Georgica Pond Water Quality Restoration Action Plan

East Hampton, Suffolk County, New York

Prepared By:

Sara Davison
Executive Director
Friends of Georgica Pond Foundation
www.friendsofgeorgicapond.org

Dr. Christopher Gobler
Endowed Chair of Coastal Ecology and Conservation
Stony Brook University
you.stonybrook.edu/goblerlab/

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Additional participants involved in plan development include:
Town of East Hampton, Village of East Hampton, East Hampton Town Trustees,
Stony Brook University, and Friends of Georgica Pond Foundation, Inc.

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1. Purpose

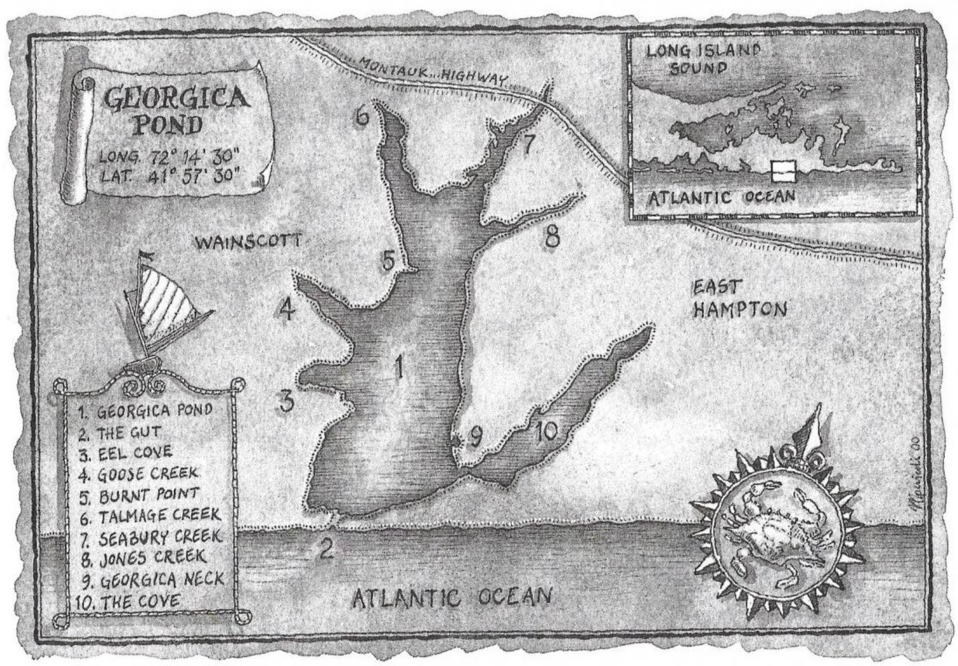
The purpose of this plan is to outline a process to restore the water quality of Georgica Pond. Recent blue-green algae blooms that have forced the seasonal closing of the pond to fishing, crabbing and recreation, low dissolved oxygen levels, and fish kills have all plagued Georgica Pond during the past five years. This plan collects known data and current research on the pond pertinent to water quality, indigenous organisms, and ecosystem function and provides user groups and governing bodies an action plan to improve conditions within the pond. This plan will also serve to meet the requirements of the New York State Department of Environmental Conservation (DEC) and the US Army Corp of Engineers (ACOE) for their issuance of maintenance dredging permits and provide a context for traditional pond openings by the East Hampton Town Trustees. It is expected that this plan will continue to evolve as new information is available and results from ongoing research and management become clear. Regular updates to the plan will be made.

2. Setting

Georgica Pond is a 290- acre coastal salt pond or lagoon (New York Natural Heritage Program, 2015) located in East Hampton Village and East Hampton Town, Suffolk County, New York. It perches on the Atlantic Ocean at Latitude: 40°55’53.5” and Longitude 72°13’47.8”. The pond’s bottomlands and inlet are owned and managed by the East Hampton Town Trustees. The pond is fed by groundwater within a watershed of approximately 4,000 acres. Approximately 59% of the watershed is developed with low density residential development (approximately 2,000 homes) as well as the business district of Wainscott, some industrial development (East Hampton Municipal Airport, a cement plant, and storage and landscaping companies), farmland and two regional schools. One third of the watershed is undeveloped including a large area of protected pine barrens forest around the East Hampton airport and 8% of the watershed is water. The pond and its immediate area is cited by the New York Department of State in their 2010 publication: *East Hampton Scenic Areas of Statewide Significance* and Georgica Pond has been designated a locally significant Coastal Fish & Wildlife Habitat by the East Hampton Local Waterfront Revitalization Plan.

The political jurisdiction of the pond is complex with the eastern shoreline within the Village of East Hampton and the western shoreline within the Town of East Hampton. In addition, certain, regulatory bodies including the NYS Department of Environmental Conservation, Suffolk County Department of Health Services and the US Army Corp of Engineers may require approvals for differing activities within the pond and/watershed. To facilitate collaboration and cooperation among these sundry groups, a "Georgica Pond Steering Committee" has been created including East Hampton Town, East Hampton Village, the East Hampton Town Trustees plus Stony Brook University, the Friends of Georgica Pond Foundation and the Nature Conservancy.

Some watershed characteristics are provided in Table 1. (Lombardo Associates, Inc., 2015)



Map 1. Names of Creeks feeding Georgica Pond

Table 1. Characteristics of Georgica Pond and its watershed.

Georgica Pond & Watershed

	No of Properties			Total Area (acres)				Pond Shoreline Length (ft)	Design wastewater flow	Groundwater from rain (gpd)	Wastewater as % of Groundwater Flow from rain
Region	Dev	Undev	Total	Dev	Undev	Water	Total				
Town	1,111	312	1,423	1,813	1,187	294	3,293	14,216			
Village	224	78	302	511	141	10	663	30,700			
Total	**1,335**	390	1,725	**2,324**	1,328	304	**3,956**	44,916	574,892	5,977,015	9.62%
Percent	77%	23%		59%	34%	8%					

3. History of Pond & Pond Openings

Historically, Georgica Pond has been opened to the Atlantic Ocean by the East Hampton Town Trustees, two or three times per year. The traditional fall opening is in October and the spring opening, which often occurred in April, has been moved to March to avoid all conflict with the federally threatened piping plover (see section 6). This practice is based on observations by colonial settlers who according to *A Poose and its Neighbors: Episodes from the History of*

*Georgica Pond and its Bar (*Pierson, 1992) observed Native Americans digging out Georgica Pond with clam shells when "the ponds were full and fish were running up or down the coast. They had, as it were, discovered a seasonal food supply and used these brackish ponds to trap it." The English colonists continued this practice using shovels or draft animal to open the pond. Today, it is opened using a mechanical backhoe.

The evidence of the regular opening of ponds by the East Hampton Town Trustees is supported in the Trustee records and historical maps. Trustee records mainly between 1870 and 1925 mention that the beaches opposite the inlets of Georgica and Hook Ponds were to be *restricted and reserved for the purpose of draining the ponds. (Our emphasis)* (East Hampton Town Trustees Records, 1870-1925). More recent records of the Trustee openings of the pond are provided in Appendix I.

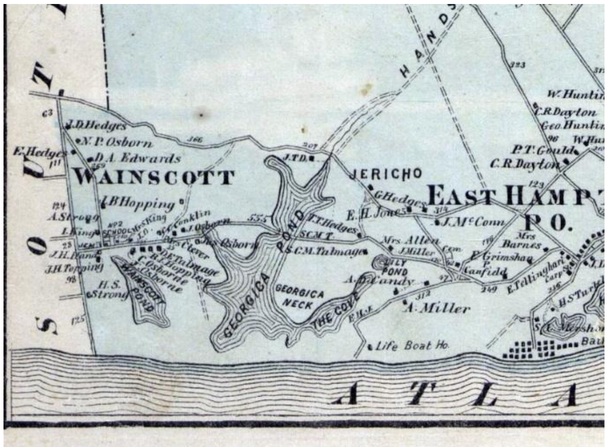
The pond also opens on its own through forces of nature including wind, storms and high tides as it does to this day. A sad notice in the *Records of the Town of East-Hampton* (1905) states "1714 Feby 5. Three young men getting fish when Georgike pond was out (tis supposed), coming home over the gut with the canoe were carried into the surf and drowned, viz: Joseph Earle, that lived with Joseph Stretton. Zebedee, son of Th. Osborn of Wainscott. John, eldest son of Matthias Hoppin."

The fishing in the pond was of significant economic importance to the early settlers so much so that they were prepared to go to court over the fishing rights. On page 8 of the East Hampton Town Trustees' records, 1826-1845, it says that in 1833, "Southampton men took fish with a seine in Georgica Pond, and the Trustees resolved to prosecute; they also decided to defend all townsmen granted permission to draw seines by the Trustees, who might be prosecuted by Southampton men or owners of land bordering the pond and who objected to East Hampton men fishing in the pond and cove. Riparian rights were investigated." On page 66 it goes on to say, "The trustees met…and agreed to institute a suit against Stephen Topping and others of the Town of Southampton for drawing a seine in Georgica Cove and pond contrary to an ordinance of this town passed the third day of May 1813."

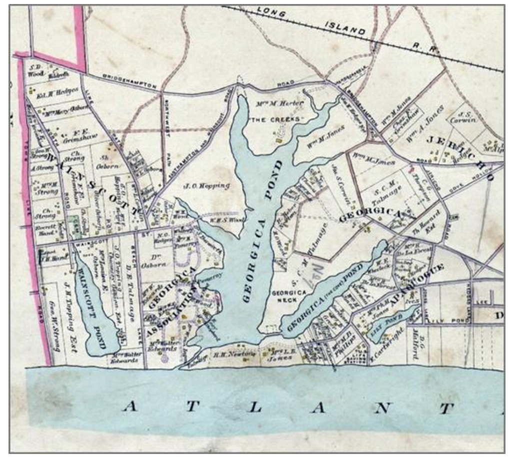
Over the centuries, there have been only minor changes to Georgica Pond's drainage and form. Surrounding woodland succumbed to farmland which has largely transitioned to low density residential development. A review of historical maps reveals only a few infrastructure changes of any note:

1. The building of Montauk Highway (Rt. 27) which crosses Talmage Creek, Seabury Creek and Jones Cove at the north end of the pond.
2. A bridge at Burnt Point the narrowest part of the pond shown on a map from 1873 was gone by the time a map was printed in 1902 (see maps 2 & 3).
3. The building of four groins in the 1960s to the east of the pond by the Army Corp of Engineers and New York State has had the most significant impact on the pond's coastal processes by intercepting the westerly moving littoral drift.
4. The addition of a storm drain which originates at Rt. 114 and flows into Georgica Cove.

