



ASW2: "Integration of Functional and Taxonomic Diversity."

October 2003

St Louis, MO, USA

What is Bio. M. E. R. G. E.?

Biotic

Mechanisms of

Ecosystem

Regulation in the

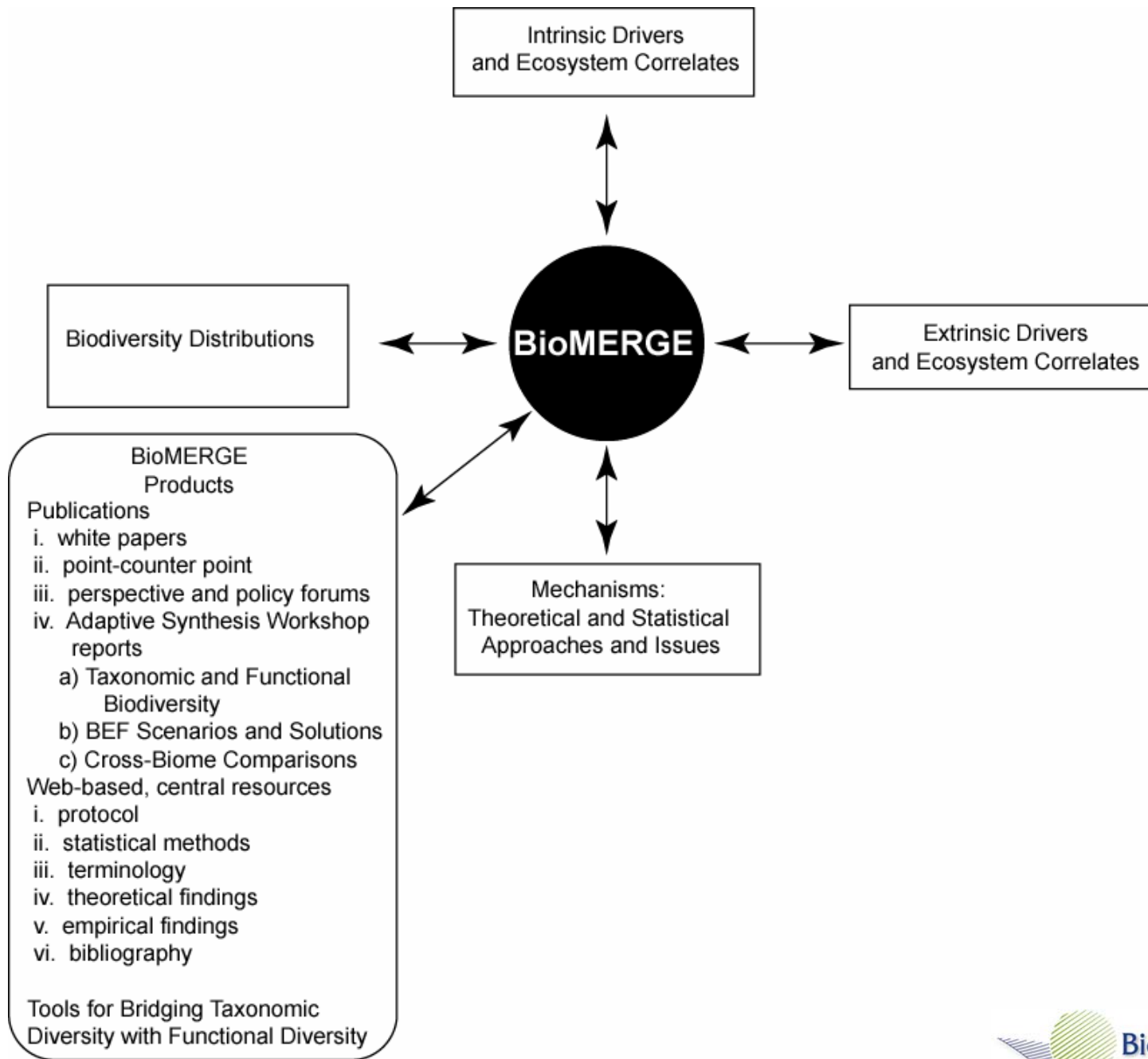
Global

Environment

In a nutshell:

Bring together those that study the diversity of our biota with those that study its functioning.





