Ecosystem Services and Tools for Wetland Management

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Outline

- Why coastal wetlands and their ecosystem services matter for wetland management
- The challenges for coastal wetland valuation
- Case Study 1: Quantifying ecosystem services and the 2012 Master Plan for coastal Louisiana
- Case Study 2: Mangrove vs shrimp farms, Thailand
- Case Study 3: Oils spills and the NRDA approach to wetland compensation in lieu of restoration
- Final remarks

References

- Barbier, E.B. 2011. *Capitalizing on Nature: Ecosystems as Natural Assets.* Cambridge University Press, Cambridge, UK.
- Barbier, E.B. 2013. "Valuing Ecosystem Services for Coastal Wetland Protection and Restoration: Progress and Challenges." *Resources* 2:213-230. Available as open access at: http://www.mdpi.com/2079-9276/2/3/213
- Barbier, E.B. 2007. "Valuing ecosystem services as productive inputs." *Economic Policy* 22:177–229.
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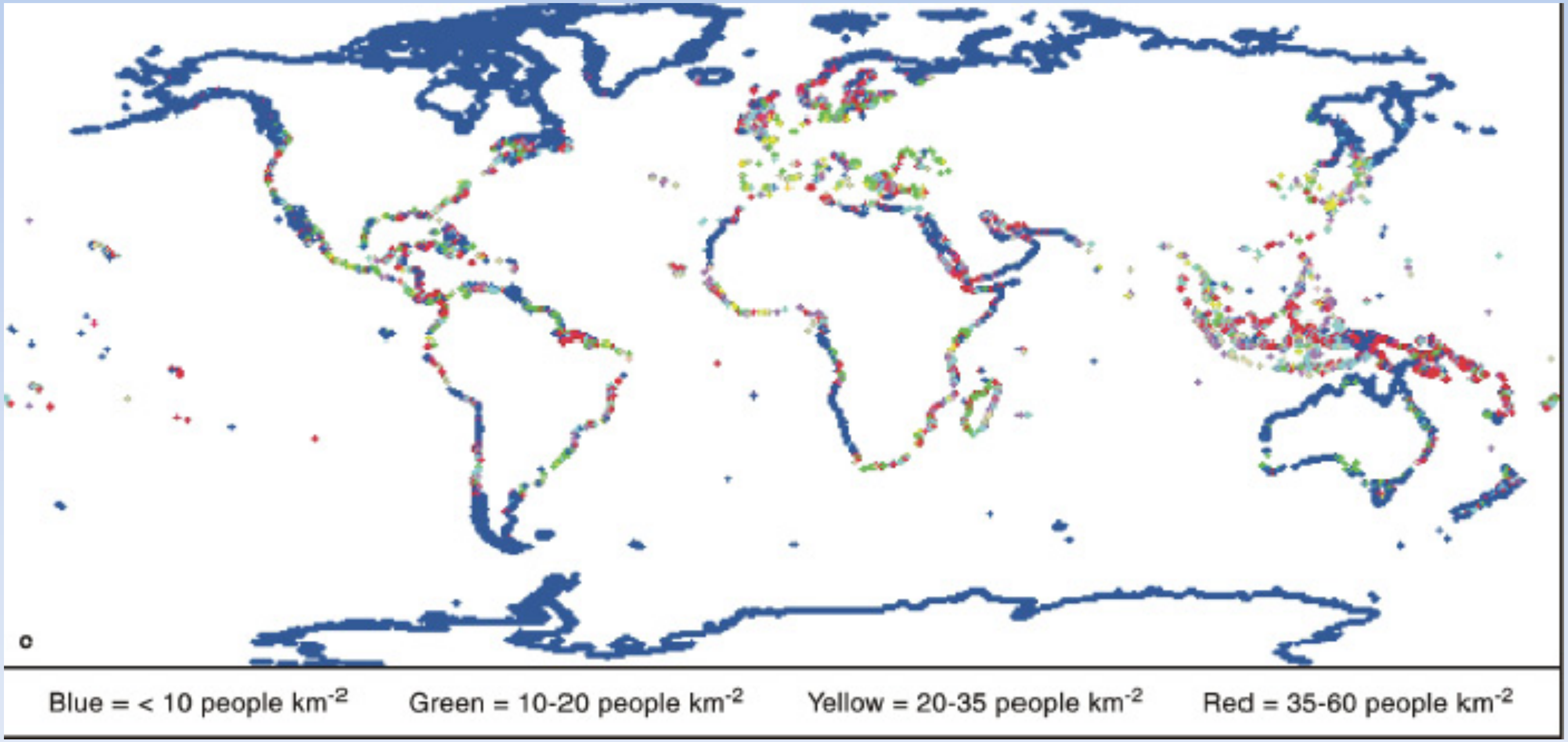
Key global coastal trends

- More than a third of the world's population lives in coastal zones, which comprise just 4% of the Earth's total land area.
- Coastal human population densities are nearly 3 times that of inland areas, and they are increasing exponentially.
- Around 14% of the population, and 21% of the urban dwellers in developing countries, live in low-elevation coastal zones.
- 50% of salt marshes, 35% of mangroves, 30% of coral reefs, and 29% of seagrasses are either lost or degraded worldwide.
- Across all the cities worldwide, about 40 million people are exposed to a one-in-100-year extreme coastal flooding event, and by 2070, it will be 150 million people.

Global areas of relatively pristine coastal regions



Decline in valuable services

- Worm et al. (2006) *Science*: The loss of coastal and estuarine ecosystems has affected three critical services:
  - the number of viable (noncollapsed) fisheries (33% decline)
  - the provision of nursery habitats such as oyster reefs, seagrass beds and wetlands (69% decline)
  - filtering and detoxification services provided by suspension feeders, submerged vegetation, and wetlands (63% decline)
- The loss of coastal wetlands and their vegetation has affected these systems' ability to protect against shore erosion, coastal flooding and storm events .
- Declining water quality may increase harmful algal blooms, fish kills, shellfish and beach closures, and oxygen depletion.
- Loss of biodiversity linked to biological invasion, and vice versa.

Why is it so difficult to quantify and value the benefits?

- NRC (2005, p. 2): "…the fundamental challenge of valuing ecosystem services lies in providing an explicit description and adequate assessment of the links between the structure and functions of natural systems, the benefits (i.e., goods and services) derived by humanity, and their subsequent values".
- Very few ecosystem goods and services are marketed, which mean they have to be valued explicitly through non-market valuation methods.
- The greatest "challenge" is in valuing the ecosystem services provided by a certain class of key ecosystem functions – *regulatory and habitat functions*.

Non-market valuation

- Very few coastal ecosystem goods and services are bought and sold in markets.
- Exceptions: some raw materials, food and fish harvests.
- Other services, such as recreation, have been routinely valued through non-market methods.
- However, most key services of coastal systems do not lead to observable marketed outputs.
- These include many services arising from ecosystem habitat and regulatory functions that benefit human beings largely without any additional input from them, such as coastal protection, breeding and nursery habitat, nutrient cycling, erosion control, water purification and carbon sequestration.

Table 1
Examples of estuarine and coastal ecosystem services and valuation studies.

