleeper, Hays, and Sandy) from the other nine ponds (Fig. 2). The five ponds are located to the right of the other nine ponds in the pond score diagram. We heard border entrants calling at all five sites (Table 1). Cricket frog, a border-entrant species excluded from the ordination and classification, was heard at Hays. The TWINSPAN site class composed of the other nine ponds was characterized by the presence of Pine Barrens and wide-ranging species and, except for Mullica, the absence of border-entrant species (Table 1).

The most obvious contrast revealed by the second DCA axis of the site ordination was between ponds with carpenter and southern leopard frogs and those without these two species (Fig. 2). Both species were present at a majority of the ponds in the lower half of this axis but were absent at most sites shown in the upper half.

Pond characterization.—The pH of all 14 ponds was low (Appendix 2). Although some of the ponds were small and all were fairly shallow, all contained water throughout the study period. While sampling for larvae, we did not observe or collect fish or salamanders in any ponds. Altered land occurred within 500 m of five ponds (Wesickaman, Sandy, Chew, Price, and Hays) and ranged from 7 to 31%.

TABLE 1. FREQUENCY OF OCCURRENCE OF ADULT ANURAN SPECIES FOR THE FIRST TWO TWINSPAN SITE CLASSES (GROUPS OF PONDS) PRODUCED FROM PRESENCE/ABSENCE DATA. Refer to Appendix 1 for the ponds comprising each site class.

Species	Abbreviation	TWINSPAN Site class 1 (n = 9)	TWINSPAN Site class 2 (n = 5)
Rana virgatipes	RVI	67	20
Hyla andersonii	HAN	89	100
Pseudacris crucifer crucifer	PCR	89	100
Rana clamitans melanota	RCL	89	100
Rana sphenocephala utricularius	RUT	56	100
Bufo fowleri	BWO	33	40
Rana sylvatica	RSY	0	80
Hyla versicolor	HVE	11	60
Pseudacris kalmi	PTR	0	80

PCA ordination.—The first PCA axis (eigenvalue = 3.94) accounted for 39% of the variation in the site-specific environmental data. This axis represented a complex environmental gradient characterized by increasing pH, emergent herbaceous vegetation cover, tree cover, and water depth range, and decreasing specific conductance, floating vegetation cover, emergent woody vegetation cover, shrub cover, open water, and pond area (Fig. 2). Specific conductance and floating vegetation had the lowest loadings, whereas pH and emergent herbaceous vegetation had the highest loadings. These four variables were selected for further analysis. Sphagnum, Furnace, Hampton, and to some degree, Chew, contrasted with the other 10 ponds (Fig. 2). These four artificial ponds displayed the highest pH and lowest specific conductance values, a high percentage of emergent herbaceous vegetation cover, a low percentage of floating vegetation cover, and clear water.

The second PCA axis (eigenvalue = 2.15) accounted for an additional 22% of the variation in the site-specific environmental data (Fig. 2). Ponds along the second axis were separated by subtle differences in the amount of open water, adjacent tree and shrub cover, and emergent woody vegetation cover. Wesickaman, a small, open water pond with high tree cover, was contrasted with the other 13 ponds.

Species-environment relationships.—We found three significant correlations between community attributes and environmental variables (Table 2). Larval species richness was positively correlated with emergent herbaceous vegetation cover and negatively correlated with specific conductance. The first DCA axis (representing adult species composition) was negatively correlated with longitude. This axis was also significantly correlated with the percentage of border-entrant species heard per pond ($r = 0.83$, $P < 0.001$). Conversely, the relationship observed for the percentage of characteristic Pinelands species heard per pond was the inverse of that found for border entrants.

The correlation analysis revealed several other relationships between community attributes and environmental variables (Table 2). However, these associations were not significant after the Bonferroni adjustment. The first DCA axis was positively correlated with percentage altered land. The second DCA axis was negatively correlated with emergent herbaceous vegetation cover. Adult species richness was negatively correlated with latitude and longitude. Larval species richness was positively correlated with pH.

Generally, larval richness was higher in clear water ponds characterized by higher pH, lower specific conductance, and a large percentage of emergent herbaceous vegetation cover (Appendices 1–2). Three artificial ponds, Hampton, Sphagnum, and Furnace, had the highest larval richness with larvae found for at least 60% of the species heard in each pond. Of the three ponds with the darkest water, lowest pH, and highest conductance values, larvae (leopard frog) were found only in Skit. Unlike Pine Barrens treefrog, green frog, and leopard frog larvae, which were found throughout a range of pH and specific conductance, spring peeper larvae were found only in Hampton, Sphagnum, and Furnace ponds where pH was high and specific conductance was low (Fig. 3).

Comparison of TWINSPAN derived site assemblages.—There was a significant difference in adult species richness between the first two TWINSPAN site classes based on adult species data (Table 3). Latitude, longitude, and percentage altered land also differed, but these results were

TABLE 2. SPEARMAN RANK CORRELATION RESULTS FOR FOUR COMMUNITY ATTRIBUTES (THE FIRST TWO DCA AXES AND ADULT AND LARVAL SPECIES RICHNESS) AND SEVEN ENVIRONMENTAL VARIABLES. Attributes significant at the Bonferroni adjusted significance level ($k = 7$ tests for each set, $\alpha = 0.05$) are indicated with an asterisk, and the initial *P*-value is shown for comparison.

