BIODIVERSITY OF THE HOBOKEN WATERFRONT

A survey of species richness, urban impact & sustainability

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Abstract

Biodiversity is essential to human survival, but is in rapid decline largely due to urbanization. To mitigate the decline, cities must become sustainable and biophilic. Biodiversity of the Hudson River Estuary (HRE) is negatively effected by urban syndromes, industrial activities, and limited public education. Resilience Adventures youth programs provide education, build connection to the HRE and encourage interest in STEM. A biodiversity survey of the Hoboken Cove/Union Drydock area was conducted by Resilience students. A total of 72 species were identified, several of which have protected status. Anadromous and juvenile fish were identified suggesting that the Hoboken waterfront is an important habitat for young fish and migrating species. Ribbed mussels, filter-feeders important to estuary health, were also identified suggesting that the study area provides essential habitat for shellfish restoration. The effects of urbanization and potential impact from increased industrial use of the Hoboken Waterfront are considered within the report. Recommendations are provided.

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Background

Humans have profoundly altered biodiversity and ecosystems around the world (Ellis, 2008). In fact, biodiversity and related ecosystem services are declining due to human activity so rapidly that scientists consider the earth to be experiencing the sixth mass extinction (Ceballos, 2015, Dirzo, 2015 & Hanksi, 2011). Pollution, overexploitation and habitat loss, often the result of urbanization, are key threats to biodiversity (Hanksi, 2011). Humans have also impacted the Earth's Systems by increasing greenhouse gasses, particularly CO_2. This has resulted in atmospheric and sea temperature rise which is driving climate change. Climate change effects are currently on track to reduce biodiversity further, threatening human life on earth.

Many people are unaware that human activity is the cause of the decline in biodiversity particularly in urban areas where there is a disconnect with nature (Miller, 2005). The loss of species may seem inconsequential to urban populations that consider themselves to be separate from the natural world (Miller, 2005). Humans depend on biodiversity for economic reasons and ecosystem services including food resources, water, fuel, medicines, soil, air, climate, genetic diversity and truly, everything necessary for life as we know it (Freeman 2012). Biodiversity can represent the web of life on a global scale or it can refer to the species and interactions within a specific ecosystem. Either way, humans are a part of this interconnected web of life and rely on it for survival (Dirzo, 2014). Loss of biodiversity through extinction or reduction in species abundance at the current accelerated rate will further limit ecosystem function and have a profound impact on humans (Dirzo, 2014).

Within the past 50 years urban areas have increased dramatically, growing rapidly in both size and population density (Picket et al., 2011). At present, over 50% of the global population are city residents. According to UN data, by 2030, more people will live in cities than in rural areas, even in developing nations. In fact, over 60% of the human population, approximately five billion people, are expected to live in urban areas by 2030 (Picket et al., 2011). Urbanization has historically contributed to a loss of biodiversity and ecosystem service function (Puth & Burns; Matteson, 2008). As example, dredging, pollution, habitat destruction and over exploitation led to localized extinction of the Eastern oyster, *Crassostreia virginica* in NY Harbor in the early 1900's (Kurlansky, 2007).

Given the pace of urban growth, in combination with declining biodiversity and ecosystem services plus rising CO_2 and increasing climate change effects, it is essential that

urban areas become sustainable (Grimm et al., 2008; Beatly & Newman 2013). In the past 20 years urban ecology has gained momentum as a field of research but much more data is needed (Rebele, 2016, Pickett, 2011). Now, it is not only apparent, but urgent, that more attention be paid to the study of urban ecosystems, which include human society, to fully understand key ecological concepts and develop strategies for sustainability (Rebele, 2016; Sanderson, 2011). Research indicates that cities can be intentionally managed to be more biophilic, meaning they provide easily accessible natural areas which sustain higher levels of biodiversity, increase ecosystem services and by design, reconnect people to nature (Beatley & Newman, 2013; Gomez-Baggethun & Barton, 2012; Matteson, 2008).

Introduction

The Hudson River Estuary (HRE) is a place of great beauty which has long supported many species of plants and animals as well as people. As such, The Hudson River Estuary, even within it's highly urbanized surroundings is designated as an estuary of national importance by the United States Environmental Protection Agency (Baron, 2016). Despite anthropogenic influence it is one of the most productive ecosystems on earth and is an essential resource for human populations (Baron, 2016; What is an estuary, n.d.).

Urban ecosystems, like the HRE, continue to be challenged by the negative effects of urbanization. According to Pickett (2011), cities both create and are negatively impacted by a variety of urban syndromes affecting soil, water, hydrology and climate. One of these syndromes, Urban Hydrology (UH), is essentially a magnification of storm water runoff due to the prevalence of impervious surfaces found in many existing cities (Picket et al., 2011) According to Picket et al., (2011) runoff increases in urban areas from 10% to 30% while groundwater decreases from 50% to 32%. This leads to almost half of precipitation travelling into waterways carrying contaminants with it (Picket et al., 2011). Urban Stream Syndrome (USS) develops from this problem, degrading streams and small waterways, and ultimately, ponds, lakes, bays and estuaries, with excess nutrients and pollutants (Picket et al., 2011). As a result of UH and USS, petroleum products including oil, grease and hydrocarbons enter waterways via runoff from parking lots, vehicle and boat maintenance areas and refueling stations (Strassler, 1999). Petroleum hydrocarbons are toxic even at low levels, resulting in

degraded water quality and declines in fish species and population abundance (Strassler, 1999). Metals also find their way to the waterways via urban runoff with industry and automobiles as the primary source (Strassler, 1999). Fish growth and survival rates can be reduced by an excess of metals. Metals can accumulate in fish tissues and biomagnify in food chains resulting in public health risks (Strassler, 1999). Estuary reptiles, such as the Diamondback terrapin, *Malaclemys terrapin* and birds of prey, such as the Osprey, *Pandion haliaetus* are also negatively impacted by the biomagnification of metals and persistent organic pollutants (NJ Endangered & Threatened Species, 2018).

