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Investigating the linkage between biodiversity and ecosystem functions in coastal areas

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Adaptive management of biodiversity and functions of coastal ecosystems

Q: Where to conserve?

A1: A site with highest biodiversity
(for conservationists)

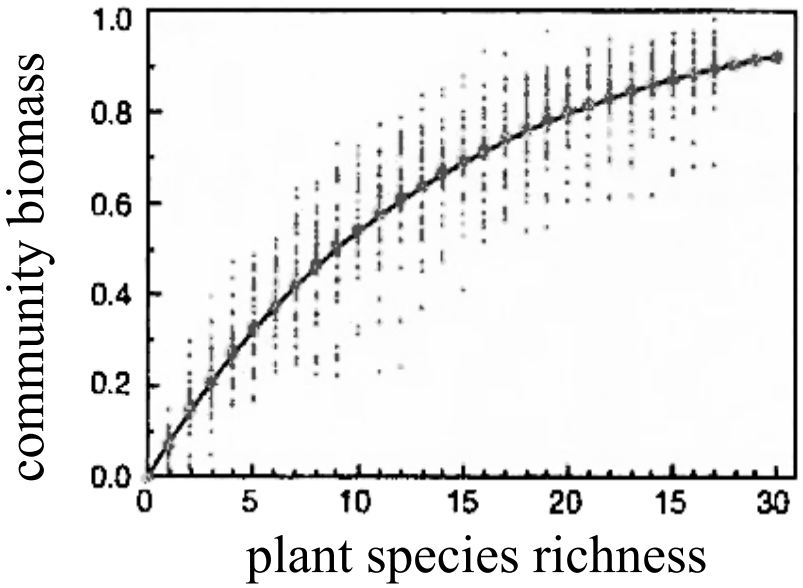
A2: A site with highest productivity
(for fishermen)

Are the answers the same?

Biodiversity enhances ecosystem functions

BD-EF relationship

Positive link between biodiversity and ecosystem functions revealed by manipulative experiments



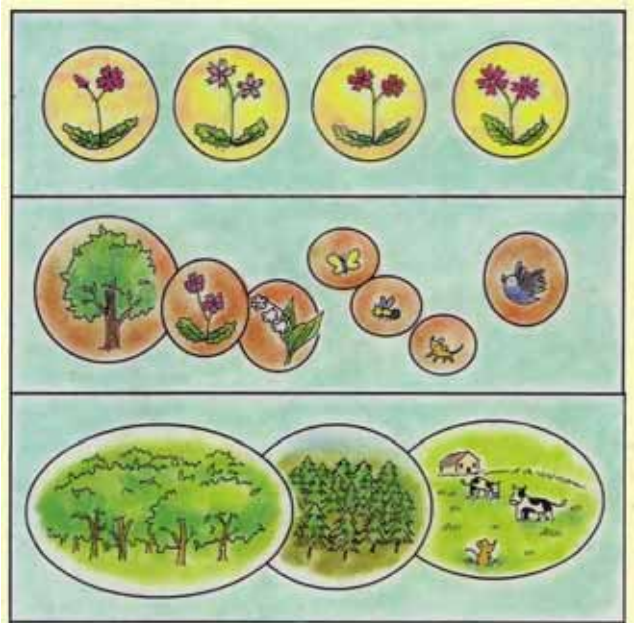
Tillman (2000)

Questions and problems

1. **Which measures of biodiversity should be used?**
2. **Does the rule hold at larger spatial scales?**

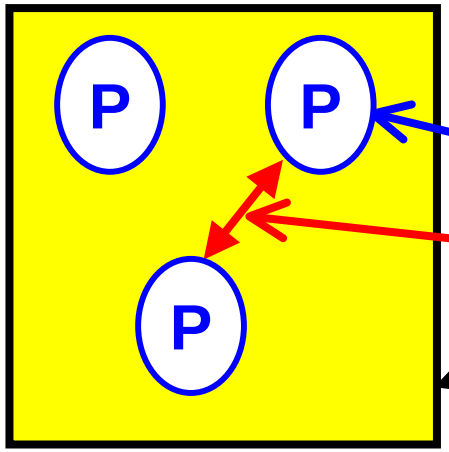
Fewer research has been done in marine ecosystems.