Attribute	DCA 1		DCA 2		Adult Species Richness		Larval Species Richness	
	r	Initial *P*-level	*r*	Initial *P*-level	*r*	Initial *P*-level	*r*	Initial *P*-level
pH	−0.04	0.904	−0.24	0.395	0.20	0.491	0.62	0.016
specific conductance	0.06	0.833	0.30	0.296	−0.23	0.424	−0.75	0.002*
% emergent herbaceous veg. cover	−0.07	0.801	−0.57	0.035	0.46	0.096	0.92	<0.001*
% floating vegetation cover	0.30	0.294	−0.07	0.786	−0.22	0.448	−0.36	0.201
latitude	−0.53	0.051	−0.18	0.535	−0.57	0.033	−0.27	0.346
longitude	−0.71	0.005*	−0.40	0.156	−0.65	0.011	−0.02	0.951
% altered land	0.61	0.022	0.29	0.312	0.39	0.167	−0.01	0.971

not significant after the Bonferroni adjustment (Table 3). The higher mean adult species richness for the TWINSPAN site class comprised of the five western ponds was due to the presence of two border-entrant species, wood frog and New Jersey chorus frog (Table 1). These two species were absent from the other nine ponds. Based on the contingency table analysis, there was no significant difference in the occurrence of the other seven species of adults between the two TWINSPAN groups.

Comparison of ponds with and without border-entrant species.—There was a significant difference in longitude between ponds where border-entrant species were heard and ponds where these species were absent (Table 4). Latitude and percentage altered land also differed, but these results were not significant after the Bonferroni adjustment (Table 4). The six ponds where border entrants were heard (Chew, Hays, Mullica, Price, Sandy, and Sleeper) are located on the western side of the study area (Fig. 1).

Comparison of artificial and natural ponds.—There was a significant difference in floating vegetation cover, pH, and specific conductance between artificial and natural ponds (Table 5). Floating vegetation cover and specific conductance were higher and pH was lower in the natural ponds compared to the artificial ponds. Larval richness and emergent herbaceous vegetation cover appeared higher in the artificial ponds, but these differences were not significant after the Bonferroni adjustment (Table 5).

Carpenter frog larvae were found only in natural ponds whereas spring peeper larvae were collected only from artificial ponds (Appendix 1). We found carpenter frog larvae only in Sandy and Gravel, which are among the largest ponds with small ranges in water level indicating more permanent water conditions (Fig. 3). We collected spring peeper larvae only from the smaller, artificial ponds with larger ranges in water depth. Based on the results of the contingency table analysis, there were no significant differences in the occurrence of any species of adult or the other three species of larvae (Pine Barrens treefrog, southern leopard frog, green frog) between these two pond types.

DISCUSSION

Our results suggest that landscape patterns and environmental resistance influence the distribution of adult and larval anurans. The distribution of adults of the four border-entrant species was related to geographic position.

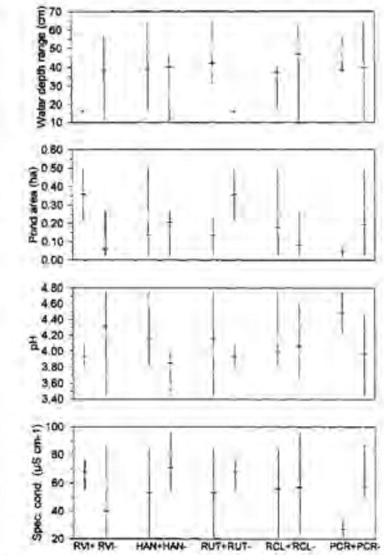

Fig. 3. Distribution of five species of anuran larvae in relation to water depth range, pond area, pH, and specific conductance. Medians and ranges are shown. For each species, (+) = adults and larvae present and (−) = adults present but larvae absent. Larvae of a species never occurred in the absence of an adult record. Refer to Table 1 for species name abbreviations.

These species were heard only at ponds located near the transition between forested and disturbed landscapes. However, we found no recruitment in the 14 ponds for any of these species. Biogeography or proximity to source waters in disturbed landscapes may facilitate dispersal by border entrants, but environmental resistance associated with acid pond waters may

TABLE 3. RESULTS OF MANN-WHITNEY TESTS BETWEEN THE FIRST TWO TWINSPAN SITE CLASSES (GROUPS OF PONDS) PRODUCED FROM ADULT ANURAN PRESENCE/ABSENCE DATA. Attributes significant at the Bonferroni adjusted significance level (k = 9 tests, $\alpha = 0.05$) are indicated with an asterisk, and the initial *P*-value is shown for comparison. Attributes are arranged in order of decreasing significance. The mean (± SD) or median is shown for each attribute. For medians, the first and third quartiles are given in parentheses.

	TWINSPAN Site class 1 (n = 9)		TWINSPAN Site class 2 (n = 5)		
Attribute	Mean or median		Mean or median		Initial *P*-level
adult species richness	4.3	(±1.6)	6.8	(±0.4)	0.003*
longitude (74°)	41′16″	(40′21″–44′23″)	46′53″	(46′37″–49′20″)	0.014
altered land (%)	3	(± 9)	15	(±12)	0.016
latitude (39°)	46′07″	(45′39″–46′52″)	42′52″	(42′35″–43′17″)	0.028
larval species richness	1.4	(±1.5)	2.6	(±0.5)	0.148
emergent herbaceous veg. cover (%)	36	(±38)	35	(±9)	0.316
specific conductance (µS cm^{-1})	58	(40–73)	56	(55–59)	0.641
pH	3.97	(3.85–4.31)	4.00	(3.97–4.06)	0.689
floating vegetation cover (%)	31	(±28)	31	(±16)	0.789

TABLE 4. RESULTS OF MANN-WHITNEY TESTS BETWEEN PONDS WITH AND PONDS WITHOUT BORDER-ENTRANT SPECIES. Attributes significant at the Bonferroni adjusted significance level (k = 7 tests, α = 0.05) are indicated with an asterisk, and the initial *P*-value is shown for comparison. Attributes are arranged in order of decreasing significance. The mean (± SD) or median is shown for each attribute. For medians, the first and third quartiles are given in parentheses.

