Integrating Wetland Restoration with Global Change Ecology

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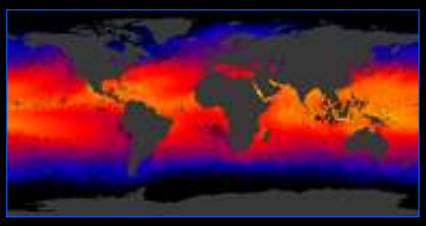
This morning my plan is to provide a more general presentation and take a more global view of restoration. In particular I would like to explore the idea of wetland restoration withing the context of a changing environment.

The earth is a dynamic and ever-changing place. Understanding and predicting how biophysical changes in the global system will affect the Earth's ecosystems and the goods and services they provide is vital to establishing sound environmental policies at local,national, and international levels..

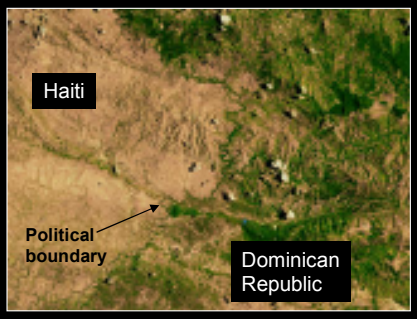
Humans are transforming the Earth at an unprecedented rate and the resultant changes in goods and services provided by natural ecosystems will have far-reaching consequences at global, regional and local scales. Understanding and predicting how biophysical changes will affect the Earth's ecosystems is vital to establishing sound environmental policies at local, national, and international levels.

What is global change ecology?

The study of how alterations in land cover, biodiversity, climate, and atmospheric composition influence the complex interactions among species and ecosystem processes at local, regional and global scales.



Sea Surface Temperature
(Visible Earth, NASA)



Haitian deforestation (Visible Earth, NASA)

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Global changes include natural phenomena such as latitudinal and seasonal variation in SST, but also anthropogenic alterations to terrestrial land cover and other activities that affect climate and biogeochemical cycles. For example—this photo shows the political boundary between the countries of Haiti and the Dominican Republic, dramatically illustrating differences in deforestation rates.

What are some global change factors relevant to wetland ecosystems and associated ecological concepts?

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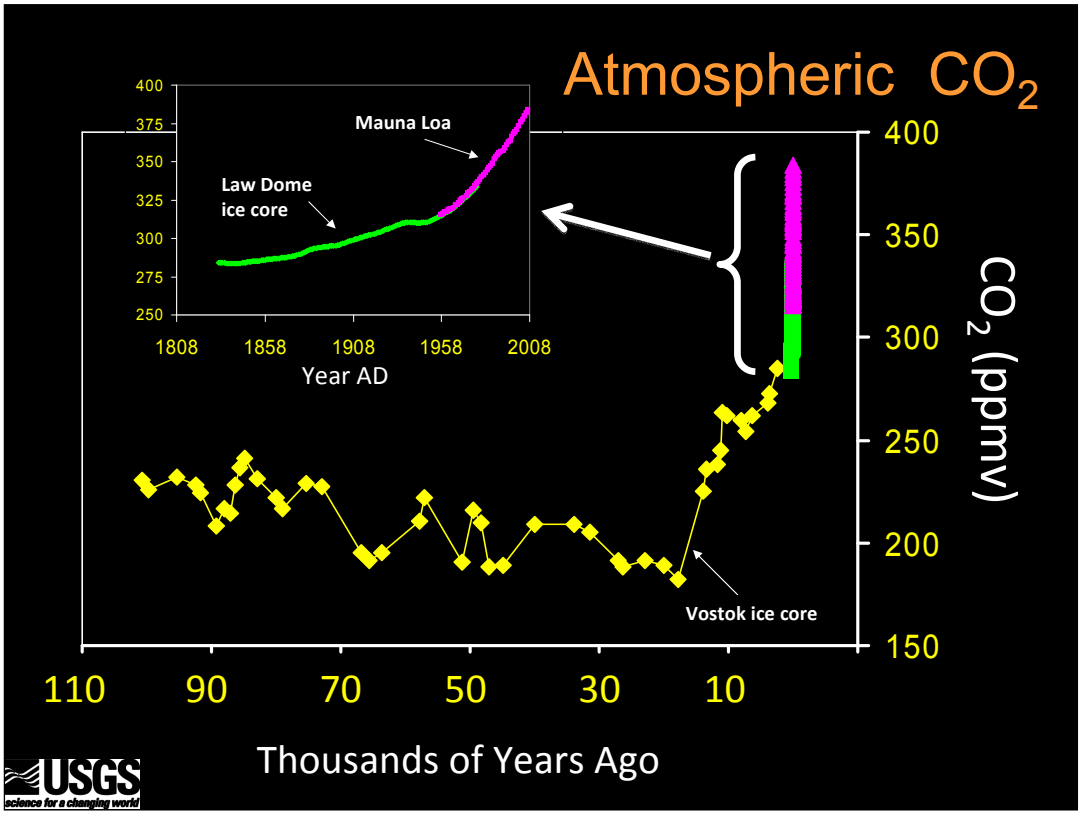
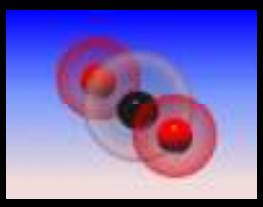
I'll next briefly review some global change factors relevant to coastal ecosystems.



