Functional Diversity

By Morgan Davies and Emily Smith

Outline

- Introduction to biodiversity and functional diversity
  - How do we measure functional diversity
  - Why do we care about functional diversity
  - Applications of an FD approach in research
  - Challenges of an FD approach
  - Conclusions

Biodiversity

- Broad
- Includes all genotypic/phenotypic variation
- Spatial and temporal variability in communities and ecosystems

Functional Diversity

- Subset of biodiversity (Tilman, 2001).
- "The range and value of those species and organismal traits that influence ecosystem functioning" (Tilman, 2001).
- More simply:
  - All organisms have roles that contribute to overall ecosystem functioning and health

Functional Diversity

- All else being equal, as species richness increases, so should functional diversity
  - More species, more traits, more functions

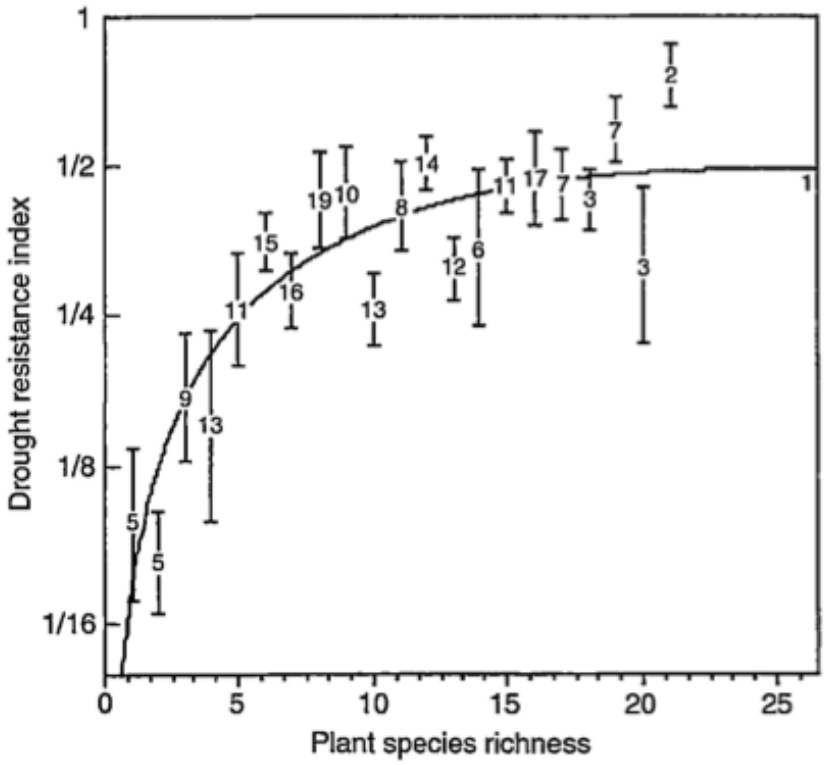


FIGURE 6 The resistance of Minnesota grassland ecosystems to drought was highly dependent on their plant biodiversity. Ecosystems containing a large number of plant species had their producuvity fall to about half of its predrought levels during a severe drought, but those containing only one or two plant species had it fall to about 1/8 to 1/12 of the predrought level.

Tilman (2001)

Functional Diversity

- Ecological importance
  - "component of diversity that influences ecosystem dynamics, stability, productivity, nutrient balance" (Tilman, 2001).
- Leading to overall ecosystem health

Why functional diversity

- Because it allow us to look at mechanisms of Diversity/Ecosystem Function dynamics
- Use multiple indices that measure aspects of a species' **distribution in niche space**
  - Continuous vs. discrete
- Function relates to wider process more than species identity

How do we measure functional diversity?

Schleuter, D., Daufresne, M., Massol, F., and Argillier, C. (2010) A User's guide to functional diversity indices, Ecological Monographs, vol. 80, n° 3, 469-484.
author-produced version of the final draft post-refeering
the original publication is available at http://www.esajournals.org/ - DOI: 10.1890/08-2225.1

"Most remarkable, however, is not how poorly traditional diversity metrics perform, but how slow ecologists have been to adopt the more powerful FD metrics."

