Restoring the Ecosystem of the Hoboken Cove

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Abstract:

In light of the proposed ferry refueling station at the Union Drydock and the Hudson Raritan Comprehensive Restoration Plan which designates the Hoboken shoreline and nearshore span as an area of "opportunity", this project focused on feasibility for the development of habitat restoration projects and public access in specific sections of the Hoboken waterfront. Using the Maxent modelling system, a spatial prioritization analysis was conducted along the 1-mile Hoboken waterfront to weigh the costs and benefits for protection of Hoboken Cove and other areas along the Hoboken waterfront versus industrial development.

We asked, which areas are best suited for the purpose of protection and habitat restoration? We weighed costs and benefits for protection of Hoboken Cove and other areas along the Hoboken waterfront versus industrial development and we considered alternatives. Which areas should be prioritized for what type of use? Our distribution models suggest that Hoboken Cove/Union Drydock, Weehawken Cove and possibly Sinatra Park on a smaller scale are waterfront areas that do support biodiversity. Our models combined with the findings within the Comprehensive restoration plan and data from the Nature Conservancy Coastal Resilience decision making tool suggest that these areas may be better suited for living shoreline restoration efforts than other, more exposed waterfront locations. Our data combined with literature review suggest that increased industrial use in Hoboken and/or Weehawken Cove would represent a loss of opportunity for improving water quality, enhancing ecosystem services, increasing public access and stabilizing the shoreline. While ferry refueling is necessary, priority must also be given to mitigation strategies which also support biodiversity and ecosystem services. We recommend engaging community stakeholders in a restoration feasibility study for Hoboken and Weehawken Cove and we advocate for more robust research to identify the best long-term solutions for ferry refueling.

Introduction

After a long history of boat building and industrial manufacturing, the mile long shore of Hoboken is now residential. The waterfront itself currently supports mixed human use, both commercial and recreational, with a long stretch of waterfront park extending to the north and south of a former industrial area known as the Union Drydock that repaired barges and other large motorized vessels (Fig1). Recently, the Union Drydock was sold to the New York Waterway Ferry Company as a refueling station. Their proposed used includes up to 80 ferry trips in and out per day plus on site storage of fuel tanks, staff vehicles and ferry busses.

Immediately adjacent to the Union Drydock is Hoboken Cove, a peaceful, sheltered park area which provides a beach with public access to the river (Fig 1). The cove is used for human powered boating, fishing and environmental education. The waterfront and Hoboken Cove in particular appears to support estuary biodiversity. Small populations of Ribbed mussels *Geukensia demissa* have been found growing wild within the rip rap along the shoreline and on the wooden pilings of the Union Drydock.

One of the critical species assisting in the ongoing effort to clean up the Hudson River is the Ribbed mussel (*Geukensia demiss*a). The Ribbed mussel removes nitrogen and other excess nutrients from our urban estuaries creating an environment more suitable to other species including plants such as Spartina cord-grass which help prevent erosion (Fondriest, 2013; Baron, 2016). Ribbed mussels have even been found effective for the bio extraction of toxins which accompany CSO effluent in urban waterways, including pharmaceuticals (Gallimany, 2017; Binelli, 2014). According to the Hudson, Raritan Comprehensive Restoration plan, the Hoboken waterfront has been identified as suitable habitat for the development of a living shoreline including the restoration of shellfish beds. (Ribbed Mussels Could Help Improve Urban Water Quality, 2017, Gallimany et al., 2017, Baron, 2016).

Based on citizen science surveys, there is an anthropogenic, though still robust ecosystem occurring within Hoboken Cove and the location is a unique public recreation site. As such, the city of Hoboken offered to buy this stretch of property from the NY Waterway and attempted legal action to ensure the protection of the area but NY Waterway refused to negotiate. The conflict is currently ongoing and highly controversial. Hoboken Cove appears to be an ideal location for habitat restoration efforts. Placing a busy industrial re-fueling station in that location could create substantially higher wave and wake levels in the small cove, potentially causing drastic changes in turbidity and reducing dissolved oxygen levels. Though subject to the rise and fall of tidal action, data suggests that the cove is protected from river currents and does not clear out readily, increasing the likelihood of hypoxia occurring (CWQT, 2018; Fondriest, 2013,). Onsite fuel tanks and vehiicle storage in addition to the action of refueling will increase the presence of both hydrocarbons and toxins due to spills and runoff. Additionally, due to the shallow depth of the area, propeller action from these ferries plus any additional dredging may re-suspend the heavy metals and POP's presently lying dormant in the silt (Schubel, 1977).

The Hudson-Raritan Comprehensive Restoration Plan (HRCRP) has designated the Hoboken waterfront as an area of opportunity for habitat restoration, increased public access and associated land acquisition (Baron, 2016). The Hudson River Estuary region spanning from Jersey City to Edgewater, which includes Hoboken, has currently been identified as a "regionally significant" habit which, despite degradation, provides an important overwintering ground and nursery for anadromous, estuarine and marine fish as well as a feeding ground, nesting site and migratory respite for a variety of birds. Restoration efforts focused on target ecosystem characteristics, as identified in the HRCRP, would improve water quality, support biodiversity and essential ecosystem services while creating a more resilient shoreline (Baron, 2016).

Our spatial prioritization analysis focuses on the 1-mile Hoboken waterfront. In light of the HRCRP which designates this shoreline and nearshore span as an area of "opportunity", we consider feasibility for the development of habitat restoration projects and public access in specific sections of the Hoboken waterfront. Which areas are best suited for the purpose of protection and habitat restoration? We also assess the impact of a proposed ferry refueling station at the Union Drydock located immediately adjacent to a public access point, specifically Hoboken Cove. Using spatial analysis, we weigh costs and benefits for protection of Hoboken Cove and other areas along the Hoboken waterfront versus industrial development and we consider alternatives. Which areas should be prioritized for what type of use? We chose to utilize the Maxent modeling system after reading an article which used Maxent to predict and model the future of razor clams (*solendida*e) (Saeedi, Basher & Costello, 2016). We are hopeful that by creating an Species Distribution Model for the Hoboken waterfront, we can address a real-time issue facing a public recreation point on the Hudson River and make the case for protecting Hoboken Cove as a restoration site.

Methods

We began our spatial analysis by generating a map depicting species presence along the Hoboken waterfront. As the base, we used a shape file of the Hoboken waterfront taken from Open Street Map. Using QGIS we then created a .001-degree grid system layer, with each unit representing a 112 meter or 367-foot square area on the waterfront map (Fig 2). Species presence point data was included in the next layer and obtained from two sources, the Hoboken waterfront biodiversity survey and iNaturalist. As both of these sources are unpublished, citizen science assessments, the presence data was checked for accuracy using two peer reviewed River Project studies, a substrate biodiversity assessment and another entitled Fishes of the Tribeca Waterfront.

