Division of Science, Research and Environmental Health

Research Project Summary

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Nutrient Reference Conditions in New Jersey Lakes Based on Analysis of Sediment Cores

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Abstract

This project was conducted to more accurately quantify reference water-quality conditions in New Jersey (NJ) lakes. An accurate quantification of reference conditions is required to support the development of numeric nutrient and other biological criteria needed in setting realistic targets for protection and restoration plans. This project provided data on historic lake nutrient conditions, including undisturbed natural conditions characteristic of the pre-European settlement period. The project had two main objectives: 1) quantify reference (pre-European settlement) trophic conditions and 2) assess the amount of change induced by anthropogenic activities on lake nutrient concentrations using diatom-based inference models. To reach these objectives, sediment cores have been collected and analyzed for diatom species present in the top core interval (present-day conditions) and bottom core interval (past lake conditions, could represent pre – or post-European). The field crew aimed to obtain 1-m long cores, which based on scientific literature should reach pre-European time in lakes from the northeastern USA. Two steps were used to determine if core bottom intervals represented the pre- European time period for each specific site: 1) pollen composition and relative abundance of Ambrosia pollen; and 2) radioisotope dating. Pb-210 radio isotope dates were used to determine if the core bottom intervals were older than ~100 years, which is the oldest age that Pb-210 can provide. Results suggest the core bottom sediments in most of the lakes were deposited at least 100 year ago; these core bottoms, may or may not reach pre-European time period. The Ambrosia pollen is a well-known chronomarker for the European settlement. Since settlement was marked by extensive forest clearing and replacement of clear-cut areas by Ambrosia plants, pollen counts of Ambrosia were used to determine if the bottom core was deposited before or after the European arrival. Bottom sediment samples from a few cores had Ambrosia pollen as high as 36 percent suggesting that they did not represent a time period prior to European settlement, while other bottom intervals had pollen assemblages atypical from today, without invasive species and with very low concentrations of Ambrosia pollen suggesting they represent the pre-European settlement time period . A total of 122 diatom samples were analyzed in top and bottom core intervals. Overall, top core sediment samples (representing current conditions) are rich in *Fragilaria crotonensis*, *Asterionella formosa* and *Fragilaria capucina.* These species are indicators of eutrophic conditions. Core bottom sediment samples are dominated by *Cyclotella michiginana,* a species indicative of low total phosphorus concentrations. The average diatom-inferred total-phosphorus concentration from all surface samples is 48 μg/L. The historic average diatom-inferred total-phosphorus concentration determined from all core bottom samples is 24 μg/L, just less than half of the current water quality standard for NJ. Total phosphorus estimates in bottom sediment samples were typically higher in impoundments than from natural lakes.

Introduction

A paleolimnological investigation funded by the New Jersey Department of Environmental Protection's (NJDEP) Division of Science, Research and Environmental Health (DSREH) in 2008 produced a 33-lake calibration set and historical total phosphorus (TP) reconstructions from sediment cores of 26 additional New Jersey lakes. The purpose of this new project was to supplement the calibration set with additional sites necessary to strengthen the predictive power of diatom-based quantitative models (transfer functions) for nutrients (phosphorus and nitrogen). These models allow the