- Cadotte et al. 2011

OIKOS 111: 112–118, 2005

Functional richness, functional evenness and functional divergence: the primary components of functional diversity

Norman W. H. Mason, David Mouillot, William G. Lee and J. Bastow Wilson

Mason et al. propose and clarify functional analogies to species richness, evenness and divergence

- Outline how to measure biodiversity via functional traits

Richness, Evenness and Divergence

We thus arrive at an overall definition of functional diversity as: the distribution of the species and abundance of a community in niche space, including:

a) the amount of niche space filled by species in the community (functional richness)
b) the evenness of abundance distribution in filled niche space (functional evenness) and
c) the degree to which abundance distribution in niche space maximises divergence in functional characters within the community (functional divergence).

Why do we care?

- Functional Redundancy

> The concept of functional redundancy is at the core of theory relating changes in ecosystem function to species loss. Functional redundancy is based on the observation that some species perform similar roles in communities and ecosystems, and may therefore be substitutable with little impact on ecosystem processes

(Rosenfeld, 2002)

- Group species together based on similarities in ecosystem functioning

Practicalities of Functional Redundancy

- Important tool for justifying conservation priorities
  - If we can't save them all, who are we going to save?
- Context
  - Functional significance of losing a species
    - 2 vs. 20 species in a functional group (Rosenfeld, 2002)
- Long-term Affects
  - What is functionally redundant at small scales may not be true with environmental change over larger scales
    - Exotics

Reality Check

- Functional Redundancy is not the answer to everything
- Development and human impacts will continue
- However, understanding functional diversity relationships will help prioritize conservation decisions and help predict the impact of various management decisions on ecosystem functioning

Photo: Tim Ennis, www.NCC.ca

Applications of functional diversity approach in research

Species, trophic, and functional diversity in marine protected and non-protected areas

Adriana Villamor [1], Mikel A. Becerro *

- Ecosystem health between marine protected and non-protected areas in Mediterranean Sea

> We need empirical evidence to support or refute the capacity of MPAs to preserve species, trophic, and functional diversity. In this study we focused on the overall reserve effect at a community level, testing whether MPA-driven changes in marine communities cause shifts in the ecological organization and functioning of the ecosystem (García-Chartón et al., 2008). Protection may increase both the number and abundance of species locally absent in a particular area, contributing to increase species richness and evenness after protection. We therefore expect higher spe-

(Villamor, 2012)

- Groupings of trophic levels
  - Top predators, Carnivores, Herbivores, etc.

Findings

- Species diversity and trophic diversity not significant between sites
- Functional diversity is significant
  - Higher functional diversity in MPAs

Table 3
Two-way Anova on species diversity, trophic diversity, and functional diversity as a function of geographic area (random factor) and protection status (fixed factor). *p*-Values under 0.05 are considered significant.

Measure	Effect	*df*	Mean squares	*F*-ratio	*p*-Value
Species diversity	Geographic area	4	0.718	6.322	0.003
	Protection status	1	0.243	4.492	0.101
	Interaction	4	0.054	0.478	0.751
	Error	17	0.114		
Trophic diversity	Geographic area	4	0.022	0.960	0.454
	Protection status	1	0.195	1.826	0.248
	Interaction	4	0.107	4.599	0.011
	Error	17	0.023		
Functional diversity	Geographic area	4	0.504	7.686	0.001
	Protection status	1	0.340	10.113	0.033
	Interaction	4	0.033	0.513	0.726
	Error	17	0.065		

Critiques

- Broad trophic groupings
  - Categories
- Enough traits?
  - Feeding mode, habitat use, life history traits
- Small sample size
  - 6 sites
- So much variation!