Turbidity refers to suspended particles in water (Fondriest, 2016). Increased runoff combined with excess nutrients from urbanization can result in increased levels of turbidity which then affects dissolved oxygen levels. (Fondriest, 2016; Sanderson, 2016). Dissolved oxygen (DO) is essential for marine organisms and many species are adversely affected when levels drop below 5ppm (Fondriest, 2016). Hypoxic, or low DO conditions, can occur in areas of the HRE as a result of nutrient overload, high temps and pollutants from increased runoff in the urban environment (Sanderson, 2016; Significant Habitats, n.d.).

Wake from commercial vessels or motorized recreational boats in shallow waters has also been shown to increase turbidity (Bilkovic, 2017; Asplund, 2000). This increase in turbidity leads to a decrease is dissolved oxygen and a reduction in light, which has been shown to negatively impact marine organisms and sea grasses as well as cause erosion (Bilkovic, 2017; Asplund, 2000). Studies show that shellfish beds are negatively impacted by waves generated from boat wake (Bilkovic, 2017; Asplund, 2000). Oyster spat survival is reduced and adult shellfish can be dislodged by boat wake (Bilkovic, 2017; Asplund, 2000). Campbell (2015) found that waves as small as 2cm can disrupt both individual and clumps of oysters (Bilkovic, 2017; Asplund, 2000).

Additionally, in the Hudson River Estuary, certain types of waterfront construction have been showed to negatively impact biodiversity (Able & Duffy-Anderson, 2006; Able, 2013). Large urban piers block light to the waters underneath, limiting the habitat and reducing biodiversity of benthic and pelagic species (Able & Duffy-Anderson, 2006; Able 2013). Permanent or long term vessel mooring can cause the same negative impacts on biodiversity (Able & Duffy-Anderson, 2006).

Threats to biodiversity also include a lack of public education (Beatley & Newman, 2013;

Dunn, 2007; Miller, 2005; Kollmuss & Argyman). A significant part of the problem is that urban populations are increasingly disconnected from nature (Miller, 2005). In the NY/NJ region, historic Native American cultures understood humans to be part of nature and indigenous teachings guided people to live in reciprocity with the earth (Kimmerer, 2013). Native American people who lived along the banks of the Hudson River Estuary and throughout the northeast, saw themselves as caretakers of the earth (Kimmerer, 2013). Modern people, living in the same location, do not tend to embrace this responsibility (Kimmerer, 2013). Today, urban dwellers typically see themselves and their city surroundings as separate from "nature". (Kimmerer, 2013, Miller, 2005). The natural world is often viewed as a far away place that takes care of itself (Kimmerer, 2013).

As for urban youth, recent research revealed that many young people are both unfamiliar with common local species and are unaware of the ways in which human activity is causing species decline (Miller, 2005). Other studies indicate that urban children have limited opportunities to experience nature and have become disconnected as a result (Louv, 2011). Research indicates that connectedness is a determinate of pro-environmental behavior (Chawla, & Derr, 2012; Tam, Lee & Chau, 2013). Lack of experience and connection with the natural world may lead to a lack of engagement in conservation (Miller, 2005).

Kudryastev (2012) notes that place-based attachment and place meaning can foster pro-environmental behavior. Combining experiential outdoor learning in a local environment with instructional guidance may be an effective tool for promoting conservation (Kudrystev, 2012). In addition, research by Larson, Whiting and Green (2011) showed that participation in outdoor recreation can influence propensity to engage in pro-environmental behaviors. Bringing students out of the classroom into a field based experience for recreation and the study of local species or ecosystems may enhance learning and bridge the disconnect noted among urban populations. According to Barnett (2011) and Hiller & Kitsanas (2014), engaging students in data collection and citizen science projects may foster a stronger commitment to stewardship and improve affinity for science.

With these issues in mind, Resilience Adventures was developed as a resource to connect urban populations to the Hudson River, encourage a healthy, active outdoor lifestyle and promote interest in STEM. The summer youth programs make use of the Hoboken cove park to provide the opportunity for children to learn kayak and paddleboard skills while discovering the

estuary through hands-on activities. (Fig 3) Research indicates that place-based environmental education programs can help urban youth build a connection to nature and foster pro-environmental behavior (Beery & Wolf-Waltz, 2014; Chawla & Derr 2012; Tam, Lee & Chau 2013; Kudryastev, 2012). Engaging students in out of school time science programs and citizen's science projects can help spark an interest in further STEM study and STEM careers (Dorsen, 2006; Dabney, 2012, Hiller & Kitsantas, 2014). As part of the Resilience summer programs young people participate in established citizen science projects including water quality monitoring along the Hoboken waterfront in conjunction with the River Project (https://www.riverprojectnyc.org/) and the New York City Water Trail Association (http://www.nycwatertrail.org/), plus oyster plot management at Pier 40 NYC in conjunction with the Billion Oyster Project (https://billionoysterproject.org/). Students also generate and participate in inquiry-based investigations of the HRE (Fig 3).

This research project focuses on urban ecology and addresses a question posed frequently by Resilience students, "Does anything live in the Hudson River?" Through field survey and literature review, this study investigates the biodiversity of the Hudson River Estuary (HRE), at specific points along the Hoboken waterfront. Maintaining biodiversity, preserving critical habitat and protecting threatened species of the HRE is a priority for many agencies including the US Army Corps of Engineers, the Port Authority of NY & NJ plus the NY/NJ Harbor Estuary Program (Baron, 2016). With this in mind, this report discusses known effects of urbanization on the ecosystem and considers the potential impact of increased industrial use within the study area.