The model includes 92 species as representative of an inter-connected northeastern, urban brackish estuary food web. Notable organisms include both threatened and indicator fish species such as the Striped Bass, *Morone saxatillus*, Shortnose sturgeon, *Acipenser brevirostram*, American eel, *Anguilla rostrata*, Alewife herring, *Alosa pseudoharengus* and the Diamond back terrapin, M*alaclemys terrapin*. We also highlight species that are considered key to restoration efforts including the Eastern oyster, *Crassostrea virginica* and particularly Ribbed mussels, *Geukensia demissa*. As filter feeders, both Eastern oysters and Ribbed mussels remove nitrogen, excess nutrients and other pollutants, making the ecosystem healthier. As oyster "farming", even for research purposes is currently illegal in the state of NJ, Ribbed mussels are better suited to bio extraction projects. Ribbed mussels may also aid in the restoration of other species such as Saltwater cordgrass, *Spartina alternaflora,* which can prevent shoreline erosion, help mitigate flooding and make the overall shoreline more resilient in the face of climate change. The full species list can be viewed in Appendix A.

Using the QGIS map grid we identified environmental variables including shoreline structure per grid square to establish baseline conditions and create raster layers. The environmental variables include combined sewer overflow outfalls, water quality, ferry ports, wave height, ferry wake, shore sun and shoreline type. The location of existing CSO outfall sites were obtained from the NJ Department of Environmental Protection Open GIS Data. Data identifying the presence of sewage as indicated by enterococcus levels was obtained from the New York City Water Trail Association Citizen Water Quality Testing Project (CWQT) and the Harbor Estuary Program State of the Estuary Report. Ferry transport docks and human recreational access points were obtained through Google Maps. Wave height and shoreline type were retrieved from Nature Conservancy NJ Coastal Resilience (TNC-NJRC) , an online decision making tool (TNC-NJCR). Shore sun and ferry wake criteria were taken from Bruno's (2002) wake impact study. Using this criteria, updated sunlight and wake values were observed and documented from different points along the shore and on the water by Noelle Thurlow. Parameters for habitat restoration including living shoreline, living breakwater, beach restoration and ecologically enhanced revetment as well as data concerning flood levels were not included as environmental layers but are considered in the discussion in conjunction with our spatial analysis. These habitat restoration and flood data was gathered from the TNC-NJCR. Current and turbidity, primarily obtained from the Davidson Laboratory and the Hudson River Environmental Conserving System (HRECOS), was also omitted as an environmental layer in the model, but is included as a factor in the discussion.

We coded the environmental variables into categories (Appendix B). Maxent was then used to assess the impact of these environmental variables on species distribution. Three analysis were conducted. One run focused on Ribbed mussels, another on shore/water birds and a third included all species present. The response curves and jacknife test generated for each run were assessed.

Results

In regard to Ribbed mussel distribution, Maxent initially generated a series of response curves showing the marginal effect of altering one variable while keeping the other six at average levels. The variables used in the assessment are strongly correlated. As a result, the marginal response curves for the models are co-linear and thus difficult to interpret. (See fig 4) This is effect is also true for the other two runs. As such, the marginal response curve charts for shore/water birds and all species are not included in the results.

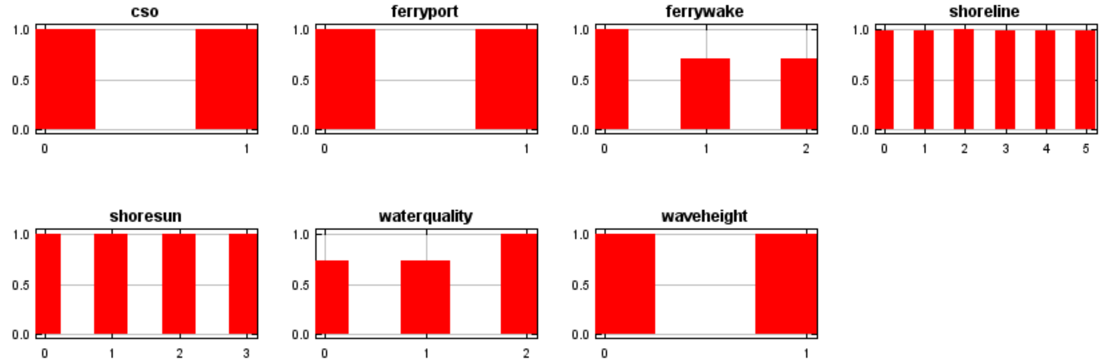

Fig 4 Ribbed Mussel Marginal Response Curves

In contrast, the response curves shown below in Fig 5 also focus on Ribbed mussels, but they represent a different Maxent model created using only one individual corresponding environmental variable. Fig 6 shows the Jackknife test which identifies the importance of each variable. The variables which appear to be the highest predictors of Ribbed mussel distribution are water quality and ferry wake, followed by wave height, shore sun and shoreline. CSO outfalls and Ferry docks themselves are not predictive according to these models.

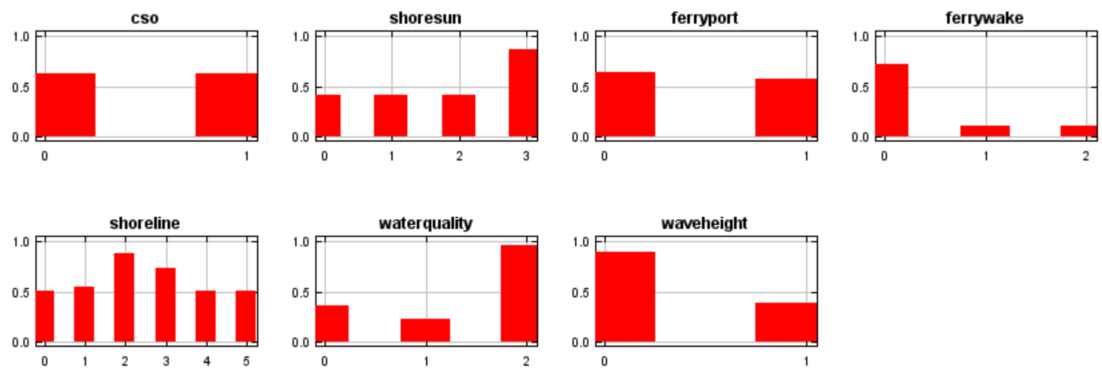

Fig 5 – Ribbed Mussel Corresponding Variable Response Curves

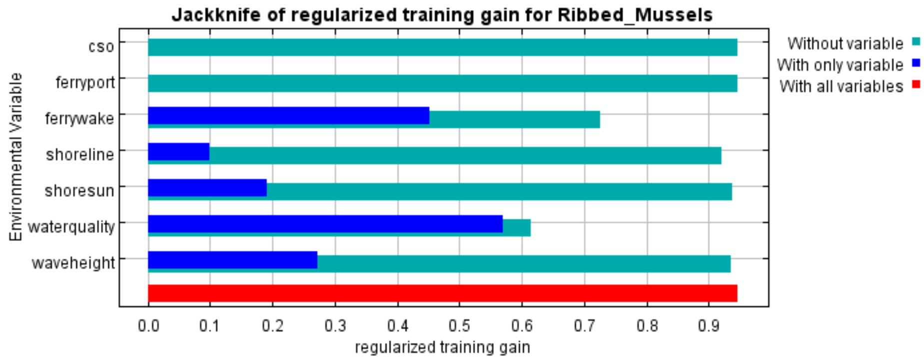

Fig 6 – Jackknife Test for Ribbed mussels

The next set of response curves Fig 7, focus on shore/water bird distribution. According to the jackknife test, water quality is the environmental variable that shows the highest training gain when used in isolation. The other variables that may be predictive of shore/water bird distribution include shore sun and shoreline type.