Conclusions

- Support for reserve effect
- Increased protection will increase biodiversity and ecosystem services
- “effect of protection may be more pronounced in the functional traits of the ecosystem than in species composition and abundance” (Villamor, 2012)

Functional over-redundancy and high functional vulnerability in global fish faunas on tropical reefs

2014. PNAS.

David Mouillot[a,b,1,2], Sébastien Villéger[a,1], Valeriano Parravicini[c,d,1], Michel Kulbicki[c], Jesus Ernesto Arias-González[e], Mariana Bender[a,f], Pascale Chabanet[g], Sergio R. Floeter[f], Alan Friedlander[h], Laurent Vigliola[i], and David R. Bellwood[b,j]

Discuss functional diversity in terms of

- functional entities (FEs): “unique combinations of functional traits”
  - Functional over-redundancy (FOR): species fall disproportionately into a small number of FEs
- Vulnerable functional entities include few species

Functional over-redundancy and high functional vulnerability in global fish faunas on tropical reefs

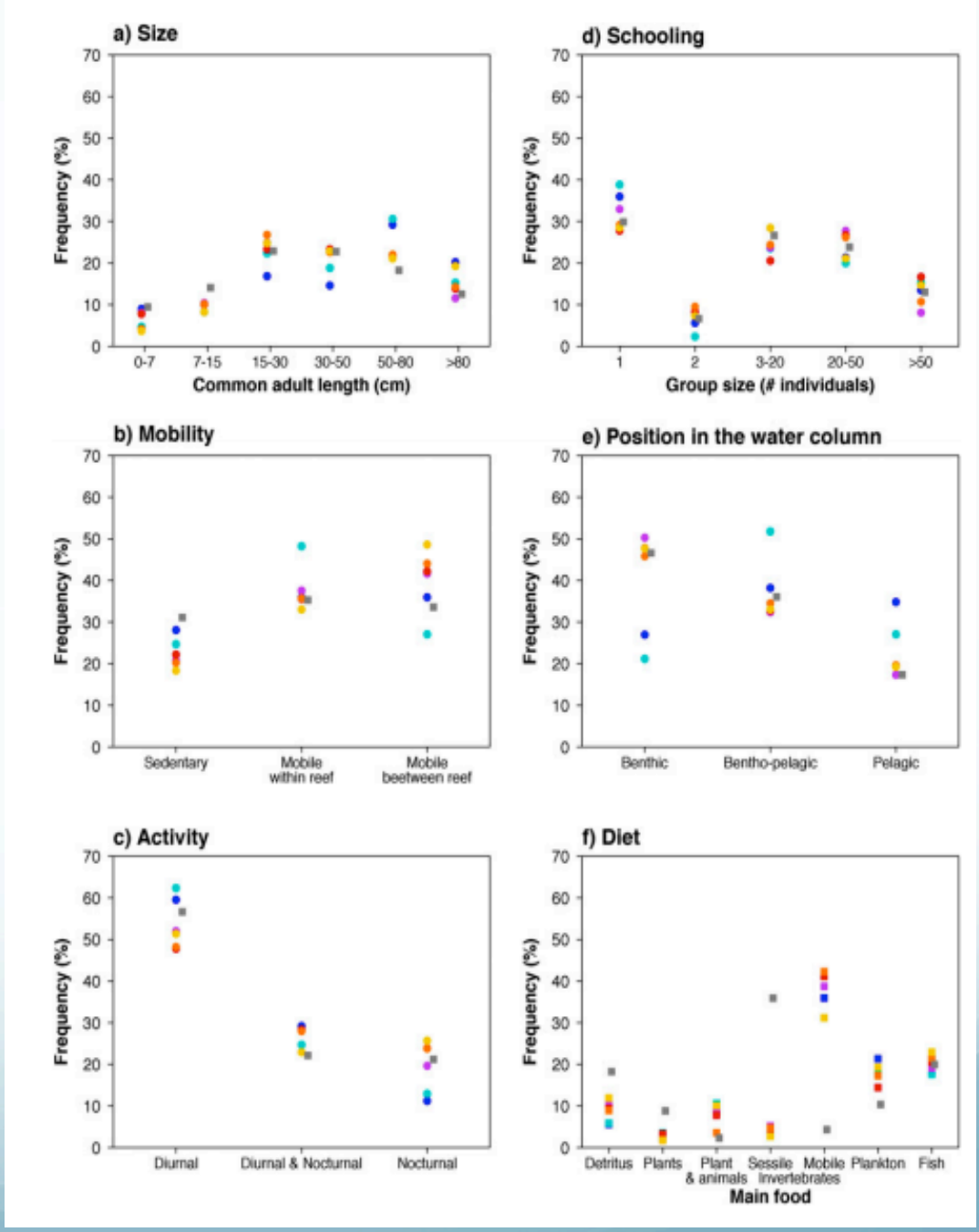
David Mouillot[a,b,1,2], Sébastien Villéger[a,1], Valeriano Parravicini[c,d,1], Michel Kulbicki[c], Jesus Ernesto Arias-González[e], Mariana Bender[a,f], Pascale Chabanet[g], Sergio R. Floeter[f], Alan Friedlander[h], Laurent Vigliola[i], and David R. Bellwood[b,j]

