Reprinted by permission of the National Wetlands Newsletter. To subscribe call 800-433-5120, e-mail orders@eli.org, or visit wwwl.eli.org.

Building Floating Wetlands to Restore Urban Waterfronts and Community Partnerships

Floating wetlands are a new technology that some cities are exploring as a means to provide potential habitat and water quality benefits. The author looks at a small-scale pilot project in Baltimore's Inner Harbor and discusses the potential benefits and challenges of floating wetlands for urban waterfronts.

By Chris Streb

As America's urban waterfronts have transformed from industrial shipping centers into mixed use and public open space, more attention has been given to the poor water quality and limited habitat value of these modified ecosystems. Cities like Philadelphia, Baltimore, and New York, to name a few, have deployed small-scale pilot projects using floating wetland (FW) technology to restore ecological services once provided by marshes and living shorelines.

FWs are designed and constructed ecosystems that mimic naturally occurring floating wetlands observed in various waterways around the world. Since land in urban areas is unavailable or difficult to reshape in a way that restores natural shorelines, FWs hold the promise of returning functions like pollutant uptake and transformation, wave attenuation, habitat, and aesthetic beautification. The measured benefits associated with the technology are still being quantified and will vary widely, depending on the application. A recent FW pilot project in Baltimore, which involves the largest installation of FWs in Maryland, has yielded notable benefits not easily measured.

Baltimore, like most cities along the Atlantic seaboard, developed into an urban area because it surrounds a harbor. At the edge of the Piedmont physiographic province, land gently slopes into relatively deep, calm tidal waters. Prior to Baltimore's development, its harbor was lined with a ribbon of tidal marshes. The marshes likely expanded during the earliest stages of Baltimore's development as sediment washing down from newly deforested colonial farms deposited along the intertidal zone. By the end of the Industrial Revolution, however, the Harbor's natural, vegetated edges had become hardened with bulkheads and piers.

In 2009, only one bit of vegetated shoreline remained along the Northwest Branch of the Patapsco River, an area known as the "Inner Harbor." Though the Inner Harbor is considered Baltimore's top destination and tourist attraction, this small stretch of vegetated shoreline was neither highly visible nor promoted as a feature. In 2010, two separate FW installations tripled the areal coverage of wetlands. By 2012, the coverage increased fivefold from 400 square feet to 2,000 square feet.

But the story of Baltimore Harbor's FWs is about more than increased acreage. It touches upon challenges and opportunities faced by Baltimore, and by many other urban, post-industrialized waterfront communities. While the Baltimore Harbor FWs hold value in that they represent a microcosm of wetlands that existed prior to colonial settlement, with ecological services that can be measured, they have also yielded social benefits that are harder to quantify. The mere act of designing, permitting, building, installing, and monitoring FWs revealed a cultural ecology of problem solving that touched upon issues ranging from water quality, ecology, and regulatory policy, to neighborhood health, civic engagement, public education, and the power of partnership.

Permitting a New Technology

Although treatment FWs have been employed to a limited extent for at least two decades, this novel technology is in its infancy as an acceptable best management practice (Burgess & Hirons 1992). The idea to install FWs in Baltimore began in 2009, when the National Aquarium of Baltimore (NAB) and the city's Office of Sustainability developed plans for a small, 200-square-foot installation in a highly visible location of the Inner Harbor. The plans required a Tidal Wetlands and Waterway permit from the Maryland Department of the Environment (MDE). Since the technology was so novel, regulators used considerable prudence, requiring the applicants to provide more information to ensure useful outcomes that could benefit future applicants and regulatory consideration.

Just a few months later, additional pressure to permit FWs came about when another applicant submitted plans in the heart of the Inner Harbor. The Waterfront Partnership of Baltimore (WPB) is the entity responsible for managing and maintaining the Inner Harbor. The organization had long recognized the negative impression that the Harbor's poor water quality and trash were making and wanted to be proactive in its restoration. In 2010, the WPB retained Biohabitats (the author's employer) to prepare the Healthy Harbor Initiative, which set out a vision to make the harbor swimmable and fishable by the year 2020. FWs were selected as the first pilot project and a symbolic gesture to raise awareness and proactively demonstrate that big problems can be solved through creativity, education, and partnership.