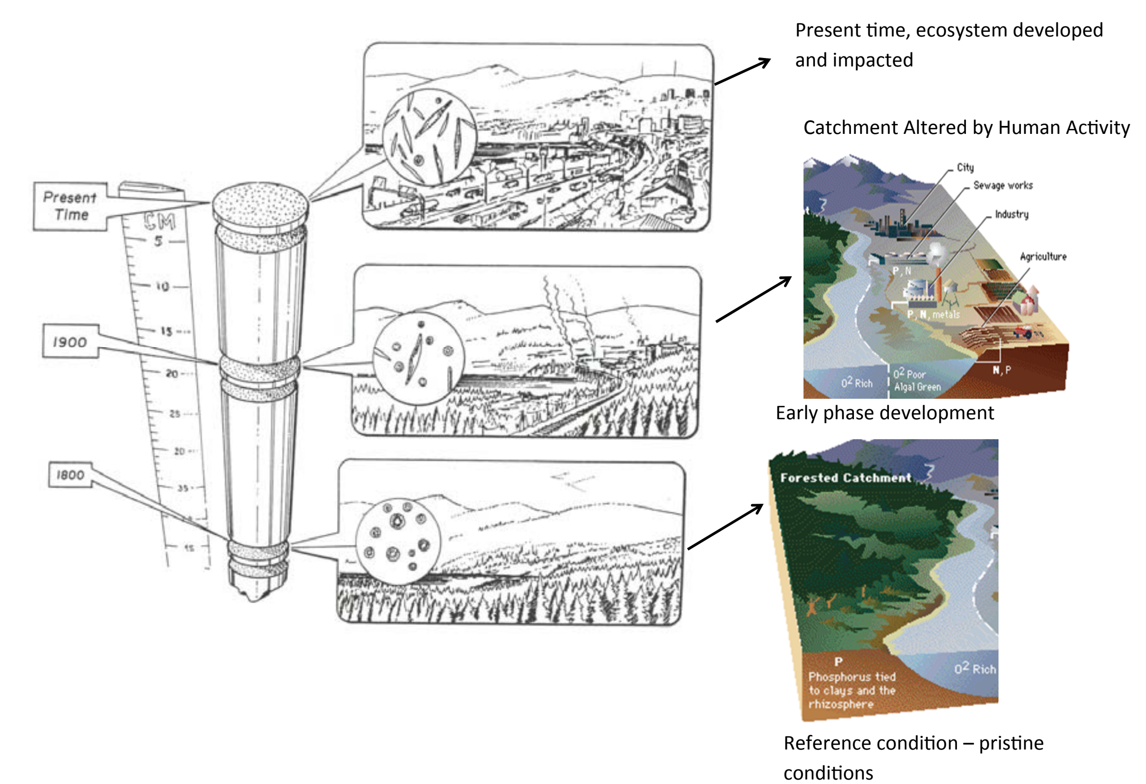


Figure 1 Using sediment cores to reconstruct past environmental conditions - the surface ("top") sample of sediment represents present-day limnological conditions, the deepest sediment sample ("bottom") represents conditions that existed prior to marked anthropogenic influences, while intermediate sediment intervals will represent different time periods in-between present day and the time represented by the core bottom. Note that diatom species identified in these sediment intervals are different and illustrate response to different pollution degrees of aquatic environment.

reconstruction of past nutrient concentrations from sediment cores used to define reference conditions in NJ lakes, prior to the European settlement.

This project used paleolimnological techniques based on the information preserved in lake sediment cores to estimate past conditions. Lakes gradually accumulate sediments layer by layer incorporating skeletal remains of micro- and macroorganisms, metals, and organic contaminants, among many other proxies. A sediment core collected from a lake can be sectioned stratum by stratum. Each stratum can be analyzed for preserved proxies providing ecological information that can be read like the pages of a history book when you have the right tool to interpret it. Each sediment interval mirrors the ecosystem characteristic of the time of deposition, going back in time from the surface interval (that represents the most recent, present-day conditions) to the core bottom that can go back for decades, centuries, or millennia, depending on the core length and sediment accumulation rates. Figure 1 illustrates how different sections of a core containing fossil remains (in this case diatoms, one of the most often used ecological and paleoecological indicators) can be used to reconstruct past environmental characteristics specific to the deposition times – e.g., 1800s, early industrial (1900s) and present impacted condition. Since diatom species that live in unimpaired environments are different from the ones that live in stressed (polluted) environments, the proportions of these species can be used as a surrogate of environmental condition. The core can be sliced continuously to provide a continuum of data that reflects conditions before and after impacts of anthropogenic and natural factors, and quantify the direction and magnitude of change when instrumental records are absent.

Methods

The main objective of this project was to quantify reference (pre-European settlement) trophic conditions in lakes from New Jersey and assess the amount of change induced by anthropogenic activities using diatom-based inference models. To reach this goal, the relationships between diatoms present in surface sediments ('modern samples') and measured water-chemistry parameters (calibration datasets) were first explored. Based on these relationships, quantitative models were developed to infer lake nutrients going back in time, since before the European settlement, representing reference or baseline conditions. Because the diatom-inferred nutrient values are directly comparable to current water chemistry samples, this information is valuable for developing lake management strategies.

Two diatom-based quantitative models were previously published by Enache et al. (2012) to reconstruct total phosphorus (TP) concentrations in the water column. One consisted of 278 lakes from the northeast US with a TP range of 0.9 to 323 µg/L. The other consisted of 33 lakes located in New Jersey. Inference models based on these regional datasets were used by Enache et al. (2012) to infer TP concentrations from fossil diatoms archived in sediments collected at the bottom of sediment cores from another 26 NJ lakes. The current project supplemented the existing NJ calibration set with additional cores originating from NJ lakes for a total of 69 lakes. The top sediment core samples were used to refine the inference models based on NJ specific sites, and the bottom core samples were used to infer past, historic lake water nutrient concentrations.

Efforts were made to collect sediment cores of about 1 meter in length in order to maximize the possibility of reaching the depositional layers from pre-European settlement. Information from the core bottom samples could therefore provide information on natural lake conditions. However, it was not always possible to obtain a core with this long of a depositional record. The lake dataset was comprised of natural lakes as well as man-made impoundments.

