Context Document: Adding Green Infrastructure Components to Stormwater Management System Ecosystem Service Logic Model

Project: GEMS
http://bit.ly/NI-GEMS

Ecosystem Service Logic Models (ESLMs) are conceptual models that summarize the effects of an intervention, such as a habitat restoration project, on the ecological and social systems. Each model links changes in biophysical systems caused by an intervention to measurable socioeconomic, human well-being, and ecological outcomes. ESLMs assume that the restoration is successful and include all potentially significant outcomes for the intervention; not all outcomes will be relevant to each individual project, depending on location and environmental conditions.

The direction of an outcome (whether the restoration will have a positive or negative influence) often depends on the specific situation or is unclear due to multiple links (arrows) leading into an outcome that may have opposite effects. Thus, language like "increased" or "decreased" is not included in the models. These models are often used to consider management with or without an intervention or to compare different interventions.

This context document includes additional information about the restoration approach and details about some of the relationships in the adding green infrastructure components to stormwater management system ESLM. It also includes a list of the references used to develop the ESLM and names of experts with whom we spoke to refine the model.

Green Infrastructure for Stormwater Management Description and Use in the Gulf of Mexico

Green infrastructure for stormwater management includes a variety of methods designed to slow or retain precipitation where it falls, rather than collecting precipitation and directing it to a centralized pond or treatment system. Green infrastructure for stormwater management includes bioswales, rain gardens, permeable pavements, green roofs, and engineered wetlands; there is currently a lack of consistent terminology and definitions among green infrastructure practitioners and researchers (Prudencio and Null 2018).

Various types of green infrastructure are being used throughout the Gulf of Mexico to manage stormwater runoff. For example, pervious pavement (Circle B Bar Reserve Environmental Educational Center, FL), engineered wetlands (Alligator Creek Stormwater Treatment Trains, FL and Powell Creek Filter Marsh, FL). Usually, green infrastructure is installed in places where stormwater is currently managed with gray infrastructure; therefore, the green infrastructure components complement the existing stormwater system. Green infrastructure is very effective at improving water quality relative to gray infrastructure used in traditional stormwater management, and it can also reduce runoff rates. It is common for multiple types of green infrastructure to be used in combination, based on engineering design for the specific area of implementation. Based on the RESTORE initial funded priorities list and proposed RESTORE projects, most stormwater-oriented projects proposed through the RESTORE process have used gray, not green, infrastructure for stormwater management.

External Factors That Influence Restoration Success

Green infrastructure exists within a larger context of development and any existing stormwater infrastructure. The ability of green infrastructure to improve water quality and reduce runoff rates depends on how the rest of the system is functioning and where the new green infrastructure is located within the system. It is generally more effective (and more cost-effective) to incorporate green infrastructure as part of new low-impact development than to retrofit existing development with green infrastructure.

Model Notes and Clarifications

Technique-Specific Effects on Water Quality: There is a lack of quantitative research comparing the effectiveness of different types of green infrastructure in improving water quality. A recent study summarized the water contaminants that can be best targeted by various types of stormwater infrastructure, including some green infrastructure types, based on a literature review (McFarland et al. 2019). For example, constructed wetlands are very effective in removing natural and synthetic organics, nutrients, heavy metals, and sediment; rain gardens and green roofs are very effective at removing nutrients and sediment; and permeable pavement is very effective at removing sediment. None of the green infrastructure methods is very effective at removing pathogens or pharmaceutical and personal care products (PPCPs), but some are moderately effective (constructed wetlands for pathogens and constructed wetlands, bioswales, rain gardens, and green roofs for PPCPs).

Effects on Existing Gray Stormwater Infrastructure: When green infrastructure reduces the amount of water entering the gray stormwater system, it can reduce the necessary capacity of the gray infrastructure system, potentially saving the community on upgrades. This is especially important in communities with combined sewer stormwater systems, since less stormwater entering these systems means a lower chance of overflows that release raw sewage, but it does not appear that any Gulf coast communities have combined sewer stormwater systems.

Drinking Water Quality and Treatment: Drinking water treatment costs are partly dependent on the initial quality of the water being treated; excess sediment, algal biomass, or algal toxins can require more intensive or different types of treatment. The effect of green stormwater infrastructure on drinking water quality and treatment is location-dependent; when green infrastructure is in a drinking water source watershed, it has the potential to improve initial drinking water quality and influence treatment costs, especially if the pre-project quality of the drinking water source is not ideal.

Air Quality and Carbon Storage Effects: These effects are not included in the ESLM because they depend on relatively large areas of trees to capture air pollutants and sequester carbon (Demuzere et al. 2014). While urban forests are sometimes included in lists of green infrastructure, large areas of trees are not generally used for targeted stormwater management.

Aesthetics: The aesthetic quality of green infrastructure can enhance property values, contribute to a sense of place and connection to the community, and create an environment more conducive to spending time outside. These effects are particularly important in impoverished areas, which

tend to lack green spaces (Dunn 2010). Therefore, the location of green infrastructure projects should be considered through an equity lens.

