Adapting floating wetland design to advance performance in urban waterfronts

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The great cities of the Mid-Atlantic, from Washington, DC to New York City, were strategically placed along the fall line where the Piedmont physiographic province transitions to the Coastal Plain. Situated at the head of the tide, this landscape position held important attributes for city building, including safe harbor for ships, local stone for construction, and proximity to steep streams suitable to run mills (Walter and Merrit 2008). But the head of tide is also an important ecological landscape threshold, where carbon, sediment and nutrients are delivered from the uplands by streams and rivers and deposited in tidal freshwater and brackish marsh systems. In undisturbed landscapes, those marshes uptake and transform pollutants in the water while providing refugia for aquatic fauna, spawning habitat for fish, and feeding grounds for migrating waterfowl. As human development has displaced these ecosystems, the connection facilitated by the beneficial ecosystem services of the tidal marsh systems has been severed (Reusser et al. 2015).

As a result, urban waters are less likely to support a healthy aquatic community. In Baltimore Harbor, fish kills due to anoxia and harmful algal blooms are common. Warning signs discouraging subsistence fishing are necessary due to toxicity, poor water quality and potential for disease. Even recreational contact is considered a risk in highly impaired urban waters. But with increasing public awareness and access to waterfronts, there is a growing demand to address pollution, improve habitat, and make open water bodies a community amenity.

One strategy to restore habitat and ecological services in urban waterways is to deploy floating wetlands (FWLs), which are constructed systems that support plants on a buoyant mat floating at the top of the water column. Constructed FWLs are an ecotechnology deployed primarily to treat polluted natural waters and wastewater, while providing critical habitat (Panlineri 2018). FWLs can also be an aesthetic amenity that can include opportunities for education and research.

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Water Quality Improvement

As FWLs have moved from novel technology to increasingly refined products, the research quantifying their water quality effects continues to be primarily derived from work in the laboratory or controlled settings, if benefits are quantified at all. A recent literature review found that fewer than 40% of scholarly papers on urban treatments to enhance ecosystem services quantify their ecological effects (Prudencio and Null 2018). Nevertheless, the available information suggests that FWLs can have important impacts on nutrient removal in urban environments. Several variations of FWL designs in urban retention ponds have been tested and found to remove significant quantities of phosphorus and nitrogen, largely through organic matter decomposition (Fang and Sample 2014). The primary productivity (McAndrew and Ahn 2017) and plant uptake rates (Keizer-Vlek et al. 2014) of the FWL system are also strong drivers of nutrient removal. Published reports also include effects in the water column below FWLs, such as lower dissolved oxygen, sulfate, nitrate, and pH, dampened diurnal temperature fluctuations, and greater alkalinity (Strosnider et al. 2017). The effects can vary over time, but long-term assessments can show peaks of almost 70% increase in dissolved oxygen, almost 90% removal of fecal coliforms, and 75% removal of nitrate in eutrophic urban ponds (Olguin et al. 2017).

Habitat Provision

Although FWLs are often touted as habitat enhancements, their primary function is usually defined in relation to water quality, which is where the bulk of the research to quantify beneficial effects has taken place. In the earliest pilot projects near the Baltimore Aquarium, FWLs were quickly colonized by algae, mussels, and other organisms. After five months in the harbor, the microcosms had gained about three times their dry weight and supported a very high density of bryozoans, hydras and various protists (Nemerson 2011). How birds and juvenile fish use FWLs designed for water quality is little known, though anecdotal evidence is abundant. At a pilot study at William and Mary University, the floating surface was regularly used by birds including herons and kingfishers. Ducks often attempt to nest on FWLs. The subsurface habitat may be more important in urban waterfronts. Where harbors and rivers are heavily armored, escape and foraging habitat is often severely restricted for juvenile fish, and the below surface substrate and ecological community likely provide important refugia for young fish. A series of case studies and examples compiled in a FWL technical workshop included several examples of fish populations supported by FWL (Andrews and Rottle 2013).