Two steps were used to determine if core bottom intervals represented the pre- European time period for each specific site: 1) radioisotope dating; and 2) pollen composition and relative abundance of Ambrosia pollen. Core bottom samples were measured for radioisotopes Pb -210 and Cs-137, and pollen analysis was performed to provide information on core age. The presence of Cs-137 indicates sedimentation after 1963, which was the end of atmospheric nuclear bomb testing. The Cs-137 activities must be interpreted with caution, as Cs is mobile in the sediment core. Pb-210 has a half-life of 22.3 years and cannot be measured after five half-lives. Thus, Pb-210 radio isotope can be used to determine if the core bottom intervals were older than ~100 years, which is the oldest age that Pb-210 can provide. Due to these limitations of radioisotopic analysis, an additional dating method is needed (Blais et al 1995) to determine if sediments were deposited prior to the European settlement and represent undisturbed environmental conditions. Pollen assemblages atypical from today likely indicate a deposition of sediments prior to the arrival of European-settlers who affected the vegetation by introducing invasive plants. Also, settlement was marked by extensive forest clearing and replacement of clear-cut areas by Ambrosia plants. Thus, a high percentage increase in Ambrosia pollen found in sediment cores constitutes a widely used chronomarker of European settlement in those lake watersheds.

Results

Radioisotope analyses

Radioisotope analyses for Pb-210 and Cs-137 were performed by Gary Krinke (Environmental Sciences for Wisconsin State Laboratory of Hygiene) and interpreted by Dr. Paul Garrison (Wisconsin Department of Natural Resources). According to the interpretation by Dr. Garrison, all bottom samples were deposited at least 100 years ago, as activities of Cs-137 and Pb-210 are below 1 pCi/gram. However, bottom samples of some lakes (e.g., Echo, Lefferts, Watchung, and Crystal Lakes) might be younger than 100 years as Cs-137 is mobile in lake sediments.

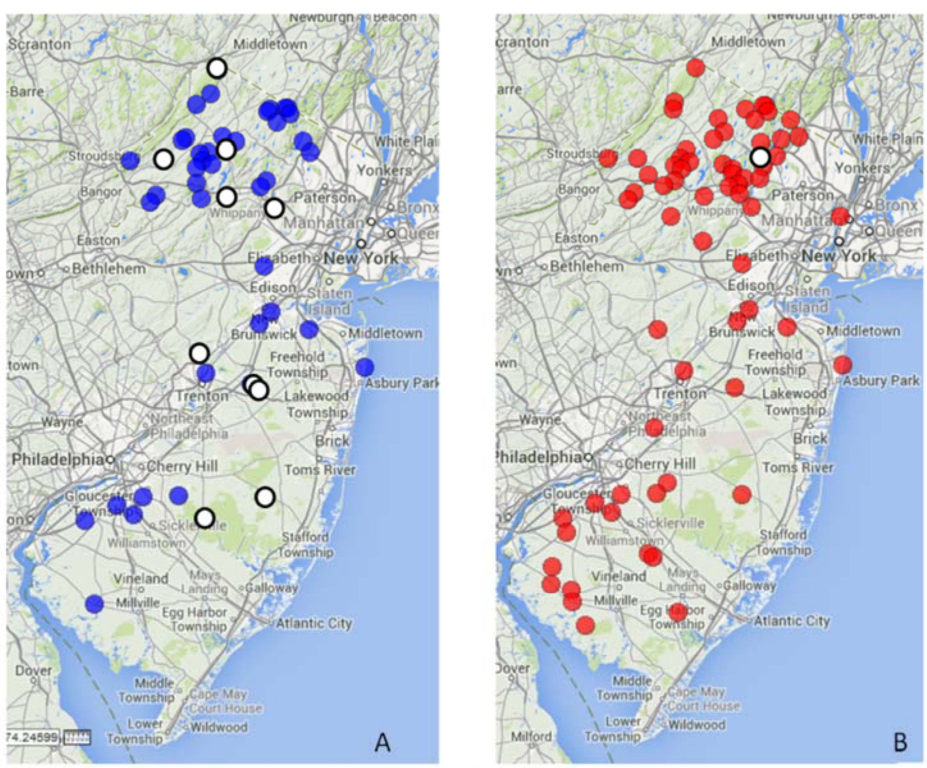


Figure 2. Location of sediment core sampling sites (i.e., lakes) with diatom counts performed in bottom sediment samples (total 53 samples; A) and surface sediment samples (total 69 samples; B). The empty circles indicate sites where diatoms were diluted by silt or charcoal and yielded low number of diatom valves or were impossible to count.

