The Noah's Ark problem and biodiversity trends for commercial fisheries in the Western and Central Pacific Ocean.

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Introduction

Introduction

- Western and Central Pacific Ocean
- World's largest Tuna fishery
- Tuna is a $4 billion annual industry
- Little known about diversity of pelagic species

Objectives

1. Determine trends in diversity since 1950 by EEZ, and overall
2. Explore approaches to analyzing economic implications of diversity
3. Develop a framework for fisheries management centered on diversity

Ecosystem based fisheries management and diversity

Ecosystem Based Fisheries Management

- Fisheries management is largely single stock
- Wide recognition of importance of an ecosystem based approach
- Barriers to implementation
- Curse of dimensionality/Stability/Stiffness issues with large numerical models
- Difficulty of developing management targets for multispecies fisheries with ecosystem based approach
- Lack of tractable tools for eco-system based fisheries management

Diversity

What is diversity?

- In a random sample of individuals how many species are there? (Fisher, 1943)
- What is the probability that any two individuals are of the same species? (Simpson)

Concept of diversity is shared across many different disciplines, ecology, economics, political science, sociology.

General diversity:

$$D = \left(\sum_i p_i^q \right)^{\frac{1}{1-q}}$$

- Fisher's alpha
- Abundance
- Simpson-Herfindahl-Hirschman $\sum_i p_i^2$
- Entropy (Uncertainty) $-\sum p_i ln p_i$

Literature

Literature

Social choice theory:

- Pattainaik and Xu (2 000)
- Bevoets and Gravel (2007)
- Nehring and Puppe (2002,2003 and 2009)

Small literature incorporating dissimilarity/similarity into diversity:

- already considered by Weitzman to a limited extent
- Leinster and Cobbold (2012)
- Bevoets and Gravel (2007)

The latter suggests richer approaches that go beyond abundance as the underlying measure

Concepts

Fractionalization

Alesian et al. Journal of Economic Growth, 2003 Fractionalization is basically the Gini-Simpson index $1 - H$

- Fragmentation of groups
- probability of interspecific encounter (Gini-Simpson index)

Partitioning (mainly biological literaure

Diversity can be partitioned into

- within population α
- between population β
- overall diversity γ

Key contribution: Applying hierarchical partitioning to exclusive economic zones

Empirics

Data

- Data are taken from the “Sea Around Us” Project (UBC) using their API (Application programming interface)
- WCPO EEZ’s are identified and catch data were downloaded
- the hierDiversity R package was used which implements standard diversity partitioning formulae

Time trends- Richness

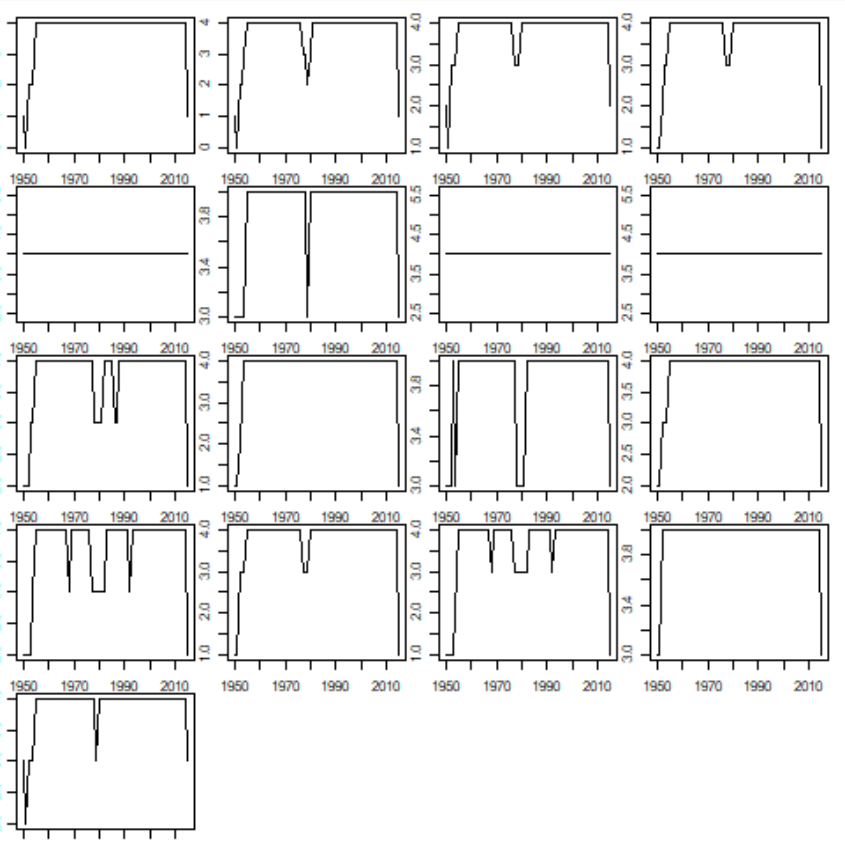

Figure 1: q=0, Abundance (Richness)

