# The ecological context for the study of biodiversity of the macrofauna of the CCFZ

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# Why studying the macrofauna of the CCFZ?

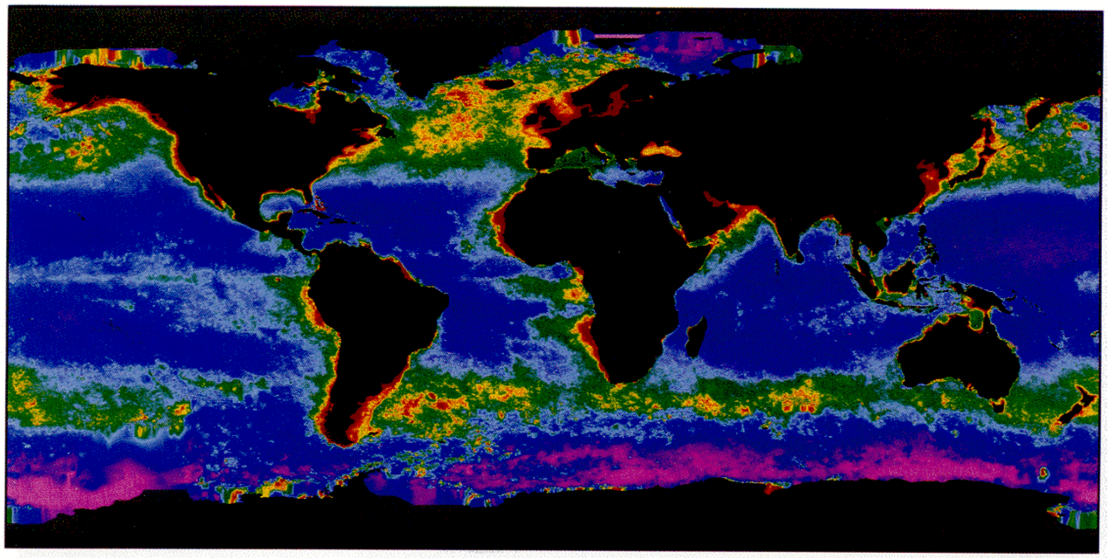
**Monitoring the consequences of nodule mining: Environmental impact assessment**

- Baseline studies
- Indicators for environmental impact assessments

**Mitigating the consequences of nodule mining: Marine spatial planning**

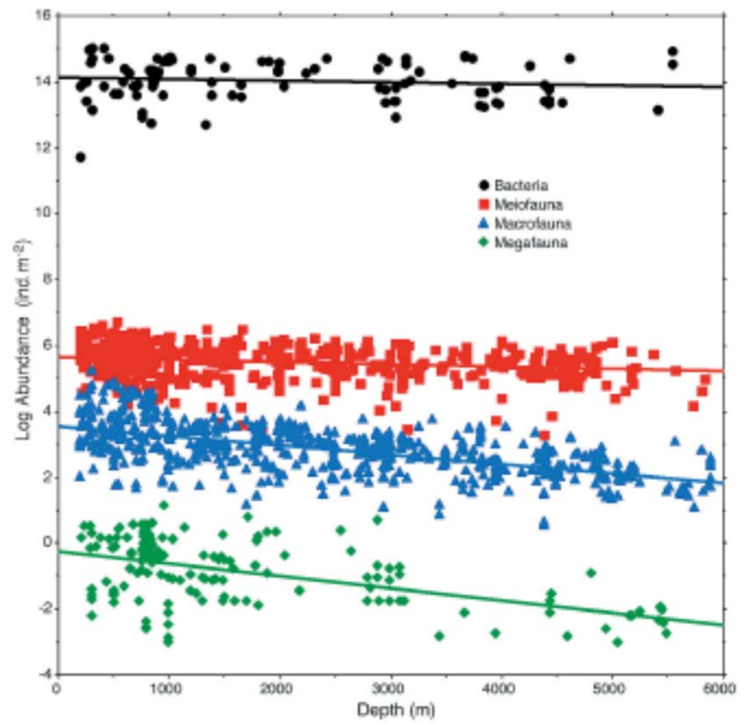
- Representativity
- Connectivity

# The ecology of macrofaunal communities in the CCFZ



Global primary production from satellite-derived data from
Behrenfeld, M.J., Falkowski, P.G., 1997. Limnology and Oceanography 42, 1-20.

