Restoring the Cat Islands of Lower Green Bay: Adaptive Restoration Approaches

What is the Cat Island Chain Restoration Project?

The Cat Island chain (Figure 1) once played an important role in protecting both coastal marshes and aquatic vegetation by dampening waves and wind, reducing erosion, and reducing water turbidity caused by sediment resuspension. The islands persisted despite natural fluctuations in lake water levels. However, in the 1970s, a series of spring storms and high water levels, combined with a shoreline hardened by rip rap, caused severe erosion and most of the land above water washed away in about 10 years, along with most of the islands' submerged aquatic beds and emergent marshes. Now, without the protective island chain, marsh vegetation along the mainland coast is also threatened.

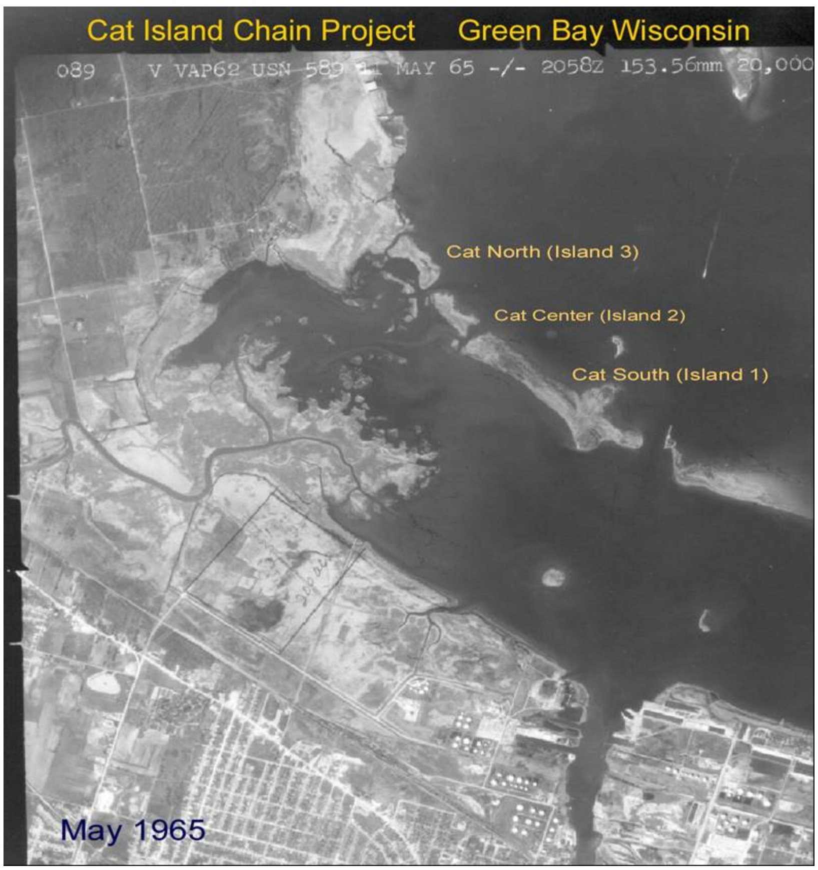

Figure 1. Historical photo (1965) of the Cat Islands. Courtesy of Smith 2005.

The Cat Island Chain Restoration Project has three main goals:

1. Accommodate ship-channel dredging by using clean spoils to rebuild the islands.
2. Create habitat suitable for the re-establishment of aquatic vegetation.
3. Restore habitats on the Cat Islands.

Specific objectives are to restore habitat diversity, reconstruct the island "footprint" (Figures 2-3) using information from the 1960s (Figure 1), improve the spawning and nursery grounds for fish species, restore nesting habitat for birds and manage for target species, provide protection for recovering submerged aquatic plant beds and marshes (Figure 4), and increase public benefits from recreational activities, such as hunting, fishing and wildlife viewing, while also reducing the impacts of human activities and construction.

The islands will be restored in phases.

Restoration will be completed in phases over several years (perhaps 20), including time for the dredged material to settle. Construction and restoration of three islands will proceed within the original island footprint (Figure 1). The spine for the three islands (Figure 2) will be constructed first, in order to provide the leeward side with full protection from waves from the beginning of the project. The westernmost island (Figures 2, 3) will likely be completed first, followed by the middle island and lastly the eastern island. A construction road will be built to provide access to the islands; upon completion, the road will be converted to berms. To decrease erosion on the islands and improve the rate of revegetation, each island will have an eight-foot stone headland on the north side of the island and a four-foot stone dike on the south side. Within the islands the slopes and soil textures will vary, creating a variety of habitats.

