Village of Bald Head Island Environmental Services Contract

2021 Annual Report

Bald Head Island Conservancy
February 7, 2022

Organization Overview

The Bald Head Island Conservancy is an independent non-profit 501(c)3 organization located on Bald Head Island in southeastern North Carolina. Founded in 1983, the Conservancy's Vision is to Champion the Sustainability of Barrier Islands through Environmental Research and Stewardship. With a full-time staff of 13, part-time staff and intern group of up to 25, and an engaged Board of Directors, the organization facilitates scientific research and provides coastal environmental services to the Village of BHI through a partnership that helps ensure the current and future health of the island's habitats and species. The Village of BHI's recognition of the link between environmental health and community well-being uniquely positions BHI to use environmental outcomes to drive wise management decisions. This report and proposal provides an overview of services that were developed in collaboration with Conservancy staff and Village of Bald Head Island managers.

Summary Statement

The Conservancy recognizes the commitment of the Village of Bald Head Island to understanding and protecting the habitats and species that make the island a special place for all residents and visitors. Similarly, the Conservancy recognizes that the Environmental Services Contract is funded by taxpayers and thus we are committed to performing all work in a fiscally sound and scientifically objective manner. In the 2021-22 Contract, the Conservancy continued valuable environmental monitoring projects in the maritime forest, tidal creeks, aquifer, and dunes, with the focus being long-term sustainability of island ecosystems and wildlife habitats. This year we have provided an overview of each project, followed by a more in-depth data or report. We hope that this report will provide Village management an opportunity to spend more time with the Environmental Services Contract data and allow for deeper understanding and discussion of Bald Head Island's natural environment.

A few highlights of the Conservancy's work for the 2021-22 Environmental Services Contract:

1. Maritime forest vegetation surveys provided baseline data for future assessment of impacts. Data may also be used for a fire susceptibility model.
2. White-tailed deer population size was estimated at 140 individuals in fall 2021. The population is still below current targets.
3. Bald Head Creek bacteriological water quality has not been of concern this year. Salinity was higher than usual, indicating decreased freshwater input. Highest nitrate concentrations on record were found in early 2021.
4. A large focus has been identifying and eradicating Beach Vitex, including use of UAV technology to increase efficiency, and a controlled experiment on treatment methods. We have been successful at eradicating many smaller plants; however, many larger sites requiring multiple treatment applications still exist.
5. The diamondback terrapin conservation project was successful, providing >150 crabpot terrapin excluder devices and beginning population surveys.
6. Predator population surveys indicate larger populations of alligators and coyotes than in past years.

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I. Forest Health

The most distinguishing characteristic of Bald Head Island among North Carolina barrier islands is its vibrant maritime forest. It is critical for the Village to protect the forest by evaluating the primary threats that could alter its basic ecological functioning such as overpopulation of deer, invasive species, storms, and saltwater intrusion into the island's freshwater aquifer.

A. Forest Vegetation Assessment

In the past few years, the Conservancy has worked with collaborators Dr. Bob Peet, Dr. John Taggart, and Dr. Jodi Forrester to re-evaluate the health of the maritime forest 10+ years after baseline data were collected in the 1980s (Peet) and mid-2000s (Taggart & Long). Paired fenced and unfenced plots were established in the early 2000s in the Bald Head Woods Coastal Reserve to evaluate impacts of deer on forest vegetation (Brewer, Taggart & Long). At that time, the target number of 200 deer was established. These plots still exist but were damaged by a series of hurricanes (Florence, Dorian, Isaias) and no longer exclude deer. Dr. Forrester and the Conservancy have collected data from these plots to provide a new baseline so that we can re-establish the exclosures and use them to evaluate deer impacts in the future.

<u>Project Goals</u>

- Evaluate forest health: species diversity, forest structure, openness, downed deadwood, disease
- Continue repairing and maintaining deer exclosures in the forest
- Compare Forrester's results to previous studies to estimate deer impacts on the forest
- No vegetation assessment was needed this year, but continued exclosure maintenance and regular assessments are recommended for the future

<u>Progress & Significant Findings</u>

- Chainsaw work to remove large trees from exclosures was completed by the NC Coastal Reserve/the Nature Conservancy's fire crew with assistance from BHIC in June 2021
- Forrester's report on vegetation diversity and downed deadwood is included: this provides baseline data for future impacts on forest
- Major findings are no large structural changes to forest since 2011, except for loss of Red Bay trees due to Laurel Wilt disease, and replacement by Carolina Laurel Cherry
- Forrester's results may be used in fire models being developed by the Coastal Reserve in the next year
- No differences between fenced and unfenced plots in 2011 or currently, but none expected currently due to fences not being intact
- Repairs of exclosure fencing will begin February 2022

<u>Future Directions</u>

We recommend continuing to maintain exclosures in the maritime forest to allow for future assessment of deer and other impacts. No vegetation surveys are proposed for the plots at this time.

Final Report: The spatial and temporal dynamics of the maritime evergreen forest of the Bald Head Woods Reserve

January 12, 2022

Dr. Jodi Forrester

Associate Professor
Department of Forestry and Environmental Resources
North Carolina State University

Objective

The objective of this report is to describe the contemporary forest structure and composition of the Bald Head Woods Maritime Forest Reserve. Measurements were completed on permanent plots established historically to compare the influence of herbivory on the vegetation in the preserve. Following Hurricane Florence, the fenced locations were re-established. The vegetation survey and protocol established with this report can be used as a baseline to compare future surveys following disturbances or to track natural growth and mortality patterns.

Introduction

Bald Head Woods is a protected maritime evergreen forest – south Atlantic subtype. It has a G2 rank – meaning it is a globally imperiled community (at high risk of extinction or elimination due to restricted range, few populations or occurrences, steep declines, very severe threats, or other factors). Earlier descriptive studies (Taggart and Long, 2015) indicate a very sparse groundlayer flora, limited by low light availability beneath the closed canopy. Measurements of light or canopy conditions and/or the establishment of additional measurement locations in newly opened areas will help to describe the regeneration dynamics of this rare forest community.

Plot status and measurements

The existing sampling design included 20 paired plots – 20 fenced and 20 unfenced plots that were established throughout BHW (2007), though fences were not maintained consistently through time. Locations were stratified to prioritize the variability across the island to capture a gradient of dune age, moisture availability and salt spray. The plots are 10m x 10m. The unfenced plots are adjacent to the exclosures and have yellow/orange ground stakes marking the corners.

In 2019, the majority of the fenced plots were repaired by NC Forest Service following Hurricane Florence. We re-located and evaluated the paired unfenced permanent plots. Two fenced plots and two unfenced plots were abandoned or destroyed due to various reasons (development, total vine dominance, etc.) An additional four plots were established in 2019 to increase the geographic spread; these new plots are all unfenced. The sample size used in the current inventory included 18 fenced and 22 unfenced plots (Fig. 1-1).

Figure 1-1 Location of permanent vegetation plots in Bald Head Woods

Geographic coordinates were recorded for all permanent plots, old and new. The southeast corner of the plot was recorded with a Bad Elf GPS unit. A distance laser measurer was used to map the remaining three corners. All tree stems (>3cm diameter at breast height) within the plots were mapped. Canopy openness was measured with a densitometer and characterized with a hemispherical photograph. Saplings and groundlayer flora were measured on smaller plots and in a manner to compare with historical datasets. Soil samples were collected and analyzed to provide a baseline of soil organic matter and nutrient status.

Results and Discussion

Overstory patterns

Tree composition and structure are similar between fenced and unfenced locations in the preserve. Fences were not maintained continuously through the past decade, but the vegetation was summarized by fence status (present or not) as a starting point for future comparisons since fence maintenance is now more frequent. Carolina laurel cherry, sand laurel oak and live oak are the dominant canopy species in the forest comprising 71-78% of the stand basal area (Table 1-1). Yaupon is the dominant understory species comprising 41-46% of the relative density, though only a small portion of basal area. Southern red cedar, American holly, pignut hickory and musclewood are the other tree species in canopy position. Wild olive and red bay are infrequent but present in the subcanopy. Tree size varied by species with the oaks and hickory being the largest in both diameter and height in the forest (Table 1-2).

The average height of the tree canopy is 15.3 m and extends to 25.3 m tall. The majority of the tree stems are in a subcanopy position, with the average height of 2.3 m, and ranging to a maximum of 15.5 m. Trees that were completely overtopped by surrounding dominant trees are approximately 1 m tall. The average crown spread for tree species was 6.8 m and crown length was 9.2 m. Canopy openness was approximately 26%, with openness of plots ranging from 17% to 42%. This range is likely high due to the effects of recent hurricanes (Florence in 2018 and Dorian in 2019).

Table 1-1. Tree species composition and structure at Bald Head Woods. Density and Basal area are summarized from stems ≥3cm diameter at breast height (DBH). The Importance Value (IV) is calculated based on relative density and relative basal area.

		Unfenced					Fenced				
Species		Density	Basal area	Rel density	Rel BA	IV	Density	Basal area	Rel density	Rel BA	IV
Scientific name	Common name	stems ha^{-1}	m^2 ha^{-1}	%	%	%	stems ha^{-1}	m^2 ha^{-1}	%	%	%
Prunus caroliniana	Carolina Laurel Cherry	514.3±61.1	5.6±0.9	30	24	27	861.1±122.4	6.4±1.2	40	25	32
Ilex vomitoria	Yaupon Holly	714.3±97.2	1.5±0.3	41	7	24	994.4±134.4	2.1±0.4	46	8	27
Quercus hemisphaerica	Sand Laurel Oak	138.1±35.5	6.2±1.4	8	27	17	61.1±18.3	2.9±1.3	3	11	7
Quercus virginiana	Live Oak	9.5±6.6	4.6±4.2	1	20	10	33.3±18.1	10.5±5.4	2	42	22
Carpinus caroliniana	Musclewood	228.6±68.4	1.5±0.6	13	7	10	100±58.3	0.4±0.2	5	1	3
Juniperus virginiana var. *silicicola*	Southern Red Cedar	28.6±12.2	1.3±0.7	2	6	4	33.3±16.2	1.9±1.2	2	8	5
Cartrema americana	Wild Olive	42.9±16.3	0.7±0.3	2	3	3	61.1±18.3	0.9±0.4	3	4	3
Ilex opaca var. *opaca*	American Holly	47.6±19.1	0.6±0.3	3	3	3	16.7±9.0	0.1±0.1	1	0	1
Carya glabra	Pignut Hickory	4.8±4.8	1.1±1.1	0	5	2	-	-	-	-	-
Persea borbonia	Red Bay	4.8±4.8	0.1±0.1	0	0	0	11.1±7.6	0.1±0.1	1	0	0
All species combined		1733.3±95.7	23±4.5				2177.8±143.6	25.3±5.8			

Live crown ratio is an indicator commonly measured in tree and forest health monitoring. The live crown ratio is the proportion of a tree supporting live foliage that is effectively contributing to tree growth. Trees with more leaves producing sugars are more likely to be healthier, stronger and more resilient to stress. Lower and large branches can help minimize wind stress. The live crown ratio for canopy trees in the preserve was estimated as 0.6 (based on an average of 41 trees in canopy position), indicating that approximatly 2/3 of the tree's total height is occupied with a live crown. This higher value indicates that the trees will respond better to storms.

Considering all trees mapped and measured in the permanent plots, 12% of the trees were standing dead. While the proportion of dead to live trees is highly variable based on the species composition, age and stand history, this estimate for the Bald Head Woods is reasonable. Other studies evaluating forests across the eastern US estimated the proportion of dead trees ranging from 5-36%. This estimate provides a reference for evaluating forest vigor or decline in the future. The majority of the snags (77%) had died recently. Red bay is now infrequent through the forest, comprising only 1% of the stems greater than 3 cm. Of those 15 red bay trees encountered, only three were still alive.

Understory patterns

The understory is dominated by yaupon, with lesser amounts of Carolina laurel cherry, red bay and musclewood. Yaupon is overwhelmingly dominant in stems greater than 50 cm tall and <3 cm in diameter (Fig. 1-2), with relative densities of 65-74% in fenced and unfenced conditions (Table 1-3). Carolina laurel cherry was co-dominant with yaupon in the lowest height class (<50 cm tall) (Fig.1-3). This was the only canopy species with notable regeneration potential during the time of survey. Seedlings of oaks and holly were infrequent (Table 1-4). Note again, that seedling counts are summarized by fenced and unfenced conditions, but no true comparison can be made at this point in time because the fences had not been actively maintained. The similarities between conditions indicate that from a sampling perspective in the future if differences are observed they may be due to the recent re-establishment of the fences.

The percent cover of the groundlayer vegetation was very similar between fenced and unfenced portions of the forest, averaging 10 or 11%. Herbaceous species accounted for only 5-6% of the estimated cover. Yaupon, Carolina laurel cherry, red bay, and cabbage palmetto are the most common woody plants in the groundlayer.

Table 1-2. Overstory and understory tree species characteristics, including average and maximum heights and diameters

	Count	Mean height (m)	Max height (m)	Mean DBH (cm)	Max DBH (cm)
Overstory species	**402**	**4.1**	**25.3**	**12.2**	**105.6**
Pignut hickory	1	25.3	25.3	53.2	53.2
American holly	15	3.2	11.1	10.8	27.1
Southern red cedar	13	9.1	17.3	21.5	42.5
Carolina laurel cherry	318	3.0	16	9.2	35.4
Sand laurel oak	46	8.3	21	21.1	47
Live oak	8	16.5	23.9	61.7	105.6
Understory species	**451**	**2.6**	**15.9**	**5.9**	**22.7**
Wild olive	21	4.8	15.9	12.7	22.7
Musclewood	68	2.9	5	7.8	18.7
Yaupon holly	346	2.4	4	5.0	13.9
Red bay	16	2.9	4	8.7	22

Table 1-3. Mean density (stems ha^{-1}) of woody species <3cm dbh (Large height class) and 50<130cm in height (Medium height class) at Bald Head Woods. Counts are based on 18 fenced plots and 22 unfenced plots.

	Unfenced		Fenced	
	Large	**Medium**	**Large**	**Medium**
Ilex vomitoria	3654.6	8690.9	3533.3	8088.9
Persea borbonia	54.6	2018.2	-	2622.2
Prunus caroliniana	181.8	527.3	555.6	1755.6
Sabal palmetto	163.6	527.3	288.9	555.6
*Sabal spp.**	272.7	527.3	155.6	333.3
Juniperus virginiana	-	-	22.2	-

*Sabal spp. includes either *Sabal minor* or *S. palmetto*

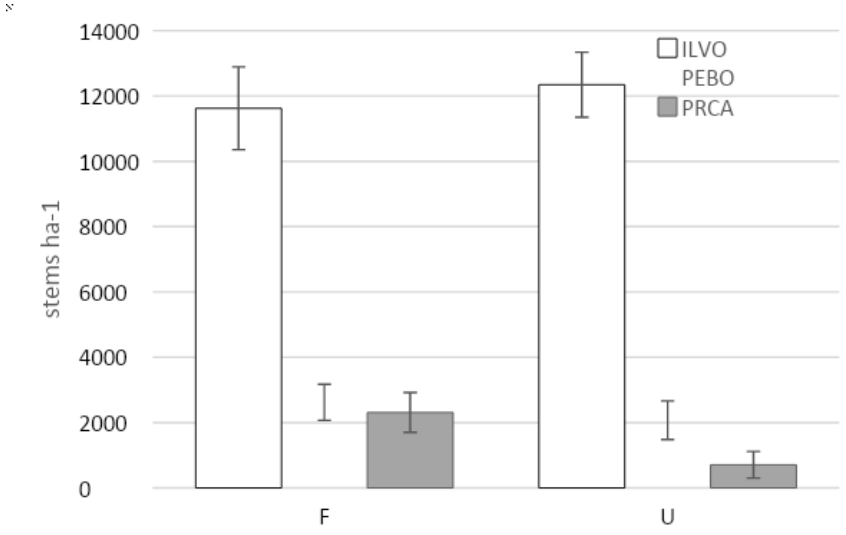

Figure 1-2. Mean density (± standard error) of dominant species in the regeneration layer of Bald Head Woods: yaupon (ILVO), red bay (PEBO), and Carolina laurel cherry (PRCA). This includes stem counts of individuals 50+ cm in height, but less than 3 cm in diameter at breast height.