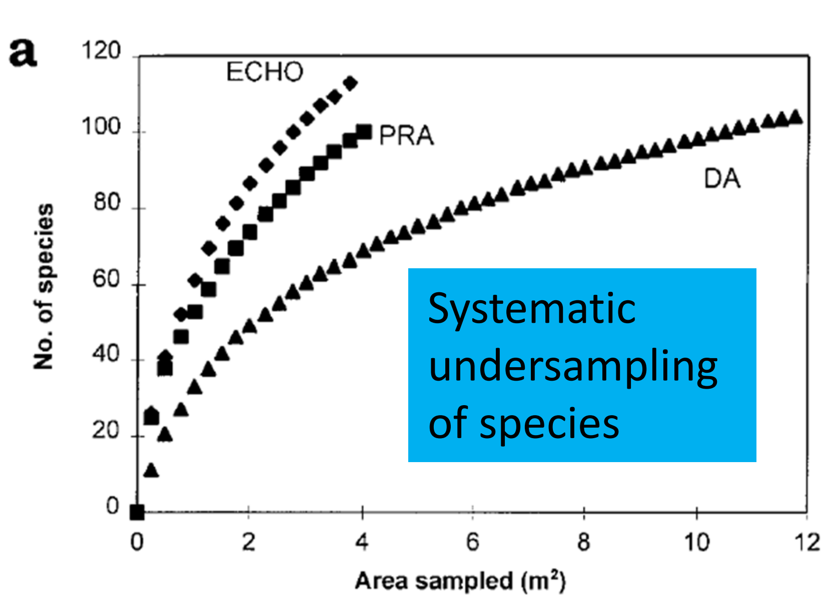
Primary production is very low in the central Pacific




Rex et al., 2006, Marine Ecology Progress Series, Vol 317:1-8, 2006

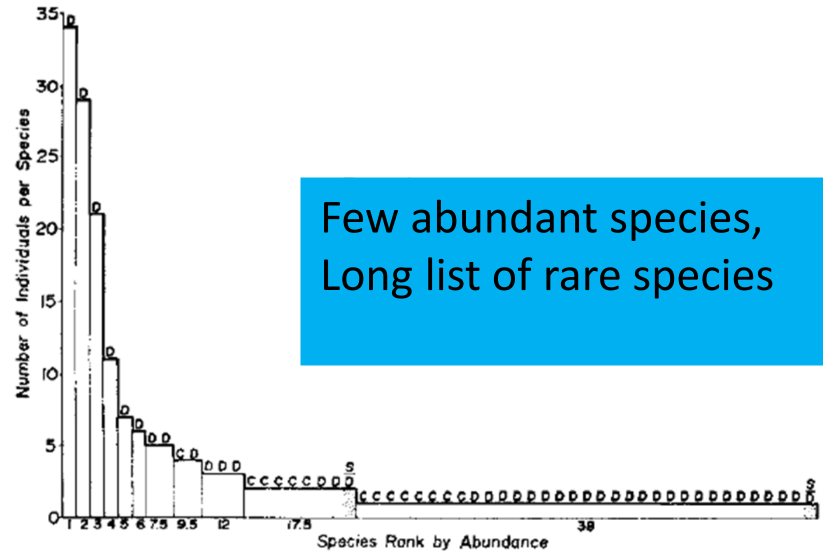
As a consequence, macrofaunal densities are very low in the CCFZ (100 ind./m$^2$ = 25 ind./core)

# The ecology of macrofaunal communities in the CCFZ




Systematic undersampling of species

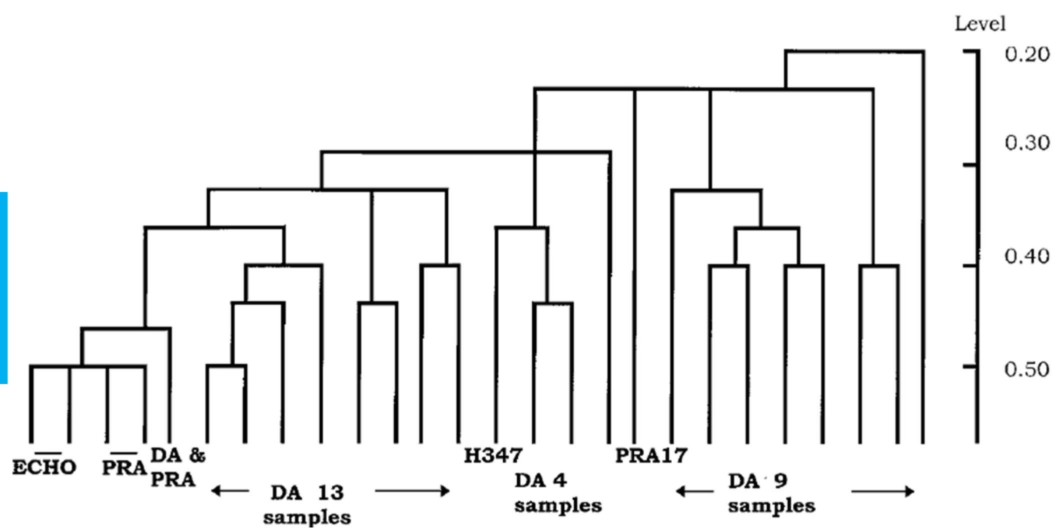
Paterson et al., 1998, Deep Sea Research II, 45: 225-251