What is Bio. M. E. R. G. E.?

- 5 year Research Coordinating Network
- Funded by NSF
- Some co-functions with GCTE and DIVERSITAS
- 20 core participants
- > 60 general participants
- Inclusive: open to all interested parties
- Mechanism for interaction: **Adaptive Synthesis Workshops**



BioMERGE Mission

- Given just two things:
 1. An inventory of species
 2. Geography
- Can one state what the likely significance of biodiversity is to the region's ecosystem functions?

Results from ASW1

Ecology Letters, (2003) 6: 567–579

REVIEW

Disentangling biodiversity effects on ecosystem functioning: deriving solutions to a seemingly insurmountable problem

Abstract

Experimental investigations of the relationship between biodiversity and ecosystem functioning (BEF) directly manipulate diversity then monitor ecosystem response to the manipulation. While these studies have generally confirmed the importance of biodiversity to the functioning of ecosystems, their broader significance has been difficult to interpret. The main reasons for this difficulty concern the small scales of the experiment, a bias towards plants and grasslands, and most importantly a general lack of clarity in terms of what attributes of functional diversity (FD) were actually manipulated. We review how functional traits, functional groups, and the relationship between functional and taxonomic diversity have been used in current BEF research. Several points emerged from our review. First, it is critical to distinguish between response and effect functional traits when quantifying or manipulating FD. Second, although it is widely done, using trophic position as a functional group designator does not fit the effect-response trait division needed in BEF research. Third, determining a general relationship between taxonomic and FD is neither necessary nor desirable in BEF research. Fourth, fundamental principles in community and biogeographical ecology that have been largely ignored in BEF research could serve to dramatically improve the scope and predictive capabilities of BEF research. We suggest that distinguishing between functional response traits and functional effect traits both in combinatorial manipulations of biodiversity and in descriptive studies of BEF could markedly improve the power of such studies. We construct a possible framework for predictive, broad-scale BEF research that requires integrating functional, community, biogeographical, and ecosystem ecology with taxonomy.

Keywords

Biodiversity, biogeography, ecosystem functioning, functional groups, research framework.