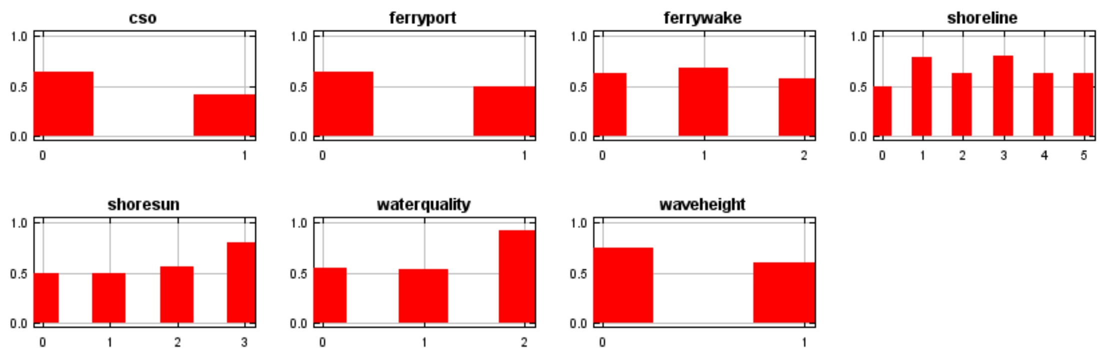

Fig 7 – Shore/water Bird Corresponding Variable Response Curves

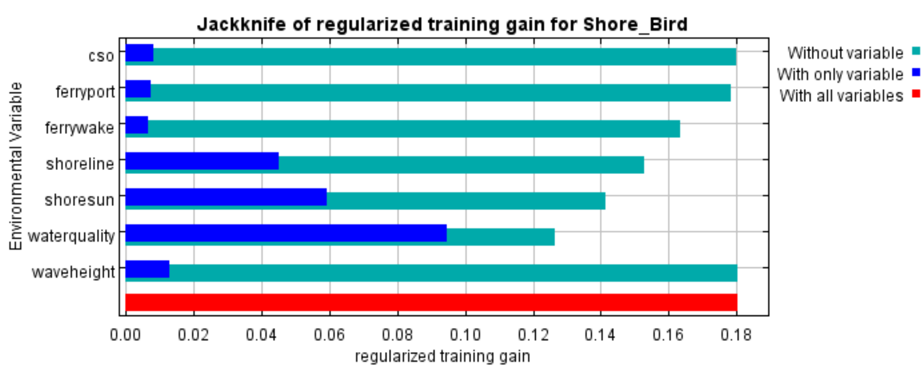

Fig 8 – Jackknife Test for Shore/Water Bird

The last run includes all estuary species present along the Hoboken waterfront. The response curves and associated jackknife test indicate that shore sun is the most predictive variable, followed by water quality, and shoreline type.

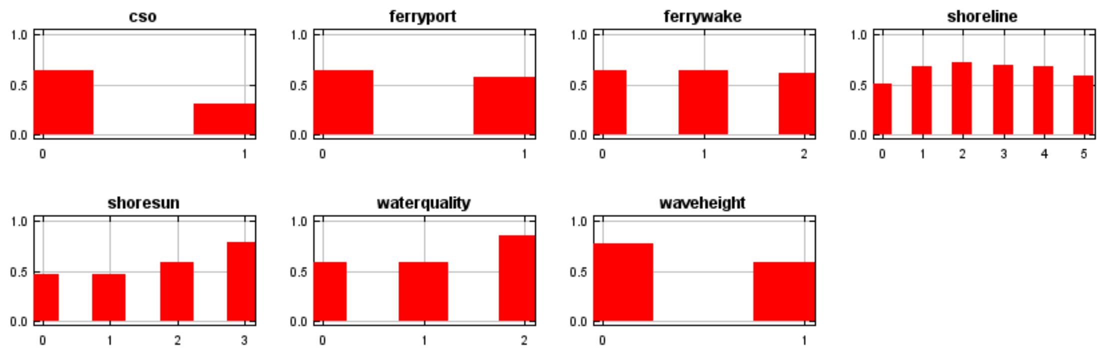

Fig 9 – All Species Corresponding Variable Response Curves

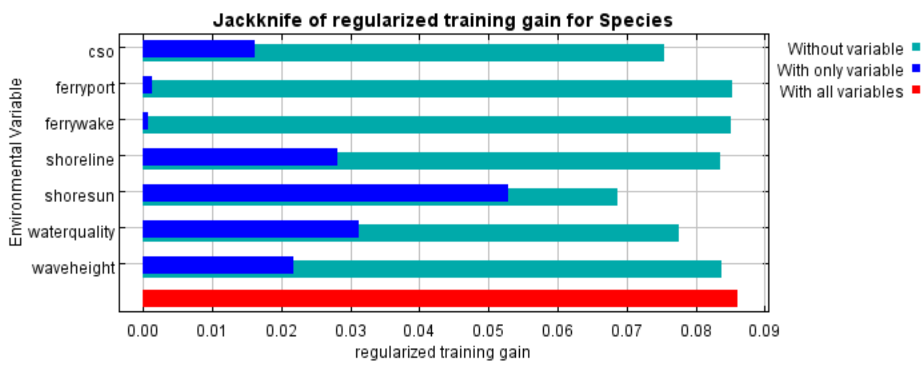

Fig 10 – Jackknife Test for All Species

The Maxent model for Ribbed mussel distribution shown in the image on the right of Fig 11 uses warm colors to depict areas on the grid that have better predicted conditions for Ribbed mussels. These correspond to actual presence locations shown in white. Colder blue colors indicate a less viable location for Ribbed mussels. The image to the left of Fig 11 overlays this grid onto the map of the Hoboken waterfront. The more suitable areas, also shown in warmer colors on the map, are found in two geographic locations known as Hoboken Cove including the adjacent Union Drydock and Weehawken Cove. The Maxent models for shore/water birds Fig 12 and all species Fig 13, also identify these same two locations as areas with more suitable environmental conditions. All three models show one additional smaller area with predictive conditions. This location is known as Sinatra Park.

Discussion:

The Maxent models in our project suggest that Hoboken Cove/Union Drydock, Weehawken Cove and possibly Sinatra Park on a smaller scale are waterfront areas which may provide greater support for estuary biodiversity than some other areas due to certain environmental conditions. Given this, it is important to consider these predictive environmental conditions in more detail.

Maxent identified water quality and ferry wake as the most predictive variables for Ribbed mussels as shown in the corresponding variable response curves. Our data indicates that the ferry wake is lower in Hoboken Cove and Weehawken cove and to a lesser extent at Sinatra Park. Although ferries do repeatedly travel past these locations, these areas may have enough space to dissipate waves, as in the case of Weehawken Cove, or they may not be located in the area of highest wake energy as in the case of Hoboken Cove (Bruno, 2002). According to Bruno (2002) the highest wake energy from high speed ferries occurs during the transition phase when these vessels plane up to their highest speeds or drop down from highest to low. A steady high speed actually creates less energetic or impactful wake (Bruno, 2002). The location of the ferry ports and current trajectory of ferry travel spare Weehawken Cove and Hoboken Cove from the highest wake energy. Additionally, ferries never enter Hoboken Cove and only dock one side of Weehawken Cove, reducing or eliminating any effects from the vessel propellers which are known to disrupt sediments and increase turbidity. This means that, at present, the water itself in Weehawken Cove and Hoboken Cove is calmer and the shorelines in both locations experience less wave energy than other more exposed shoreline areas. This effect is further supported by surface current data collected 24 hours per day by The Urban Ocean Observatory at Davidson Laboratory, Stevens Institute of Technology (Fig 14). The Davidson Laboratory data indicates that Hoboken Cove and Weehawken Cove and to a lesser extent, Sinatra Park experience significantly less river current than other areas (Fig 14).