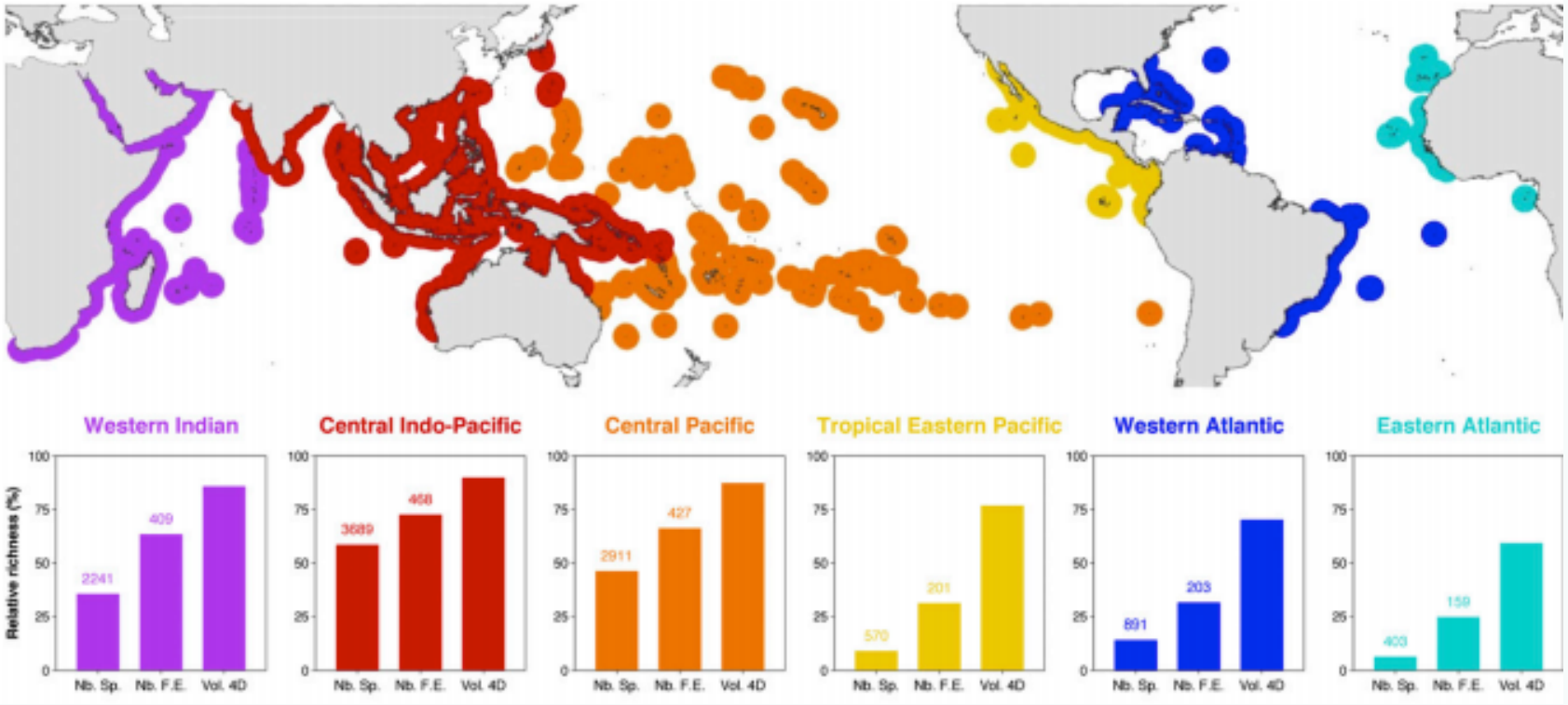
6 functional traits ➔ 5,670 theoretical functional entities (FEs)