Time trends - Entropy

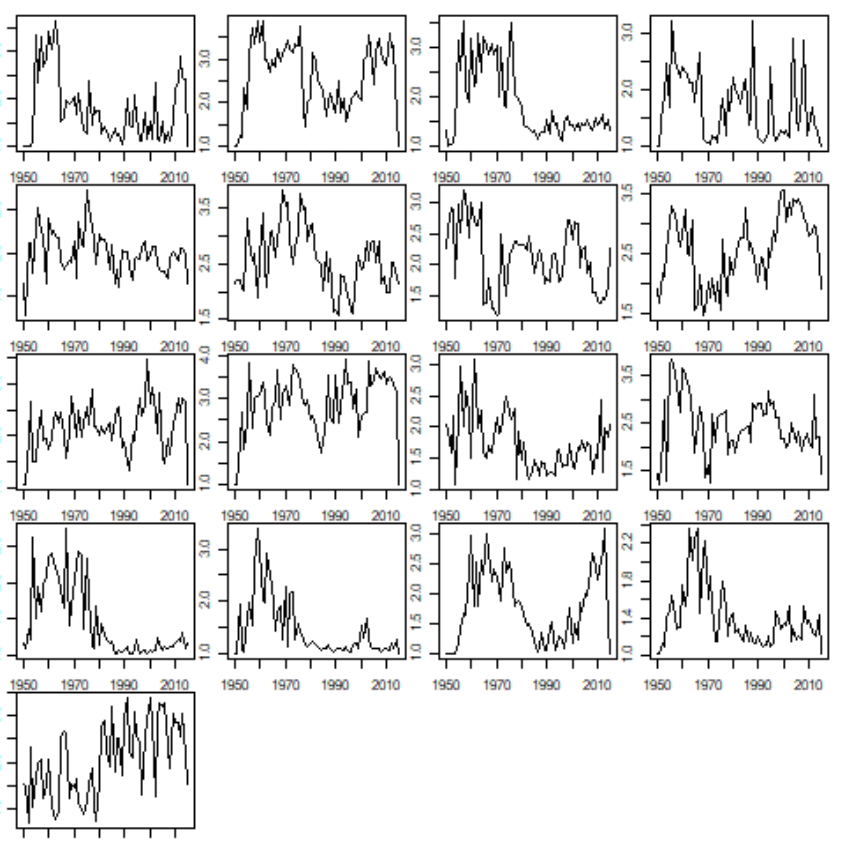

Figure 2: q=1, Shannon entropy

Time trends - Simpson-Herfindahl

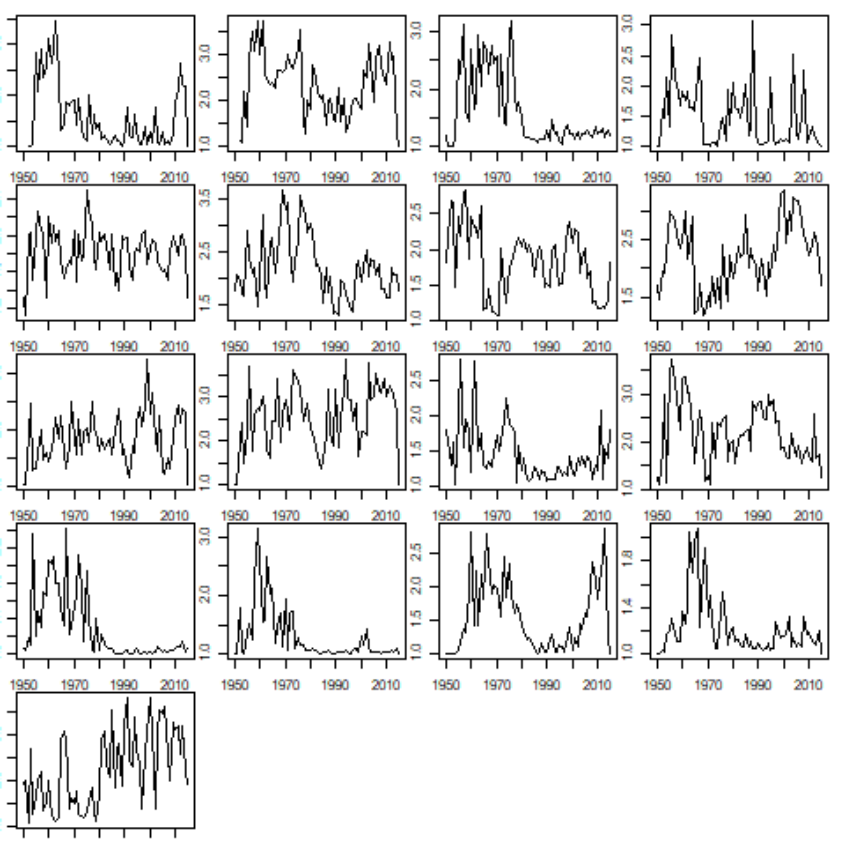

Figure 3: q=1, Simpson-Herfindahl

Time trends - γ: Entropy and Simpson-Herfindahl

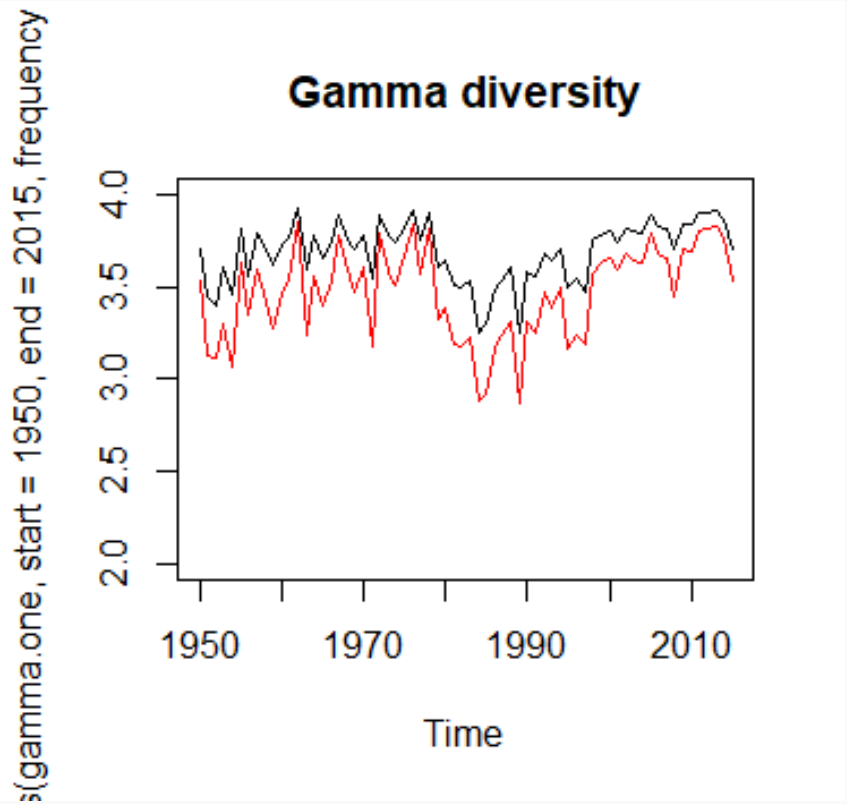

Figure 4: q=1,2, γ

Extensions/future Work

Polarization

Esteban and Ray Econometrica, 1994 Relates to incomes: To calculate this use catch values and apply the following formula

$$P(\pi, y) = K \sum \sum \pi_i^{(1+\alpha)} \pi_j |y_i - y_j|$$

- where y is log income and π is the population.
- $\alpha$and K are parameters.
- α is not the α diversity measure here.
- Population can be human or fish stock depending on purpose of calculating polarization.

Noah's Ark

Weitzman, On diversity, QJE, 1992, The Noah's Ark Problem, Econometrica, 1998

Problem: What species to place on the Ark to maximize the sum of utility and diversity

This is a constrained optimization problem:

$$\max -P\left\{W(P)+U(P)\right\}$$

subject to the probability of survival being bounded

$p_i \in [\underline{P}_i, \overline{P}_i], \forall i$ and the overall budget constraint for preservation

$$\sum C_i \left(\frac{P_i - \bar{P}_i}{\bar{P}_i - \underline{P}_i}\right) = B$$

where $W(P)$ is some diversity measure and $U(P)$ utility of as a proxy commercial value

Conclusion

Conclusion

- Considerable cross-over between economic and biological theories of diversity
- Data are available (via API) that allow for application of hierarchical diversity models to fisheries management units
- Numerous R packages now implement these measures
- Preliminary results can be extended to analyze polarization between fishing nations which may have an impact on international fisheries agreements
- Further work to be done on optimization
- Fisheries managers might like to consider modified Kobe plots with diversity rather than stock on one axis (what should target reference points for diversity be?)

Contact

Thanks for listening!

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