Few abundant species, Long list of rare species

Hessler & Jumars, 1974, Deep Sea Research, 21: 185-209

Low level of similarity among samples




Paterson et al., 1998, Deep Sea Research II, 45: 225-251

# Studying the macrofauna of the CCFZ: The issues

**Monitoring the consequences of nodule mining: Environmental impact assessment**

- Baseline studies
- Indicators for environmental impact assessments

➡ **Methodological issues**

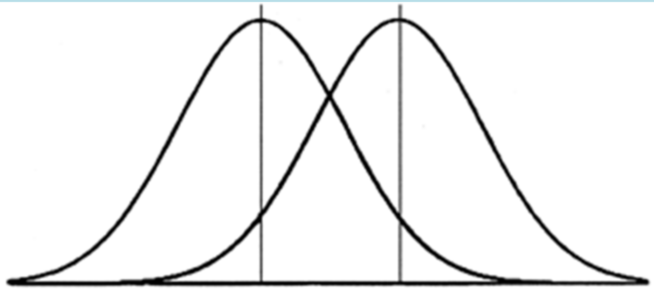
**Mitigating the consequences of nodule mining: Marine spatial planning**

- Representativity
- Connectivity

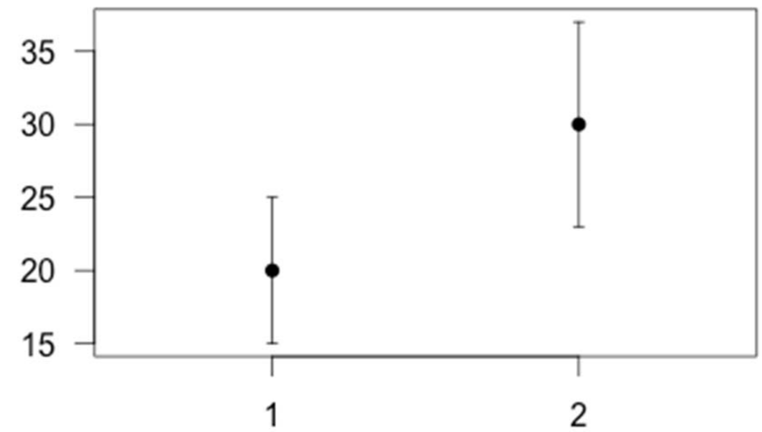
➡ **Theoretical issues**

# Methodological issues: the power of statistical analyses

Variation in nature: distribution of all possible values of eg density among two populations



Sampling to estimate the mean and variance of eg density of two populations




Statistics to test whether eg the densities of the two populations are similar or not

Hypothesis: $H_0 \quad \bar{x}_1 = \bar{x}_2$

$H_1 \quad \bar{x}_1 \neq \bar{x}_2$

| Hypothesis | $H_0$ is true | $H_1$ is true |
| --- | --- | --- |
| $H_0$ accepted | Good | Type II error, Probability β |
| $H_0$ rejected | Type I error, Probability α | Good |

Probability β is a function of variance, effect size and sample size

# Methodological issues: the power of statistical analyses

A rough but simple approach to illustrate the relationship between effect size, sample size and statistical power:

**Sample size**

Precision of density estimate (D) :

$$D = \frac{\sqrt{s^2/n}}{\bar{x}}$$

x = mean density
$s^2$ = variance
n = number of samples

Assuming a random distribution:

$$S^2 = \bar{x}$$

Thus:

$$n = \frac{\bar{x}}{\bar{x}^2 D^2}$$

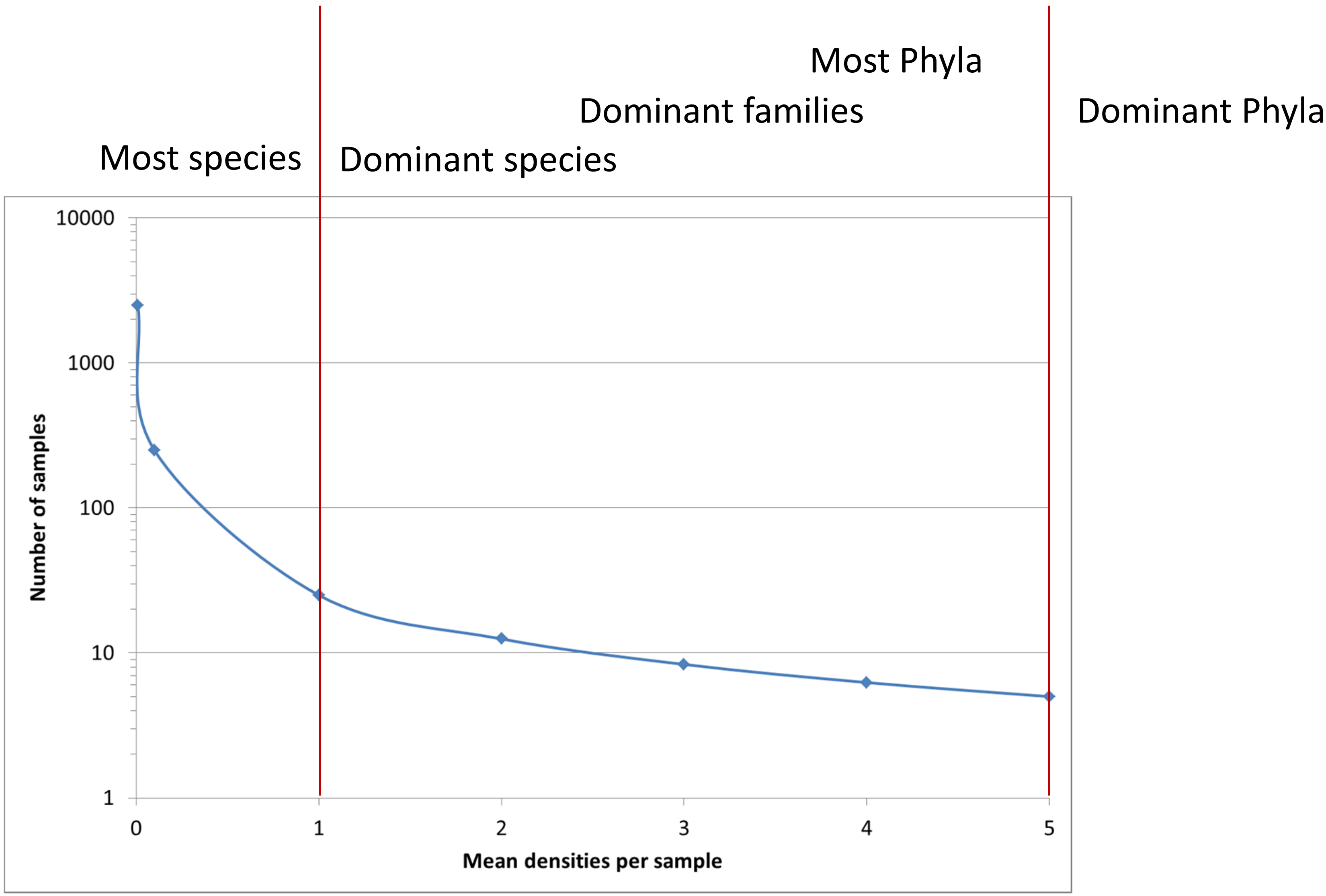
**Effect size**

A precision of 20% (D=0.2) is needed to detect a 50% reduction in mean densities

So

$$n = \frac{\bar{x}}{\bar{x}^2 0.2^2}$$

# Methodological issues: the power of statistical analyses



# Methodological issues: Conclusions

- Due to low densities, the sampling effort required to achieve reasonable statistical power at species level is huge (unrealistic?)

- Due to the long list of rare species, species composition is highly variable, which also imped the power of multivariate analyses

- Larger sample size, epibenthic sledge?