Ecosystem structure and function	Ecosystem services	Valuation examples
Attenuates and/or dissipates waves, buffers wind	Coastal protection	Badola and Hussain (2005), Barbier (2007), Costanza et al. (2008), Das and Vincent (2009), King and Lester (1995), Wilkinson et al. (1999).
Provides sediment stabilization and soil retention	Erosion control	Huang et al. (2007), Landry et al. (2003), Sathirathai and Barbier (2001).
Water flow regulation and control	Flood protection	Morgan and Hamilton (2010), Turner et al. (2004).
Provides nutrient and pollution uptake, as well as retention, particle deposition, and clean water	Water purification and supply	Breaux et al. (1995), Turner et al. (2004), van der Meulen et al. (2004).
Generates biogeochemical activity, sedimentation, biological productivity	Carbon sequestration	Barbier et al. (2011).
Climate regulation and stabilization	Maintenance of temperature, precipitation	No studies.
Generates biological productivity and diversity	Raw materials and food	Janssen and Padilla (1999), King and Lester (1995), Naylor and Drew (1998), Nfotabong Atheull et al. (2009), Ruitenbeek (1994), Sathirathai and Barbier (2001).
Provides suitable reproductive habitat and nursery grounds, sheltered living space	Maintains fishing, hunting and foraging activities	Aburto-Oropeza et al. (2008), Barbier (2003, 2007), Barbier and Strand (1998), Bell (1997), Freeman (1991), Janssen and Padilla (1999), Johnston et al. (2002), Lange and Jiddawi (2009), McArthur and Boland (2006), Milon and Scrogin (2006), Samonte-Tan et al. (2007), Sanchirico and Mumby (2009), Smith (2007), Swallow (1994), White et al. (2000)
Provides unique and aesthetic landscape, suitable habitat for diverse fauna and flora	Tourism, recreation, education, and research	Bateman and Langford (1997), Birol and Cox (2007), Brander et al. (2007), Brouwer and Bateman (2005), Coombes et al. (2009), Johnston et al. (2002), King and Lester (1995), Landry and Liu (2009), Lange and Jiddawi (2009), Mathieu et al. (2003), Milon and Scrogin (2006), Othman et al. (2004), Tapsuwan and Asafu-Adjaye (2006), Turner et al. (2004), Whitehead et al. (2008).
Provides unique and aesthetic landscape of cultural, historic or spiritual meaning	Culture, spiritual and religious benefits, bequest values	Bateman and Langford (1997), Milon and Scrogin (2006), Naylor and Drew (1998).

Barbier, E.B. 2012. "A Spatial Model of Coastal Ecosystem Services." *Ecological Economics* 78:70-79.

Case Study 1: Quantifying ecosystem services and the 2012 Master Plan for coastal Louisiana

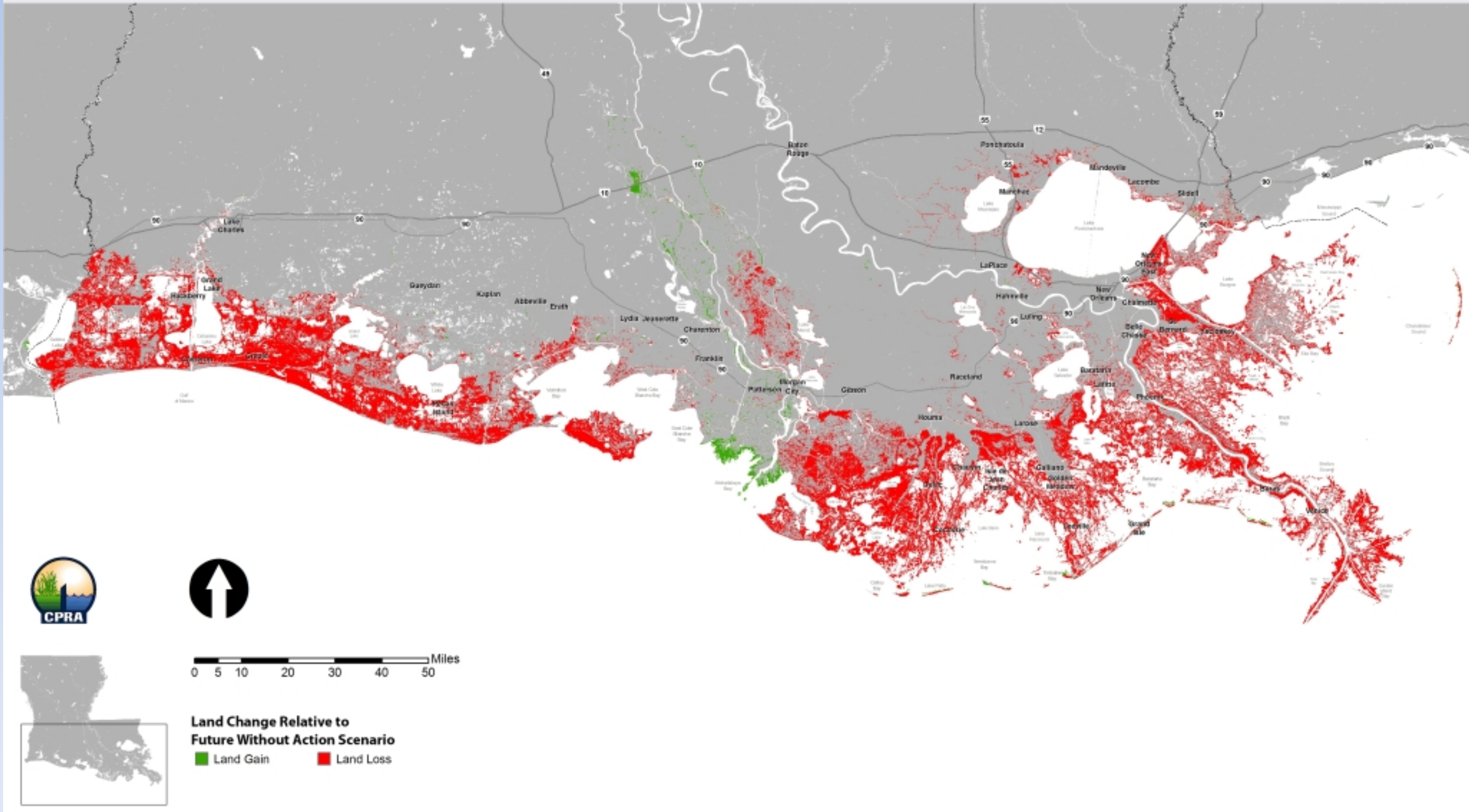
- Barbier, E.B. 2013. “Valuing Ecosystem Services for Coastal Wetland Protection and Restoration: Progress and Challenges.” *Resources* 2:213-230. Available as open access at: http://www.mdpi.com/2079-9276/2/3/213