Map 2 1873 showing Burnt Point Bridge



Map 3. 1902. Burnt Point Bride is gone



4. Endangered Species and Aquatic Communities

4.1. <u>Endangered Species</u>

Both the federally threatened and state endangered Piping Plover (*Charadrius melodus)* and the state threatened Least Tern *(Sterna antillarum)* nest on the sandy beach and dune edge on the Atlantic Side of Georgica Pond. The intertidal mud and sand flats of the pond provide feeding habitat. These populations are managed by the East Hampton Town Department of Natural Resources under the auspices of the East Hampton Management & Protection Plan for Threatened and Endangered Species (Town of East Hampton, 2015). The following table with data compiled by the East Hampton Town Natural Resources Department shows the last eleven years of nesting pair data. Diligent work by the Town Natural Resources Department has resulted in this increasing trend.

Table 2. Georgica Pond Beach Nesting Shorebirds

YEAR	Piping Plover Pairs	Least Tern Pairs
2010	2	81
2011	4	NS
2012	4	23
2013	3	5
2014	2	22
2015	3	24
2016	6	48
2017	6	60
2018	6	?
2019	7	48
2020	3	35

A nesting pair of the New York State threatened Bald Eagles *(Haliaeetus leucocephalus)* was documented at the pond in 2019. A large pitch pine (*Pinus rigida)*on a privately-owned house lot served as the nest tree. At least one chick successfully fledged. Successfully fledging was not documented in 2020. Protection of vegetated buffers and large trees near the pond is essential for their persistence at the pond.

4.2. <u>Aquatic Vegetation</u>

The submerged aquatic plant community of Georgica Pond is comprised of sago pondweed (*Stuckenia pectinata*), filamentous green algae (*Cladophora vagabunda*), and clasping leaf pondweed (*Potamogeton perfoliatus*). Sago and clasping leaf pondweed are rooted perennial aquatic plants; *Cladophora vagabunda* is a green algae that establishes attached to the substrate via a holdfast, but may break from the substrate and persist as massive free-floating mats (up to 0.5m thick) in the water column. Free-floating *Cladophora* may settle in rooted stands of sago pondweed.

The plant density and species composition in Georgica Pond varies annually based on meteorological conditions and the condition of the pond's inlet. Plant density also varies annually and spatially from low-density conditions, i.e. sparse or occasional widely spaced shoots, to high-density conditions where biomass densely fills the water column. Density of submerged aquatic plants and macroalgae has typically been greatest in the sheltered creeks in the freshwater headwaters of Georgica Pond and Georgica Cove, with lower density observed in the more dynamic, mineral substrate of the nearshore and deepwater zones of the main basin.

Stands of submerged aquatic plants begin to develop early in the growing season (late April), but do not become well-developed until early June when warmer water temperate supports higher growth rates. As the summer progresses, warm temperatures and an abundance of nutrients support high growth rates and biomass accumulation of *Cladophora* and sago pondweed. During peak accumulation, sago pondweed shoots may fill the water column and then grow laterally along the water surface. Stony Brook University reported dense plant growth would foul the propeller of the small outboard motor on their skiff used for environmental monitoring. In 2014-2015, dense masses of *Cladophora* were observed throughout Georgica Pond.

Descriptions of the species composition of the submerged aquatic plant community are based on observations from 2014-2018, observations of harvested biomass in 2016-2018, and monitoring in 2019. *Cladophora* was dominant in Georgica Pond in 2014-2015, both years with abundant spring precipitation and early closures of the pond inlet. Sago pondweed dominated the submerged aquatic plant community in 2016-2018, perhaps due to less abundant rainfall and lower pond water level and control of *Cladophora* via harvester. In 2016, *Cladophora* was the second most abundant plant to sago pondweed, while clasping leaf pondweed was second most abundant in 2017 and 2018. The pond inlet remained open for nine months from October 22, 2018 to July 25, 2019—perhaps the longest documented opening of the pond. Submerged aquatic plant densities were anecdotally much lower in 2019 compared to previous years with sparse and trace densities of sago pondweed observed throughout much of the pond and various marine algae present including *Ulva lactuca, Enteromorpha sp.*, and *Ulva intestinalis*.

In June 2019, the submerged aquatic plant density was quantitatively evaluated using a double-sided rake at 80 locations throughout Georgica Pond. The submerged aquatic plant density was relatively evenly distributed throughout Georgica Pond with 61.25% of sites yielding no to trace amounts of submerged aquatic plants and 30% of sites yielding plants filling less than 25% of the rake. Only 8.75% of sites yielded plants filling 25 to 100% or more of the rake; these sites tended to be located within the creeks draining into Georgica Pond. Sago pondweed was observed at 31.25% of sampling locations. *Ulva lactuca* was observed at 26.25% of sampling locations and *Cladophora vagabunda* was observed at 10% of sampling locations.

Submerged aquatic plant density and species composition maps from 2019 prepared by Stony Brook University are provided below (Figures 1, 2). Monitoring of the submerged aquatic plant community in Georgica Pond will continue in future growing seasons.

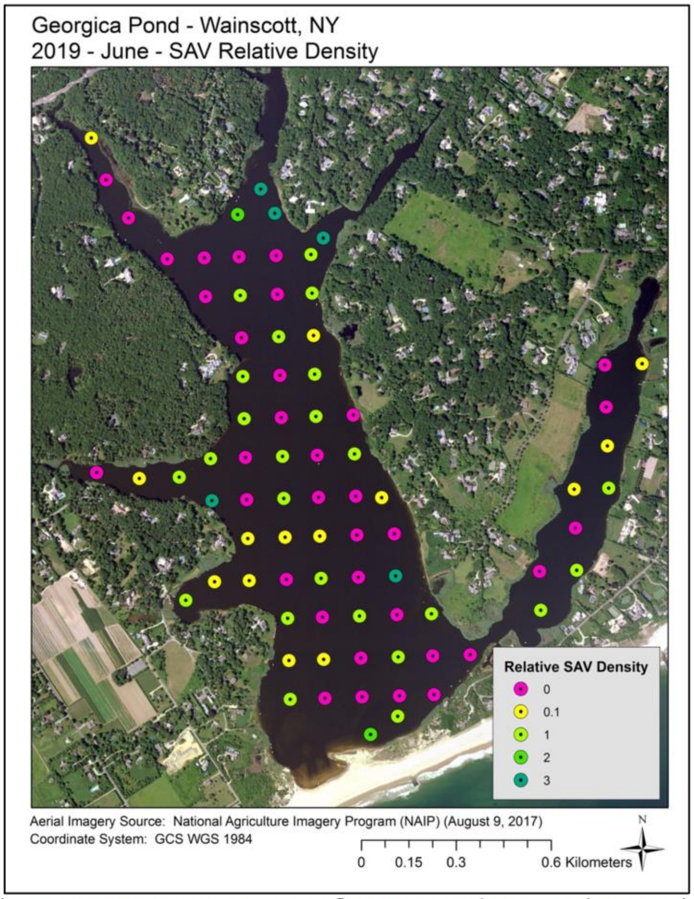


Figure 1. Relative Submerged Aquatic Plan Density at 80 locations throughout Georgica Pond.

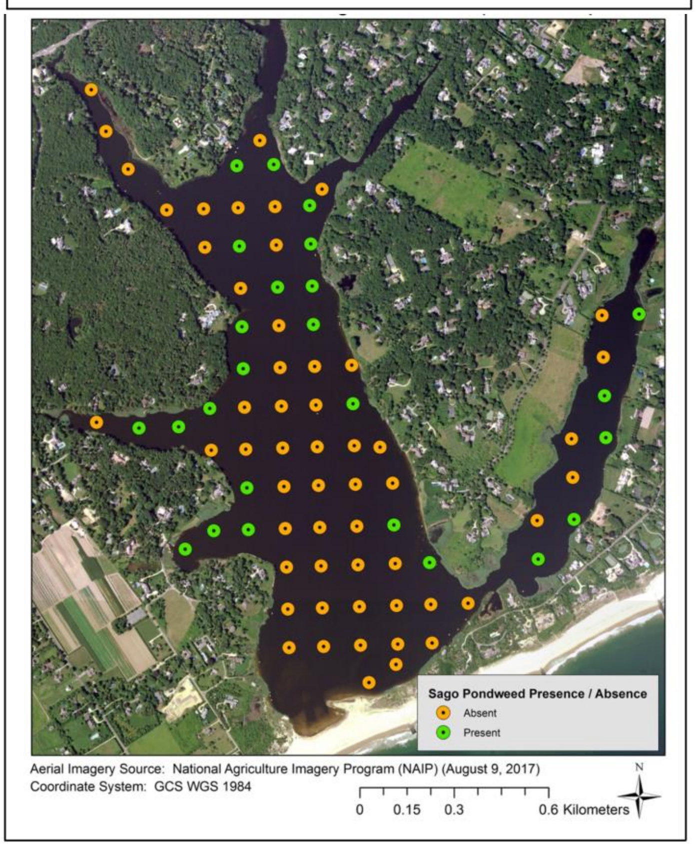


Figure 2. Distribution of Sago Pondweed throughout Georgica Pond.