Elevated CO2--concentrations have increased from 280 ppm in preindustrial times to 384 ppm today and will continue to rise well into the future even if we stop all activities contributing to it today.

Atmospheric CO_2



Corkscrew Swamp, Florida USA

Ecological Concepts: Plant competition, species diversity, plant-herbivore interactions

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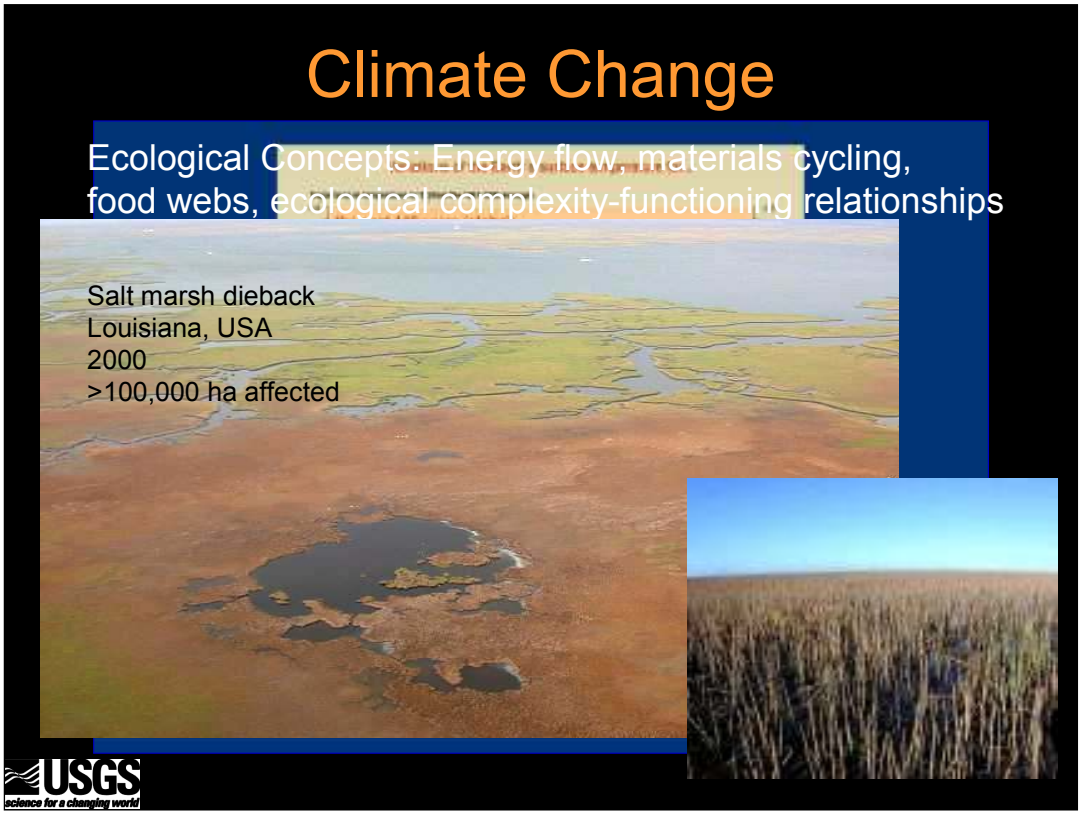
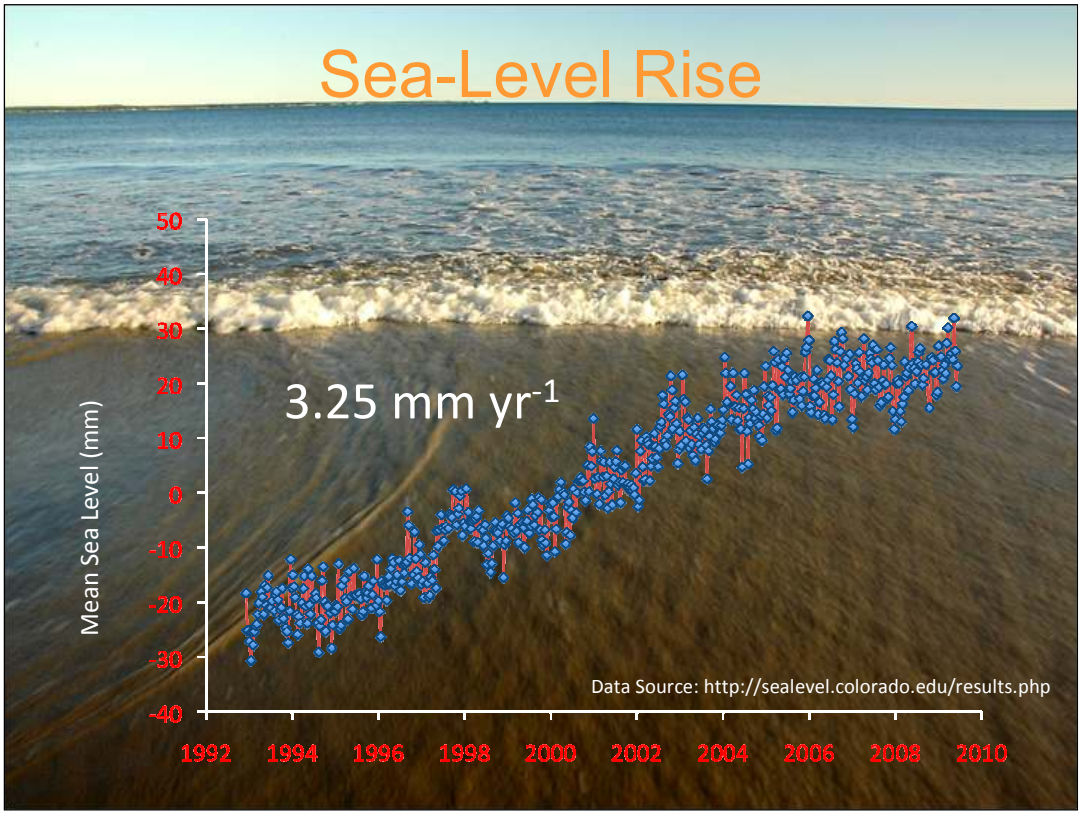
CO2 is not only a greenhouse gas, but has a direct effect on plant growth and plant tissue chemistry. An example of an ecological concept that is relevant to CO2 is plant competition and conditions for species exclusion. Plant species respond differentially to CO2 enrichment and relative competitive ability may be altered leading to shifts in community dominance. Changes in plant tissue chemistry could alter plant-herbivore interactions