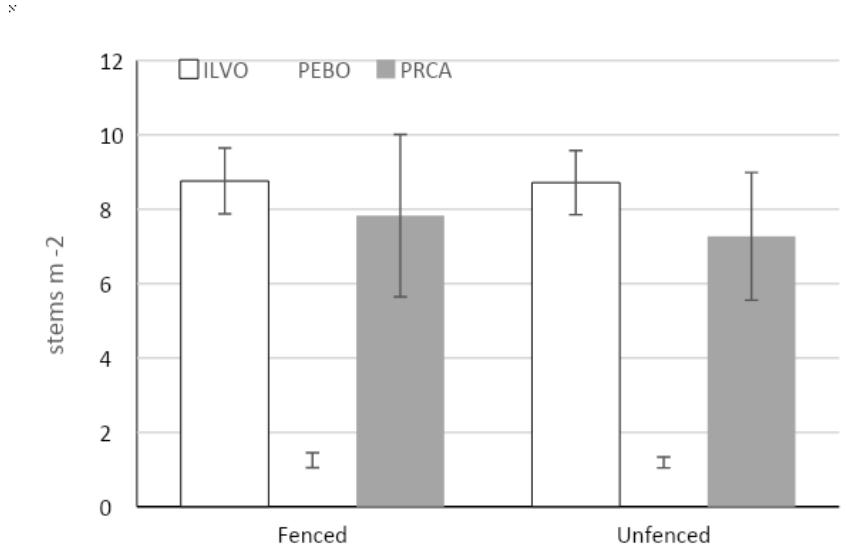

Figure 1-3. Mean stem density (± standard error) of three dominant woody groundlayer species: yaupon (ILVO), red bay (PEBO), and Carolina laurel cherry (PRCA). These represent the smallest size class, regeneration layer <50 cm in height.

Table 1-4. Mean density (stems meter^{-2}) of woody species in groundlayer (smallest height class, stems <50 cm tall) at Bald Head Woods. Counts are based on 18 fenced plots and 22 unfenced plots.

	Unfenced	**Fenced**
Ilex vomitoria	34.85	35.03
Prunus caroliniana	29.07	31.31
Persea borbonia	4.76	4.99
Quercus virginiana	0.42	0.74
Quercus hemisphaerica	0.27	0.38
Sabal spp.*	0.24	0.29
Sabal minor	0.40	0.13
Ilex opaca	0.01	0.04
Juniperus virginiana	0.02	0.01
Cartrema americana	0.01	0.00

*Sabal spp. includes either *Sabal palmetto* or *S. minor*

Table 1-5. Summary of soil (upper 15 cm) properties based on 40 samples.

	Mean	Minimum	Maximum
Physical properties			
Clay %	1.4	0.7	1.9
Silt (%)	3.0	1.3	4.8
Sand (%)	95.6	93.4	97.6
Chemical properties			
Total Exchange Capacity (meq/100 g)	13.0	5.2	21.7
pH	5.7	4.8	6.8
Organic Matter (%)	4.5	2.2	8.9
Soluble Salts (mmhos/cm)	0.06	0.03	0.12
Ca (%)	56.5	30.3	84.0
Mg (%)	10.7	7.1	13.4
K (%)	0.7	0.4	1.0
Na (%)	1.0	0.6	1.8

Dead wood

The density and basal area of standing dead trees was 303 stems per hectare and 3.4 m^2 per hectare, respectively. The volume of downed dead woody material was estimated for both coarse (10 cm diameter and up) and fine size classes of downed debris. The volume of coarse

materials was 49.8 m^3 per ha and the volume of fine materials was 26.3 m^3 per ha. The biomass of logs is approximately 8 Mg per ha, based on a literature derived density. Coarse materials on average covered 2% of the ground surface area (ranging from 0.04% - 6%). Dead fine materials covered approximately 33% of the ground area. Leaf litter covers 84% of the ground surface and is approximately 2 cm deep.

These metrics are within the range of values reported for southeastern forests. A preliminary search yielded no other maritime forests reporting dead wood quantities and characteristics for more focused comparison.

Environmental variables

The soils are variable throughout the reserve, with the average soil texture including more than 95% sand, 3% silt, and 1% clay. The soluble salt values were well below values that would be concerning for plant growth. Nutrient concentrations are listed in Table 1-5.

Canopy density was estimated at each permanent plot using multiple methods. The spherical densiometer provides a quantitative description of canopy openness (or closure). Hemispherical photos taken at plot center were also used to quantify openness, model light availability and serve as a reference for future comparisons.

These abiotic variables were compared with groundlayer cover and seedling density to assess whether light or soil characteristics were related to plant species composition and abundance. Seedling density was not related to light or canopy openness, but did show relationships to soil properties (particularly salts, Ca, Mg, and B). Groundlayer cover was positively related to canopy openness, with understory plant cover increasing with canopy openness (particularly the cover yaupon and cherry).

Disturbance patterns

The vegetation of this system has a structure and composition that is influenced primarily by wind events. Natural fire was likely infrequent in this plant community and therefore plays an unimportant role in the natural dynamics of the system (Evans and Pyne 2014). Mature live oaks are classified as “fire avoiders” and sand laurel oaks as “fire mesophytes” (Varner et al. 2016) based on traits such as bark thickness and leaf flammability, among others. The litter does not easily burn (Stalter and Odum 1993) and both species are relatively fast growing. The dominance of fire-susceptible species and lack of fire-tolerant species such as pine, indicates that fire has not been a common occurrence.

Another potential stressor to the forest is altered salt spray deposition patterns caused by fragmentation. Maritime forests and the characteristic vegetation can recover from large wind disturbance and associated salt spray or overwash events (hurricanes). Breaks in the canopy caused by small clearings and roads may change deposition patterns allowing increased salt deposition into the forest.

Continued efforts

Several earlier studies have described the vegetation status across the island and within the reserve. An earlier vegetation survey in 1988 indicates the presence of several species that are no longer common in the forest. Laurel wilt and dogwood anthracnose have decreased the occurrence of red bay and dogwood from the island.

Forest conditions are similar to those measured in 2011 by Taggart and Long (2015). The woody species composition and sparse herbaceous groundlayer is similar one decade later. One considerable change is the importance of *Prunus caroliniana*. The importance of laurel cherry in both the canopy and regeneration layers has increased, while the frequency of red bay has

declined since the earlier inventory. Cherry will likely continue to increase in importance within the forest, while the presence of laurel wilt will suppress red bay.

Sample sizes have continued to increase through surveys and time, which is helpful to capture the variable conditions within the forest. Separating the influence of herbivory is a challenge because of the effort required to maintain the fences. Considerable progress has been made on recovering data from earlier vegetation surveys on the island (including CVS data, from 1988 and 2018, and data from UNCW in 2007 and 2011). Time is needed to reformat so that formal (quantitative) comparisons can be made. Ongoing vegetation monitoring is important to track the health of the current tree canopy, the regeneration layer that will lead to the future forest canopy, and any arrival of new, potentially invasive species. Other southern maritime forests have noted problems due to wavyleaf grass and camphor tree in particular.

References

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B. Deer Management

The Conservancy quantifies the island's white-tailed deer population and analyzes the efficacy of the immunocontraceptive GonaCon for managing the population (current target = 200 deer). This data is then used to provide recommendations for deer population management. Sound population management decisions ensure stable and productive island habitats that continue to provide ecosystem services (e.g., storm protection, positive elevation growth, biodiversity, enhanced tourism, and recreation).

Project Goals

- Monitor the population size of BHI's white-tailed deer herd
- Evaluate impacts on ecosystem and determine need for management
- Data leads directly to Conservancy's recommendations to the Village for renewal of the immunocontraception permit
- Combination of both summer spotlight (male:female ratios) and fall camera index (population number of females and fawns) needed for accurate estimates
- Weekly telemetry tracking of collared does from immunocontraception project continues until collars drop off (4 collars remain, this is likely the last year)
- Data analysis and proposal writing for new immunocontraception permit if requested

Progress & Significant Findings

- Fall 2021 Camera Index: 140 individuals = 97 does, 38 bucks, 5 fawns (Fig. 1-4, see attached Deer Population Report)
- Summer 2021 Spotlight Survey: 126 individuals, female:male ratio of 2.55
- Population size is below target of 200 deer; there are an estimated 35 unvaccinated does (immunocontraception permit requires ≧ 30 viable does).

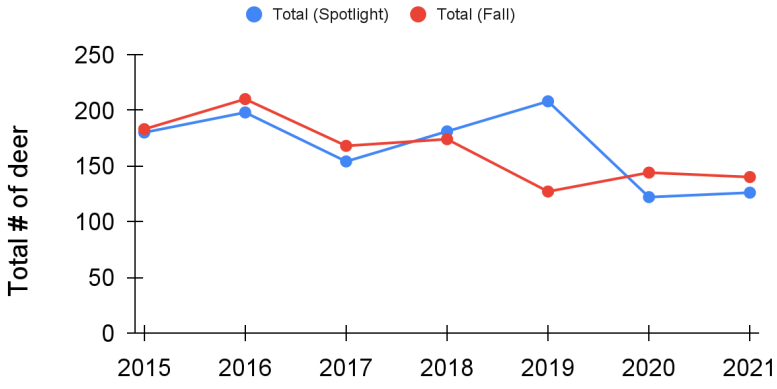


Figure 1-4. White-tailed deer population size, 2015 - present. Immunocontraception operations began in 2014. Official population numbers are estimated using fall camera surveys; spotlight surveys provide sex ratios and a comparison to historical data.

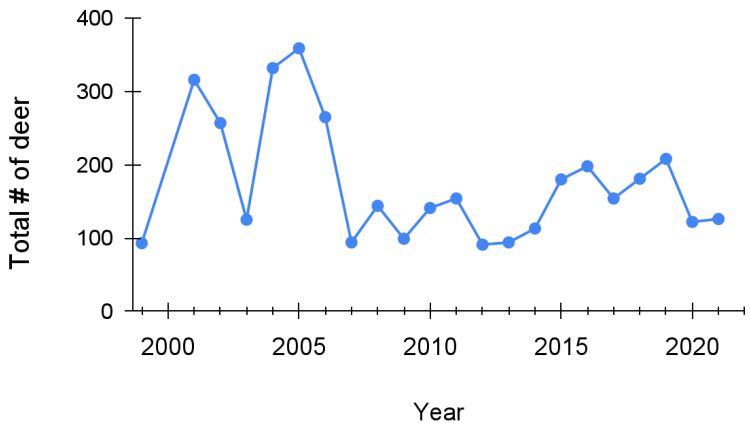


Figure 1-5. Historical deer population index using spotlight surveys, 1999 - present.

Future Directions

We recommend continued monitoring of the deer population using the same methods, and using this data to inform the decision whether to pursue a permit for immunocontraception operations in Spring 2024. See below for more information on immunocontraception.

Deer Population Report

Summary

Bald Head Island provides habitat for white-tailed deer (*Odocoileus virginianus*). The island provides a mild climate, lack of predators and disease, no hunting, and year-round food sources. This allows the deer to thrive and can potentially lead to overpopulation of the deer. A study on the island determined that a population of 200 or fewer individuals showed minimal impacts to the maritime forest, which provides invaluable ecosystem services to the island. From 2015 - 2020, Bald Head Island managed the deer herd with a non-lethal management plan using immunocontraception. Immunocontraceptives work to control animal population by prohibiting an animal from reproducing through the use of injected contraceptives that work with the animal's immune system. Since 2019, we have found that the deer population numbers have been under the target 200 number. To monitor the population, we conduct two population surveys methods (spotlight surveys and trail camera indices) to determine the population trends throughout time.

Population Estimates

Two population survey methods were used: spotlight surveys and camera indices. Summer spotlight surveys have been conducted on BHI since the late 1990s and are used primarily to determine the doe:buck ratio and to examine population trends through time. Camera indices use mark-recapture methodology and are used to get a more precise estimate of the doe population.

Baited camera indices can be biased towards bucks, so we calculated sex ratios gathered during the summer spotlight survey where there is assumed to be less bias. The doe:fawn ratio was determined from the camera index as most fawns are too young in summer to be accurately represented in the summer spotlight surveys.

Spotlight surveys are conducted during the summer (June-August). Surveys are conducted via a golf cart with planned routes that start 30 minutes after sunset. There are 7 routes (see Figure 1-6) that are randomized before each survey, to see different routes during different times of night. The survey is conducted using red light spotlights on both sides of the cart, surveying as far as the spotlight will reach. When a deer is seen, the sex, age, and any ear tags are noted.

Data from the 2021 summer spotlight survey showed an average of about 15 deer per night. The sex ratio was 2.55 female:male. The total BHI deer population was estimated to be 126 individuals in summer 2021 (Table 1-6).

The fall camera index ran for 17 days: November 5 - 21, 2021 (see Figure 1-7 for camera locations). We estimated the doe population on Bald Head Island using the Chapman variation of the Peterson formula:

$$N=(M+1)(C+1)/(R+1)$$

where N = population estimate, M = number of marked individuals in the population, C = total number of female deer occurrences (marked and unmarked), R = total number of marked occurrences. The values of C and R were summed from all sites each day and throughout the index to calculate N. The population index was considered complete once the daily population estimate stabilized.

Within the previous two years, 62 distinct marked does had been spotted on the island and were known to be alive, so it was estimated that there were 35 unmarked adult does on the island at the beginning of 2022 for a total of 97 adult female deer on BHI. The total BHI deer population was estimated to be 140 individuals in fall 2021 (Table 1-6). The fawn population in 2020-2021 was estimated at 5 based on a very detailed analysis of the fall 2021 photo set. This estimate is slightly higher than last year's estimate of 3 individuals, but is low compared to estimates in the 20s-30s of fawns from the beginning of the project in 2015.

Figure 1-6. Summer spotlight routes

Figure 1-7. Trail camera location for fall of 2021.

Table 1-6. White-tailed deer age/sex class structure and total population estimates. Survey Type: C = camera index; S = spotlight survey.

	Feb 2015	Summer 2015	Nov 2015	Mar 2016	Summer 2016	Nov 2016	Mar 2017	Summer 2017	Fall 2017	Summer 2018	Fall 2018	Summer 2019	Fall 2019	Summer 2020	Fall 2020	Summer 2021	Fall 2021
Survey Type	C	S	C	C	S	C	C	S	C	S	C	S	C	S	C	S	C
Does	48	84	73	57	107	109	83	101	94	111	98	143	86	79	91	89	97
Fawns	29	32	55	49	23	28	11	8	20	22	19	1	3	4	9	2	5
Bucks	40	64	55	44	69	73	55	51	54	65	57	64	38	39	44	35	38
Total	117	180	183	150	198	210	149	160	168	198	174	208	127	122	144	126	140

C. Deer Immunocontraception

The research permit from the NC Wildlife Resources Commission to conduct captures and administer GonaCon™ to manage the deer population size has now expired, and to continue using immunocontraception to manage the BHI deer population would require a new permit. The decision-making process depends on the target deer population number, actual deer population number, budget allocation by the Village, and seasonal timing. The previous permit used a target population number of 200 deer, and required leaving 30 viable (unvaccinated) does. Based on deer population numbers below the target set by the NCWRC permit, the Conservancy recommended a continued pause in the immunocontraception program for spring 2022. The Village may decide to pursue a new research permit this year, which would allow immunocontraception operations to begin in spring 2024. Alternatively, the Village could pursue an operational permit, but it is unknown whether the NCWRC would approve such a permit. Below we outline a few factors that should be considered in whether to pursue a permit.

Target Deer Population Number

The target population of 200 deer was based on a study done by Taggart and Long (2015) in the BHI maritime forest in 2011. No observable impacts from deer browsing were found when fenced plots (excluding deer) and unfenced plots (allowing deer access) were compared for tree density and species composition. Approximately 200 deer were on the island at that time. However, a previous study by Stransky (1969) recommended a capacity of 19 deer/km^2 for healthy barrier island habitats, and Sherrill et al. (2010) recommended managing the BHI deer population to its level in 2007 - 2009, which was 15 - 17 deer/km^2. As of 2021, Bald Head Island had 27 deer/km^2 of available deer habitat, and deer habitat is decreasing as development continues. This is potentially putting more strain on the maritime forest. The Conservancy and partners are pursuing long-term study about impacts of deer and other stressors on the maritime forest, but currently the data do not exist to allow us to re-evaluate sustainability of the deer population or carrying capacity of the island. A more conservative population target number might be between 15 - 19 deer/km^2, which would be equivalent to a maximum of 102 deer on BHI with current available habitat. A new permit proposal could request management of the herd to this target level.

