Ecological Engineering and Ecosystem Restoration

History, definitions, and principles

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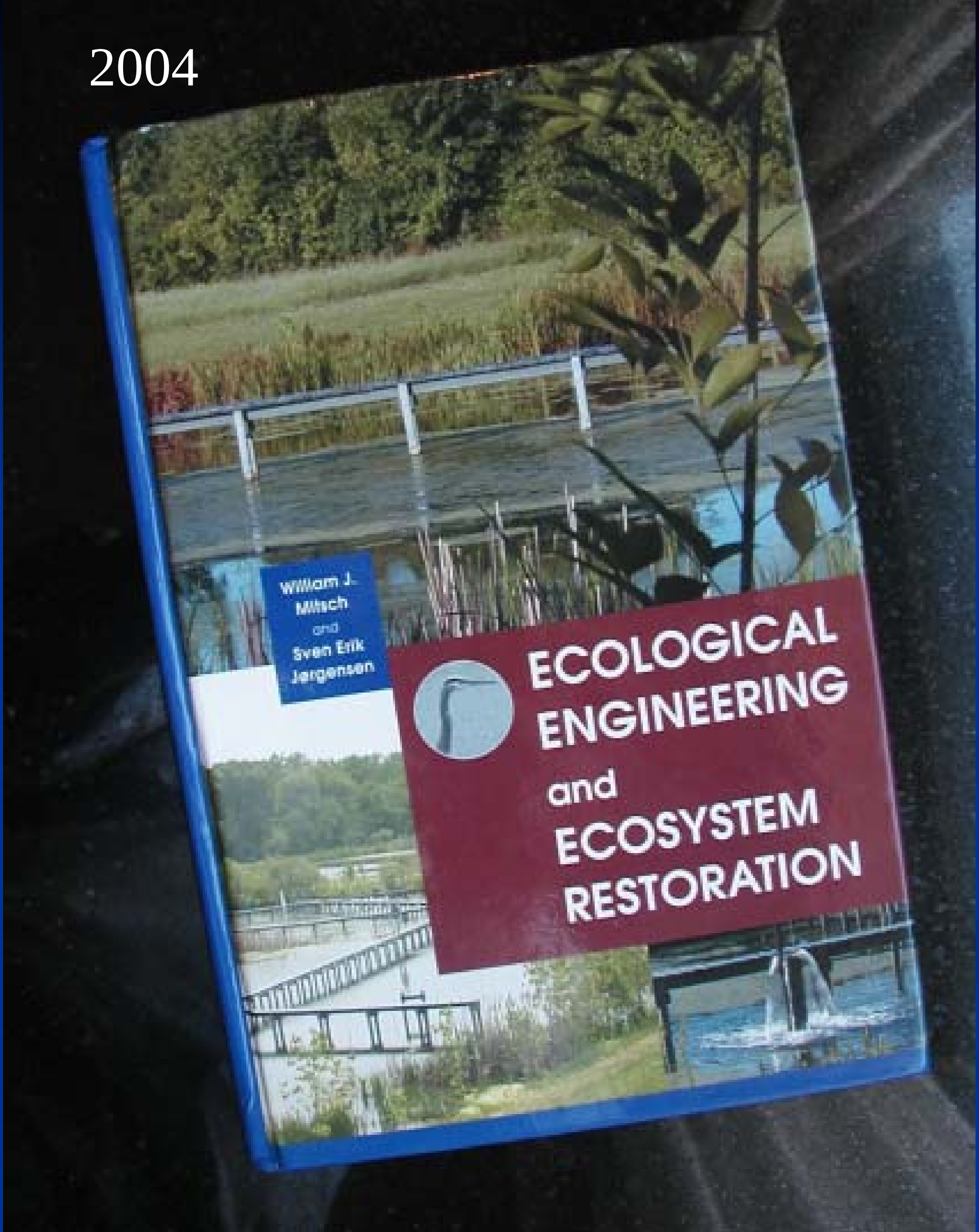
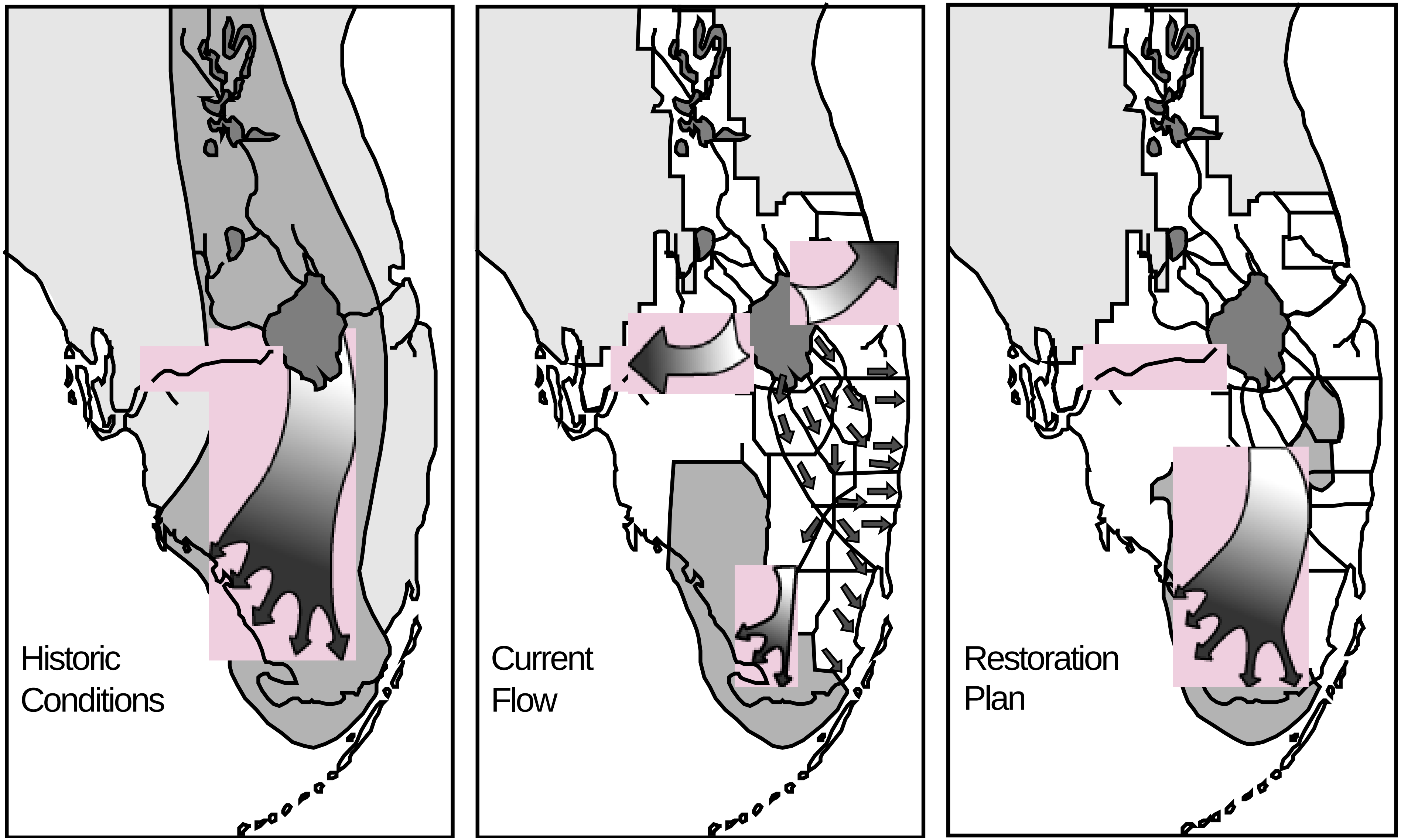
2004


William J. Mitsch
and
Sven Erik Jørgensen
ECOLOGICAL ENGINEERING
and
ECOSYSTEM RESTORATION

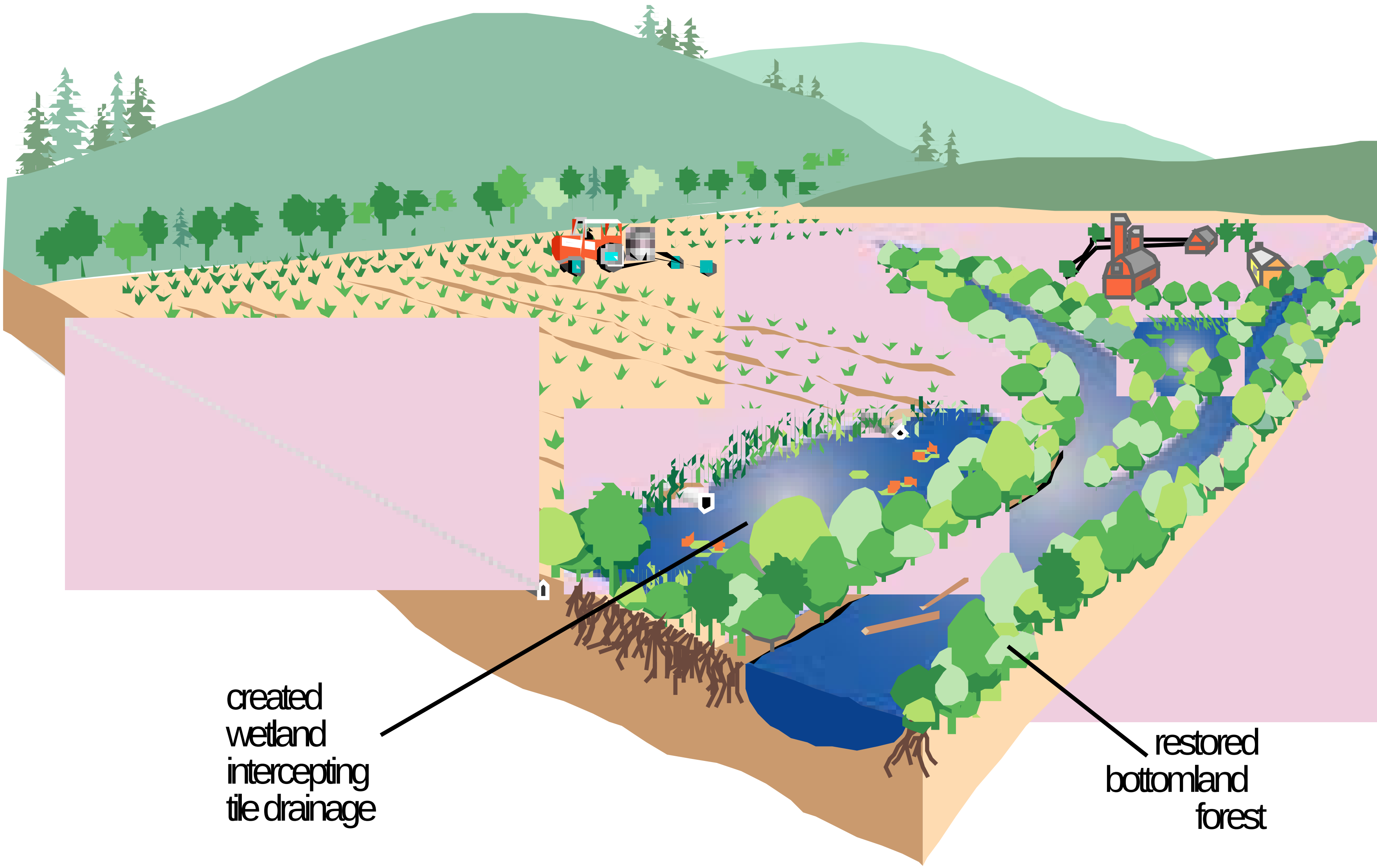
Everglades Restoration, Florida



Everglades Restoration, Florida

Delta Restoration, Louisiana

Mississippi River Basin Restoration, USA



River Channel Restoration, Skern River Denmark

River Channel Restoration, Skern River Denmark

Wetland Creation/ Restoration Columbus, Ohio

6.1 ha mitigation wetland


Olentangy River Wetland Research Park Columbus, Ohio
12-ha wetland research facility on Ohio State University campus