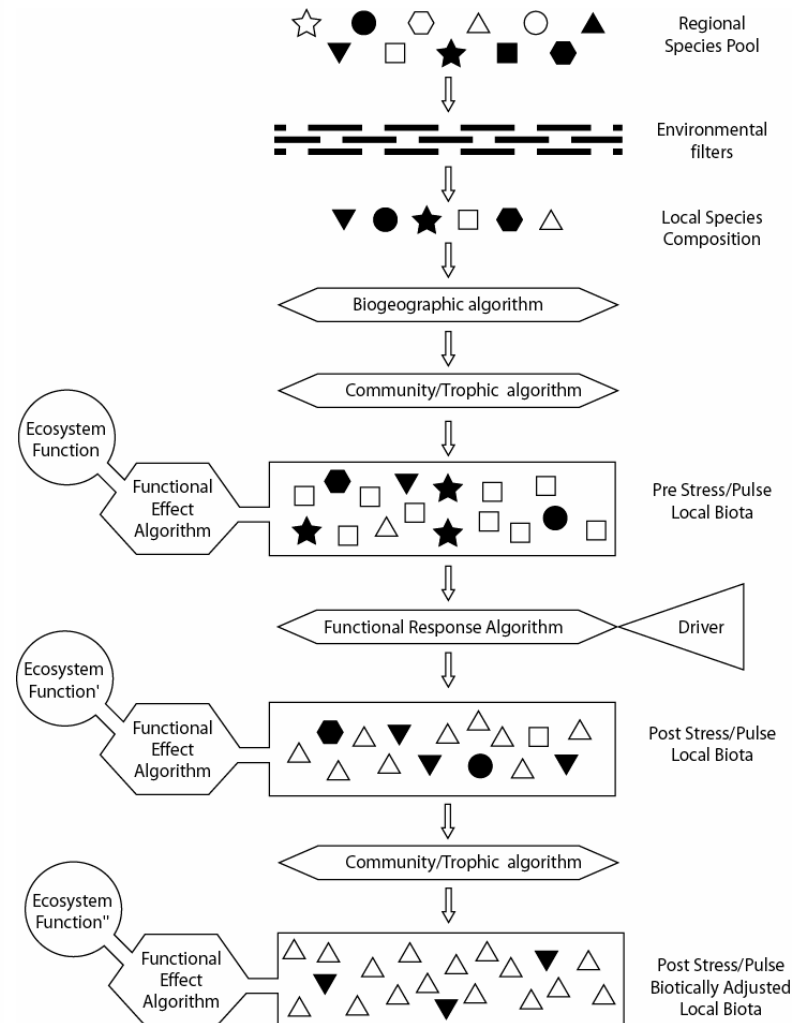
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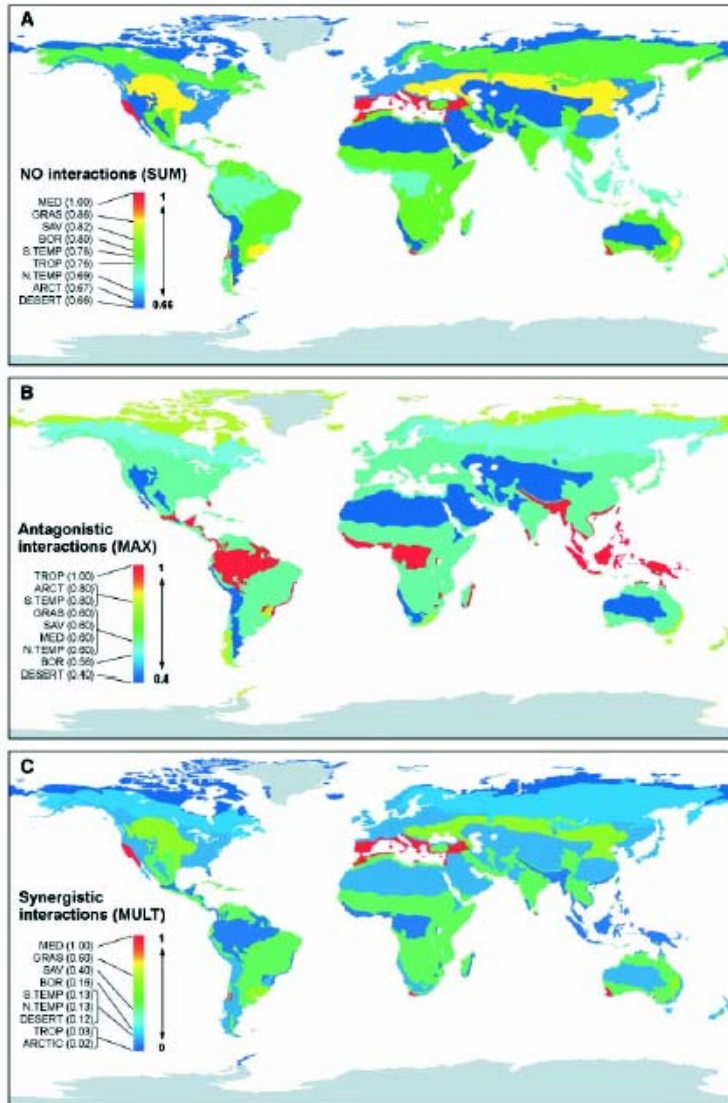
INTRODUCTION

The study of the ecosystem consequences of biodiversity loss represents a synthetic field of ecological research that seeks to understand how changes in species composition, distribution, and abundance alter ecosystem functioning (Schulze & Mooney 1993; Kinzig *et al.* 2002; Loreau *et al.* 2002b; Naeem 2002c). In this work, ecosystem functioning refers specifically to biogeochemical activities, such as production, community respiration, decomposition, nutrient cycling, or nutrient retention. As changes in biodiversity are widespread, findings from this research have received considerable attention (Naeem *et al.* 1994; Hooper &

Vitousek 1997; Naeem & Li 1997; Tilman *et al.* 1997; Wardle *et al.* 1997; Hector *et al.* 1999; Sankaran & McNaughton 1999; Emmerson *et al.* 2001; Engelhardt & Ritchie 2001; Paine 2002; Pfisterer & Schmid 2002), but these findings have been and continue to be difficult to interpret (Guterman 2000; Kaiser 2000; Naeem 2002a). Synthesis and consensus are emerging, however, and the central challenges are being identified (Hughes & Petchey 2001; Loreau & Hector 2001; Loreau *et al.* 2002b) for biodiversity and ecosystem functioning (BEF) research to become a predictive science. The question for BEF research is no longer whether biodiversity matters, but how it matters (Rosenfeld 2002).