Current Deer Population Number

The “official” deer population camera census of does and fawns is conducted in fall, when fawns are mobile and able to be counted on cameras (Fig. 1-4). This number is combined with the sex ratio determined from summer spotlight surveys (Fig. 1-5) to estimate the total population size. The decision about how many females to capture and vaccinate with GonaCon™ depends on the target population size and the number of viable (unvaccinated) females remaining in the population. This number is generally available from the Conservancy in January. The Conservancy proceeds with captures and vaccination of the target deer list in February - April, after Brunswick County hunting season. See Fig. 1-8 for the past seasonal cycle or population surveys informing the immunocontraception program.

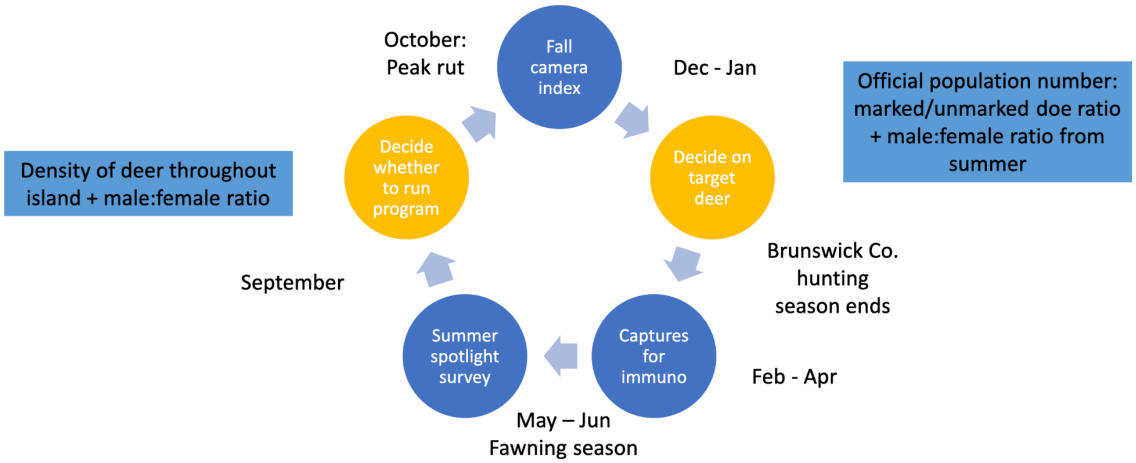


Fig. 1-8. Current annual cycle of deer management operations on BHI.

Immunocontraception Logistics

The ideal time to administer GonaCon™ would be in fall during the rut, when females have the highest hormone levels (Fig. 1-9). However, NCWRC regulations require captures to be conducted after hunting season, mostly because of the sedative drugs used for captures, and the slight chance that a deer dosed with these drugs could migrate to an area where hunting is occurring and be consumed by humans. Hiring and training of the capture team and ordering of GonaCon™ from the USDA also takes time. This means that the Village's budgetary decision to conduct immunocontraception operations must occur 9 months before captures begin, and that the permitting process must be complete >9 months prior to the desired start of immunocontraception operations. We currently do not know how long the permitting process with WRC would take after submission of a permit proposal. A new permit proposal could request allowing captures to be conducted in fall, or at least to begin at the end of hunting season but during urban archery season.

If a permit is not pursued this year and the deer population remains below target, writing the immunocontraception permit application can be revisited each year. Once a research permit begins, WRC will expect it to be used each year.

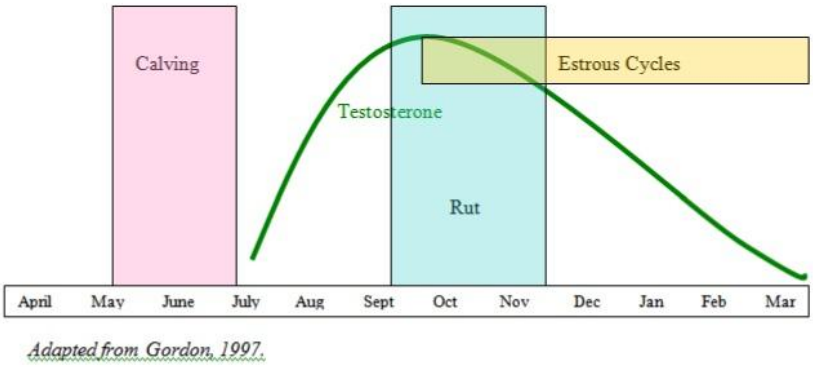


Figure 1-9. White-tailed deer reproductive cycle. Currently, immunocontraception operations must occur in February - April, which is towards the end of females' estrous cycle, possibly reducing the efficiency of the drug.

Future Directions

The Conservancy will make final recommendations for the immunocontraception operations after discussion with the Wildlife Resources Commission and the Village. We paused operations last year since the number of individuals in the population remained well below 200, the efficiency at capturing the remaining single-dose deer was low in 2020, and the likelihood is high that coyotes are exerting strong control over fawn numbers (see Fig. 5-3 - Predator data). At this time there is not strong evidence that the current population is causing harm to the maritime forest, an impact on the health of the deer herd. Additionally, there is no indication that population numbers are likely to exceed the target in the next year or two.

D. Bald Head Woods Well Monitoring

The Bald Head Woods Monitoring Advisory Group is focused on securing the ecological functioning of Bald Head Woods by: 1) assessing hydrologic conditions within BHW, 2) analyzing the potential effects of water withdrawals from the aquifer below BHW, and 3) making recommendations about management actions to prevent or mitigate those effects. The Conservancy verifies accuracy and precision of continuous depth-to-water (DTW) measurements in 16 wells associated with Bald Head Woods (BHW) monthly and shares those data with the BHW Monitoring Advisory Group. The Monitoring Plan also requires assessment of vegetation in BHW after 5 years of water withdrawals.

Project Goals

- Evaluate aquifer levels below the Bald Head Woods Maritime Forest Reserve
- Provide data to Applied Resource Management (ARM) to ground-truth automated sampling equipment
- Assess vegetation species composition in BHW swales (low-lying areas) as required by the Monitoring Plan

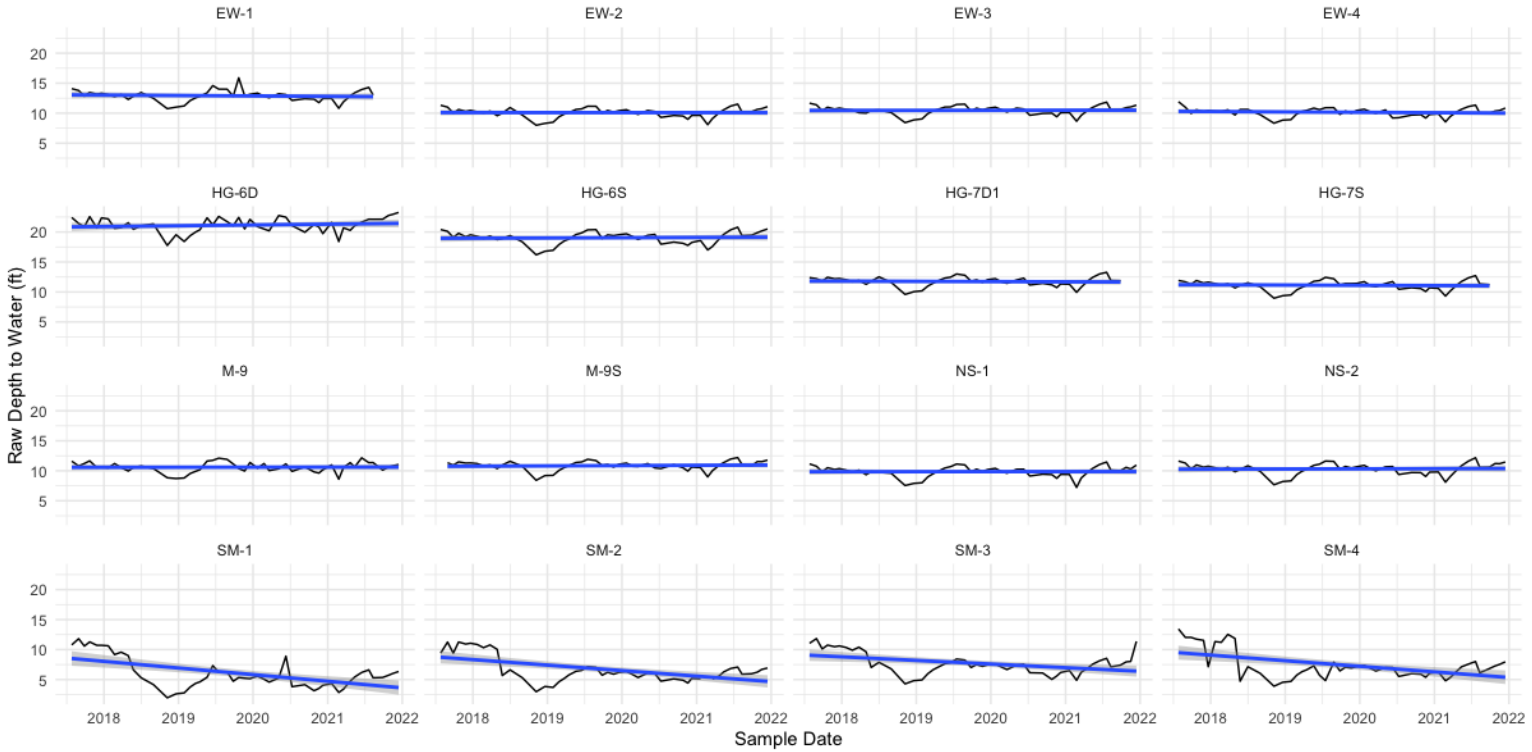
Progress & Significant Findings

- Monthly depth-to-water data has been collected and shared with ARM (Fig. 1-10)
- 2021 was a relatively dry year, as shown by larger raw depth-to-water measurements (larger distance to groundwater)
- Swales are currently empty and available for vegetation assessment if summer 2022 stays relatively dry

Future Directions

The need for continued monitoring is decided on by the BHW Monitoring Advisory Group, but we recommend continuing to monitor groundwater levels in the Reserve through the next potentially dry period. The Conservancy proposes conducting vegetation surveys in the swales at the end of the growing season (September 2022).

Fig. 1-10. Bald Head Woods Wells. Raw depth to water (DTW) indicates distance from the well casing to groundwater, therefore a higher DTW value indicates less groundwater in the well. In 2021, raw DTW was higher than average. Swales were dry as of January 2022 and available for vegetation surveys.



EW-1, EW-2, EW-3, EW-4: Follow east-west transect in forest just south of Federal Road
HG-6D, HG-6S: located on dune ridge on the south edge of the forest
HG-7D1, HG-7S: located in middle of island by Edward Teach extension, wells removed in 2021
M-9, M-9S: located along Federal Road
NS-1, NS-2: follow north-south transect in forest
SM-1, SM-2, SM-3, SM-4: swale marsh wells in forest

II. Bald Head Creek and Salt Marsh Health

The tidal creek-salt marsh complex supports an abundance of resident and visitor activities including recreational fishing, kayaking, and birding. Further, the root system of a healthy marsh plant community stabilizes the island's soundside by resisting strong erosional forces produced by semi-diurnal tides and storm surges. Thus, understanding the health of Bald Head Creek and its bountiful salt marsh habitat is a key aspect of the sustainability of Bald Head Island's way of life. However, understanding this system is challenging because its health is influenced by many factors including chemical loads in the Cape Fear River, stormwater runoff on Bald Head and Middle Islands, and natural and human induced alterations to creek flow.

A. Creek Water Quality

Project Goals

- Gain a comprehensive understanding of Bald Head Creek water quality
- Investigate potential deleterious human influences on the health of the tidal creek complex
- Weekly monitoring of physical attributes (temperature, salinity, dissolved oxygen, turbidity, pH), chlorophyll, and nutrients (nitrogen and phosphorus) at 4 sites
- Quarterly sampling at two sites to monitor diurnal changes, especially hypoxia
- Shoreline survey for potential sources of contamination if triggered by high fecal coliform concentrations from regular monitoring (Creek Bacteria project), or under high and low flow conditions

Progress & Significant Findings

- Salinity has been higher than average this year (Figure 2-1).
- Dissolved oxygen and pH have been on the lower side of average in 2021
- Nitrate was the highest on record in early spring 2021. Nitrate generally peaks in winter and has primarily a downstream (river/ocean) source.
- Chlorophyll data were collected for the first time in 2021. Chlorophyll is a plant pigment indicative of plant biomass, particularly floating phytoplankton. It is an indicator of food availability for higher trophic levels and is also an indicator of water quality, since high phytoplankton biomass can be caused by high nutrient concentrations and can lead to low dissolved oxygen concentrations (eutrophication). In 2021, we saw a typical seasonal pattern of chlorophyll concentrations with a spring phytoplankton bloom around late March - April, and a large summer bloom from late June - September (Fig. 2-3). Chlorophyll concentrations were higher than we expected to see based on similar sites in the region (>20 ug/L in mid-summer at Cape Creek and Site 3, with slightly lower concentrations downstream (Site 1)).
- Pheophytin is a degradation product of chlorophyll, indicating dead or detrital plant biomass. Seasonal patterns for pheophytin were not as distinct as chlorophyll (Fig. 2-3), but pheophytin concentrations were higher upstream (Site 3) than downstream (Site 1), which is typical of shallower tidal creeks that may have a large component of resuspended marsh detrital material making up the floating plant matter.
- Shoreline sampling for fecal coliform sources will be conducted during a high rainfall event in spring 2022.

Future Directions

We recommend continuing with creek water quality monitoring using the same methods in 2022. Data will be enhanced by a grant-funded project with NC State University to deploy a YSI EXO data sonde that will allow continuous monitoring of water quality at the creek mouth.

B. Creek Bacteria

Project Goals

- Inform the Village about potential wastewater inputs, potential need for creek closures for public health, and shoreline sampling for bacteria sources
- Biweekly monitoring for fecal coliforms from 4 sites

Progress & Significant Findings

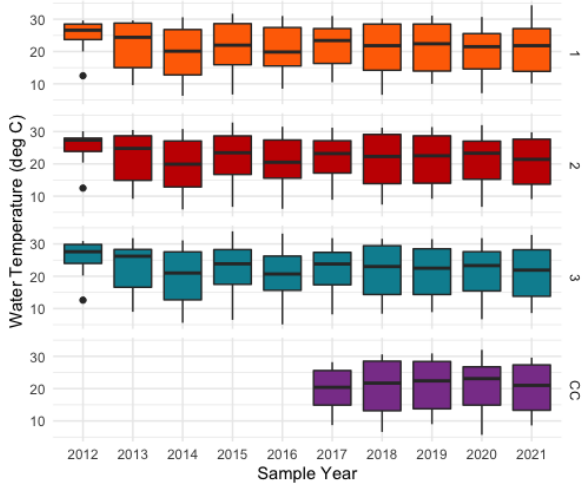
- Creek fecal coliform bacteria concentrations have been low in 2021 after very high numbers in August 2020 (Figure 2-4).

Future Directions

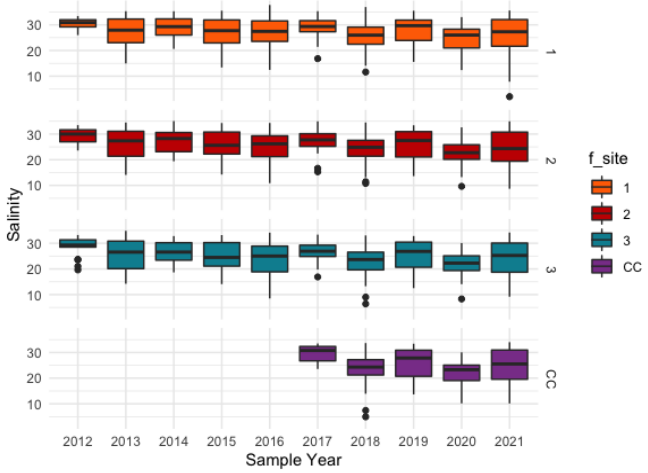
We recommend continuing with the same level of sampling in 2022-23. Bacteriological data will be further enhanced by the NCSU grant-funded project, which includes a continuously-collecting data sonde as well as microbiological sampling for bacterial source tracking. The ultimate goal is to use the data stream and machine to predict issues with microbial water quality in real time. Data will be shared with the public on the BHIC website.