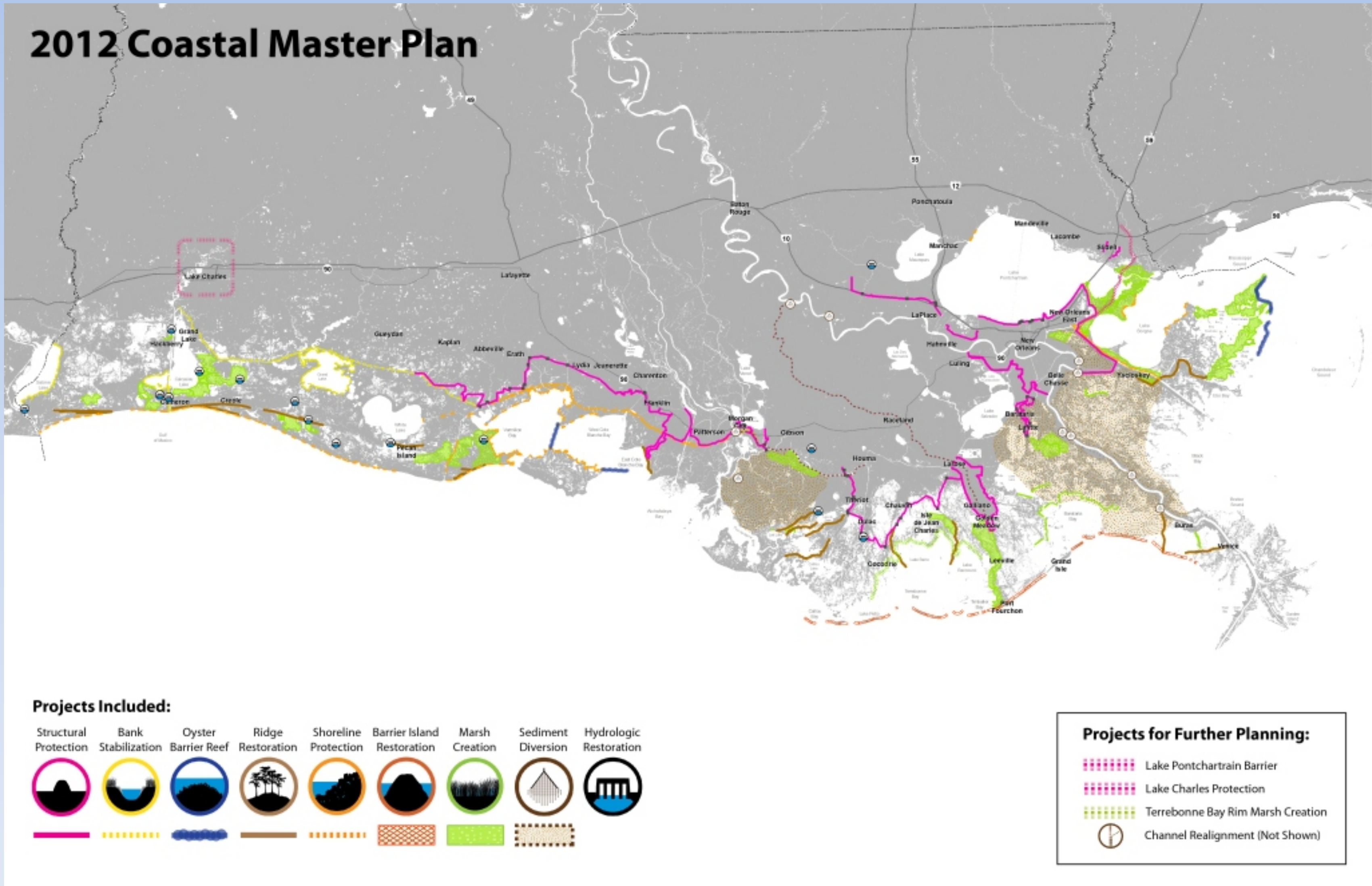
Case Study 1: Background

- Coastal Protection & Restoration Authority (CPRA) of Louisiana. 2012. *Louisiana's Comprehensive Master Plan for a Sustainable Coast*. Office of Coastal Protection and Restoration, Baton Rouge, LA.
- Louisiana contains about 40% of the wetlands of the lower 48 United States, but has historically accounted for about 80% of total US wetland losses.
- Lost 1,880 km^2 of coastal land since the 1930s, and could lose another 1,750 km^2 over the next 50 years.
- The 2012 Master Plan proposes to build 545 to 859 mi^2 of new land, much of it restored marsh, over the next 50 years to provide storm protection and other ecosystem benefits

Louisiana's 2012 Coastal Master Plan

Less Optimistic Environmental Scenario




2012 Coastal Master Plan
Projects Included:
Structural Protection
Bank Stabilization
Oyster Barrier Reef
Ridge Restoration
Shoreline Protection
Barrier Island Restoration
Marsh Creation
Sediment Diversion
Hydrologic Restoration
Projects for Further Planning:
Lake Pontchartrain Barrier
Lake Charles Protection
Terrebonne Bay Rim Marsh Creation
Channel Realignment (Not Shown)

Role of quantifying ecosystem services

- A total 248 restoration projects were individually evaluated in terms of their effects on 14 ecosystem services over a 50-year period.
- No direct quantification of the 14 ecosystem services, but instead focused on proxy characteristics of the coast, such as provision of habitat (i.e. habitat suitability indices) and other factors that can support these services.
- Not only were these various metrics used to evaluate an individual project's effect on ecosystem services, but also to examine the collective coast wide effect of groups of projects on those services.

Ecosystem Service	Quantification Approach
Alligator	Estimated habitat suitability index based on how different combinations of water, vegetation and land characteristics support alligator habitat
Crawfish (wild caught)	Estimated habitat suitability index based on how different combinations of water, vegetation and land characteristics support crawfish habitat
Oysters	Changes in oyster habitat were predicted through a habitat suitability model that accounted for land change, water, and bottom characteristics.
Shrimp (white and brown)	Habitat suitability models were developed for juvenile brown shrimp and juvenile white shrimp to predict changes in habitat based on water and vegetation characteristics.
Saltwater fisheries	A habitat suitability model for juvenile speckled trout was used to reflect changes to saltwater fisheries, based on water and vegetation characteristics.
Freshwater fisheries	A habitat suitability model for largemouth bass was developed, which incorporated changes in water and submerged aquatic vegetation characteristics.
Waterfowl	A combination of habitat suitability models for mottled duck, gadwall, and green winged teal was used to estimate waterfowl habitat changes based on predicted changes to water, vegetation and land characteristics.
Other coastal wildlife	Habitat suitability models for muskrat, river otter, and roseate spoonbill were developed based on water, vegetation, and land characteristics.
Nature-based tourism	A model was developed to estimate the potential for nature based tourism, which measured human access to high quality habitats for wildlife near coastal tourism centers, such as barrier islands and wildlife management areas. The species used to describe this service included: alligator, roseate spoonbill, river otter, muskrat, neotropical migrants, and waterfowl.
Support for agriculture and aquaculture	A model was developed that evaluated salinity characteristics and frequency of flooding in upland areas. This index includes lands that are in production for rice, sugarcane, cattle, farmed crawfish, and other agricultural and aquaculture activities.
Nutrient uptake	A model was developed to predict effects on nitrogen removal in open water, sediment, and wetlands.
Carbon sequestration	A wetland morphology model was used to estimate effects on carbon storage potential, which allows for variation in carbon storage with the type of wetland, the acreage, and the annual vertical accretion of soil.
Freshwater availability	A suitability model was developed to evaluate salinities in close proximity to strategic assets or populated areas.
Storm surge/wave attenuation	Estimated the effects of storm surge and waves on coastal communities, based on the location and amount of land in proximity to population centers, type of vegetation, and land elevation

Limitations

- For specific species that are harvested for commercial or recreational purposes, such as alligator, crawfish, oysters, shrimp and other fisheries, the habitat suitability index (HSI) may be a reasonable proxy.
- Difficulties arise for using HSI for other species, such as waterfowl and other coastal wildlife, as it is unclear what the ultimate benefit to humans of having higher or less abundance of these species might be.
- Quantifying nutrient uptake, carbon sequestration, freshwater availability and storm surge/wave attenuation does not provide a good indication of how these various ecological functions may translate into valuable benefits.