According to our Maxent models and actual presence data, water quality correlates with the presence of Ribbed mussels in our study. Correlation does not necessarily indicate causation.

The water quality data actually shows that lower water quality exists more frequently in Hoboken Cove. Maxent indicates that this lower water quality is predictive of Ribbed mussels. We suspect that water quality may be lower in Hoboken Cove as a result of cove size plus limited current and wave energy. While it cannot be proven from this study, nor can it be proven from the water quality data, it appears that Hoboken Cove may not “flush out” as readily as some other areas, possibly resulting in the lower water quality.

While Maxent indicates that the lower water quality is predictive of the Ribbed mussels, this does not necessarily mean the mussels have chosen an area of poorer water quality to live. It is likely that other variables such as the low energy conditions, near shore depth and shoreline structure (rip rap) are actually stronger factors or greater predictors. That said, the fact that the mussels are actually present in this poorer water quality area and that Maxent interpreted the low water quality as predictive of Ribbed mussel presence may indicate that the mussels are well suited to survive in poorer conditions. This survivability could be important for Ribbed mussel restoration efforts which aim to “clean” low quality estuary water through bio extraction and thus this aspect warrants further study. Collecting targeted species presence data at more points along the Hoboken waterfront grid would be a next step to consider for a more thorough model.

Beyond water quality, shore sun and shoreline type were predictive variables for shore/water birds and all species. These variables are correlated so they are difficult to separate for analysis. Additionally, in assessing shoreline criteria it is likely we used too many different types in relation to our sample size. Had we limited the criteria or used a larger species sample size or smaller grid size, the shoreline type may have shown more significant results. This is an area of opportunity for further study and is highly relevant for restoration efforts. In general, our modeling indicates that waterfront areas with a “softer edge” either sand or rip rap that are not covered by pier, walkway or “hard edge” bulkhead, and thus receive more sun light, appear to support more species. While not specified in the Maxent modeling, these “softer edge” areas along the Hoboken waterfront that appear to have better predictive conditions for all species are also points of public access to the water for recreation or educational use. Connecting urban populations to place-based, waterways and other natural areas has been shown to increase the likelihood of pro-environmental behavior (Chawla, 2012; Kudryovsky, ; urban waterways.

In considering the question of shoreline restoration as opposed to increased industrial use, the Nature Conservancy and Arkema (2013), note that the East Coast of the United States is highly vulnerable to sea level rise and increased storm strength and frequency related to climate change. Natural coastal habitat such as reefs, shellfish beds, sea grass beds, intertidal aquatic vegetation, marsh and dunes have been shown to offset these risks (Arkema, 2013). In fact, Arkema's (2013) research indicates that natural habitats currently protect 67% of coastal areas in the United States. Urbanization is increasing in the US and throughout the world and it typically leads to habitat destruction. According to Arkema (2013), loss of existing protective habitat in coastal areas would expose a much larger portion of the coastline, essentially doubling the already massive area of impact from climate change and exposing double the number of vulnerable populations (specifically elderly and low income) living near coastal areas (Arkema, 2013).

Improving or restoring coastal habitats with a "living shoreline" can mitigate climate change effects and improve ecosystem service function. A living shoreline is a nature-based technique which can include native vegetation such as marsh grasses and sea grasses plus clean sediments and organic, biodegradable materials plus oyster castles, breakwaters and reef seeded with native shellfish. They are best suited to low energy or moderate energy locations. Based on our models, Hoboken Cove and Weehawken Cove are not only predictive of estuary species presence, but they appear to have suitable environmental conditions for shoreline restoration efforts. This is further supported by the Nature Conservancy's online decision-making tool which indicates that these cove locations meet six out of seven essential criteria for the restoration of a living shoreline breakwater --tidal range, ice cover, salinity, wave height, shoreline slope and near shore slope -- and seven out of seven criteria for another technique known as ecologically enhanced revetment -- all criteria plus shoreline change rate (Coastal Resilience, n.d.).

In considering the impact of increased industrial use of Hoboken Cove and Weehawken Cove, it may be important to remember that although Ribbed mussels and all species identified in our models currently exist within a degraded, urbanized estuary, a ferry refueling station placed at the Union Drydock within Hoboken Cove has the potential to negatively impact these populations and would certainly be a deterrent to any restoration efforts requiring low or moderate energy locations. Studies indicate that motorized vessel wake in shallow waters disrupts shellfish beds through forceful wave action and causes shoreline erosion (Bilkovic, 2017; Asplund, 2000, Bruno, 2002). Boat wake has also been shown to increase turbidity, cause hypoxic conditions and kill fin fish, shellfish and plants (Bilkovic, 2017; Asplund, 2000). Dredging and turbulence from motorized vessel propeller action can also re-suspend heavy metals and POPs from sediments. Legacy contaminants, which are likely to be present in sediments of the Union Drydock, can re-enter food chains and bio magnify at higher trophic levels negatively affecting the reproduction and survival rates of shellfish, finfish, reptiles and birds as well as posing a significant human health risk (Schubel, 1977; Carson, 2002, Baron, 2016).

Our model shows sunlight to be a predictor of biodiversity. In support of this finding, peer reviewed studies indicate that excess shade from large docked vessels and large piers has been shown to reduce light for plant growth and decrease biodiversity (Able & Duffy-Anderson, 2006; Able, 2013). Additionally, although the water quality in Hoboken Cove is already lower than other waterfront areas, urban runoff from impermeable pavers in near shore vehicle/vessel maintenance areas could degrade the water quality further (Sanderson, 2016; Fondriest, 2016; Significant Habitats, n.d.). Even small hydrocarbon spills during re-fueling have been shown to have a negative impact on waterways by limiting growth and reproduction of fish as well as other benthic species (NY Sea Grant, n.d. & Strassler, 1999).

Conclusion

While further study is needed, our distribution models suggest that Hoboken Cove/Union Drydock, Weehawken Cove and possibly Sinatra Park on a smaller scale are waterfront areas that support biodiversity. Our models combined with the findings within the Comprehensive restoration plan and data from the Nature Conservancy Coastal Resilience decision making tool suggest that these areas may be better suited for living shoreline restoration efforts than other, more exposed waterfront locations. Positioning a busy ferry refueling station next to Hoboken Cove would expose the area to the highest wave energy as each ferry travels in and out, transitioning between speed levels. The increased wake combined with propeller action in the shallow waters of Hoboken Cove is likely to increase turbidity and may reduce dissolved oxygen levels, negatively impacting the species currently present. Increased motorized vessel traffic and associated wake in this relatively small cove may also prevent human recreational use of the area and potentially prohibit restoration efforts. Choosing to increase industrial use in Hoboken and/or Weehawken Cove would represent a loss of opportunity for improving water quality, enhancing ecosystem services, increasing public access and stabilizing the shoreline. Urbanization is increasing, biodiversity is declining rapidly and sea levels are predicted to inundate the Hoboken waterfront (Fig 15). While ferry refueling is necessary, priority must also be given to mitigation strategies which also support biodiversity and ecosystem services. We recommend engaging community stakeholders in a restoration feasibility study for Hoboken and Weehawken Cove and we advocate for more robust research to identify the best long-term solutions for ferry refueling. Thoughtful planning supported by careful spatial analysis can help create a shared and truly sustainable urban waterfront.