Before issuing permits, the MDE had concerns regarding the technology. The most significant concern was that FWs would not be recognized as a substitute for natural wetlands. This could lead to the slippery slope of agencies or developers seeking to mitigate impacts to jurisdictional wetlands with FWs, particularly when land is expensive, as it is near waterfronts. Further, with commercial FW vendors claiming their products possess more surface area than natural wetlands for biofilm growth and water treatment potential, one could see how this new technology might lead to FWs being pushed as technology that is better than natural wetlands. Another cited concern was that the FWs might shade or displace submerged aquatic vegetation (Mallison et al. 2001). This was not considered a problem in the Inner Harbor, but certainly applied to shallower waters around the Chesapeake Bay. Although FWs are generally thought to improve water quality, the MDE pointed to literature citing potentially deleterious effects, including lower dissolved oxygen, excessive organic loadings from detritus and concentration of metals or other contaminants. There were also concerns that the FWs would attract waterfowl that could add to the bacterial loadings already impairing the Harbor. Invasion by terrestrial weeds, long-term buoyancy, and overall durability were also concerns.

To address these concerns, the MDE limited both FW installations to 200 square feet each and required, as part of the permit, that a monitoring program be set in place. With permits in hand, both the NAB and the WPB set off on implementing two separate FWs at their respective and highly visible locations. Although the author was only involved in the WPB FW design and implementation, the permits were linked by the requirement to monitor both installations while preparing one report on the findings.

Newly planted floating wetlands. Photo courtesy of Biohabitats Inc.

The FW Systems

Understanding the benefits of FWs is challenging for a variety of reasons, but perhaps most significant is the variety of ways to manufacture FWs. The NAB purchased the proprietary Biohaven™ Floating Island, which is constructed of recycled plastic mesh (made from polyethylene terephthalate) and buoyant marine foam. The Biohaven™ was planted by community volunteers and deployed in a canal between Piers 3 and 4, adjacent to the aquarium's entrance and tethered in place with a duckbill anchor.

The WPB took a different approach, with the intent of maximizing community engagement, education, and outreach. They hired Biohabitats to design an FW based on the idea that it could serve to illuminate the connection between the everyday actions of people living in the watershed and the quality of Baltimore Harbor's water. During the development of the Healthy Harbor Initiative, Biohabitats suggested that FWs could be constructed using floating plastic bottles collected from the Harbor itself.

There was a general sense that there was power in this simple idea; that a problem plaguing the city (trash washing from streets into the Harbor through the storm drains) could be used as a material source for building an ecologically engineered solution to improve water quality and habitat. Biohabitats' FW design consists of buoyant plastic soda bottles sandwiched by planting media. The media is retained within two frames of wood and plastic mesh. Biohabitats patented this design to keep the system open source for nonprofits or other grassroots watershed groups to employ (Streb 2010). For purposes of this article, although we have never branded the system, we will refer to them as Bio-flotsam FWs.

Education and Partnership

Although the premise behind the Bio-flotsam FWs was to maximize educational opportunities, an unexpected outcome was the degree to which partnerships with other entities developed. Funding for the first installation of Bio-flotsam FWs came from a grant obtained by Harbor WaterKEEPER (now housed within Blue Water Baltimore (BWB)) for a stormwater project that was deemed infeasible. The Bio-flotsam FWs served the goals of both the WPB and WaterKEEPER and initiated an ongoing relationship between the groups.

To build the Bio-flotsam FWs, the WPB and Biohabitats began working with the Living Classrooms Foundation (LCF), an organization dedicated to educating city youth with hands-on, experiential education. With their campus on the Inner Harbor, the LCF also provided a base station for Bio-flotsam FWs construction.

The first step for constructing was to collect plastic bottles from the Harbor. The dread of picking through Baltimore City's skimmer boats was averted with help from Clearwater Mills LLC. They had recently installed a unique trash intercept at one of the local outfalls. Clearwater Mills' innovative design uses a waterwheel to turn a conveyor which lifts floatable materials from the water and deposits them in a dumpster. By simply standing at the conveyor during a storm, bottles with lids were selected from the screen.

With buoyancy and other materials required for the Bio-flotsam FWs in hand, LCF students (4th to 8th grade) were prepped for assembly. The bottles became a tangible vehicle for education. Many of these students had never considered that runoff from their neighborhoods drains to the Harbor, carrying litter from the streets. They also learned that wetlands serve as nature's water filter and provide important habitat for fish, birds, and terrestrial wildlife. Most importantly, the students helped assemble the FWs, and in the process, gained a sense of ownership of the Bio-flotsam FWs that is renewed every time they see the grasses floating on the surface of the Harbor.