For many NY/NJ urban residents, the Hudson River exists in very close proximity. Yet, most people cross over it, drive around it, walk along it and live adjacent to it often without even considering its importance. It is not surprising then that Resilience students had many questions about this urban ecosystem. Many people do not realize that the southern portion of the Hudson River is an estuary where salt and fresh water blend to form a brackish habitat (What is an estuary, n.d.). Estuaries combine high nutrient content from the sea and surrounding watershed They also provide protection from strong ocean waves (What is an estuary, n.d.). These features allow estuaries to serve as nurseries for fish and other aquatic organisms as well as a home-base and migratory stopover point for a diverse array of aquatic and avian species (What is an estuary, n.d.). Estuary species are uniquely adapted to the brackish habitat, allowing them to survive and

simultaneously support the ecosystem by providing essential services (What is an estuary, n.d.). As example, estuary species like oysters and mussels clean water through filtration (What is an estuary, n.d.). As filter feeders they take in what they need from the nutrient rich waters, at the same time removing or containing dirt, silt, algae and other impurities (What is an estuary, n.d.).

Hoboken is a waterfront city located on the banks of the HRE, directly across from mid-town Manhattan. It is nicknamed "the mile square city" because of its land size. Technically it is two square miles when counting underwater areas (United States Census). In 1609, when Henry Hudson first explored the area, Hoboken was an island where the Lenni Lenape people lived in seasonal encampments, harvesting fish and oysters from the estuary and farming along the banks, living in balance with the natural ecosystem of the time ("The Hudson River Estuary," n.d.).

After Henry Hudson's famous exploratory visit, the area was settled by the Dutch ("The Hudson River Estuary," n.d.). Over time, the Lenni Lenape were displaced and the area became populated by Europeans ("The Hudson River Estuary," n.d.). Small scale farming continued but the land became "owned" by Europeans as opposed to "shared" as was the Lenni Lenape practice (A Walk Through Hoboken, 2013). Following European settlement, significant anthropogenic alteration has occurred in the HRE and Hoboken waterfront and wetlands, including dredging, filling and development (Significant Habitats, n.d.).

In the late 1700's, Hoboken was a rural retreat for New Yorkers who wished to get away from the city (A Walk Through Hoboken, 2013). New Yorkers enjoyed the Hoboken waterfront, visiting a local natural spring for its healing waters and spending leisure time (A Walk Through Hoboken, 2013).

A hundred years later the recreational value of Hoboken shifted and by the early 1900's Hoboken had become an industrial capital. Manufacturing plants dominated the landscape with ship building yards occupying the entire waterfront. (A Walk Through Hoboken, 2013).

By the 1950's, the shipbuilding industry began to suffer under a wartime freeze. The Hoboken shipyards fell into disrepair and corruption (A Walk Through Hoboken, 2013). Some refer to the Hoboken waterfront as a "Post Industrial Wasteland" during this era (A Walk Through Hoboken, 2013).

At this same time in the 1950's, the HRE had become extremely polluted with heavy metals, solvents, polychlorinated biphenyls (PCBs), asbestos and sewage as there were no

regulations regarding use of the water. The HRE was condemned as an open sewer (Cronin & Kennedy, 1997, pp. 18-19). Keystone species that shape and balance natural estuary ecosystems, like the Eastern Oyster, were overexploited and had largely disappeared (Kurlansky, 2012).

In 1966, fisherman activists organized to protest the dumping of chemicals in the river and block the creation of a hydro electric plant which threatened fish (Cronin & Kennedy, 1997). With legal help, the group made use of a long standing law that the river belongs to all people (Cronin & Kennedy, 1997). The group formed the Riverkeeper organization and eventually by 1972, the Clean Water Act was put into law and dumping pollutants into the river became illegal (Cronin & Kennedy, 1997).

Twenty years later, in the early 90's, citizen activists in Hoboken made use of this same premise, that both the river and riverfront belong to all people. The Fund for a Better Waterfront (FBW) formed a vision of the entire Hoboken waterfront as a public park (Plan for the Hoboken Waterfront, n.d.).

Since the early 90's, development companies created sought-after high rise apartments with luxury waterfront residences, increasing the human population in Hoboken over 30% ("Hoboken Demographic", n.d.). It is now the fourth most densely populated place in the United States with over 53,000 residents. ("Hoboken, New Jersey Demographics" 2016). Through the work of the FBW, the City of Hoboken and citizens' advocacy, publically accessible waterfront parks were created in conjunction with this residential development.

Today, the FBW vision has largely been realized. Most of the Hoboken waterfront is a public park with a continuous waterfront walkway. In addition, the Hudson River ecosystem is much healthier and more robust (The Hudson River Estuary, n.d.). The estuary is once again a source of inspiration and outdoor recreation for many people. In 2009, more than 40,000 people paddled or rowed in NY harbor (Citizens Water Quality Testing, 2011). In 2014 there were 6,500 people participating in public swimming events in the river and harbor plus thousands more at beaches (Riverkeeper, 2015). Hoboken waterfront parks support these activities by creating access to the water, hosting fishing piers, picnic areas and human powered boating sites. Residents and guests value these waterfront parks, visiting by the thousands to enjoy food trucks, stunning views and opportunities for outdoor activities in a more natural setting. The Hoboken waterfront is once again a recreational retreat.

Clearly, the Hoboken Waterfront and the HRE have gone through many changes over the

past 200 years. Research indicates that despite the negative effects of urban syndromes, the Hudson River Estuary continues to support a variety of species. However, a literature review revealed no documentation of species occurring in the waters surrounding Hoboken. In order to gain an understanding of the species richness of the Hoboken waterfront, a simple biodiversity survey was conducted through observation and live collection within the area spanning from Pier 13 south to the Union Drydock (Fig 1).