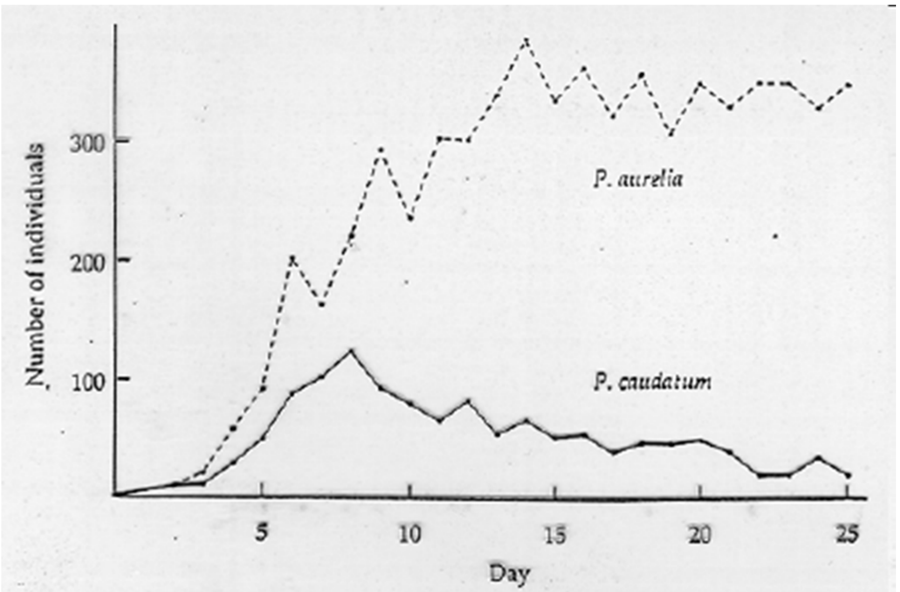
- Taxonomic sufficiency: Can we use lower taxonomic resolution (eg family) to monitor the impact of mining activities?

➡ **Do you need species identifications ?**

INTERNATIONAL SEABED AUTHORITY

## Theoretical issues: the co-existence of species and maintenance of diversity

Empirically: the Gause law (1934)

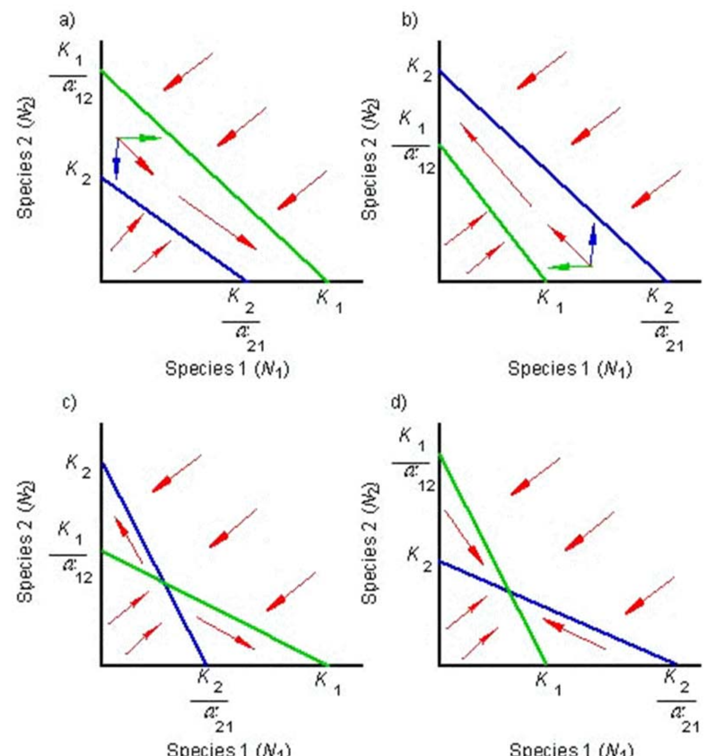



**Competitive exclusion:**
**Two species using the same resources can not co-exist in the same place**

Theoretically : the Lotka-Volterra model

$$\frac{dN_1}{dt} = r_1 N_1 \frac{(K_1 - N_1 - \alpha_{12} N_2)}{K_1}$$

$$\frac{dN_2}{dt} = r_2 N_2 \frac{(K_2 - N_2 - \alpha_{21} N_1)}{K_2}$$



## Theoretical issues: the co-existence of species and maintenance of diversity



work has arisen from an interest in extending the concepts of the struggle for existence put forward as an evolutionary mechanism by Darwin practically a century ago. Such work, of which Lack's recent contributions provide a distinguished example, tends to concentrate on relatively stable interacting populations in as undisturbed communition as possible. Another fertile field of research has been provided by the sudden increases in numbers of destructive animals, often after introduction or disturbance of natural environments. Here more than one point of view has been apparent. Where emphasis has been on biological

