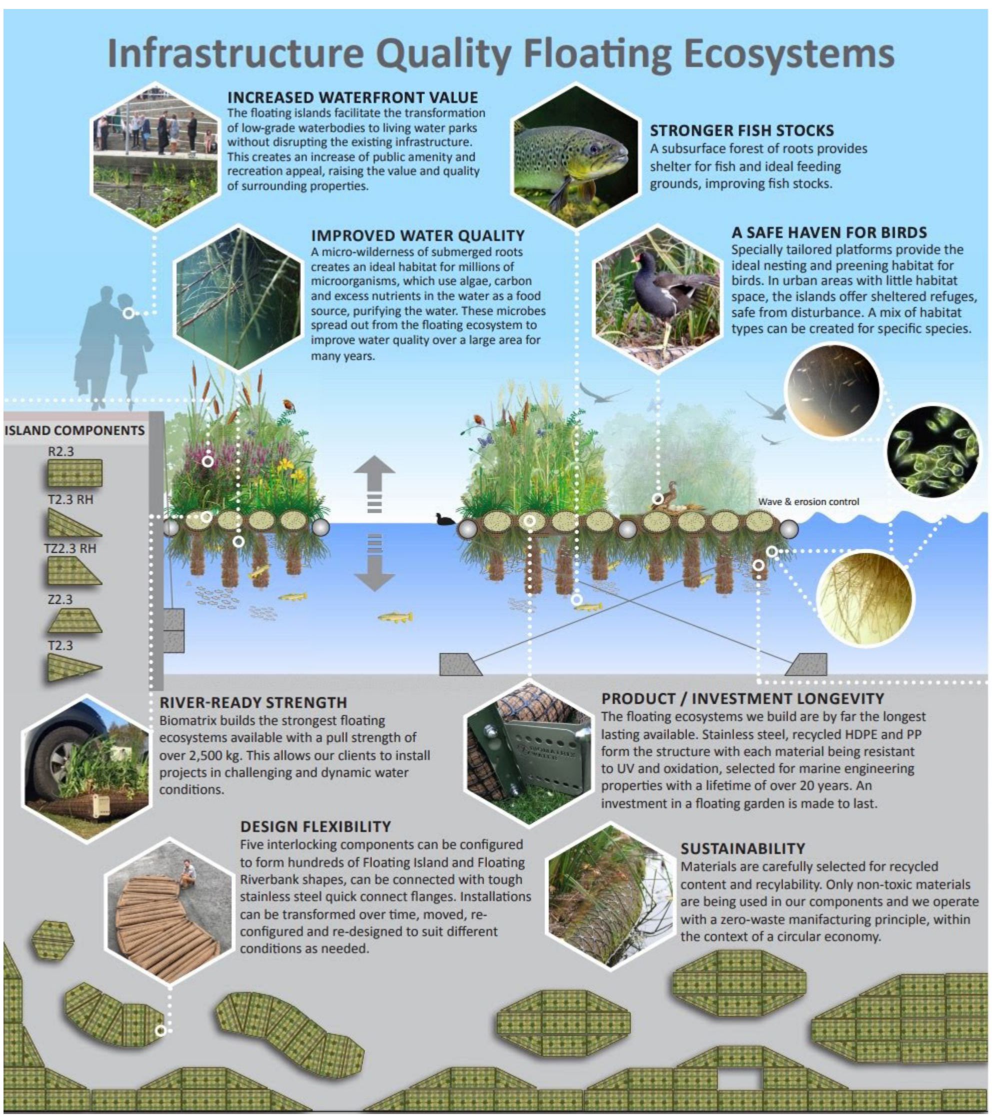
Structural Floating Wetlands: Achieving Ecosystem Services in Heavily Modified Waterbodies

Galen Fulford[1], Biomatrix Water, Moray, Scotland

INTRODUCTION

Floating ecosystems are now being employed in waters and along waterways around the globe. They provide "natural ecosystems" in these heavily modified environments. They beautify urban shorelines, help improve water quality, all while providing habitat for fish, birds, and other wildlife (Figure 1.) In this paper I present some examples of my company's applications of this technology with an emphasis on the ecosystems provided to these urban landscapes. Let's begin by introducing one of our projects in France.

FIGURE 1. Overview of floating ecosystems.