Climate change is another global driver refering to changes in temperature and precipitation patterns. Such global drivers of change will have a direct effect on ecological complexity, which will influence ecosystem functioning.



Sea-level rise another global change factor that is important to coastal wetlands and other lowlying areas due to increases in inundation and saltwater intrusion.

Sea-Level Rise

Ecological Concepts: habitat stability, plant-soil interactions

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Some concepts related to slr include habitat stability and plant-soil interactions. For example some coastal wetlands have been shown to self-adjust to slr by accumulating organic matter in addition to mineral accretion on the soil surface. For some coastal wetlands, the presence of the vegetation is key to allowing those systems to keep up with slr.

Storms and Hurricanes

Hurricane Katrina (Visible Earth, NASA)

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Another factor important for coastal wetlands is periodic disturbance by hurricanes or typhoons. With global warming and increases in sst, the intensity of storms will increase.

Storms and Hurricanes

Ecological Concepts:
Disturbance dynamics, succession, life-history strategies, ecological adaptation

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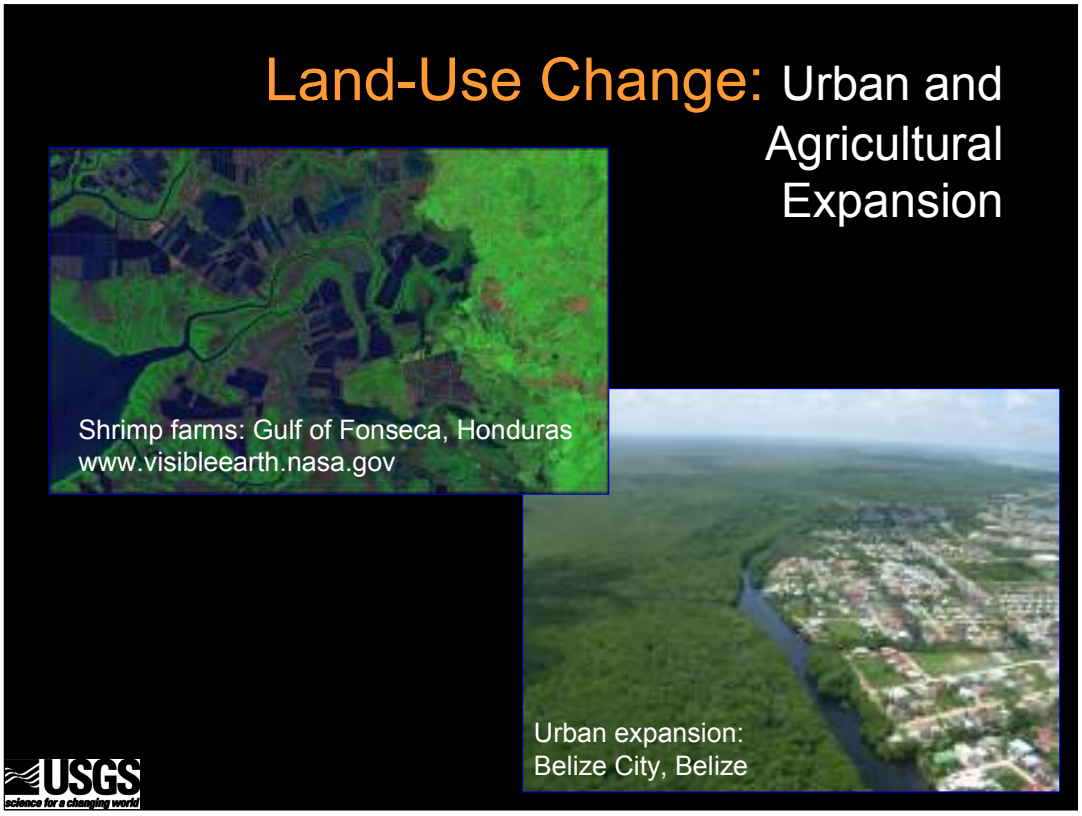
Ecological concepts include disturbance theory and succession, life-history strategies, and ecological adaptation



Human activities that have local impacts, but are significant when considered on a global scale include land-use change such as urban and agricultural expansion. The photo in the lower right shows a mangrove forest that has been cleared for expansion of Belize City. The upper photo shows huge areas of coast converted to shrimp ponds on the Pacific coast of Honduras.