THE FORMALISATION OF THE NICHE AND THE VOLTERRA-GAUSE PRINCIPLE

*Niche space and biotop space*

Consider two independent environmental variables $x_1$ and $x_2$ which can be measured along ordinary rectangular coordinates. Let the limiting values permitting a species $S_1$ to survive and reproduce be respectively $x'_1$, $x''_1$ for $x_1$ and $x'_2$, $x''_2$ for $x_2$. An area is thus defined, each point of which corresponds to a possible environmental state permitting the species to exist indefinitely. If the variables are independent in their action on

**The ecological niche**

Vol. XCV, No. 882 The American Naturalist May–June, 1961

THE PARADOX OF THE PLANKTON*

G. E. HUTCHINSON

Osborn Zoological Laboratory, New Haven, Connecticut

The problem that is presented by the phytoplankton is essentially how it is possible for a number of species to coexist in a relatively isotropic or unstructured environment all competing for the same sorts of materials. The

A RIOT OF SPECIES IN AN ENVIRONMENTAL CALM: THE PARADOX OF THE SPECIES-RICH DEEP-SEA FLOOR

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*Ecology Letters*, (2004) **7**: 601–613 doi: 10.1111/j.1461-0248.2004.00608.x

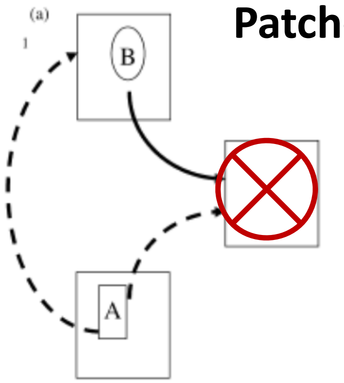
**REVIEW**

# The metacommunity concept: a framework for multi-scale community ecology

M. A. Leibold,[1]* M. Holyoak,[2] N. Mouquet,[3,4] P. Amarasekare,[5] J. M. Chase,[6] M. F. Hoopes,[7] R. D. Holt,[8] J. B. Shurin,[9] R. Law,[10] D. Tilman,[11] M. Loreau[12] and A. Gonzalez[13]

**Table 1** Terms used to define scales of organization and population dynamics in metacommunities

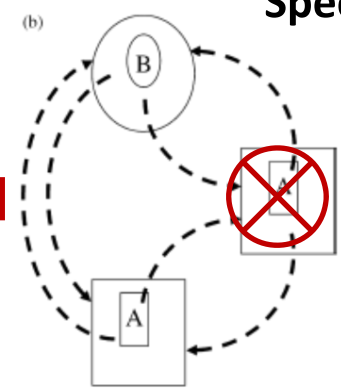
| Term | Definition |
|---|---|
| Ecological scales of organization | |
| Population | All individuals of a single species within a habitat patch |
| Metapopulation | A set of local populations of a single species that are linked by dispersal (after Gilpin and Hanski 1991) |
| Community | The individuals of all species that potentially interact within a single patch or local area of habitat |
| Metacommunity | A set of local communities that are linked by dispersal of multiple interacting species (Wilson 1992) |
| Metacommunity paradigms | |
| Patch dynamics perspective | A perspective that assumes that patches are identical and that each patch is capable of containing populations. Patches may be occupied or unoccupied. Local species diversity is limited by dispersal. Spatial dynamics are dominated by local extinction and colonization |
| Species-sorting perspective | A perspective that emphasizes the resource gradients or patch types cause sufficiently strong differences in the local demography of species and the outcomes of local species' interactions that patch quality and dispersal jointly affect local community composition. This perspective emphasizes spatial niche separation above and beyond spatial dynamics. Dispersal is important because it allows compositional changes to track changes in local environmental conditions |
| Mass-effect perspective | A perspective that focuses on the effect of immigration and emigration on local population dynamics. In such a system species can be rescued from local competitive exclusion in communities where they are bad competitors, by immigrate from communities where they are good competitors. This perspective emphasizes the role that spatial dynamics affect local population densities |
| Neutral perspective | A perspective in which all species are similar in their competitive ability, movement and fitness (Hubbell 2001). Population interactions among species consist of random walks that alter relative frequencies of species. The dynamics of species diversity are then derived both from probabilities of species loss (extinction, emigration) and gain (immigration, speciation). |