	Ponds without border-entrant species (n = 8)		Ponds with border-entrant species (n = 6)		
Attribute	Mean or median		Mean or median		Initial *P*-level
longitude (74°)	41'16"	(40'21"–43'23")	47'31"	(46'41"–49'02")	0.003*
latitude (39°)	46'14"	(45'40"–46'58")	43'05"	(42'39"–44'48")	0.039
altered land (%)	3	(±9)	12	(±12)	0.050
emergent herbaceous veg. cover (%)	39.0	(±38.0)	30.0	(±14.8)	0.796
specific conductance (μS cm^{-1})	58	(37–72)	58	(55–64)	0.796
pH	4.06	(3.87–4.36)	3.99	(3.93–4.05)	0.846
floating vegetation cover (%)	33	(±29)	28	(±15)	0.949

prevent recruitment. Environmental resistance of acid waters may also influence the distribution of fish species in the Pinelands (Hastings, 1984; Graham and Hastings, 1984; Zampella and Bunnell, 1998). A study of 17 stream sites in the Mullica River basin showed that fish species not native to the Pinelands were found only in streams impacted by upgradient land use and with pH > 5.5 (Zampella and Bunnell, 1998).

There are several possible explanations for the lack of recruitment by border entrants and Fowler's toad, including low adult frequency and abundance, sampling error, and sensitivity to pond chemistry. The lower abundance and overall frequency of occurrence among the 14 ponds for border entrants and Fowler's toad may have reduced the probability of larvae being found in any one pond. Because male advertisement calls are important for attracting females (Duellman and Trueb, 1986), small choruses may not be as effective as larger choruses. Thus, the overall potential for recruitment may have been less than that of the more abundant and common species.

Although our sampling effort was rigorous and thorough, it is possible that our sampling interval may have been too infrequent to collect Fowler's toad larvae because of their shorter larval period (Wright and Wright, 1949). However, this is unlikely because toads are typically synchronous breeders and we did collect toad larvae from nearby puddles during pond sampling events. Because we timed our sampling with ontogeny, it is doubtful that we missed the entire larval period for any species that we heard.

Pond chemistry is the factor most likely responsible for the lack of larval recruitment among border-entrant species and Fowler's

TABLE 5. RESULTS OF MANN-WHITNEY TESTS BETWEEN ARTIFICIAL AND NATURAL PONDS. Artificial ponds were excavated borrow pits. Attributes significant at the Bonferroni adjusted significance level (k = 9 tests, α = 0.05) are indicated with an asterisk, and the initial *P*-value is shown for comparison. Attributes are arranged in order of decreasing significance. The mean (± SD) or median is shown for each attribute. For medians, the first and third quartiles are given in parentheses.

	Artificial ponds (n = 4)		Natural ponds (n = 10)		
Attribute	Mean or median		Mean or median		Initial *P*-level
floating vegetation cover (%)	8	(±3)	41	(±22)	0.005*
pH	4.44	(4.37–4.54)	3.94	(3.86–3.99)	0.005*
specific conductance (μS cm^{-1})	36	(26–43)	66	(57–73)	0.005*
emergent herbaceous veg. cover (%)	70	(±30)	22	(±16)	0.019
larval species richness	3.0	(±0.8)	1.4	(±1.3)	0.048
longitude (74°)	41'07"	(40'49"–42'40")	46'12"	(43'33"–47'46")	0.322
altered land (%)	7.4	(±14.9)	6.9	(±10.0)	0.743
latitude (39°)	46'02"	(45'03"–46'11")	45'03"	(42'58"–46'34")	0.777
adult species richness	5.8	(±1.0)	5.1	(±2.1)	0.716

toad. Dark-colored, acid waters can be toxic to many species of anurans (Saber and Dunson, 1978; Freda and Dunson, 1986; Karns, 1992). Interspecific differences in hatching due to low pH have been well documented for anurans (Gosner and Black, 1957; Dunson and Connell, 1982; Sadinski and Dunson, 1992). Gosner and Black (1957) demonstrated in the laboratory that, except for wood frogs, the border-entrant species that we encountered were more acid sensitive than the characteristic Pinelands species. They did not test Fowler's toads. In field transplant experiments by Freda and Dunson (1986), Fowler's toad embryos suffered high or complete mortality at and below pH 4.31, although toads indiscriminantly called from ponds regardless of pH and their ability to hatch in the pond.

The dark color of Pinelands waters is caused mainly by humates (Patrick, 1996). Egg mass density and hatching success have been reported to be inversely related to concentrations of total or dissolved organic carbon (DOC; Clark and Hall, 1985; Gascon and Planas, 1985). In laboratory studies, high concentrations of organic (humic and fulvic) acids normally found in dark, high DOC waters have been shown to cause embryonic mortality (Freda et al., 1990). Descriptions of darkened, rubbery egg masses with curled embryos have been reported for eggs exposed to low pH and high concentrations of organic acids (Freda et al., 1990). Other studies have attributed fungal infections to low pH (Gascon and Planas, 1986; Leuven et al. 1986). Low pH can also affect larval development and survival (Freda and Dunson, 1985; Freda et al., 1991; Freda and Taylor, 1992). Vegetation structural complexity has been shown to reduce insect predation on anuran larvae (Babbitt and Jordan, 1996; Babbitt and Tanner, 1997).