Olentangy River Wetland Research Park Columbus, Ohio

Floodplain Forest Restoration

Treatment Wetland, Central Ohio

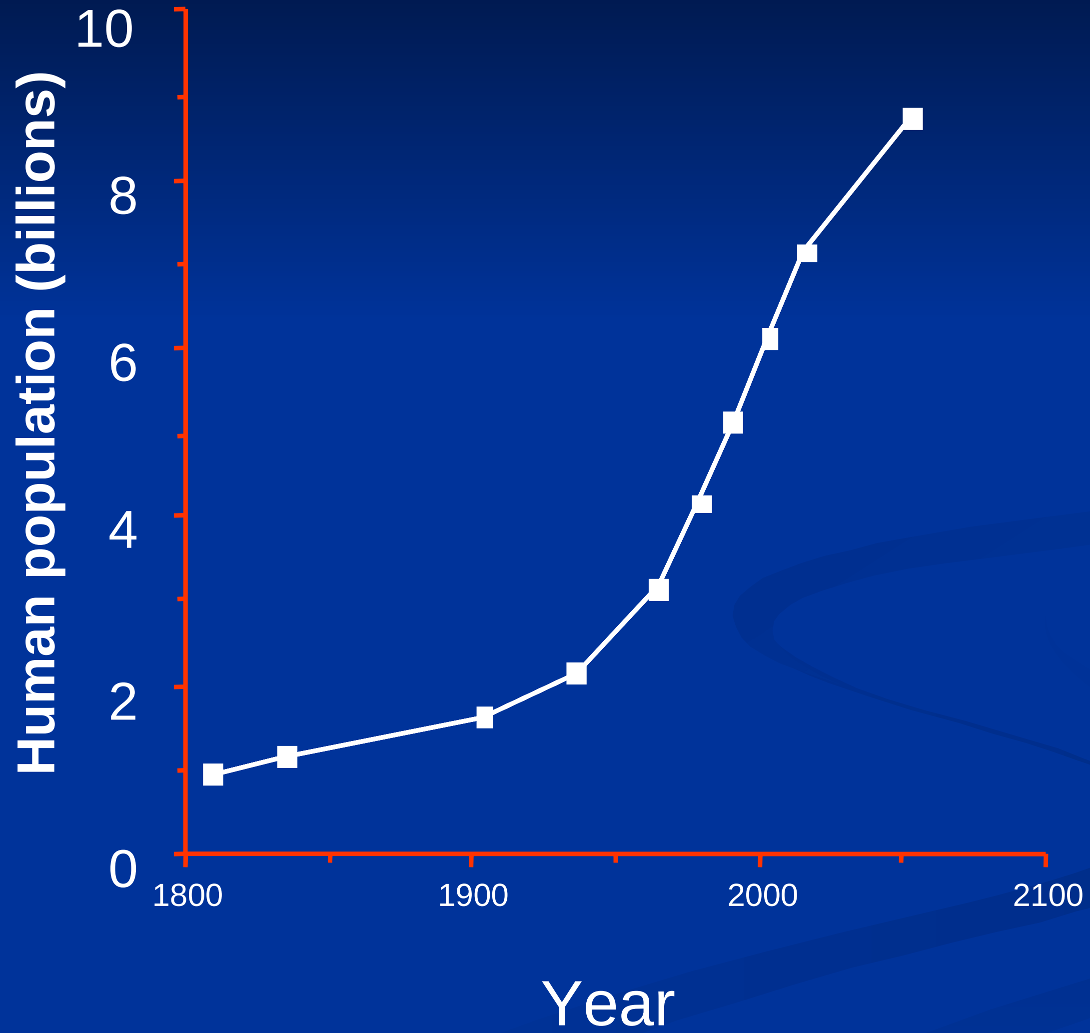
Salt Marsh Restoration, New Jersey

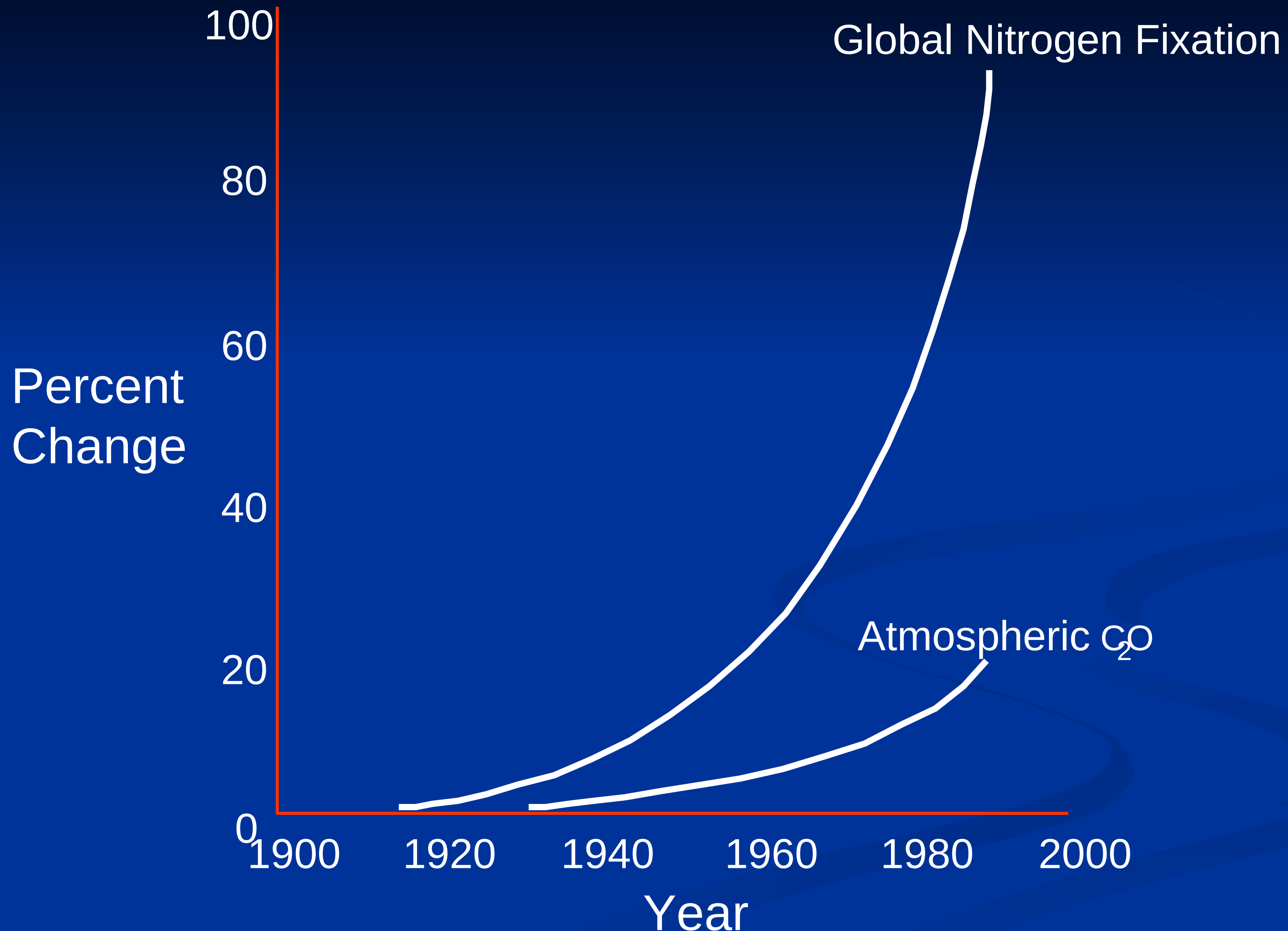
Salt Marsh Restoration, New Jersey

Biosphere 2, Arizona

Biosphere 2, Arizona

Change in population 1805-1999 and an optimistic (but realistic) prognosis 1999-2050




Global Nitrogen Fixation
Atmospheric CO_2
Percent Change
100
80
60
40
20
0
1900
1920
1940
1960
1980
2000
Year