Pollen Analysis

A high percentage of *Ambrosia* pollen is used to indicate disturbance from the European settlement. Dr. Ababneh (Cornell University) performed pollen analysis on 26 sediment samples. *Ambrosia* pollen percentages decreased significantly from the bottom to top sediments in the following lakes: Farrington (16 to 3%), Jeddys Pond (36 to 6%), Lefferts Lake (24 to 4%) suggesting these cores do not date back prior to colonization. *Ambrosia* pollen was found in the top sample in Echo Lake but not in the bottom sediments. In Stony Lake, the percentages are insignificant (less than 0.4% in top and bottom sediments). In Chesler Lake and Saginaw Lake there was not enough material to establish a reliable count of 300 pollen grains or more, and thus results cannot be provided based on the samples examined. Samples from another six sites had poor pollen preservation and counts were not possible.

Diatom Analysis

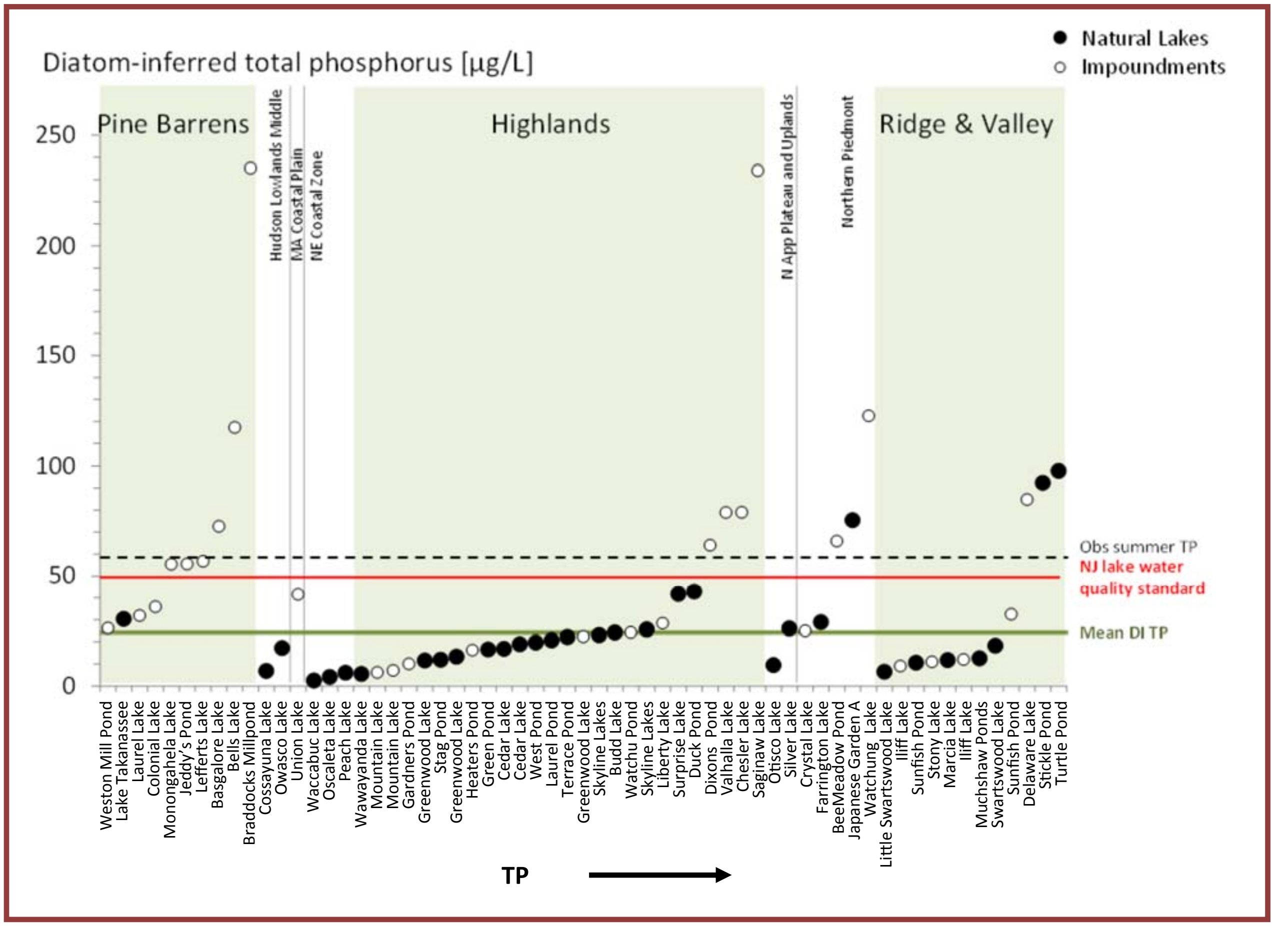
This report summarizes diatom analyses obtained through this project in addition to results from previous studies performed by the Academy of Natural Sciences. A total of 122 diatom samples (53 from sediment core bottoms and 69 from surface sediments) have been analyzed since 2008 (**Fig. 2; Table 1** and **2**). Thirty-seven bottom samples and 20 surface samples have been analyzed for diatoms in the funding period provided by this study (2011 to 2014). Some core bottom samples were difficult to count because of high silt content (e.g., Chesler Lake, Highlands ecoregion) or presence of charcoal (e.g., Decou Pond, Stone Tavern and Assunpink Lakes in the Atlantic Coastal Pine Barrens Ecoregion) (**Fig. 2**). Charcoal presence in these bottom samples may indicate natural fires, or controlled burn by the Lenape tribes to improve plant yields and hunting conditions (Stansfield 1998), or the production of bog iron, which was common in southern NJ during the revolutionary war period.