Land-Use Change:
Altered Hydrology

The Netherlands dike system
(Visible Earth, NASA)

Mosquito ditching: Southeast Florida
(www.googleearth.com)

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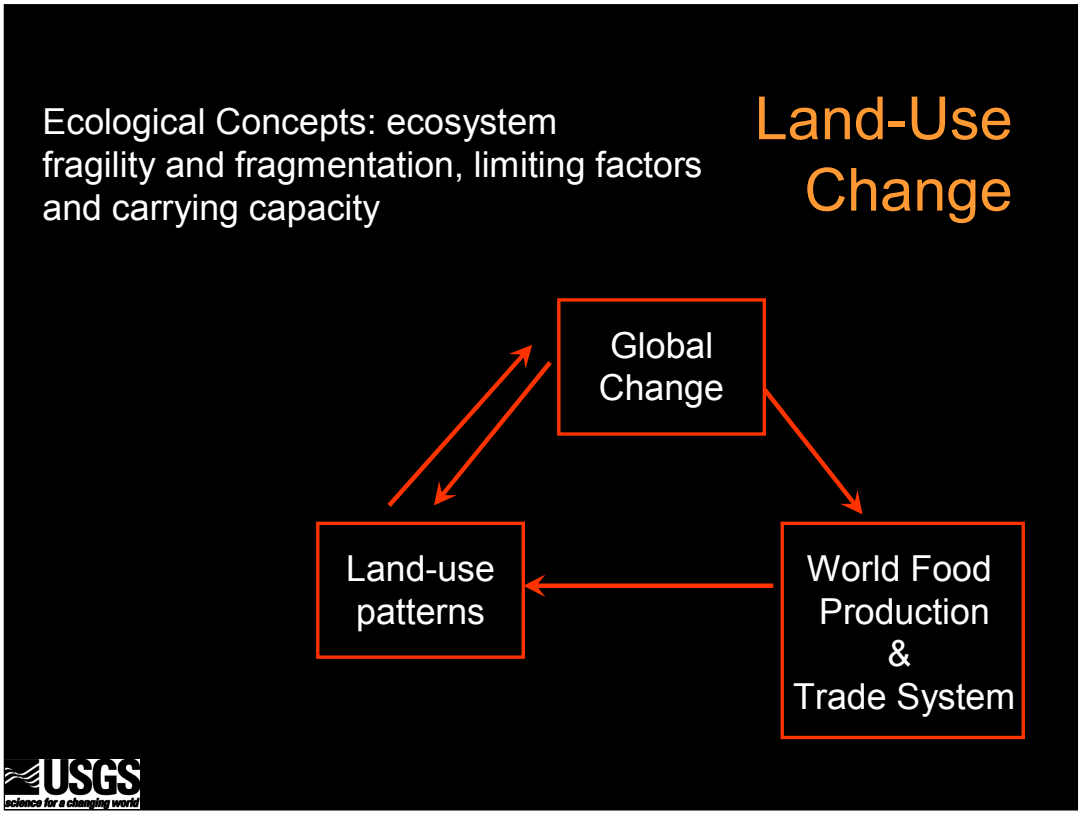
Hydrological modification is a common practice worldwide in wetlands to control for flooding for example or mosquito abatement, and is a major concern because it often eliminates flood pulsing and restricts sediment delivery, processes vital to the health of coastal ecosystems.



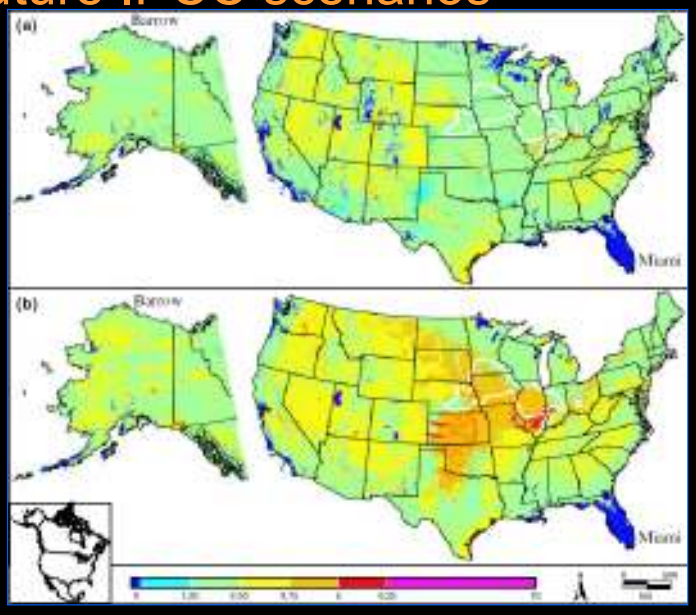
Some ecological concepts related to land-use change include ….Global changes in climate, sea-level, and storm activity will affect land-use patterns in the coastal zone both from direct effects as well as through changes in the world food production and trade system in response to changing environmental conditions.

So now that we have in mind some global drivers and ecological concepts, why should global change be considered in planning restoration projects? The goal of restoration is to rehabilitate degraded ecosystems to some target condition, which is often the historical, pre-disturbance state. However, future changes in global weather patterns, climate regimes, atmospheric CO2 concentrations, and land-use may render such a goal unrealistic. Increasing evidence suggests that such changes are already altering natural ecosystems, so that identifying an appropriate goal for restoration becomes increasingly difficult.