Figure 2-1. Creek Physical Characteristics 2012 - 2021.
Boxplots indicate median and 25 - 75% quartiles. Bald Head Creek sites were downstream (Site 1), mid-creek (Site 2), upstream (Site 3), and Cape Creek (CC). 2021 was an average year for temperature, salinity, dissolved oxygen, and pH, with slightly higher salinities corresponding to a relatively dry year.

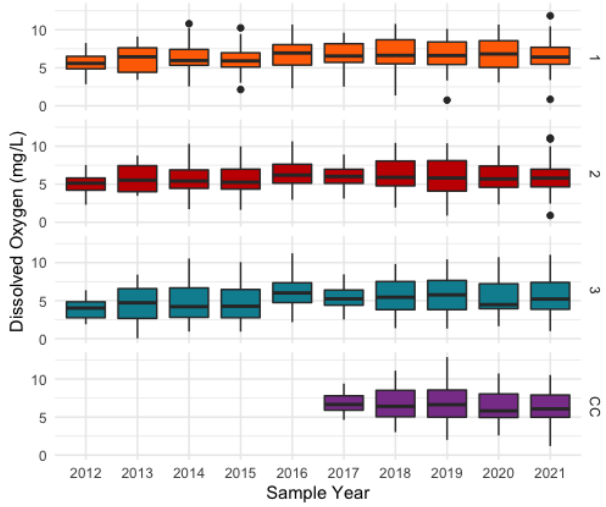
Water Temperature



Salinity



Dissolved Oxygen



pH

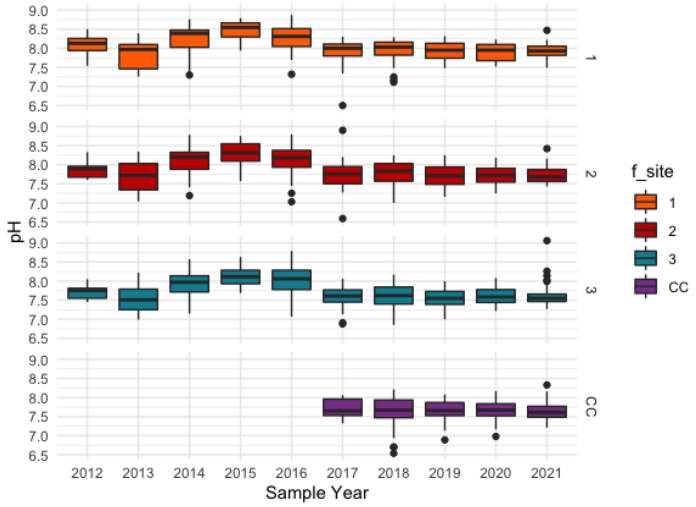


Figure 2-2. Bald Head Creek Water Quality Data: Dissolved Nutrients 2017 - 2021. Bald Head Creek sites downstream (Site 1), mid-creek (Site 2), and upstream (Site 3) and Cape Creek (CC). The most notable trend in nutrients was high nitrate concentrations at the beginning of the 2021. This persisted at all four sites, with highest concentrations downstream indicating primarily a riverine source of nitrate. Ammonia concentrations were variable but mostly low, except for a spike at site 3 at the end of summer, which may be a seasonal pattern (similar timing in 2019). Phosphate concentrations were low in 2021. N:P ratios were higher at the beginning of 2021 than previous years, following the pattern of high nitrate levels. Primary production possibly starts the year being limited by phosphate concentrations, then moves into N limitation in spring and summer.

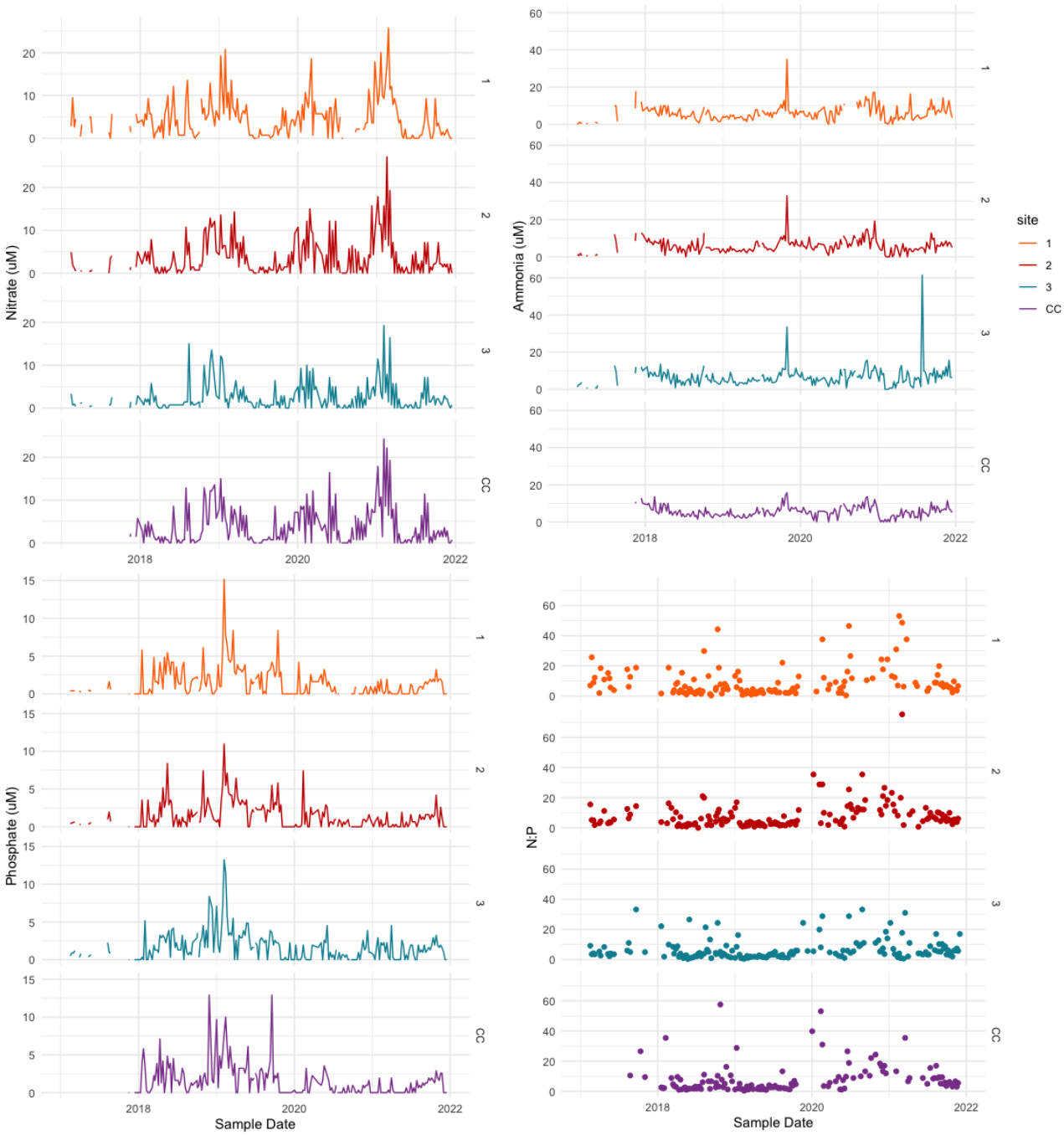


Figure 2-3. Bald Head Creek Chlorophyll and Pheophytin, 2021.

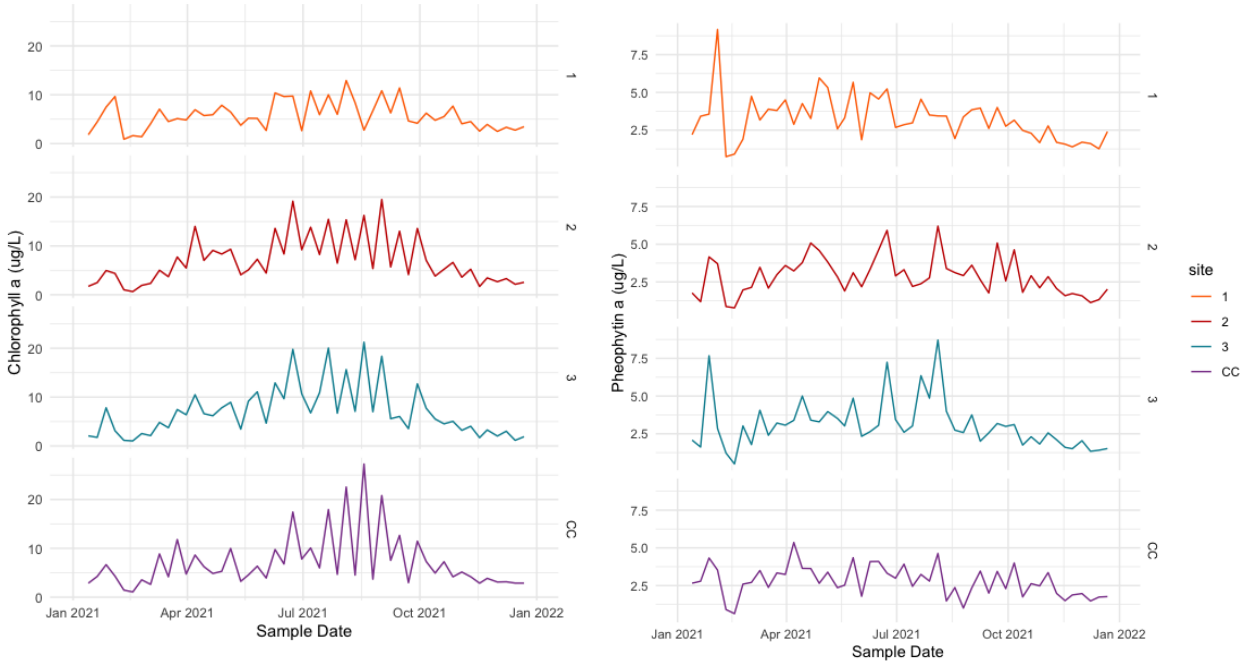
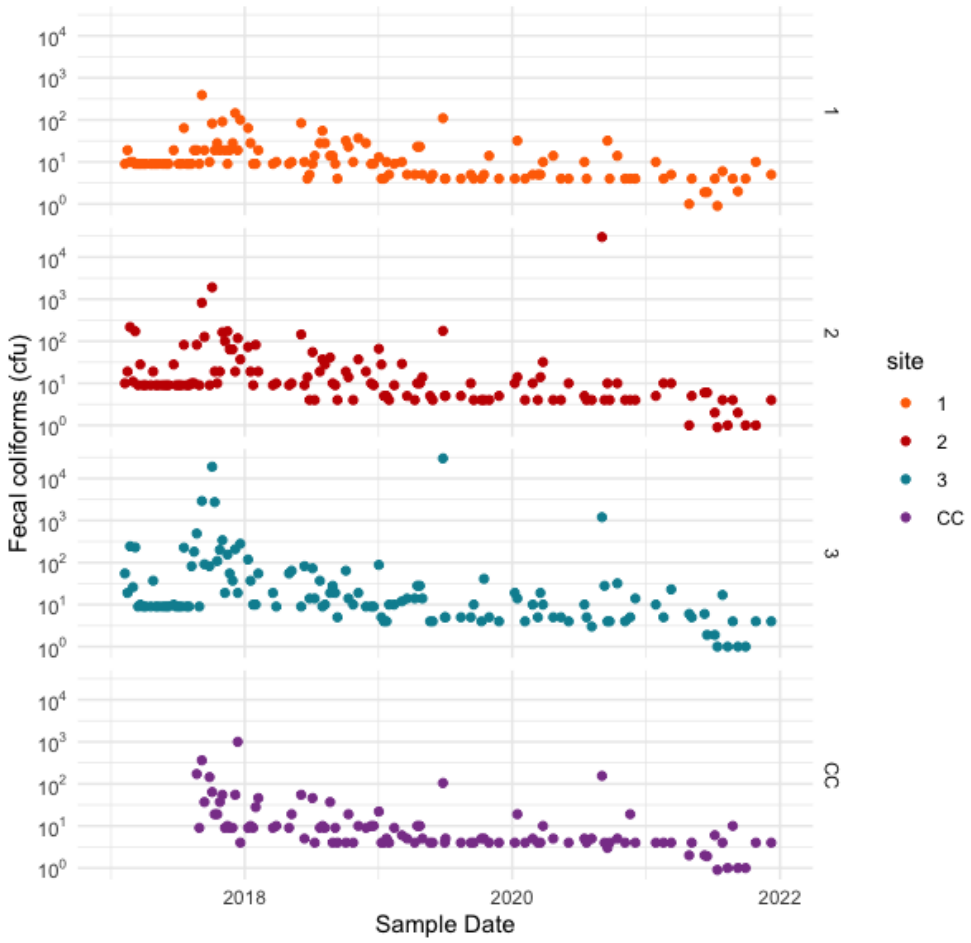


Figure 2-4. Bald Head Creek Water Quality Data: Bacteria 2017 - 2021
Fecal coliform bacteria (shown here on a logarithmic scale) for Bald Head Creek sites downstream (Site 1), mid-creek (Site 2), upstream (Site 3) and Cape Creek (CC). Bacteria densities were always <100 cfu/100 ml in 2021, and usually <10 cfu/100 ml or undetectable. Bacteria levels have decreased substantially since sampling began in 2017.



III. Aquifer Health

The Village's ability to supply much of its own drinking water, which reduces utility costs to taxpayers, and its commitment to maximizing reuse of water, are central tenets of projects aimed at understanding the island's freshwater resources. Further, the island's susceptibility to drainage issues and flooding has dictated an extensive stormwater management plan for which an understanding of the infiltration of rainfall into the aquifer is important. The aquifer also supplies fresh water to the maritime forest, creek, and marsh, providing habitat to plants and animals that should be sustained. Our collaborator Dr. Peter Zamora created a groundwater model in 2020-21 to predict the volume of available fresh water, saltwater intrusion, pumping volumes, river channel deepening, and sea level rise scenarios. This year that model was used to predict response of the aquifer to precipitation events such as Hurricane Florence.

A. Aquifer Volume and Water Quality

Project Goal

- Examine the response of the BHI aquifer to water usage and environmental emergencies (e.g., drought, storm events, outside contaminant inputs) by collecting data for analysis of aquifer storage volume and aquifer water quality
- Monthly sampling for depth-to-water and quarterly sampling (pumping) for water quality

Progress & Significant Findings

- 2021 measurements exhibit a relatively stable water supply, with peaks in groundwater levels corresponding to substantial rainfall events
- Historical analysis for wells measured since 2009 indicates a slight increase in aquifer volume through time for many wells. Perimeter wells in the dunes on South Bald Head Wynd (M-1, M-2) had the most noticeable increase through time (Figure 3-1).
- Groundwater conductivity levels have been mostly in the acceptable range since monitoring began, particularly at interior well sites. Several peripheral wells show signs of saltwater intrusion, with the highest conductivities measured at Middle Island sites and perimeter sites at the southwest of the island (Cape Fear Trail, BHI Club)
- High ammonia levels in some wells are still of concern, but do not seem to be from a recent wastewater source.

Future Directions

We recommend continued monitoring of aquifer volume and water quality.

Figure 3-1. Groundwater height relative to mean sea level (MSL). Positive values are higher than MSL, negative values are below. Most wells show a lower than average aquifer volume in 2021, but an overall upward trend through time.