Which measure of biodiversity ?



1. Definition at different biological levels

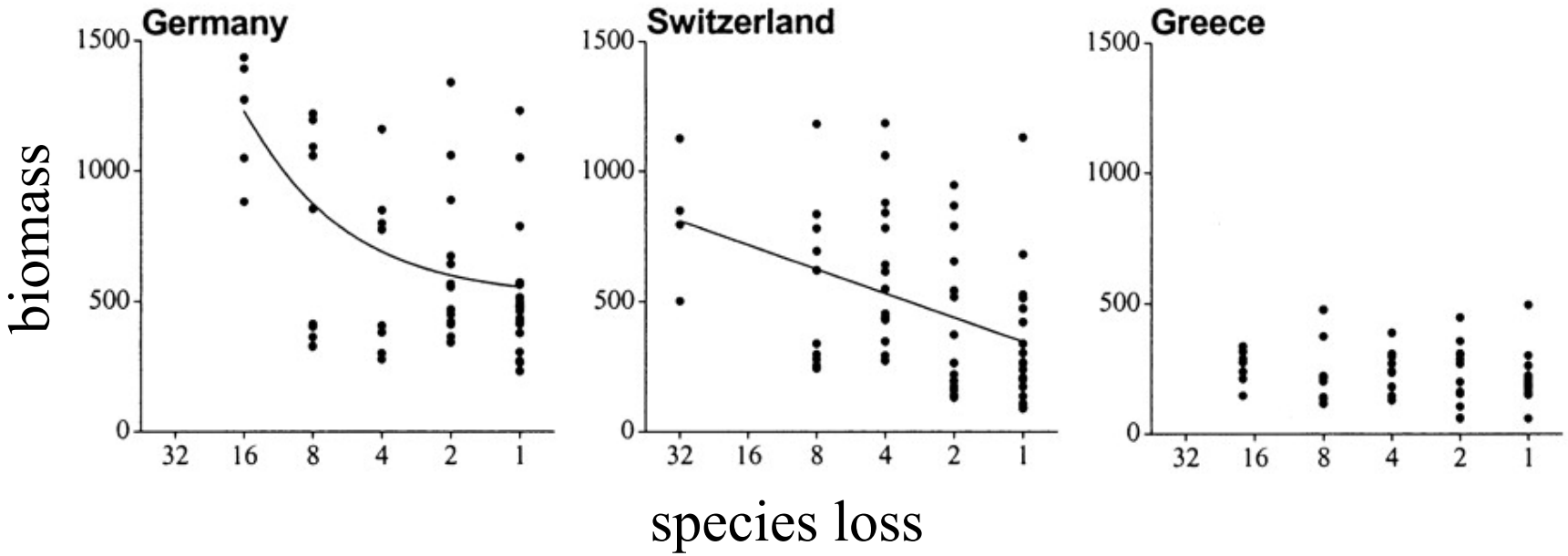
- Genetic diversity at population level
- Species diversity at community level
- Landscape diversity at ecosystem level



2. Spatial scale of biodiversity

- α diversity: diversity within a patch
- β diversity: difference between patches
- γ diversity: diversity of whole area

BD-EF relationship changes among regions



Hector et al (1999)

Environmental factors interfere with BD-EF relationship at broad spatial scales.

Purpose of the present study

Investigating possible relationships among environmental factors, biodiversity and ecosystem functions in coastal habitats

Environmental gradients
- **Resource availability**
- **Modulators (temp, pH)**
- **Disturbance regime**

Biodiversity
- **Composition**
- **Richness and evenness**
- **Species interactions**

Ecosystem functions
- **Productivity**
- **Resistance and Resilience**
- **Stability**