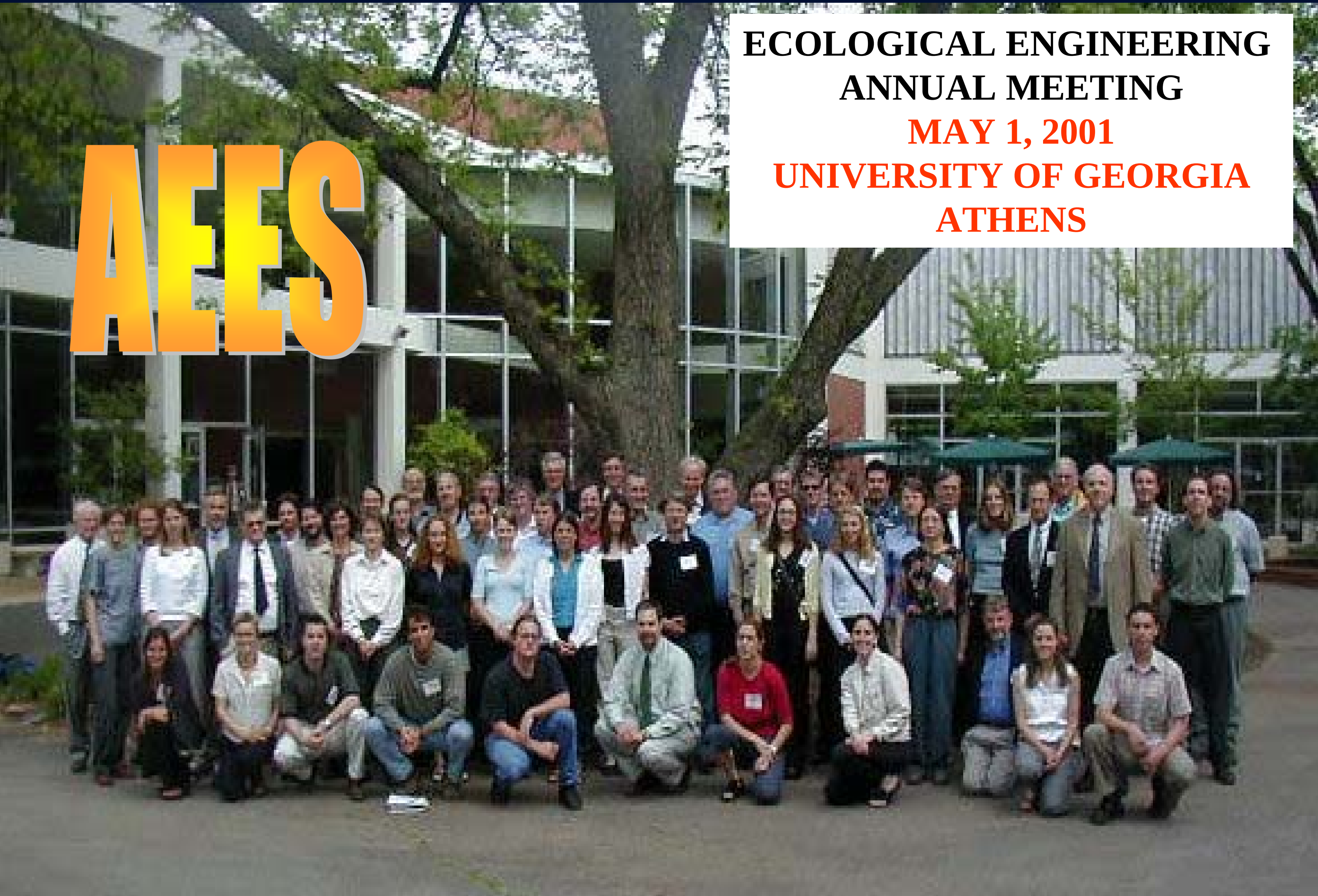
History of Ecological Engineering

- H.T. Odum (1960s) mention of ecological engineering in several publications
- Ma Shijun (1960s-70s in China; 1985 in Western literature) "father of ecological engineering in China"
- Ecotechnology of Uhlmann, Straskraba and Gnauek (1983-1985)
- Mitsch and Jørgensen ecological engineering book (1989)
- First ecological engineering meeting in Trosa Sweden (1991) followed by Etnier and Guterstam book (1991, 1997)

History of Ecological Engineering

- *Ecological Engineering* journal started (1992)
- Ecological engineering workshop in Washington DC at National Academy of Sciences (1993)
- IEES started in Utrecht, The Netherlands (1993)
- SCOPE project in ecological engineering and ecosystem restoration established in Paris (1994 - 2002)
- Discussions of American ecological engineering society in Columbus (1999); AEES first meeting, Athens, GA (2001)
- Mitsch and Jørgensen (2004) and Kangas (2004) ecological engineering textbooks completed


ECOLOGICAL ENGINEERING
WORKSHOP
MARCH 15-16, 1999
THE OHIO STATE UNIVERSITY
COLUMBUS


AEES
ECOLOGICAL ENGINEERING
ANNUAL MEETING
MAY 1, 2001
UNIVERSITY OF GEORGIA
ATHENS

SCOPE International Workshops on Ecological Engineering and Ecosystem Restoration

Workshop Title	Location/ Date	Publication in Ecol Eng
Remediation of ecosystems damaged by environmental contamination	Tallinn, Estonia November 1995	Mitsch and Mander, 1997
Ecological engineering in developing countries	Beijing, China October 1996	Wang et al., 1998
Ecological engineering applied to river and wetland restoration	Paris, France July 1998	Lefeuvre et al., 2002
Ecology of post-mining landscapes	Cottbus, Germany March 1999	Hüttl and Bradshaw, 2001

Ecological Engineering

the design of sustainable ecosystems that integrate human society with its natural environment for the benefit of both

Goals of Ecological Engineering

1. the restoration of ecosystems that have been substantially disturbed by human activities such as environmental pollution or land disturbance; and
2. the development of new sustainable ecosystems that have both human and ecological value.

Ecological Restoration

the return of an ecosystem to a close approximation of its condition prior to disturbance

Terms that are synonyms, subdisciplines, or fields similar to ecological engineering

- synthetic ecology
- restoration ecology
- bioengineering
- sustainable agroecology
- habitat reconstruction
- ecohydrology
- ecosystem rehabilitation
- biospherics
- biomanipulation
- river and lake restoration
- wetland restoration
- reclamation ecology
- nature engineering
- ecotechnology
- engineering ecology
- solar aquatics

Contrasts with Other Fields

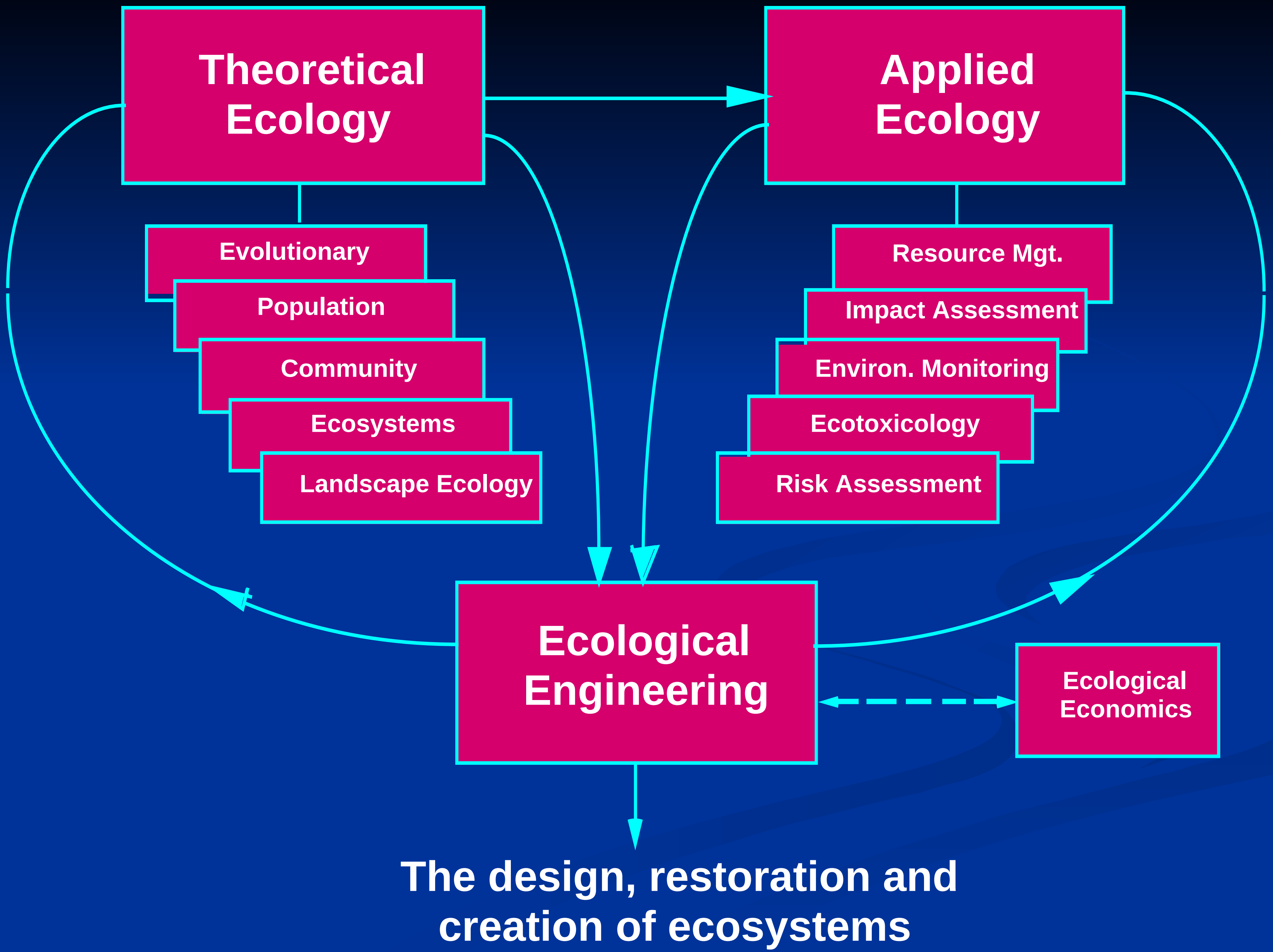
- Environmental engineering
- Biotechnology

Comparison of ecotechnology and biotechnology

Characteristic	Ecotechnology	Biotechnology
Basic unit	Ecosystem	Cell
Basic principles	Ecology	Genetics; cell biology
Control	Forcing functions, organisms	Genetic structure
Design	Self-design with some human help	Human design
Biotic diversity	Protected	Changed
Maintenance and development costs	Reasonable	Enormous
Energy basis	Solar based	Fossil fuel based

Contrasts with Other Fields

- Environmental engineering
- Biotechnology
- Ecology


Theoretical Ecology
Applied Ecology
Evolutionary
Population
Community
Ecosystems
Landscape Ecology
Resource Mgt.
Impact Assessment
Environ. Monitoring
Ecotoxicology
Risk Assessment
Ecological Engineering
Ecological Economics
The design, restoration and creation of ecosystems

Contrasts with Other Fields

- Environmental engineering
- Biotechnology
- Ecology
- Ecotechniques/Cleaner Technology
  - Industrial Ecology