Performance

The intent of FW installations is to restore some of the environmental services once provided by historical tidal marshes. These services

Reprinted by permission of the National Wetlands Newsletter. To subscribe call 800-433-5120, e-mail orders@eli.org, or visit wwwl.eli.org.

Floating wetlands in Baltimore's Inner Harbor. Photo courtesy of Biohabitats Inc.

include nutrient removal, nutrient processing and metabolism, reduction of the effects of eutrophication, heavy metal sequestration, carbon sequestration into plant biomass, improved water clarity, food, structure and refuge for fish and nekton, and habitat for insects, birds, and other biota (Nemerson 2011).

To determine if the FWs provided any of these services, the NAB and the University of Maryland's Sea Grant Extension Program monitored the two FWs in the Inner Harbor. Since the small footprints of the FWs were deployed in an open water body of significant volume and area, it was recognized that direct measurements of water quality differences would yield insignificant results.

To assess the potential for nutrient uptake and reduction, the NAB created and installed microcosms of the FWs. These microcosms consisted of the primary media used in both the Biohaven and Bio-flotsam FWs. Once installed in the Inner Harbor, the microcosms were quickly colonized by a host of organisms, including bryozoans, hydras, and various protists. Filter feeders, such as false dark mussels, set in mid-summer and polychaete worms became established by late summer. The microcosms were taken into the lab and evaluated for their ability to absorb nutrients. The populations of filter feeders were estimated for the FWs based on densities of organisms found on the subsamples.

It was observed that the colonized microcosms of FW media rapidly drew nutrients from the surrounding waters and assimilated them into the biofilm. The study was not able to conclude the fate of the nutrients or the long-term behavior of the ecosystem with respect to nutrient reduction, but it appears that the FWs provide a means for transferring nutrients and particulates to higher trophic levels where they are at least temporarily sequestered. The FWs were also observed to become favorite refuge for fish and crabs. Waterfowl, such as night heron, were observed on multiple occasions, perched on the FWs seeking prey.

From a durability standpoint, the FWs held up reasonably well over time. The Bio-flotsam FWs were damaged by Hurricane Irene due to their lateral tethering and exposure to high winds. This led to the development of simple adaptations to the design and tethering system that would dramatically improve durability. The success of the pilots encouraged the WPB to scale up the Bio-flotsam FWs installation, and they obtained a revised permit for 2,000 square feet of Bio-flotsam FWs.

Scaling Up

Increasing the footprint of the Bio-flotsam FWs tenfold required a more significant interorganizational effort and additional fundraising. Local corporations, looking for volunteer opportunities, played a significant part in the scale-up. The LCF received donations of materials and volunteer hours to build Bio-flotsam FW platforms. Again, the FWs served as an educational tool and a means of building awareness regarding the state of the Harbor, with adults as the students. They have also adopted the Healthy Harbor Initiative as a whole and built a curriculum around the theme for teaching science, technology, and math.

The Bio-flotsam FWs were installed as a high-profile Earth Day event in April 2012. The effort became an exercise in organizational partnership. Between the WPB, the NAB, the BWB, the LCF, and Biohabitats, we coordinated and worked with almost 200 volunteers of all ages to construct and install the Bio-flotsam FWs in front of Baltimore's World Trade Center.

The installation became a media event, even garnering national recognition from cable networks. The excitement included the mayor of Baltimore, as well as state and federal officials, all supporting the civic goal of restoring the Harbor to swimmable and fishable conditions. Students from the LCF prepared remarks for these media events, demonstrating the power of children to voice a sense of hope and optimism in the face of extraordinary environmental challenges.

The 2,000 square feet of Bio-flotsam FWs were installed without a hitch and have had a full growing season. They survived Hurricane Sandy and other wind events and continue to attract attention. An interpretive sign has been installed to educate all passersby and help build greater civic awareness. The FWs continue to be monitored and we will have a growing understanding of their value. But perhaps the most impressive aspect of the Baltimore Harbor FW installation is the way this small gesture of intention (toward the big goal of restoring the Inner Harbor) has had such a positive, communitywide effect. ■

Acknowledgements

The bioflotsam floating wetlands were made possible by the generous funding of the Abell Foundation.

