Context Document: Sewage System Improvements 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 sewage system improvements 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.

Sewage System Improvements Description and Use in the Gulf of Mexico

Sewage system improvements include two specific techniques: converting basic septic systems to either centralized sewer systems or advanced septic systems, and repairing existing sewage system components.

The transition from decentralized, basic septic systems to a centralized sewer system as the method for wastewater treatment is usually done in a spatially defined area. New sewer lines are installed to serve that area, and individual properties are connected to the sewer lines and their existing septic tanks decommissioned. Some Gulf coast communities, especially in Florida, are working to move from septic to sewer to reduce nutrient loads to local water bodies. Septic systems are common in the Gulf of Mexico region. While data on regional rates of septic system failure are not available, it is likely that there are many places where septic to sewer conversions would enhance water quality, especially given the less than ideal conditions for septic systems (high water table, sandy soils) that are likely to be exacerbated as sea level rises. An alternative to septic to sewer conversion is replacing basic septic systems, consisting of a septic tank and soil treatment system, with advanced septic systems that use aerobic treatment or filters to reduce nutrient, pathogen, and total suspended solids in the effluent (Goguen 2018). Certain types of advanced septic systems are much more effective than basic septic systems in areas with high water tables (EGSD 2017).

Repairing leaks or other defects in existing sewage system components is necessary to prevent untreated sewage from moving into surface and groundwater (Staufer et al. 2012). Inflow of surface water and infiltration of groundwater into sewage systems through these defects can cause sanitary sewer system overflows due to excess flow volume; overflows release untreated wastewater into streets and waterways (Beheshti et al. 2015). Infiltration also increases the amount of water treated in wastewater treatment plants, resulting in higher treatment cost (National Small Flows Clearinghouse 1999).

External Factors That Influence Restoration Success

The success of septic to sewer conversion projects depends on property owners' willingness to switch from septic to sewer once the new sewer lines are installed. In many local government projects, the municipality or county pays for the sewer line installation, but the costs of connecting to the sewer line and retiring the septic system are the responsibility of the property owner. Combined with the monthly wastewater fee to use the sewage system (compared to periodic septic system maintenance) and the disruption and unsightliness of construction, many property owners do not want to make the change to sewer. Projects likely need to cover the entire cost of sewer connection and maybe provide additional incentives to ensure adequate buy-in.

The success of sewage system repair is determined by how well the existing system defects were detected (and therefore whether key defects were repaired) and the effectiveness of the repairs. Both identifying system defects and assessing performance of system repairs is difficult due to the size of sewage system, difficulty accessing the sewage infrastructure, and the many factors that influence system performance (e.g., precipitation patterns, number of users) (Staufer et al. 2012).

Model Notes and Clarifications

Disruption from Construction: Implementing sewage system improvements requires extensive construction activities, often in residential areas. This can disrupt daily life and access to businesses through street and sidewalk closures and construction noise. These disruptions are included in the ESLM through the construction disruption node, which is linked to three socioeconomic outcomes (yellow boxes): mental health and psychological well-being, economic activity of local businesses, and social disruption from project. These relationships are all shown with dashed arrows, representing the relatively short-term nature of the disruption relative to the project lifespan.

Effects on Groundwater and Surface Water Quality: Septic systems have high normal discharge rates of nutrients, and when they aren't functioning properly (due to age, lack of regular inspections and maintenance, or site conditions) they contribute even more nutrients and pathogens (Mallin 2013, Reay 2004). Nutrients and pathogens can move into groundwater via percolation, into surface water via runoff (especially in areas with high water tables), and between ground and surface water. Converting septic systems to sewer systems prevents this contamination. Similarly, repairing leaks in existing sewage system components prevents release of untreated sewage into the groundwater system.

Drinking Water Treatment Costs: Both ground and surface water are used as drinking water sources, and high levels of nitrates and pathogens can cause increased treatment costs. This is more likely in surface water sources, which are used in municipal drinking water that is regularly tested and treated as necessary (Jensen et al. 2012). Quality issues in groundwater used for drinking water via private wells are unlikely to be detected and addressed, so costs associated with groundwater treatment are not included as an outcome in the model.

Public Water Closures: Coastal and near-coastal water bodies in the Gulf of Mexico are occasionally closed for public uses, including swimming, recreational fishing, and commercial harvest, when poor water quality threatens public health. Pathogen and algal toxin concentrations exceeding regulatory standards are frequent reasons for these closures. While public water closures protect public health, they impact economic activity associated with the recreational uses and seafood harvest that are limited by the closures. This effect is represented in the ESLM through the links (arrows) from public water closures to the relevant human activity nodes (light blue boxes) and economic activity outcomes (yellow boxes). Public water closures may not be entirely effective at protecting the health of noncommercial (recreational and subsistence) harvesters, especially those who are not local to the area and may not be aware of closures (Reich et al. 2015).

Nitrates, Algae, and Toxins: Algal blooms, including blooms of species that produce harmful toxins, are common occurrences in the Gulf of Mexico. While nutrients are one driving factor of algal growth, and specific criteria for nutrient loads have been set for many water bodies, the relationship between nutrients, algae, and toxins is complex. This is in part due to the many other estuary conditions that influence algal blooms, including inflow, water circulation, stratification, and salinity (Roelke and Pierce 2011), and because the many algal species that exist in the Gulf of Mexico respond differently to nutrients (Davidson et al. 2014). In some cases, blooms of Karenia brevis have been associated with low N:P ratios, but researchers emphasize that "neither the quantity nor the ratio of inorganic nutrients can explain blooms" and that hydrodynamics often override nutrient effects at local scales (Heisler et al. 2008, Davidson et al. 2014). Despite the difficulty in linking nitrates to specific harmful algal blooms, public officials in Florida have identified failing septic systems as a major culprit in recent algae issues and pushed for conversion to sewer (Vock 2019).

Adjacent Habitats: Seagrasses are adversely affected by eutrophication through a variety of mechanisms, including lower light penetration due to high algae growth and direct toxicity of nitrogen compounds (Burkholder et al. 2007). Therefore, reductions in surface water nitrate loading associated with septic to sewer conversion may benefit nearby seagrass beds.

Disease Surveillance (Not Included in Model): There is ongoing work to determine if the SARS-CoV-2 virus can be detected in wastewater samples from WWTPs as a way to monitor the prevalence of COVID-19 at the community level (Sherchan et al. 2020). In theory, transitioning an area from septic to sewer could create an opportunity to monitor rates of COVID-19 (or other diseases) among those residents. Because this is an emerging area of research, the potential for increased disease surveillance is not included in the ESLM.

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

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Participants at GEMS regional workshop (March 2020)

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