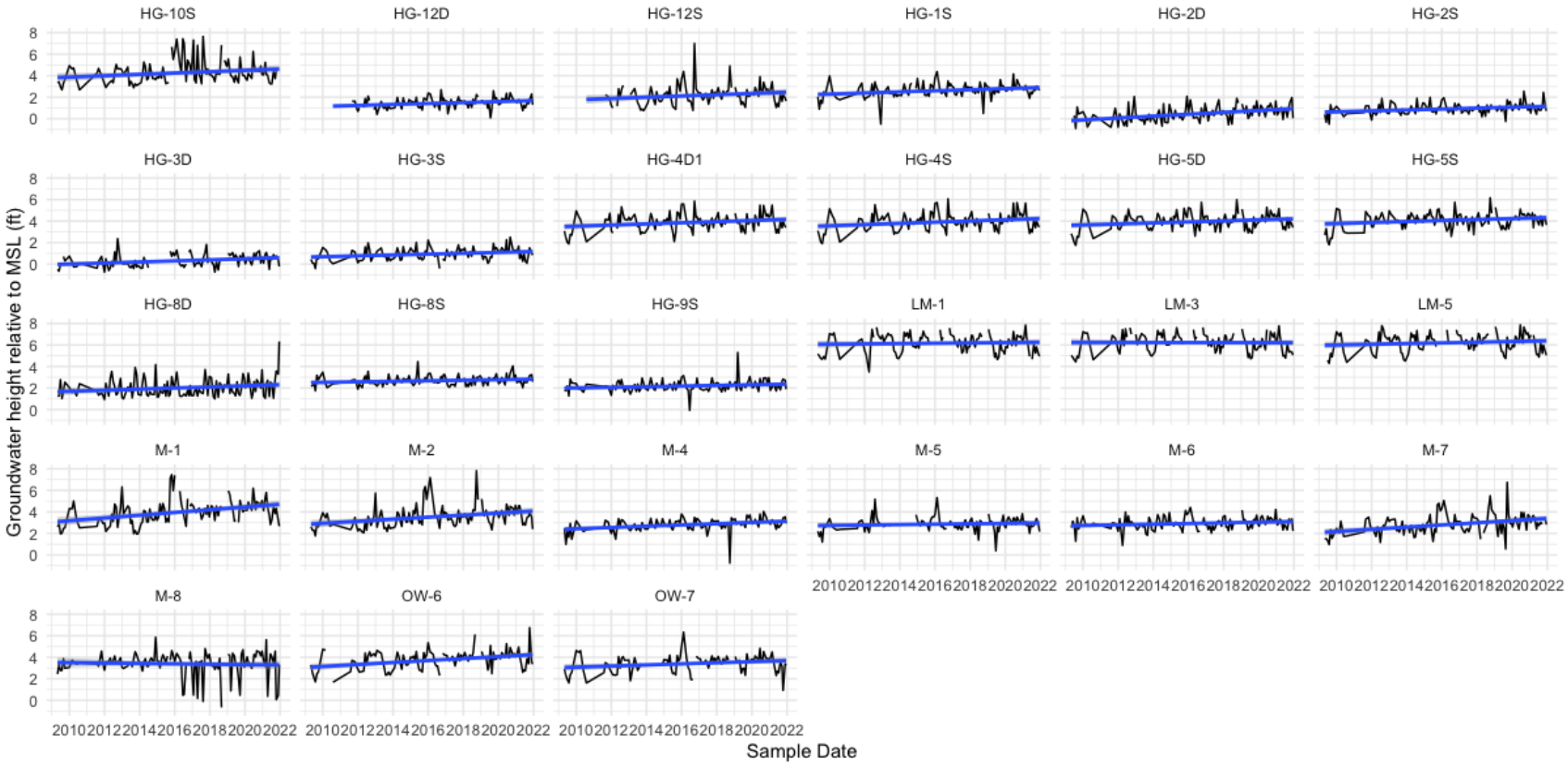


Figure 3-2. Boxplots indicating median groundwater height for all wells in the deep (top) and surficial (bottom) aquifer. The year 2021 has slightly lower groundwater volume than previous years.

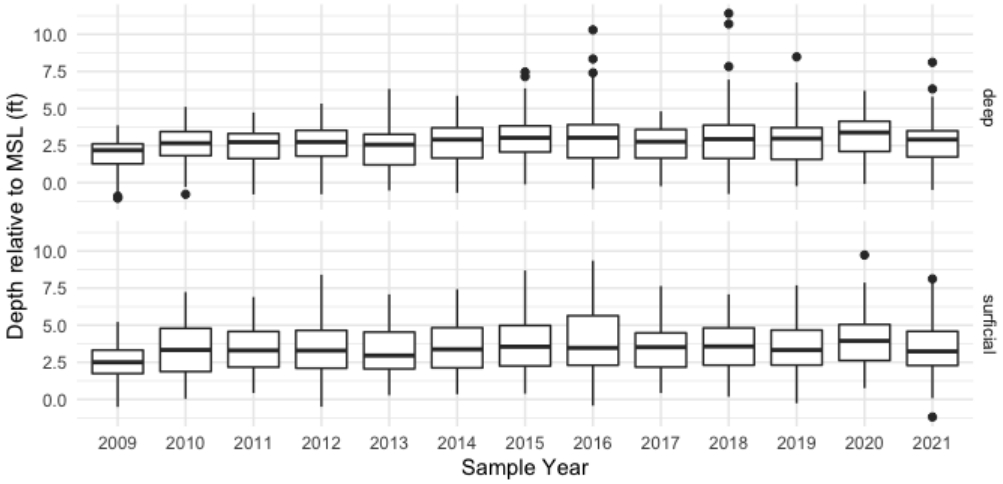


Figure 3-3. Boxplots indicating median groundwater height for all wells by location on Bald Head Island. All locations had slightly lower groundwater volume in 2021 than previous years.

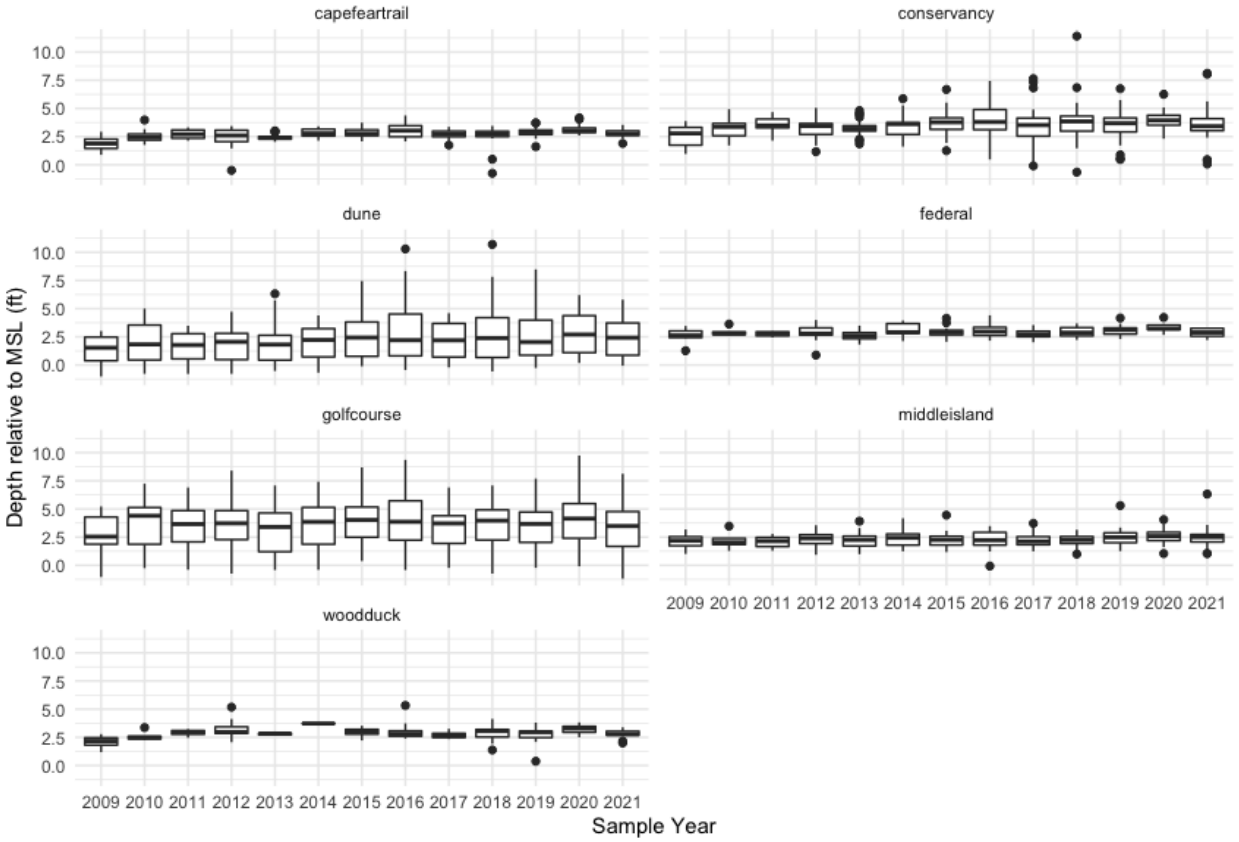


Figure 3-4. Well water conductivity vs. sample date. Water quality has been sampled from a subset of wells since 2014. Most wells have consistently low conductivity (fresh water), but some have more variable or high conductivity. For example, wells HG-2D and HG-2S are just south of the BHI Club and M-4 is on Cape Fear Trail, to the southwest of the island. Wells HG-8D, -8S, -9S are on Middle Island. All of these wells show saltwater intrusion to varying degrees. HG-2S is interesting because low conductivity seems to correspond to wet periods (2018-2019, late 2020), and high conductivity seems to correspond with periods of drought (late 2021). Wells in the interior of the island have low conductivity, indicating no saltwater intrusion to date.

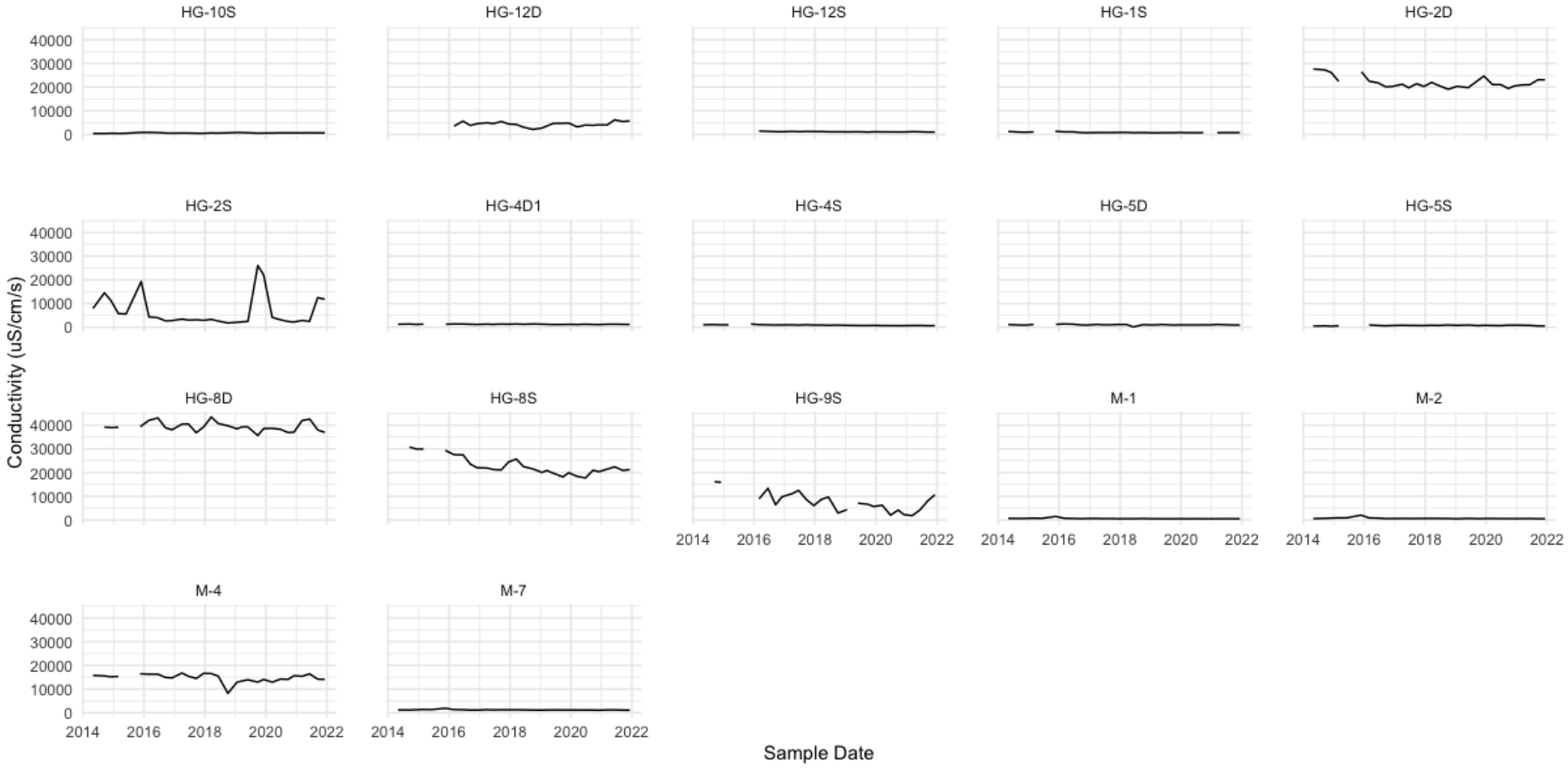


Figure 3-5. Well water ammonia vs. sample date. Nutrient sampling began in 2017. In general, higher ammonia concentrations were found in wells that also had higher conductivity (Fig. 3-4), which tend to be on the periphery of the island. For example, wells HG-2D and HG-2S are just south of the BHI Club and M-4 is on Cape Fear Trail, to the southwest of the island. Wells HG-8D, -8S, -9S are on Middle Island. Ammonia can have natural sources, such as decaying marsh plant material, or wastewater sources. In 2020, we tested groundwater for fecal coliform, and concentrations were all below detection, ruling out a fresh wastewater source for ammonia.

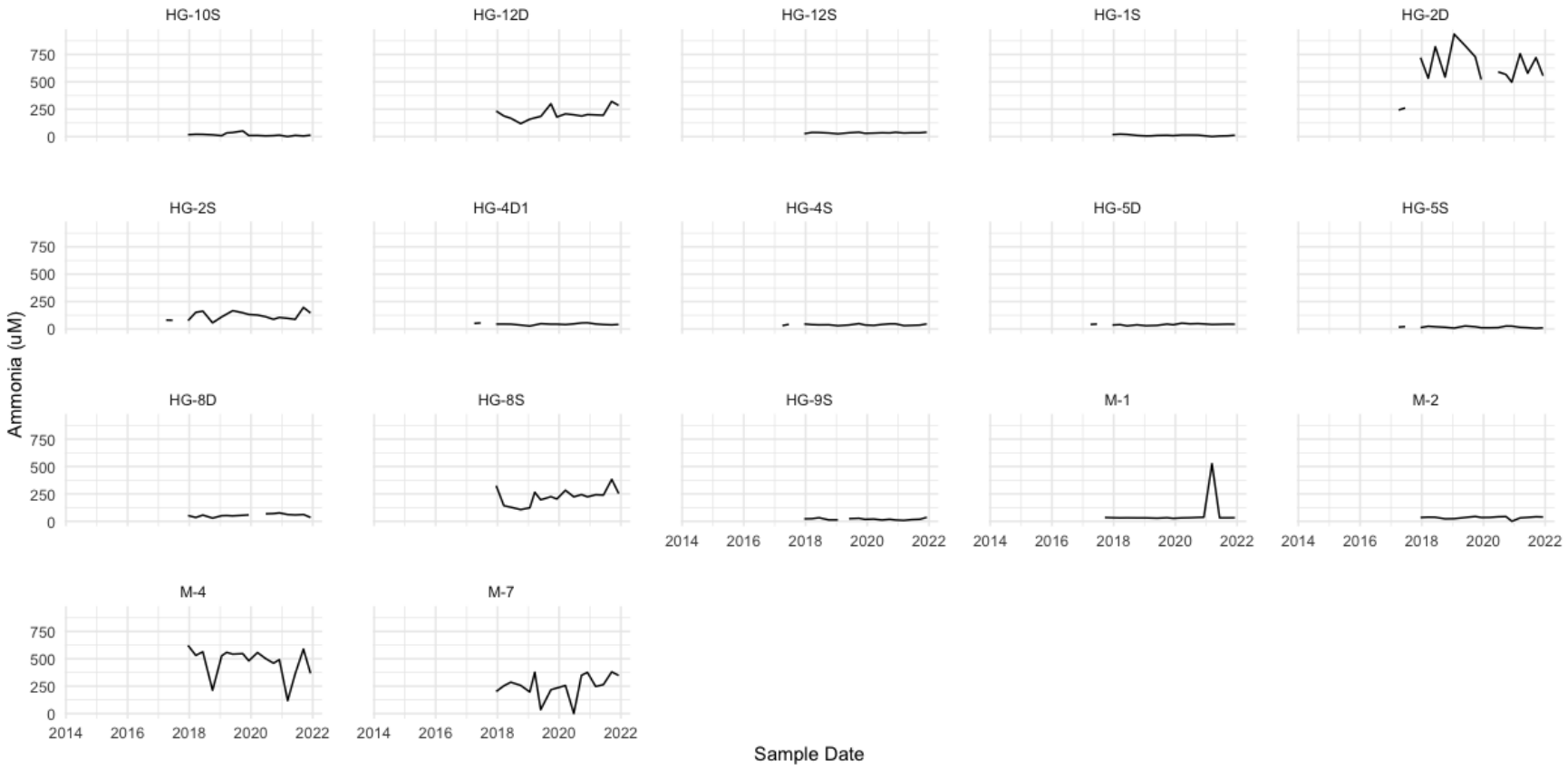


Figure 3-6. Well water nitrate. Groundwater nitrate had slightly different patterns than ammonia (Fig. 3-5). HG-5S has had the highest nitrate concentrations in the past year, and this well is located on the golf course. While these concentrations are below what is considered “contaminated” for drinking water, it is important to be aware that it is possible that fertilizers are leaching into the aquifer.