Submerged aquatic plant beds provide important ecological functions and benefits. Submerged aquatic plant beds provide shelter for forage fish and juvenile fish, and serve as substrate for eggs for demersal-laying species. Submerged aquatic plant beds may serve as substrate for the epiphytic growth of algae and grazing habitat for microinvertebrates. Biological sampling by Stony Brook University indicates that various invertebrates utilize Georgica Pond's submerged aquatic vegetation beds as habitat including gamarid amphipods, damselfly nymphs, snails such as minute hydrobia (*Hydrobia totteni*), caddisfly larvae, and isopods including *Cyanthus polita* and *Idotea phosphorea*. Blue crabs use submerged aquatic plant beds as forage and nursery grounds for juvenile crabs and shelter during mating and molting. The starchy tubers of Sago pondweed are an important food resources for breeding and overwintering waterfowl.

Submerged aquatic plants have direct and indirect effects on harmful algae blooms and water quality parameters (such as dissolved oxygen and nutrient concentrations). Substrate within submerged aquatic plant beds may influence phytoplankton assemblages by serving as substrate for seeding or initiating blooms of phytoplankton or habitat for phytoplankton grazers. Submerged aquatic plant beds are also important components of the nutrient cycles in water bodies, both uptaking nutrients from water column and substrate and releasing nutrients to the water column upon senescence. Decomposition of senescenced submerged aquatic vegetation in late summer may release/increase biologically available nutrients, thereby fostering harmful algae blooms, and may consume dissolved oxygen adversely impacting fish communities and increasing the likelihood of fish kills.

4.3. Finfish

Finfish species that utilize Georgica Pond's submerged aquatic plant beds have been monitored and inventoried from 2016-2019 by the Gobler and Peterson laboratories of Stony Brook University, SOMAS (Appendix II). Bycatch and beach seine sampling data suggests that these habitats are mostly utilized by relatively small, low trophic level finfish species including silversides (*Menidia menidia* and *Menidia beryllina*), juvenile eels (*Anguilla rostrata*), killifish (*Fundulus diaphanous*), fourspine stickleback (*Apeltes quadracus*), sheepshead minnow (*Cyprinodon variegatus*), and mummichog (*Fundulus heteroclitus*). Northern pipefish (*Syngnathus fuscus*), alewife (*Alosa pseudoharengus*), and rainwater killifish (*Lucania parva*) are present at very low abundance. These fish provide prey for larger finfish, blue crabs, wading birds and waterfowl. Predatory fish that forage for prey fish around the margins of submerged plant beds include adult white perch (*Morone americana*) and summer flounder (*Paralichthys dentatus*).

4.4. Invertebrates

Additional invertebrate species that utilize Georgica Pond, per data collected by the Gobler and Peterson Laboratories (Appendix II), include blue crabs (*Callinectes sapidus*), minute hydrobia (*Hydrobia totteni*), grass shrimp (*Palemonetes pugio*), three different types of gamarid amphipods, isopods (*Cyanthus polita* and *Idotea phosphorea*), damselfly nymphs, caddisfly larvae and pupae, and a polychaete worm.

Blue Crab (*Callinectes sapidus*)

Blue crabs inhabit shallow estuarine and coastal waters, where they are an important ecological and predatory species in salt marshes and seagrass (SAV) communities. Both overwintering and summer blue crabs were inventoried. No overwintering blue crabs were found using the blue crab dredge during February and March of 2017. All crabs caught in summer were adult males and appeared to have overwintered in the pond. No larval crabs were found in larval tows. Research on where in the pond the adult blue crabs overwinter and how the population is sustained within a temporarily open estuary is continuing.

4.5. Plankton Community

Annual studies indicate that the phytoplanktonic community of Georgica Pond is comprised of green algae, cyanobacteria (blue-green algae), brown algae, and cryptophytes. Genre identified in these studies are as follows:

- Green algae: *Scenedesmus*, *Chlamydomonas*, *Selenastrum*, *Pediastrum*
- Cyanobacteria: *Microcystis*, *Anabaena*, *Aphanizomenen*, *Planktothrix*, *Cylindrospermopsis*, *Synechococcus*
- Brown algae: *Melosira*, *Navicula*, *Thalassiosira*, *Cocconeis*, *Fragilaria*, *Prorocentrum*

Overall, total algal biomass levels have decreased since the initiation of harvesting in 2016 (Figure 3). Cyanobacteria abundance was an order of magnitude lower in each of the three years of harvesting, compared to 2015 prior to harvesting (Figure 4). According to the 2018 Final Report from the Gobler laboratory, in harvester years, cyanobacteria never bloomed to the extent that it excluded other phytoplankton species.

Within each season, data suggests that relatively small cyanobacteria blooms tend to occur in the late summer between August-September. While this seasonal trend still appeared present during harvesting years, the total abundance of cyanobacteria was much lower than pre-harvest years, allowing its coexistence with the several other types of phytoplankton listed above. In fact, from 2016 to 2018 Georgica Pond exhibited some of the lowest levels of blue-green algae present in lakes and ponds throughout Suffolk County, while in 2014 to 2015 Georgica Pond had the highest levels of blue-green algae throughout the County.

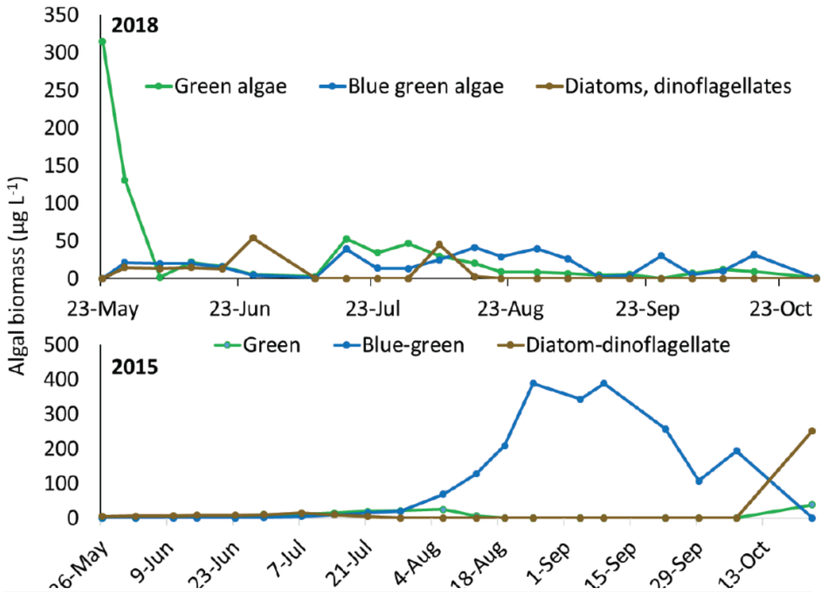


Figure 3. Comparison of algal biomass levels present in Georgica Pond in 2015 and 2018.
Data from C. Gobler 2019 Final Report, *Evaluation of macroalgae and aquatic plant harvesting as a means for improving water quality in Georgica Pond* (February 2019).

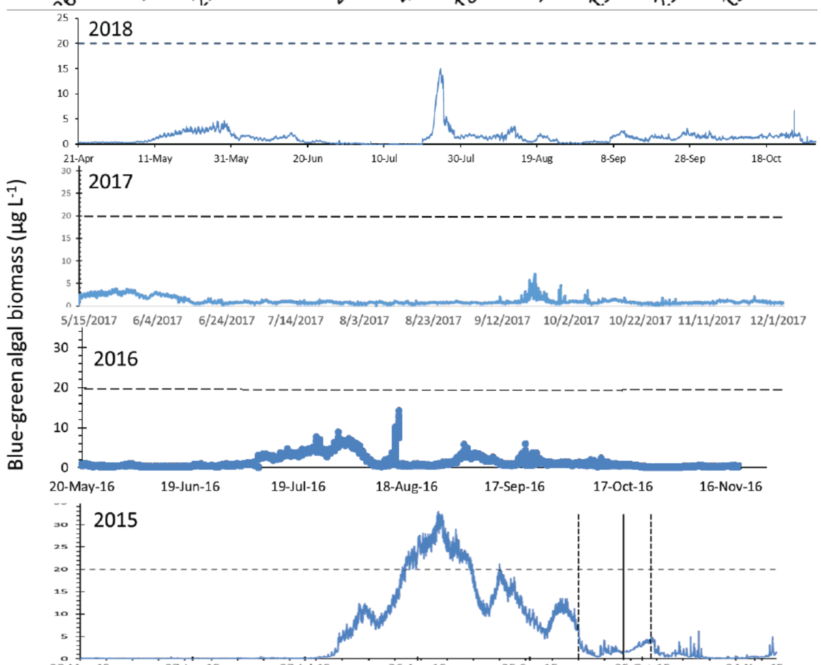


Figure 4a. A comparison of blue-green algal biomass levels present in 2015, 2016, 2017, and 2018. Data from C. Gobler 2019 Final Report, *Evaluation of macroalgae and aquatic plant harvesting as a means for improving water quality in Georgica Pond* (February 2019).