While observations were conducted throughout the entire area, species collection occurred only in specific locations (Fig 1). The species collection sites include a 60 ft (approx.) industrial use wooden pier known as the Union Drydock and the adjacent cove known as the Hoboken Cove. The shoreline of the Union Drydock includes sloping rip rap and some vertical hard edge layered with wooden beams and rip rap. The shoreline of the cove includes a sloping sandy beach as well as rip rap adjacent to a paved jogging/biking trail within a grassy park. Planted shrubs and trees are present in this park. Wild-growing vegetation exists in disturbed edges of the shoreline. Only one tree is actually next to the water. The area surrounding the park is highly urbanized with approximately 90% impermeable pavement & roadway plus the Union Drydock parking lot and residential apartment buildings. The water depth within the cove and under the Union Drydock Pier ranges from 2 feet to 15 feet. Seaweeds and algae are visible on the rip rap, pilings, pier edges and floating in the water. No other aquatic vegetation is visible.

METHODS

Estuary species occurring adjacent to or under specific piers and along the shoreline were collected an average of three days per week on a weekly basis, for six weeks, during July and August from 2014 - 2017. The collection and identification was completed by Resilience Adventures staff assisted by local college and high school students, adult volunteers and local children ages 2 through age 14 as part of a summer camp program. Crab traps, fish traps, hand nets and seine nets were used as the primary collection tools.

One crab trap and one fish trap were placed at various points along the north side of the Union Drydock on each day of collection in order to access different water depths. Water depth ranged from 2-15 feet. The seine net was used at depths of 1–3 feet. Collectors walked with the net, sweeping transects parallel to shore along the Hoboken Cove waterfront. All organisms collected were carefully released shortly after observation. Avian species and terrestrial plant

identification occurred opportunistically during kayak and paddleboard trips. Identification books, species guides and websites were used to identify and name organisms. Local fisherman supplied additional information.

RESULTS/DISCUSSION

A total of seventy-two (72) species were identified within this biodiversity study as occurring in Hoboken waters and along the waterfront, including forty-nine (49) aquatic organisms, twenty-two (22) avians and two (2) terrestrial plants (Fig 2). There were many species of terrestrial plants visible along the waters edge and growing on the Union Drydock pier that were not counted in this survey. In addition, a variety of spiders and insects, including pollinators were visible on the Union Drydock pier, Pier 13, Hoboken Cove beach and along the waterfront rip rap. These species were neither identified nor counted in this assessment, however it is important to note that they exist as their appearance suggests that there are many more species present in theses locations.

Among the species identified in this survey, eight are classified as either species of special concern, threatened or endangered by federal and/or state regulations (Fig 2). These organisms include one mammal (**Humpback whale**, *Megaptera novaeangliae*), one reptile (**Diamondback terrapin**, *Malaclemys terrapin*), two fin fish (**American Eel**, *Anguilla rostrata* & **Shortnose sturgeon**, *Acipenser brevirostrum*) and four avian species (**Osprey**, *Pandion haleatus*, **American kestrel**, *Falco sparverius*, **Common tern**, *Sterna hirunda* and **Black-crowned Night-heron** *Nycticorax, nycticorax*). Additionally, certain species identified in this survey, such as the **Eastern oyster** (*Crassostreia virginica*), **River herring/Shad** (*Clupeidae*) and **Striped bass** (*Morone saxitilis*) are under careful watch to preserve sustainability as their populations were previously decimated and have only recently made a comeback (Billion Oyster Project, n.d.; Shad, 2018; Bass Fishing, n.d.).

Estuaries serve as nurseries, protecting the young of many species from rougher ocean conditions (What is an estuary, n.d.). The fin fish collected in this study were smaller than the expected full adult size for the species. Exact age of each species was not determined as part of this study, however, several of the smaller fish were identified as juveniles according to species guide books. Estuaries are also known to provide essential feeding grounds and growing areas for diadromous fish. Several fin fish identified in this study are migrating species. the American

Eel is considered catadramous, making its way from fresh water to the ocean to spawn. Striped Bass, Shortnose Sturgeon and herring are anadromous, spending time in the estuary before returning to fresh water to lay eggs or in some cases spawning in brackish estuary waters (Hudson Marine Fishes, n.d.). Diamondback terrapins, a species of special concern in NJ were also observed several times per year, swimming within the waters of Hoboken Cove and under the Union Drydock. The presence of juvenile and diadromous fish species plus Diamondback terrapins suggest that the Hoboken Cove/Union Drydock area may be critical habitat for both young fish and migrating species of fish and reptiles.

Other aquatic organisms identified may not have protected status, however they provide essential ecosystem services. As example, Mud snails, Grass shrimp, a variety of crabs and other **crustaceans** plus **benthic invertebrates** such as amphipods recycle detritus from the river bed (Levinton, 2006). They also serve as food for higher level consumers such as Sturgeons, American eels, Diamondback terrapins and Striped bass as well as other fish and birds. In this survey, these invertebrates were the species found most frequently under and along the edge of the Union Drydock, suggesting that the pier provides favorable habitat for detritus feeders.

Benthic fish species such as the **Oyster toadfish** *Opsanus tau* were also collected on more than one occasion from areas along the edge and under the Union Drydock pier. These fish live on the estuary floor, camouflaging themselves from predation in protected, shady areas and darting out to catch small fish or mollusks. Although these species are not currently listed as endangered, they are considered important for marine research as they are able to withstand pollution and remain out of water for extended periods. They have a unique vocalization technique, a vestibular system similar to humans and extremely fast twitching muscles, the quickest of all fish species (Oyster toadfish, 2018). As such, the species is also seen as essential for medical research (Oyster toadfish, 2018). Toadfish have been studied to find solutions for human cardiac issues, balance disorders and hearing impairments. They've been sent into space to help scientists better understand the way balance is affected by changes in gravity. The presence of Oyster toadfish suggests that Hoboken Cove and the Union Drydock also provides a suitable habitat for scientifically important benthic species.

