Evaluating the impact of the Sewage Treatment Plant's effluent discharge in the Peconic River on bird biodiversity

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Abstract:

The Long Island Central Pine Barrens region is a unique ecosystem that boasts high levels of biodiversity. Brookhaven National Laboratory (BNL), a multipurpose national research facility, is located within this region and researchers on site monitor wildlife populations continuously. The Sewage Treatment Plant (STP) at BNL has historically discharged effluent into the upstream reaches of the Peconic River, and in 2011, the Environmental Assessment (EA) recognized the negative impacts on the ecosystem. To remain in accordance with the permits issued through the State Pollutant Discharge Elimination System and to accommodate the EA, BNL stopped the discharge of effluent into the river, installed a new post-aeration filtration system at the STP, and constructed recharge basins on nearly 2 hectares of the former WW I era sand filter beds. The goal of these actions is to decrease the concentration of heavy metals in the ecosystem and to maintain the biodiversity in the area. Avian point count surveys are a monitoring technique in place and have been conducted annually since 2000 on multiple transects throughout the laboratory. BNL is part of the Atlantic Flyway and provides habitat for hundreds of migratory bird species. The present study examined if stopping the STP's effluent discharge in 2014 impacted bird biodiversity on the Peconic River transect. Statistical analysis revealed that there is no substantial, immediate impact on bird species richness, diversity, or evenness in the 4 sites studied along the Peconic River. Although there may not be an immediate impact, future monitoring is needed to determine if there is a long term impact on bird biodiversity. Ultimately, an adaptive management technique should be adopted to respond to any negative changes in wildlife populations at BNL.

Introduction:

Brookhaven National Laboratory (BNL) is a multipurpose research institution that is located in the Long Island's Central Pine Barrens region. The Long Island Pine Barrens possess the greatest biodiversity in the state of New York (The Long Island Pine Barrens Society 2016). The Peconic River, the longest groundwater-fed river in New York and the longest river on Long Island, also flows through the Central Pine Barrens region (U.S. Fish and Wildlife Service 1997). A freshwater aquifer lies below the area and provides drinking water to the residents of Long Island (Zeng at al. 2013). The Sewage Treatment Plant (STP) at Brookhaven National Laboratory, in accordance with the State Pollutant Discharge Elimination System (SPDES) issued by the New York State Department of Environmental Conservation (NYSDEC), has treated and discharged about one million gallons of effluent each day since 1969 (Greenberg 2016). This effluent has historically been discharged into the dry riverbed of the upstream reaches of the Peconic River. These discharges have resulted in high levels of heavy metal concentrations, polychlorinated biphenyls, and radionuclides in the Peconic river ecosystem (BNL 2012). Rapiejko et al. (2001) found that the effluent discharged from the STP contributed largely to increased photon-emitting radionuclides and uranium, plutonium, and americium in the sediment along the Peconic River. If the process of discharging effluent remained unaltered, BNL would not be able to meet the water quality based effluent limits (WQBELs) specified in the modified SPDES permit (BNL 2011). After careful monitoring and multiple remediation efforts, BNL ceased the discharge of STP effluent into the Peconic River by September 2014 (BNL 2015). This decision was influenced by the negative environmental impacts highlighted in the Environmental Assessment (2011) (Appendix).

The 2011 Environmental Assessment recommended that BNL take action to remedy the unsustainable practices in place, and BNL accommodated. Restoration of river reaches and sediment can be difficult to achieve, but by September 2014, BNL installed a new post-aeration filtration system at the Sewage Treatment Plant and constructed recharge basins on nearly 2 hectares of the former WW I era sand filter beds (Bateman et al. 2015). Removing sand filters from the treatment process eliminates a substantial source of metals from the effluent (BNL 2011). The former chlorine house at the former outfall was demolished, the former sand filter beds were isolated, and the discharge to the Peconic River was eliminated (BNL 2011). By the end of September 2014, the effluent had been redirected from discharging to the Peconic River to discharging to the recharge basins. Due to these changes, the Peconic River has returned to an intermittent state at the western edges, similar to it's historic state preceding WW I (BNL 2011). Additionally, in January 2016, native grasses and wildflowers were planted at the former sand filter beds to restore habitat.