Lessons learned

- Provides some guidance to the shift in key habitats and some relevant services as a result of the Master Plan.
- The selected MP projects are likely to provide larger benefits from increases in alligator, freshwater fisheries and waterfowl habitat, while coastal wildlife, shrimp and saltwater fishery habitats are likely to stay at current levels.
- There may be a 10-20% decrease in suitable habitat for oysters, but in many coastal areas will also experience increase in salinity levels that will enhance oyster cultivation.
- Freshwater could increase by 40%, and there will be significant increases in carbon sequestration and nutrient uptake.
- Tourism and suitable agricultural land will rise slightly.
- Allows for differing climate change and sea level rise scenarios.

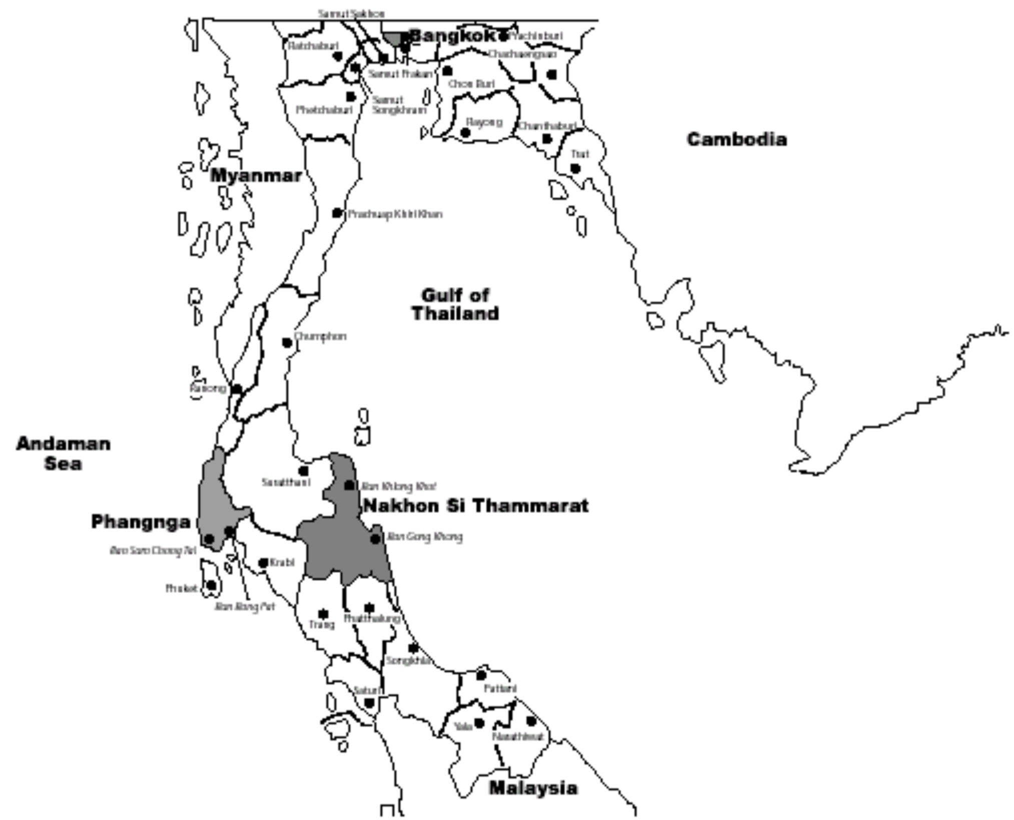
Case Study 2: Mangroves vs Shrimp Farms, Thailand

- Barbier, E.B. 2007. "Valuing ecosystem services as productive inputs." *Economic Policy* 22:177–229.
- Barbier, E.B. 2011. *Capitalizing on Nature: Ecosystems as Natural Assets.* Cambridge University Press, Cambridge, UK.

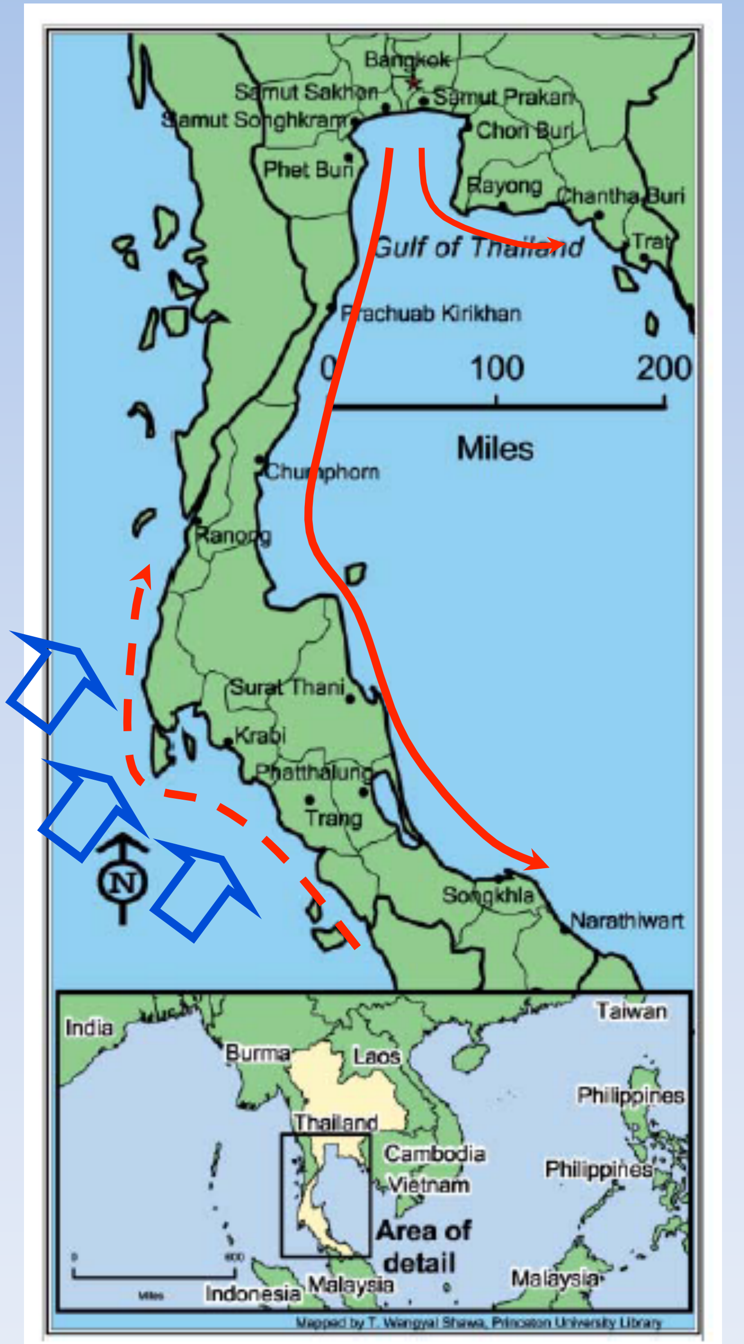
Case Study 2: Background

- Since 1961,Thailand has lost from1,500 to 2,000 km^2 of coastal mangroves, or about 50-60% of the original area.
  - The main cause has been shrimp farms and other coastal developments.
- Mangrove deforestation has focused attention on three principle mangrove ecosystem services:
  - collection of wood and non-wood mangrove products
  - nursery and breeding habitats for off-shore fisheries,
  - and as natural "storm barriers" (storm protection service).
- Many coastal communities have been affected by the decline in fisheries and loss of income from harvesting
- The 2004 Asian Tsunami focused attention on the storm protection service.