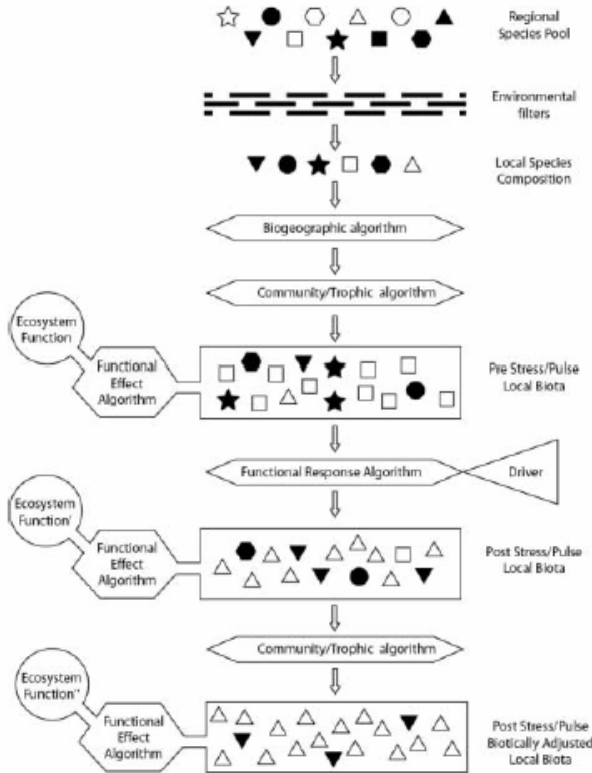
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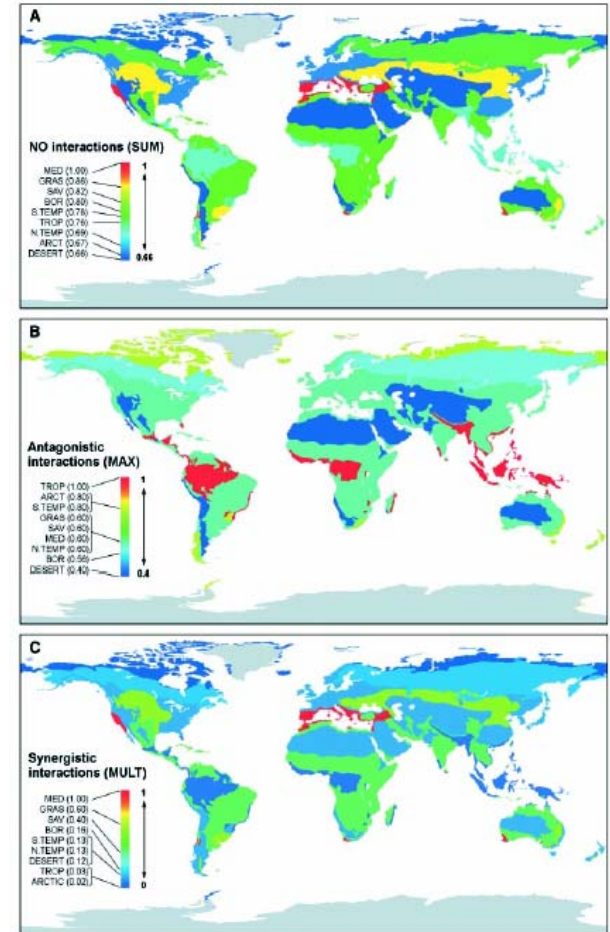


- Policy is made even in the absence of scientific information
- We know human accelerated environmental change affects biodiversity
- We know biodiversity affects ecosystem functioning
- How do we effectively synthesize and communicate this knowledge

Objective for ASW2



Translate



i.e. Begin process of translating conceptual model into useful output using functional existing data on species distributions, functional traits and diversity/ecosystem function relationships

Goals for ASW 2

- Identify 3-4 data sets where we have data on biota, their effect and response traits, and measures of ecosystem functioning (may require synthesis of large biotic inventories with trait data)
- Derive effect and response algorithms for these data sets
- Predict new levels of ecosystem function given addition of a driver to the system (how much does biodiversity matter?)
- Critically evaluate of proxies/shortcuts (e.g. FD, functional groups, scaling relationships)
- Identify key gaps in our data/model

Challenges for ASW2

- How far can we get using readily available data?
- What data are necessary to fully implement model?
- Can we get these data?
- If not are there ways around this?
- Can we produce useful product?