The island chain is expected to protect the leeward waters from waves. This will improve growing conditions for submersed and floating aquatic vegetation. The islands and aquatic vegetation should stabilize lake sediments and improve water clarity.

What is unique about the Cat Island Chain restoration project?

The project involves multiple islands of large size to be constructed in a location that will draw public attention and at high cost. The substrate will be bare initially. Because islands will be built within a large lake, they will be subject to wind, waves, ice, and water level variations, all of which will challenge ecosystem development. Some undesirable birds will likely use the site, potentially repelling other species. Desirable birds will need cover, nesting habitat and foods that might need to be introduced. The Cat Island chain historically withstood most of these challenges, but methods of restoring resilience are uncertain.

Residents in the area will experience construction activity for years of restoration. Opinions will likely vary about the benefits and costs of restoration, what the islands should look like and how they should be used after the island chain is completed.

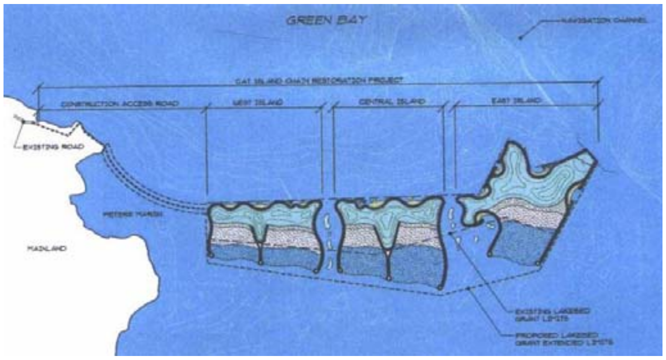

Figure 2. Plan for the restoration of Cat Islands. From Baird et al. (2005).

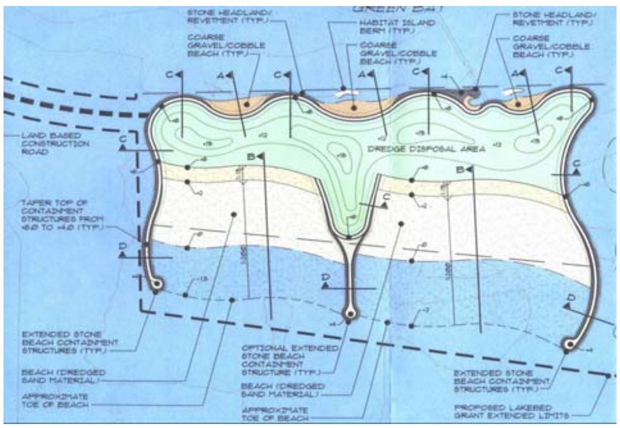

Figure 3. Detailed plan for the westernmost island. From Baird et al. (2005).

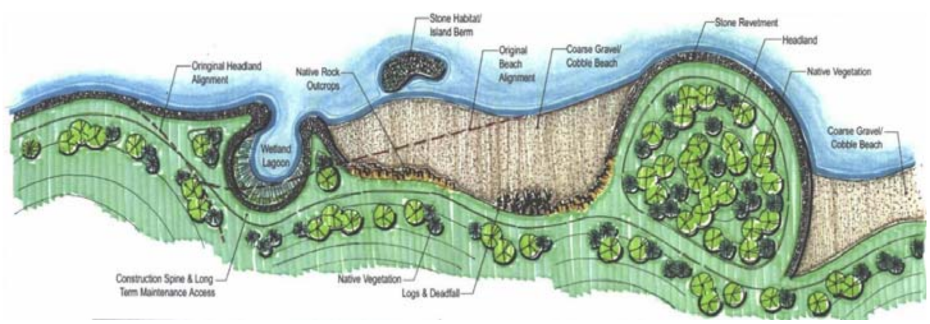

Figure 4. Vegetation and beaches would "soften" the edge of the constructed islands. From Baird et al. (2005).

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are needed to see this picture.

Figure 5. Example of erosion control in Ireland. From Hawe 2005.

What makes the restoration project suitable for an adaptive approach?

The Cat Island chain provides many opportunities for adaptive restoration (Zedler 2005). It is an area that can be both experimented on and revegetated at the same time. Importantly, it is an island chain, and is naturally subdivided for experimental restoration. Very few (if any) entire island chains have been restored, and the Cat Island chain would provide researchers with an excellent opportunity to try different adaptive restoration techniques on each island.