The 6,316 tropical reef fish fill 11.4% of these FEs

6 functional traits

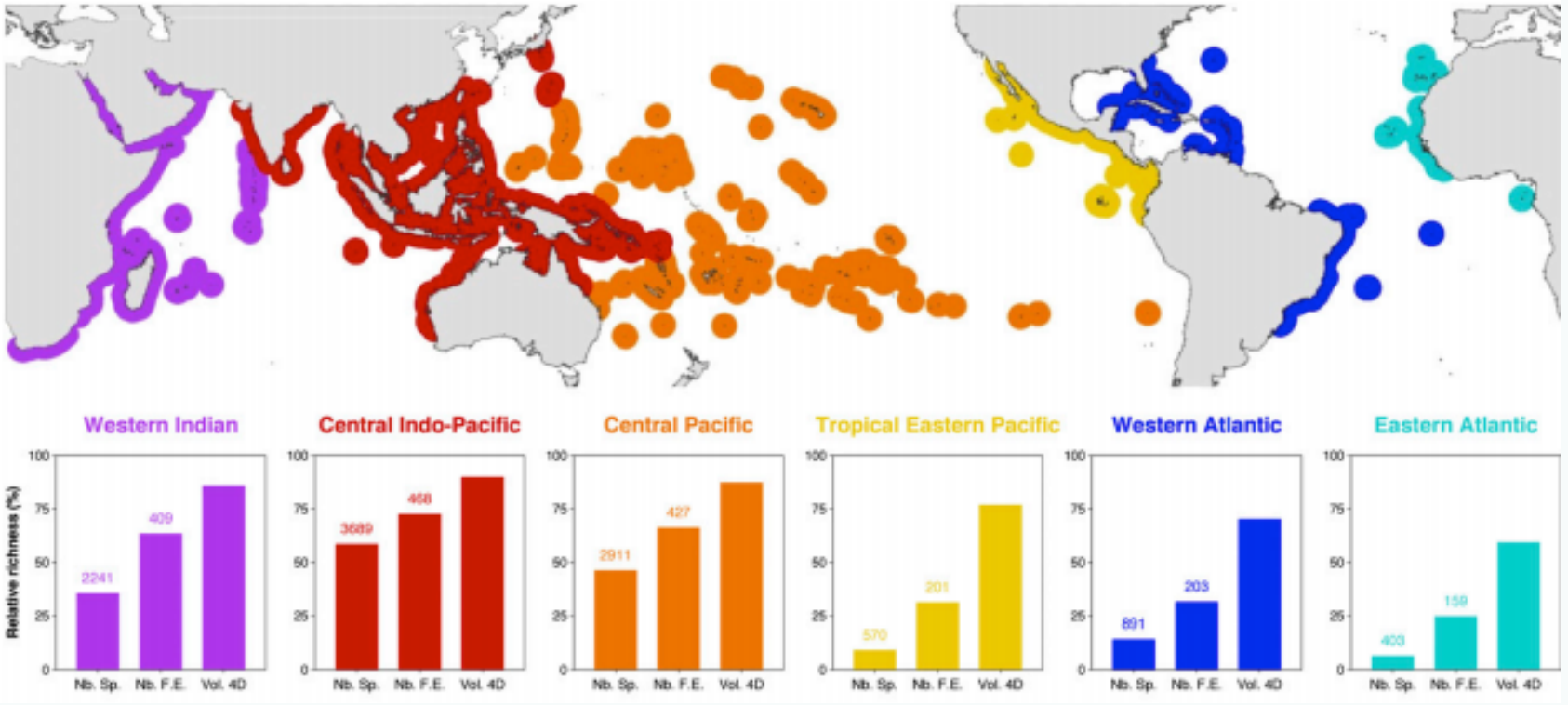
- Fish body size
- Mobility
- Period of activity
- Schooling Behaviour / Gregariousness
- Vertical position in the water column
- Diet