Aesthetic and Educational Benefits

Wetlands are known to contribute to quality of life, offering nature encounters and an experience of beauty (Pederson 2018). Their aesthetic value and provision of cultural ecosystem services are the subject of emerging research, especially in Europe. Visitor's perceptions of ecological and aesthetic values are strongly influenced by aquatic vegetation (Cottet et al. 2013). Managers also recognize the educational value of FTWs, both in raising visitor awareness of ecological topics such as nutrient loads and habitat loss, and for focused research and study in settings such as University campuses (McAndrew and Ahn 2017).

CASE STUDIES

In recent years, three FWL projects in the Baltimore and Washington, DC area have attempted to maximize these benefits in field situations. This paper shares the primary design lessons and modifications developed over the course of those three projects. Although many of the project objectives were met in each case, the process revealed a series of lessons in FWL design and maintenance. If floating wetlands are to become a viable means of contributing benefits along urban waterfronts, it is imperative for the design community to share these challenges alongside the resulting modifications and insights. The following case studies chronicle a recent journey of refining FWL design for resource managers, design consultants and producers of commercial units.

Bio-Flotsam at Baltimore's World Trade Center

In 2010, two small pilot installations of FWLs were deployed in Baltimore Harbor for the Healthy Harbor Initiative - an effort to catalyze improving the Inner Harbor to swimmable and fishable conditions. Both projects were permitted for 200-square foot installations in two locations. The National Aquarium of Baltimore purchased and installed a Biohaven^{TM} Floating Island, which is constructed of recycled plastic mesh (made from polyethylene terephthalate or PET) and buoyant marine foam. The Bio-Flotsam FLWs were constructed using buoyant plastic bottles, collected from the Harbor itself, sandwiched between PET media. The PET media was then retained within two frames of wood and plastic mesh. Both pilot systems survived for at least two growing seasons. Efforts were made to evaluate whether the FWLs were generating ecosystem services such as nutrient transformation and removal, improved water clarity, and refugia for insects, birds, fish and nekton. Scientists at the National Aquarium in Baltimore documented the colonization of the media by bryzoans, hydras, false dark mussels and polychaetes (Nemerson 2011).

In 2012, the Bio-Flotsam installation was expanded from 200-square feet to 2000-square feet (Streb 2013). (Figure 1) The same pilot design with small modifications to strengthen the connections was implemented. No exclosure fencing was used. During the first two years, the FWLs supported vigorous growth. Smooth cordgrass (*Spartina alterniflora*) grew more than 6 feet in its second year and largely crowded out other species, such as rose mallow (*Hibiscus moscheutos*). The project was celebrated as an example of community building and public engagement (Streb 2013).

In 2015, several FWL units were replaced as the biomass accumulation began to exceed the available buoyancy provided by the plastic bottles. Much of the biomass accumulation (bio-fouling) was due to barnacles, mussels, and other benthic marine organisms. As the units sat lower in the water, vegetative growth was stymied. Moreover, the successful growth of the FWLs attracted waterfowl

FIGURE 1. Bio-flotsam - portion of the full build-out (Summer 2012).

as feeding or nesting sites. This placed added pressure on the plants. In time, these units became bare of vegetation. Floatable waste collected on the units and was more visible. Nylon connections began to abrade and break, periodically forcing the system to fall out of alignment. Since the grasses were not subject to diurnal tidal flooding due to the platform design, the grasses did not become saturated detritus and naturally fall away. This required the harvesting of above-water biomass each spring to lighten the units and introduce sunlight to the base of PET media for new shoots to grow, which also extended the life of each unit.

Replacement units were built by volunteers and installed in each year from 2016-2018. Due to the waterfowl population, each new unit required fencing to enable vegetation establishment. However, the fences were often breached. Shortly thereafter, plants were either eaten, trampled, or used for nesting.

FIGURE 2. Bio-flotsam – volunteer planting event (Spring 2012).

FIGURE 3. Bond Street Canal project (Summer 2017).