Difference between current conditions and future IPCC scenarios

IPCC Scenario B2 (moderate greenhouse gas increases)

IPCC Scenario A2 (rapid greenhouse gas increases)



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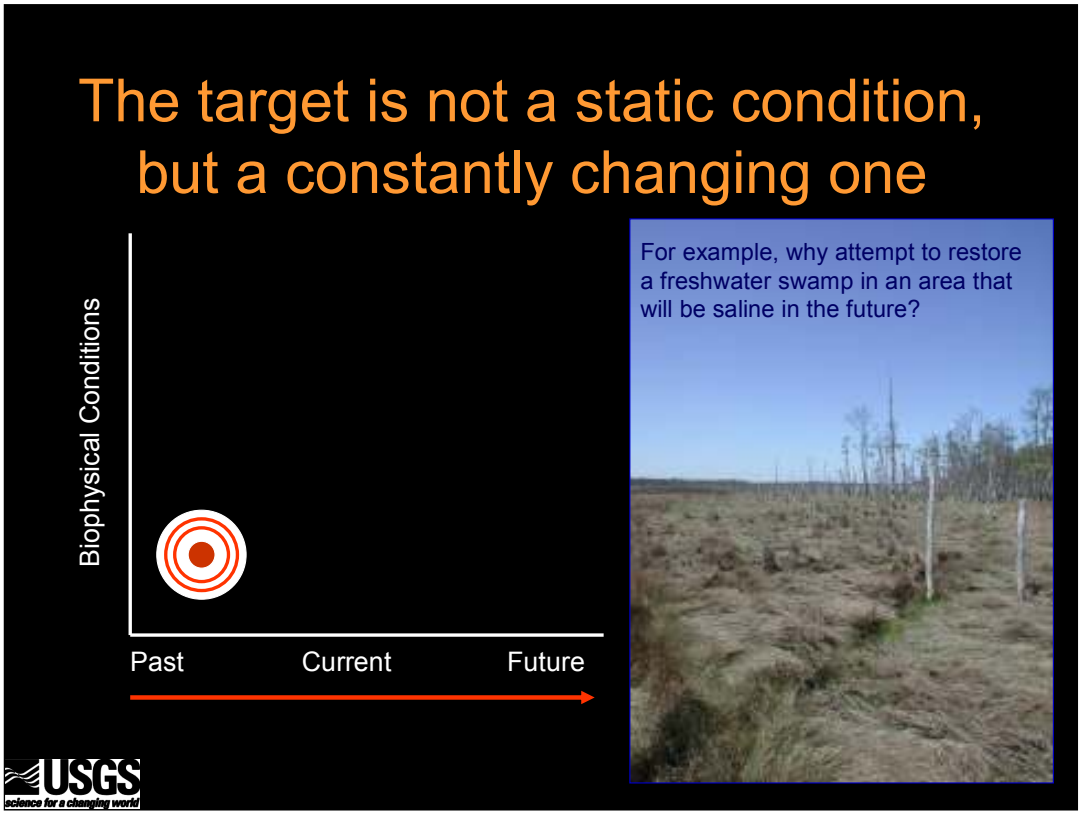
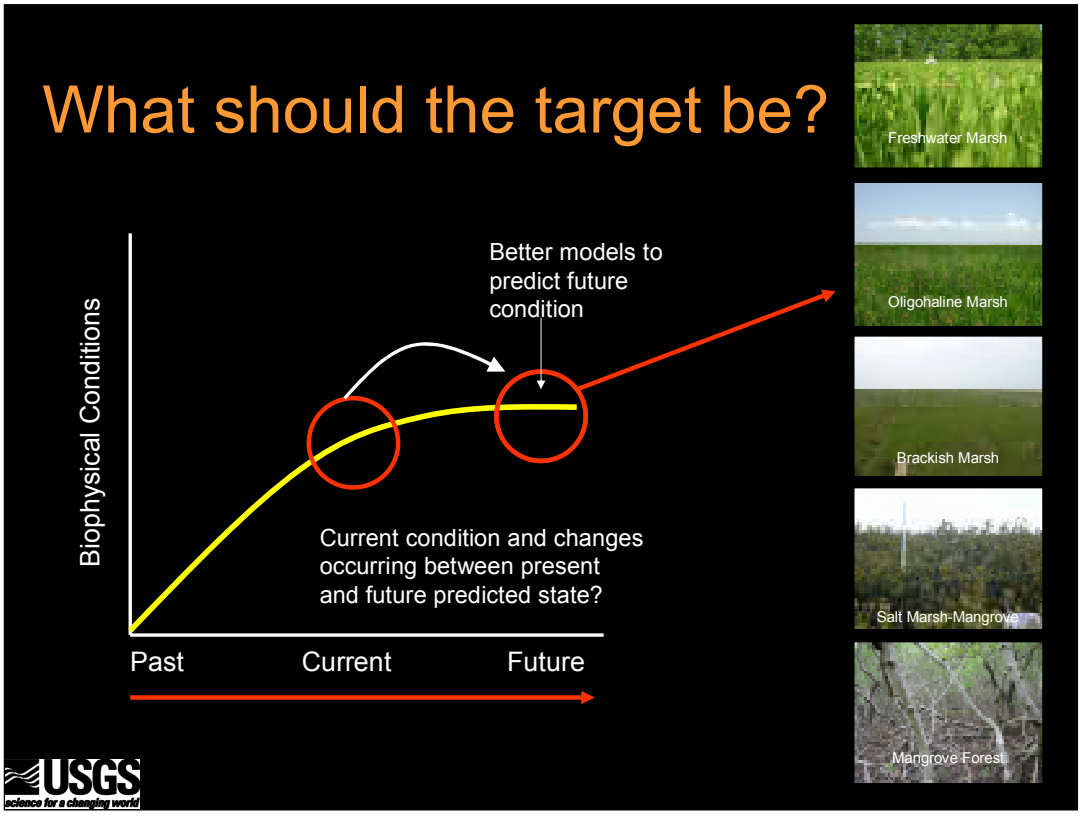
Saxon et al. (2005)

Recent work suggests that under future scenarios of greenhouse gas emissions, half of the area in the US could not be sustained in its historic, pre-settlement conditions of precipitation, temperature, and soils (Saxon et al. 2005).