BNL is located within the Atlantic Flyway and it consequently hosts more than 200 passing bird species (Audubon 2014). Birds are often considered to be effective indicators of the health of an ecosystem. They are impacted by the physical and chemical influences of their environments. Due to increasing impacts from sources such as climate change, pollution, habitat loss and fragmentation, and the ever-growing human population, it has become critical to monitor bird populations now more than ever (American Bird Conservancy 2016). Researchers in the Environmental Protection Division of BNL have been monitoring bird populations on-site via point count surveys since 2000. Point count surveys are a common method used in wildlife management to obtain count data which is then used to estimate

parameters such as abundance and density of avian populations (Ralph et al. 1995). These studies often include a double-observer approach in which 2 or more researchers conduct the surveys to increase the probability of detection of species. Any species that is seen or heard within a designated amount of time is recorded and this is repeated at multiple stations along a transect (Ralph et al. 1995).

The purpose of this study is to evaluate how bird populations along the Peconic River transect at BNL are responding to the changes in the ecosystem. Specifically, we evaluate any changes in bird species richness and diversity before and after BNL ceased the discharge of effluent into the Peconic River, essentially causing the western section of the river to dry up. The immediate impact on bird species in the area will provide inference for future management decisions. Due to the strong relationship between abundance and the likelihood of a population's persistence, this analysis may ultimately contribute to the conservation of invaluable migratory bird populations.

Methods:

Study Area:

This study took place at BNL, which is located in Suffolk County on Long Island, New York. The Long Island Central Pine Barren ecosystem runs through the laboratory. This system is characterized by pitch pine (Pinus rigida) and various oak species that contribute heavily to the macro habitat of the area while the understory layers are primarily dominated by huckleberry (*Gaylussacia baccata*), bearberry (*Arctostaphylos uva-ursi*), blueberry (*Vaccinium pallidum*), and wintergreen (*Gaultheria procumbens*) (U.S. Fish and Wildlife Service 1997). The Peconic River is a slow-moving, naturally acidic, and nutrient-poor freshwater stream ecosystem (U.S. Fish and

Wildlife Service 1997). This study took place at 4 stations along the Peconic River transect (Fig. 1).