Each FWL unit was 4 feet by 8 feet rectangles. (Figure 2) This size was ideal for volunteers to carry the units and plant, but too small to support a person. Moreover, a structure of these dimensions was subject to flipping; when a listing unit was flipped over due to wave action. All maintenance had to be performed by boat. Over time, the need for maintenance exceeded available budgets. As the FWL array looked progressively disorderly, the site owner asked that they be removed in the summer of 2018. The units were relocated to a marina where there was less exposure to the public. Disposal of several units was challenging, as the weight with biomass and water saturation required a motorized winch to lift out of the water.

Lessons Learned

- Biomass accumulation due to marine animal fouling exceeded buoyant force over time.
- Buoyancy elements integrated into planting media confined the unit to a short lifespan. Without ease of separating the media from the buoyancy, once the media was fully colonized by marine animals and the buoyancy was compromised, the whole unit was unsalvageable. Inability to physically occupy the wetland surface made maintenance difficult, required multiple vessels in most cases and was extremely time consuming and expensive.
- Small unit size was helpful for installation, but layout required complicated tethering plan which provided multiple points of failure, was extremely time consuming to repair/replace/navigate, and exceptionally difficult to remove any one unit from the mass.
- Accumulation of trash was an ongoing problem that also detracted from the structure's aesthetic quality. Flotsam included invasive and volunteer plants, which resulted in several wetlands to host common reed (*Phragmites australis*) and/or arrow-leaved tearthumb (*Polygonum arifolium*).
- Goose exclosures were difficult to work around during replanting, trash removal, and tethering replacement and were largely ineffective in prohibiting goose use, although far more effective than doing nothing.

- Accommodating nesting Canada geese made any maintenance effort potentially hazardous.
- Maintenance effort was costly, time-consuming and constant (broken tethering, dead plantings from herbivory, severe trash accumulation).
- Volunteer planting events occasionally yielded inconsistent planting depths which led to large die-offs.
- Planting of *Spartina alternifolia* outperformed/overtook other plantings over time.
- Any fabric hanging in the water was colonized by false dark mussels, which provided additional habitat and water quality benefits beyond the wetlands themselves.

Bond Street Living Canal in Baltimore

The Bond Street Canal Living Canal FWLs (Figure 3) were installed in May 2017 with the goal of providing water quality benefits and improving aesthetics to the canal adjacent to the owner's waterfront office building. The project presented an opportunity to distill the lessons learned from the Bio-Flotsam project into a next generation design. The Bond Street FWLs were designed to:

- Be constructed of durable materials,
- Separate buoyancy platform from planters,
- Include modular planters that enable removal for cleaning, research, or relocation, and
- Possess adequate reserve buoyancy to support standing access for maintenance.

A fundamental design change was to separate the buoyancy element from the planting media, which allowed for an exchange of planting media without the complete disassembly/disposal of the entire FWL. The buoyancy structure was fabricated using three parallel square aluminum tubes, capped at both ends, set about 5 feet apart and framed together. The media was also reimagined as being set in modular frames attached to the structure and could be removed or replaced, if desired. The modular frames were redesigned oyster cages - wire cages used in oyster aquaculture. To secure the cages to the structure, pontoons were oriented at a 45-degree angle (diamond shape in section) and fitted the cages with "wings" where by using its own weight to taper lock it into place (Figure 4). A similar media (unwoven PET panels) was used as the Bio-Flotsam design but was made thicker and specified with planting holes to be completed during fabrication. Planting was installed by student volunteers from local nonprofit foundation.

The first arrangement of the 1000-square foot installation was staggered to maximize edge and visual impact (Figure 5). Within the first two weeks, this arrangement was noted to be especially proficient at trapping floatable trash. The client asked that the system to be rearranged to create a continuous line of FWL. This new arrangement facilitated less trapping and easier access (Figure 3).

Plant establishment was hampered primarily by goose pressure and, to a lesser extent, by planting installation. To address the planting installation concern first, the adaptation of the installation process to the media hole size, site influences and plant material resolved the issue. The pre-drilled planting holes afforded the plug the benefits of wet-feet, wide spacing and deep media penetration. However, some plugs weren't snug in the media and caused many plantings to fail. Sited in an active harbor, wave energy from boat traffic contributed to a washing out of plug soil when not tightly contained. Additionally, *Hibiscus* specifically appeared not to have a highly fibrous root system and didn't hold the soil especially well. To resolve the issue, replacement soil plugs were wrapped with a woven coir/burlap fabric (both were used independently) prior to installation.