As in our study, Freda and Dunson (1986) also found that humanmade ponds in the Pinelands were higher in pH compared to natural ponds. Gosner and Black (1957) reported that spring peepers, gray treefrogs, New Jersey chorus frogs, and wood frogs typically breed within the Pinelands in altered, nonsphagnaceous areas of higher pH, such as pools in flooded fields and gravel pits. Although the distribution of spring peepers was consistent with this premise, we found no association between artificial ponds and any of the border-entrant species. Our finding that Pine Barrens treefrogs can successfully breed in certain humanmade habitats has significant management implications because of their endangered status in New Jersey.

Anuran populations are maintained through replacement, that is, recruitment to the adult stage, and/or dispersal from source areas. Pond chemistry may vary between years (Sadinski and Dunson, 1992), which may allow for recruitment in some years and not in others. This could be important for the maintenance of local populations in stressful environments. In similar, chemically rigorous habitats in northern Minnesota, anuran populations in low pH bogs may be sustained by dispersal from nearby less stressful fen sites (Karns, 1992). Population maintenance through dispersal is most likely to occur in contiguous landscapes if a source is nearby (Laan and Verboom, 1990; Gulve, 1994) but, with good colonizers, can occur even with severely isolated water bodies (Edenhamn, 1996). We heard large choruses of spring peeper, Fowler's toad, and Pine Barrens treefrog at Mullica but found no larvae. The closest potential source of anurans to Mullica is a forested intermittent stream approximately 635 m to the southeast. Although one radioactively tagged Pine Barrens treefrog has been documented to move a distance of 106 m during a single breeding season (Freda and Gonzalez, 1986), it is unknown whether such a large population of these treefrogs could persist solely through long-distance dispersal. Movements and colonization potentials for spring peeper and Fowler's toad are also not clearly known. To assume that dispersal alone sustains these populations indicates that Mullica is a sink habitat (mortality is greater than natality) and never a source (natality is greater than mortality) for these anurans (Forman, 1995; Dias, 1996). Perhaps dispersal and occasional recruitment during favorable chemical conditions play a role in anuran community dynamics in the Pinelands and other acid water systems.

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NEW JERSEY PINELANDS COMMISSION, P.O. BOX 7, NEW LISBON, NEW JERSEY 08064. E-mail: (JFB) science@njpines.state.nj.us. Send reprint requests to JFB. Submitted: 11 Jan. 1998. Accepted: 25 Jan. 1999. Section editor: S. T. Ross.

APPENDIX 1. MAXIMUM CALLING RANKS FOR 10 ANURAN SPECIES FROM 14 PONDS IN THE NEW JERSEY PINELANDS. When present, the number of larvae found are indicated in parentheses. Sites are ordered according to their position along the first DCA axis of the adult species ordination. Classification of species as Pine Barrens, wide ranging, and border entrant follows Conant (1979). Maximum calling rank: 1 = 1, 2 = 2–5, 3 = 6–10, and 4 = > 10 individuals calling. Artificial ponds (borrow pits) are Hampton, Sphagnum, Furnace, and Chew.

Aurhane	Frequency of occurrence	Skit	Hampton	Sphagnum	Gravel	Furnace	Mullica	Albert-son	Roberts	Wesicka-man	Sandy	Chew	Price	Hays	Sleeper
TWINSPAN site class		■	■	■	■	■	■	■	■	■	□	□	□	□	□
Pine Barrens species															
Rana virgatipes	7	1	1	1	3 (> 10)	1	1	0	0	0	3 (1)	0	0	0	0
Hyla andersonii	13	4	3 (> 10)	4 (> 10)	2	3 (> 10)	4	2	3	0	4 (> 10)	4 (> 10)	3 (2)	4 (> 10)	4 (> 10)
Wide-ranging species															
Pseudacris crucifer crucifer	13	4	4 (> 10)	3 (5)	2	4 (2)	4	3	0	4	4	4	4	4	4
Rana clamitans melanota	13	0	1 (> 10)	2	2	2	1	1 (1)	1	2	3 (> 10)	2	4 (> 10)	1	2 (> 10)
Rana sphenocephala utricularius	10	2 (> 10)	3 (> 10)	2 (> 10)	3	2 (> 10)	0	0	0	0	3	2 (> 10)	2 (1)	2 (3)	4 (1)
Bufo fowler	5	2	1	0	0	0	4	0	0	0	0	1	1	0	0
Border-entrant species															
Rana sylvatica	4	0	0	0	0	0	0	0	0	0	1	0	1	2	1
Hyla versicolor	4	0	0	0	0	0	2	0	0	0	0	2	1	0	1
Pseudacris kalmi	4	0	0	0	0	0	0	0	0	0	2	3	0	2	2
Acris crepitans crepitans	1	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Adult species richness		5	6	5	5	5	6	3	2	2	7	7	7	7	7
Larval species richness		1	4	3	1	3	0	1	0	0	3	2	3	2	3

APPENDIX 2. POND ATTRIBUTES FROM 14 PONDS IN THE NEW JERSEY PINELANDS. Sites are ordered according to their position along the first DCA axis of the adult species ordination. Water color is ranked as clear (1), intermediate (2), or dark (3). Artificial ponds (borrow pits) are Hampton, Sphagnum, Furnace, and Chew.