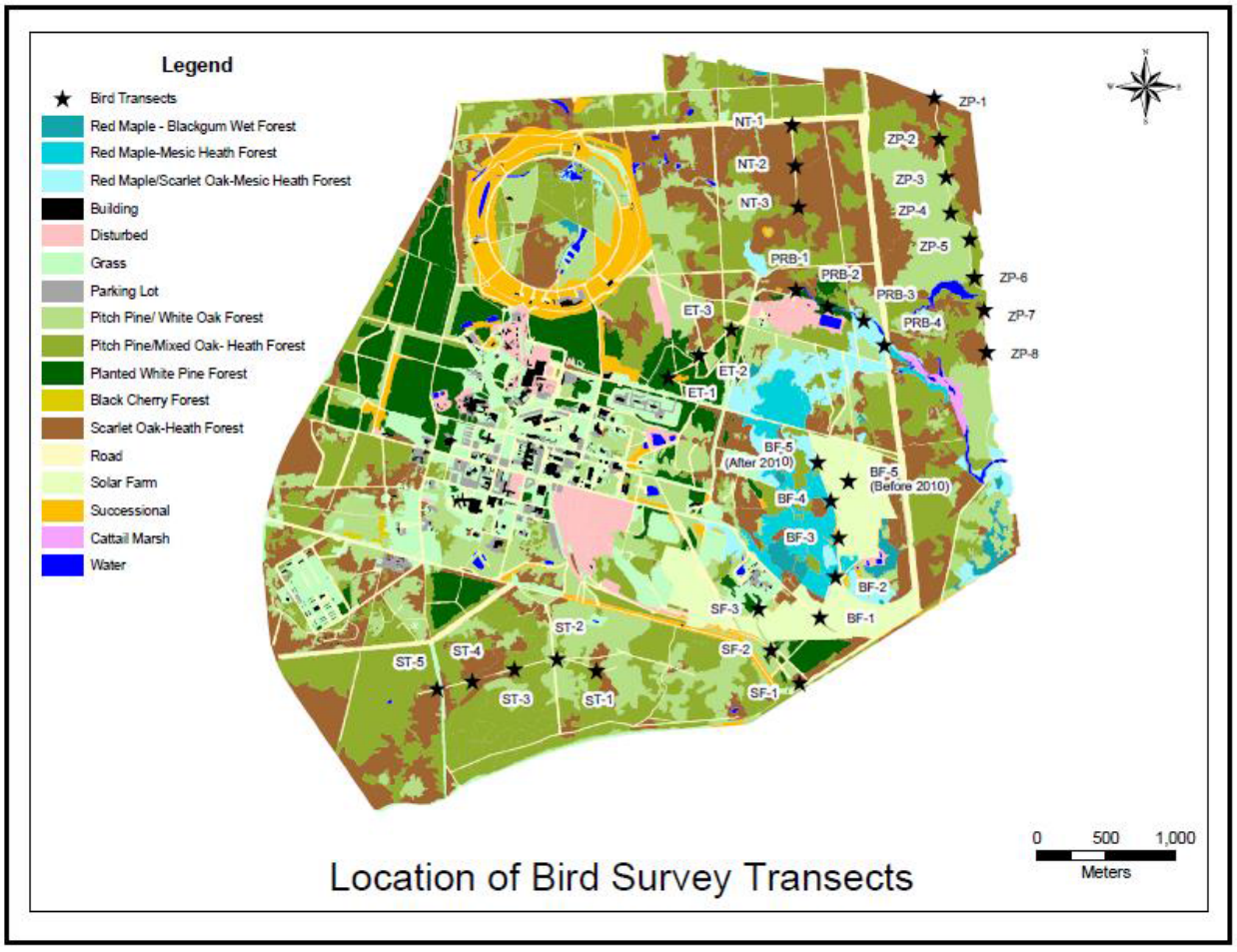

Figure 1: The locations and distribution of the bird point count survey transects and stations after 2010 across several habitats at Brookhaven National Laboratory in Suffolk County, New York.

Data Collection:

The point count technique has been used to monitor bird populations at BNL annually from 2000 to the present (BNL 2015). When surveys began in 2000, point count bird surveys were conducted in 5 transects: Biology Field (BF), East Trenches (ET), North Transect (NT), Peconic River (PRB), and South Transect (ST). Each transect has multiple stations (Figure 1). The

radius of every station is approximately 150 meters to ensure that there is enough space for observation, but no two stations are adjacent. There were 20 station locations in total within the 5 transects. The Z-Path transect was added in 2002, which totaled 28 stations surveyed. In 2010, a solar farm was developed on site at BNL. The solar farm is 81 hectares in size and the Solar Farm (SF) transect with 4 additional site locations were subsequently added. Throughout BNL, there are currently 7 transects in varying habitats, totaling 31 point count stations. Each station is identified by the initials of the respective transect location and a number (Fig. 1). During a survey, each transect location point is observed for a 5-minute period. All birds seen or heard during this time period are recorded by two observers. The Kestrel® 4000 portable weather station was applied during the survey. The data recorded includes start and stop time, start and stop temperature, dew point, relative humidity, wind speed, and wind direction. All survey data was recorded into a Microsoft Excel® spreadsheet for analysis.

Data Analysis:

Statistical analysis was performed using Microsoft Excel®, Version 15.19.1 (2016). Statistical analysis is conducted on the Peconic River point count data comparing the isolated 2015 data to the complete summarized data set from 2000-2014, which represents the individuals present prior to the changes at the STP. Bird species richness, Simpson Diversity Index, and Shannon Wiener Evenness within each bird count station along the Peconic river are evaluated.

Results:

The biodiversity analysis calculated various useful parameters including species richness (S), Simpson's Index (D), Simpson's Index of Diversity (1-D), the Shannon-Weiner Index (H), and

the Shannon-Weiner Index of Evenness (E). Higher biodiversity boasts ecosystem productivity and is often indicative of a healthy system. Species richness represents the number of species in the study area during the survey. The Simpson's Index symbolizes the probability that 2 individuals randomly selected from the sample will be of the same species. Inversely, the Simpson's Index of Diversity represents the probability that 2 individuals randomly selected from the sample will be of different species. The Shannon-Weiner Index is the number of individuals observed for each species in the sample plot. Lastly, the Shannon-Weiner Index of Evenness is a measure of how similar the abundance of different species is. These estimates were determined for each site on the Peconic River transect both before and after the STP stopped discharging effluent into the Peconic River in 2014 (Table 1).