Workshop Structure

Aquatic

Katia Engelhardt

Martin Solan

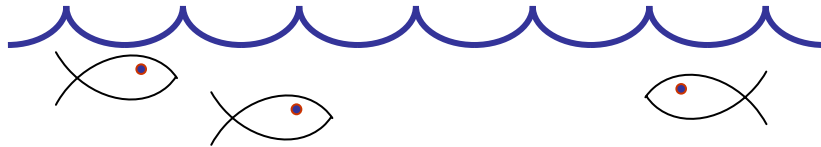
Brad Cardinale

Jonathan Chase

Amy Downing

Jennifer Ruesink

Diane Srivastava



Tropical

Jason Bradford

Oliver Phillips

Rob Colwell

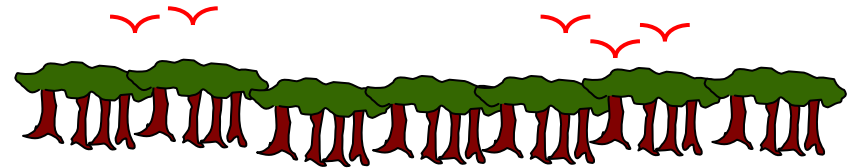
Po Garden

Ivette Perfecto

Peter Raven

Mahesh Sankaran

Jim Solomon



Grasslands

Andy Hector

Clarence Lehman

Jason Fridley

David Hooper

Jennie McLaren

Amy Symstad

Natalia Perez-Harguindeguy

Justin Wright



Theoretical

Shahid Naeem

Sandra Diaz

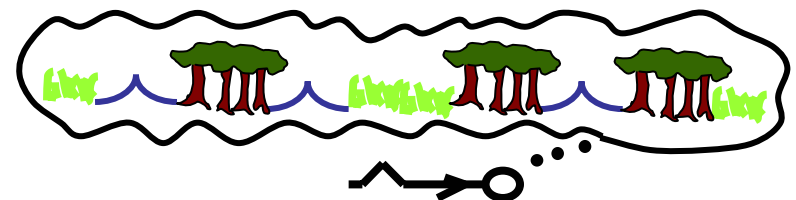
Jennifer Hughes

Claire Jouseau

Sandra Lavorel

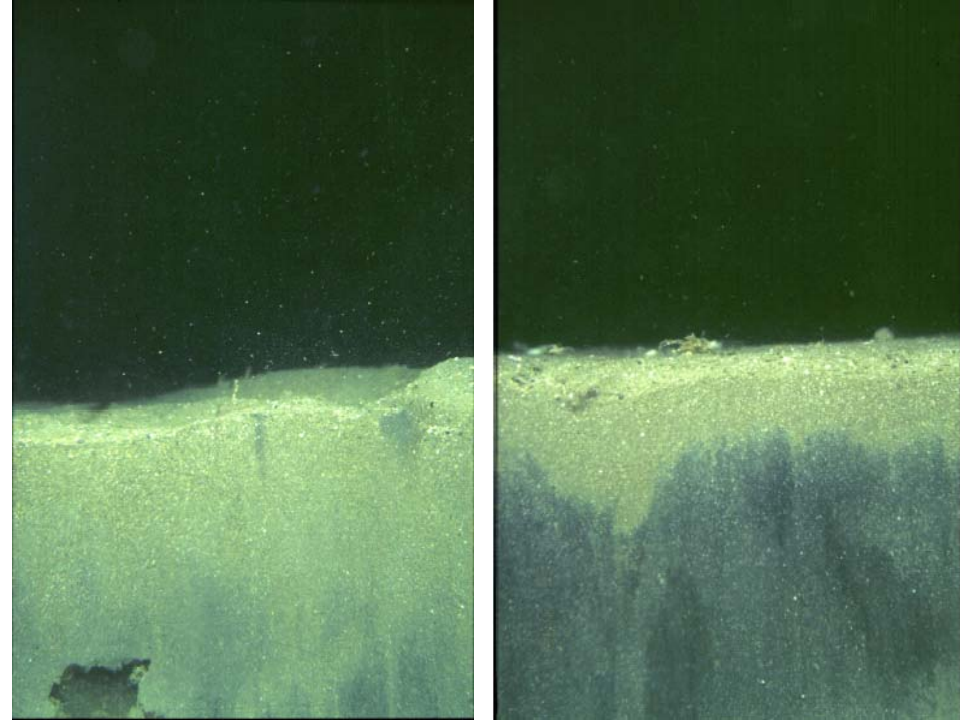
Peter Morin

Owen Petchey



Aquatic Group: Data

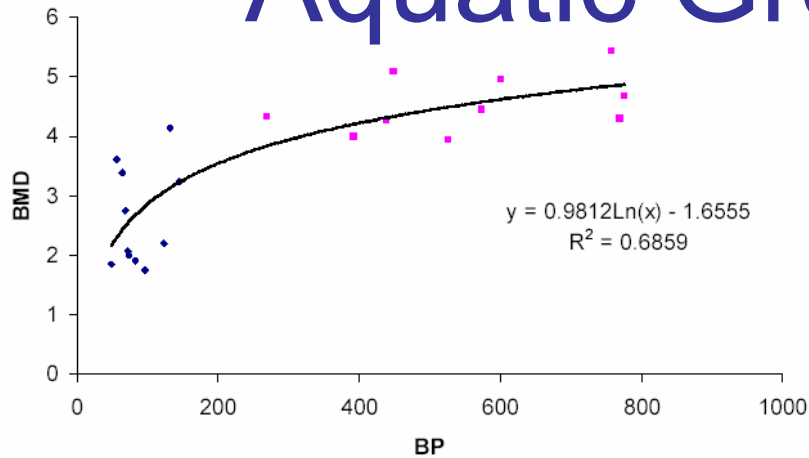
- Dataset on benthic community of Galway Bay, Ireland. 2 sites, many sampling dates
- Functional classification of species based on body size, burrowing depth, reworking mode
- Response: Biotic Mixing Depth (BMD)



Sediment profiles from unpolluted (left) and polluted (right) sites in Galway Bay. Note shallower depth of BMD in polluted site due to lower functional diversity of bioturbators.