Habitat-fishery linkages and mangrove loss in Thailand



Abandoned shrimp farm and polluted sludge waste discharged from shrimp pond next to mangroves, Southwest coast of Thailand.


Bangkok
Samut Sakhon
Samut Prakan
Samut Songkhram
Chon Buri
Phet Buri
Rayong
Chantha Buri
Gulf of Thailand
Trat
Prachuab Kirikhan
0
100
200
Miles
Chumphorn
Ranong
Surat Thani
Krabi
Phatthalung
Trang
Songkhla
Narathiwart
N
India
Taiwan
Burma
Laos
Philippines
Thailand
Cambodia
Vietnam
Philippines
Area of detail
Indonesia
Malaysia
Malaysia
Mapped by T. Wangyal Shawa, Princeton University Library

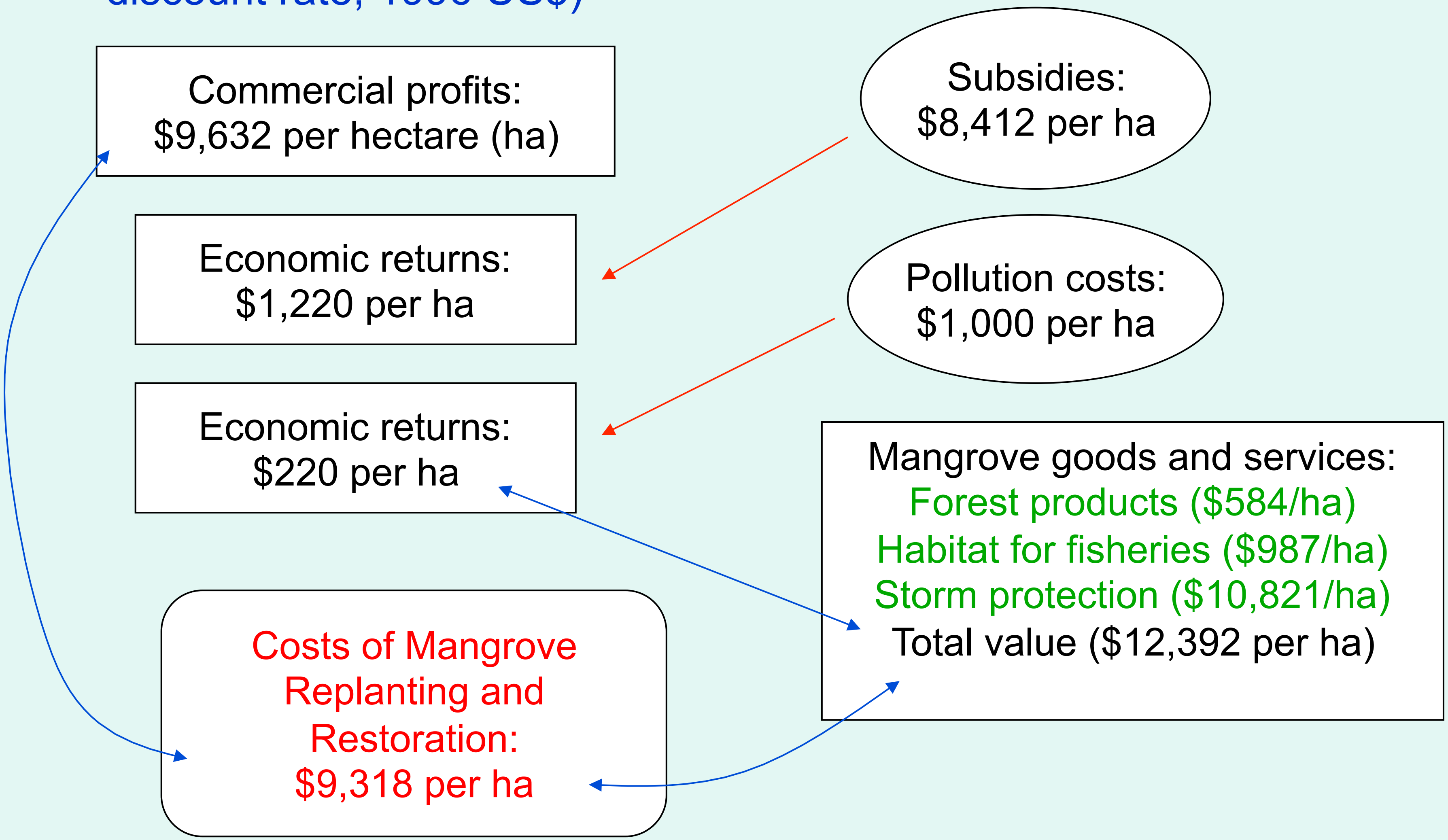
Unhurt mangrove forest behind the two washed villages by the 26 Dec 2004 Tsunami at Praphat Beach of Ranong, Thailand (9^{o} 22.476'N, 98^{o} 23.861E).

The badly damaged Avicennia forest at Ban Nam Khem, Phang Nga,Thailand (8^o 52.082'N, 98^o 16.583'E).