The resounding blast on the conch shell echoes out from beneath the concrete covered section of the River Vilaine, as the floating orchestra emerges from the darkness of the concrete covered river onto the open water channel (Figure 2). The river is walled with tall hard edges of stone, built to protect the city from seasonal floodwaters. After decades of standing as a stark grey channel at the centre of the historic French town of Rennes, the river is beginning to come to life again. The floating orchestra strikes up a resounding tune and moves upstream between the soft green edges of a series of floating riverbanks.

The floating riverbanks curve along both sides of the watercourse supporting rushes, sedges and bulrush (*Juncus, Carex,* and *Scirpus*) and many other species that thrive by absorbing nutrients from the water. Blossoms of devil's bit (*Succisa pratensis*), Valerian (*Valeriana officinalis*) and Joe-Pye weed (*Eutrochium* spp.) provide a new and welcome soft foreground to the stone façade of the Musee des Beaux-Arts. Arrayed along the riverbank and its bridges some 300+ people are gathered for the inauguration of "les jardin flottant." As the music plays, bees sip nectar from the water mint (*Mentha aquatica*), while damselflies zip from stalk to stalk. Fishermen cast their lines along the wetland's sheltering edge overhung with European water-plantain (*Alisma plantago)* and marsh marigold (*Caltha palustris*).

1 Correspondence author contact: galen@biomatrixwater.com.

FIGURE 2. The "Floating Orchestra" in Rennes, France.

FIGURE 3. Floating riverbanks in Rennes.

Today the water is calm, with a gentle steady flow, but a few weeks ago, heavy summer rains turned the river into a fast-flowing channel, with flow velocities of over a meter per second increasing the water level by nearly two meters within a few hours. The floating riverbanks rose to the occasion – as they were engineered to – rising vertically with the water guided by vertical cables anchored to the ancient stone riverbank at the top of the embankment and secured to concrete counter weights below water level (Figure 3). Protecting the floating riverbanks from woody material and other floating debris that accompanies flood waters are deflectors, built into the prow of each ecosystem like the bow of a ship. This new floating ecosystem contains over 6800 native aquatic plants supported by 268 interlocking structural floating ecosystem modules. It was installed over the course of a few weeks with no major engineering work or modifications to the historic city infrastructure, providing the ancient city of Rennes with a living wetland ecosystem, the largest "floating riverbank" of its kind ever constructed.

ACHIEVING EFFECTIVE ECOSYSTEM SERVICES FROM FLOATING WETLANDS

The floating riverbanks of Renne demonstrate how engineered and biological design can soften the hard edges of heavily modified waterways to create a vibrant transition between urban and wild. This kind of floating wetland project provides local governments and urban planners with a template for increasing and enhancing functional green spaces that improve habitat, biodiversity and water quality along with quantifiable ecosystem service benefits.

On a chilly morning this February 2019 on the Canal Saint Martin in Paris, ecosystems enthusiasts arrive and a truck rolls up and out come the building blocks of a new

FIGURE 4. Launching a new ecosystem in Paris.

FIGURE 5. The floating park in Manchester. A spring day beside the Flaming Gardens Bridgewater Classical Concert Hall, Manchester, UK.

structural Floating Ecosystem, ready to launch on the Canal. Submerged fish shelters manufactured by Ecocean are inserted in to the Biomatrix Modules in a few hours, and suddenly Paris has a new wetland ecosystem (Figure 4).

A series of floating ecosystems installed in Hastings (United Kingdom, UK) is actively treating sewage-contaminated runoff and has been key to improving water quality and reopening a public beach. Water treatment by the floating wetlands reduced enterococci by over 80% and E. coli by more than 90%. In Manchester (UK) a series of floating ecosystems on a public pond has been key to reducing chemical oxygen demand (COD) from >40mgl to <10mgl while increasing the water clarity from 0.3m to over a meter (Naismith 2014). In this industrial context floating ecosystems integrated with aeration and circulation work to provide primary water treatment, reducing brewing and distilling wastewater from biological oxygen demand (BOD) of 1263mgl inflow down to 83mgl outflow. From the habitat perspective floating ecosystems provide safe nesting areas for terns, ducks, swans, and loons. On the public well-being side, multiple studies are showing the health benefits which green space, particularly in urban areas, can provide (Figure 5; e.g., Gianferrara and Boshoff 2018).