Adaptive management of biodiversity, ecosystem functions and services

Case studies at two different habitats

Seagrass beds in Tokyo Bay

Rocky intertidal community along the Pacific coast of Japan

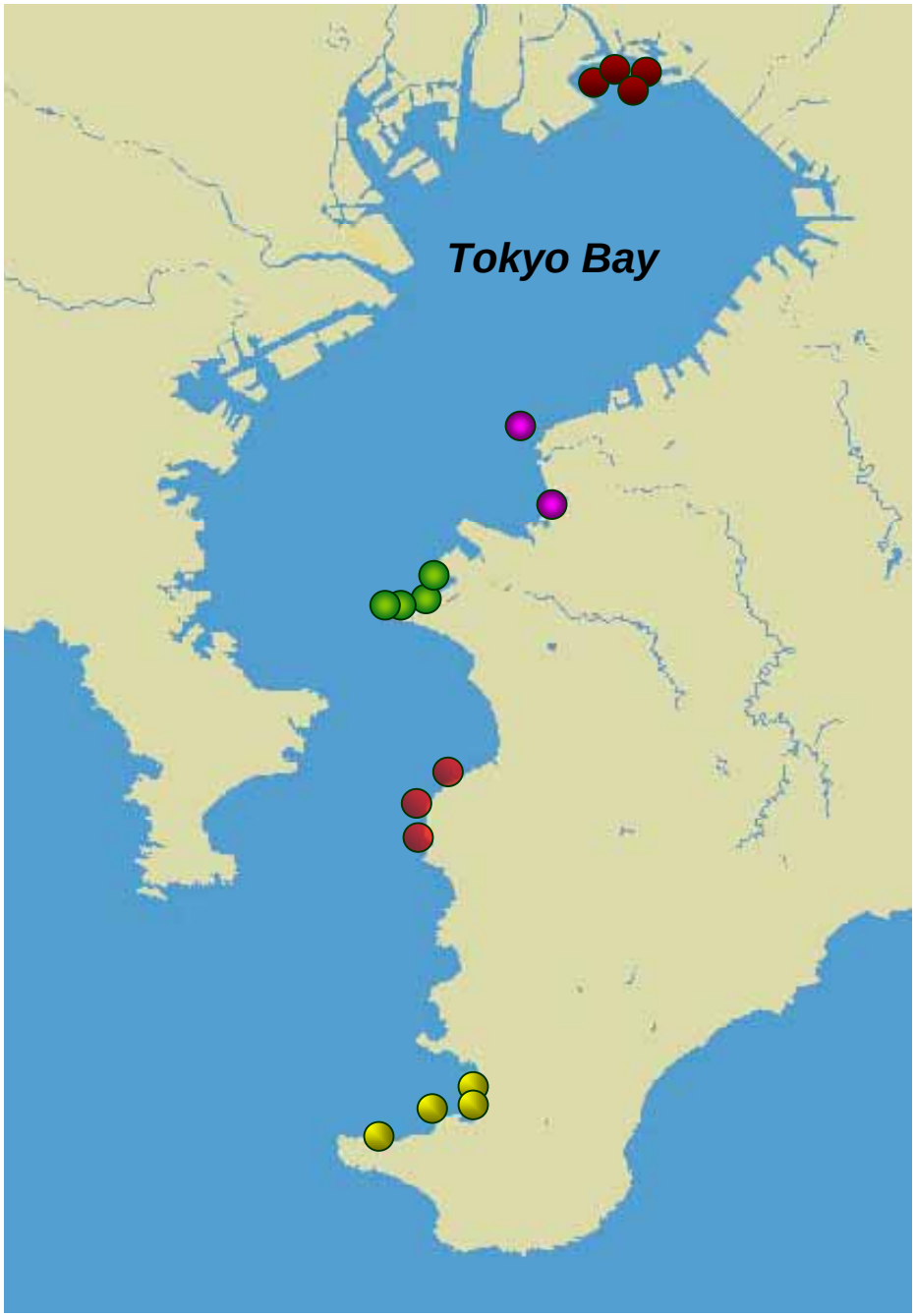
What is seagrass bed?