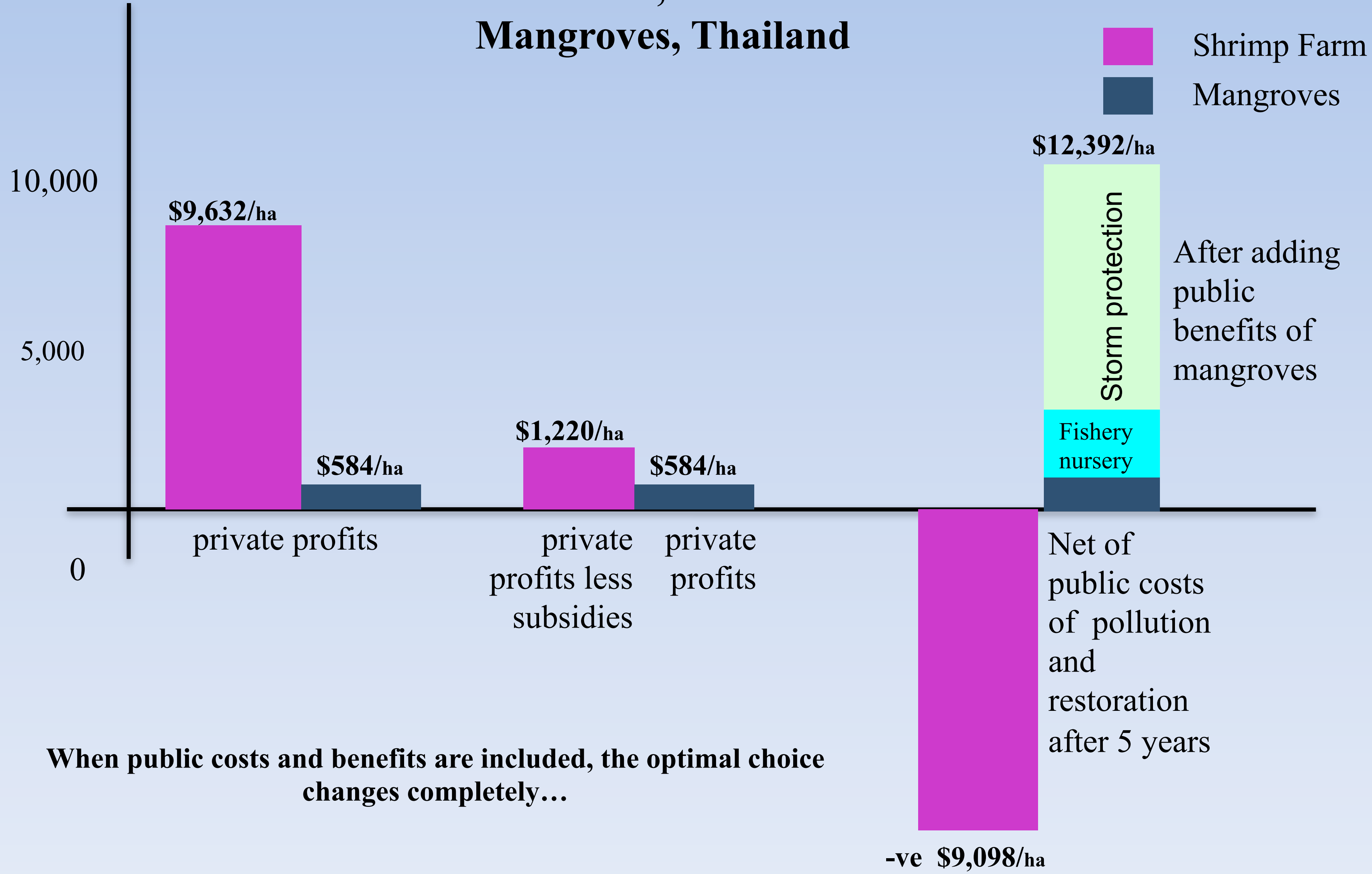
Thick and strong prop roots of Rhizophora buffered the tidal waves; behind the zone, all trees appear intact at Ban Nam Khem, Phang Nga, Thailand (8^o 52.006'N, 98^o 16.710'E).

Valuing the tradeoffs

- Economic Benefits of Shrimp Farming (NPV, 10% discount rate, 1996 US$)
- Environmental Impacts of Pollution and Mangrove Loss



Private Profits, Public Losses: Mangroves, Thailand



When public costs and benefits are included, the optimal choice changes completely…

Lessons learned

- The case study illustrates that the value of mangrove services, such as their habitat support for coastal fisheries, collected products and storm protection, are significant.
- These services should not be ignored in future mangrove land management decisions.
- Tradeoffs may have important distributional impacts
- Also relevant to coastal wetland rehabilitation in US Gulf States and mangrove restoration in the Indian Ocean.

Case Study 3: Oils spills and the NRDA approach to wetland compensation in lieu of restoration

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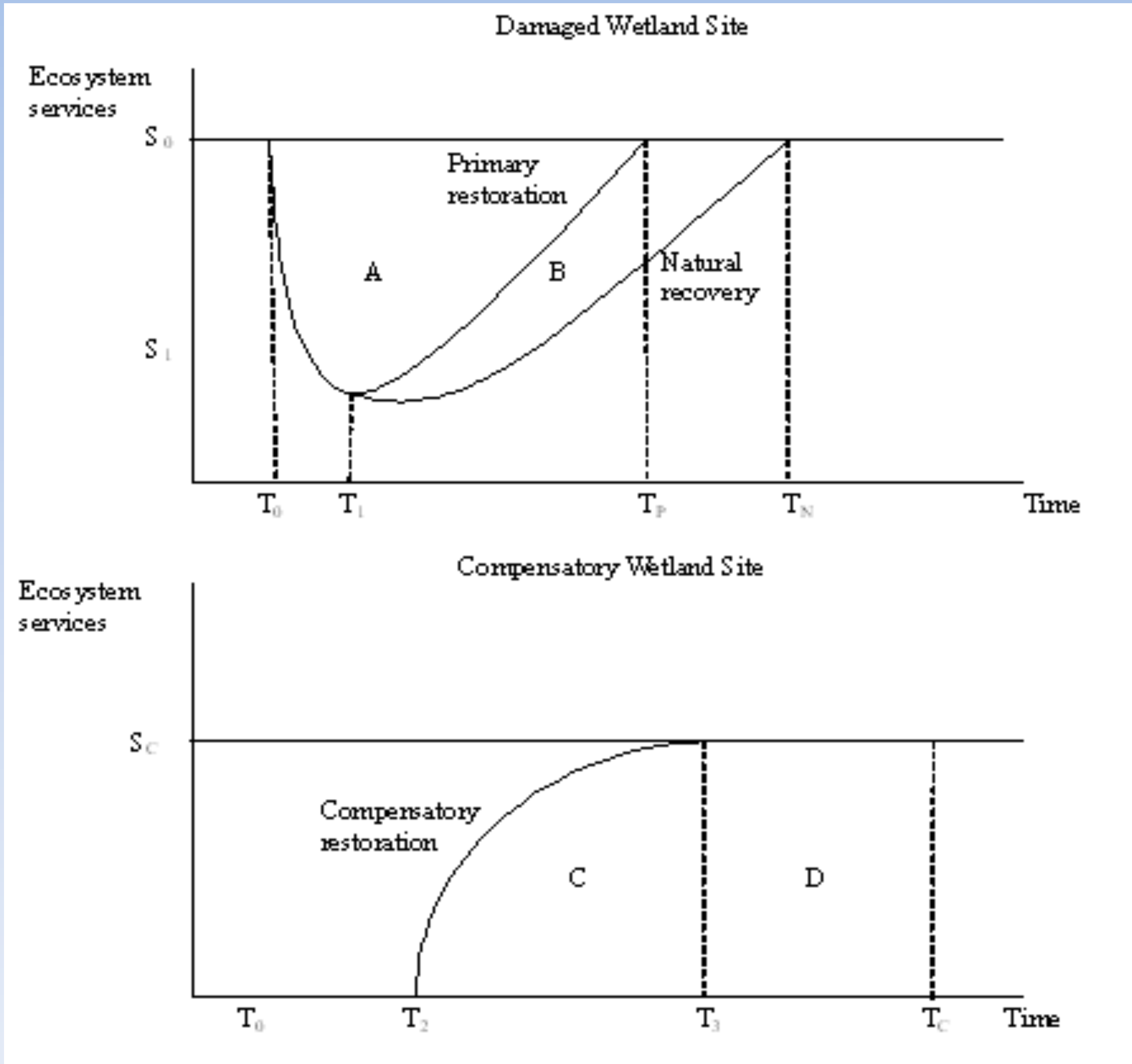
Case Study 3: Background

- Since the 1990 Oil Pollution Act, parties releasing oil into the environment are liable for:
  - the cost of cleaning up those releases, and
  - monetary compensation for injury (damages) to natural resources caused by the releases.
- The National Oceanographic and Atmospheric Administration (NOAA) is responsible for assessing the effects of any spill, through a Natural Resource Damage Assessment (NRDA).
- The NRDA relies less on valuation than *habitat equivalency analysis*, especially for damaged coastal wetlands.