Phased construction makes it possible to begin work adding vegetation to the west island (Figure 3) while others are being constructed. This suits adaptive restoration. Phasing restoration allows researchers to learn what changes may need to be made for a specific area and then to implement these changes in a subsequent phase. The information gained by restoring the first island will help improve restoration of the next two islands.

The many unknowns and the phased construction make it suitable for adaptive restoration. Knowledge gained from experiments in the early phases can guide restoration in subsequent phases.

Unknowns and promising approaches.

Among the unknowns are how best to configure the topography to reduce environmental stress, how to amend the soils to support plants and animals, what vegetation to introduce, how to attract desirable animals and how to reduce threats, such as invasive species. Below we ask these and other questions and indicate approaches that could be tested in an adaptive restoration framework.

•How can topography be modified to increase biodiversity support and ecosystem functioning?

Topographic heterogeneity can ameliorate stressful environmental conditions. Mounds or ridges arranged perpendicular to prevailing winds have been shown to decrease erosion and protect plants from wind stress (Duwel et al., 1994). In a landfill restoration site, mounding had a positive effect on plant performance presumably by alleviating flood stress (Ewing, 2002). Furthermore, human-made pits have been linked to increased soil moisture content and increased organic matter accumulation in arid ecosystems (Boeken and Shackak, 1994, Whisenant et al., 1995). Incorporating pits and mounds in the Cat Island topography could reduce wind stress in this highly exposed site and improve the quality of the dredged soils, better preparing the site to support native vegetation.

The addition of topographic heterogeneity has been referred to as a "bet-hedging" strategy in restoration (Vivian-Smith, 2001). By increasing the diversity of habitats available, we increase our chances of creating suitable conditions for plant growth. Germination and survival of seedlings can be highly associated with specific microsite conditions (Oswald and Neuenschwander, 1993: Jones and del Moral, 2005). Topographic heterogeneity has also been associated with greater diversity, species richness and evenness (Vivian-Smith, 1997). The effects of topographic heterogeneity on plant establishment could be tested on the Cat Islands. After the soil has drained, sets of pits and mounds of varying sizes could be created. These landforms could be seeded and later monitored for germination and establishment. The most successful technique could be incorporated into other sites.

Aboveground obstacles (or traps) can improve vegetation establishment. Obstacles such as logs and rocks are effective at retaining soil, nutrients, and organic matter (including seeds) that may ordinarily be lost to erosion (Whisensant, 1999). In addition to these indirect benefits, rocks and logs directly help plants establish by creating unique germination sites and providing protection (Slocum, 2000). If box elder trees volunteer on site and need to be cut, the wood could be used to encourage fungi, microbial diversity, and invertebrates. Erosion by wind and water will be a problem on the initially barren Cat Islands. Obstacles could be strategically placed in sites that are prone to erosion. Effectiveness of the obstacles could be judged by comparing soil accumulation or erosion and species abundance or richness to adjacent sites without obstacles.

Traps can be installed to reduce wind and waves or to collect organic matter. Dead wood could also serve as a seed trap. Experiments could compare areas with and without traps at different positions, such as distances from the windward edge of the island. In Ireland, sand traps constructed out of branches have been used to control wind erosion on soft soils (Hawe 2005). Traps woven of branches were relatively easy and cheap to construct in Ireland (Figure 5). Brush fences have been tested as a means to establish submersed aquatic vegetation in Green Bay (Robinson 1996); they might be more effective once the island chain offers wave protection.

Windbreaks are rows of trees strategically planted on the windward side of a site, perpendicular to prevailing winds, to provide wind protection. In addition to drastically reducing wind speed, windbreaks alter site conditions by increasing relative humidity, soil and air temperature, and soil moisture (Lal, 1990). It is recommended to plant fast growing species. Taller trees provide protection for greater distances, but smaller trees or shrubs are often used to fill in gaps between tall trees (Whisenant, 1999). Windbreaks could facilitate the vegetation of the Cat Islands by ameliorating site conditions. Native trees and shrubs could be tested for their utility as windbreaks. Some example of species that could be tested as windbreak plants include: cotton wood, box elder, gray dogwood, willow and other species, perhaps including conifers for all-season protection. In addition to providing protection, the rows of trees and shrubs would add diversity and complexity to the Cat Island vegetation.