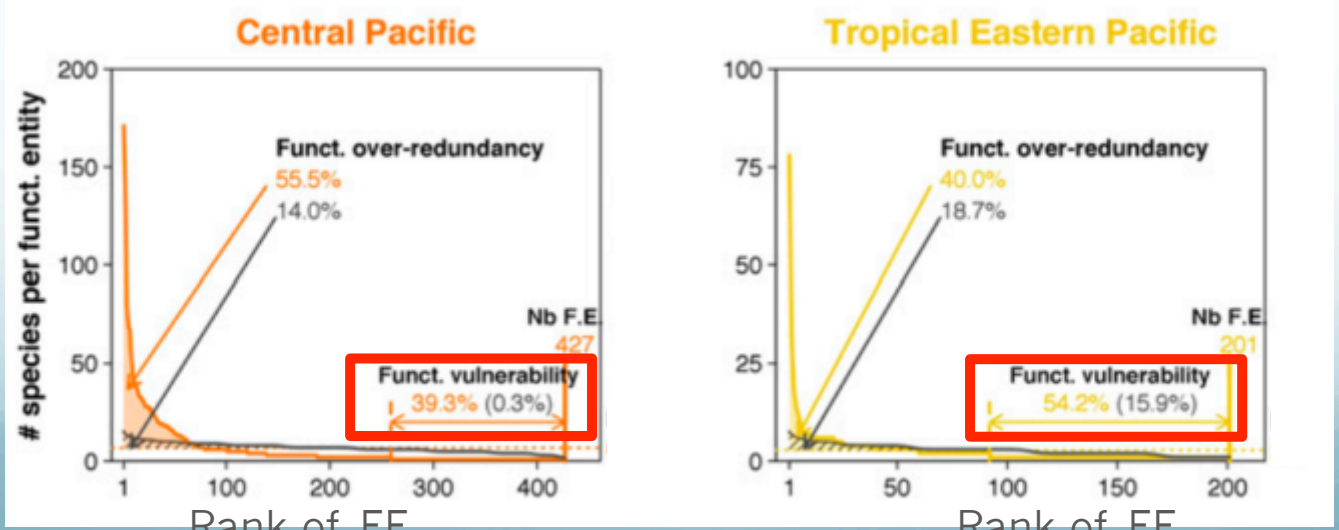




- Number of species
- Number of FES
-

(% relative to global pool)


Western Indian
Central Indo-Pacific
Central Pacific
Tropical Eastern Pacific
Western Atlantic
Eastern Atlantic
Relative richness (%)
2241
409
3689
468
2911
427
570
201
891
203
403
159
Nb. Sp.
Nb. F.E.
Vol. 4D


Central Pacific
species per funct. entity
Funct. over-redundancy
55.5%
14.0%
Nb F.E.
427
Funct. vulnerability
39.3% (0.3%)
Rank of FE
Tropical Eastern Pacific
Funct. over-redundancy
40.0%
18.7%
Nb F.E.
201
Funct. vulnerability
54.2% (15.9%)
Rank of FE

Conclusions

ingly, the level of FOR is consistent across the six fish faunas, meaning that, whatever the richness, over a third of the species may still be in overrepresented FEs whereas more than one third of the FEs are left without insurance, these levels all being significantly higher than expected by chance. Thus, our study shows that, even in high-diversity systems, such as tropical reefs, functional diversity remains highly vulnerable to species loss. Although further investigations are needed to specifically address the influence of redundant vs. vulnerable FEs on ecosystem functioning, our results suggest that the promised benefits from tropical biodiversity may not be as strong as previously thought.