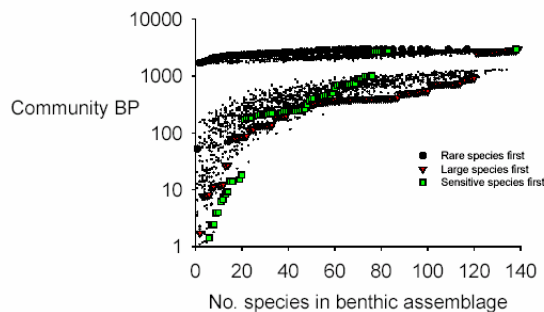
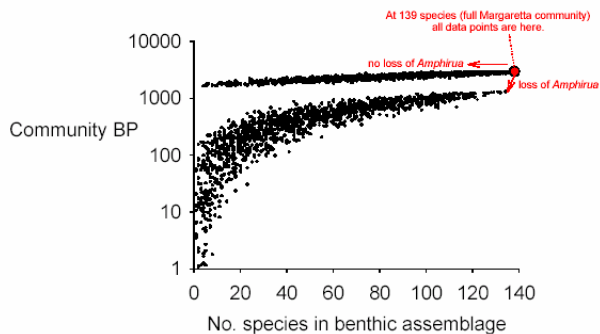
Photos and data courtesy of M. Solan

Aquatic Group: Progress



- Developed relationship between community bioturbation potential (BP) and Biological Mixing Depth (BMD)

- Explored effects of biodiversity loss via
 - Random species loss
 - Body size model (largest species first)
 - Abundance model (rarest species first)
 - Pollution model (sensitive species first)



Aquatic Group: Next Steps

- Allow for compensation within and among functional groups following extinction
- Couple benthic and pelagic food webs
- Increase scale by using same analysis on data from Chesapeake Bay that has greater spatial and temporal extent

Grasslands Group: Data

- Data primarily from Cedar Creek (MN) BioCON experiment
- Measurements of many functional traits on most species in experiment made by Craine et al 2002
- Response: Above-, below-ground productivity, N retention, % transmittance. Can use N and CO₂ treatments to examine effects of changing drivers.