VERSATILITY OF CONSTRUCTED FLOATING WETLANDS

Fully structural floating wetland ecosystems can now effectively meet rigorous environmental and material challenges, allowing engineered wetland ecosystems to be established on the waterscape in literary thousands of potential locations. They can be constructed along hard-edged brick, steel or concrete sheet pile walls in city centers (Figures 6 and 7). Flooding conditions with fast flows and changing water levels are increasingly the norm due to climate change (Vitousek et al. 2017) and the increase of impervious areas within the watershed (Shuster et al. 2005). In order to effectively establish wetland ecosystems within this dynamic environment, floating wetlands require a support structure which will rise up, sometimes as much as 3-7 meters during flood conditions, and the capacity to deflect debris and surging flood flows. These wetlands can be planted and established to resist the grazing pressures of local and migratory bird species and to be stable enough to walk on for access, pruning and litter collecting purposes.

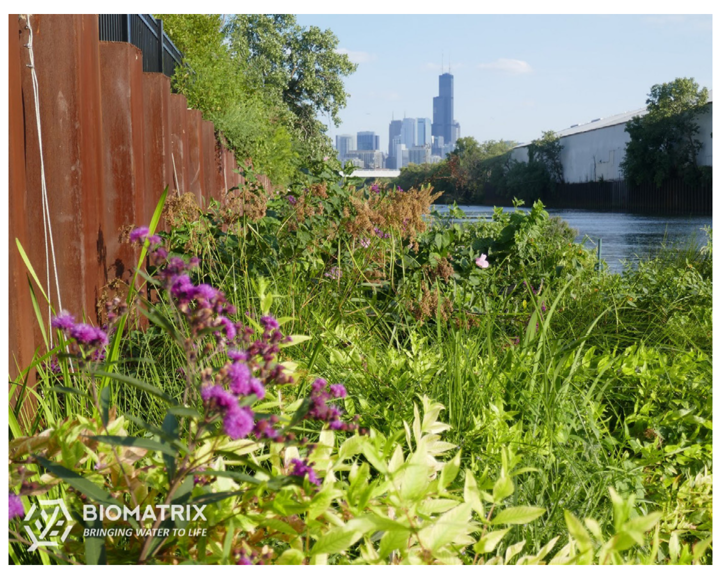
The strength of materials and construction has significantly increased with structural systems providing adjustable rigidity and or pivoting flexibility for wavy sites variable and adjustable across two axes. The latest round of independent destructive testing of Biomatrix Floating Ecosystem modules achieved a tensile interlocking strength over 4 tonnes per module (Figure 1). The tesselated interlocking components make design and installation both robust and user-friendly and over 70% of the new wetland creation projects that Biomatrix designs now being installed by volunteers and local wetland enthusiasts.

There are now multiple technical component options for such systems including modules with submerged gravel beds and others with wetland trees and complex shapes, walkways, open water sections and increased buoyancy areas (Figure 8).

Floating Ecosystems are increasingly being explored for application in areas with heavy pollution loading, and subsequent low dissolved oxygen levels. In this instances, Floating Ecosystems incorporating more advanced features including multiple stages of aeration, circulation, containment membranes, engineered biofilm carriers, and on-board controls.

FIGURE 6. Floating wetland along flood alleviation wall, Northwich.

FIGURE 7. Floating riverbank – part of "Wild Mile Chicago" in the United States. (See https://www.wildmilechicago.org/about-us for additional information.)



These active floating islands can either be powered by mains electricity or by solar power to achieve a water quality management system that captures the sun's energy both through photovoltaic energy generation as well as through photosynthetic energy generation from the plants (Figure 9).

For example, a solar powered "active island reactor" was recently launched in one of the world's most polluted rivers - the Adyar River in Chennai, India. The river water, has a typical BOD over one hundred milligrams per litre and a dissolved oxygen level less than 0.1 mgl (Biomatrix field testing January 2019).

The island integrated 2.2k2 of solar panels bolted to the structure of the floating ecosystem modules.

The 48-volt DC current from the solar panels is converted to 400 volts alternating three-phase current to drive two industrial submersible aerators. The aerators pump the river water into a 35,000-litre submerged membrane containment "tank" for treatment by a combination of aeration, floating wetland root systems, and engineered biofilm media carriers. The internal process can be characterized as solar powered floating ecological version of the well-known integrated fixed film activated sludge (IFAS) process.

24-hour time controls manage energy consumption, influent filling, and aeration stages, while the control system is web-linked via Global System for Mobile communications (GSM). The island floats independency in the river without cables to the shore, whereas real-time monitoring and control can be carried out via GSM from anywhere in the world. The system has a Person Equivalent treatment capacity of 200 PE.