Attribute	Skit	Hampton	Sphagnum	Gravel	Furnace	Mullica	Albertson	Roberts	Wesickaman	Sandy	Chew	Price	Hays	Sleeper
Median pH	3.83	4.69	4.31	3.88	4.49	3.85	3.97	3.74	4.15	4.06	4.39	3.91	4.00	3.97
Median specific conductance (μS cm^{-1})	71	23	40	73	27	75	58	90	57	56	52	66	59	55
Water color	3	1	1	2	1	3	2	3	2	2	1	2	2	2
Pond area (ha)	0.12	0.04	0.03	0.16	0.02	0.24	0.04	0.02	0.05	0.54	0.22	0.18	0.06	0.24
Mean pond center depth (cm)	30.2	51.7	53.5	38.5	51.7	40.8	29.6	31.6	61.8	89.0	41.9	63.0	68.6	50.5
Water depth range (cm)	38.9	37.2	23.9	15.4	56.3	10.7	40.3	45.9	47.0	16.8	64.0	39.3	47.2	31.2
Percentage altered land	0	0	0	0	0	0	0	0	26	7	30	31	17	0
Latitude (39°)	47'52"	45'57"	46'22"	44'49"	46'07"	45'39"	41'10"	47'17"	46'52"	42'35"	42'23"	42'52"	45'18"	43'17"
Longitude (74°)	36'51"	41'16"	40'21"	43'16"	40'58"	48'09"	44'23"	39'22"	46'14"	46'37"	46'53"	49'20"	51'06"	46'09"
Percentage perimeter shrub cover	100	90	75	95	90	90	75	100	50	100	85	85	100	90
Percentage perimeter tree cover	0	10	25	5	10	10	25	0	50	0	15	15	0	10
Percentage emergent woody veg.	0	0	0	15	0	10	10	0	20	10	0	30	15	5
Percentage emergent herbaceous veg.	20	90	80	15	85	5	10	0	15	45	25	25	40	40
Percentage floating vegetation	20	5	10	50	10	15	70	80	20	45	5	35	30	40
Percentage open water	60	5	10	20	5	70	10	20	45	0	70	10	15	15

Copy of the Pine barrens tree frog BSR draft report that was sent out for peer review

BIOLOGICAL STATUS REVIEW of the Pine Barrens Treefrog *(Hyla andersonii)*

EXECUTIVE SUMMARY

The Florida Fish and Wildlife Conservation Commission (FWC) directed staff to evaluate all species listed as Endangered, Threatened or Species of Special Concern as of 1 September 2010. Public information on the status of the Florida population of the pine barrens treefrog was sought from September 17 through November 1, 2010. A five-member biological review group (BRG) met on November 9-10, 2010. Group members were Bill Turner (FWC lead), Ryan Means (Coastal Plains Institute), Kelly Jones, Paul Moler (independent consultant), and John Himes (FWC) (Appendix 1). In accordance with rule 68A-27.0012 F.A.C, the BRG was charged with evaluating the biological status of the pine barrens treefrog using criteria included in definitions in 68A-1.004 and following protocols in the *Guidelines for Application of the IUCN Red List Criteria at Regional Levels (Version 3.0)* and *Guidelines for Using the IUCN Red List Categories and Criteria (Version 8.1)*. Please visit http://myfwc.com/WILDLIFEHABITATS/imperiledSpp_listingprocess.htm to view the listing process rule and the criteria found in the definitions. The BRG concluded from the biological assessment that the pine barrens treefrog did not meet criteria for listing. Based on the BRG findings, literature review, and information received from the public and independent reviewers, staff recommends delisting this species.

This work was supported by a Conserve Wildlife Tag grant from the Wildlife Foundation of Florida.

BIOLOGICAL INFORMATION

Taxonomic Classification – The pine barrens treefrog (*Hyla andersonii* Baird, 1854) is a distinct species within a highly speciose genus. The specific epithet reflects the location where the first specimen was reportedly collected: Anderson, South Carolina.

Life History and Habitat Requirements – The life history characteristics and habitat requirements of the pine barrens treefrog have been summarized by Means and Moler 1978, Means in Moler (1992), and Means in Lannoo (2005). Breeding occurs in low pH (acidic, generally < 4.5) wetlands called seepage bogs. These bogs are created when rains saturate sands overlying an impermeable clay layer. Unable to pass through the clay, the rainwater moves laterally and seeps out on the nearby hillsides. Near the seepage, the vegetation consists mainly of herbs (herb bog), but downslope the bog is often dominated by woody plants (shrub bog). Herb bogs are characterized by sundews (*Drosera* spp.), pitcher plants (*Sarracenia* spp.), sedges, and grasses with extensive *Sphagnum* moss. Pine barrens treefrogs breed in shallow (usually < 10 inches), clear pools of water in the herb bogs. Adults forage in the shrub bogs, which contain black titi (*Cliftonia monophylla*), swamp titi (*Cyrilla racemiflora*), tall gallberry (*Ilex coriacea*), and sweet bay (*Magnolia virginiana*). Means and Moler (1978) suspected woody plant encroachment into herb bogs, often as a result of fire suppression, increased evapotranspiration, thus reducing seepage and making sites less suitable for the treefrogs. Disturbances that remove woody vegetation, such as power line rights-of-way, mimic historically fire-maintained seepage conditions (Means and Moler 1978). Male pine barrens treefrogs call sporadically when seepage water fills breeding pools (Moler 1981). Pine barrens treefrogs have been heard calling as early as March and as late as the third week in September in Florida (Means 1992). Pine barrens treefrog choruses often have fewer than 10 calling males (Means and Moler 1978, Moler 1981). Tadpoles have been collected from May through August (Means 1992). Pine barrens treefrogs are known to forage up to 105 m from breeding sites (Means 2005). Egg masses contain between 800 and 1,000 eggs, which hatch in 3-4 days. If Florida populations have development times similar to New Jersey populations, the tadpoles would metamorphose in 50-75 days (Means 2005).