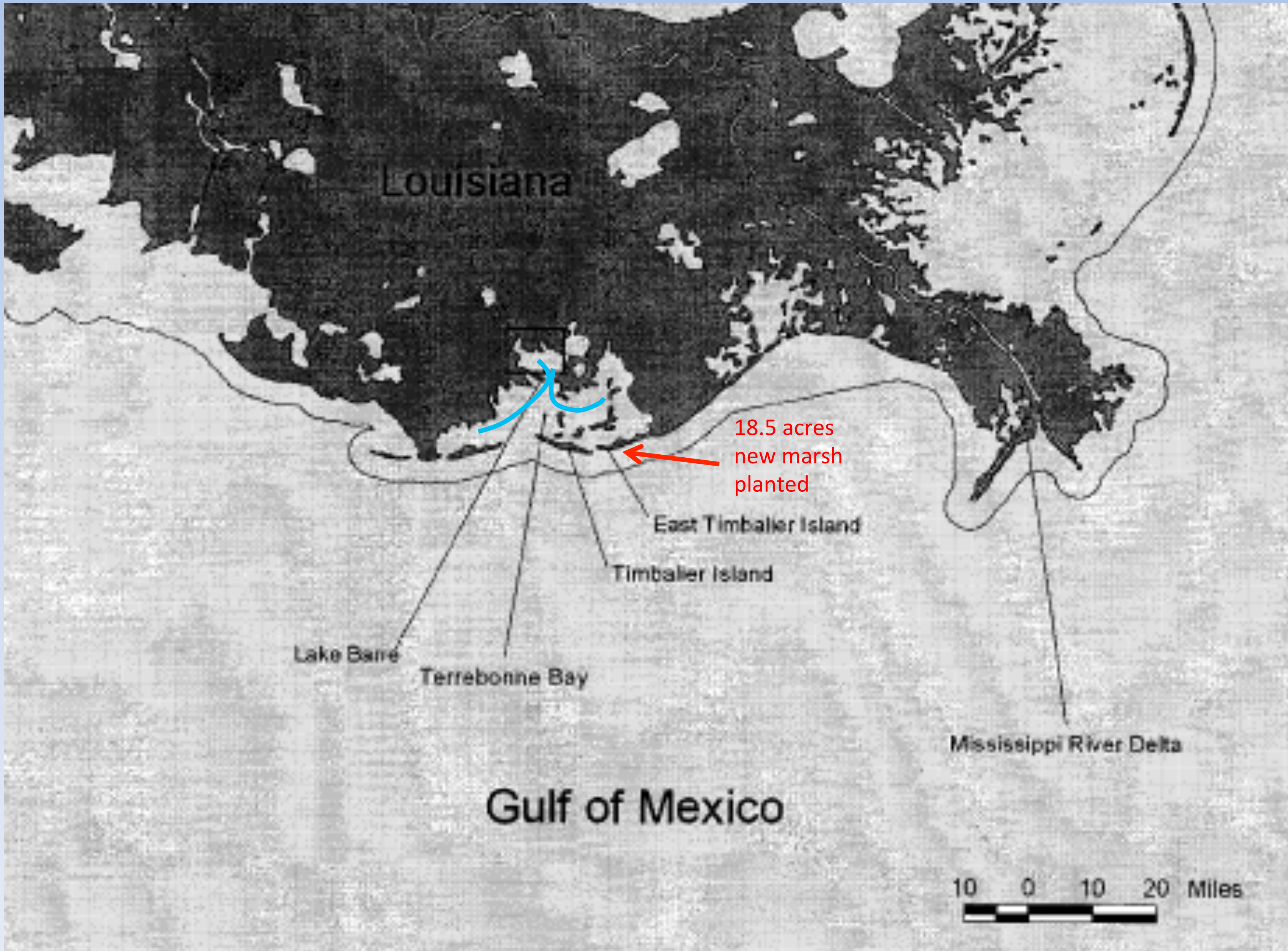
Habitat equivalency analysis

- NOAA: "The principal concept underlying the method is that the public can be compensated for past losses of habitat resources through habitat replacement projects providing additional resources of the same type."
- Three steps:
  - quantifying the interim losses in natural resource services arising from damages to a coastal and marine resource
  - estimating the scale of compensatory restoration required to offset these service losses.
  - Compensation is then sought from the responsible party for the present value monetary costs of the compensatory restoration project
- Compares services to services; valuation is not necessary.


Damaged Wetland Site
Ecosystem services
S 0
S 1
Primary restoration
A
B
Natural recovery
T0
T1
TP
TN
Time
Compensatory Wetland Site
Ecosystem services
S C
Compensatory restoration
C
D
T0
T2
T3
TC
Time

Lake Barre, LA oil spill

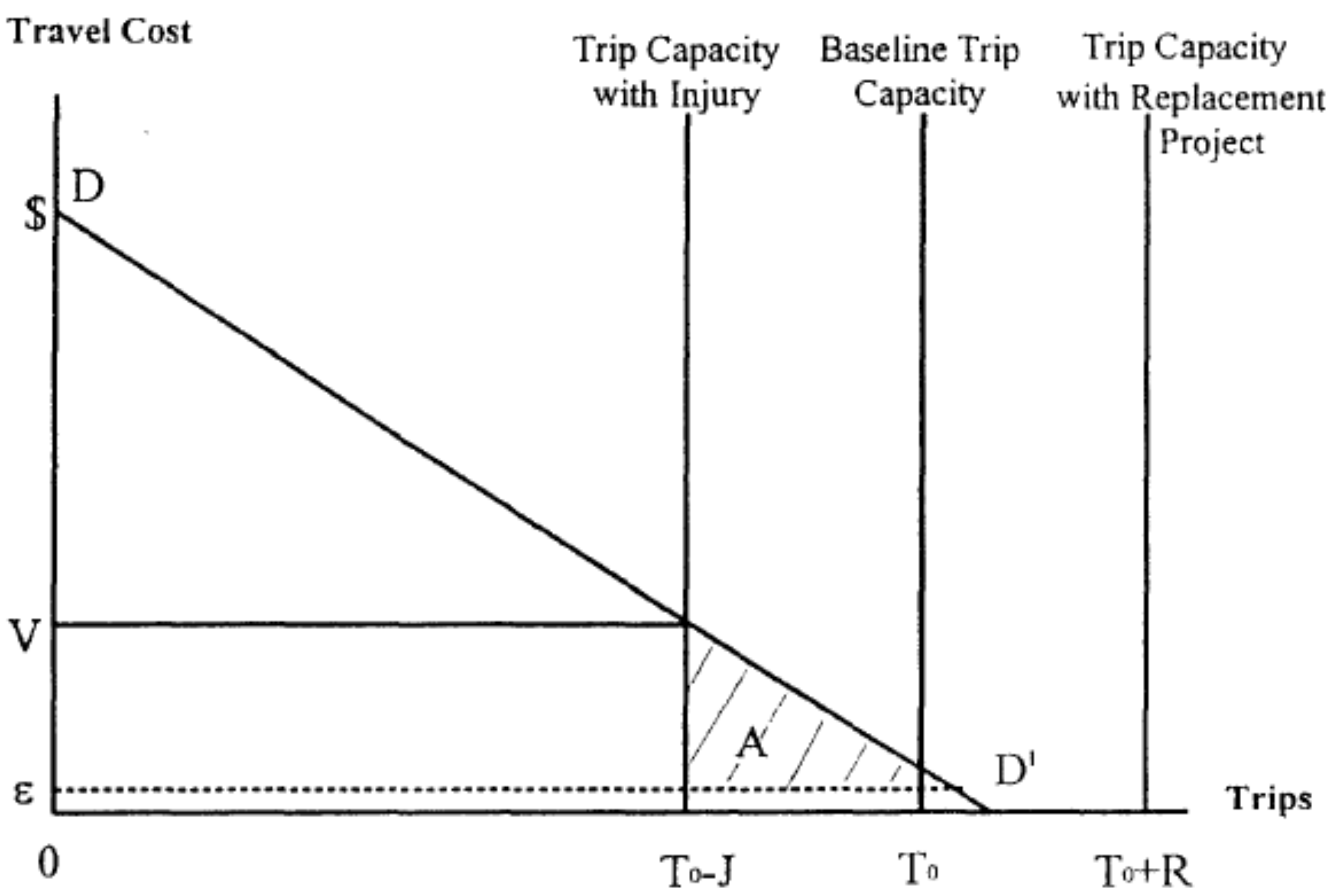
- A Texaco oil pipeline rupture on May 16, 1997 discharged 6,561 barrels of crude oil in Lake Barre, Louisiana.
- Over 4,300 acres of estuarine salt marshes.
- More than 95% of the affected area suffered only limited service losses with full recovery occurring after four months.
- The HEA concluded that planting 18.5 acres of new salt marsh on East Timbalier Island would compensate for the interim marsh, aquatic fauna and bird losses.
- Due to vegetation spreading, the created marsh would eventually reach 58 acres.
- Texaco agreed to undertake the marsh creation on the barrier island.