FIGURE 4. Bond Street buoyancy separation.

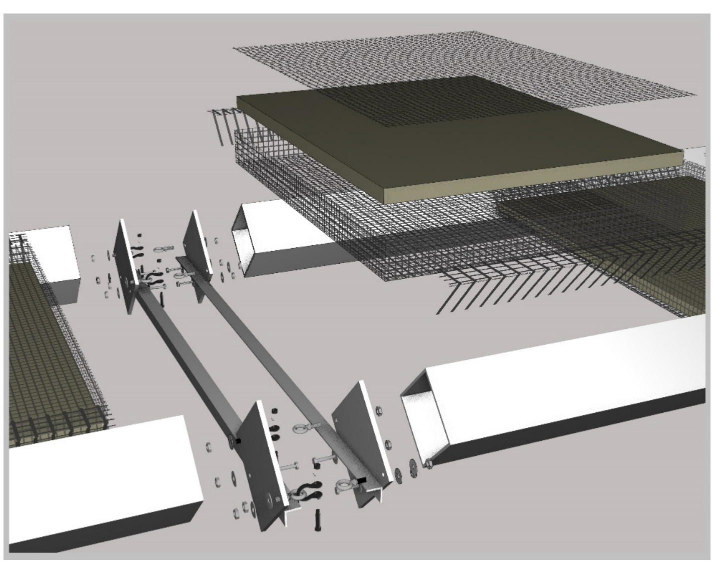

FIGURE 5. Bond Street project- original orientation (Spring 2017).

The added width better accommodated the hole diameter and protected the soil from being washed out.

Resident geese herbivory and impacts from their waste products was the single largest contributor of planting growth suppression and failure. Metal wire arches were placed over the media to inhibit access. However, the wire arches were both strong enough and the openings small enough (approximately 1 inch) that the material could support multiple geese who continued to feed on the grasses, creating a topiary effect. Those arches were later replaced with new wire fenced arches. The gaps in the wire were 4 inches which prevented the geese from walking on the arches and allowed the plants to get established. Aside from managing invasive *Polygonum* and thinning of senesced leaf material, the plants have continued to prosper through their second year.

The FWL array was tethered at multiple points. Wave energy generated from wind and boat traffic keeps the system continuously engaged. Nylon lines were attached to steel shackles. After the first year, connections were found to abrade and break. The lines have been replaced with chain. Stainless steel hardware fastening the pontoons also periodically failed. This was only resolve when diagonal cross braces were installed to stiffen the pontoon frames.

Lessons Learned

- Upgrades to buoyancy enabled standing access, greatly facilitating management.
- Wire frames holding plant media are more easily moved.
- Media colonized with plants and community of filter feeders creates the possibility of researching water quality benefits in a controlled mesocosm study versus an open water installation.
- Appropriate exclusion fencing was necessary for establishing plants.
- Steel chain connections were necessary in this high energy environment.
- Stiffening the buoyant framework has reduced mechanical failure rates of connecting hardware.
- Flotsam was reduced by arranging FLWs so that gaps and corners were minimized.
- Flotsam accumulation on wetland continued to be a problem, as the units sit nearly level with the water surface.
- *Polygonum arifolium* is observed throughout the wetlands and must be manually weeded to suppress its growth.

District Wharf in Washington, DC

The District Wharf is an urban waterfront revitalization effort along the Washington Channel, a freshwater tidal system connected to the Potomac River in Southwest DC. A cluster of FWLs, elliptical in shape (Figure 6), were envisioned, designed and installed adjacent to a new public pier as an aesthetic amenity, for habitat and to provide incidental water quality improvement.Though the project presented similar challenges and standards of success, the District Wharf is anticipated to be utilized throughout the year by tourists and residents. Therefore, the FWLs required a more refined and aesthetically rich approach.