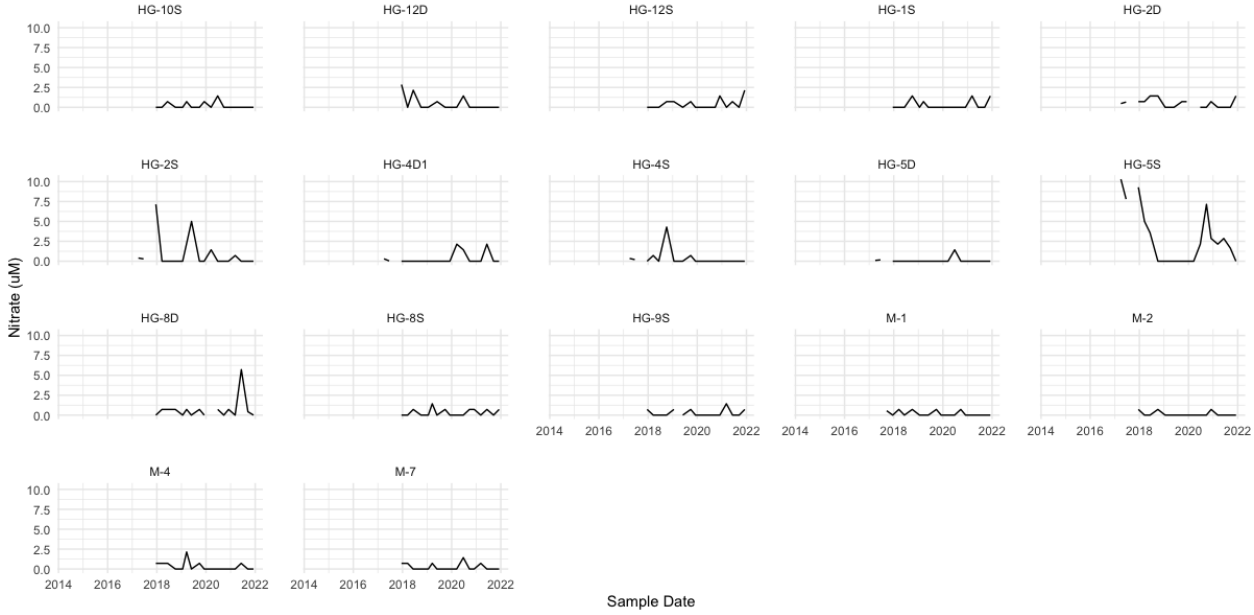
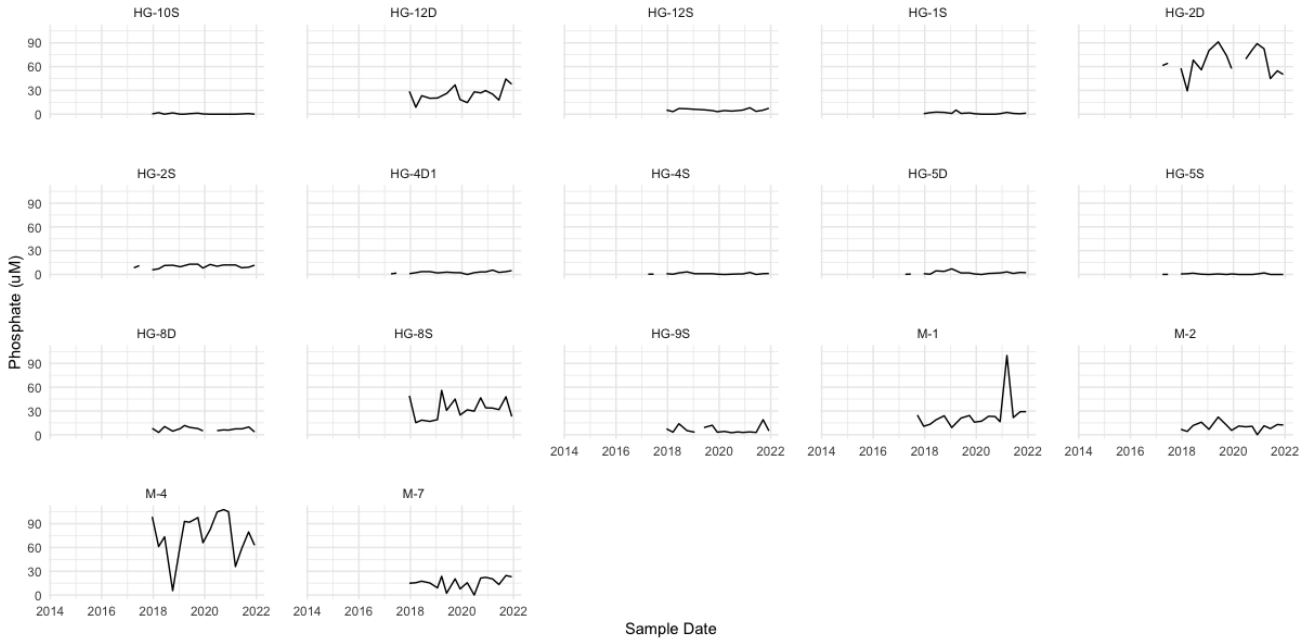


Figure 3-7. Well water phosphate. Phosphate had more of a similar pattern to ammonia than to nitrate. Concentrations were highest in wells at the southwest periphery of the island.



B. Aquifer Modeling

The Zamora Aquifer Model uses island topography, creek and ocean bathymetry, sediment characteristics, and depth to water data to simulate response of the BHI aquifer to groundwater withdrawals and precipitation events (Fig. 3-8). An animation of the modeled aquifer's response to Hurricane Florence can be viewed at https://www.dropbox.com/s/m3fv6re1ssk47mf/Peter%20Zamora%20-%20bhiflorenceflood3.mp4?dl=0. Dr. Zamora and Conservancy staff will be available to discuss the model results (forthcoming in a separate report) with the Village in 2021-22.

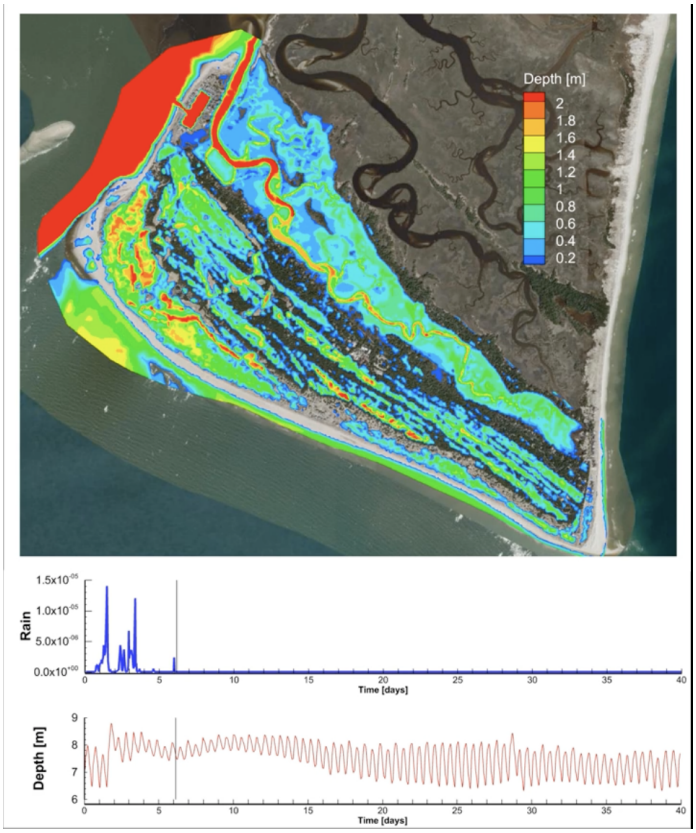


Fig. 3-8. Screenshot of Zamora BHI Aquifer Model simulation of Hurricane Florence. Flooding is indicated by warmer colors (depth relative to mean sea level). Picture taken after maximum flooding when precipitation had ceased (day 5 in lower graph). The model indicates flooding still occurring on the island 40 days after the hurricane, which on-the-ground reports confirm.

Future Directions

In the remainder of spring 2022, the groundwater model could be used with different precipitation scenarios, or the topography could be modified to simulate changes due to stormwater mitigation measures (joining lagoons, creating outfalls, etc.). No new modeling efforts are proposed for the 2022-23 contract.

IV. Dune Health

Native dune species properly designed by nature for barrier island habitats hold together the island's dune system against the forces of wind and water. Invasive species such as Beach Vitex are a substantial threat to many types of these native dune plants and must be vigorously controlled. Also, healthy dunes provide critical habitat for our threatened nesting sea turtle population. In 2020-21, the Conservancy intensified efforts to treat all existing plants after substantial interruptions in 2018 and 2019 due to hurricanes. In 2021, unoccupied aerial vehicle (UAV) technology has allowed visualization of Vitex plants, and added a controlled experiment on herbicide effectiveness.

Beach Vitex

Project Goals

- Find and eradicate existing Beach Vitex to prevent species proliferation and to allow for growth of native dune-building species
- Use UAV technology to make vitex identification more efficient and reduce costs in future years
- Conduct a controlled experiment on eradication methods and season of herbicide application

Progress & Significant Findings

- All of known Vitex sites were treated in 2021 (Table 4-1)
- There was a net loss of 56 Beach Vitex sites from 2019 - 2021
- Aerial surveys with UAV were successful at detecting and identifying Beach Vitex during the growing season
- Total of 11 flight days, covered approximately 800 acres, and took 5,974 photos
- The amount of Beach Vitex on the South Beach dune ridge is 146 plants taking up about 1,592 square meters of plants
- Preliminary experimental data shows higher percent control of herbicide-treated plants than non-treated plants; these differences were more apparent in plants treated during the growing season (Figs. 4-3, 4-4, 4-5).

Table 4-1. Beach vitex treatment progress, January 2022

	2021
Observed sites	195
In treatment	134
Treated this year	130
Not found	44
Dead	12
Controls not to be treated	5
Remaining to be treated	0
Dead or not found	56
% observed sites dead or not found	29

Future Directions

We recommend continuing with the current Beach Vitex treatment plan, focusing on application of herbicides during the growing season. We recommend continuing to use the UAV for plant identification and measurement of plants for assessment of treatment progress.

Utilization of Unmanned Aerial Vehicles (UAV) to detect Beach Vitex

Methods

Flights

BHI Conservancy has conducted UAV flights for the monitoring of the invasive dune plant, Beach Vitex. Flights were conducted using a DJI Inspire 2 equipped with a Zenmuse X5S camera. The DroneDeploy application was used to control the UAV. The UAV was flown at an altitude of 200 ft with a camera resolution of 0.5 inches/pixel. Flights were conducted during the beach vitex growing season, from May 14 - July 29, 2021. In total, 5,974 images were taken, covering approximately 800 acres of dune area. Images were uploaded and analyzed using ESRI ArcMap Geographic Information Systems (GIS) program.

Image Analysis

Individual images were uploaded and processed in DroneDeploy, exporting them as GeoTiffs, images that are georeferenced. GeoTiff images were uploaded to GIS, then were clipped to be easier to work with. The working area was set to a 1:250 scale fixed extent to view for beach vitex from a consistent height. Beach Vitex was identified in the imagery by its long runner and vibrant green coloration (Fig. 4-1), and plants were digitally delineated.

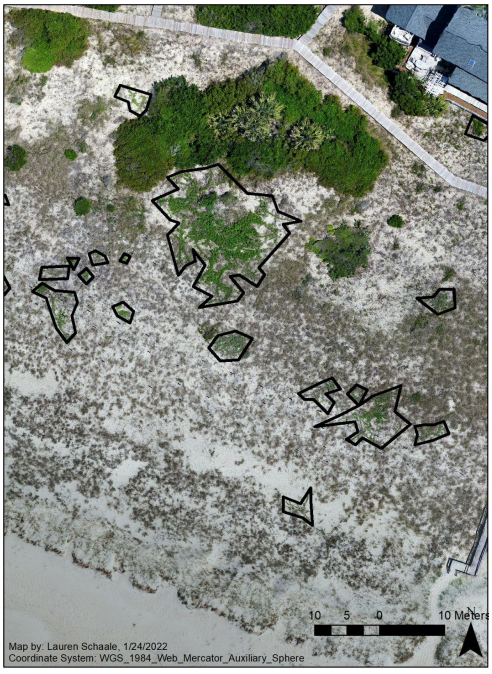


Figure 4-1. Area in frontal dune ridge of Killegray Ridge.

Results

A total of 1,592 m^2 of Beach Vitex were identified from UAV imagery, with individual plants ranging in size from 0.41 - 267 m^2 (Table 4-2). These measurements will be used for future comparisons.

Beach Vitex had the most presence on the South Beach dunes (Fig. 4-2). Areas that had the most vitex were Sandspur Trail, Brown Pelican Trail, Scotch Bonnet Lane, and Killegray Ridge.

Table 4-2. Measurements of Beach Vitex made using UAV imagery, South Beach, 2021

Individual plant count	146
Plant minimum size (m^2)	0.41
Plant maximum size (m^2)	266.6
Total plant area (m^2)	1592.3
Mean plant size (m^2)	10.9

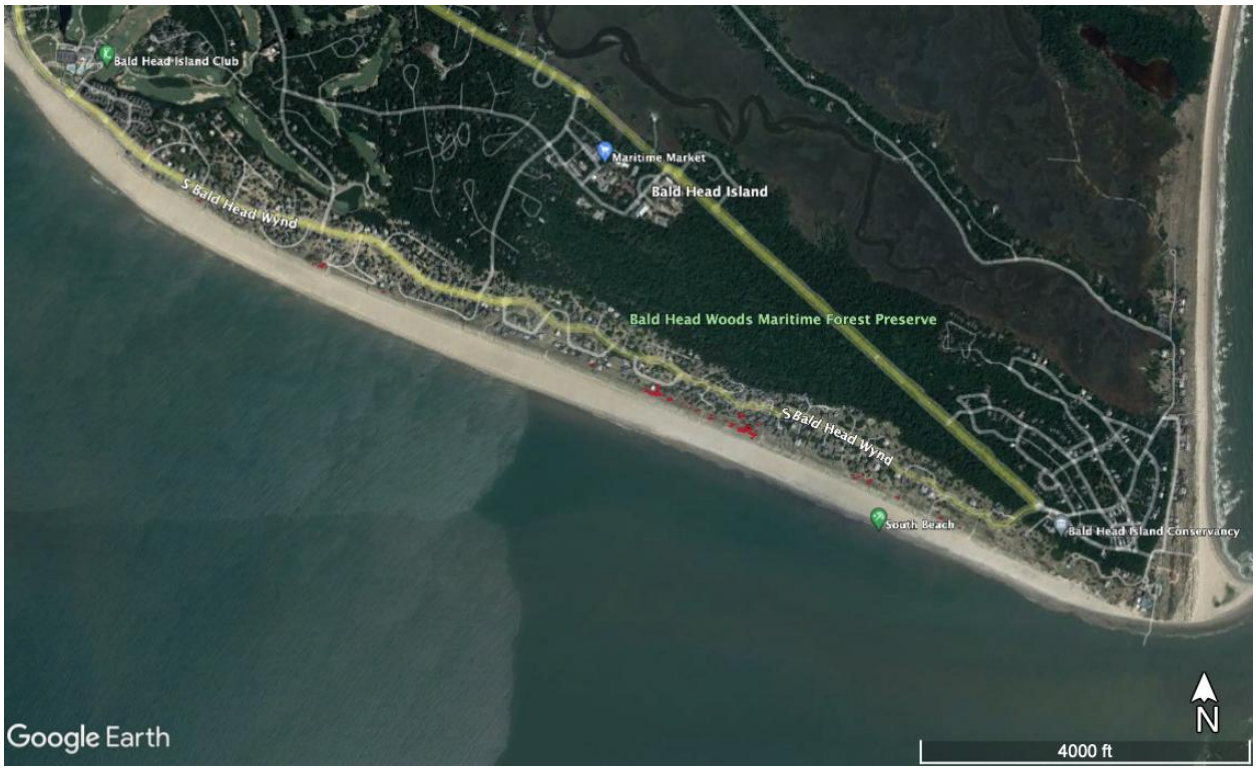


Figure 4-2. Locations of Beach Vitex identified (red areas) via the UAV imagery. Hotspots include Brown Pelican Trail, Killegray Ridge, Scotch Bonnet Lane, and Sandspur Trail.