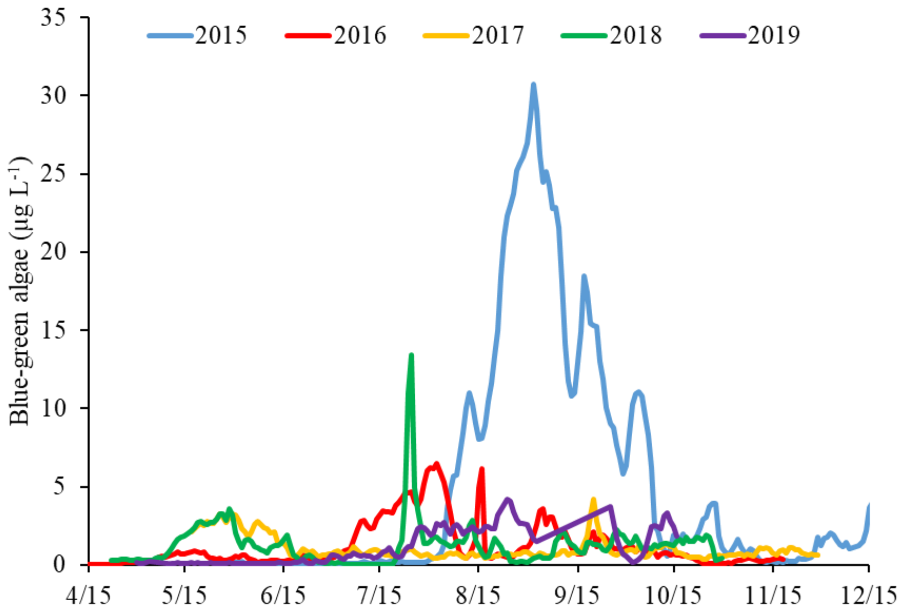


Figure 4b. Continuous blue-green algae concentrations (µg/L) taken from a monitoring buoy in Georgica Pond from 2015 – 2019.

5. Recreation

Georgica Pond is a highly valued community resource. The Town of East Hampton prohibits motorized boats with certain exceptions for research and baymen. Non-motorized boating such as canoeing, kayaking, sailing, and paddle boarding is very popular in the summer. Users often put in at the Route 27 rest stop and paddle to the ocean beach. Access points are currently limited to two locations and efforts to preserve and improve those access points are on-going. Sailing is also popular with the launch area at Eel Cove in the Georgica Association which is available to Georgica Association members. Recreational crabbing for blue crabs occurs in summer with baited lines laid out near the beach. Recreational fishing in the pond occurs to a lesser degree. Recreational and commercial harvest of shellfish in Georgica Pond is prohibited by NYSDEC due to elevated levels of potential pathogenic bacteria.

6. Commercial Fishing

In the last decade with the arrival of significant HABs and fish kills, the commercial fishing at Georgica Pond has declined significantly. There are a handful of commercial fisherman who still use the pond to catch bait fish, eels, and crabs when conditions are suitable. The pond is closed to bivalve shellfishing by the NYSDEC.

7. Pollution and Nutrient Source Analysis

Dr. Christopher Gobler of Stony Brook University's School of Marine and Atmospheric Sciences (SOMAS) has been studying the water quality and sources of pollution at Georgica Pond since 2013 as part of a town-wide water monitoring program funded by the East Hampton Town Trustees. In 2015, his work was expanded to include real-time telemetry buoy monitoring and to identify threats and make recommendations for remediation by the Friends of Georgica Pond Foundation, Inc. His preliminary findings from 2014 - 2019 are provided in Appendix III.

Briefly, Georgica Pond currently suffers from an array of water quality and habitat impairments. Since 2013, the Gobler Laboratory has documented a series of significant water quality impairments in Georgica Pond including anoxia (no oxygen), fish kills, macroalgal blooms, blue-green algal blooms, and elevated levels of the cyanotoxin, microcystin. These events worsen during summer (July - September) and are most problematic during late August and into September. As a result of blue-green algal blooms with elevated levels of cyanotoxins, Georgica Pond has been sporadically closed for harvesting of blue crabs during late summer and fall.

Experimental investigations by the Gobler Laboratory have demonstrated that the growth of the macroalgae *Cladophora*, blue-green algae, and other algae and phytoplankton in the pond are all promoted primarily by excessive nitrogen but can be further promoted by the combination of nitrogen and phosphorus. Because the pond can vary in salinity from 2 to 30 PSU and because groundwater is highly enriched in nitrogen but not phosphorus, the relative importance of nitrogen and phosphorus is likely to change from month-to-month and season-to-season. With phosphorus mostly likely to control primary producers when temperatures and salinity are low, and nitrogen becoming more important when salinity and temperatures are higher. Given the dynamic nature of this system, a management approach that seeks to restrict the delivery of both nitrogen and phosphorus is warranted.

To support the development of a watershed-based management plan, nutrient budget models have been developed by Dr. Gobler for both nitrogen and phosphorus and are provided in Figures 5 & 6. The aerial extent of the Georgica Pond watershed was determined using Suffolk County's LiDAR elevation data, topographical maps demarking the surface watersheds (HUC 12), and groundwater flow patterns, which have been previously found to generally follow hydraulic gradients established by surface topography (Schubert, 1998).

The first model used to predict the total dissolved nitrogen input into the Georgica Pond was the Nitrogen Loading Model (NLM) (Valiela *et al.* 1997). The model is available through the Nitrogen load web-based modeling tool (nload.mbl.edu) described in Bowen *et al*. (2007) and used in Bowen and Valiela (2004) and recently in Kinney and Valiela (2011b), among others. The NLM uses information about land use in a defined watershed to predict both the amount of nitrogen that is released into the watershed from various sources and how much of it ends up in a corresponding waterbody. This model requires accurate land-use and land cover information, such as area of agriculture, residential areas, and impervious surfaces as well as other environmental data gathered from scientific literature, GIS data, USGS reports, the Town of East Hampton, and Suffolk County as described in Table 1. For this study, the model was updated to use constants and data specific to Georgica Pond, East Hampton, and Suffolk County.

The NLM is a good fit for watersheds such as Georgica Pond that are a mix of residential, forested, and agricultural lands. The NLM assumes that the primary transport mechanism for nitrogen entering the bays from each watershed is ground-water flow. This assumption is consistent with data available for the Georgica Pond as there is little inflow to the bay from streams and geologically, Long Island is composed of unconsolidated sands that allow for relatively easy transport of groundwater to coastal bays.[18] The NLM assumes that all nitrogen entering the bays from external sources originated from atmospheric deposition to the watershed, wastewater, or fertilizer. This study also includes atmospheric deposition directly to the surface water of the Bays. Valiela *et al*. (1997) validated this model by comparing its nitrogen load prediction to empirically measured nitrogen levels. They found the NLM's results to be statistically indistinguishable from measured concentrations and that a linear relationship exists between the percent contributions from wastewater that the NLM predicted and the stable isotope signature for wastewater expected from known isotopic nitrogen values of nitrate in groundwater. The NLM is one of the most inclusive nitrogen loading models regarding the transformation and transport of nitrogen as it travels from watershed to estuaries (Bowen & Valiela, 2001). The NLM utilizes multiple features within the model for each subwatershed; these features include: number of buildings; buildings within 200 meters of shore; surface area of the subwatershed; area of freshwater wetlands; agriculture; golf courses; parks and athletic fields; freshwater ponds; and, impervious surfaces, and were obtained from the Town of East Hampton and Suffolk County. The model also includes a list of inputs assigned default values based on an extensive metadata analysis (Table 1; Valiela *et al.*, 1997). These model defaults were changed when local and site-specific information were available. For example, a recent study by Young *et al*. (2013) of denitrification in Long Island's aquifer, found that the 15% of nitrogen in groundwater is denitrified rather than the 35% assumed by Kinney and Valiela (2011b). The NLM has a 12% standard error coefficient (Valiela *et al.*, 1997). Specific details of the NLM followed Gobler and Stinette (2016).

A Volumetric Flux Model (VFM) was created to predict nitrogen and phosphorus loads to the bays based on the volume of water that discharges from the watershed into the bay and the nitrogen concentrations in groundwater, streams, and runoff within the watershed. The VFM has been used successfully to predict nitrogen loads to several Long Island estuaries, bays, and harbors including West Neck Bay on Shelter Island, North Sea Harbor in Southampton, and Flanders Bay in Riverhead (Gobler & Sañudo-Wilhelmy, 2001; Gobler & Boneillo, 2003; Koch & Gobler, 2009). This model relies on the assumption that groundwater discharge to the bay is equal to the recharge of the aquifer. In contrast to the NLM, which breaks down the nitrogen load into sources (i.e. wastewater v. fertilizer), the VFM differentiates nitrogen inputs by transport mechanism: stream flow, surface runoff, or groundwater flow. The methods used here largely followed those of Gobler and Stinette (2016).

The NLM and VFM were combined along with additional information to create an independent hybrid model. Specifically, benthic fluxes were added to the model based on the methods of Gobler *et al*. (2001) with sediment cores collected during multiple seasons and the precise flux of nutrient from the cores incubated under ambient conditions quantified. Bird inputs were estimated as per Fleming and Fraser (2001).

With regard to nitrogen loading to Georgica Pond (Figure 5) it was found that the majority of nitrogen entering the Pond (50%) emanates from septic tanks and cesspools of the more than 2,000 homes within the Pond's watershed. Sediments were estimated to be the second largest source of nitrogen, representing 22% of the total load of this element. Sediment analyses confirmed this finding as about 80% of the pond bottom is comprised of muddy sediments with a high level of organic matter (up to 13% by mass). Atmospheric deposition represented a significant portion of the total nitrogen load to the pond (21%). Much of this load was to the 2,500-hectare watershed (17%) and then was delivered to the Pond while a smaller fraction was deposited directly into the Pond (4%). Fertilizer represented a small fraction of the total nitrogen load to the Pond (5%) with much of that nitrogen associated with agriculture in the northeastern extent of the watershed. Waterfowl were found to be a minor source of nitrogen (1%). The large majority of nitrogen is specifically delivered via groundwater flow (75%), with input from stream flow and runoff being minor.

With regard to phosphorus loading to Georgica Pond (Figure 6) it was found that the majority of phosphorus entering the pond (60%) emanates from the organic-rich, muddy sediments across the pond bottom. Fertilizer represented a larger fraction of the total phosphorus load to the pond (15%) with much of that phosphorus associated with agriculture in the northeastern extent of the watershed (9%) and residential fertilizer accounting for an addition 6%. Septic tanks and cesspools were a minor source of phosphorus (4%) as most wastewater phosphorus gets retained within aquifer sediments, being bound to clays and sands. Atmospheric deposition represented a minor portion of the total phosphorus load to the pond (3%) while waterfowl were found to be slightly more important (6%). Surface runoff was also a significant source of phosphorus, being 11% of total inputs.