•How will the hydrological regime (e.g., hydroperiod and water flow patterns) determine distributions of plant and animal communities?

Patterns of co-occurrence and distribution area of plant species are strongly influenced by abiotic factors. For Great Lakes coastal wetlands, fluctuating lake water levels are a key factor that can determine how the floristic patterns develop on the restored Cat Islands. The lake level fluctuations can occur (1) in short terms, as response to individual water rising/ falling events, (2) seasonally, based on the annual fluctuation of the hydrological cycle of the Great Lakes basin, and (3) interannually, reflecting varying precipitation and evaporation within the drainage basins. Among these, the interannual fluctuations are usually the greatest. Lake levels can range from 3.5 to 6.5 feet (1.3-2.5 m; EPA, 2002) from year to year. Given that Lower Green Bay lies near the tension zone, such water level changes could significantly affect the type of vegetation established in the constructed islands' ecosystem. Thus, one cannot predict the elevations at which native plant species should be planted, and an experimental approach would be needed to identify the optimal elevation (water level) at the time of planting.

•How can soil formation be accelerated?

Will microorganisms, plants and animals readily grow in the dredge spoil substrate? Will texture, OM, pH, or redox conditions limit vegetation? To what extend will soil amendments (e.g., conditioners, mulch) be needed? The restoration of ecosystem function is a necessary first step in the establishment of sustainable plant cover on degraded sites (e.g. Bradshaw, 1996; Fierro et al., 1999). *Soil amendments*, defined by Munshower (1994) as any additions to surface soils or overburden before or soon after planting, are often used to jumpstart changes in the rooting medium that provide better conditions for plant growth on degraded soils. These changes include macronutrient or micronutrient additions, increases in organic matter, raising or lowering pH, improved hydrologic properties, reduced erosion, and temperature modification.

Because many types of amendments have been tested in restoration sites, experiments could test the effects of many alternatives that could improve plant growing conditions, choosing from the following:.

Fertilizers are made up of organic matter and/or inorganic chemicals and usually include nitrogen, phosphorus, and potassium. Application rates should be adjusted to the specific species and soil being treated, as fertilization is not necessary when the surface soil contains an adequate amount of organic matter. Vegetation responses to increased nutrient pools often include increased weed production and decreased diversity (e.g. Bedford et al., 1999; Woo and Zedler, 2002).

Organic Amendments. In general, addition of organic matter stimulates development of macro and microorganisms and activates nutrient cycling processes. According to Munshower (1994) Mulches are organic materials applied to the surface of a disturbance after seeding. These include paper, wood residues, straw, and native hay. Organic amendments are applied to a site before seeding and include manure, compost, and sewage sludge. Surface mulches are primarily used to reduce erosion by reducing surface wind velocities, shielding raindrop impact, reducing evaporation, trapping small particles, reducing surface temperatures and preventing soil crusting. However, surface mulches have limited impact on soil structure and nutrient cycling, unless they are incorporated into the soil. Surface mulches are subject to erosion themselves, and thus are often held in place by crimping (least expensive), tackifiers, mats (most expensive), or a combination of the three.

Organic amendments stimulate soil microorganisms by providing carbon and usually nitrogen in readily available forms. Benefits can include improved soil structure, increased infiltration, reduced erosion, lower surface temperatures, and increased seedling establishment and germination. However, nitrogen must be added to soils when certain amendments (especially wood products and straw) or large quantities of organic matter are used to avoid disruption of the C:N ratio. As a general rule, the soil C:N ratio should be maintained between 12:1 and 20:1 (Munshower 1994). Additionally, a study by Zink and Allen (1998) has shown that using organic amendments without nitrogen addition may actually increase the ability of native plants to compete with exotics on degraded lands by reducing nitrogen availability.

Soil amendments can be grown on site using cover crops (see below). Legumes in particular improve degraded soils by increasing soil nitrogen and stimulating the nitrogen cycle. However, legumes have high phosphorus requirements, and thus still likely require fertilization.

Compost is another good soil conditioner, since C:N ratios are almost always less than 20:1, depending on the contents of the original composted material. Composts are low cost and can be used as a fertilizer if the C:N ratio is lower than 12:1 (Munshower 1994). In addition to the benefits of organic amendments listed, compost increases water infiltration and holding capacity, as well as the capacity for cation exchange. The effects of sewage sludge on soils are similar to that of compost, but it also often contains elevated levels of potentially toxic metals. A study by Fierro et al. (1999) produced similar increases in water retention and cation exchange capacities, and accelerated the establishment of seeded tall wheat grass (*Agropyron elongatum*) using paper de-inking sludge supplemented with different rates of nitrogen and phosphorus. Manures do not disrupt the nitrogen balance, but animal wastes contain a high quantity of salt and should be avoided if salinity is a problem.