<http://www.lter.umn.edu/biocon/>

Craine et al. 2002. Functional traits, productivity and effects on nitrogen cycling of 33 grassland species. *Functional Ecology* **16**:563-574



Grasslands Group: Progress

- Developed 3 models of “Functional Effects Algorithms” (FEAs)
 1. Determine EF of each species in monoculture. EF of mix = biomass weighted sum of EFs of constituent species
 2. Incorporates species interactions: EF of mix = determined by EF of constituent species in mix rather than in monoculture
 3. Incorporates “trait density” measures – i.e. traits where dispersion of values is more important than mean of values (e.g. rooting depth and phenology)
- Traits identified as important in regulating ecosystem function in large-scale studies (e.g. SLA) not significant predictor at local scale
- Hypothesis – environment selects for minimal variation in key traits that are important at broad scale. Other traits are more important at controlling small-scale variability in ecosystem functioning.

Grasslands Group: Next Steps

- Clean up data from BioCON experiment and fill in functional trait “holes”
- Develop appropriate “*trait density*” statistics
- Select traits for model based on mechanistic assumptions
- Compare 3 FEA models & success of functional traits selected based on local analysis vs. large-scale analysis
- Potential future papers looking at FEAs when confronted with altered drivers; look across ecosystems to determine what functional traits are important for determining ecosystem functioning

Tropical Group: Data

- RAINFOR data set: 1 ha plots surveyed 9-23 years – all individuals mapped and measured
- Traits: wood density (taxonomic), pioneer index, cation association, moisture association, N-fixer (taxonomic)
- Response: Changes in distribution/composition & biomass accrual



Tropical Group: Progress

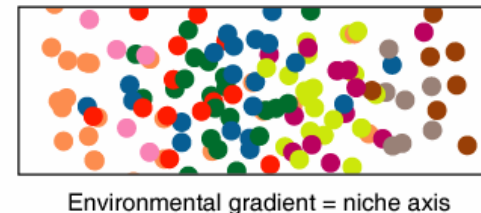
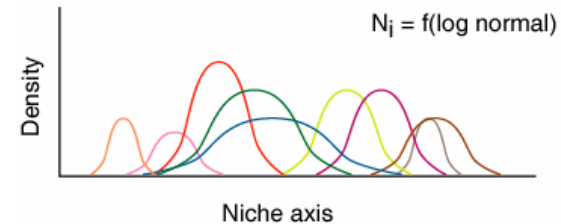
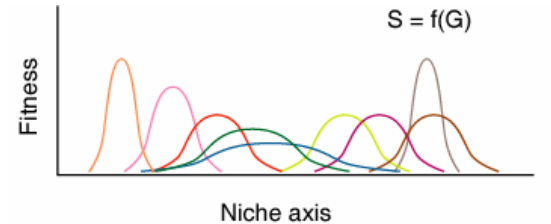
- Integration of trait data base
- Recognition of orthogonal functional traits: pioneer index (measured by wood density) and size (measured by basal area)
- Used long-term data to estimate how increases in CO₂ affect distribution of functional traits – small decrease in median wood density

Tropical Group: Next Steps

- More refined trait measurements (e.g. wood density for all species)
- Estimate standing forest biomass and turnover rates given changes in distribution of functional traits
- Incorporate additional drivers (wood harvesting)
- More efficient database design to allow for further analyses
- Incorporate stem data from more recent surveys