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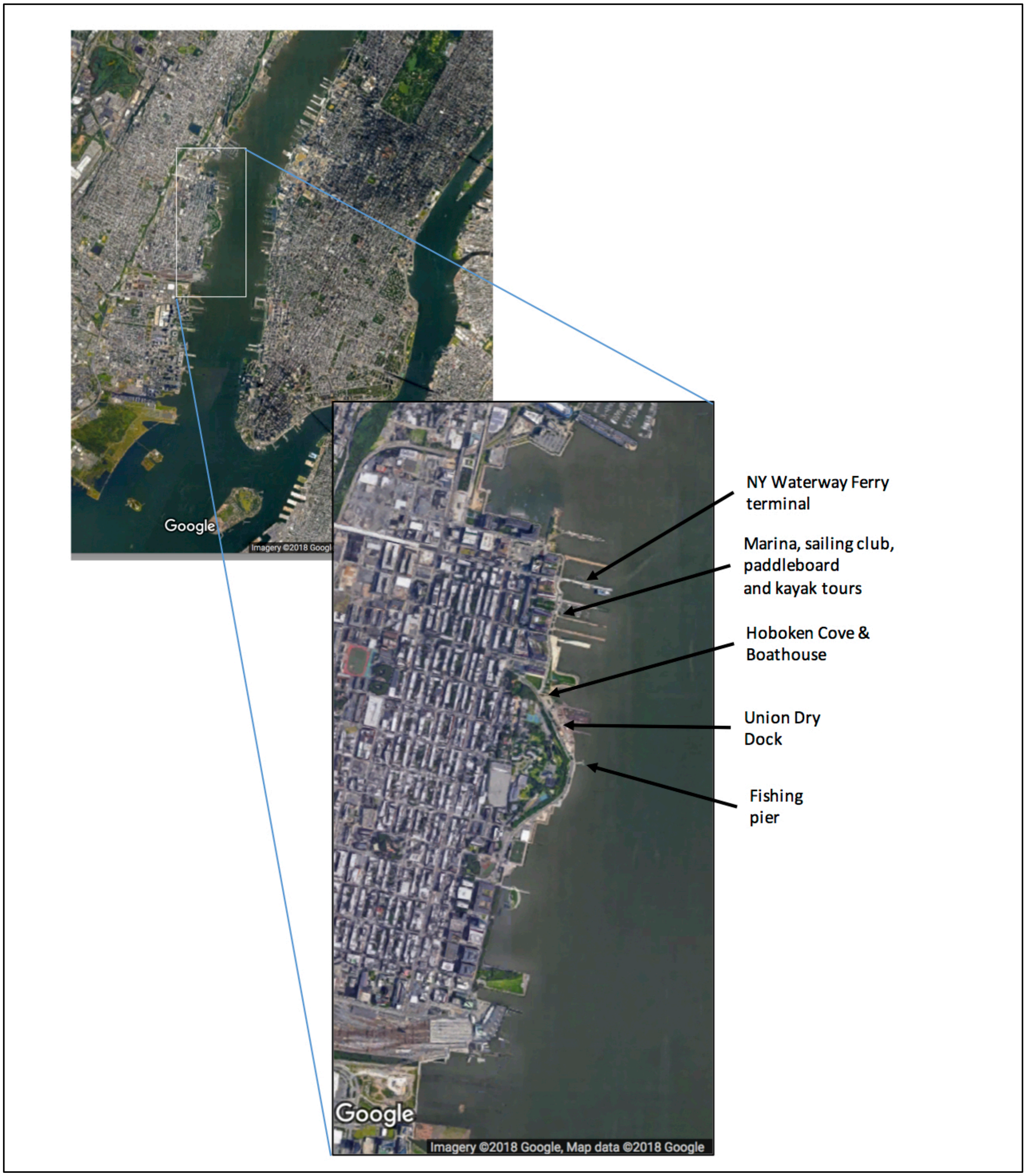