By considering restoration in the context of global change, we see that the target is not a static condition, but a constantly changing one. This concept can be restated with a specific example:

This does not mean that historical or reference sites are not important, just that they should not be the only consideration in restoration planning.



So what should the target be? One approach is to predict what the environmental conditions will be at some point in the future, say 10 years from now and design for that anticipated state. First, we must accurately predict what those conditions will be, requiring much better models than we now possess. Also, how do we restore for a future state under current conditions and also deal with the changes occurring between present and the future state?

Another Approach

……is to target ecosystem attributes that directly address the dynamic nature of the situation, i.e., design for resilience so that the system can persist in the face of global change (Harris et al. 2006).

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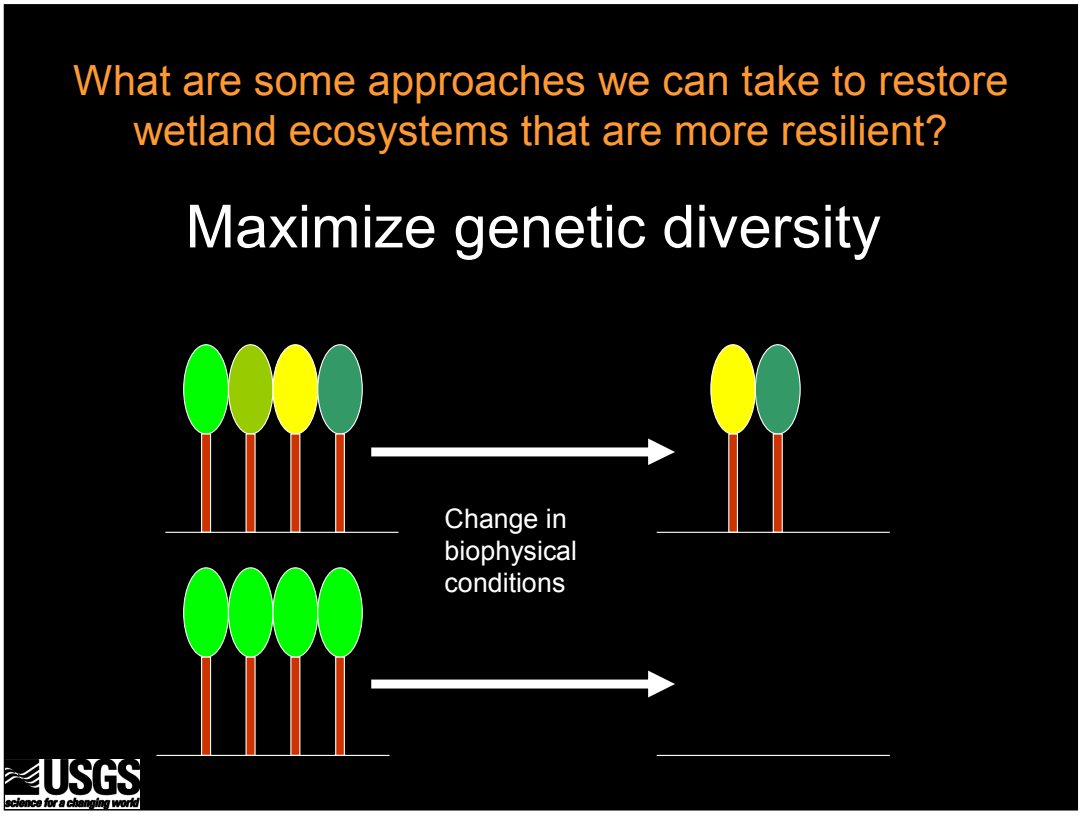
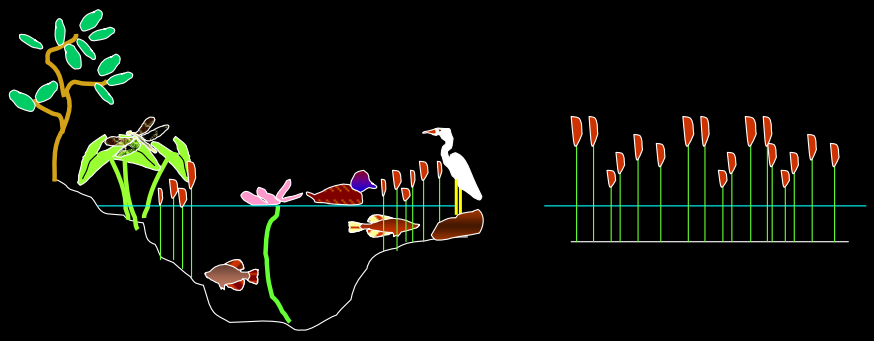
Another approach is to target ecosystem attributes that directly address the dynamic nature of the situation, i.e., design for resilience so that the system can persist In the face of global, regional, and local changes.