Implications

- 1/3 of FEs represented have no insurance (constant across 6 regions)
- Implications for resilience
- A more complex understanding of high diversity regions

However

- Low number of traits used
- Large scale observational data
- Categorical data used for traits

Journal of Applied Ecology

British Ecological Society

Journal of Applied Ecology 2011, **48**, 1079–1087 doi: 10.1111/j.1365-2664.2011.02048.x

REVIEW

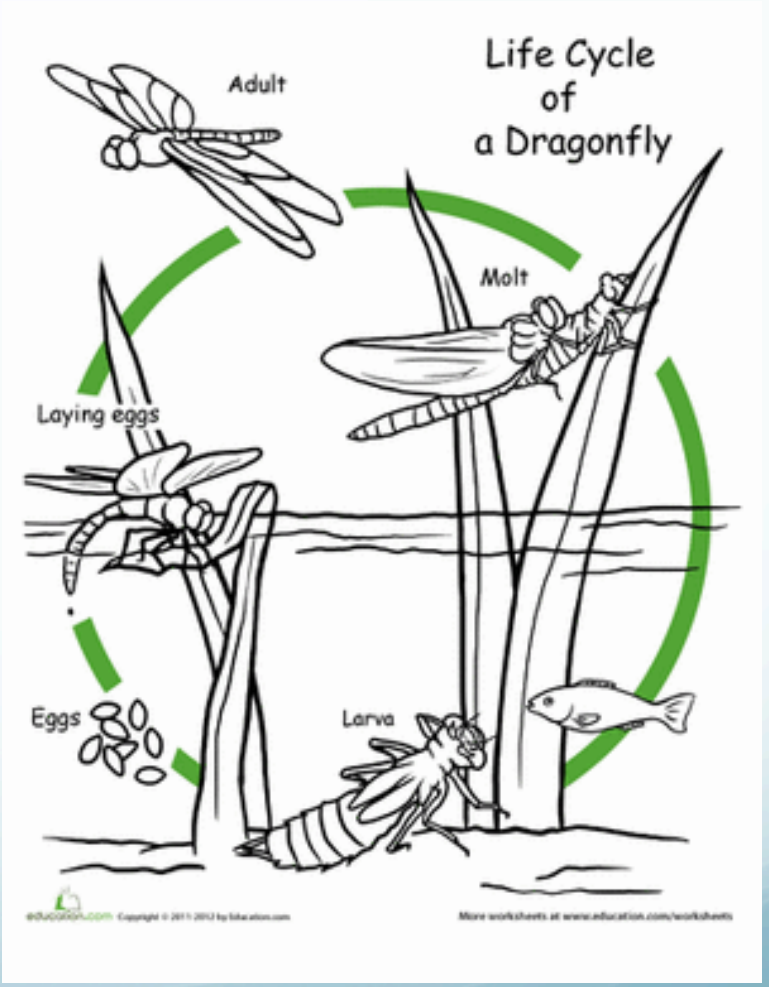
Beyond species: functional diversity and the maintenance of ecological processes and services

Marc W. Cadotte*, Kelly Carscadden and Nicholas Mirotchnick

- See future for FD in conservation decision making – link to stability
- Problematizes aspects of FD
  - Relative explanatory power
  - Correlation with sp. richness

Functional diversity and species concept

- High intraspecific variation in FD
- Continuous variation at a range of levels of organisation



Challenges with a functional diversity approach

- Phylogenetic diversity can be as accurate a predictor of ecosystem function
- Difficult to know what to measure and to accurately determine FD

Photo credit: Tilman. Biologists sample plant biomass at the Cedar Creek Long-Term Ecological Research site.

Why use functional diversity?