With increased concern for material sustainability, particularly to plastics in the ocean, the utmost attention to the engineering details and use of materials must be applied. Effective floating ecosystems must incorporate a combination of biological as well as long-lasting marine engineered materials, which provide structural integrity to satisfy the rigorous planning requirements of engineers, municipal planning agencies, and navigation and waterway authorities.

Contemporary floating ecosystem construction must incorporate a circular economy approach in its material selection, using materials that can be recycled and which do not contaminate the environment. There is also awareness of some of the impurities which some materials contain, such as polystyrene (Huff and Infante 2011), polyurethane foams, polyvinyl chloride PVC, among others.

CONCLUSION

The development of engineered, reliable floating wetlands, like the Biomatrix Floating Ecosystems, provides new opportunities for wetland scientists, engineers and urban designers to establish wetlands in challenging urban locations. The primary drivers motivating the increased implementation of floating ecosystems include: a) increased urban population and expanding urban areas (United Nations Population Division 2014), b) an increased awareness of the benefits ecosystems can provide to people, and c)

FIGURE 8. Floating wetland walk, Royal Dock, London, England.

significant water quality challenges in urban areas, with stormwater pollution, wastewater overflows, and lack of habitat in heavily modified waterways.

Urban areas are one of the most beneficial locations where such wetlands can be established to mitigate the negative effects of urbanization and climate change. Biomatrix Water has experienced a significant increase in demand for robust structural floating ecosystems in urban areas, with over 800 modules being manufactured in 2018 almost entirely for implemented in the built environment (see http://www.biomatrixwater.com/casestudies/case-studies/ for highlights of some projects). Floating wetlands are now becoming a common feature in the contemporary urban planner and landscape architect's palette of green infrastructure solutions.

Along with "living roofs" and "living walls" now come "living waterways" with their floating wetlands. One important difference from the others is that floating wetlands require no watering or fertilizer while actually improving water quality and producing the myriad other benefits associated with wetland functions (e.g., ranging from supporting pollinators, birds, and butterflies, providing habitat for fish and ducks, and recreational amenities for people).

The World Health Organisation report on Urban Green Space Interventions and Health (WHO 2017) emphasizes the value that contact with natural systems can provide to human wellbeing. This uplift is particularly significant in areas where contact and exposure to natural systems would otherwise be substantially limited – urban areas. The urban ecosystem projects can inspire and integrate cultural and artistic events. For example, the floating ecosystems at Bridgewater Hall in Manchester will have a new symphony composed in their recognition in early 2019 which will be played at the water's edge, thereby bringing together, ecology, art, and urbanism for a unique sound and experience. We will have to wait to report back on how the plants respond to the music. ■

REFERENCES

Gianferrara, E. and J. Boshoff. 2018. Health, Wealth and Happiness – the Multiple Benefits of Green Infrastructure. PERFECT Expert Paper 1. Planning for Environment and Resource efficiency in European Cities and Towns. London, UK. https://www.interregeurope.eu/fileadmin/user_upload/tx_tevprojects/library/file_1535017470.pdf

Huff, J., and P. Infante. 2011. Styrene exposure and risk of cancer. *Mutagenesis* 5: 583-584.

Naismith, D. 2014. Investigation into condition and potential improvements of Boggart Hole Clough water quality. Unpublished Wetland and Wildlife Trust report to Biomatrix Water and the Manchester City Council, Manchester, UK.

Shuster, W., J. Bonta, H. Thurston, E. Warnemuende, and D.R. Smith. 2005. Impacts of impervious surface on watershed hydrology: a review. *Urban Water Journal* 2: 263-275.

United Nations Population Division. 2014. *World Urbanization Prospects: The 2014 Revision.*

Vitousek, S. P.L Barnard, C.H. Fletcher, N. Frazer, L. Erikson and C.D. Storlazzi. 2017. Doubling of coastal flooding frequency within decades due to sea level rise. *Scientific Reports* 7: 1399.

World Health Organization (WHO). 2017. Urban Greenspace Interventions and Health: A Review of Impacts and Effectivness. Available from: http://publichealthwell.ie/node/1098051 [Accessed: 23rd March 2019].

FIGURE 9. Floating island with solar power to drive aeration through submersible Venturi aerators all managed and powered completely onboard the island with GSM remote controls and monitoring.