Fig 1 – Hoboken Mixed Use Waterfront

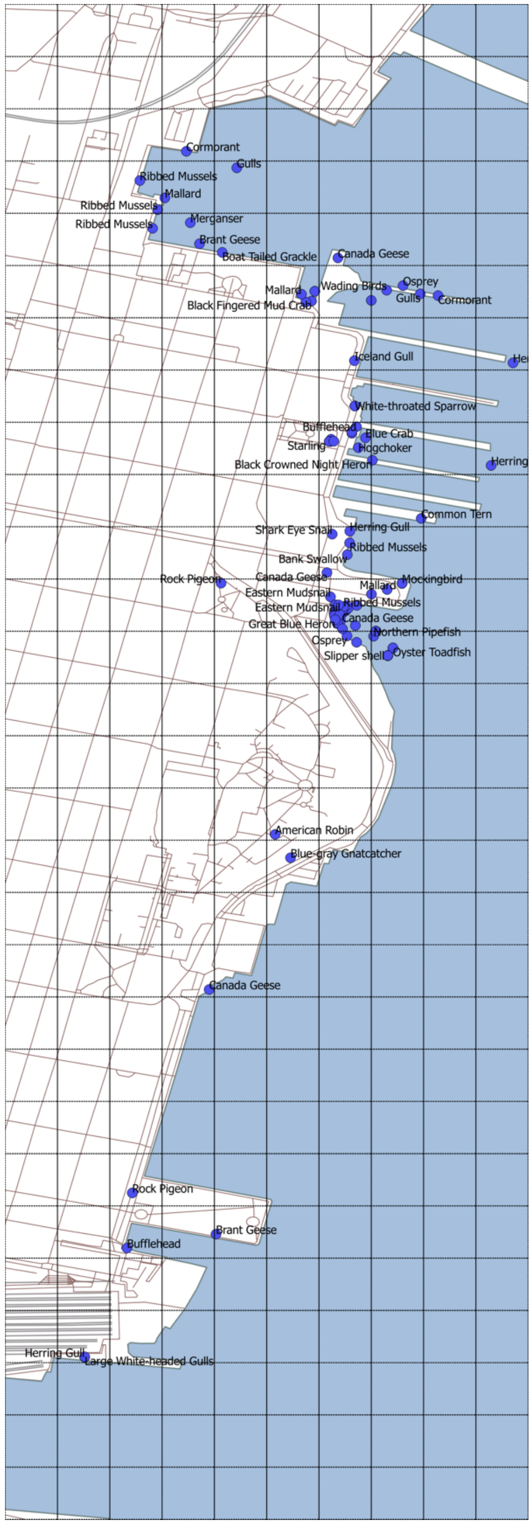

Fig 2 – Hoboken Waterfront Shape File with Grid

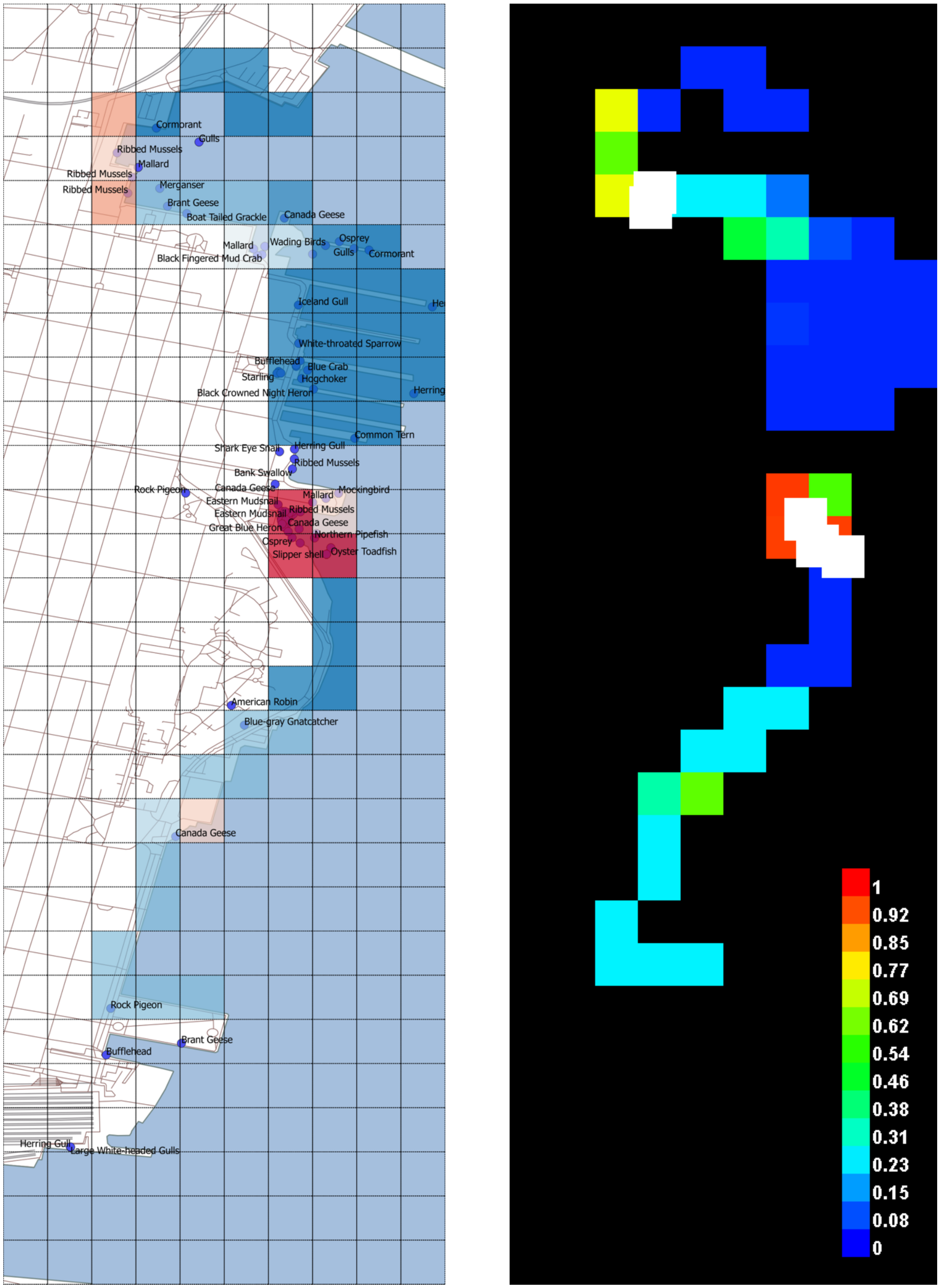

Fig 11 - Ribbed Mussels distribution

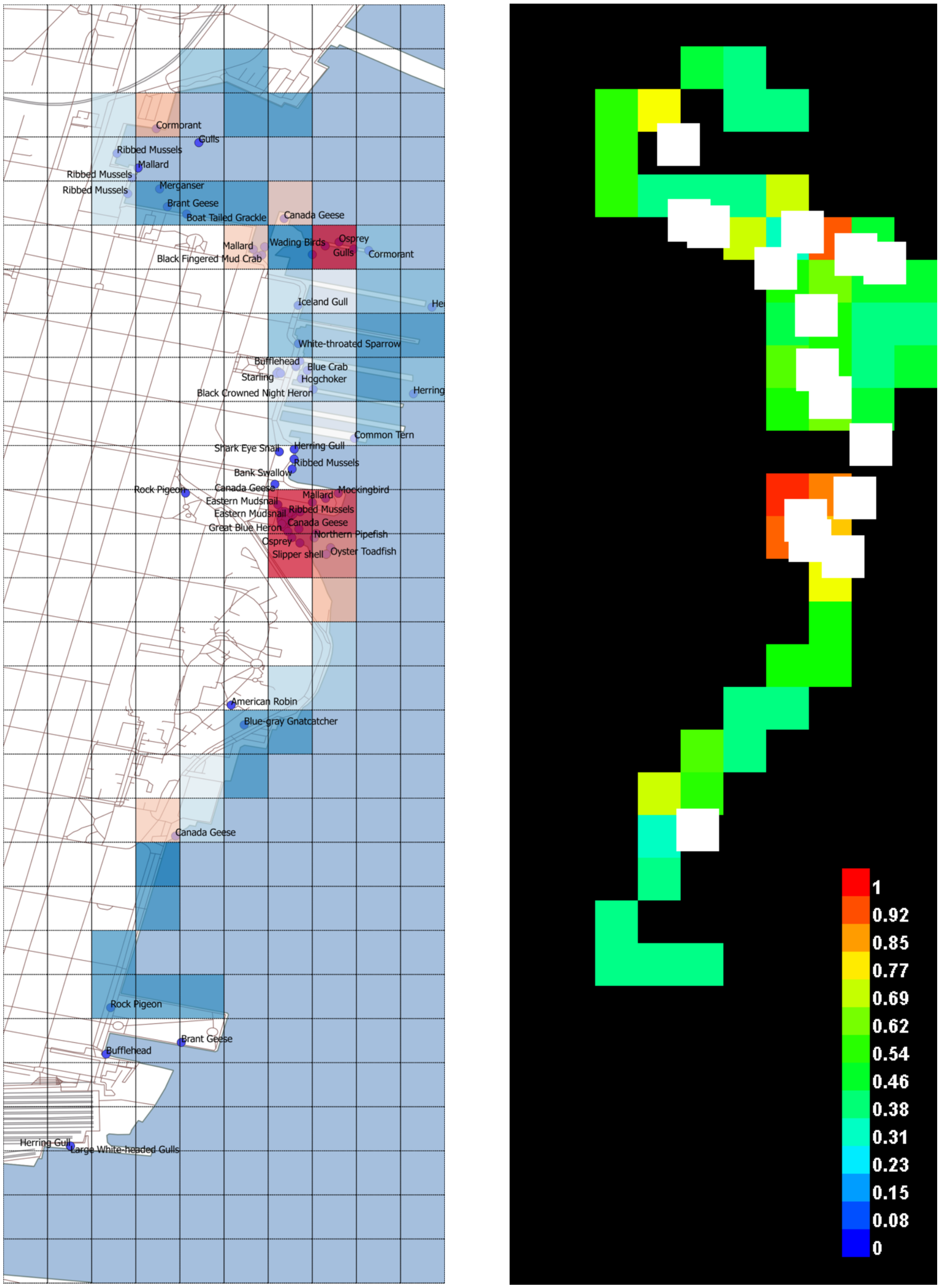

Fig 12 – Shore/water Bird Distribution Model

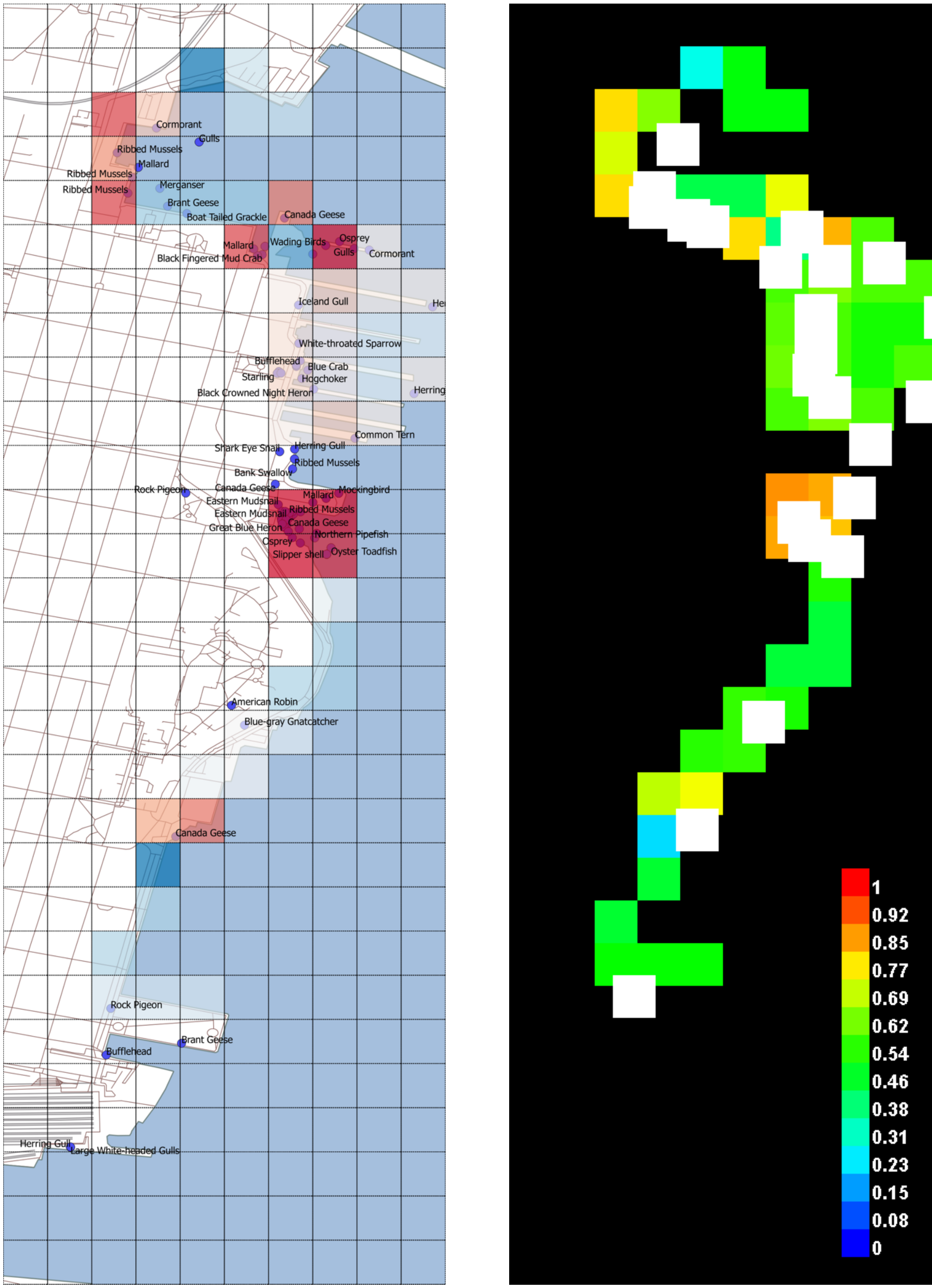

Fig 13 - All Estuary Species Distribution Model

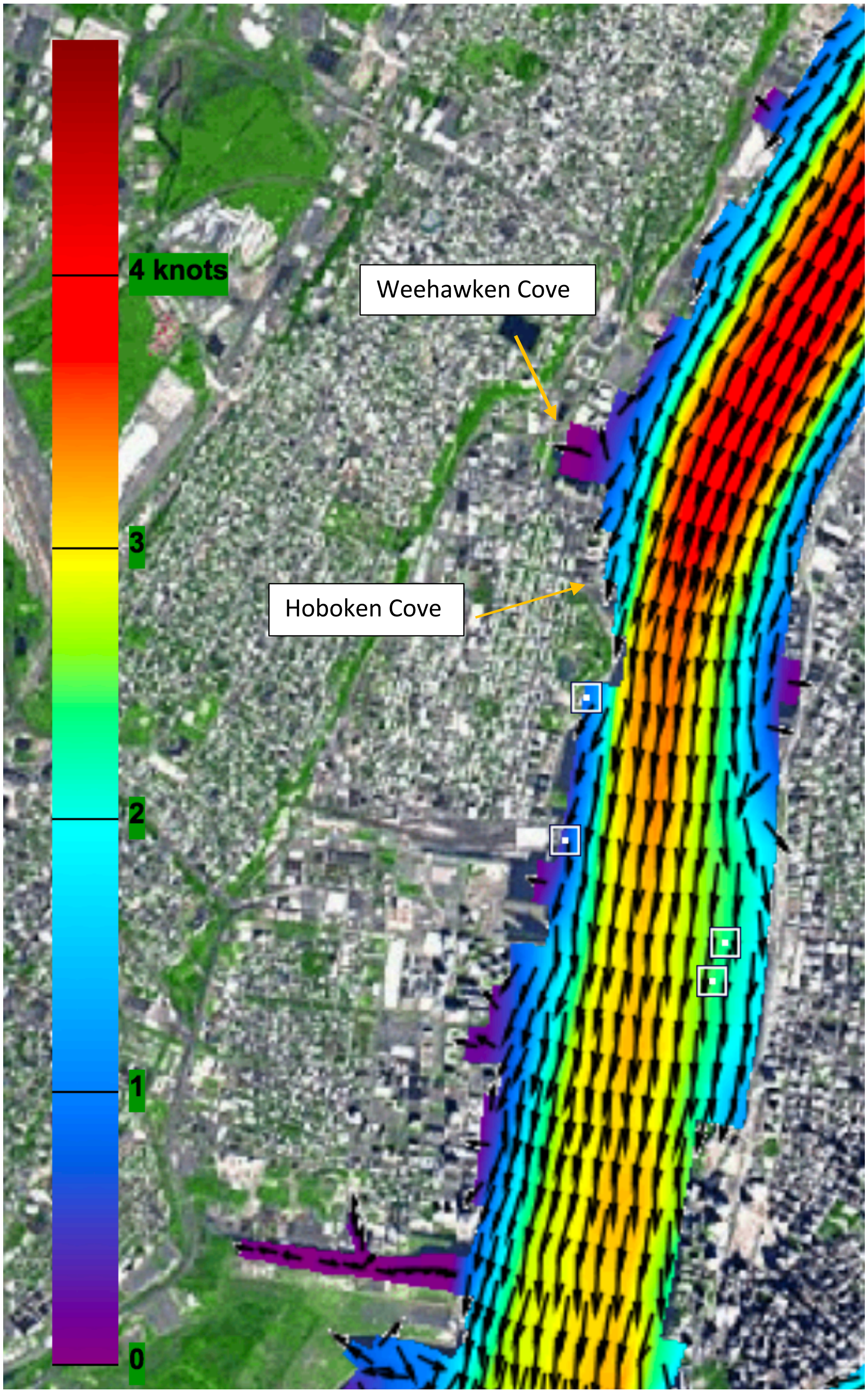

Fig 14 – Hudson River Surface Currents in Knots

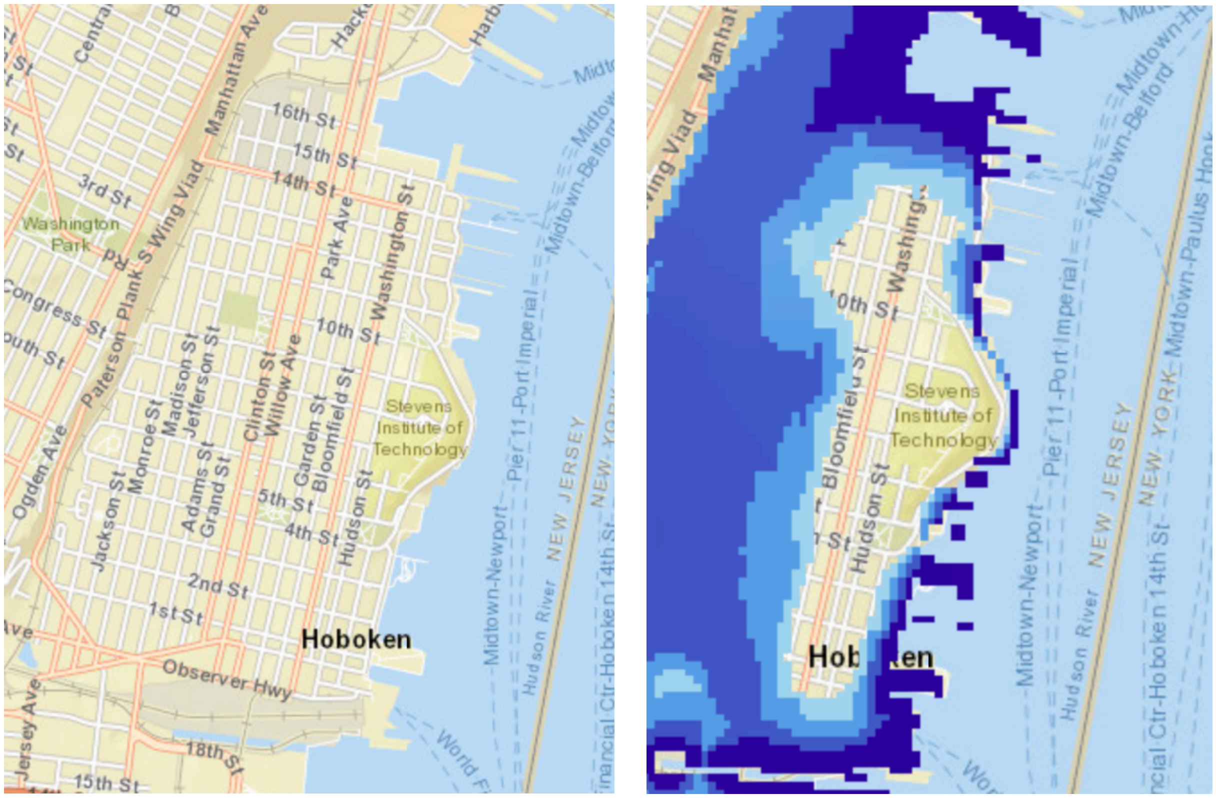

Fig 15 – Category 1 Storm Surge

Appendix A

Accipiters
American eel
American Kestrel
American Robin
Atlantic Mud Crab
Atlantic Silverside
Atlantic Surf Clam
Bank Swallow
Black Backed Gull
Black Crowned Night Heron
Black Fingered Mud Crab
Black-and-white Warbler
Blackfish
Blue Crab
Blue-gray Gnatcatcher