**Patch-dynamic**

sp A best competitor
sp B best colonizer
= competition-colonization trade-off

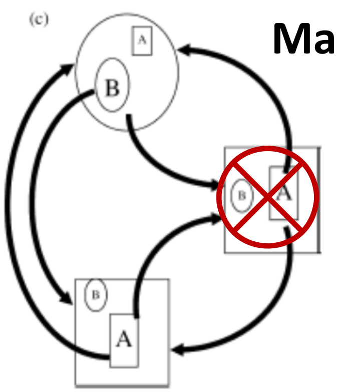
- Fast recovery spB, slow recovery spA
- Medium risk of local exctinction




**Species sorting**

Sp A and sp B have their own niches, dispersion is not large enough to influence their distribution

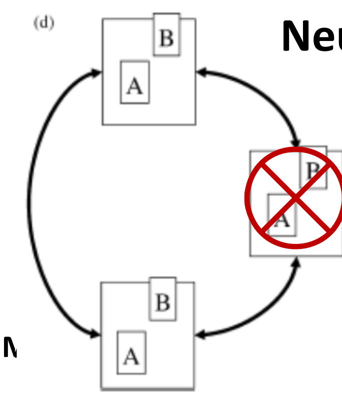
- Slow recovery spA and spB
- High risk of local exctinction




**Mass effect (source-sink)**

Sp A and sp B have their own niches but dispersion is large and allows species to co-exist in the same patch.