- A metric for diversity that has a mechanistic connection to ecosystem functioning – **the niche**
- New insights come from shifting from species to other measures of diversity
  - Functional redundancy and vulnerability
- Strong implications for conservation

IslandNature.ca

Thank you

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With special mention of

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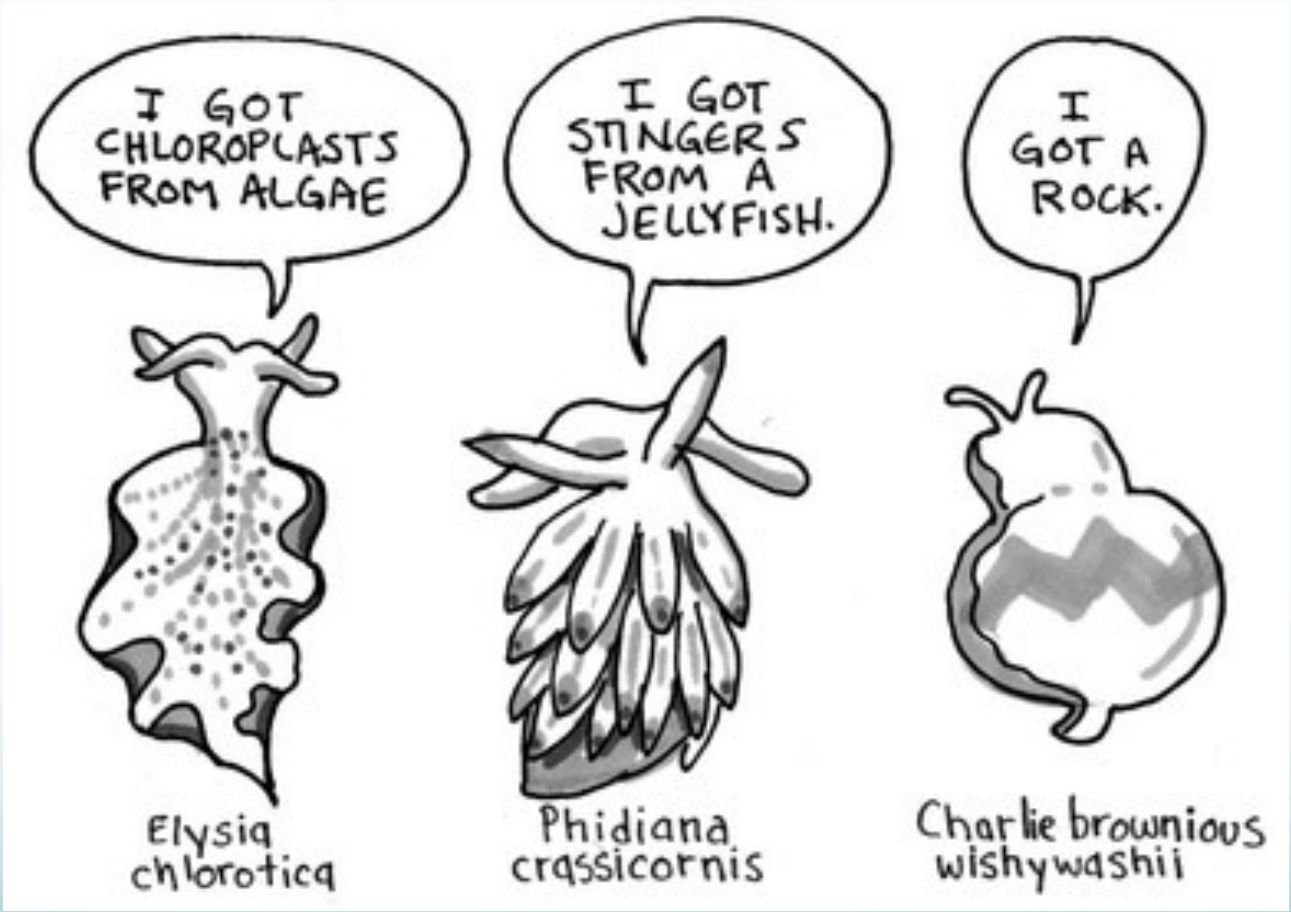
Questions?


I GOT CHLOROPLASTS FROM ALGAE
Elysia chlorotica
I GOT STINGERS FROM A JELLYFISH.
Phidiana crassicornis
I GOT A ROCK.
Charlie brownious wishywashii