Table 1: List of locations with diatom counts from bottom samples of sediment cores.

Site Name	Sample Depth	Collection Date	Latitude	Longitude	Ecoregion
Assunpink Lake	22.5 - 23.5	09/18/2013	40.216	-74.517	Atlantic Coastal Pine Barrens
Atsion Lake-14	56.0 - 57.0	09/16/2012	39.742	-74.735	Atlantic Coastal Pine Barrens
Basgalore Lake	47.0 - 48.0	06/23/2008	39.733	-75.283	Atlantic Coastal Pine Barrens
Bee Meadow Pond	36.5 - 37.5	06/24/2008	40.834	-74.410	Northern Piedmont
Bells Lake-18	40.0 - 41.0	11/16/2011	39.753	-75.061	Atlantic Coastal Pine Barrens
Braddocks Millpond-19	41.0 - 42.0	08/13/2013	39.822	-74.850	Atlantic Coastal Pine Barrens
Budd Lake	47.5 - 48.5	08/19/2013	40.871	-74.745	Northern Appalachian and Atlantic Maritime Highlands
Cedar Lake-06	59.5 - 60.5	10/25/2011	40.912	-74.472	Northern Appalachian and Atlantic Maritime Highlands
Chesler Lake	42.0 - 43.0	10/20/2011	40.871	-74.629	Northern Appalachian and Atlantic Maritime Highlands
Colonial Lake	35.5 - 36.5	09/11/2012	40.256	-74.724	Atlantic Coastal Pine Barrens
Crystal Lake-03	50.0 - 51.0	09/17/2013	41.034	-74.242	Northern Piedmont
Decou Pond	57.0 - 58.0	05/06/2013	39.815	-74.456	Atlantic Coastal Pine Barrens
Dixons Pond	41.5 - 42.5	07/10/2008	40.936	-74.444	Northern Appalachian and Atlantic Maritime Highlands
Farrington Lake·09	41.0 - 42.0	11/02/2011	40.430	-74.477	Northern Piedmont
Gardners Pond	74.5 - 75.5	11/21/2011	41.005	-74.739	Northern Appalachian and Atlantic Maritime Highlands
Greenwood Lake-03	42.5 - 43.5	07/02/2008	41.167	-74.335	Northern Appalachian and Atlantic Maritime Highlands
Greenwood Lake-03	59.0 - 60.0	11/03/2011	41.167	-74.335	Northern Appalachian and Atlantic Maritime Highlands
Heaters Pond-02	48.5 - 49.5	08/04/2009	41.072	-74.585	Northern Appalachian and Atlantic Maritime Highlands
Iliff Lake-01	50.0 - 51.0	08/26/2008	41.032	-74.715	Ridge and Valley
Iliff Lake-01	66.0 - 67.0	07/15/2013	41.032	-74.715	Ridge and Valley
Jeddy's Pond	56.5 - 57.5	11/28/2011	39.433	-75.239	Atlantic Coastal Pine Barrens
Lake Takanassee	50.0 - 51.0	07/07/2009	40.277	-73.989	Atlantic Coastal Pine Barrens
Laurel Lake	46.0 - 47.0	06/24/2009	39.818	-75.014	Atlantic Coastal Pine Barrens
Laurel Pond	59.5 - 60.5	10/30/2013	41.181	-74.425	Northern Appalachian and Atlantic Maritime Highlands
Lefferts Lake-12	51.5 - 52.5	11/01/2011	40.410	-74.245	Atlantic Coastal Pine Barrens
Liberty Lake	32.5 - 33.5	10/17/2011	40.883	-74.954	Northern Appalachian and Atlantic Maritime Highlands
Little Swartswood Lake	67.0 - 68.0	05/15/2014	41.085	-74.815	Ridge and Valley
Marcia Lake-01	73.5 - 74.5	05/20/2014	41.318	-74.667	Ridge and Valley
Monongahela Lake	42.5 - 43.5	07/01/2008	39.789	-75.136	Atlantic Coastal Pine Barrens
Mountain Lake-01	48.0 - 49.0	07/28/2008	40.859	-74.984	Northern Appalachian and Atlantic Maritime Highlands
Mountain Lake-01	75.0 - 76.0	09/04/2013	40.859	-74.984	Northern Appalachian and Atlantic Maritime Highlands
Rosedale lake	72.5 - 73.5	05/03/2013	40.330	-74.756	Northern Piedmont
Saddle Bog	65.5 - 66.5	06/26/2013	41.236	-74.703	Ridge and Valley
Saginaw Lake-02	24.5 - 25.5	11/22/2011	41.022	-74.624	Northern Appalachian and Atlantic Maritime Highlands
Skyline Lakes-03	43.5 - 44.5	08/27/2008	41.072	-74.272	Northern Appalachian and Atlantic Maritime Highlands
Skyline Lakes-03	74.0 - 75.0	09/16/2013	41.072	-74.272	Northern Appalachian and Atlantic Maritime Highlands
Stag Pond	48.0 - 49.0	08/19/2009	40.993	-74.697	Northern Appalachian and Atlantic Maritime Highlands
Stickle Pond	93.0 - 94.0	05/21/2014	41.028	-74.753	Ridge and Valley
Stone Tavern-11	76.5 - 77.5	09/18/2013	40.197	-74.485	Atlantic Coastal Pine Barrens
Stony Lake-01	31.0 - 32.0	11/30/2011	41.200	-74.770	Ridge and Valley
Sunfish Pond	37.5 - 38.5	08/12/2008	41.003	-75.073	Ridge and Valley
Sunfish Pond	65.5 - 66.5	09/25/2013	41.003	-75.073	Ridge and Valley
Surprise Lake	74.0 - 75.5	06/19/2013	41.186	-74.347	Northern Appalachian and Atlantic Maritime Highlands
Swartswood Lake	63.5 - 64.5	05/23/2014	41.074	-74.835	Ridge and Valley
Terrace Pond	41.0 - 42.5	06/06/2013	41.139	-74.394	Northern Appalachian and Atlantic Maritime Highlands
Turtle Pond	61.5 - 62.5	08/19/2008	40.981	-74.769	Ridge and Valley
Watchu Pond	---	08/11/2010	40.928	-74.770	Northern Appalachian and Atlantic Maritime Highlands
Watchung Lake-09	47.5 - 48.5	11/18/2011	40.636	-74.454	Northern Piedmont
Wawayanda Lake-02	45.0 - 46.0	08/25/2009	41.176	-74.438	Northern Appalachian and Atlantic Maritime Highlands
West Pond	83.0 - 84.0	10/03/2013	41.185	-74.354	Northern Appalachian and Atlantic Maritime Highlands
Weston Mill Pond	52.0 - 53.0	08/29/2013	40.471	-74.419	Atlantic Coastal Pine Barrens
White Lake-Sparta	73.5 - 74.5	09/26/2013	41.088	-74.649	Ridge and Valley
White Lake-Hardwick	55.0 - 56.5	05/12/2014	41.000	-74.914	Ridge and Valley