These models are meant to be refined with time. For example, one major recommendation of phase one of studying Georgica Pond was to dredge sediments as a means to increase the volume of Georgica Pond and to remove a key source of nitrogen and phosphorus to overlying waters.

While dredging the entire pond might be desirable, the logistical feasibility of such an approach is not tenable. Hence, it is important that as much information as possible can be generated in advance of any dredging so that it can be done in a cost-effective manner that maximizes environmental benefit to the pond. Toward that end, a project was conducted to quantify the precise amounts of nitrogen and phosphorus emanating from Georgica Pond sediments which to date have only been estimated and have been assumed to be uniform in space and time. Dr. Stuart Waugh of Stony Brook University led this effort quantifying the rates at which phosphorus and nitrogenous nutrients emanate from sediments. Furthermore, the rates at which nitrogen in sediments is converted to innocuous nitrogen gas (also known as denitrification) was also quantified (See Appendix IV for Dr. Waugh's report). This is highly important as some organically-enriched sediments can undergo denitrification at a high rate while others do not. Quantification of the precise rates at which nitrogen and phosphorus are released from sediments as well as the quantification of any denitrification in those sediments will guide future plans to dredge Georgica Pond and will further permit a refinement of nitrogen and phosphorus budget constructed for the Pond in 2015.

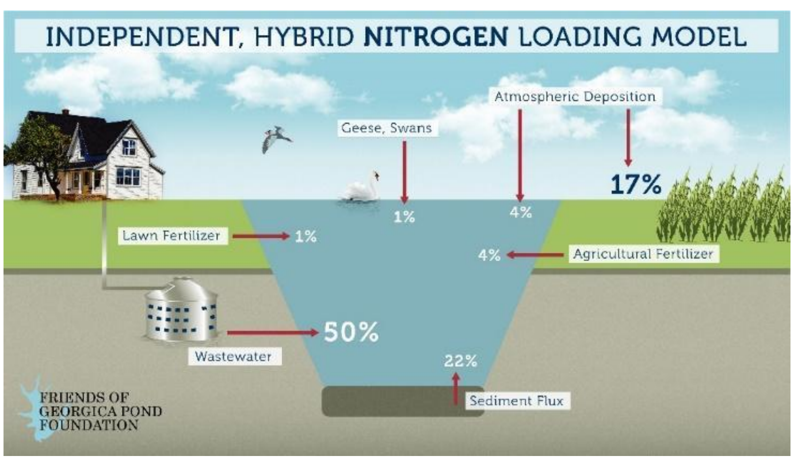


Figure 5. Gobler Independent Hybrid Nitrogen Loading Model

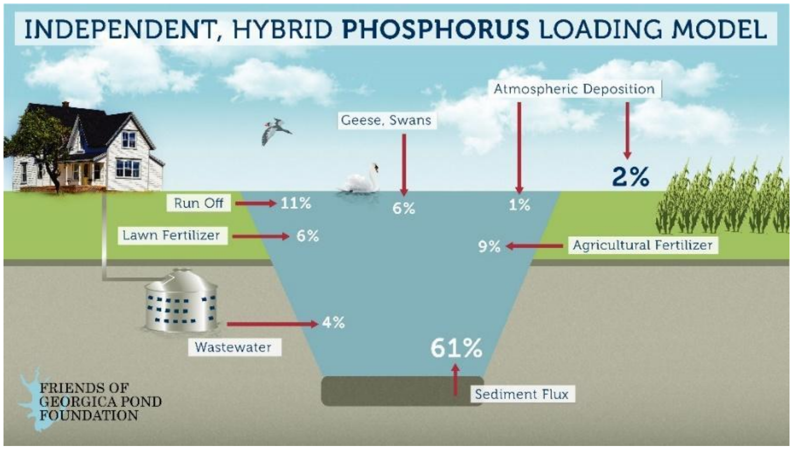


Figure 6. Gobler Independent, Hybrid Phosphorus Loading Model

8. Continuous monitoring of Georgica Pond

In 2015, a monitoring buoy was installed within Georgica Pond that provides the continuous levels of temperature, dissolved oxygen, pH, salinity, chlorophyll a, and blue-green algae (Figure 7). The telemetry buoy is secured in the deepest area of the pond in the southeast corner. This device has proved extremely useful for detecting the emergence of blue-green algae blooms and hypoxic / anoxic events, all of which can emerge rapidly and some of which may be present on a transitory basis, for example the occurrence of nocturnal hypoxia. This device has been equally important for observing the sudden changes that occur in Georgica Pond following the opening of the ocean inlet. For example, this buoy clearly demonstrates that opening of the Pond leads to a rapid drop in water level, a *temporary* dip in oxygen levels, and then the initiation of tidal flushing of Georgica Pond. Examples of these data sets can be found within Appendix III of this report. Buoy data is seasonally available via https://you.stonybrook.edu/georgicapond/buoy/ , the Friends of Georgica Pond website: www.friendsofgeorgicapond.org and the East Hampton Town Trustees website www.ehtrustees.com

Figure 7. Telemetry water quality buoy installed April through November 2015 – 2019.

8.1. USGS Pond Level Monitoring Gage

Since June of 2003, the United States Geological Service (USGS) has maintained a real-time pond level gage for the purposes of monitoring pond water levels (Figure 8). Real-time data from the pond level gage can be obtained at the USGS website www.usgs.gov or the Friends of Georgica Pond Website www.friendsofgeorgicapond.org. This project is funded in part by the Village of East Hampton, Friends of Georgica Pond Foundation and the USGS. The gage is located on the southern edge of Georgica Cove. This device has proven useful for demonstrating the precise and relative changes in depths associated with the opening and closing of the Pond, superimposed over normal seasonal cycles of maximal freshwater input (spring) and maximal evapotranspiration (summer) [Figure 9].

Figure 8 USGS Pond Level Telemetry Gage

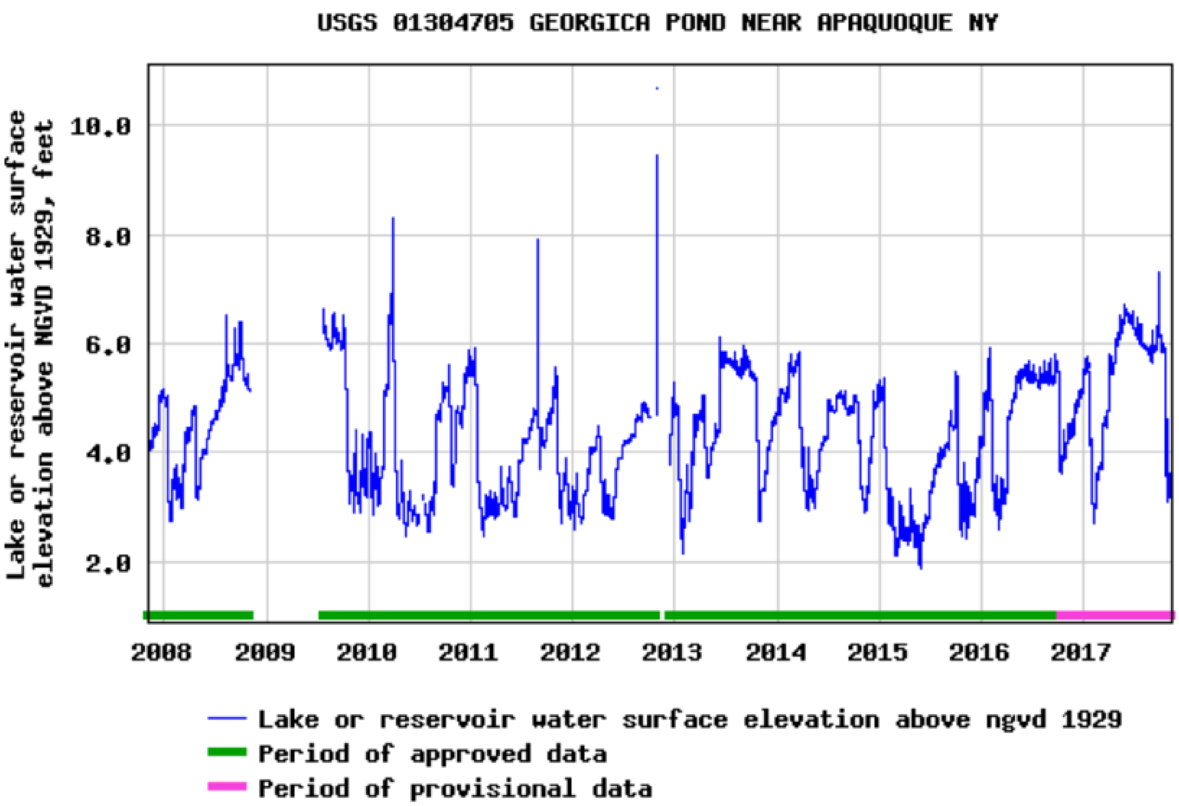


Figure 9. 10-year record of water level in Georgica Pond

8.2. <u>Microbial Source Tracking</u>

In 2017, the Gobler Lab began a 2-year investigation of pathogenic bacteria entering the pond. Tributaries feeding the pond were selected as sampling locations and DNA-based microbial source tracking was used to identify the source of fecal contamination. In Georgica Pond two major sources of fecal bacteria were detected: dog/small mammal and birds. The relative proportion of these two groups changed with the season. Readings at obvious storm water runoff sources including the Cove Hollow pipe and the Rt 27 Rest Stop confirm high bacterial counts often exceeding EPA recreational water standards. Readings at these two locations taken since 2015 by the Surfrider Foundation also confirm the high levels. Dr. Gobler's report is attached as Appendix VIII.