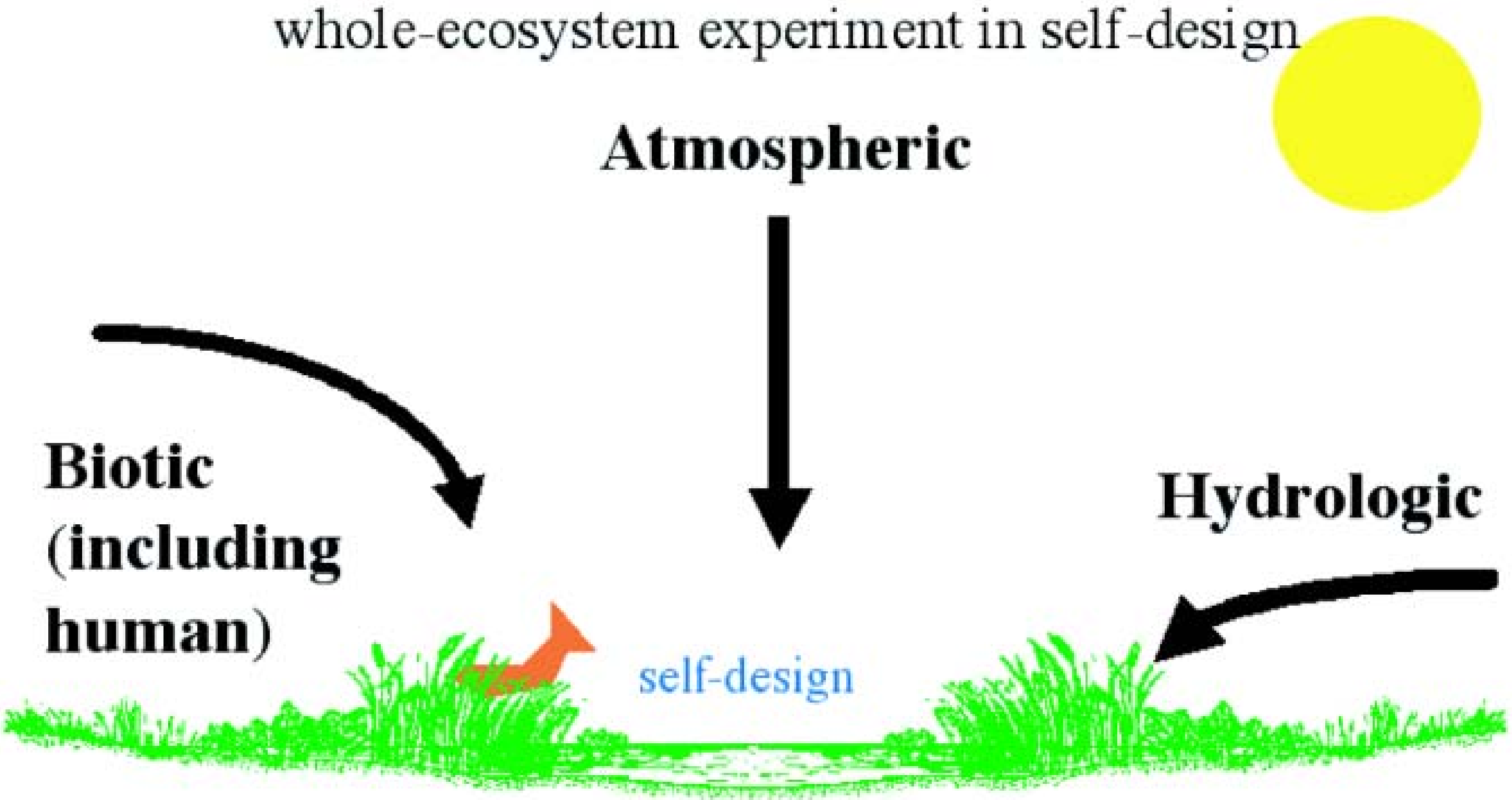
Ecological Engineering Principles

Self-design

The application of self-organization in the design of ecosystems

Systems categorized by types of organization (modified from Pahl-Wostl, 1995)

Characteristic	Imposed organization	Self-organization
Control	externally imposed;	endogenously imposed;
	centralized control	distributed control
Rigidity	rigid networks	flexible networks
Potential for adaptation	little potential	high potential
Application	conventional engineering	ecological engineering
Examples	machine	organism
	fascist or socialist society	democratic society
	agriculture	natural ecosystem



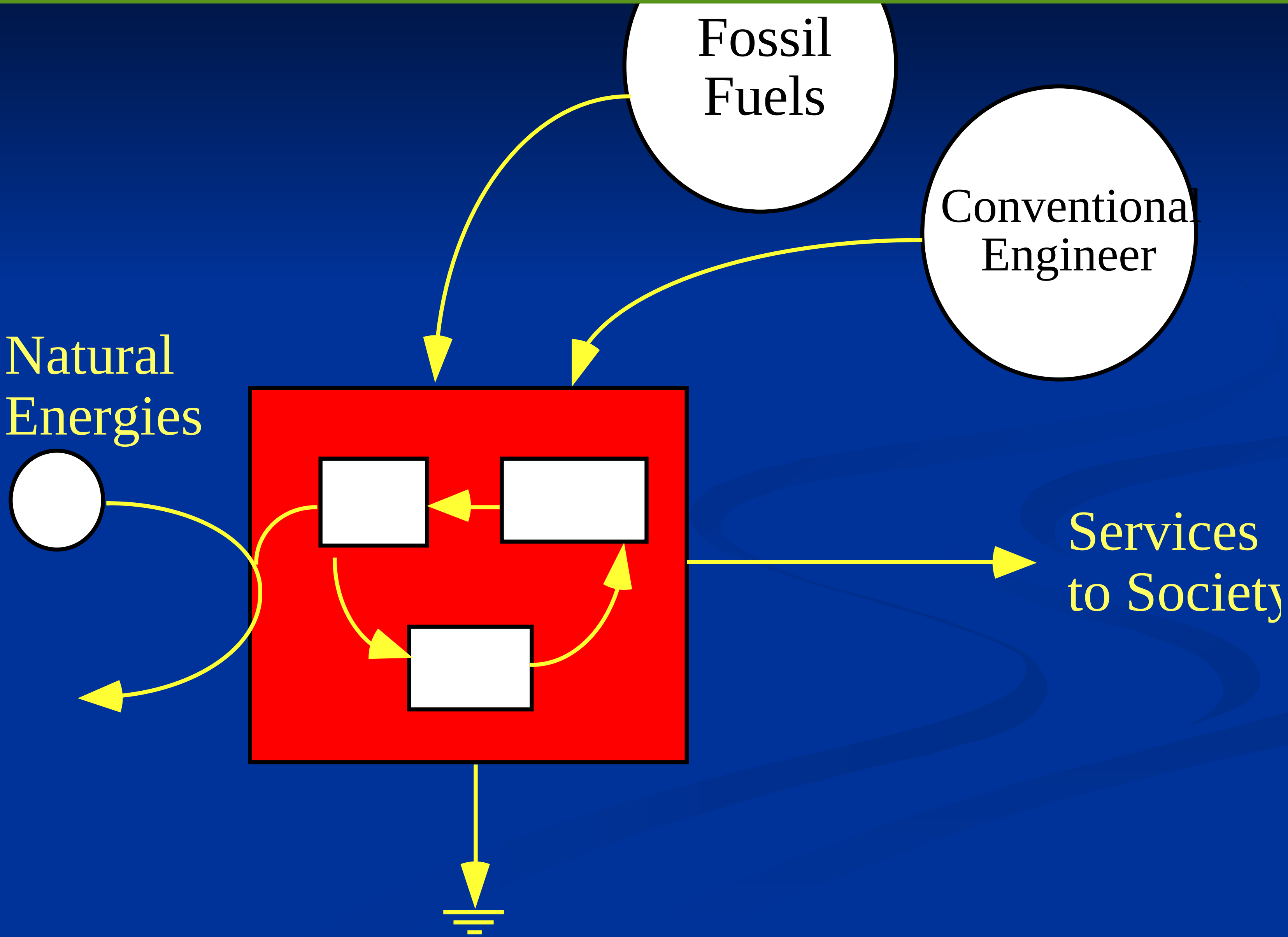
Sources of Biotic Propagules for Self-Design

The Acid Test

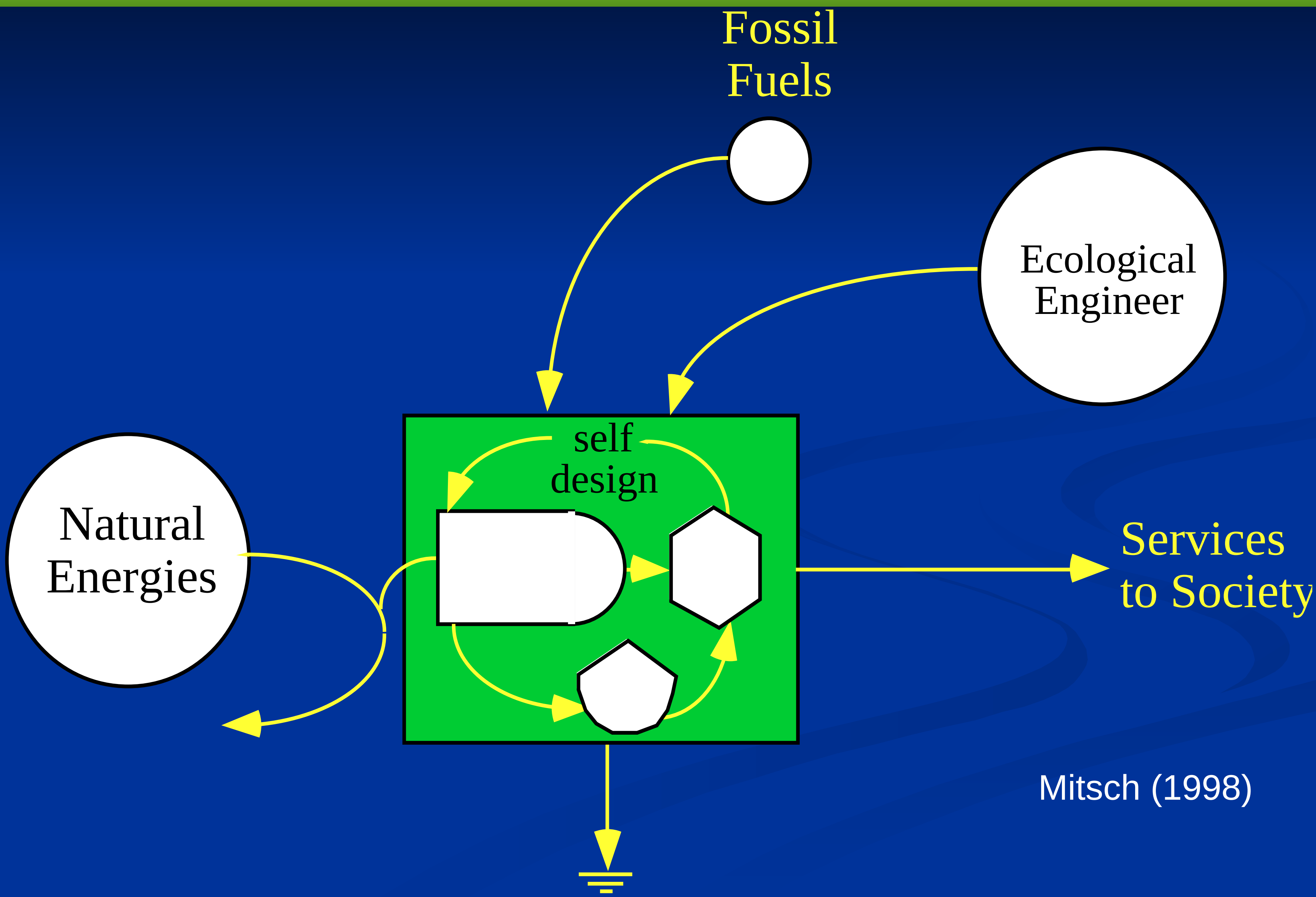
A Systems Approach

Nonrenewable Resource Conservation

Conventional Engineering



Ecological Engineering



Mitsch (1998)

Ecosystem Conservation

"To keep every cog and wheel is the first precaution of intellegent tinkering."

Aldo Leopold

Ecological Design Principles

1. Ecosystem structure and function are determined by the forcing functions of the system.
2. Energy inputs to the ecosystem and available storage of matter are limited.
3. Ecosystems are open and dissipative systems.
4. Attention to a limited number of factors is most strategic in preventing pollution or restoring ecosystems.
5. Ecosystems have some homeostatic capability that results in smoothing out and depressing the effects of strongly variable inputs.
6. Match recycling pathways to the rates to ecosystems to reduce the effect of pollution.