Further, **Ribbed mussels** *Geukensia demissa* were found living in the rip rap along the shoreline and in holes in the wooden pilings of the Union Drydock (fig 4). These mussels are filter feeders and like oysters, can remove nitrogen and other excess nutrients plus other

impurities, improving the water quality (Galimany, 2013 & 2017; Hudson, 2016). Oysters are considered essential to estuary restoration efforts, however they cannot legally be cultivated in NJ due to concerns over human consumption (Galimany, 2013 & 2017; Hudson, 2016). Ribbed mussels are not eaten or sold commercially and they can filter nearly as much as oysters (Galimany, 2013; Hudson, 2016). Ribbed mussels typically grow in intertidal zones and support the growth of Spartina cord-grass thus they can be used to help prevent erosion and restore a living shoreline (Galimany, 2013; Hudson, 2016). Recent studies also show that these versatile mussels can also flourish completely submerged, thus they can be grown from hanging plots in hard edge, bulkhead situations (Galimany, 2013; Hudson, 2016). Successful restoration of filter feeders is crucial to ongoing clean-up efforts and improving the health of the estuary (Hudson Raritan Restoration Plan, 2016, Billion Oyster Project, n.d.). According to the Hudson, Raritan Comprehensive Restoration plan (2016), the Hoboken waterfront has been identified as habitat suitable for restoration shellfish beds.

This survey does not represent a comprehensive listing of species, nor does it indicate full species richness or abundance, however it does reveal that there is a diversity of life in the waters surrounding Hoboken. All of the species identified are essential to estuary food webs and the health of the estuary ecosystem. Some of the species identified have protected status and still others are critically important for restoration efforts. Thus, a full natural resources assessment of the study area is warranted.

While the organisms identified in this study currently exist within a degraded, urbanized estuary, certain changes in use of the Union Drydock and other waterfront areas would likely damage these populations. As example, dredging is known to destroy habitat, increase turbidity and reduce biodiversity (Kurlansky, 2007). Motorized vessel wake in shallow waters has been found to disrupt shellfish beds through forceful wave action (Bilkovic, 2017; Asplund, 2000). Boat wake has also been shown to increase turbidity, cause hypoxic conditions and kill fin fish, shellfish and plants (Bilkovic, 2017; Asplund, 2000). Excess shade from large docked vessels and larger piers has been shown to reduce light for plant growth and decrease biodiversity (Able & Duffy-Anderson, 2006; Able, 2013). Urban runoff via impermeable pavers in vehicle/boat maintenance areas has been shown to degrade water quality (Sanderson, 2016; Fondriest, 2016; Significant Habitats, n.d.). Even small petroleum spills during boat re-fueling can have a big impact on waterways (NY Sea Grant, n.d.). Hydrocarbons disrupt fish reproduction and reduce

both growth and reproduction of other benthic species (NY Sea Grant, n.d. & Strassler, 1999). This points again to the need for a professional biodiversity assessment and detailed pollution prevention plan before any new waterfront construction or increased industrial use of the study area is considered.

CONCLUSION

To mitigate biodiversity loss and be resilient in the face of climate change, cities must become more sustainable (Beatley & Newman, 2013; Gomez-Baggethun & Barton, 2012; Matteson, 2008). There is clearly a robust ecosystem existing in the waters surrounding Hoboken. This study indicates that organisms designated by state and federal law as threatened and endangered as well as species of special concern do occur in the Hoboken Cove/Union Drydock location. This survey identifies species which provide important ecosystem services and are essential to the Hudson Raritan Comprehensive Restoration plan, particularly the ribbed mussel. Anadromous fish are also identified in this study suggesting that the Hoboken Cove/Union Drydock area provides critical habitat for both migrating species and shellfish. Augmenting industrial use within the study area without regard to biodiversity, including increases in boat traffic, wake, shade, dredging and petroleum discharge would cause a reduction in water quality, negatively impact many of the species present and limit restoration efforts. The US Army Corps of Engineers, the Port Authority of NY & NJ plus the NY/NJ Harbor Estuary Program have prioritized the maintenance of biodiversity, preservation of critical habitat and protection of threatened species within the HRE (Baron, 2016). Thus, a professional biodiversity assessment is recommended for the Union Drydock and Hoboken Cove region. This would allow experts to develop a plan for enhancing biodiversity and creating a more sustainable, resilient Hoboken waterfront.

To develop eco-conscious, resilient citizens, cities must become more biophilic. Urbanization is increasing (Beatley & Newman, 2013; Gomez-Baggethun & Barton, 2012; Matteson, 2008). As time goes on, many people will only experience nature in urban settings (Miller & Hobbs, 2002; Dunn, 2006). This makes a strong case for creating access to nature. Outdoor recreation and place-based environmental education in urban areas can increase human connection to nature and the potential for pro-environmental behavior. (Chawla & Derr, 2012; Miller & Hobbs; 2002, Miller, 2005; Dunn, 2006 and Beatley, 2013). The Hudson river

represents a healthy natural escape for city dwellers, the last wilderness in an extremely urban landscape. The EPA notes that "people have a strong emotional attachment to water, arising from its aesthetic qualities--tranquility, coolness, and beauty" (Muthukrishnan, 2004). According to the World Health Organization, water-based recreational activities have a positive influence on health and well-being (Healthy Recreational Waters, 2003). The adult and youth paddling programs which occur in Hoboken Cove are important components of a healthy lifestyle and precursors to pro-environmental behavior. Outdoor recreation on the river coupled with citizen science and inquiry-based projects can also promote an interest in STEM for urban youth.