9. Phragmites australis

In 2017-2018 a study by Ray Hinkel of AECOM was commissioned to inventory and map the *Phragmites* at the pond. Genetic analysis was conducted to be certain that the Georgica Pond strain was the invasive variety. Findings include: more than 60% of the shoreline is invaded by *Phragmites*, and that the species occupies 10% of the total pond area. The brackish conditions at Georgica Pond are ideal for *Phragmites*. Increased salinity could discourage the proliferation of *Phragmites* and opening the pond may benefit the native brackish shoreline habitat at the southern end of the pond. The Hinkle study is attached in Appendix V.

10. Management Objectives & Pond Opening Decision Making Context

The long-term management objective for Georgica Pond is to restore the water quality to the USEPA water quality guidelines for nitrogen and phosphorus (0.02 µg per L total P and 0.45 µg per L total N) and reduce bacterial contamination to NYSDEC-approved levels for shellfishing and NYSDOH approved levels for swimming. There are many steps necessary to reach these two goals and pond opening is not viewed as the primary technique to restore water quality, although opening the pond can address immediate water quality issues such as blue-green algae blooms and severe flooding conditions. As stated in the historical overview, the purpose of the traditional pond openings was to enhance fisheries including migration of fish and crab and their juveniles and larvae to and from the pond to the ocean. Georgica Pond is an important nursery for bait fish, eels and the blue crab. (Gobler and Peterson, 2019; New York State Department of State, 2007). A better understanding of this dynamic is needed. As a primarily brackish pond, the connection to the ocean on a seasonal basis is important to maintain species balance, help control invasive species such as *Phragmites*, carp, and harmful species such as blue-green algae. In addition, dissolved oxygen levels improve after pond openings established tidal cycles (Gobler, 2015)

The observations made in Georgica Pond since 2014 provide important insight and further confirmation regarding the effects of pond opening on water quality and water levels. In 2014 and 2015, the toxic blue-green algae blooms in the pond ended following the opening of the inlet. The three factors considered as likely contributors towards this rapid occurrence included:

1. Tidal Transport. The induction of tidal exchange with the ocean facilitates the export of the blue-green algae to the ocean.
2. Increased Salinity. Higher salinities brought to the pond via the ocean water created salt conditions which were not conducive to blue-green algae that thrive under freshwater and

low salinity conditions. *Anabaena* can only tolerate salinities below 15 (Moisander *et al*. 2002) and *Microcystis* thrives at salinities below 10 (Orr *et al*. 2004)

3. Lower Temperatures. Blue-green algae abundances generally parallel temperatures (Paerl & Huisman, 2008).

Further evidence of the role of ocean salinity in discouraging blue-green algae in Georgica Pond was produced from an experiment conducted in 2015 by Dr. Christopher Gobler. On August 14th water was collected from the south end of Georgica Pond with high levels of blue-green algae. This water was diluted by half with filtered pond water or filtered ocean water, the former leaving the salinity unchanged but the later raising salinity levels from 13 to 21. After 48 hours, blue-green algae levels in the low salinity water increased slightly whereas levels in the higher salinity water declined by 40%. (see Appendix III). This outcome suggests that raising salinity in Georgica Pond is a means for successfully mitigating blue-green algal blooms.

The presence of a toxic blue-green algae bloom (higher than 25 µg per L) is a key environmental parameter that can be mitigated by a pond opening and the introduction of high salinities to the pond. Georgica Pond's water levels and salinity are highly responsive and dynamic. In 2015, following the closure of the inlet in June, salinity dropped from over 30 PSU to below 15 PSU in only 31 days; levels low enough to support blue-green algae, which bloomed shortly thereafter. In 2019, a similar change in salinity occurred in less than three weeks.

Data from the pond gage show that occasional high-water marks have been observed over the last 10 years. In the Spring of 2017, the pond was not opened as part of the practice of traditional spring openings as the presence of nesting piping plovers prevented the spring opening. Due to heavy rainfalls, and no spring opening, pond levels reached 6.5 ft. above sea level, near the record highs. This was one foot higher than the same time in 2016, there was widespread standing water in low areas and flooding of basements and septic systems near the pond.

- **The presence of water levels higher than 5.5 feet as measured by the USGS pond gage could trigger a pond opening to alleviate localized flooding and potential contamination from inundated septic systems.**
- **The pond must not be opened during the piping plover breeding window which runs from April 1 to August 31. If all plover chicks have fledged prior to August 31, the regulatory agencies may be petitioned to allow earlier pond opening.**
- **Should a public health, natural resource impact, or storm-related emergency occur during the breeding window, an emergency inlet opening request would be made to the NYSDEC and U.S. Fish & Wildlife Service (USFWS). All parties would need to agree to a previously established and approved emergency opening protocol that would ensure that the endangered nesting species would not be impacted.**

Beyond the ability to improve water quality conditions, opening the cut of Georgica Pond to the Atlantic Ocean has numerous other ecological benefits. When the cut is open land derived nutrients that enter the Pond are tidally flushed to the ocean. In his 2015 modeling of nutrient loads to and from Georgica Pond, Dr. Gobler determined that keeping the cut open for longer reduces the amount of watershed-based nutrient reductions needed to achieve EPA guideline levels of nitrogen and phosphorus. For example, tidal exchange with the ocean was estimated to flush 1,400 lbs. of N per month and a six-month opening instead of two months would reduce the amount of nitrogen load reduction needed from 93% to 80% and a ten-month opening (as occurred in 2018-

2019) would require only a 60% reduction in watershed nitrogen loads to achieve EPA target concentrations of nitrogen.

Duration of pond openings should be further examined to quantify beneficial results compared to any negative impacts.

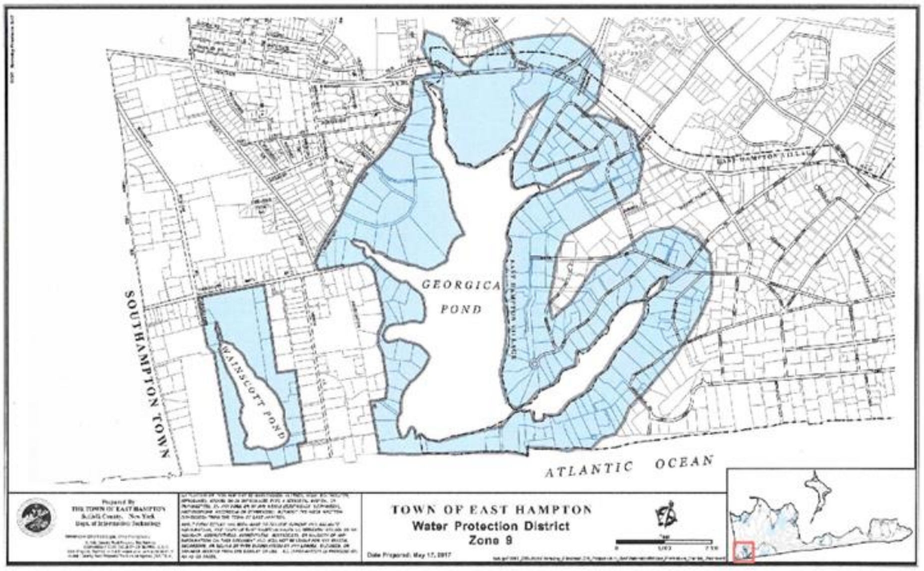
Fig 10. An aerial photo from 2015 showing the gut which opened naturally on land owned by the Georgica Association west of the Trustee's parcel (thin rectangle). Note extensive sand shoals within the pond.

Beyond the specifications regarding the conditions under which the Pond should open, it is the consensus of all Georgica Pond stakeholders that the East Hampton Town Trustees should open the pond in the center of the sandy beach on land owned by the Trustees (SCTM #300-15-5-17, Figure 10). Locating the cut as centrally as possible will reduce any potential erosion to neighboring private property owners. A Memorandum of Understanding between the East Hampton Town Trustees and the Georgica Association, the neighbor to the west, agreeing to the location, notice, access and use of dredged sand was signed by the Trustees and the Georgica Association in August of 2017 and is included in Appendix VI. A series of satellite photographs of the pond from 1994 to 2016 show that of the 17 images, half of them show the pond with the inlet open.

11. Management Plans Beyond Pond Openings

11.1. Septic Upgrades

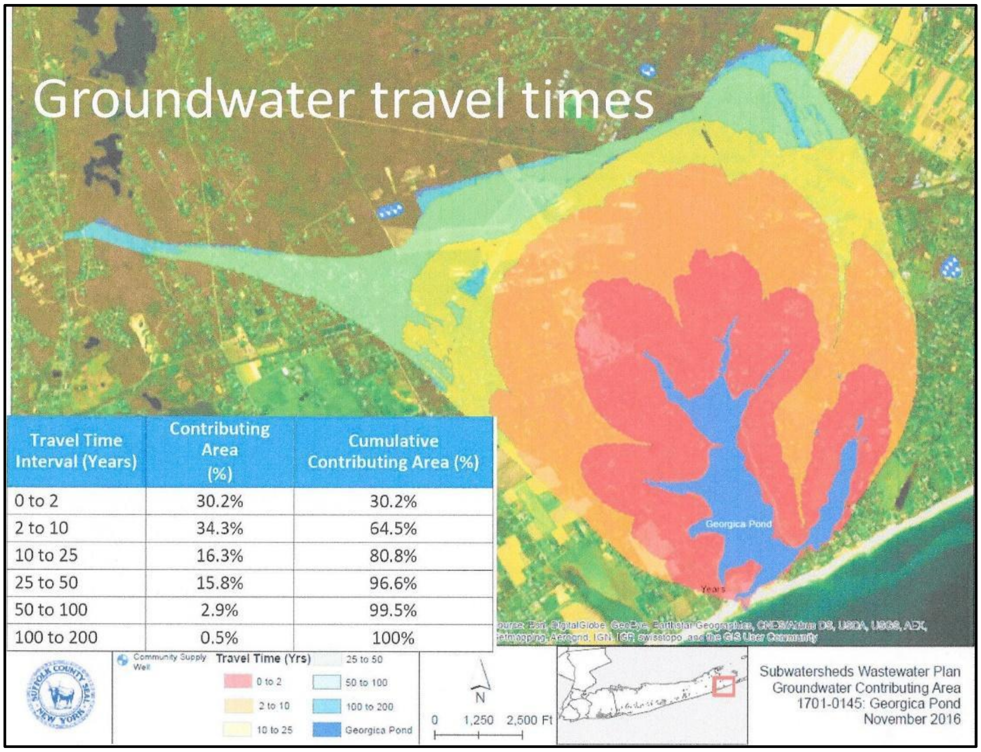
Because the largest source of nitrogen to Georgica Pond is wastewater from residential septic systems, a plan to reduce this input is imperative to improving the water quality of Georgica Pond. Working with local government and Suffolk County, the Friends of Georgica Pond Foundation has launched a septic upgrade campaign for the Georgica Pond watershed. This campaign is intended to encourage voluntary upgrades in conjunction with the Town of East Hampton and Village of East Hamptons recent code changes which require low-nitrogen systems for all new construction and major renovation and makes a rebate available to homes in the Town and Village’s “Water Protection Districts”.