References

Burgess, Neal D. & Graham J.M. Hirons, *Creation and Management of Artificial Nesting Sites for Wetland Birds*, 34 J. Envtl. Mgmt. 285-95 (Apr. 1992).

Headley, Tom R. & Chris C. Tanner, Auckland Regional Council, NIWA Client Report: HAM2006-123, Application of Floating Wetlands for Enhanced Stormwater Treatment: A Review (Nov. 2006).

Nemerson, David, National Aquarium and Waterfront Partnership of Baltimore, Initial Assessment of the Habitat Value, Local Water Quality Impacts and Nutrient Uptake Potential of Floating Island Wetlands in the Inner Harbor, Baltimore, MD: A Report to the Maryland Department of the Environment (Feb. 2011).

Streb, Chris A., Publication of Patent Application No:12/831,889, Treating Water Using Floating Wetland Made of Plastic Waste (2010).

Yocom & Bernard, from page 23

61. One example is the Red Top Mine on Marsh Mountain just east of Aleknagik, which produced about 120 flasks of mercury through 1970 and apparently has not been in production since then. *See* Donald J. Grybeck, USGS, Alaska Resource Data File, New and Revised Records Version 1.5, at 564-66 (2008), *available at* http://ardf.wr.usgs.gov/ardf_data/1225.pdf. Although the acres of impact are not identified in the Alaska Resource Data File (ARDF), it can be inferred from the 10,000 feet of surface dozer trenching and about 1,480 feet of underground workings described in the ARDF that the acreage is fairly small. The ARDF description of the mine's geology gives no indication of any aquatic resources similar to those at the Pebble site.
62. 40 C.F.R. §230.93(a)(3).
63. *Id.* §230.93(h)(1)(iv).
64. *Id.* §230.93(b)(3).
65. *Alaska District In-lieu Fee Sponsors*, Corps, Alaska District (last visited Jan. 18, 2013), http://www.poa.usace.army.mil/Portals/34/docs/regulatory/AlaskaDistrictIn-lieuFeeSponsors.pdf.
66. *See Southwest Alaska Salmon Habitat Initiative*, The Conservation Fund (last visited Jan. 17, 2013), http://www.conservationfund.org/alaska_hawaii/alaska/southwest_ak_salmon. This effort is aided, in part, by donations from the Bristol Bay Native Corporation.
67. The Conservation Fund, A Prospectus to Establish and Administer the Alaska Statewide In-Lieu Fee Compensatory Mitigation Program at 12 (July 2011).
68. Alaska Department of Natural Resources, Division of Parks and Outdoor Recreation, Wood-Tikchik State Park Management Plan, at 2-2, 7-11 (map) (Oct. 2002), *available at* http://dnr.alaska.gov/parks/plans/woodt/wtplan4mb.pdf.
69. 40 C.F.R. §230.93(b).
70. *See* Woody & O'Neal (2010), *supra* note 37; *Anadromous Waters Catalog* Alaska Department of Fish & Game (last visited Jan. 17, 2013), http://www.sf.adfg.state.ak.us/SARR/awc/.
71. Jeffrey C. Davis & Gay A. Davis, *The Influence of Stream-Crossing Structures on the Distribution of Rearing Juvenile Pacific Salmon*, 30 J. North Am. Benthological Soc'y 1117-28 (Dec. 2011); Mindi B. Sheer & E. Ashley Steel, *Lost Watersheds: Barriers, Aquatic Habitat Connectivity, and Salmon Persistence in the Willamette and Lower Columbia River Basins*, 135 Transactions Am. Fisheries Soc'y 1654-69 (Nov. 2006).
72. David M. Price et al., *Fish Passage Effectiveness of Recently Constructed Road Crossing Culverts in the Puget Sound Region of Washington State*, 30 North Am. J. Fisheries Mgmt. 1110-25 (2011).
73. Helen Neville et al., *Influences of Wildfire, Habitat Size, and Connectivity on Trout in Headwater Streams Revealed by Patterns of Genetic Diversity*, 138 Transactions Am. Fisheries Soc'y 1314-27 (2009); John E.B. Wofford et al., *Influence of Barriers to Movement on Within-Watershed Genetic Variation of Coastal Cutthroat Trout*, 15 Ecological Applications 628-37 (2005).