Additional industrial activity, particularly motorized vessel use, in the Union Drydock/Hoboken Cove area would elevate the risk for paddling and environmental programs along the Hoboken waterfront. A significant increase in motorized vessel traffic in the Hoboken Cove area could prevent human powered boating along the Hoboken Waterfront altogether, limit opportunity for urban youth and essentially take river access away from the people. This study suggests that the Hoboken waterfront is an important biophilic resource for urban residents. With this perspective, the waterfront could be restored as a living shoreline, enhanced to support greater biodiversity and designated for increased recreation and educational programming.

The HRE belongs to all people and all organisms that call it home. It is an essential resource and important for industry as well. It should be shared for the benefit of all but the ecosystem must be maintained. Industrial use of the waterfront is not necessarily counter to urban sustainability. Industries like commuter ferries which reduce personal automobile use and thus CO_2 emissions could be environmentally beneficial if located carefully and managed intentionally. Increased industrial use of the Hoboken waterfront without careful consideration for biodiversity and human recreational use, however will exacerbate environmental degradation of the HRE, limit biophilic resources and ultimately reduce sustainability. In the words of Grimm (2008), "Cities…represent both the problems and solutions to sustainability challenges of an increasingly urbanized world". This view offers two opposing sides of a coin, but regardless whether heads or tails wins the toss, humans will only win in the long run with sustainable, biophilic cities and eco-conscious citizens.

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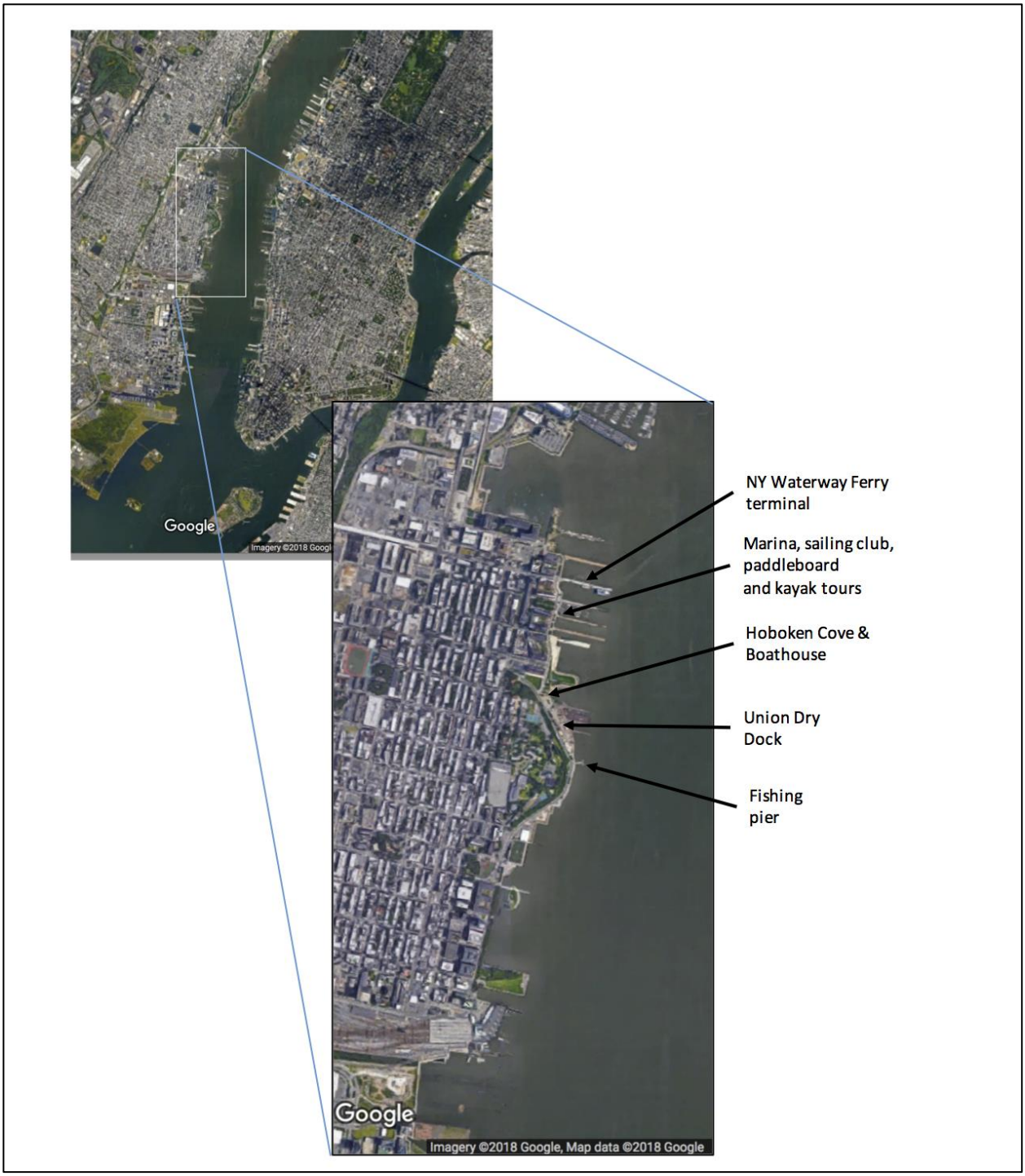