The effects of each amendment will depend on site conditions, species compositions, and properties of the amendments themselves. Straw and hay contain seeds and might inadvertently introduce weedy species. Prairie or meadow hay is likely to contain seeds of both native and unwanted species. A study by O'Brien and Zedler (in press) used kelp compost to increase vegetation establishment in a southern California salt marsh, including increased cordgrass *(Spartina foliosa)* biomass, while another study by Gibson et al. (1994) showed that amendments using straw and alfalfa (with or without added nitrogen) lost nitrogen quickly, and thus had limited impact on the growth of cordgrass *(Spartina foliosa).*

Another way to accelerate natural succession is to salvage soil from local, remnant wetlands that are earmarked and permitted to be developed. Soil can be salvaged from a site that contains desirable plant species and imported to a restoration site to increase plant cover and species richness (see Brown and Bedford 1997). In a freshwater wetland restoration of an abandoned sand mine in South Brunswick, New Jersey, the imported wetland seed bank was found to be the major contributor to species richness and plant density (Vivian-Smith and Handel, 1996). Non-native and invasive plants may be part of the seed bank therefore monitoring and invasive plant removal is recommended.

• Which plant species will colonize the islands?

Wisconsin vegetation. The *Vegetation of Wisconsin* (Curtis 1959) is the obvious source for lists of species that make up the state's naturally-occurring plant communities. Information on beach, wetland, shrub carr, and some upland vegetation types would be useful in selecting target assemblages. Here, we highlight concepts in the restoration ecology literature that are especially relevant to vegetating bare sites.

Pioneer plants are the first stage of the developing plant community. These plants act as 'autogenic ecosystem engineers', because the plant structures themselves alter the environmental conditions through trapping sediment and organic debris (Edwards et al. 1999). Seed traps could identify the plant species that will naturally return to the Islands (Wiede et al. 2005).

Cover crops could be planted to stabilize soil, improve soil structure and water penetration, improve establishment conditions by maintaining soil moisture and adding nutrients and organic matter; they can reduce establishment by invasive species (Whisenant 1999; Munshower 1993; Altieri et al. 2005). Appropriate species are ones that quickly produce a large root system and abundant above ground biomass. They are typically tilled into the soil before they set seed. The Cat Island restoration project could benefit from planting cover crops if there is a lag between the time the soil drains and planting begins or if the soils are low in organic matter or nitrogen. Examples of cover crops that would be appropriate on this site are winter rye and Canadian rye. The use of nitrogen-fixing legumes as cover crops on degraded soils is common, as they help to increase soil nitrogen and stimulate the nitrogen cycle. However, legumes might require fertilization with phosphorus.

Nurse plants are used to protect other plants from wind or intense sunlight.

Examples of species that can buffer wave action. The American lotus (*Nemujmbo lutea)* is a rapidly growing floating-leaved aquatic plant that buffers wave action (R. Hefty, Madison City Parks, pers. comm.). Hard-stemmed bulrush (*Schoenoplectus acutus*) is an important clonal emergent plant that reproduces vegetatively. It is a target species due to its ability to tolerate wave action and slow erosion.

Cluster plantings. Planting seedlings in tight clusters can facilitate vegetation development, because each individual helps buffer the others from the effects of wind and extreme temperatures; in addition, a collection of plants can slow erosion or even collect sediments to create mounds. O'Brien and Zedler (in press) advocate planting clusters in stressful sites; others advocate planting diverse assemblages (Callaway et al. 2003), nurse plants, and/or cover crops (Holmgren et al. 1997).

Attracting birds to disperse seeds. Handel (1997) and Vivian-Smith and Handel (1996) recommend installing bird perches for birds to bring in seeds. Constructed bird perches have been shown to increase the amount of seed arriving to a site. In a forest restoration site, 150 times more seeds fell in sites with constructed perches compared to sites without perches (McClanahan and Wolfe, 1993). The Cat Islands could be propagule-limited. The inclusion of perches in the restoration plan could alleviate this problem. Perches can be created in a variety of ways. For example, erecting dead trees with a pole-driving machine (McClanahan and Wolfe, 1993) or planting clumps of trees and shrubs (Robinson and Handel, 1993). However, caution should be used before widely implementing this procedure on the Cat Islands. Experiments should be performed to investigate what types of birds would visit these perches, which types of seed they disperse. If it appears that the birds themselves or the seeds they are dispersing pose any threats to the restoration, this practice should be avoided.