Map 4. East Hampton water protection districts for Georgica and Wainscott Ponds.

With approximately 2,000 homes in the entire watershed and decadal travel times of groundwater across the entire watershed (Map 5), this is a long-term project. The highest priority homes for upgrading septic systems are the 75 pond-front homes and, secondarily, the approximately 280 homes in the 2-year groundwater travel time (Map 5). As of May 2020, 33 legacy septic systems within the 2-year groundwater travel time zone have been replaced (14) or are in planning/permitting (19) to be replaced.

Outreach activities have included hosting educational workshops and one-on-one meetings to assist homeowners with educational information on the technology and administrative requirements. This is ongoing and adapting as the local and county programs continue to change. Local workshops organized by the Town of East Hampton and local NGOs have also been used to promote low nitrogen septic systems.



Map 5. *Groundwater travel time map provided by Suffolk County Subwatershed Wastewater Plan.*

11.2. <u>Maintenance Dredging</u>

There is a well-established history of NYSDEC and ACOE permits allowing the Town and Trustees to perform maintenance dredging at the mouth of Georgica Pond to address the shoaling (flood tidal delta) of the pond. A review of East Hampton Town Trustee recent files documented 10-year maintenance dredging permits issued in 1989-1990, 2003-2013, and 2018-2028. Maintenance dredging to remove sand shoals which build up at the mouth of Georgica Pond have multiple benefits to Georgica Pond:

- Increasing the depth of the pond, lowering water temperatures and dilution of nutrients and contaminants.
- Deepening passage from Georgica Cove to the main pond, allowing the Cove to better exchange with the pond.

- Improve the effectiveness of traditional pond openings.

Sand recovered during the dredging is used to nourish nearby dunes as per the NYSDEC permit #1-4724-01190/00013.

11.3. Fine Sediment Dredging

Much of the bottom of Georgica Pond consists of a thick layer of mud and silt particularly in some of the feeder creeks and Georgica Cove (see Figure 11). Pond sediments were mapped in the 2015 Gobler Study and removal of this thick layer in parts of the pond could eliminate a significant source of phosphorus and nitrogen fueling algal blooms in the pond. Five test sites were selected in 2016 and sampled for contaminants of concern for NYSDEC with respect to disposal of dredged sediments. Two samples (Seabury Creek and Goose Creek) were free of contaminants while elevated levels (above the minimum, below the maximum) of lead, chromium and mercury were found in the main pond, Georgica Cove and Talmadge Creek. In 2017, Dr. Stuart Waugh of SOMAS, Stony Brook University sampled pond sediments to further quantify the amounts of nitrogen emanating from Georgica Pond sediments as well as rates of denitrification. Dr. Waugh's report is attached in Appendix IV. The Waugh report concluded that the amount of denitrification in Georgica Pond sediments is low and that in addition to phosphorous, Georgica Pond sediments are a strong nitrogen source. This finding strengthens the conclusion that dredging of muddy sediments will mitigate a large nitrogen source to the pond.

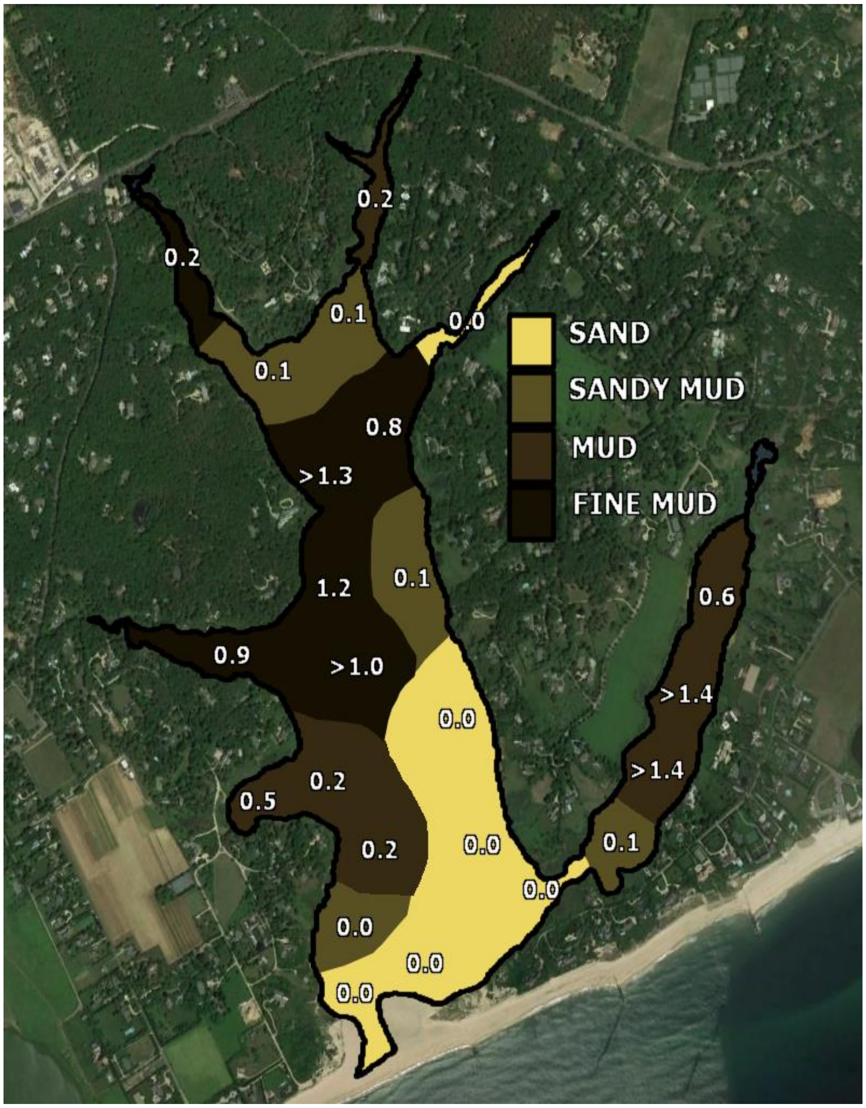


Figure 11. Sediment composition of Georgica Pond and thickness of muds (Gobler, 2015)

All these efforts are being made towards gathering the information needed to initiate a fine sediment dredging plan for the pond. A pilot dredging project was initiated in 2018 at the top of Georgica Cove approved by the NYSDEC permit #1-4724-01190/00010, Army Corps permit #NAN-2016-01054 and the East Hampton Town Trustees and the Village of East Hampton. *Phragmites* roots and fine sediments were removed using a hydrorake and small suction dredge. The project was concluded in 2020 and was a modest success. Flow in the channel was increased and access was improved. The actual amount of fine sediment removed was below the anticipated amount and technological and site limitation prevented further removal. The difficulty of access and de-watering sites at the pond are limiting factors.

11.4. Aquatic Plant and Macroalgae Harvesting

From 2016-2018, a NYSDEC license to collect was issued to Dr. Christopher Gobler and the East Hampton Town Trustees to use an aquatic weed harvester to remove macrophytes from the water column as an experimental nutrient bioextraction strategy to minimize the intensity of blue-green algae blooms (Gobler, 2016-2018; Appendix II). In 2014 and 2015 in Georgica Pond, dense blooms of *Cladophora* degraded during the summer and were succeeded by blue-green algal blooms that likely fed off of the nitrogen and phosphorus released by *Cladophora*. The same pattern of succession has also been observed in neighboring Wainscott Pond. During 2016 – 2018, macrophytes harvested included *Cladophora* sp., *Stuckenia pectinata and Potamogeton perfoliatus.* Table 3 compares the total loads harvested in each year and the percent of the summer nitrogen and phosphorus loads removed by this process.

Table 3. Macrophyte Harvest at Georgica Pond

YEAR	Lbs. Harvested	% N Removed	% P Removed
2016	55,740	10%	20%
2017	32,700	6%	12%
2018	93,140	15%	18%

By-catch analysis of the harvester was conducted in 2018 and the details of the project are provided in Appendix II.

Macrophyte harvesting has correlated with a statistically higher dissolved oxygen levels during the summer and reductions in the intensity and duration of blue-green algae blooms within Georgica Pond (Figures 12, 13). While there was no harvester and no blue-green algae in 2019, the Pond was open to the ocean until almost August, prohibiting salinities that would allow for blue-green algae growth until September and prohibiting direct comparisons of this parameter to prior years.