Ecological Design Principles

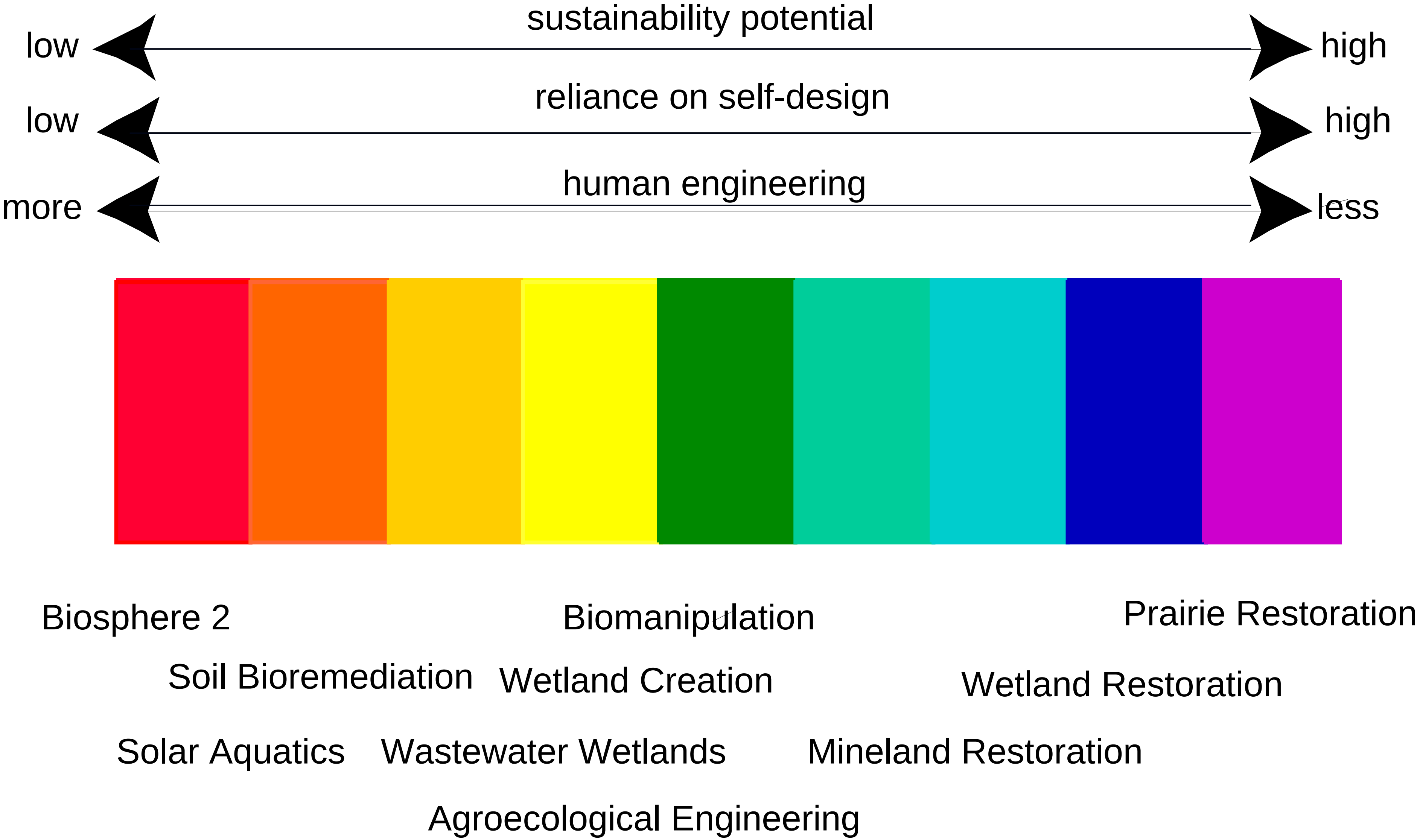
7. Design for pulsing systems whenever possible.
8. Ecosystems are self-designing systems.
9. Processes of ecosystems have characteristic time and space scales that should be accounted for in environmental management.
10. Biodiversity should be championed to maintain an ecosystem self-design capacity.
11. Ecotones, transition zones, are as important for ecosystems as membranes are for cells.
12. Coupling between ecosystems should be utilized wherever possible.

Ecological Design Principles

13. The components of an ecosystem are interconnected, interrelated, and form a network, implying that direct as well as indirect effects of ecosystem development need to be considered.
14. An ecosystem has a history of development.
15. Ecosystems and species are most vulnerable at their geographical edges.
16. Ecosystems are hierarchical systems and are parts of a larger landscape.
17. Physical and biological processes are interactive. It is important to know both physical and biological interactions and to interpret them properly.
18. Ecotechnology requires a holistic approach that integrates all interacting parts and processes as far as possible.
19. Information in ecosystems is stored in structures.

Classification of Ecological Engineering

Classification According to Sustainability


sustainability potential
low
high
reliance on self-design
low
high
human engineering
more
less
Biosphere 2
Biomanipulation
Prairie Restoration
Soil Bioremediation
Wetland Creation
Wetland Restoration
Solar Aquatics
Wastewater Wetlands
Mineland Restoration
Agroecological Engineering

Classification According to Function

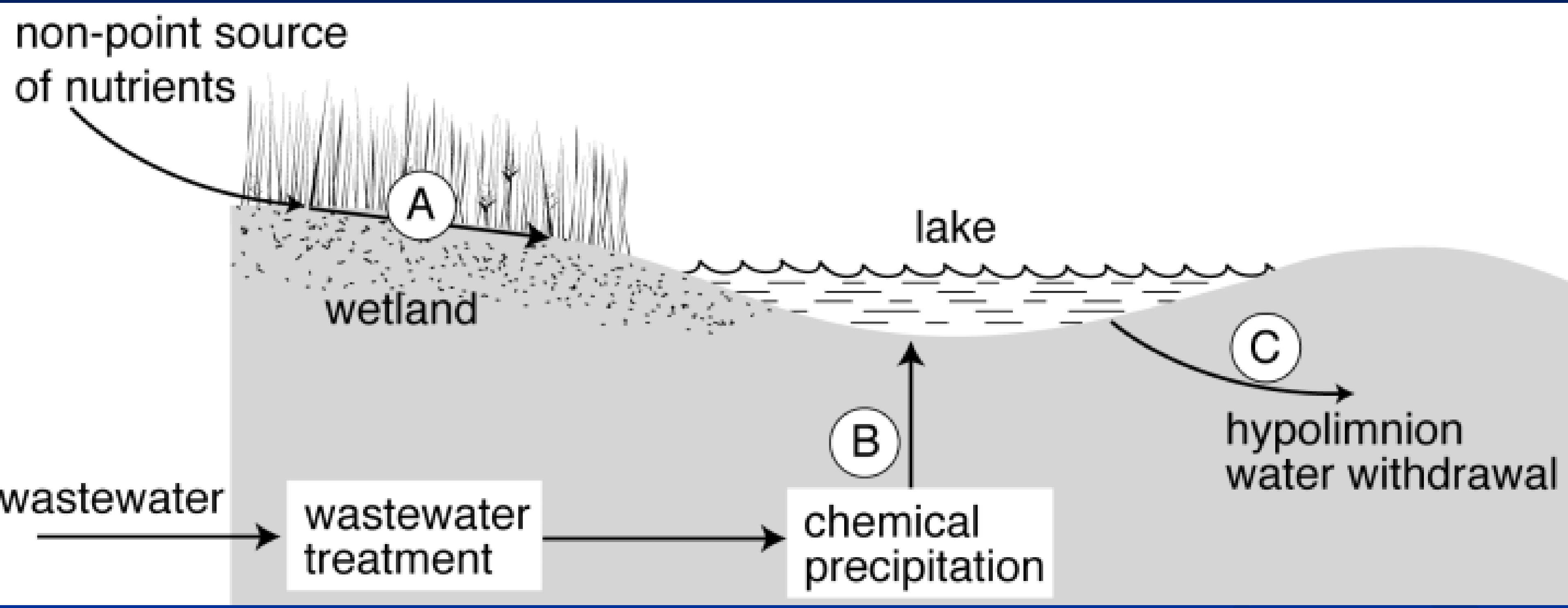
Functional classification

- Ecosystems are used to reduce or solve a pollution problem
- Ecosystems are imitated or copies to reduce a resource problem
- The recover of ecosystems is supported
- Existing ecosystems are modified in an ecologically sound way
- Ecosystems are used for the benefit of humankind without destroying the ecological balance

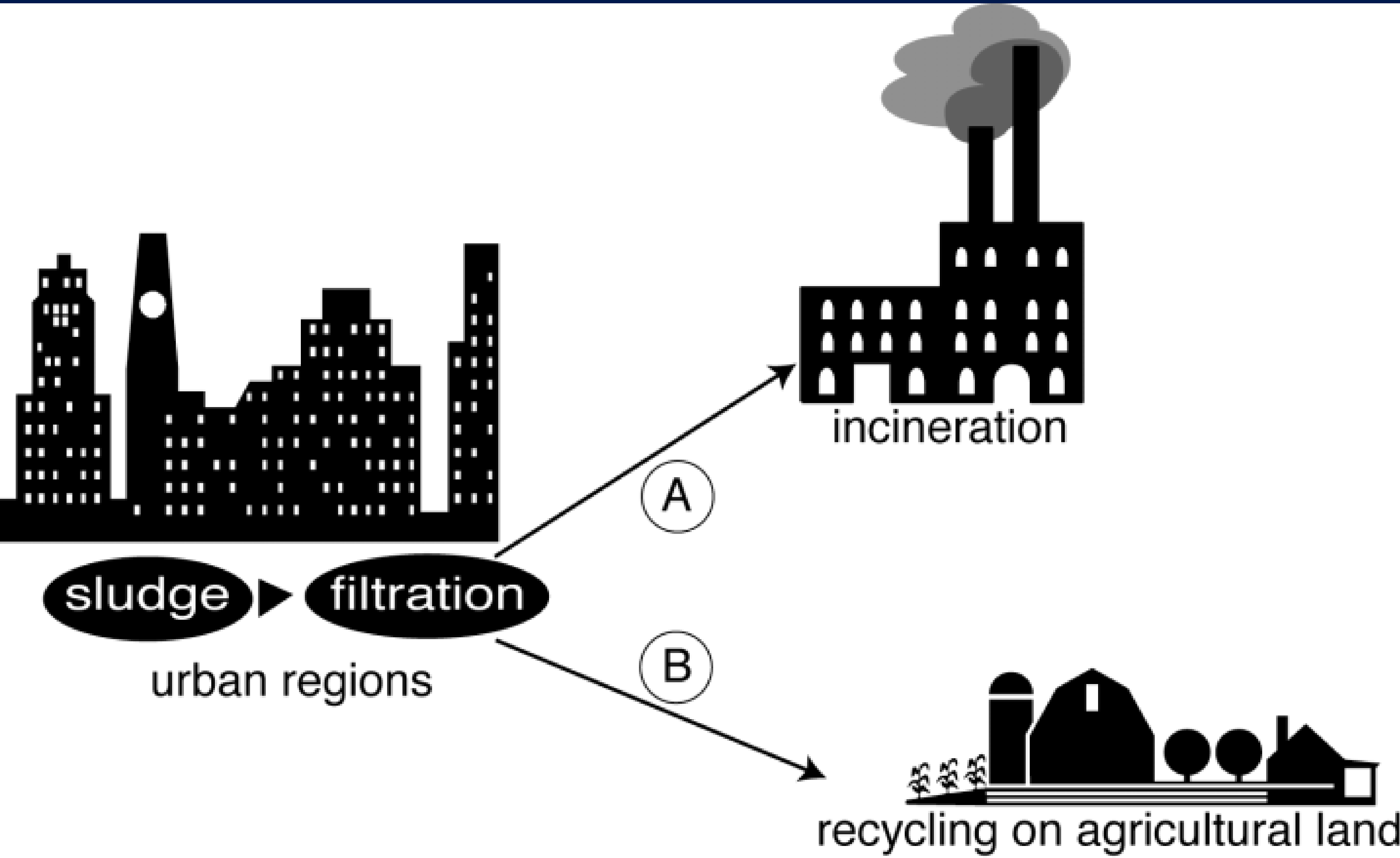
Examples of ecological engineering approaches for terrestrial and aquatic systems according to types of applications.