Nutrition for Communities: This as an expected socioeconomic outcome of restoration projects can come from two sources: changes in fish and shellfish harvesting, and changes in land-based hunting on restoration areas. For this model, the source of nutrition is mainly from changes in fish and shellfish harvesting.

Experts Consulted

Eban Bean, University of Florida

Eve Brantley, Auburn University

Lisa Krimsky, Florida Sea Grant

References

Allaire, M., H. Wu, and U. Lall. 2018. "National Trends in Drinking Water Quality Violations." *PNAS* 115(9): 2078–2083. www.pnas.org/cgi/doi/10.1073/pnas.1719805115.

Center for Neighborhood Technology and American Rivers. 2010. The Value of Green Infrastructure: A Guide to Recognizing Its Economic, Environmental, and Social Benefits. https://www.researchgate.net/publication/274861481_The_Value_of_Green_Infrastructure_A_Guide_to_Recognizing_Its_Economic_Environmental_and_Social_Benefits.

Demuzere, M., K. Orru, O. Heidrich, E. Olazabal, D. Geneletti, H. Orru, et al. 2014. "Mitigating and Adapting to Climate Change: Multi-Functional and Multi-Scale Assessment of Green Urban Infrastructure." *Journal of Environmental Management* 146: 107–115. https://www.sciencedirect.com/science/article/pii/S0301479714003740.

Dunn, A. 2010. "Siting Green Infrastructure: Legal and Policy Solutions to Alleviate Urban Poverty and Promote Healthy Communities." *Boston College Environmental Affairs Law Review* 37(1): 41–66. https://heinonline.org/HOL/Page?handle=hein.journals/bcenv37&collection=journals&id=43&startid=&endid=68.

Glibert, P.M., C.A. Heil, D.T. Rudnick, C.J. Madden, J.N. Boyer, and S.P. Kelly. 2009. "Florida Bay: Water Quality Status and Trends, Historic and Emerging Algal Bloom Problems." *Contributions in Marine Science* 38: 5–17. https://www.researchgate.net/publication/284306213_Florida_Bay_water_quality_status_and_trends_historic_and_emerging_algal_bloom_problems.

Golden, H.E. and N. Hoghooghi. 2018. "Green Infrastructure and Its Catchment-Scale Effects: An Emerging Science." *WIREs Water* 5: e1254. https://onlinelibrary.wiley.com/doi/full/10.1002/wat2.1254.

Hopkins, K.G., J.V. Loperfido, L.S. Craig, G.B. Noe, and D.M. Hogan. 2017. "Comparison of Sediment and Nutrient Export and Runoff Characteristics from Watersheds with Centralized Versus Distributed Stormwater Management." *Journal of Environmental Management* 203: 286–298. https://www.sciencedirect.com/science/article/pii/S0301479717307491?via%3Dihub.

Liu, Y., B.A. Engel, D.C. Flanagan, M.W. Gitau, S.K. McMillan, and I. Chaubey. 2017. "A Review on Effectiveness of Best Management Practices in Improving Hydrology and Water Quality: Needs and Opportunities." *Science of the Total Environment* 601–602: 580–593. https://www.sciencedirect.com/science/article/pii/S0048969717313207.

Mallin, M.A., M.I.H. Turner, M.R. McIver, B.R. Toothman, and H.C. Freeman. 2016. "Significant Reduction of Fecal Bacteria and Suspended Solids Loading by Coastal Best Management Practices." *Journal of Coastal Research* 32(4): 923–931. https://www.jcronline.org/doi/full/10.2112/JCOASTRES-D-15-00195.1.

McFarland, A.R., L. Larsen, K. Yeshitela, A.N. Engida, and N.G. Love. 2019. "Guide for Using Green Infrastructure in Urban Environments for Stormwater Management." *Environmental Science: Water Research & Technology* 4. https://pubs.rsc.org/en/content/articlelanding/2019/EW/C8EW00498F#!divAbstract.

Odefey, J., S. Detwiler, K. Rousseau, A. Trice, R. Blackwell, K. O'Hara, et al. 2012. "Banking on Green: A Look at How Green Infrastructure Can Save Municipalities Money and Provide Economic Benefits Community-Wide." A Joint Report by American Rivers, the Water Environment Federation, the American Society of Landscape Architects, and ECONorthwest. https://www.asla.org/uploadedFiles/CMS/Government_Affairs/Federal_Government_Affairs/Banking%20on%20Green%20HighRes.pdf.

Prudencio, L. and S.E. Null. 2018. "Stormwater Management and Ecosystem Services: A Review." *Environmental Research Letters* 13: 033002. https://doi.org/10.1088/1748-9326/aaa81a.

Sauer, E.P., J.L. VandeWalle, M.J. Bootsma, and S.L. McLellan. 2011. "Detection of the Human Specific Bacteroides Genetic Marker Provides Evidence of Widespread Sewage Contamination of Stormwater in the Urban Environment." *Water Research* 45: 4081-4091. https://www.sciencedirect.com/science/article/pii/S004313541100251X?via%3Dihub.