Population Status and Trend – The population status of the pine barrens treefrog in Florida is poorly understood because of their relatively recent discovery (Christman 1970). Populations are thought to have declined since pre-settlement times as a result of habitat degradation from fire suppression and other factors (Means and Moler 1978, Enge 2002, Means 2005).

Geographic Range and Distribution – Pine barrens treefrogs are found in three regions of the eastern U.S.: the Florida Panhandle and adjacent Alabama, the New Jersey Pine Barrens, and the Fall Line Sand Hills of the Carolinas (NC and SC) (Means 2005). Unknown in Florida until 1970 (Christman 1970), the species has now been recorded from 177 sites in Santa Rosa, Okaloosa, Walton, and Holmes counties (Endries et al. 2009), as well as from adjacent Escambia, Geneva and Covington counties, Alabama (Moler 1981, Moler pers. commun. 2010).

Quantitative Analyses – Two PVA models have been calculated for pine barrens tree frogs in Florida (Endries et al. 2009). One of these models considered all potential habitat, while the other considered only potential habitat on managed lands. The predicted baseline growth rate for both models was 0.9979. The probability of extinction in the next 100 years under both of these demographic parameters was 0%, although the model run on all potential habitat showed a high probability of a decline (i.e., 54% probability of a 60% decline) (Endries et al. 2009).

BIOLOGICAL STATUS ASSESSMENT

THREATS – Pine barrens treefrogs are adapted to low pH bogs. This habitat is a low nutrient ecosystem that is very sensitive to changes in water chemistry and flow (Means 2005, Bunnell and Ciraolo 2010). Bunnell and Ciraolo (2010) found that the pine barrens treefrog was also vulnerable to reduction in water depth at breeding sites from water table drawdowns. Pine barrens treefrogs are dependent on early successional fire-maintained bog habitat. Fire suppression allows woody plants to invade the bog habitat, increasing evapotranspiration and reducing seepage from the soil. The availability of seepage water is critical to pine barrens treefrog breeding habitat (Means and Moler 1978). Blackwater State Forest and Eglin Air Force Base (EAFB) make extensive use of prescribed fire, which should benefit local populations of pine barrens treefrogs (Printiss and Hipes 1999, U.S. Air Force 2010). Encroachment by invasive plants, particularly Chinese tallow tree (*Sapium sebiferum*), likewise degrades the bog habitat (Jackson 2004). Feral hogs (*Sus scrofa*) are present on EAFB and can damage treefrog habitat through their rooting. EAFB has a Feral Hog Management Plan for reducing the feral hog population (U.S. Air Force 2010). Global warming threatens pine barrens treefrogs through longer drought periods, more severe storms and floods, less available water, the effects of increasing temperatures, and sea level rise (Field et al. 2007). Severe droughts, like those predicted from climate change, have been implicated in declines of several amphibian species, including the southern leopard frog (*Lithobates sphenocephala*) in South Carolina during a 26 year period (Daszak et. al. 2005). Pathogens and parasites also threaten Florida bog frogs. A chytridiomycete fungus, *Batrachochytrium dendrobatidis* (chytrid), has been implicated as a cause of disease epidemics and subsequent population declines of amphibians in many parts of the world. Chytrid is not yet known to be responsible for any amphibian die-offs in the Southeast (Daszak et. al. 2005). Ranaviruses are likely a greater threat to amphibians than chytrid in North America (Gray et al. 2009b). Catastrophic die-offs of wild amphibian populations from ranaviruses have occurred in >30 states and 5 Canadian provinces (Green et al. 2002, Gray et al. 2009a). Although ranaviruses are pathogenic to both adult and larval amphibians, mortality rates tend to be higher for larvae (Gray et al. 2009a). A die-off of hundreds of ranid tadpoles in 2 ponds in Withlacoochee State Forest, Hernando County, FL, was apparently caused by an unnamed *Perkinsus*-like (or alveolate) microorganism (Davis et al. 2007, Rothermel et al. 2008). Pine barrens treefrogs and their larvae are probably preyed on by many creatures that hunt in their habitat. Bronze frogs (*Lithobates c. clamitans*), two-toed amphiumas (*Amphibuma means*), red salamanders (*Pseudotriton ruber*), banded pigmy sunfish (*Elassoma zonatum*), and turtles are all potential predators of larval pine barrens treefrogs. Banded water snakes (*Nerodia fasciata*) and common ribbon snakes (*Thamnophis sauritus*) feed on adults (Means 2005). Enge (2002) trapped mole kingsnakes (*Lampropeltis calligaster rhobomaculata*) in bogs within the Florida range of the pine barrens treefrog. Eastern mudsnakes (*Farancia a. abacura*), eastern gartersnakes (*Thamnophis s. sirtalis*) and cottonmouths (*Agkistrodon piscivorus*) are also possible predators of pine barrens tree frogs in Florida (Enge 2002).

STATEWIDE POPULATION ASSESSMENT – Available data on the Florida pine barrens treefrog population were evaluated relative to each of the five criteria for state listing under Rule 68A-1.004 F.A.C. There are two steps in assessing the status of a regional population: (1) use FWC criteria for a preliminary categorization and (2) investigate whether conspecific populations outside the region may affect the risk of extinction within the region.

LISTING RECOMMENDATION

The pine barrens tree frog did not meet listing criteria, although it met some sub-criteria. The pine barrens treefrog has a sufficiently small extent of occurrence and area of occupancy to meet the first part of the Geographic Range Criterion, but it meets only one of the three other sub-criteria (b. continuing decline). The BRG thought that declines in habitat (b.) would continue, but that the species was not severely fragmented (a.) or subject to extreme fluctuations (c.). Staff recommends delisting the pine barrens treefrog based on the findings of the BRG and current biological information about the species. The BRG and staff recommend that protecting the pine barrens treefrog from commercial take be specified in the management plan, because both groups thought the species would be targeted for the pet trade.