Ecological Engineering Approaches	Terrestrial Examples	Aquatic Examples
1. Ecosystems are used to solve a pollution problem	Phytoremediation	Wastewater wetland
2. Ecosystems are imitated or copied to reduce or solve a problem	Forest restoration	Replacement wetland
3. The recovery of an ecosystem is supported after disturbance	Mine land restoration	Lake restoration
4. Existing ecosystems are modified in an ecologically sound way	Selective timber harvest	Biomanipulation
5. Ecosystems are used for benefit without destroying ecological balance	Sustainable agroecosystems	Multi-species aquaculture

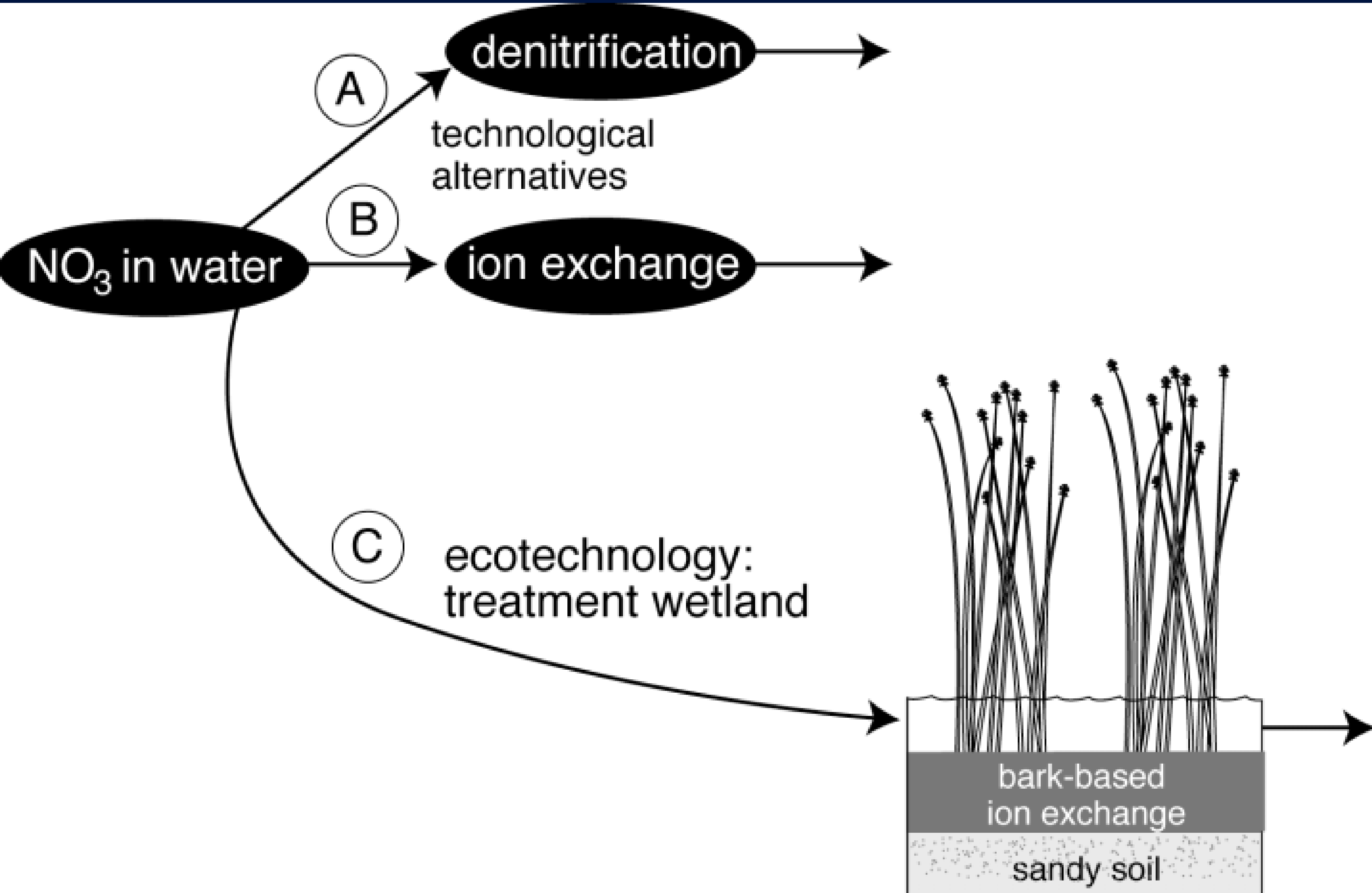
Solving or reducing a pollution problem



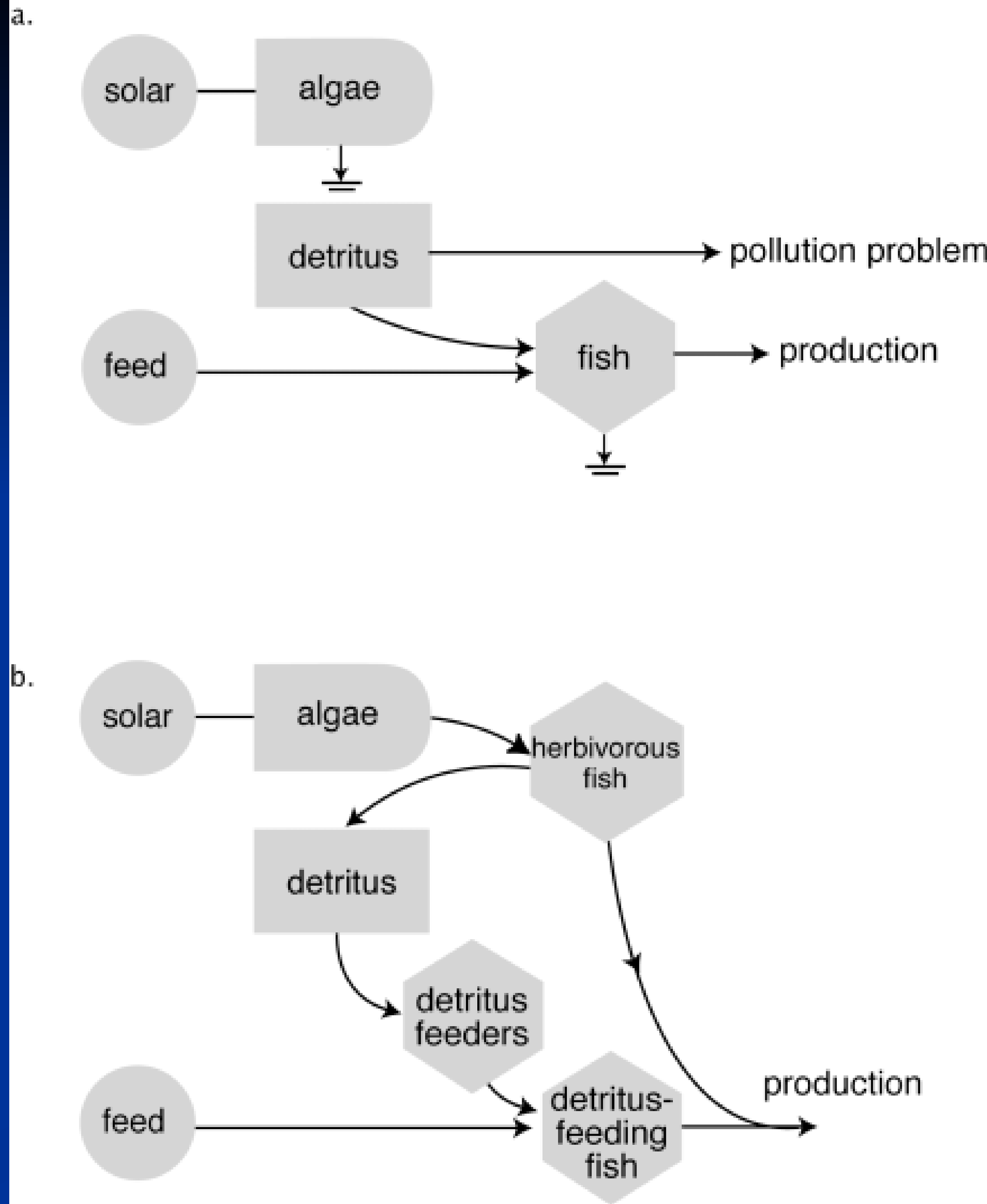
Solving or reducing a pollution problem



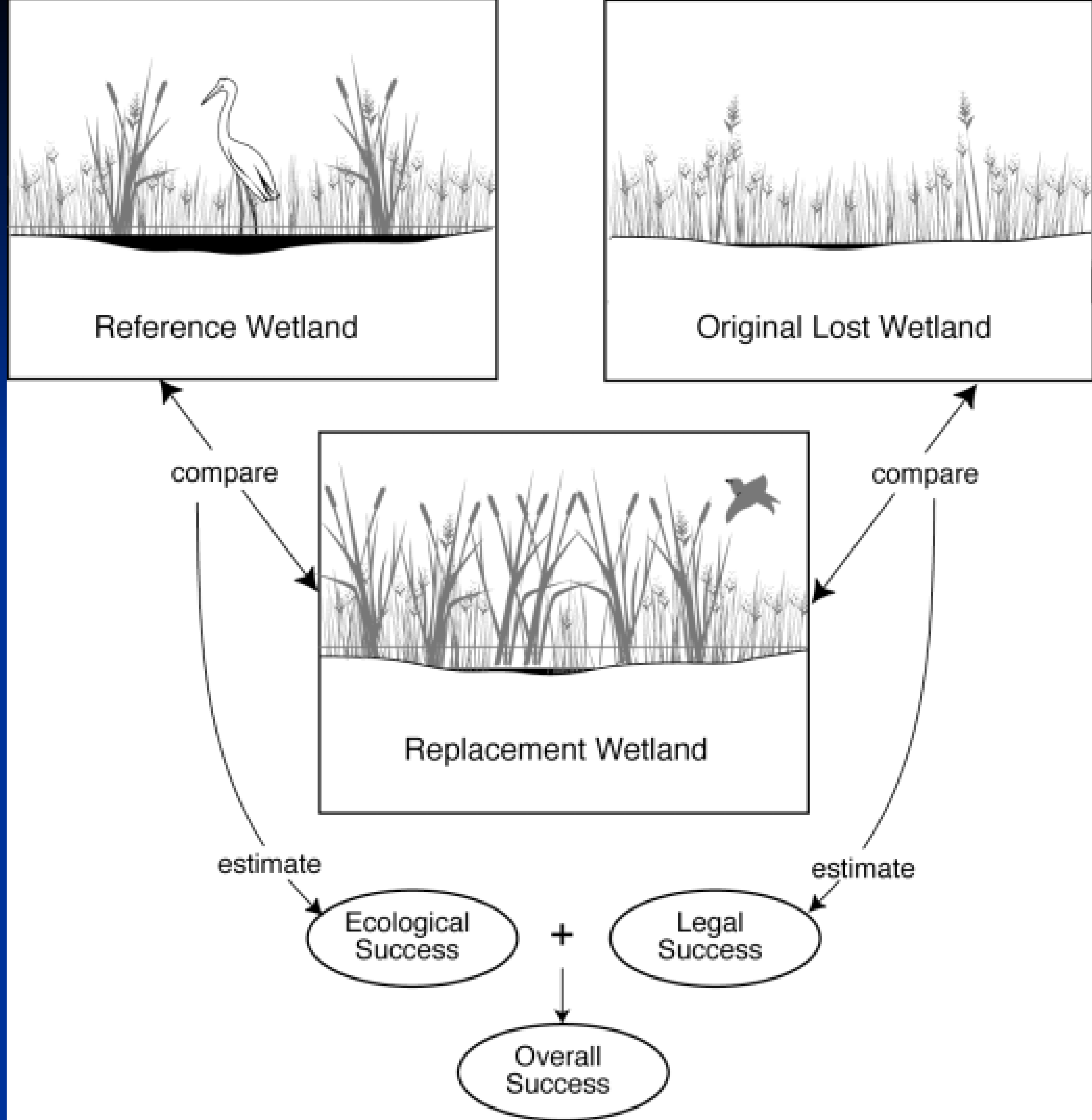
Solving or reducing a pollution problem