Controlling vegetation composition. Herbicide can be applied to surrounding undesirable vegetation to encourage the growth of desirable seedlings. Using a combination of seedling shelters and herbicide is most effective for seedling growth and survival (Sweeney et al. 2002).

On-site nurseries. Because a large area will likely need to be planted, we suggest establishing on-site nurseries to provide seed. Small plantings can then produce propagules for larger plantings, which can produce seeds and other propagules for large-scale plantings.

Planting assemblages of native species. Information in Curtis (1959) can suggest assemblages of species to be planted and appropriate locations/habitats for their introduction. We suggest planting specie-rich assemblages in clusters. One can then compare survival, growth, and structure of the various assemblages with different soil amendments and/or different application rates. Similar approaches work in the aquatic zone. Russ Hefty (Madison City Parks, pers. comm. 2005) is using 8x8-ft herbivore exclosures to create wave buffers just upstream of Lake Mendota, where a 1.5-mile fetch is eroding sedge meadows. He introduces plantings that he grows in wire mesh baskets, anchors the large plants in situ, and allows them to expand vegetatively. They quickly grown beyond their exclosures, where herbivory becomes a problem, but waves are buffered. He also uses wire fence "tubes" anchored to bottom to protect rhizomes and tubers from herbivores. In another trail, he laid farm fencing on the substrate to deter carp. All of these techniques are ripe for experimental analysis.

Detering herbivores by shielding plants. Seedling shelters can be used to protect seedlings from herbivory. Experiments could compare plantings with and without tree tubes or fencing.

•Additional questions

Many more questions will arise before and during restoration. Which animals will arrive on their own, and which will take up residency? What threats will need to be abated? Will toxic materials accumulate? What disturbances will inhibit vegetation establishment (debris, wind, waves, vandals)? Which invasive plants and animals will be most problematic? Can we scale up restoration practices, since some procedures work well at small scales but not at large scales? The Cat Islands offer unique opportunities to test restoration measures at multiple spatial and temporal scales.

Making the project experimental

It is not always obvious how to set up restoration as experiments to "learn while restoring." The following six steps are guidelines:

•Choose treatments to compare. Treatments are variables that are manipulated by the experimenter. An example might be to test the ability of increased habitat heterogeneity to aid in establishing more diverse vegetation. Creating small pits might increase establishment and diversity of desired plant species, and pits of different sizes and depths could be compared.

•Replicate the treatments. Replication is the repetition of experimental treatments, which reduces variability in experimental results, increasing their significance and the confidence with which conclusions can be drawn from the experiment. Example: plots with equal size pits could be created in many different locations.

•Measure key responses. Response variables are quantities that vary in a way that is related to the treatment manipulation. Example: Plant biomass could be the response variable used to measure the effectiveness of pit creation treatments.

•Monitor outcomes. Monitoring is the process of checking, observing, or keeping track of something for a specific period of time or at specified intervals. It is critical in assessing changes at a location to determine future actions to be taken. Example: Monitoring vegetation in artificially created pits allows for analysis of changes over time.

•Interpret results. What effect did the treatments have based on response variables? Were the results statistically significant?

•Use to design next phase: How can the knowledge gained from an experiment be used to design the next phase of experiments? What new questions were raised?

Conclusion:

The restoration of the Cat Island chain offers many opportunities to learn while restoring. Its large scale, plans for multiple islands, long time frame, and phased construction plan make the project highly amenable to an adaptive restoration approach (cf. Zedler 2005). Also, the severe site conditions (bare substrate, wind and waves) and the long list of unknowns suggest the need to "learn while restoring. Hence we suggest that attempts to vegetate the site and attract animals be conducted in phased experiments, with knowledge gained from each phase used to design the next phase, asking new questions and testing new alternatives in subsequent phases. Because the site will be bare and severe, we give highest priority to testing methods that will make the environmental conditions more benign (suitable for plant growth). These are increasing the topographic heterogeneity of the dredge-spoil island surfaces and decreasing wave force in the area planned to support submersed aquatic vegetation. As methods are tested and evaluated, students and other researchers will simultaneously advance both the practice and science of restoration.

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