SUMMARY OF THE INDEPENDENT REVIEW

To be included after the peer review.

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Biological Status Review Information Findings

Species/taxon:	Pine Barrens Treefrog
Date:	Oct 26.2010
Assessors:	John Himes, Kelly Jones, Ryan Means, Paul Moler, Bill Turner
Generation length:	1 - 2 years

Criterion/Listing Measure	Data/Information	Data Type*	Criterion Met?	References
*Data Types - observed (O), estimated (E), inferred (I), suspected (S), or projected (P). Criterion met - yes (Y) or no (N).				
(A) Population Size Reduction, ANY of				
(a)1. An observed, estimated, inferred or suspected population size reduction of at least 50% over the last 10 years or 3 generations, whichever is longer, where the causes of the reduction are clearly reversible and understood and ceased[1]	There are no data to suggest a 50% decline in the last ten years.	S	N	Endries et al. 2009, Means 1992
(a)2. An observed, estimated, inferred or suspected population size reduction of at least 30% over the last 10 years or 3 generations, whichever is longer, where the reduction or its causes may not have ceased or may not be understood or may not be reversible[1]	There are no data to suggest a 30% decline in the last ten years.	S	N	Endries et al. 2009, Means 1992
(a)3. A population size reduction of at least 30% projected or suspected to be met within the next 10 years or 3 generations, whichever is longer (up to a maximum of 100 years) [1]	There are no data to suggest a 30% decline in the next ten years, but potential of collection for the pet trade should be addressed in the management plan by suggesting protective rules.	S	N	Endries et al. 2009, Means 1992
(a)4. An observed, estimated, inferred, projected or suspected population size reduction of at least 30% over any 10 year or 3 generation period, whichever is longer (up to a maximum of 100 years in the future), where the time period must include both the past and the future, and where the reduction or its causes may not have ceased or may not be understood or may not be reversible.[1]	There are no data to suggest a 30% decline in the next ten years.	S	N	
[1] based on (and specifying) any of the following: (a) direct observation; (b) an index of abundance appropriate to the taxon; (c) a decline in area of occupancy, extent of occurrence and/or quality of habitat; (d) actual or potential levels of exploitation; (e) the effects of introduced taxa, hybridization, pathogens, pollutants, competitors or parasites.				
(B) Geographic Range, EITHER				
(b)1. Extent of occurrence < 20,000 km^2 (7,722 mi^2) OR	Using areas of counties of occurrence, estimate is 3862 mi^2.	E	Y	using GIS data Beth Stys pers. commun. 2010
(b)2. Area of occupancy < 2,000 km^2 (772 mi^2)	Area of occupancy estimated at 220 mi^2 from FWC habitat coverage.	E	Y	using GIS data Beth Stys pers. commun. 2010 and Endries et al. 2009

AND at least 2 of the following:				
a. Severely fragmented or exist in ≤ 10 locations	Estimated more than 10 locations from GIS, not severely fragmented.	E	N	Treated every site in a tributary as location using GIS
b. Continuing decline, observed, inferred or projected in any of the following: (i) extent of occurrence; (ii) area of occupancy; (iii) area, extent, and/or quality of habitat; (iv) number of locations or subpopulations; (v) number of mature individuals	Continuing decline in habitat quality of plant succession due to ongoing fire suppression	I	Y	
c. Extreme fluctuations in any of the following: (i) extent of occurrence; (ii) area of occupancy; (iii) number of locations or subpopulations; (iv) number of mature individuals	Although most frog populations fluctuate, no extreme fluctuations are indicated in literature. Frog populations fluctuate naturally, but this was not considered extreme by the group.	I	N	
(C) Population Size and Trend				
Population size estimate to number fewer than 10,000 mature individuals AND EITHER	The group had great difficulty reaching a conclusion, but majority vote (3 to 2) was for more than 10,000 individuals.	E	N	Means 1992, Endries et al. 2009
(c)1. An estimated continuing decline of at least 10% in 10 years or 3 generations, whichever is longer (up to a maximum of 100 years in the future) OR	The group had great difficulty reaching a conclusion because of concerns over future habitat decline.	S	N	
(c)2. A continuing decline, observed, projected, or inferred in numbers of mature individuals AND at least one of the following:	Some continuing decline is probable from habitat loss.	I	Y	Endries et al. 2009
a. Population structure in the form of EITHER	Suspect that at least one sub-population (Yellow River) is greater than 1000 individuals.	S	N	
(i) No subpopulation estimated to contain more than 1000 mature individuals; OR				
(ii) All mature individuals are in one subpopulation		I	N	
b. Extreme fluctuations in number of mature individuals	Surveys indicate relative stability of calling males across years.	I	N	K. Jones pers. commun.
(D) Population Very Small or Restricted, EITHER				
(d)1. Population estimated to number fewer than 1,000 mature individuals; OR	The number of localities was stated as 177 in Endries et al. 2009. Means (1992) stated that most sites had fewer than 10 calling males. Assuming a 1:1 sex ratio, there would be about (20 x 177) 3,540 PBTFs	E	N	Endries et al. 2009
(d)2. Population with a very restricted area of occupancy (typically less than 20 km^2 [8 mi^2]) or number of locations (typically 5 or fewer) such that it is prone to the effects of human activities or stochastic events within a short time period in an uncertain future	Greater than 8 mi^2 (see above).	E	N	Endries et al. 2009