Louisiana
18.5 acres
new marsh
planted
East Timbalier Island
Timbalier Island
Lake Barre
Terrebonne Bay
Mississippi River Delta
Gulf of Mexico
10 0 10 20 Miles

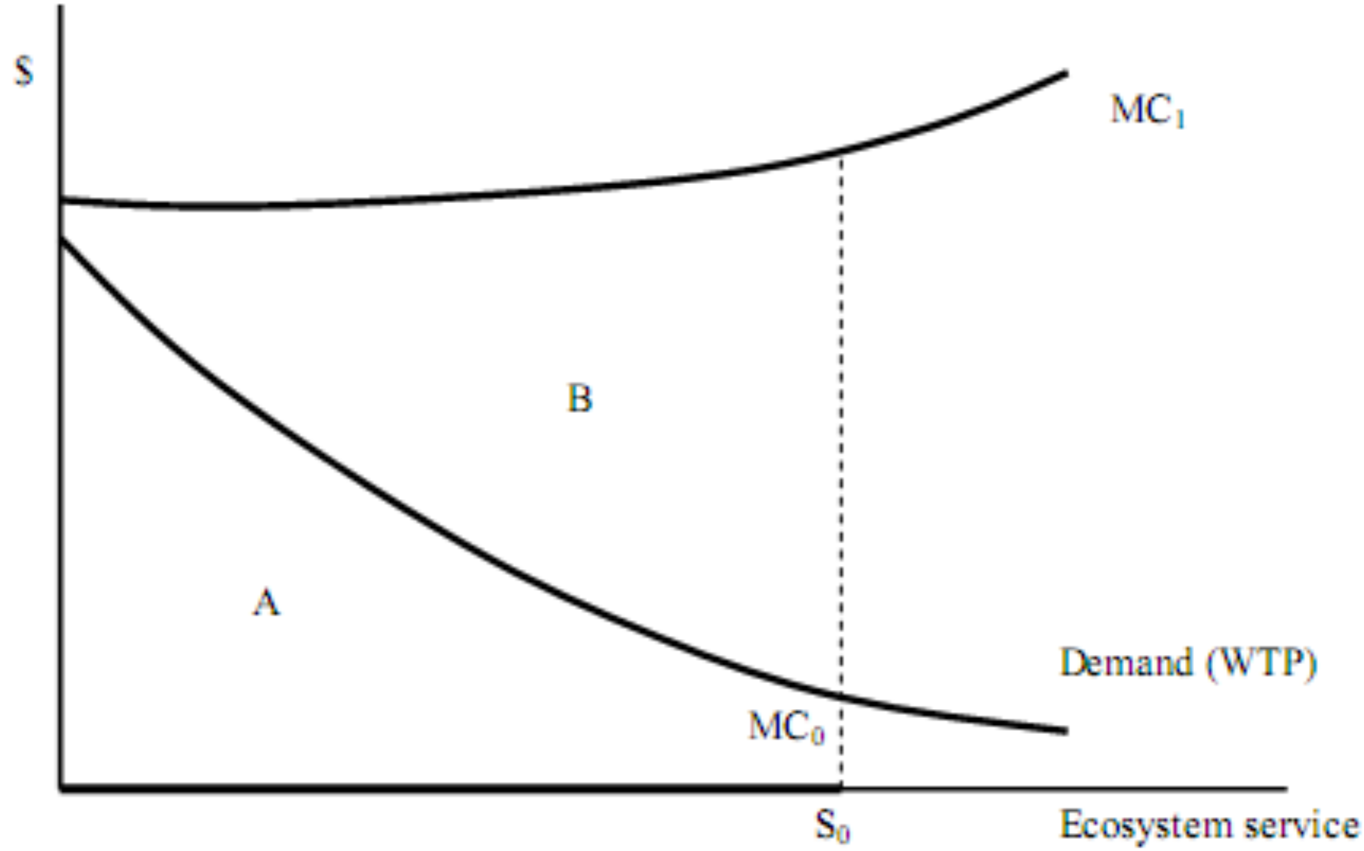
Pros and cons of HEA

- Pros:
  - Restoration is emphasized from the beginning of the NRDA.
  - Protracted and costly litigation is often avoided.
  - Ensures that enough money is collected to implement complementary restoration.
  - Not necessary to conduct valuation studies.
- Cons:
  - Assumes a preference for compensation with the same services that were damaged.
  - Assumes a fixed proportion of habitat services to habitat value.
  - Assumes a constant real value of services over time.
  - Baseline may vary.
  - May have effects on overall aggregate supply and demand of some services.
  - May not be related to actual costs and benefits of restoration.

Demand for Wildlife Refuge Hiking Trips



Benefits and Costs of Compensatory Restoration of a Wetland



Lessons learned

- Coastal wetland restoration and compensatory mitigation will feature prominently in Louisiana and other coastal states.
- Developing methods of assessing natural resource damages, such as the effects of oil spills on coastal wetlands, which reduce costly litigation and expedites funding for restoration is an important objective.
- But there also need to be much more consideration of the long-term ecological establishment of wetland structure and functions and of the economic benefits derived from any resulting wetland goods and services.

Final remarks

- There has been considerable progress in valuing key goods and services provided by coastal wetlands.
- Valuation can identify tradeoffs, including the costs and benefits of various coastal management options, and contribute to assessing management effectiveness.
- However, to assist coastal management and policy, quantitative assessment need not always require valuation of ecosystem benefits.
- If employed properly, quantifying and in some cases valuing coastal and estuarine goods and services will aid decision-making by policymakers and local communities with respect to their use and conservation of various coastal systems.