Beach Vitex Treatment Experiment

This experiment tests the interactive effects of two treatment methods and three treatment seasons on control of the invasive plant, Beach Vitex (*Vitex rotundifolia*) on Bald Head Island. On BHI, almost all Beach Vitex plants have been previously treated with imazapyr, which makes this experiment differ from previous studies. Treatment methods include “Hack and Paint” (“H”: current treatment method involving slicing into plant runners and painting with the imazapyr herbicide), “Remove and Paint” (“R”: cutting the plant at the soil surface, removing above-ground vegetation and painting the stump/stem with imazapyr), and Control (“C”: cutting plant back to same level as herbicide treatments but applying no herbicide). Treatments were applied to plants before the growing season (early March), in the growing season (June), and at the end of the growing season (September). Four replicate plants were used for each treatment method within each season (36 plants total, 12 plants per season). Plants used for this experiment were growing in a variety of locations (primary dune, secondary dune, residential yards) on Bald Head Island. Plants have been treated with imazapyr within the year prior to the experiment, but were still living and classified as “medium” sized, without obvious connections to other plants.

Methods
Plants were randomly assigned to “H”, “R”, or control treatments. On the treatment date, all runners were cut back to approximately 1 m (except for “R” treatments, immediately cut to 2” of soil surface). Non-herbicide control treatments consisted of removing BV stems to within 5 cm (2 in) of the main stem. The treatments consisted of: H - slicing plant runners horizontally to the cambium and applying 2 ml imazapyr herbicide (50% v/v solution of Arsenal AC Concentrate - 53% active ingredient, 27% ai total) per plant; and R - cutting off one main stem per plant with clippers and removing it and spotting 2 ml of the herbicide solution on the stem immediately following cutting.

Experimental plants were visually rated with 0 = no control and 100 = complete kill (defoliated and brown) at 1, 3, and 8 months after treatment (MAT). “Impact” includes yellowing, stunting, and lack of growth. Regrowth is removed from the plants and fresh weight will be determined after 8 months. Plants will be observed for regrowth annually for at least 3 years after the initial experiment period.

Preliminary Results
For plants treated in March, there was no substantial difference in treatment types visible at 1 month after treatment (MAT), likely because assessment was in April prior to the main growing season (Fig. 4-3). By 3 MAT (June), the untreated “Control” plants were growing, but showing about 75% impact on average, while the plants treated with herbicide (“Hack” and “Remove”) were more successfully controlled (Fig. 4-3). The March-treated plants were assessed in November at 8 MAT, and all plants showed more control than June, but this was also when plants begin to go seasonally dormant, so little growth was expected to be observed. Herbicide treatments (“Hack” and “Remove”) still had noticeably more effect on plants than non-herbicide “Control” treatments. The “Remove” treatment had 0 regrowth over the course of the 8-month experiment.

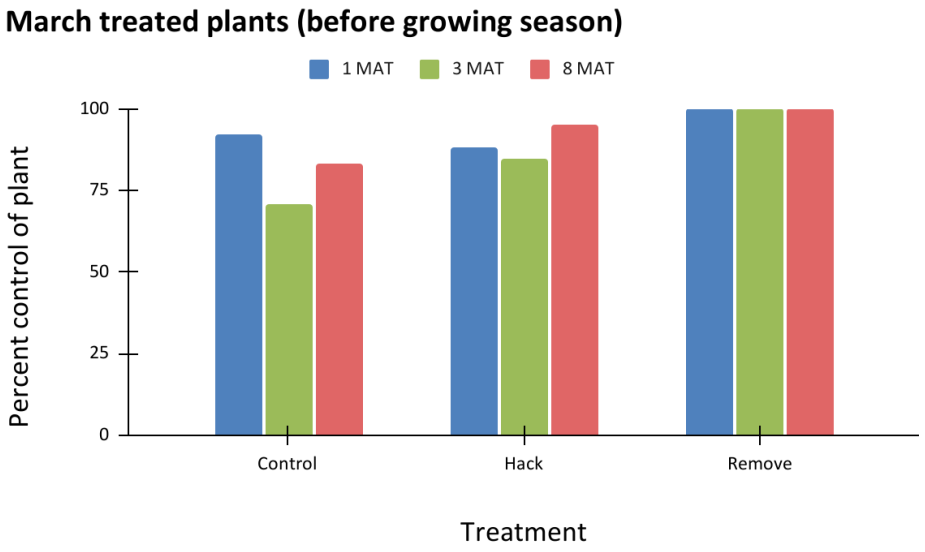


Figure 4-3. Plants treated in March, control of plant growth 1 and 3 months after treatment (MAT)

For June-treated plants, the difference between untreated control plants and herbicide-treated plants was obvious at 1 MAT. Herbicide-treated plants were almost 100% controlled, while untreated plants were <50% affected. Impact on herbicide-treated plants stayed consistent 3 MAT (Fig. 4-4). These plants will be assessed at 8 MAT in February 2022.

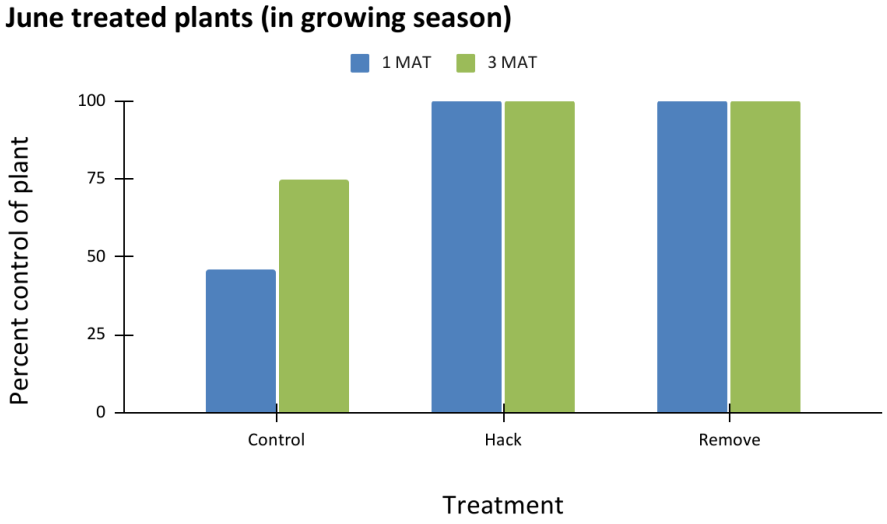


Figure 4-4. Plants treated in June, control of plant growth 1 and 3 months after treatment (MAT)

September-treated plants have shown similar results to June-treated plants so far. Major impacts of herbicide could be seen at both 1 and 3 months after treatment (Fig. 4-5). These plants will be assessed in June for their final 8 MAT assessment.

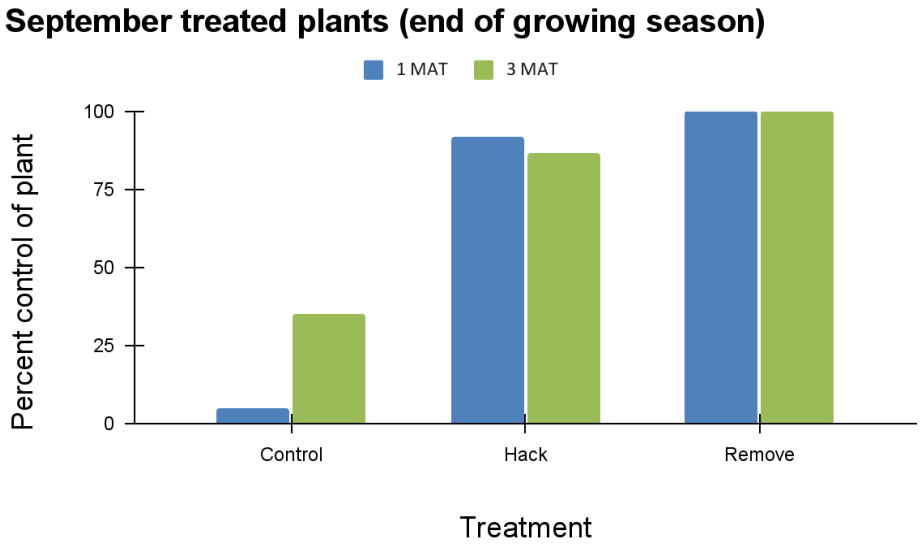


Figure 4-5. Plants treated at the end of the growing season, control of plant growth 1 and 3 months after treatment (MAT)

Preliminary Conclusions

It is apparent that imazapyr is an effective control for both “Hack and Paint” and “Remove and Paint” methods, at least in the short-term. It is not clear yet whether “Remove and Paint” is significantly more effective than “Hack and Paint,” and removing live plant material has the added labor and complication of disposal without spreading.

The reason some “impact” on untreated control plants is being seen in this study could be for two reasons: 1) cutting the plant to standard size prior to herbicide application has some impact, and 2) all plants had been treated with imazapyr in the past.

V. Wildlife Health

Bald Head Island is rich in a diversity of wildlife, and the community strives to live in harmony with nature. The Conservancy monitors, protects, and advises the Village on management of wildlife species that can have negative interactions with humans, resulting in either unsafe situations for humans or harm to the animal. Current projects focus on predators that are of concern to residents and visitors, and on shorebirds and diamondback terrapins that need special protection.

A. Predator Populations

Project Goals

- Monitoring of alligator and canid relative numbers and locations on the island
- Evaluation of predator management methods when needed
- Additional understanding about locations, home ranges, and movements of alligators will be achieved by collaboration with Dr. Scott Belcher (NCSU) to apply satellite tags to up to 5 alligators >5 feet in length (funded by 2021-22 Contract). This information will be immediately useful to address public safety and visitor concerns about habits of large alligators

Progress & Significant Findings

- There were at least 30 alligators on the island in summer 2021, with the majority of these being 1-3 ft in length and found at Golf Course hole 15 (Figure 5-2)
- Alligators larger than 7 feet were regularly spotted at Holes 1, 6, 11, & 15
- Alligator satellite tagging is planned for spring 2022
- Coyote densities were higher on roads and the golf course in summer 2021 than any previous year 2018-2020 (Figure 5-3).
- Despite being present in high numbers, coyotes were less successful at infiltrating sea turtle nests in 2020 and 2021 than 2019 due to improvements in nest predator exclusion cage material partially funded by the Village in 2020
- 5 sea turtle nests were lost to coyote depredation in the 2021 season. Of these, 3 nests were unprotected, 1 had a metal cage, and 1 had a MasterNet cage
- Negative coyote interactions with island residents have increased this year. We are aware of one dog that was attacked by a coyote (visual by owner). The Conservancy has received a number of comments about coyote population size by the concerned public.

Future Directions

We propose to continue with summer alligator spotlight surveys and will plan to continue tracking the individuals tagged in spring from the 2021-22 contract funds. We plan to continue conducting observational surveys of canid presence during deer spotlight and summertime sea turtle patrols.

To determine coyote population numbers and connectivity to surrounding mainland areas, we propose undertaking a one-year study to sample scat to identify numbers of individuals on BHI using molecular methods. This would also allow identification of individuals that may be more problematic, and assess their home ranges (see below for more details). We have identified a professor from NC State (Dr. Liz Kierepka) who has experience conducting the laboratory analysis of coyote scat, and who would conduct

the analysis for the cost of supplies only. This pilot study has potential to be expanded upon by the NC Wildlife Resources Commission in the future to analyze exposure of mesocarnivores to rodenticides throughout the state.

BHI's Alligator Population

Objective

The goal of summer alligator spotlights surveys is to understand and estimate Bald Head Island's alligator populations, to reduce possible unexpected/negative human interactions and provide management recommendations.

Background

Bald Head Island possesses diverse, healthy habitats that are home to a variety of wildlife species. The wildlife exists in a delicate balance, with prey species population levels controlled by predators and predator populations limited by the number of prey species present. In recent years the population sizes of these species have fluctuated; however, little is known about their population dynamics. The BHI alligator population is centered on the west end of the island, where they are found in golf course lagoons and other man-made ponds. Alligators are occasionally seen in the salt marsh or on the ocean beach. Human-alligator interaction poses a potential threat to both humans and alligators on BHI. Therefore, understanding the population structure and individuals' movements between lagoons will assist in reducing unexpected/negative interactions. Weekly nighttime spotlight surveys in summer allow the BHI Conservancy to assess the current population status and provide management recommendations.

Spotlight Survey Results

In summer 2021, we conducted 12 nighttime alligator surveys. Our survey area included all BHI Club Golf Course ponds, Ibis Sanctuary Pond, Villas, and the Wildlife Overlook (Fig. 5-1). The average number of observed alligators viewed nightly in 2021 was 30 per night. The most alligator sightings were at golf course holes 1A, 6, 11, and 15. Notably, Hole 15 had one large alligator (7-10 ft) and about 21 smaller alligators (1-3 ft) observed during almost every survey. Throughout the summer, there seemed to be quite a bit of movement of the alligators. For example, at Hole 10 on one night there were three 4-6 ft alligators observed. The next week, there was only one 4-6 ft alligator seen in that pond. The population structure (relative sizes of individuals) seems stable, but more years of data are needed to determine long-term trends. Reports of visitors fishing and feeding alligators persist, and Conservancy staff continue to participate with Village and BHA leaders on public education efforts about wildlife safety.

In spring 2022, the Conservancy will be collaborating with the Belcher Lab from NC State University to conduct alligator satellite tagging to further understand the locations and movements of alligators and advise public safety concerns.

Figure 5-1. Map of all locations and the route for the 2021 alligator spotlight surveys. Some ponds had multiple areas surveyed. This was done to try to cover as much of the observable pond area as possible.