With the Bond Street wetlands completed, the District Wharf FWLs again presented an opportunity to extract lessons from the previous design and make a better product. The new design conceptualized an aluminum band around the perimeter, resembling a weightless, floating aluminum ring occupied by plants (Figure 6). This design element is owed much to the eventual success of the project because it resolved several problems that would have otherwise been present. Not only does it hide the structure and provide a clean, consistent edge, it also acts as a structural frame to further secure the buoyant elements together. Additionally, the band prevents the accumulation of flotsam on the wetland, which detracts from the aesthetic value and is a key importer of invasive plant material to the system, otherwise requiring increased maintenance costs. The ellipses consist of two layers of buoyancy in the form of aluminum pontoons. Pontoons placed on the bottom of the structure are flooded to regulate the elevation of the units. Having the ability to adjust where the units sit in the water column is expected to extend the life of the system as well as facilitating management.

Another significant redesign was the elimination of the cages and replacing them with an underlying fiberglass support deck upon which the media would sit. The support deck provides uniform support and can be occupied by several people at once, whereas the cages at Bond Street provided enough support for just one person. The media was cut with 45-degree angles on the edges to help secure the media panels in place as with Bond Street.

A third major difference worth noting is the process behind the planting establishment to the media. Unlike Bond Street FWLs, the PET media panels were shipped directly to the nursery to pre-grow the plants in the media prior to installing onsite (Figure 7). The primary goal for pre-growing plants into the media was to ensure substantial establishment for a scheduled September install date. It was also hoped that the plants would be more resistant to site stresses, including herbivory and sun intensity. Since the Washington Channel is freshwater, salinity acclimation was not necessary. The pre-grown panels were shipped to the site for installation with large root mats spread under and throughout the media. Posts and wire line were strung across the units to reduce herbivory pressure. In Spring of 2018, an area of the line was compromised, and a Canada goose female nested on the unit. Upon her eggs hatching, she left the unit and the exclosure was repaired.

Lessons Learned

- Pre-growing the plants in the media can yield a more immediately aesthetic product, but care should be taken to acclimate plants from nursery to open water.
- Perimeter and interior cabling is an important, if imperfect, defense against herbivory.
- Planting palette was designed with herbivory-prone species in the center and less desirable plants along the perimeter.

DISCUSSION

FWLs are an ecological prosthetic along urban waterfronts aimed at restoring a semblance of the ecological functions severed due to urbanization. FWLs cannot compensate for the comprehensive elimination of natural marshes along urban waterfronts, but they can be employed to provide meaningful benefits. In the U.S. mid-Atlantic region, a few generations of FWLs have been deployed in tidal waters, each with new adaptations to better educate, beautify, provide habitat, improve water quality, or enable research. The following lessons learned from case studies in the Baltimore-Washington DC area are presented as considerations for resource managers, design consultants and producers of commercial units.

FIGURE 6. District Wharf (Summer 2018).

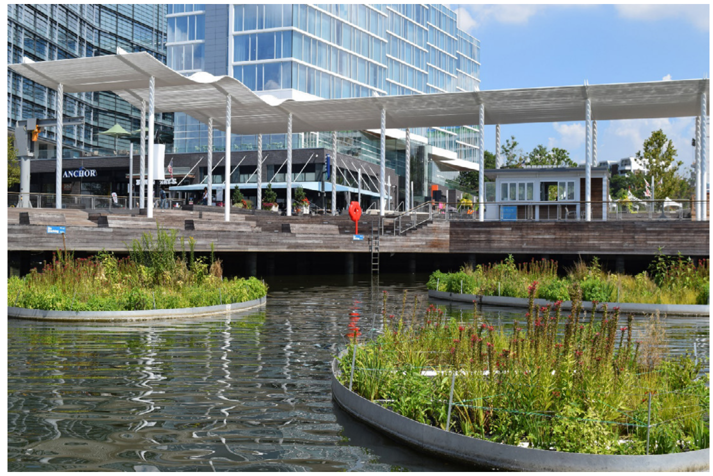

FIGURE 7. District Wharf - planting media grow-out at Wicklein's Nursery (Summer 2017).