Fig 1 – Map of study biodiversity survey area

Resilience Adventures Hoboken Waterfront Biodiversity Survey 2014 - 2017					
Location *	**Species ****	**Survey Type**	**Evidence Type *****	**Notes**	
Union Drydock	Rock weed (Fucus vesiculosus)	Personal Observation	Live Sighting	First Hand Account	Sea weed
Union Drydock	Sea lettuce (Ulva lactuca)	Personal Observation	Live Sighting	First Hand Account	Algae
Union Drydock	Sour Weeds (Desmarestia Spp)	Personal Observation	Live Sighting	First Hand Account	?
Channel - Union Drydock	Humbpack Whale (Megaptera novaeangliae)	Personal Observation	Live Sighting	First Hand Account	Mammal
Pier 13 - Union Drydock	Harbor Seal (Phoca vitulina)	Personal Observation	Live Sighting	First Hand Account	Mammal
Union Drydock	Hermit Crab (Pagurus)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Blue crab (Callinectes sapidus)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	green crab (Carcinus maenas)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Jonah crab (Cancer borealis)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	spider crab (Libinia emarginata)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Atlantic mud crab (Panopeus herbstii)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Horseshoe Crab (Limulus polyphemus)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Idotea Isopod (Idotea Spp)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Corophid amphipod (Corophiidae)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Scud - Gammarid Amphipod	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Grass/Shore shrimp (Palaemonetes spp.)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Sea Pill Bug (Sphaeromatidae)	Personal Observation	Live Sighting	First Hand Account	Crustacean
Union Drydock	Slipper shell (Crepidula fornicata)	Personal Observation	shells only	First Hand Account	Mollusk
Union Drydock	Ribbed Mussel (Geukensia Demissa)	Personal Observation	Live Sighting	First Hand Account	Mollusk
Union Drydock	Blue Mussel (Mytilus edulis)	Personal Observation	Live Sighting	First Hand Account	Mollusk
Union Drydock	Oyster Drill (Urosalpinx Cinerea)	Personal Observation	Live Sighting	First Hand Account	Mollusk
Union Drydock	Eastern Oyster (Crassostrea virginica)	Personal Observation	shells only	First Hand Account	Mollusk
Union Drydock	Northern Rock Barnacle (Semibalanus Balanoides)	Personal Observation	Live Sighting	First Hand Account	Maxillopoda
Union Drydock	Eastern mud snail (Ilyanassa Obsoleta)	Personal Observation	Live Sighting	First Hand Account	Gastropod
Union Drydock & Hoboken Cove	Diamondback terrapin (Malaclemys terrapin)	Personal Observation	Live Sighting	First Hand Account	Reptile
Union Drydock	Oyster Toadfish (Opsanus Tau)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	American eel (Anguilla rostrata)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Bunker Fish (Brevoortia tyrannus)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Atlantic Silverside (Menidia menidia)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Mummichog (Fundulus Heteroclitus)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Northern Pipefish (Syngnathus Fuscus)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Blackfish (juvenile) (Tautoga onitis)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Summer Flounder (Paralichthys dentatus)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Pier 13 - Union Drydock	Herring/Shad (juvenile, unknown species)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Hake (juvenile)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Union Drydock	Striped Bass (juvenile) (Morone saxatilis)	Personal Observation	Live Sighting	First Hand Account	Fin fish
Hoboken Cove	Shortnose Sturgeon (Acipenser brevirostrum)	Personal Observation	Deceased (found on beach)	First Hand Account	Fin fish
Union Drydock	Comb Jelly (Ctenophora)	Personal Observation	Live Sighting	First Hand Account	Ctenophore
Union Drydock	Moon Jelly (Aurelia aurita)	Personal Observation	Live Sighting	First Hand Account	Scyphozoa
Union Drydock	Brown Bushy Bryozoan (Bugula Neritina)	Personal Observation	Live Sighting	First Hand Account	Bryozoa
Union Drydock	Lionsmane Jelly (Cyanea capillata)	Personal Observation	Live Sighting	First Hand Account	Cnidaria
Union Drydock	Clam worm (Nereis Spp)	Personal Observation	Live Sighting	First Hand Account	Annelida
Union Drydock	Sea Grape (Molgula manhattensis)	Personal Observation	Live Sighting	First Hand Account	Tunicate
Union Drydock	Sea Squirt (Ascidiella Aspersa)	Personal Observation	Live Sighting	First Hand Account	Tunicate
Union Drydock	Solitary Tunicate (unknown species)	Personal Observation	Live Sighting	First Hand Account	Tunicate
Union Drydock	ColonialTunicate (unknown species)	Personal Observation	Live Sighting	First Hand Account	Tunicate
Union Drydock	Colonial Tunicate (unknown species)	Personal Observation	Live Sighting	First Hand Account	Tunicate
Union Drydock	Pigeon (Columba livia)	Personal Observation	Live Sighting	First Hand Account	Avian
Union Drydock	black back gull (Larus marinus)	Personal Observation	Live Sighting	First Hand Account	Avian
Union Drydock	Canada Geese (Branta canadensis)	Personal Observation	Live Sighting	First Hand Account	Avian
Maxwell Place	Brant Geese (Branta bernicla)	Personal Observation	Live Sighting	First Hand Account	Avian
Weehawken - Hoboken Cove	Osprey (Pandion haliaetus)	Personal Observation	Live Sighting	First Hand Account	Avian
Hoboken Cove	Red tailed Hawk (Buteo jamaicensis)	Personal Observation	Live Sighting	First Hand Account	Avian
Hoboken Cove	Cormorant (Phalacrocoracidae)	Personal Observation	Live Sighting	First Hand Account	Avian
Shipyard Waterfront	American Kestral (Falco sparverius)	Personal Observation	Live Sighting	First Hand Account	Avian
Pier 12 & Union Drydock	Common Tern (Sterna hirundo)	Personal Observation	Live Sighting	First Hand Account	Avian
Pier 13 - Hoboken Cove	Black Crowned Night Herron (Nycticorax nycticorax)	Personal Observation	Live Sighting	First Hand Account	Avian
Shipyard Park - Maxwell Place	Herring Gull (Larus argentatus)	Personal Observation	Live Sighting	First Hand Account	Avian
Hoboken Cove	Mallard (Anas platyrhynchos)	Personal Observation	Live Sighting	First Hand Account	Avian
Weehawken - Hoboken Cove	Merganser (Mergus merganser)	Personal Observation	Live Sighting	First Hand Account	Avian
Shipyard Waterfront	House Finch (Haemorhous mexicanus)	Personal Observation	Live Sighting	First Hand Account	Avian
Shipyard Waterfront	White throated sparrow (Zonotrichia albicollis)	Personal Observation	Live Sighting	First Hand Account	Avian
Maxwell Waterfront	Bank Swallow (Riparia riparia)	Personal Observation	Live Sighting	First Hand Account	Avian
Shipyard Park - Maxwell Place	Starling (Sturnus vulgaris)	Personal Observation	Live Sighting	First Hand Account	Avian
Maxwell Waterfront	Catbird (Dumetella carolinensis)	Personal Observation	Live Sighting	First Hand Account	Avian
Maxwell Waterfront	Mockingbird (Mimus polyglottos)	Personal Observation	Live Sighting	First Hand Account	Avian
Shipyard Park - Maxwell Place	Sparrow (Passer domesticus)	Personal Observation	Song only	First Hand Account	Avian
Shipyard Waterfront	Flicker (Colaptes auratus)	Personal Observation	Deceased (hit window)	First Hand Account	Avian
Maxwell Waterfront	Sycamore (Platanus occidentalis)	Personal Observation	Live Sighting	First Hand Account	Tree
Maxwell Waterfront	Rugosa Rose (Rosa rugosa)	Personal Observation	Live Sighting	First Hand Account	Shrub