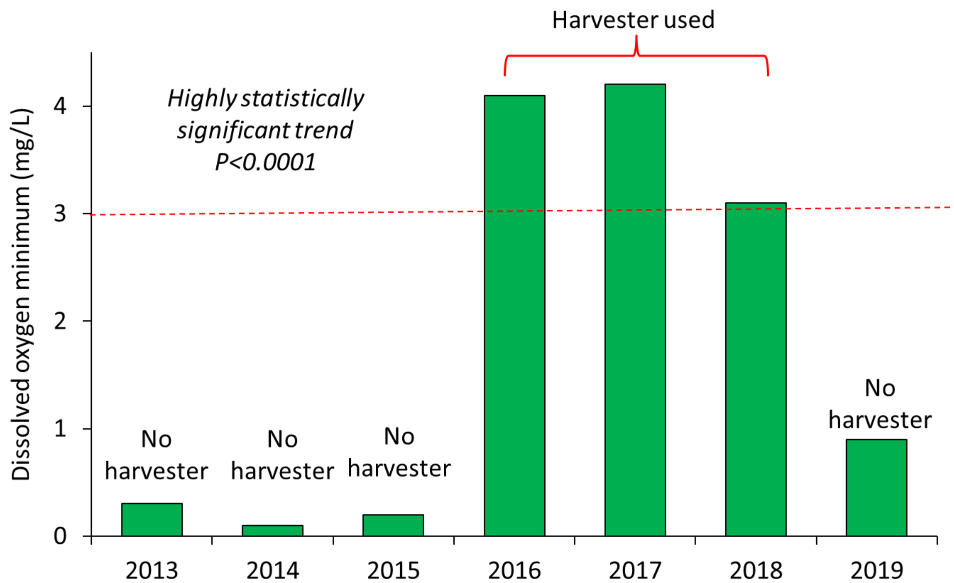


Figure 12. Summer minimum dissolved oxygen in Georgica Pond, 2013 - 2019

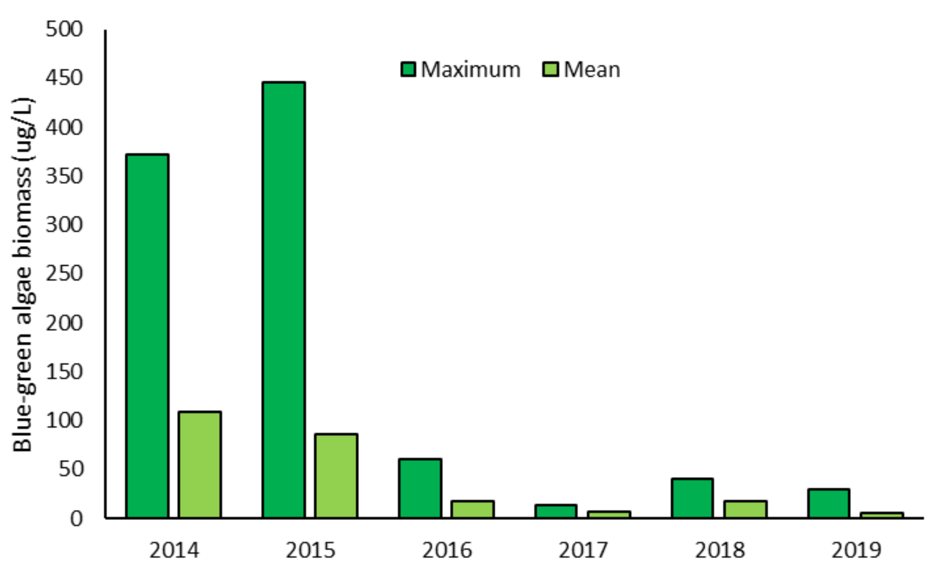


Figure 13. Blue-green algae levels in Georgica Pond, 2014-2019

Due to the success of the pilot project, FOGP is proposing to continue to perform annual aquatic vegetation and macroalgae harvest using the same methods as the pilot project. In 2019, FOGP applied for NYSDEC wetlands permits and an East Hampton Town Natural Resource Special Permit.

No macrophyte harvesting took place in 2019. Sampling in June and September of aquatic vegetation and fish and small crustaceans was conducted by Dr. Brad Peterson to document conditions in the absence of the harvester. Ultimately, the reduction of macrophyte growth by reducing nutrient inputs from the watershed to the pond will obviate the need for mechanical harvest of macrophyte blooms. In the meanwhile, the data suggests this bioextraction approach has a positive effect on water quality and a minimal effect of aquatic life in the pond.

11.5. Natural Vegetation Buffers

Working with the Town, Town Trustees and Village of East Hampton and other organizations, FOGP utilizes newsletters, policy statements, and workshops with property owners to educate and advocate for upland vegetative buffers on private and public properties; and for reduction or elimination of fertilizer use within the Georgica Pond watershed. Where regulatory opportunities arise, the Town, Village and Trustees have been advocating and/or requiring them. Through this effort, over 150 acres of privately owned land in the Pond's Water Protection District are maintained without synthetic fertilizers, and the number of parcels with lawns to the edge of the Pond has been reduced to 10 properties (Figures 14-16).

Figure 14. A newly planted buffer of native species on Georgica Cove.

Figure 15. The same area, the following year, June, 2017

Figure 16. A well-established native plant buffer on the west shore of Georgica Pond

11.6. Reduction of Fertilizer Use

Current NY State Law prohibits the application of fertilizer within 20 feet of water bodies. In addition, there is a prohibition on the use of all fertilizer between November 1 and April 1 (Suffolk County Local Law 41-2007). These laws are not enforced and FOGP with the Town and Village is working to educate residents on the role excessive use of fertilizer plays in harmful algal blooms and the overall health of the pond. Excessive irrigation on residential lots also enables excessive fertilization and runoff into the pond. Including irrigation in outreach efforts is needed. New approaches working with the landscaping industry are needed. Toward this end, FOGP have encouraged residents to work with landscape architects such as Edwina von Gal of the Perfect Earth Project who promote the use of all natural and native yards that are free of fertilizers.

11.7. Storm Water Runoff

As discussed in the Action Plan, two major storm water discharge points directly impact Georgica Pond at Georgica Cove (Cove Hollow Road) and Talmage Creek (Route 27 Rest Area). Working with the Village and Town of East Hampton, a remediation plan is being implemented to mitigate the direct discharge from the Cove Hollow Road discharge pipe by diverting storm water though bio swales, drywell installations, and the installation of storm water drainage filters.

At Talmage Creek, the NYS Route 27 rest stop and severe stormwater overflows from Route 27 (Montauk Highway) cause extremely high bacteria counts. This site is a public access point, where day-trippers launch kayaks and other non-motorized watercraft. Friends of Georgica Pond has funded a preliminary assessment for stormwater improvements at this site, has received a $75,000 county WQRPP matching grant for the project, and is working closely with NYSDOT and the Town of East Hampton to develop a stormwater management plan. A draft concept plan by Greenman-Pedersen, Inc. was completed in 2019 which recommends the construction of a bioswale and Fabco filter inserts into storm drains. Funding from the East Hampton Town CPF fund is being requested for a final engineering plan to mitigate stormwater and improve access at this site.

11.8. Land Acquisition

Approximately 34% of the land area in the Georgica Pond watershed is undeveloped (East Hampton Town Wide Wastewater Management Plan, 2015). Some of this land is preserved; however, approximately 11 % of the land in the Georgica Pond watershed is unprotected vacant land. The most important parcels for preservation within the Georgica Pond watershed have been identified by the Town's Community Preservation Fund (CPF) Plan. CPF funds could be used for strategic purchases where cost is not a prohibitive factor. In addition, the Georgica Pond Steering Committee will engage in all local, County, and State planning to ensure that appropriate and accurate information is included for the Georgica Pond watershed to minimize impact on the pond. In 2020, the Peconic Land Trust purchased a 1.4-acre property on the pond which formerly housed a restaurant. The restaurant and its septic systems are being removed and the site restored to a passive park.

11.9. Mute Swans

The Georgica Pond stakeholders will stay informed on the NYSDEC recommendations for non-native mute swan management. Mute swans are voracious herbivores and aggressive to recreational users of the pond and very abundant on the pond in summer (60+). They are cited as threats to coastal salt ponds by The New York Natural Heritage Program. DNA analysis of pond bacteria by the Gobler Lab in 2017 indicate that avian DNA constituted approximately 24% of the total bacteria counted and in 2018 accounted for the majority of fecal bacteria. Mute swan contribution to the total avian measurement, however, cannot be separated at this time.

11.10. Climate Change

Sea level rise will have a significant impact on Georgica Pond and may result in the pond eventually being permanently connected to the ocean. The transition to a tidal system would have a profound impact on some of the biota dependent on the pond and obviate the need for pond letting. A number of dwellings around the pond would be threatened. Opportunities to move the most vulnerable homes away from the ocean and pond, particularly on the west side of the gut should be explored. Every opportunity to relocate vulnerable septic systems away from the ocean side and pond side should be acted on by regulatory agencies or voluntarily by property owners.

Warmer temperature wrought by climate change will also impact the pond in many ways. Blue-green algae grow faster at warmer temperatures (Paerl & Huismann, 2008). Given the expected rise in temperatures this century (IPCC, 2018) and the increased nutrient loading expected with increased rainfall (Sinha *et al*., 2017), efforts to stem the flow of nutrients to Georgica Pond will become even more important as climate change progresses.

12. Future Research

A better understanding of the dynamics and biota of Georgica Pond will help manage and protect the pond's water quality and overall ecology. Some areas for future consideration include:

1. Better delineation and understanding of blue crab overwintering habitat
2. Experimental introduction of oysters as a means of water quality improvement (this was begun by the Gobler Lab, Stony Brook University in 2019)
3. Experimental installation of Permeable Reactive Barriers (PRBs) as a means of reducing nitrogen in groundwater entering the pond (a first design is completed and installation is expected in 2021).
4. Better understanding of fish and crab migrations between the pond and ocean
5. Potential for constructed wetlands in appropriate locations.
6. Improved techniques for *Phragmites* removal and revegetation with native species.

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14. Appendices

I. Recent East Hampton Town Trustee records of Georgica Pond Openings

II. Aquatic Weed Harvester Reports

III. Gobler Summaries

IV. Waugh Report

V. Hinkle Report

VI. M.O.U. between the East Hampton Town Trustees and the Georgica Association

VII. Satellite Photos

VIII. Microbial Tracking Report