	Bio-Flotsam	Bond Street	District Wharf	Recommended Practice
Herbivory Protection	Mesh perimeter – limited protection	Wire arches – inhibits nesting, good protection	Cable wiring – good protection, needs monitoring	Wire arches work, cable wiring shows positive results
Planting Survival	Medium - Consistent herbivory pressure	Medium – Rough start but resolved	High – Well established	Establish plants offsite prior to project install
Aggressive or undesirable volunteer plants	Slow invasion	Established early; highly competitive with plantings	Added metal barrier to prevent intrusion, especially via floating mats	Incorporate perimeter barrier
Trash Accumulation	High accumulation	Medium/High accumulation	Minimal accumulation	Incorporate perimeter barrier
Maintenance Access	Challenging: structure cannot support a person	Medium – can support a person	Superior - structure supported multiple people	Supporting multiple people should be design parameter
Aesthetic Value	Compromised by uneven surface, trash accumulation, and herbivory	Medium – Trash, moderate herbivory pressure, one flowering plant	High – Metal bar gave clean aesthetic and prevented trash, herbivory was better controlled, and plant survival and flowering was high	Preventing trash, consistent buoyancy and plant palette are critical to high aesthetic value

Aesthetics

Reintroducing vegetation to conceal and beautify urban bulkheads and marine infrastructure is the first perceived benefit associated with FWLs. Regardless of whether the true purpose of the FWLs was to provide habitat or improve water quality, the visual appearance of the system will be the primary criteria through which the public and the client determine performance. Nassauer (1995) postulated that ecological quality may not be appreciated without cues indicating human intention. In support of this contention, the Bio-Flotsam FWLs were embraced when they were lush with vegetation and the array was orderly and symmetric. However, as time and weather strained and broke connections, exclusion fencing was breached, vegetation browsed and trash made visible, the FWLs became unsightly and the property owner asked that they be removed.

Truly understanding the site context may help inform the degree to which attention is given to the aesthetics of the FWLs. In general, the more populated and closer the system is placed before viewers, the more important high aesthetic design standards are for the FWLs.

At the District Wharf FWLs, the four installed units are characterized by their elliptical shape defined by a 10-inch aluminum curb around the perimeter. The freshwater marsh community may be considered wild and unmanaged but given that they are contained and framed by the urbane edge, the public and client reception has been positive. These particular FWLs seem to delight by fusing the intention of providing ecological habitat into objects of landscape art.

Durability

FWLs were placed in open tidal water systems. The continuous exposure to sun, wind, and wave action over time weathered and degraded the structural integrity of the tethering and platforms supporting the plants. Failures to the tethering were observed within the first two years of the installation of the Bio-flotsam array in Baltimore and occurred with more frequency over time. One factor observed was corrosion. Nylon lines were tied to galvanized or stainless-steel shackles. In salt water, the surface of the shackles developed pits and abrasive mounds that cut through the nylon tethering lines, particularly with wind and wave action keeping the units rocking. Platforms also were observed to be impacted by weather.

The first pilot of the Bio-flotsam systems wood frames were broken open during a tropical storm. The first installation of the National Aquarium FWLs were built without any rigid materials. The PET media began to weaken with photodegradation and delaminate as the system experienced tensile stress from anchored steel cables countering the upward force as the unit floated. At the Bond Street Living Canal project, high wave energy from boat traffic keeps the FWLs in continuous motion causing nylon tethers to wear and break.

At the District Wharf FWLs, the aluminum band around the perimeter of the units stiffens the structure. The tethering is steel cable anchored to concrete blocks. No failures have occurred to date, nor is there any indication of any risk after one year. At the Bond Street Living Canal, all connections have been upgraded to galvanized chain to reduce the risk of abrasion observed with nylon lines. In both systems, the PET media is used only to support the plants and benthic organisms. The top of the media is treated to defend against ultraviolet degradation. As the media is under no tensile stress and protected from sun, there has been no indication of degradation.