(E) Quantitative Analyses				
e1. Showing the probability of extinction in the wild is at least 10% within 100 years	A PVA model run on all potential habitats showed a high probability of a decline (i.e., 54% probability of a 60% decline over 100 years). Approximately 48% of the potential habitat was on managed lands, which resulted in a much smaller abundance than the model using all potential habitats. Given the reduced abundance on managed lands, an increased risk of a decline was evident (i.e., 94% probability of a 60% decline), but the risk of extinction remained 0%.	E	N	Means 1992, Endries et al. 2009

Initial Finding (Meets at least one of the criteria OR Does not meet any of the criteria)	Reason (which criteria are met)
Initial finding is that species does not meet criteria for listing.	
Is species/taxon endemic to Florida? (Y/N)	N

1	Species/taxon:	Pine Barrens Treefrog
2	**Biological Status Review Information** Date:	Oct 26.2010
3	Regional Assessment Assessors:	John Himes, Kelly Jones, Ryan Means
4		Paul Moler, Bill Turner
5		
6		
7		
8	Initial finding	
9		
10	2a. Is the species/taxon a non-breeding visitor? (Y/N/DK). If 2a is YES, go to line 18. If 2a is NO or DO NOT KNOW, go to line 11.	N
11	2b. Does the Florida population experience any significant immigration of propagules capable of reproducing in Florida? (Y/N/DK). If 2b is YES, go to line 12. If 2b is NO or DO NOT KNOW, go to line 17.	Y
12	2c. Is the immigration expected to decrease? (Y/N/DK). If 2c is YES or DO NOT KNOW, go to line 13. If 2c is NO go to line 16.	Do Not Know, although likely
13	2d. Is the regional population a sink? (Y/N/DK). If 2d is YES, go to line 14. If 2d is NO or DO NOT KNOW, go to line 15.	No
14	If 2d is YES - Upgrade from initial finding (more imperiled)	
15	If 2d is NO or DO NOT KNOW - No change from initial finding	No change
16	If 2c is NO or DO NOT KNOW- Downgrade from initial finding (less imperiled)	
17	If 2b is NO or DO NOT KNOW - No change from initial finding	
18	2e. Are the conditions outside Florida deteriorating? (Y/N/DK). If 2e is YES or DO NOT KNOW, go to line 24. If 2e is NO go to line 19.	
19	2f. Are the conditions within Florida deteriorating? (Y/N/DK). If 2f is YES or DO NOT KNOW, go to line 23. If 2f is NO, go to line 20.	
20	2g. Can the breeding population rescue the Florida population should it decline? (Y/N/DK). If 2g is YES, go to line 21. If 2g is NO or DO NOT KNOW, go to line 22.	
21	If 2g is YES - Downgrade from initial finding (less imperiled)	
22	If 2g is NO or DO NOT KNOW - No change from initial finding	
23	If 2f is YES or DO NOT KNOW - No change from initial finding	
24	If 2e is YES or DO NOT KNOW - No change from initial finding	
25		
26	Final finding	No change

APPENDIX 1. Biological Status Review Group Biographies.

Dr. John H. Himes received his Ph.D. from the University of Southern Mississippi, M.S. from Louisiana State Medical Center, and B.S. from the University of Mississippi. He is currently a regional biologist for FWC. He has published many papers on southeastern herpetofauna.

Kelly Jones received his M.S. in Biology from Ball State University. He is currently the project manager for the Virginia Polytechnic Institute and State University team working with red-cockaded woodpeckers, Florida bog frogs, reticulated flatwoods salamanders, and gopher tortoises on Eglin Air Force Base. He has short notes in press on distribution and natural history of native and exotic herpetofaunal species in the Florida panhandle.

Ryan C. Means received both his M.S. in Wildlife Ecology and Conservation (2001) and his B.S. in Zoology (1996) from the University of Florida. He is a wildlife ecologist with the Coastal Plains Institute in Tallahassee, FL. His research interests focus on ecology and conservation of ephemeral wetlands and associated amphibian fauna in the southeastern Coastal Plain. Ryan has many other interests, including wilderness exploration, archaeology, paleontology, and anything related to being in the outdoors.

Paul E. Moler received his M.S. in Zoology from the University of Florida in 1970 and his B.A. in Biology from Emory University in 1967. He retired in 2006 after working for 29 years as a herpetologist with FWC, including serving as administrator of the Reptile and Amphibian Subsection of the Wildlife Research Section. He has conducted research on the systematics, ecology, reproduction, genetics, and conservation biology of a variety of herpetofaunal species in Florida, with primary emphasis on the biology and management of endangered and threatened species. He served as Chair for the Florida Committee on Rare and Endangered Plants and Animals in 1992–94, Chair of the Committee on Amphibians and Reptiles since 1986, and editor of the 1992 volume on amphibians and reptiles. Paul has >90 publications on amphibians and reptiles.

William M. Turner received his B.S. from Erskine College and M.S. in Biology from the University of South Alabama. From 2003 to 2007, he was the Herpetological Coordinator for the Wyoming Game and Fish Department. In Wyoming, he conducted statewide surveys for amphibians and reptiles, focusing on emerging amphibian diseases and the impacts of resources development on native reptiles. Since 2007, he has been the Herp Taxa Coordinator for FWC in the Division of Habitat and Species Conservation. He has conducted research on native amphibians and reptiles in Florida, Alabama, and Wyoming that has resulted in several published papers and reports.

APPENDIX 2. Summary of public comments that were received 17 September–3 November 2010 regarding the proposed reclassification of the pine barrens treefrog.

Although he did not make a comment, John F. Bunnell, Chief Scientist of the Pinelands Commission, New Lisbon, NJ, submitted several publications during the commenting period for which we are thankful.

Appendix 4. Information and comments received from the independent reviewers