- Fast recovery spA and spB
- Low risk of local exctinction

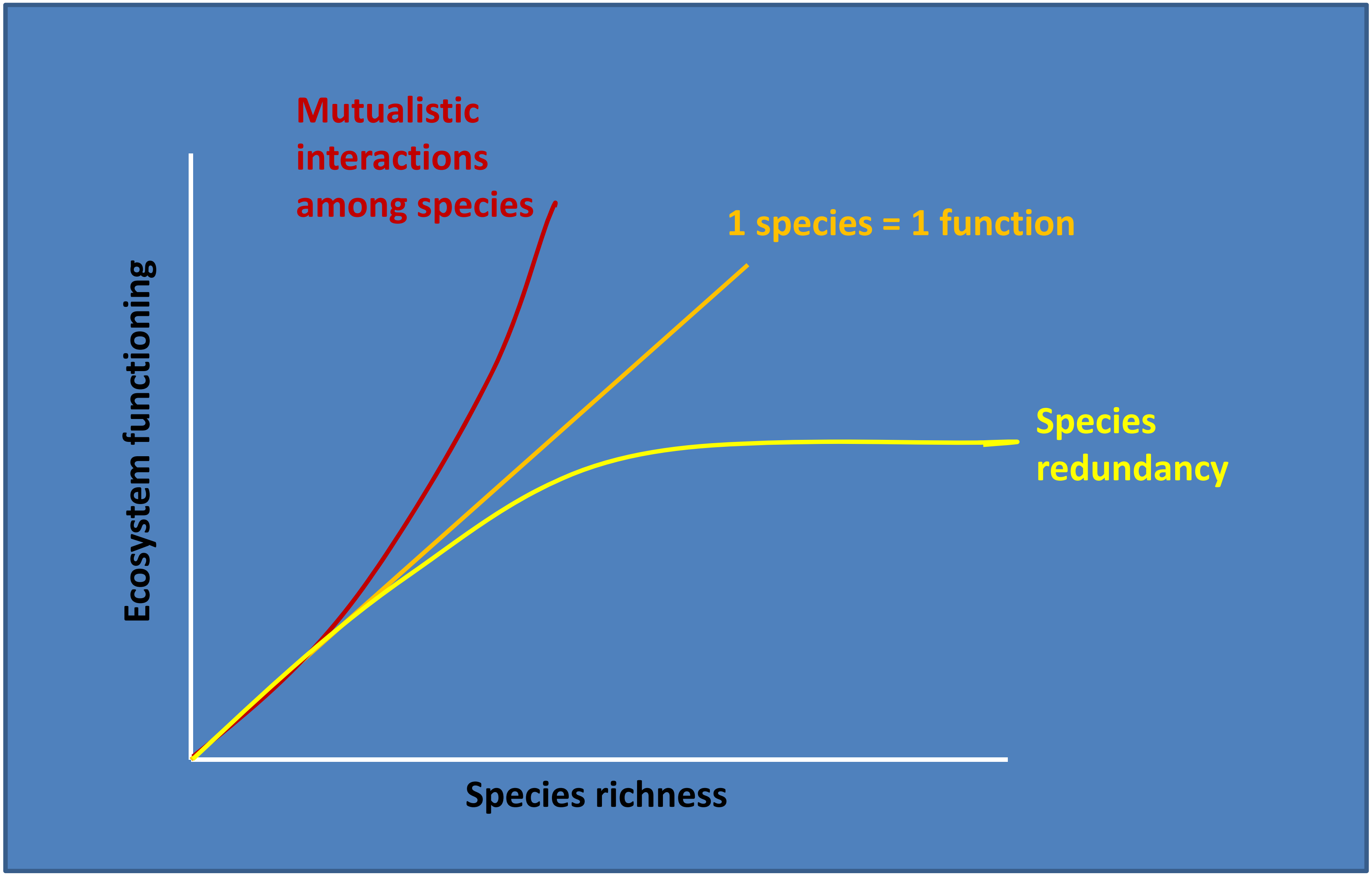



**Neutral**

Sp A and spB share the same niche and have similar dispersion abilities

- Fast recovery
- Low risk of extinction

# The rare species, functional redundancy and ecosystem functioning

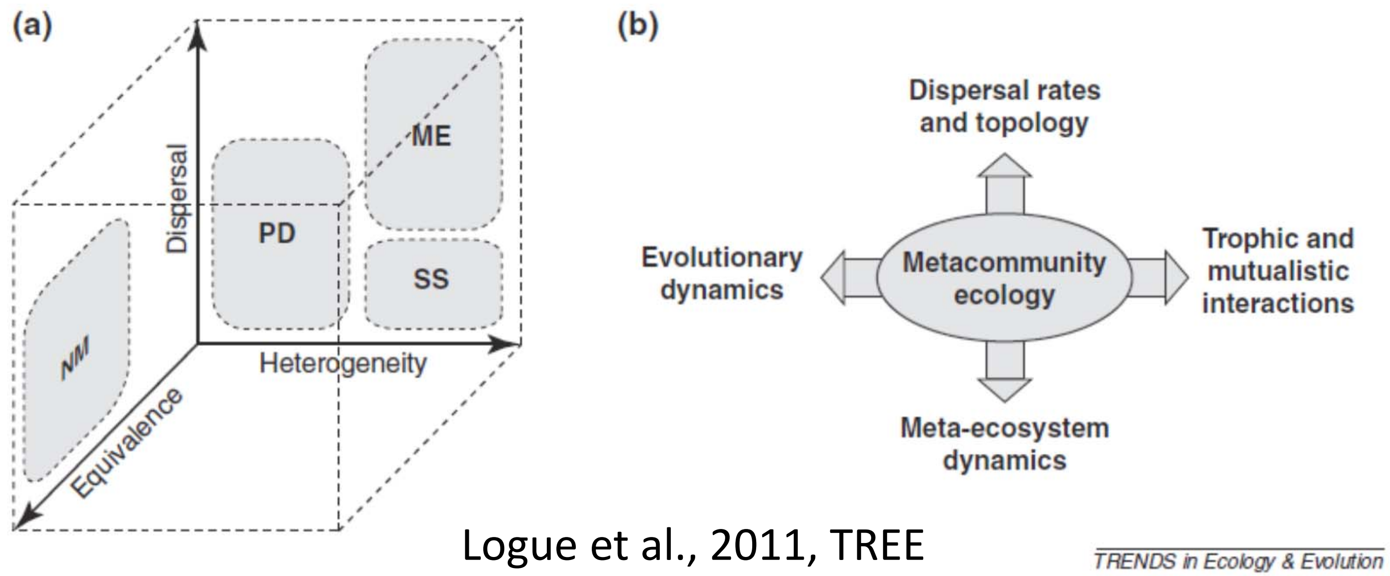


# Theoretical issues: Conclusions

To be able to predict the long-term consequences of mineral mining we need to understand mechanisms for diversity maintenance in the abyss, particularly knowledge on:

- Life history traits, dispersal, population dynamics
- Scales of heterogeneities
- Biological interactions

➡ **Consistent identifications of species across the CCZ**




Logue et al., 2011, TREE