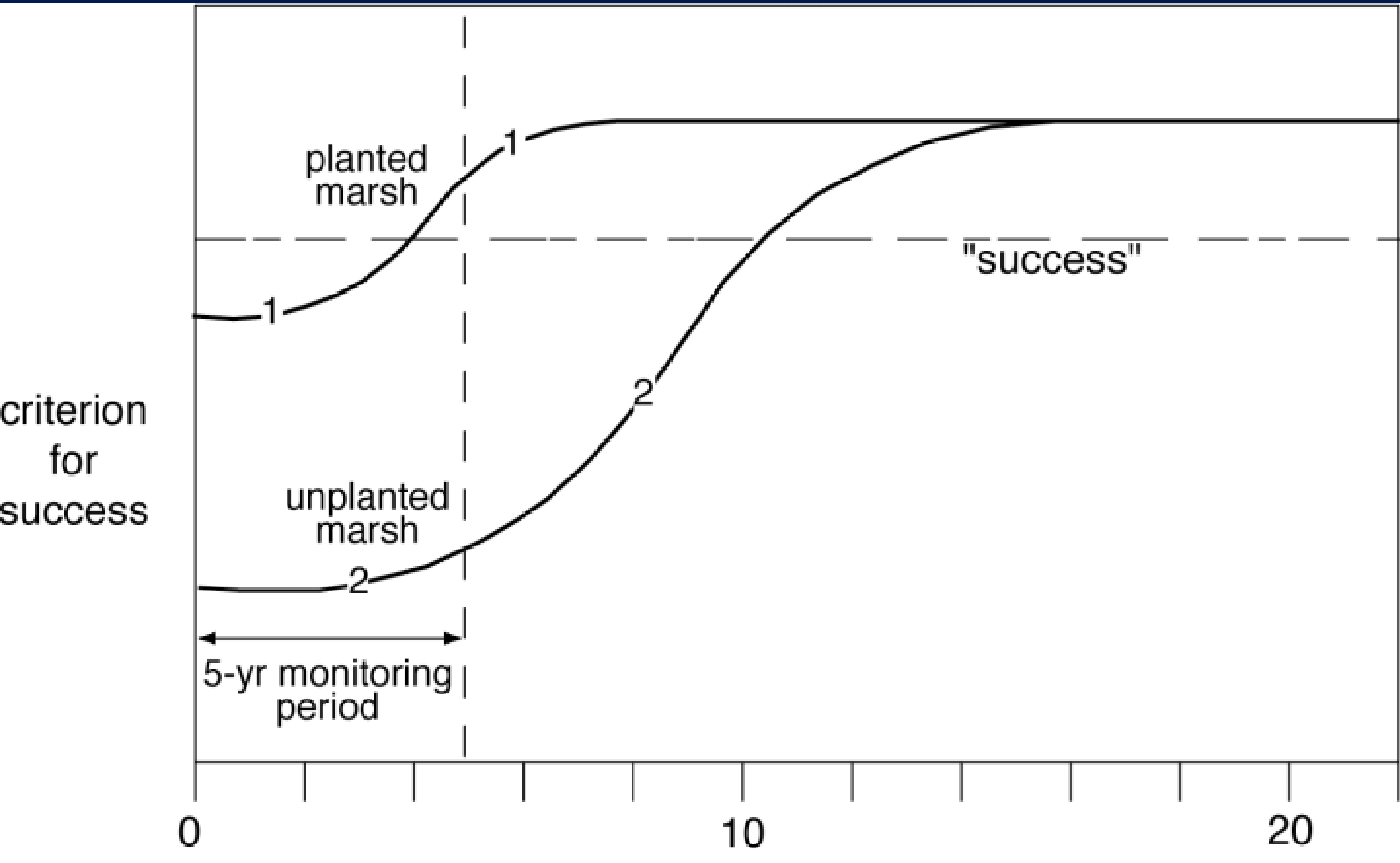
Imitating or copying ecosystems



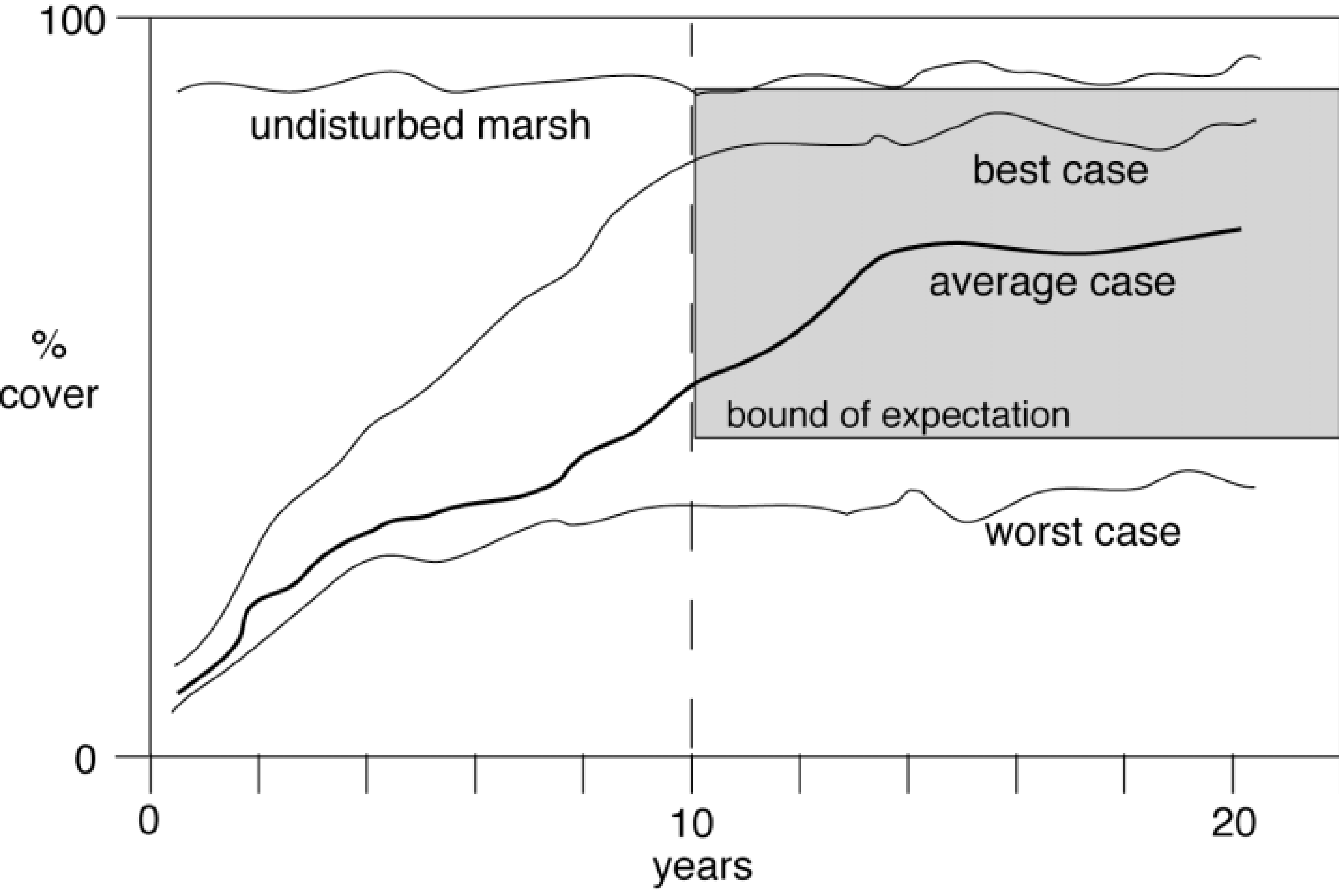
Imitating or copying ecosystems



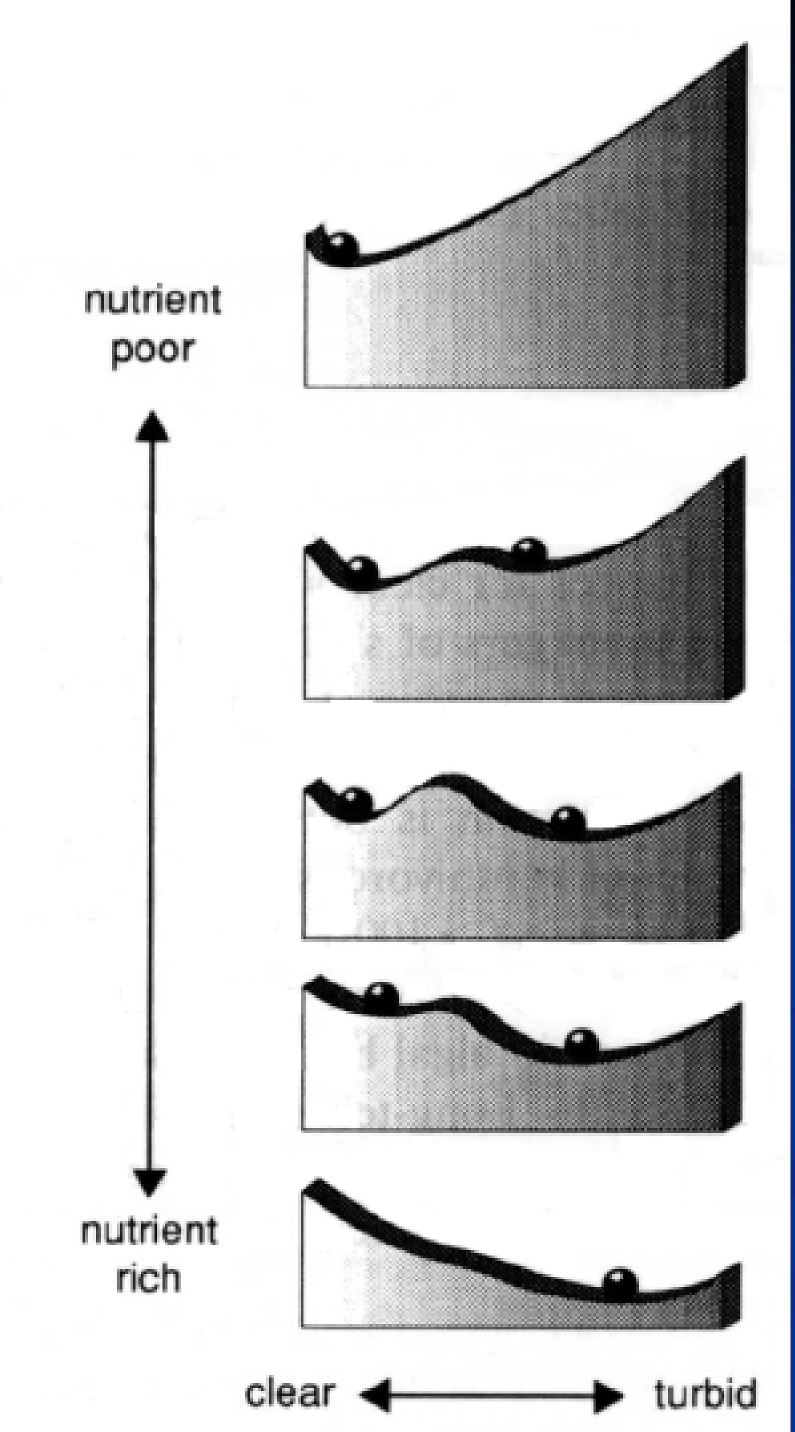
Supporting ecosystem recovery



Supporting ecosystem recovery



Modifying existing ecosystems in an ecologically sound way—Biomanipulation



Source: Hosper and Meijer, 1992

Classification According to Scale

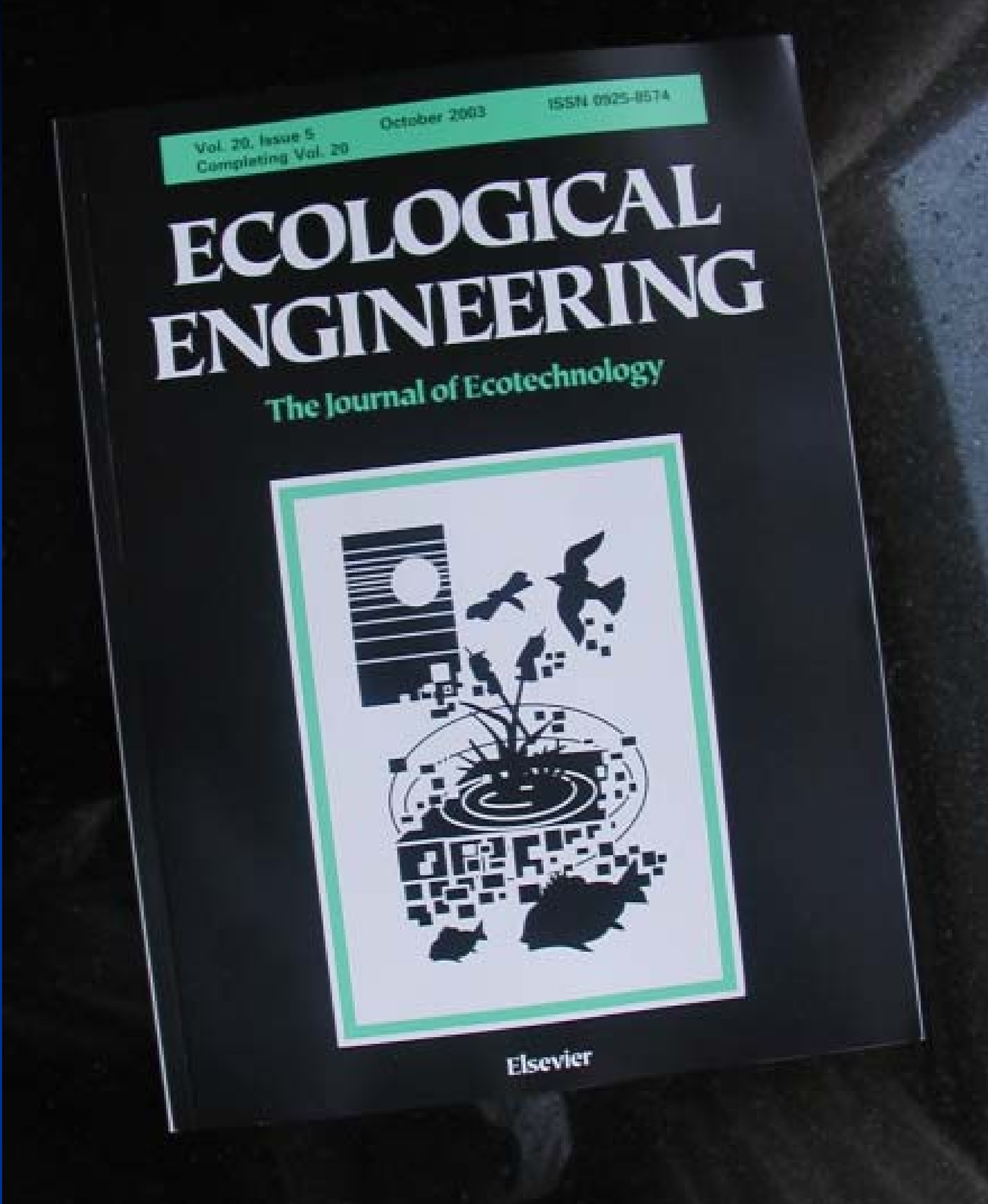
- Mesocosm scale
- Ecosystem scale
- Regional scale

When to Use Ecotechnology

1. The parts of nature affected, directly and indirectly, must be determined.
2. Quantitative assessment of impact of all alternatives must be carried out.
3. Project needs to include entire system, including human impacts and affected ecosystem.
4. Optimization should include short and long-term effects.
