Context Document:
Seagrass Restoration 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 seagrass restoration 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.

Seagrass Restoration Description and Use in the Gulf of Mexico

Seagrass restoration projects in the Gulf of Mexico include transplanting seagrass into restoration sites (very common), seeding seagrass (less common, newer technique), and modifying sediment to facilitate seagrass growth (usually used in combination with transplanting or seeding). Many seagrass restoration projects in the Gulf of Mexico, especially in Florida, are done to mitigate seagrass loss due to development, as required by the Clean Water Act (Rezek et al. 2019).

Some projects attempt to benefit seagrass by addressing water quality issues; these are not explicitly included in the ESLM, but if such a project were to increase the quantity or quality of seagrass habitat, many of the impacts and outcomes would likely be similar to those shown in the ESLM.

External Factors That Influence Restoration Success

Seagrass restoration success can be influenced by many external factors, including water quality (causing nutrient stress and lack of light availability), physical damage from boats, and natural causes such as disease and storms. Water quality, especially eutrophication, is a strong predictor of restoration success (van Katwijk et al. 2016). In a global meta-analysis, larger-scale restoration (planting more shoots or seeds) correlated with increased seagrass survival and growth rates, likely due to lower vulnerability to stochastic disturbances and positive density-dependent feedbacks (van Katwijk et al. 2016). Projects aiming to repair localized vessel damage to seagrass beds are generally more successful than those attempting to establish seagrass in a nonvegetated area (Rezek et al. 2019).

Model Notes and Clarifications

Uncertain relationships: Uncertain relationships are shown as dashed links in the ESLM. This indicates that the exact relationship is not well understood or that some characteristic of seagrass restoration makes it unclear whether the relationship will occur as a result of restoration. Specific uncertainties are discussed below.

Seagrass effects on pathogens: The dashed links from "sediment stabilization" and "seagrass quantity or quality" to "pathogen concentration" indicate uncertainty about the mechanism by which seagrasses influence bacteria concentrations and whether the relationship is relevant in the Gulf of Mexico. This is an area of ongoing research; work in Indonesia and Puget Sound has shown lower bacteria concentrations in coral reefs and marine mussels near seagrass meadows compared to nearby nonseagrass areas (Lamb et al. 2017). Because similar effects were seen in two very different areas, it is reasonable to think that the same process may be occurring in the Gulf of Mexico, but this has not been studied directly. The mechanism of this effect has not been identified; possibilities include direct effects of a seagrass-produced biocide on bacteria or indirect effects via seagrass influence on water oxygenation, turbidity, or pH changes. Similarly, the dashed links from "pathogen concentration" to "waterborne disease" and "disease incidence at aquaculture facilities" indicates a lack of knowledge about which pathogens in the Gulf of Mexico are influenced by seagrass, and whether they pose health risks to people or species grown in aquaculture. *Vibrio* species are among those commonly influenced by seagrass in other areas (Lamb et al. 2017); several *Vibrio* species in the Gulf of Mexico are human pathogens, but many more are not.

Wildlife viewing: The dashed link from "seagrass quantity or quality" to "species important to wildlife viewing" reflects concerns about whether the size of seagrass restoration projects is sufficient to support the larger species important to wildlife viewing (manatees, green sea turtles). While these species do use seagrass habitats, seagrass restoration projects are generally on the smaller side and unlikely to draw species into new areas or increase the number of individuals in an area.

Fish populations: Seagrass beds provide shelter and food for fish species, especially for temporary protection (e.g., from predators) or for certain parts of their life history. Seagrass is often described as a critical nursery habitat for fish, but research addressing this role is scarce, and findings about the importance of seagrass for juvenile fish recruitment are mixed. The location of a seagrass project relative to other seagrass beds and other fish habitats can influence survival rates within the seagrass bed and the ability of fish to move from seagrass into habitats needed for other life stages (Gillanders 2007).

Seagrass species effects: There are multiple species of seagrass in the Gulf of Mexico; they differ in their growth rates and physiologies, and therefore may have different outcomes (in type or magnitude). Biodiversity, other species using the seagrass habitat, and carbon storage and sequestration commonly came up as effects that might be influenced by seagrass species. Practical considerations often determine the species used in restoration projects (e.g., *Halodule wrightii* is widely used for transplanting because it's fast growing), so it may not be feasible to select seagrass species based on differences in expected outcomes.

Experts Consulted

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References

Bradley, K. and C. Houser. 2009. "Relative Velocity of Seagrass Blades: Implications for Wave Attenuation in Low-Energy Environments." *Journal of Geophysical Research Earth Surface* 114(F1). https://agupubs.onlinelibrary.wiley.com/doi/epdf/10.1029/2007JF000951.

Christianen, M.J.A., J. van Belzen, P.M.J. Herman, M.M. van Katwijk, L.P.M. Lamers, P.J.M. van Leent, and T.J. Bouma. 2013. "Low-Canopy Seagrass Beds Still Provide Important Coastal Protection Services." *PLOS One* 8(5): e62413. https://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0062413&type=printable.

Duarte, C.M., T. Sintes, and N. Marbá. 2013. "Assessing the CO_2 Capture Potential of Seagrass Restoration Projects." *Journal of Applied Ecology* 50: 1341–1349. https://besjournals.onlinelibrary.wiley.com/doi/pdf/10.1111/1365-2664.12155.

Gillanders, B.M. 2007. "Seagrasses, Fish, and Fisheries." In Larkum, A.W.D., Orth, R.J., and Duarte, C.M., eds. *Seagrasses: Biology, Ecology, and Conservation*. Dordrecht, The Netherlands: Springer. https://link.springer.com/content/pdf/10.1007%2F978-1-4020-2983-7.pdf.

Lamb, J.B., J.A.J.M. van de Water, D.G. Bourne, C. Altier, M.Y. Hein, E.A. Fiorenza, N. Abu, J. Jompa, and C.D. Harvell. 2017. "Seagrass Ecosystems Reduce Exposure to Bacterial Pathogens of Humans, Fishes, and Invertebrates." *Science* 355(6326): 731–733. https://science.sciencemag.org/content/355/6326/731.abstract.

Rezek, R.J., B.T. Furman, R.P. Jung, M.O. Hall, and S.S. Bell. 2019. "Long-Term Performance of Seagrass Restoration Projects in Florida, USA." *Scientific Reports* 9: 15514. https://doi.org/10.1038/s41598-019-51856-9.

Van Katwijk, M.M., A. Thorhaug, N. Marbá, R.J. Orth, C.M. Duarte, G.A. Kendrick, …, and J.J. Verduin. 2015. "Global Analysis of Seagrass Restoration: The Importance of Large-Scale Planting." *Journal of Applied Ecology* 53(2): 567–578. https://besjournals.onlinelibrary.wiley.com/doi/full/10.1111/1365-2664.12562.

Waycott, M., C.M. Duarte, T.J.B. Carruthers, R.J. Orth, W.C. Dennison, S. Olyarnik, …, and S.L. Williams. 2009. "Accelerating Loss of Seagrasses across the Globe Threatens Coastal Ecosystems." *PNAS* 106(30): 12377–12381. https://www.pnas.org/content/106/30/12377.short.

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