Table 2: List of locations with diatom counts from surface samples of sediment cores.					
Site Name	Sample Depth	Collection Date	Latitude	Longitude	Ecoregion
Algonquian Waters Lake	0.0 - 0.5	08/14/2009	41.059	-74.368	Northern Appalachian and Atlantic Maritime Highlands
Allamuchy Pond	0.0 - 0.5	07/15/2009	40.911	-74.817	Northern Appalachian and Atlantic Maritime Highlands
Ames Lake-06	0.0 - 0.5	07/30/2009	40.952	-74.501	Northern Appalachian and Atlantic Maritime Highlands
Amwell Lake-10	0.0 - 0.5	07/20/2009	40.400	-74.842	Northern Piedmont
Basgalore Lake	0.0 - 0.5	05/23/2008	39.733	-75.283	Atlantic Coastal Pine Barrens
Bee Meadow Pond	0.0 - 0.5	05/24/2008	40.834	-74.410	Northern Piedmont
Bells Lake-18	0.0 - 0.5	11/15/2011	39.753	-75.051	Atlantic Coastal Pine Barrens
Braddocks Mill Pond-19	0.0 - 0.5	08/13/2013	39.822	-74.850	Atlantic Coastal Pine Barrens
Braddocks Mill Pond-19	0.5 - 1.0	08/13/2013	39.822	-74.850	Atlantic Coastal Pine Barrens
Cedar Lake-06	0.0 - 0.5	10/25/2011	40.912	-74.472	Northern Appalachian and Atlantic Maritime Highlands
Chesler Lake	0.0 - 0.5	10/20/2011	40.871	-74.629	Northern Appalachian and Atlantic Maritime Highlands
Colonial Lake	0.0 - 0.5	09/11/2012	40.256	-74.724	Atlantic Coastal Pine Barrens
Culvers Lake-01	0.0 - 0.5	08/20/2009	41.173	-74.771	Ridge and Valley
Decou Pond	0.0 - 0.5	05/05/2013	39.815	-74.456	Atlantic Coastal Pine Barrens
Dixons Pond	0.0 - 0.5	07/10/2008	40.936	-74.444	Northern Appalachian and Atlantic Maritime Highlands
East Lake	0.0 - 0.5	08/18/2008	40.975	-74.356	Northern Appalachian and Atlantic Maritime Highlands
Farrington Lake-09	0.0 - 0.5	11/02/2011	40.430	-74.477	Northern Piedmont
Foxs Pond-06	0.0 - 0.5	07/15/2008	40.907	-74.517	Northern Appalachian and Atlantic Maritime Highlands
Gardners Pond	0.0 - 0.5	11/21/2011	41.005	-74.739	Northern Appalachian and Atlantic Maritime Highlands
George Lake	0.0 - 0.5	07/15/2009	40.800	-74.785	Northern Appalachian and Atlantic Maritime Highlands
Girl Scout Pond	0.0 - 0.5	07/23/2009	40.966	-74.496	Northern Appalachian and Atlantic Maritime Highlands
Glovers Pond	0.0 - 0.5	07/29/2009	40.948	-74.890	Ridge and Valley
Greenwood Lake-03	0.0 - 0.5	07/02/2008	41.167	-74.335	Northern Appalachian and Atlantic Maritime Highlands
Greenwood Lake-03	0.0 - 0.5	11/03/2011	41.167	-74.335	Northern Appalachian and Atlantic Maritime Highlands
Harrisonville Lake-18	0.0 - 0.5	07/05/2009	39.682	-75.265	Atlantic Coastal Pine Barrens
Heaters Pond-02	0.0 - 0.5	08/04/2009	41.072	-74.585	Northern Appalachian and Atlantic Maritime Highlands
Heritage Lakes-02	0.0 - 0.5	08/05/2009	41.143	-74.564	Ridge and Valley
Hospitality Lake	0.0 - 0.5	07/01/2009	39.604	-74.888	Atlantic Coastal Pine Barrens
Iliff Lake-01	0.0 - 0.5	08/25/2008	41.032	-74.715	Ridge and Valley
Jeddy's Pond	0.0 - 0.5	11/28/2011	39.433	-75.239	Atlantic Coastal Pine Barrens
Lake Takanassee	0.0 - 0.5	07/07/2009	40.277	-73.989	Atlantic Coastal Pine Barrens
Laurel Lake	0.0 - 0.5	05/24/2009	39.818	-75.014	Atlantic Coastal Pine Barrens
Lefferts Lake-12	0.0 - 0.5	11/01/2011	40.410	-74.245	Atlantic Coastal Pine Barrens
Liberty Lake	0.0 - 0.5	10/17/2011	40.883	-74.954	Northern Appalachian and Atlantic Maritime Highlands