Table 1: Summary of biodiversity analysis of avian point count data conducted for 4 sites along the Peconic River transect at Brookhaven National Laboratory in Upton, NY. S represents species diversity; D represents the Simpson's Index; 1-D represents the Simpson's Index of Diversity, where 1 is indicative of the most diversity and 0 is the least diverse. H indicates the Shannon-Weiner Index, and E represents the Shannon-Weiner Index of Evenness, where 1 is completely even and 0 is not even. The analysis conducted from 2000-2014 was summarized and averaged to obtain the following values. Values were computed by Microsoft Excel®.

Time	Site #	S	D	1-D	H	E
2000-2014	PRB-1	22.3	0.0620	0.9380	3.2276	0.7704
2015	PRB-1	29	0.0552	0.9448	3.0073	0.8931
2000-2014	PRB-2	22.3	0.0528	0.9472	3.2863	0.8164
2015	PRB-2	28	0.0579	0.9421	2.9507	0.8855
2000-2014	PRB-3	24.6	0.0610	0.9390	3.2254	0.7755
2015	PRB-3	29	0.0479	0.9521	3.0810	0.9150
2000-2014	PRB-4	25.1	0.0703	0.9297	3.1315	0.7712

2015	PRB-4	25	0.0745	0.9255	2.7741	0.8618

Species richness was greater in 2015 than the average species richness from 2000-2014 for sites PRB-1, PRB-2, and PRB-3. Species richness was about the same between years at PRB-4 (Fig. 2). Typical Shannon-Weiner Index values generally range between 1.5 and 3.5 in most ecological studies. The values analyzed in this study were all on the higher end of that range, indicating both high species richness and evenness in the study areas. The Shannon-Weiner Index of Evenness, E, was greater at all sites in 2015 than 2000-2014 (Fig. 3).

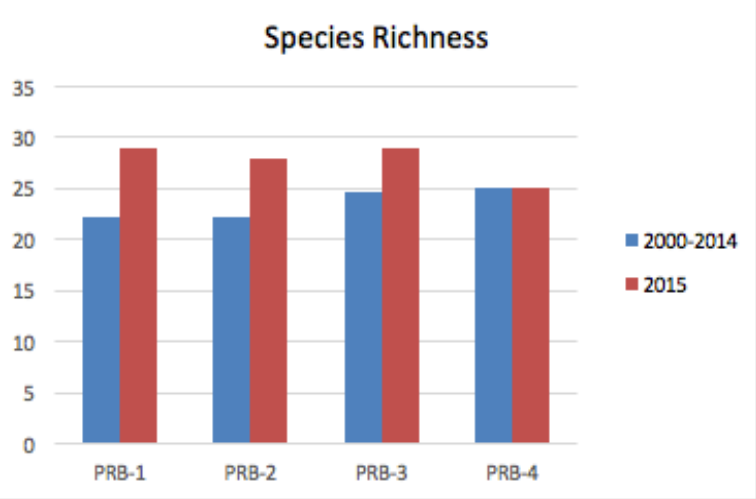

Figure 2. A comparison of species richness values from 2000-2014 and 2015. Data was collected from point count surveys conducted along the Peconic River Transect at Brookhaven National Laboratory in Upton, NY. PRB-# represents the 4 sites sampled along the transect. The values from 2000-2014 represent the average from those years.

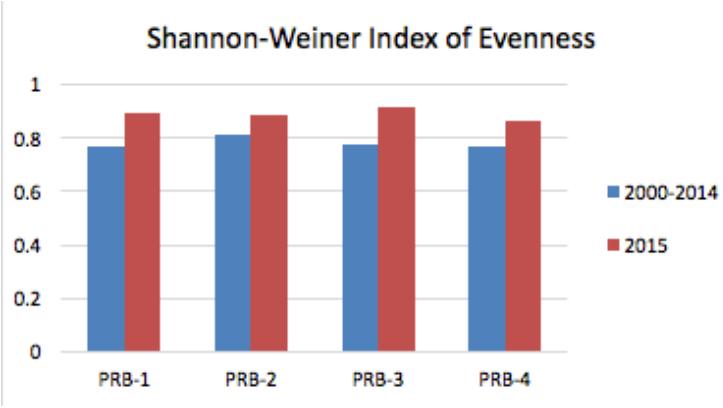

Figure 3. A comparison of the calculated Shannon-Weiner Index of Evenness values from 2000-2014 and 2015. Data was collected from point count surveys conducted along the Peconic River Transect at Brookhaven National Laboratory in Upton, NY. PRB-# represents the 4 sites sampled along the transect.