What are some approaches that will promote resilience in the face of global change?One key to ensuring resilience of an ecosystem is genetic diversity, both interspecific and intraspecific. Clearly, a more genetically diverse community will be better buffered against environmental change than one dominated by a single genotype. However, this is an area where many questions remain unanswered.

What are some approaches we can take to restore wetland ecosystems that are more resilient?

Maximize spatial heterogeneity in resources and stress factors



Heterogeneous

Homogeneous

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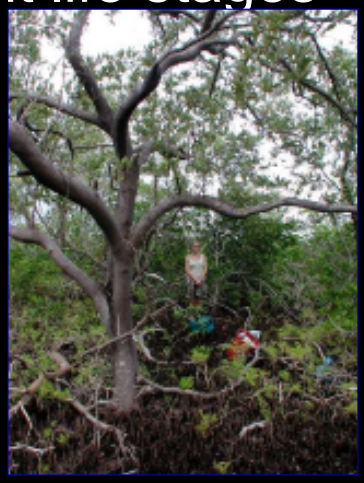
To promote and sustain biodiversity, the environment must be sufficiently diverse to support If site conditions are homogeneous, then one species may outcompete all others and dominate the system, rendering it more vulnerable in the event the environment changes in the future.

What are some approaches we can take to restore wetland ecosystems that are more resilient?

Maximize spatial heterogeneity to support different life stages



Mangrove forest, Belize

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Plant and animal species also have different requirements at different life stages. Spatial heterogeneity can be used to ensure that all conditions are present to support sustainability of the component species.

What are some approaches we can take to restore wetland ecosystems that are more resilient?

Use information about historical and geological change to guide restoration

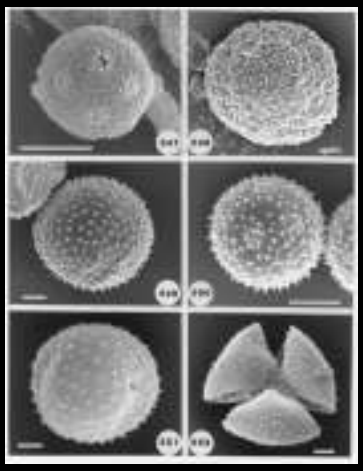
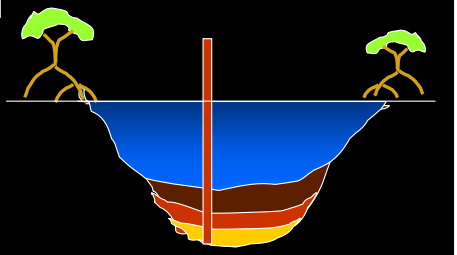


Photo: www.pollen.usda.gov



Use information about historical and geological change to guide restoration: Instead of just using static states as a goal for restoration, paleoreconstructions can be used to develop models of how wetland systems responded in the past to changes in the biophysical regime and use them to guide restoration plans for future scenarios.

What are some approaches we can take to restore wetland ecosystems that are more resilient?

Plan with a landscape perspective, rather than just for site-specific conditions.

- Anticipate species migration and spatial shifts of natural and human systems (e.g. identify barriers to inland retreat of marshes)
- Anticipate fragmentation and plan ways to maintain connectivity between fragmented sections of a restored system and with adjacent ecosystems
- Anticipate future changes in the surrounding landscape controlling movement of nutrients, sediment, and pollutants into the restored system

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Everglades
Image: NASA

Plan with a landscape perspective, rather than just for site-specific conditions:

- Plan for species migration and spatial shifts in position of the system (e.g., identify barriers to inland retreat of marshes);
- Anticipate fragmentation and ways to maintain connectivity between fragmented sections of a restored system;
- Anticipate future changes in surrounding landscape controlling movement of nutrients, sediment, and pollutants into the restored system.

What are some approaches we can take to restore wetland ecosystems that are more resilient?

Use multiple restoration techniques within a single larger project.

1. Information for future efforts

2. Increase overall resilience of the restored system

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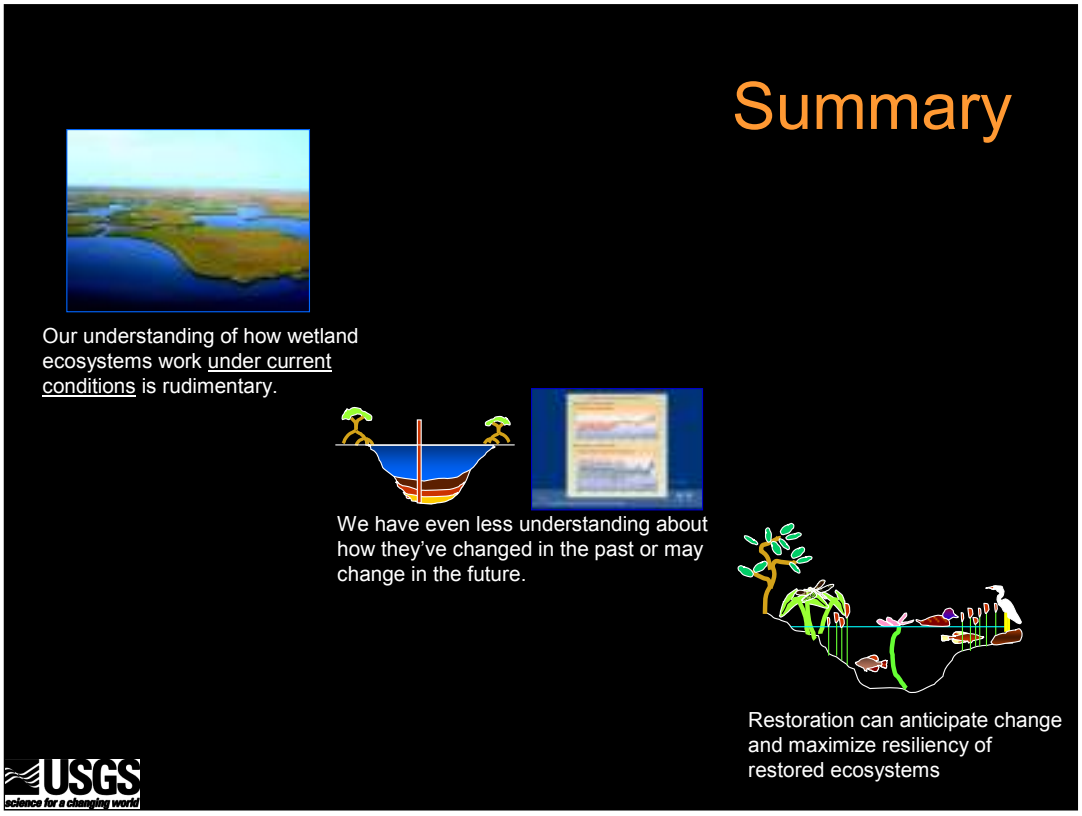
Photos: Courtesy of Mike Materne