5. Renewable and nonrenewable resource use should be quantified.
6. Uncertainty should be accounted for in ecological and economic components.

The Future of Ecological Engineering and Ecosystem Restoration

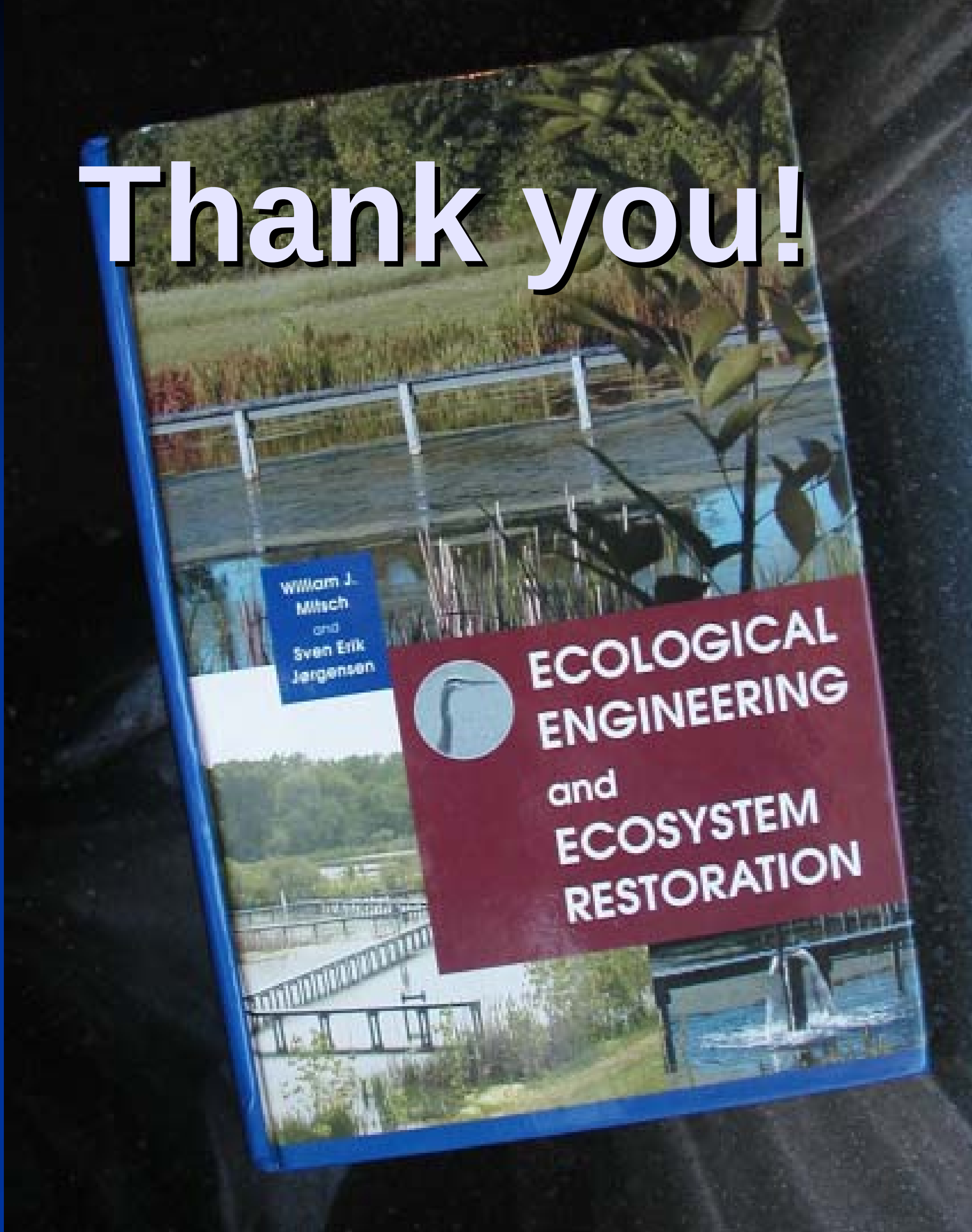
American Ecological Engineering Society: http://aeesociety.org



Information on the book:
http://swamp.osu.edu

American Ecological Engineering Society:
http://aeesociety.org

Thank you!



Some major references

- Mitsch, W.J. and S.E. Jørgensen. 2004. Ecological Engineering and Ecosystem Restoration. John Wiley & Sons, Inc., New York. 411 pp.
- Kangas, P. 2004. Ecological Engineering. CRC Press, Boca Raton, FL.
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- Ecological Engineering: The Journal of Ecotechnology. Elsevier Science. ISSN 0925-8574 Vol 1 -20 (1992-present)