KEY
Species of Special Concern:
Threatened
Endangered

Fig 2 – Biodiversity survey species list

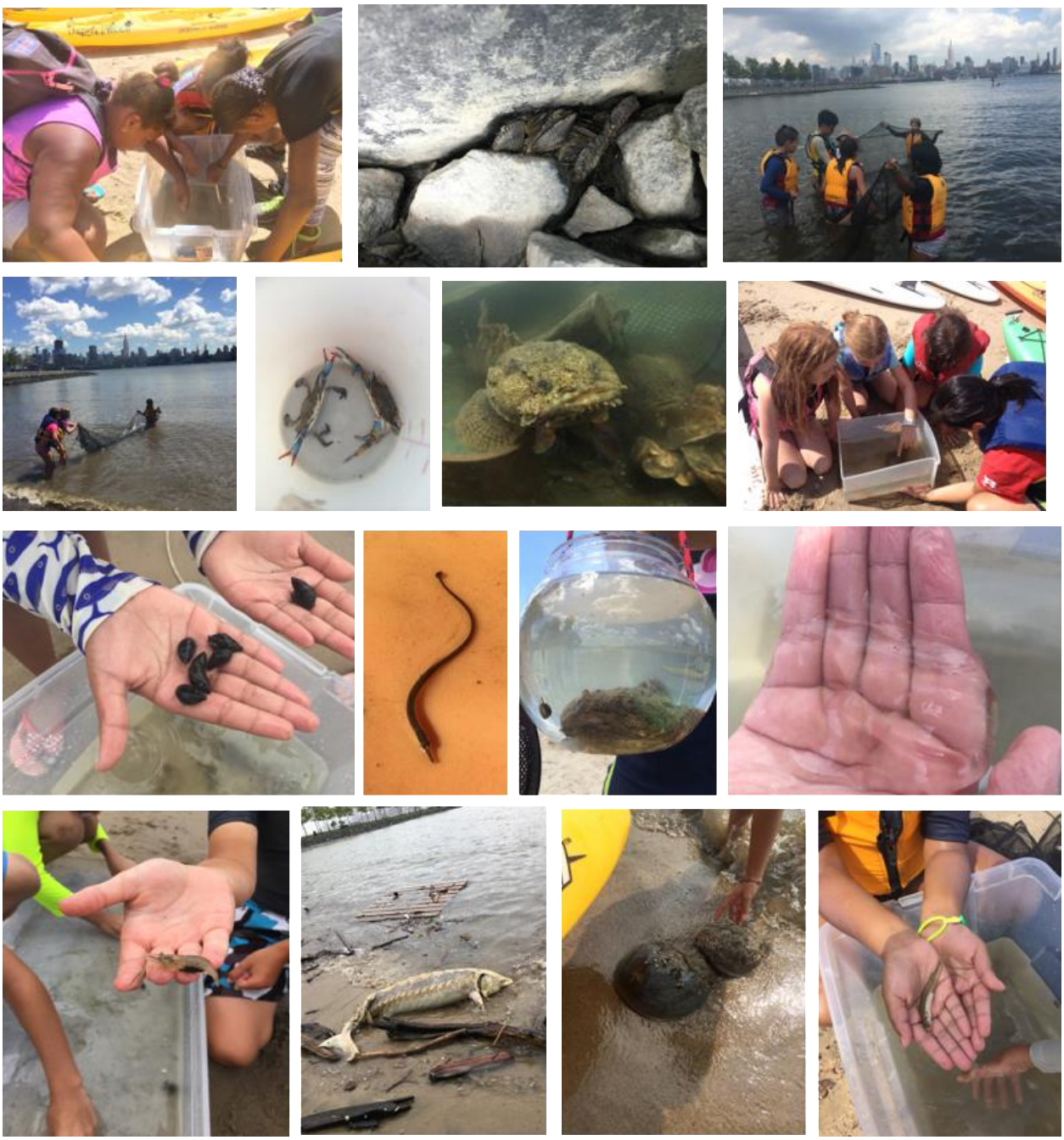

Fig 3 – Images of students conducting the field research and a sample of estuary species found in Hoboken Cove and the Union Drydock areas. (Photo credit: Noelle Thurlow)

Fig 4 - Ribbed Mussels, *Geukensia demissa*, (Photo Credit: Noelle Thurlow)
Found in rip rap along Hoboken waterfront and in pockets on wooden beams of Union Drydock.