Buoyancy

A factor contributing to the life of FWLs in brackish water is the reserve buoyancy. In Baltimore, all FWLs installed to date have provided colonization sites for a variety of benthic organisms. These organisms represent the base of the estuarine food web. With filter feeders, including hydroids, barnacles, mussels and anemones, these organisms may help clarify urban waters. However, as populations grow on FWLs, the buoyancy of the units has been compromised overtime. At the Bio-Flotsam FWLs, biofouling rates of 1.5 pounds per square foot were observed. Units with designed buoyancy of roughly 6 pounds per square foot sat below water after four years. As the units sunk lower in the water column, the plant community shifted toward *Spartina alterniflora* before becoming unvegetated.

Units designed for the Bond Street Living Canal, the District Wharf and National Aquarium addressed this concern by separating the growing media (PET) from the floating structure. Each of these newer systems include reserve buoyancy with the ability to optimize the elevation of the growing media by including water ballast. As organisms foul the structures, water can be pumped from the ballast so that plants are not drowned. After one year of installation, the District Wharf FLWs have shown no evidence of biofouling as it is the only FWL reviewed in tidal freshwater. The National Aquarium FLW has been actively managed by the owner to optimize elevation for supporting the desired plant community.

Understanding the potential for biofouling is an important factor for determining the long-term buoyancy and function of a proposed FWL. Biofouling can be managed by designing adequate reserve with a means to adjust the plant media elevation. Over the long term, designing a structure that can be cleaned and planting media can be replaced will extend the life of the FWLs and increase the sustainability of the project.

Herbivory

Urban waterfronts in the mid-Atlantic region have limited habitat for waterfowl. The introduction of FWLs along waterfronts can provide additional feeding and nesting locations. In Baltimore, early pilot projects were vegetated after the first year of installation without fencing. However, mallard duck and geese soon discovered the habitat, causing new units installed over the ensuing years to require fencing and exclosures to protect marsh plants from waterfowl.

At the Bio-Flotsam FWLs, vertical posts with plastic netting were installed around the perimeter of each unit. The fences were prone to being overcome by waterfowl. In these cases, the breached FWLs were never able to support plants due to herbivory, trampling, or being pulled for nest materials.

At the Bond Street Living Canal, several steel wire arches were installed over the planting beds. The first system used rigid wire with 1-inch openings. Geese were observed standing on the units and cutting stems protruding through the wire. A second installation using wire fencing with 4-inch openings was found to inhibit geese from accessing the plants from above. After the first year, the arched wire exclosures were concealed by vegetation.

The District Wharf FLWs waterfowl exclosure was constructed with wire lines strung on aluminum posts around the perimeter and through the middle of each unit. Some herbivory has been observed but was limited to a few locations. One female goose nested and brooded her clutch of eggs in Spring of 2018 where a few lines were compromised. The lines were repaired, and no additional pressure has been observed in that location.

CONCLUSION

As urban waterfronts increasingly transform into publicly accessible civic spaces, people are connecting to the natural water bodies that made their city a desirable place for human society. With access comes awareness and a demand for improved water quality and habitat along these waterfronts. FWLs are akin to ecosystem prosthetics, restoring some of the ecological services lost with the conversion of tidal marshes into urban centers. The benefits of FWLs are that they can be deployed to provide habitat in waterways that have been dredged or channelized and now consist of deep water. The flexibility of application can be used to enhance the aesthetics of urban waterfronts, creating gardens on the water that may conceal infrastructure. Water quality benefits of the FWLs continue to be studied. Perhaps the greatest benefit of FWLs installed along urban waterfronts are that they serve to reflect the ecosystem that was once a part of that place. This type of engagement with the public can communicate and educate the need for improving urban waters as a valuable habitat for wildlife.

Advances in FWL design and management require resource managers, design consultants and manufactures to share successes and failings. Three case studies were reviewed to show how unexpected challenges were employed to improve structure design for durability and to reduce maintenance efforts. ■

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