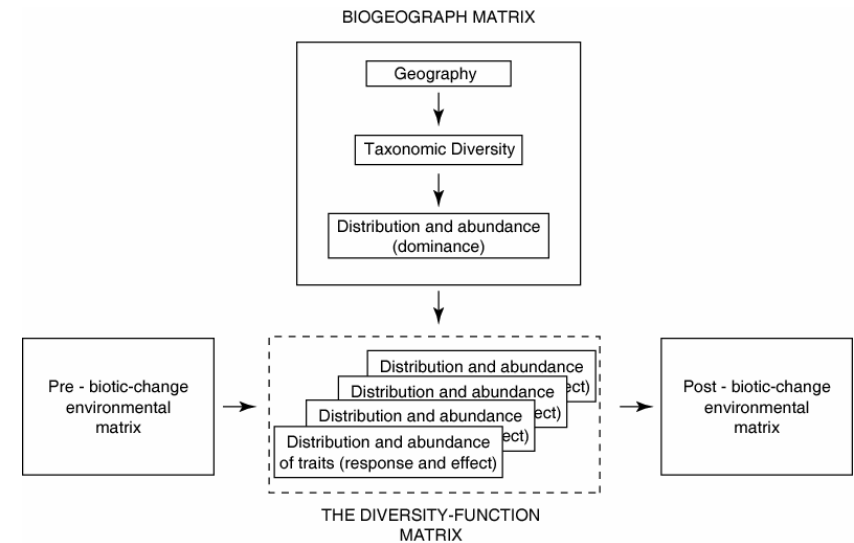
Theoretical Group: Principles

- A fundamental theoretical BEF framework founded on basic ecological principles would serve to integrate findings from the case studies (aquatic, grassland, and tropical)
- A theoretical framework needs to integrate principles from
 - Community ecology
 - Eltonian pyramid
 - Trophic structure/dynamics
 - Scaling rules
 - The niche
 - The biotope
 - Ecosystem ecology
 - Abiotic constraints on ecosystem/biogeochemical processes
 - Coupled patterns of material cycling and energy flow
 - Biogeography
 - “Log-normalish” patterns of distribution and abundance
 - Gradient effects
 - Island effects



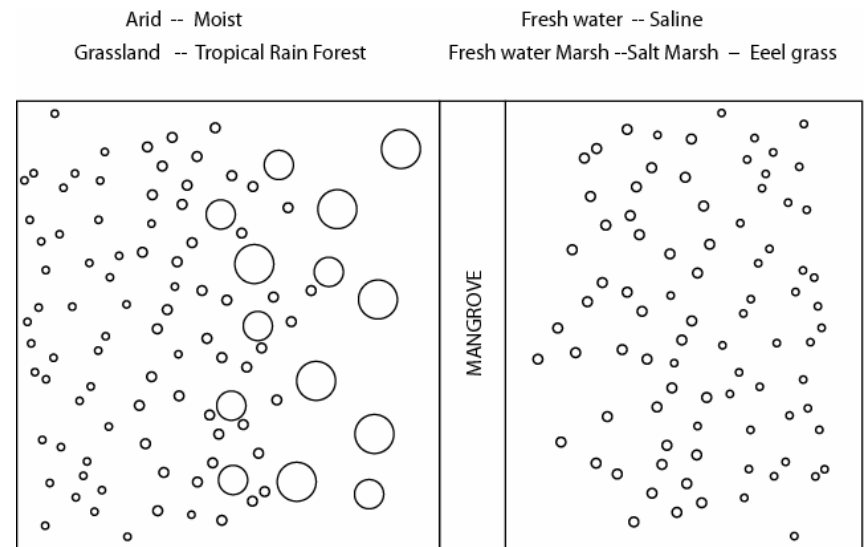
Theoretical Group: Progress

- We developed a theoretical BEF framework that can be examined by simulation
- We developed an algorithm for constructing the biogeographic matrix that creates a biota consistent with biogeographical principles
- We developed an algorithm for constructing the response-effect matrix that structures the biota consistent with community and ecosystem principles



Theoretical Group: Next Steps

- Conduct simulations and compare findings with current empirical evidence
- Refine framework and improve precision
- Restructure framework for grasslands, tropical, and estuarine systems
- Simulate four scenarios
 - Type I. Invasion. New species are added from other ecosystems.
 - Type II. Over-exploitation. Dominant species are over-exploited.
 - Type III. Random extinction. No particular driver is considered.
 - Type IV. Forced. Increasing eutrophication.



ASW2 Conclusions

- Significant progress made in translating measures of biodiversity and functional traits into ecosystem function in some ecosystems
- Generally, datasets that allow for this are rare
- Need more complete measures of functional traits of species
- Need better measurements of role of functional diversity in controlling ecosystem functioning
- Significant progress was made in refining the theoretical framework for BEF
- Need to test framework by model building and simulation