Longwood Lake	0.0 - 0.5	07/29/2008	40.982	-74.540	Northern Appalachian and Atlantic Maritime Highlands
Lower Aetna Lake-19	0.0 - 0.5	07/08/2008	39.861	-74.802	Atlantic Coastal Pine Barrens
Lower Aetna Lake-19	0.0 - 0.5	09/24/2008	39.861	-74.802	Atlantic Coastal Pine Barrens
Lower Sylvan Lake-20	0.0 - 0.5	05/29/2009	40.054	-74.860	Atlantic Coastal Pine Barrens
Lower Twin Lake	0.0 - 0.5	08/05/2008	41.012	-74.297	Northern Appalachian and Atlantic Maritime Highlands
Lummis Mill Pond	0.0 - 0.5	05/30/2009	39.346	-75.182	Atlantic Coastal Pine Barrens
Marcia Lake-01	0.0 - 0.5	05/20/2014	41.318	-74.667	Ridge and Valley
Monongahela Lake	0.0 - 0.5	07/01/2008	39.789	-75.136	Atlantic Coastal Pine Barrens
Mountain Lake-01	0.0 - 0.5	07/28/2008	40.859	-74.984	Northern Appalachian and Atlantic Maritime Highlands
North Hudson Parklake-05	0.0 - 0.5	07/09/2009	40.803	-73.999	Northern Piedmont
Panther Lake-01	0.0 - 0.5	08/19/2009	40.966	-74.736	Northern Appalachian and Atlantic Maritime Highlands
Rainbow Lakes-06	0.0 - 0.5	08/25/2009	40.882	-74.463	Northern Appalachian and Atlantic Maritime Highlands
Ravine Lake-08	0.0 - 0.5	05/15/2008	40.716	-74.634	Northern Appalachian and Atlantic Maritime Highlands
Rhodo Lake	0.0 - 0.5	05/17/2009	39.495	-75.339	Atlantic Coastal Pine Barrens
Scarlet Oak Pond	0.0 - 0.5	08/11/2009	41.081	-74.191	Northern Piedmont
Sheppard Pond-03	0.0 - 0.5	08/12/2009	41.137	-74.228	Northern Appalachian and Atlantic Maritime Highlands
Silver Lake	0.0 - 0.5	05/10/2009	39.473	-75.248	Atlantic Coastal Pine Barrens
Skyline Lakes-03	0.0 - 0.5	08/27/2008	41.072	-74.272	Northern Appalachian and Atlantic Maritime Highlands
Spring Valley Lake	0.0 - 0.5	08/07/2008	41.005	-74.940	Ridge and Valley
Stag Pond	0.0 - 0.5	08/19/2009	40.993	-74.697	Northern Appalachian and Atlantic Maritime Highlands
Stephen Lake	0.0 - 0.5	05/19/2008	39.395	-74.750	Atlantic Coastal Pine Barrens
Stone Tavern-11	0.0 - 0.5	09/01/2008	40.197	-74.485	Atlantic Coastal Pine Barrens
Stony Lake-01	0.0 - 0.5	11/30/2011	41.200	-74.770	Ridge and Valley
Sunfish Pond	0.0 - 0.5	08/12/2008	41.003	-75.073	Ridge and Valley
Surprise Lake	0.0 - 0.5	06/19/2013	41.186	-74.347	Northern Appalachian and Atlantic Maritime Highlands
Sycamore Lake	0.0 - 0.5	06/18/2008	39.558	-75.335	Atlantic Coastal Pine Barrens
Tamarack Lake-02	0.0 - 0.5	07/28/2009	41.094	-74.538	Northern Appalachian and Atlantic Maritime Highlands
Terrace Pond	0.0 - 0.5	06/06/2013	41.139	-74.394	Northern Appalachian and Atlantic Maritime Highlands
Turtle Pond	0.0 - 0.5	08/19/2008	40.981	-74.769	Ridge and Valley
Watchu Pond	0.0 - 0.5	08/11/2010	40.928	-74.770	Northern Appalachian and Atlantic Maritime Highlands
Watchung Lake-09	0.0 - 0.5	11/18/2011	40.636	-74.454	Northern Piedmont
Wawayanda Lake-02	0.0 - 0.5	08/25/2009	41.176	-74.438	Northern Appalachian and Atlantic Maritime Highlands
West Pond	0.0 - 0.5	10/03/2013	41.185	-74.354	Northern Appalachian and Atlantic Maritime Highlands
Weston Mill Pond	0.0 - 0.5	07/09/2008	40.471	-74.419	Atlantic Coastal Pine Barrens
Valhalla Lake-06	0.0 - 0.5	08/12/2013	40.933	-74.374	Northern Appalachian and Atlantic Maritime Highlands