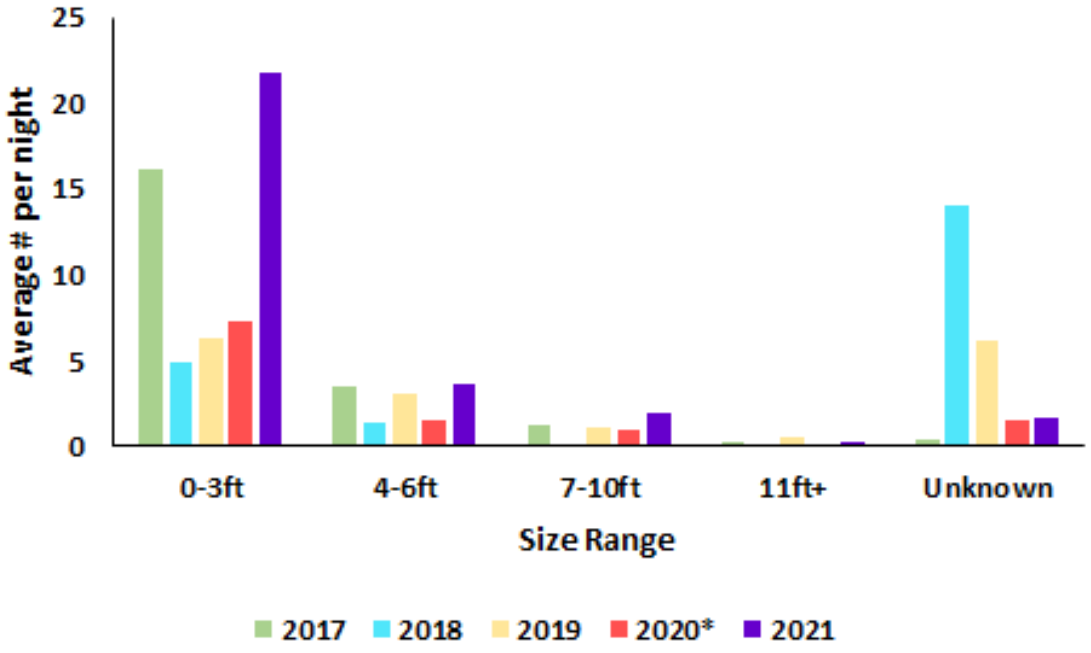


Figure 5-2. Average number of alligators per night at golf course & other sites, 2017-2021 spotlight surveys. Note: 2020 data only covered half of the sites from previous years.

Coyotes

Coyote sightings on summer nighttime spotlight surveys with a consistent route and survey effort have increased in 2021 compared to previous years (Fig. 5-3). There were significantly more sightings per night in 2021 than 2018. Most sightings were on the golf course.

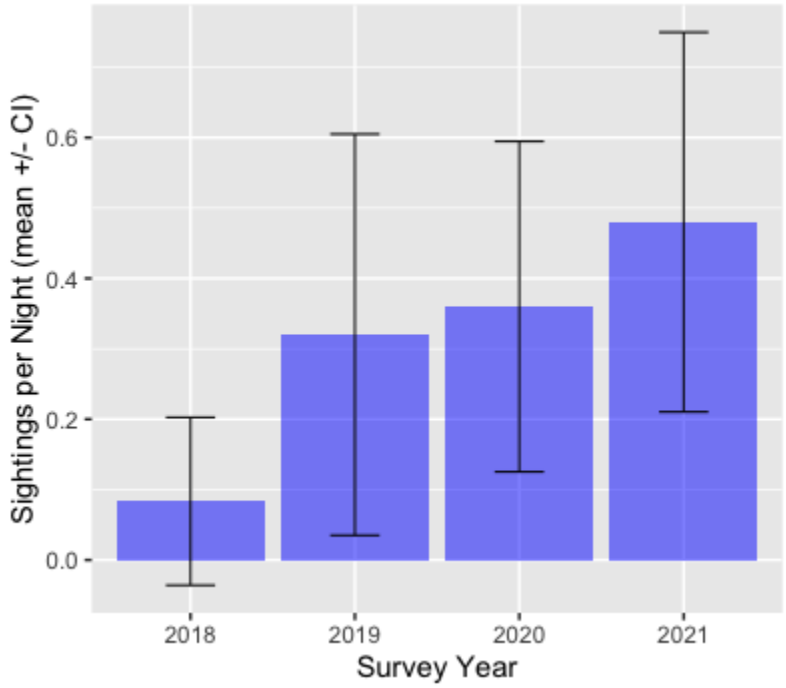


Figure 5-3. Coyote sightings during deer spotlight surveys, average number of sightings per night

Coyote activities on beaches in summer have been documented by the sea turtle team with increasing effort through time. In 2019, over 2,000 sea turtle eggs were lost to coyote depredation, and only depredation attempts were noted (as opposed to other coyote sightings/activities), with an average of 1.0 depredation activities per night. In 2020, we began testing different predator exclusion cage types to resist coyote infiltration into nests. In 2020, other types of activities (i.e., traveling, investigation) were also noted when coyotes were seen during sea turtle patrols. Depredation attempts decreased relative to other activities in 2020, but there were still 1.02 coyote activities per night, despite having fewer sea turtle nests and sturdier cages in place. In 2021, all coyote activities were noted while personnel were on the beach or when prints/evidence indicated coyote presence near sea turtle nests. An average of 4.94 coyote activities per night were noted in summer 2021. While numbers of coyote activities are not directly comparable from year to year, it is clear that coyotes are a consistent presence on the beaches, forest, golf course, and roads of Bald Head Island.

Efforts to document numbers of coyotes and behaviors of individuals have relied on opportunistic sightings, which likely severely underestimate the coyote population and do not differentiate between individuals, such as “problematic” coyotes who have learned to infiltrate sea turtle nests or who act aggressively towards pets, versus individuals who mostly stay to themselves. A more accurate count of coyote numbers could be conducted by tagging individuals, either with physical or molecular tags. Applying a physical tag would require capturing (trapping) and releasing the animals, which has additional benefits, but may not be politically supported on Bald Head Island. Alternatively, molecular methods can be used to

noninvasively sample the coyote population using their scat. Fresh scat would be collected during daily surveys throughout the island for approximately two weeks, preserved, and sent to a collaborator who has experience with these methods. She and her students would use a molecular tag to probe the samples and confirm the species and sex. Sequencing of the animal's DNA would allow differentiation of individual coyotes. The individual DNA sequences would then be counted to determine the approximate number of individuals.

Collection of additional scat samples from Fort Fisher and Southport would allow comparison of family lineages to determine the source population for BHI coyotes. Individual coyotes could be mapped to locations on BHI to determine their home range and habits. This information would help answer numerous questions from the public about the number of coyotes, the number of packs/family groups, and the habits of individuals. Additionally, this information could be helpful for public safety and also for future possible management of the coyote population.

B. Bird Conservation

Project Goals

- Conduct weekly shorebird nest checks in spring, participate in state and international shorebird surveys
- Protect nesting shorebirds with symbolic beach postings
- Educate public about protection of nesting shorebirds by posting a scientist for a few hours weekly with our spotting scope to allow the public to view the nests
- Bi-weekly transect count surveys at different locations around the island to identify different species that use BHI

Progress & Significant Findings

- BHIC placed protective postings at Beach Accesses 1 and 11 in spring 2021
- There was one successful observed nesting pairs of Wilson's Plovers in summer 2021, with 3 chicks at Access 11
- In July 2021, one Least Tern nested to the right of Access 13; this area was posted and observed for 2 weeks before the nest was abandoned (most likely due to either heat or no other Least Terns or colonial waterbirds nesting nearby)
- No other colonial waterbirds or Piping Plovers nested on BHI in 2021
- Results of transect counts included observing 65 different species, finding that at least 18 different shorebirds and seabirds are the most prevalent birds, and that a small group of threatened shorebirds, Red Knots (*Calidris canutus*) were observed on BHI in November (see Figure 5-7)

Future Directions

The Conservancy proposes to continue monitoring nesting shorebirds and setting up protective postings for the nesting season. We will continue our collaboration with State and Federal agencies and participate in Waterbird surveys. We propose to continue bi-weekly bird surveys to continue to learn about which species are seen on the island during different parts of the year. In addition, we will continue to document our wildlife encounters.

Background

Bald Head Island provides habitat for 244 documented avian species, more than half of all species documented for the state of North Carolina. Of these 244 species, eight are shorebird species listed as species with special state or federal protections. BHI has been designated by Audubon as an Important Bird Area. Shorebird species diversity is intrinsically linked to island biodiversity and ecosystem health. The BHI Conservancy has previously observed (in 2017) Least Terns (*Sternula antillarum*) (Fig. 5-5) that nest in a large colony on South Beach. The most common nesting species we currently see is the Wilson's Plover (*Charadrius wilsonia*) (Fig. 5-4). Wilson's Plovers are considered a species of special concern in North Carolina. They are a small, heavy-billed shorebird and specialize in hunting fiddler crabs. The Conservancy puts up a protective posting with signs and brightly-colored cord to provide awareness and protection for these sensitive species. In addition to nesting shorebird monitoring, the Conservancy added bi-weekly bird surveys to our work this fall. This was to observe the number of species that utilize the island and to find other species of concern that may use the island throughout the year. In addition, the most common emergency wildlife calls we receive are related to birds, whether the bird is injured or a nest/chick is misplaced.

Nesting Shorebirds

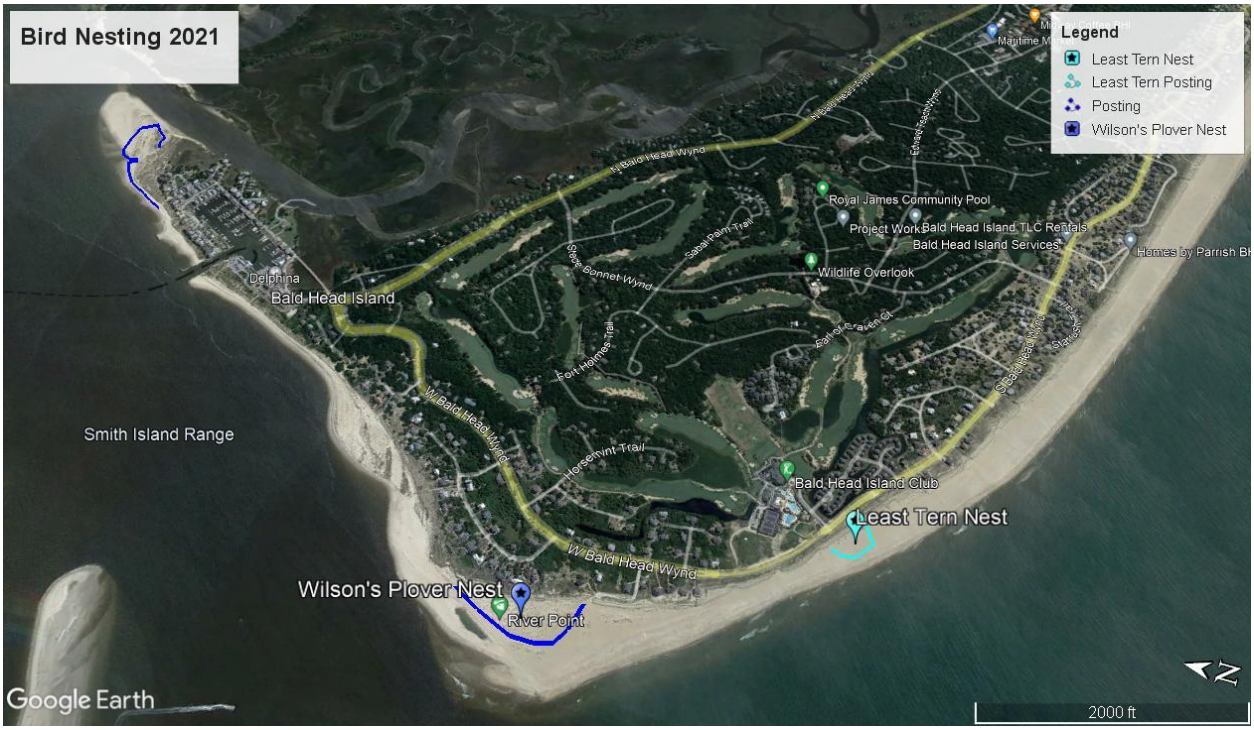
Figure 5-4. Wilson's Plover female with 3 chicks.
(Photo Credit: Robin Prak)

Figure 5-5. 2021 Least Tern nest.

Significant Findings

In 2021, BHIC placed protective postings at Beach Accesses 1 and 11 (Fig. 5-6). Nesting areas were monitored weekly throughout spring and summer. There was one successful nesting pair of Wilson's Plovers. The pair was located at Access 11 and successfully hatched 3 chicks (Fig. 5-4). We carefully observed this pair from when the eggs were laid to when they hatched. The incubation period of this nest was about 25 days (April 21 to about May 15). Chicks were observed out of the nest on May 17. Near the end of July, one Least Tern was observed with a nest near access 13 (Fig. 5-5). The Conservancy team immediately posted this area. The nest had one egg and there were several other Least Terns nearby. The nest was incubated for about two weeks before it was abandoned.

Figure 5-6. West side of BHI. Blue lines represent posting locations and blue marker represent the Wilson's Plover nest. Teal line and marker represents posting of Least Tern nest and area.



On June 1, 2021, the Conservancy participated in annual surveys for the Colonial Waterbird Census and Piping Plover Breeding Census. We walked Access 1 to 3 and used the UTV for surveying from Access 5 to the Fort Fisher border, but did not observe colonial breeding species or Piping Plovers in the 2021 survey window. Conservancy scientists participated in the NC Waterbirds Committee Meeting.

Bi-weekly Bird Surveys

Bi-weekly bird surveys of 4 sites started on September 23, 2021. Survey sites were access 1, Kent Mitchell Trail, North Woods Trail, and the Shoals. Surveys used transect counts, which is walking an area and observing birds via calls and presence.

Significant Findings

The total number of different species spotted from September to December 2021 was 65. The most common types of birds we observed were shorebirds and seabirds (18 different species). The most sightings we had were of Sandwich Terns (343 individuals) (Fig. 5-7). Some notable species that migrated through BHI in the fall were the Common Yellowthroat and American Redstart. Other notable species that migrated to BHI for the winter were Yellow-rumped Warblers, Red Knots, Hooded Mergansers, and Double-crested Cormorants. BHI sees large numbers of Yellow-rumped Warblers and Double-crested Cormorants in the winter months. Red Knots are considered threatened in North Carolina. We observed about 20 Red Knots in November at Access 1.

Conclusion

The Conservancy is providing valuable shorebird protection and conservation data on resident and migratory birds to State and Federal agencies.

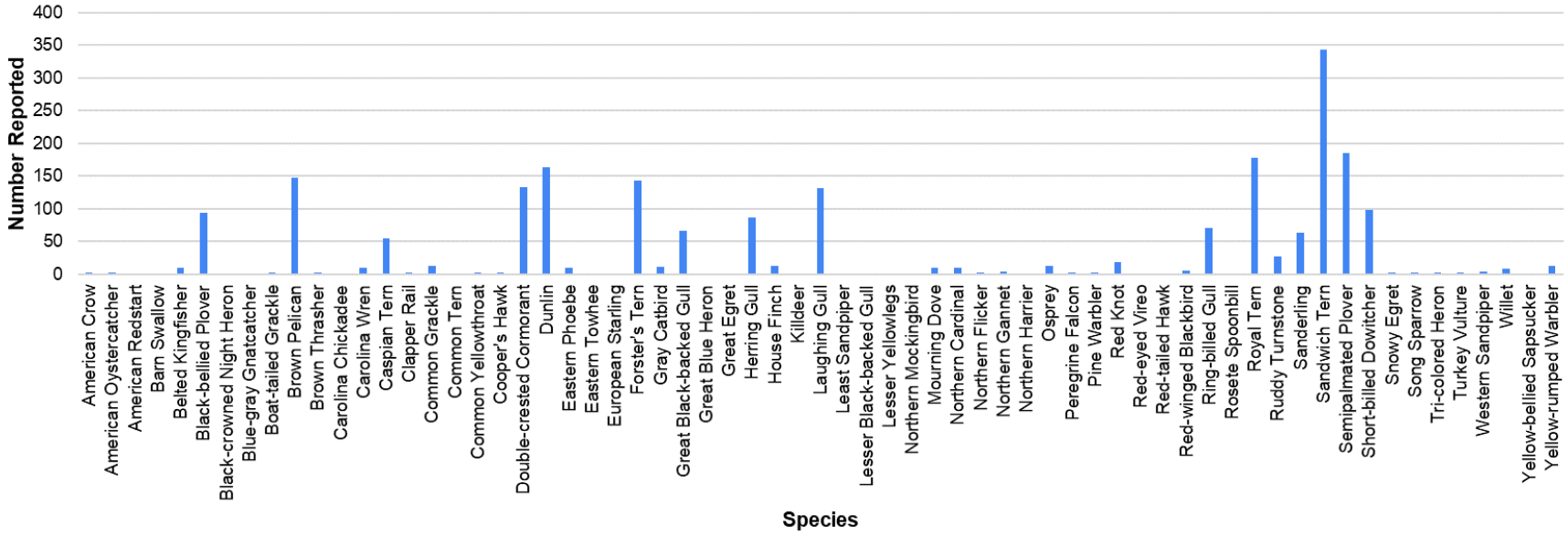


Fig. 5-7. Number of individuals reported per species; 65 species total, from September to December 2021.