Use multiple restoration techniques within a single larger project. The multiple outcomes that will result will not only provide valuable information for future restoration efforts, but will increase overall system resilience because the subsystems created by each approach may differentially respond to future change and disturbance.



Our understanding of how coastal ecosystems work under current conditions is rudimentary. We have even less understanding about how they may change in the future and what effects these changes will have on ecosystem goods and services. Restoration projects can be designed to anticipate changes in the environment and to maximize the resiliency of restored systems, leading to ecosystems that are better buffered against future changes.

Information Gaps

- We need to better understand what controls the resilience of wetland ecosystems.
- We need more information on feedback relationships, e.g., between the biological (plant) communities and marsh accretionary processes.
- We need more information on controls of species geographical distributions (temperature sensitivity, dispersal barriers) and likely changes in species ranges under future climate scenarios.

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Information Gaps

- We need more information on species-specific responses to factors associated with global change (flooding, salinity, drought, temperature, physical disturbance, nutrients).
- We need a better understanding of the linkages between ecological complexity and ecosystem functioning.
- We need more information about the linkage between foundation species and ecosystem services.

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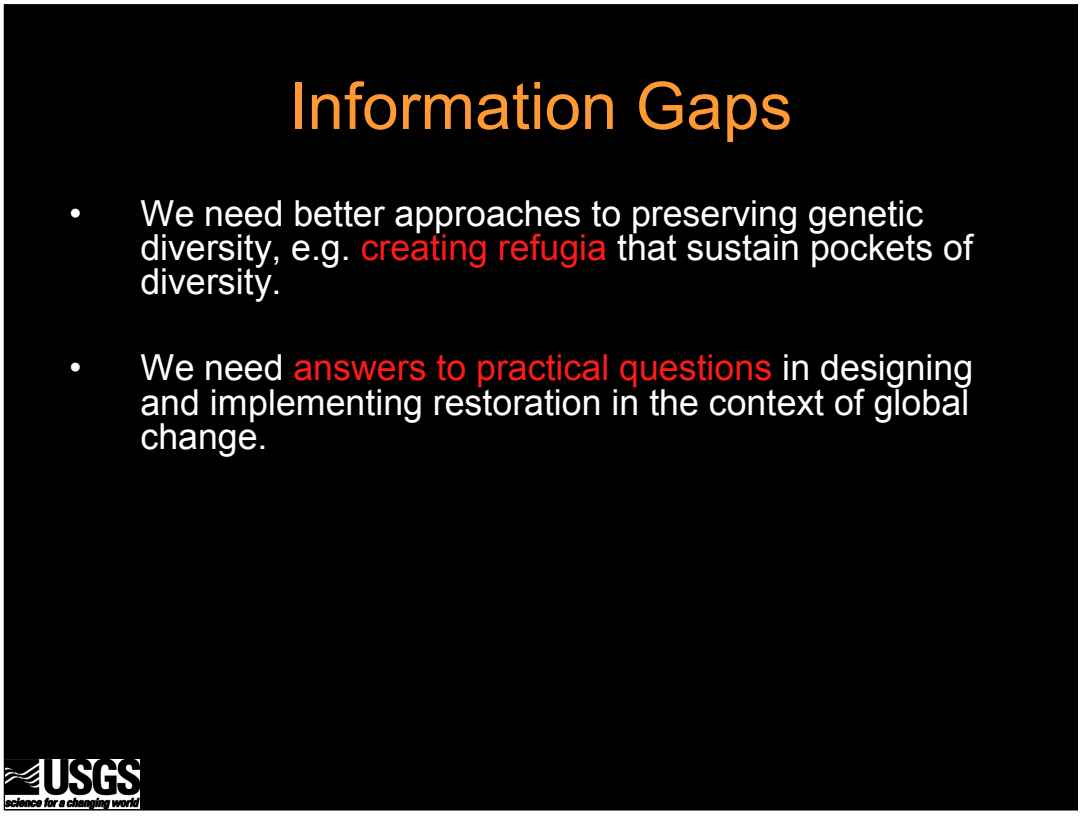

I hope these ideas have made sense and will stimulate further discussion at this symposium.