Discussion/Management Implications:

Estimating biodiversity indices of populations of interest provides an important management step for wildlife professionals. The data collection protocol was standardized so as to control for sources of variation that affect detectability. For instance, the data was collected by the same two professionals, Timothy Green and Ernie Lewis, for all sampling occasions from 2000-2015. By having the same knowledgeable and seasoned observers for every sample occasion, the detection probability is maximized and bias errors are minimized (Fryxell et al. 2014). This also assures that the data collection was completed with constant bias (Fryxell et al. 2014). Ultimately, this consistency during sampling reduces error and estimates can be calculated with greater confidence. The data was determined to be non-parametric for this study.

The species richness (S) reported in the results indicates that bird species are relatively diverse at BNL. Across all sites, there was at least 22.3 bird species detected on average. Although there was higher species richness in 2015 across all sites, we cannot conclude that

bird species richness necessarily increased. The values of S for 2015 are within the normal range (16-31) of species that contributed to the averages for 2000-2014. The Simpson's Index of Diversity (1-D) values are all high (close to 1) and did not vary greatly between years. Similarly, the Evenness values were reported to be high. The sample size was large enough in the 2000-2014 data set that the estimates are precise and can confidently represent the bird biodiversity during that time. In 2015, however, the sample size is not large enough to make sound conclusions on whether or not the STP effluent discharge is impacting bird biodiversity. It appears as though the there are no substantial, immediate impacts on bird biodiversity along the Peconic River.

The goal of this study was to monitor the impact that the STP's effluent discharge has on bird biodiversity using avian point count survey techniques at 4 sites along the Peconic River. The result of the statistical analysis reveals that there are no immediate impacts on bird biodiversity, however, future monitoring is needed to determine if there will be a long term impact. Future work could examine both bird biodiversity and abundance after multiple years. This would allow greater confidence in results due to a larger sample size. As aforementioned, there is a strong relationship between abundance and the persistence of a population in an ecosystem. Therefore, if biodiversity continues to not be impacted, perhaps abundance will be impacted and this relationship should be examined in the future. Ultimately, an adaptive management strategy should be adopted to accommodate any results that may negatively impact wildlife populations at BNL.

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Appendix:

Table 1: Summary of the Potential Environmental Impacts on ecological resources if no action was taken by BNL and the expected impacts of ceasing the discharge of effluent into the Peconic River and redirecting it to groundwater (EA, 2011).

Comparison Factors	**No Action: BNL Historic Operations**	**Discharge to Groundwater**
General Information	No change from historic BNL operations.	BNL installed a new final filtration system at the Sewage Treatment Plant (STP), built new recharge basins, and the former chlorine house was demolished at the former outfall. The former sand filter beds were isolated and the discharge to the Peconic River was eliminated.
Ecological Resources	Continued release of copper, iron, lead, mercury, nickel, and zinc to the Peconic River above WQBELs. Mercury would continue to leach out of the sand filter beds at a concentration of 70 ng/L or higher, potentially affecting biota. Peconic River flows would be maintained even during drought conditions.	**Construction Effects on Migratory Birds** - Tree clearing would have minor impacts due to loss of nesting habitat. Clearing would be timed to minimize impacts (i.e. winter months) if practical to do so. **Operation Effects on Migratory Birds** – New recharge basins would provide additional habitat for shorebirds like killdeer and the restoration of the sand filter beds would improve habitat for open field species like eastern bluebird, tree swallows, and sparrows. Changes to the Peconic River would result in some improved habitat for shorebirds without negative effects for other species.
Water Resources	Surface waters would continue to receive STP effluents with Mercury at ~70ng/L concentration along with other metals above WQBELs.	Discontinuing discharges to the Peconic River would result in the river functioning as it did before WW I; flows east of BNL would not be changed from the current state and onsite flows between gauging station HE and HQ would become seasonally intermittent. The groundwater mound under the current sand filter beds would eventually dissipate and the new groundwater recharge system would likely create a new groundwater mound that would join existing groundwater which would travel south and east from the STP area. No significant impacts would occur to groundwater and no

		production wells would be impacted from the recharge system due to added filtration of wastewaters prior to discharge. The current wastewater effluent quality meets all NYS groundwater effluent standards.