74. Ray Hilborn et al., 2003. *Biocomplexity and Fisheries Sustainability*, 100 Proc. Nat'l Acad. Sci. 6564-68 (May 27, 2003); Schindler et al. 2010, *supra* note 40.
75. Willa Nehlsen et al., *Pacific Salmon at the Crossroads: Stocks at Risk From California, Oregon, Idaho, and Washington*, 16 Fisheries 4-21 (Mar.-Apr. 1991); Ken Bates et al., Washington Department of Fish and Wildlife, Design of Road Culverts for Fish Passage (2003).
76. *Fish Passage Improvement Program*, Alaska Department of Fish and Game (last visited Jan. 18, 2013), http://www.adfg.alaska.gov/index.cfm?adfg=fishpassage.projects.
77. PLP EBD, app. B, ch. 15, *supra* note 44.
78. Paul S. Kemp et al., *Qualitative and Quantitative Effects of Reintroduced Beavers on Stream Fish*, 13 Fish & Fisheries 158-81 (2012).
79. Michael M. Pollock et al., *Hydrologic and Geomorphic Effects of Beaver Dams and Their Influence on Fishes, in* The Ecology and Management of Wood in World Rivers 213–33 (S.V. Gregory et al., eds. 2003).
80. *Id.;* Robert S. Rupp, *Beaver-Trout Relationships in the Headwaters of Sunkhaze Stream, Maine*, 84 Transactions Am. Fisheries Soc'y 75-85 (1954); Mason D. Bryant, *The Role of Beaver Dams as Coho Salmon Habitat in Southeast Alaska Streams*, *in* Proceedings of the Olympic Wild Fish Conference 183-92 (James M. Walton & Douglas B. Houston eds. 1983); Richard Gard, *Effects of Beaver on Trout in Sagehen Creek, California*, 25 J. Wildlife Mgmt. 221-42 (July 1961).
81. Nehlsen et al., *supra* note 75; Sheer & Steel, *supra* note 71.
82. Chris M. Bunt et al., *Performance of Fish Passage Structures at Upstream Barriers to Migration*, 28 River Res. & Applications 457-78 (2012).
83. David W. Roscoe & Scott G. Hinch. *Effectiveness Monitoring of Fish Passage Facilities: Historical Trends, Geographic Patterns and Future Directions*, 11 Fish & Fisheries 12-23 (2010); Bunt et al., *supra* note 82; Cheri Patterson, Operations and Maintenance of Fishways for River Herring in New Hampshire Coastal Rivers (National Conference on Engineering & Ecohydrology for Fish Passage, June 6, 2012) (last visited Jan. 17, 2013), http://scholarworks.umass.edu/fishpassage_conference/2012/June6/33/.
84. David W. Roscoe et al., *Fishway Passage and Post-Passage Mortality of Up-River Migrating Sockeye Salmon in the Seton River, British Columbia*, 27 River Res. & Applications 695-705 (2011).
85. Tim O'Brien et al., Arthur Rylah Institute for Environmental Research Technical Report Series No. 216, Department of Sustainability and Environment, Review of Fishways in Victoria 1996-2009 (2010); Washington Department of Fish and Wildlife, Hydraulic Project Approval, Fishway Structures in Freshwaters Statewide, Control No. 117192-1 (June 2, 2009).
86. *See Frequently Asked Questions,* National Oceanic and Atmospheric Fisheries Service (last visited Jan. 17, 2013), http://www.nwfsc.noaa.gov/resources/search_faq.cfm?faqmaincatid=3.
87. Mark R. Christie et al., *Genetic Adaptation to Captivity Can Occur in a Single Generation*, 109 Proc. Nat'l Acad. Sci. 238-42 (2011); Dylan J. Fraser, *How Well Can Captive Breeding Programs Conserve Biodiversity? A Review of Salmonids*, 4 Evolutionary Applications 535-86 (2008).
88. Schindler et al., *supra* note 40.
89. Peter S. Rand et al., *Ecological Interactions Between Wild and Hatchery Salmonids: An Introduction to the Special Issue*, 94 Envtl. Biology Fishes 1-6 (2012).
90. *See* Mark Yuasa, *Bill Introduced by Senator Maria Cantwell Would Help Boost Wild Salmon Runs*, Seattle Times, Aug. 6, 2011, *available at* http://seattletimes.com/html/reeltimenorthwest/2015837836_bill_introduced_by_senator_mar.html (discussing introduction of the Pacific Salmon Stronghold Conservation Act of 2011).