Overall, top core sediment samples (representing current conditions) are rich in *Fragilaria crotonensis*, *Asterionella formosa* and *Fragilaria capucina.* These species are indicators of eutrophic conditions. Core bottom sediment samples are dominated by *Cyclotella michiginana,* a species indicative of low TP concentrations. *Aulacoseira ambigua* and *Achnanthidium minutissimum* were found dominant in both top and bottom samples. The mean observed summer TP from all



NJ panel lakes (measured by the Bureau of Freshwater Monitoring, between 2005 - 2011) is 58 µg/L. The water quality standard for lakes in NJ is 50 µg/L. The mean of all diatom-inferred surface samples is 48 µg/L. The average diatom- estimated historic TP for all core bottom samples is 24 µg/L, just less than half of the current water quality standard for NJ (**Fig. 3**). Total phosphorus estimates in bottom sediment samples were typically higher from impoundments than from natural lakes. This difference might reflect trophic upsurge after impoundment.

Conclusions

This project represents a continuing effort, started in 2008, to estimate historic water quality and lake reference nutrient concentrations inferred from diatoms preserved in lake sediments. Sampling was initiated for this phase of the effort in 2011. During this study, 37 bottom samples and 20 surface samples were analyzed for diatom species. Reconstructions of total phosphorus (TP) in core bottom samples revealed that the mean TP was 24 µg/L, which is less than half of the current water quality standard for NJ of 50 µg/L.

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RESEARCH PROJECT SUMMARY

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