Boat Tailed Grackle
Brant Geese
Brown Bushy Bryozoan
Brown Creeper
Bufflehead
Bunker Fish
Canada Geese
Catbird
Channeled Dog Winkle
Clam worm
Colonial Tunicate
Comb Jelly
Common - Red Eared Slider
Common Tern
Cooper's Hawk
Cormorant
Corophid Amphipod
Diamondback Terrapin
Double-crested Cormorant
Eastern Mudsnail
Eastern Oyster
European Starling
Flicker
Golden-crowned Kinglet
Grass/Shore shrimp
Green Crab
Gulls
Hake
Harbor Seal
Hermit Crab
Herring Gull
Herring/Shad
Hogchoker
Horseshoe Crab
House Finch
Humpback Whale
Iceland Gull
Idotea Isopod
Jonah crab
Large White-headed Gulls
Lionsmane Jelly
Mallard
Merganser
Moon Jelly
Mourning Dove
Mummichog
Northern Cardinal
Northern Mockingbird
Northern Pipefish
Northern Rock Barnacle
Osprey
Oyster Drill
Oyster Toadfish
Perch-like Fishes
Pigeon
Red tailed Hawk
Ribbed Mussels
Rock Pigeon
Rock weed
Scud - Gammarid Amphipod
Sea Grape
Sea Pill Bug
Sea Squirt
Shark Eye Snail
Shortnose Sturgeon
Slipper Shell
Soft-shelled Clam
Solitary Tunicate
Sparrow
Spider Crab
Starling
Striped Bass
Summer Flounder
Wading Birds
White Perch
White-breasted Nuthatch
White-throated Sparrow

Appendix B

Environmental Variables Coding:

Shoreline:	0 = Bulkhead 1 = Shaded Riprap 2 = Riprap 3 = Beach 4 = Piling field 5 = Large Urban Pier
Wave height:	0 = < 1 ft. 1 = 1.1 – 2.0 ft. 2 = 2.1 – 3.0 ft. 3 = > 3 ft.
CSO:	0 = No 1 = Yes
Ferry wake:	0 = No/low wake 1 = Medium wake 2 = High wake
Water quality:	0 = 0 – 25% samples exceed 35 cells/ml 1 = 25 – 50% 2 = 50 – 75% 3 = 75 – 100%
Ferry port:	0 = No 1 = Yes
Shore sunlight:	0 = Shaded 1 = < 2 hours/day 2 = 2 – 10 hours/day 3 = > 10 hours/day