- A unit of coastal landscape consisting of seagrasses, i.e., “flowering plants living in the sea” (Do not confuse with seaweeds!)
- Known as most productive habitats in the world (annual productivity exceeding tropical rain forest)
- Harbor diverse plant and animals species, forming “hot spot” of biodiversity in marine ecosystems

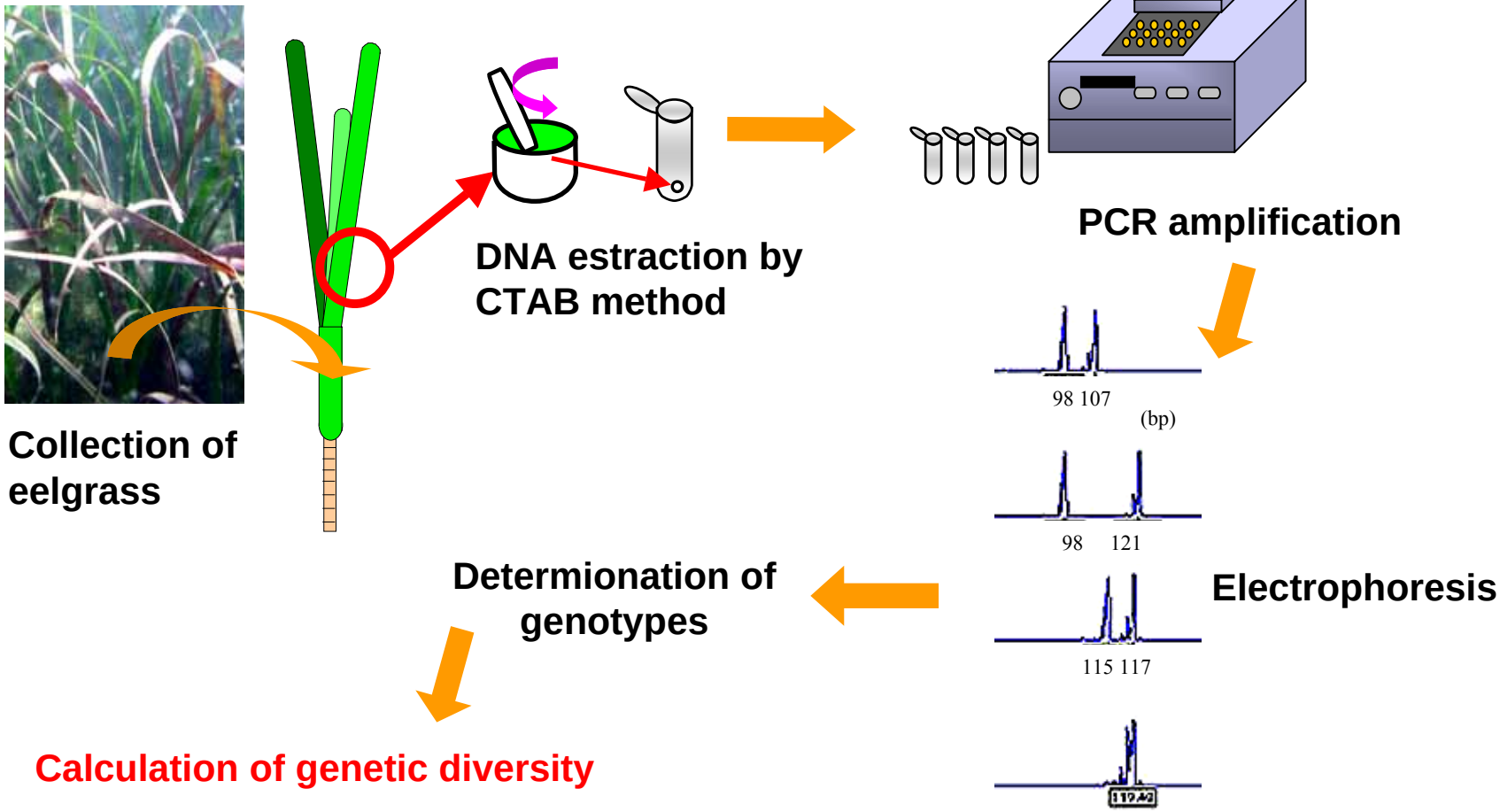
Study sites

17 stations in 5 areas established in a nested design (although not perfectly designed)

Seagrass bed in Futtsu



Analysis of genetic diversity of eelgrass using microsatellite DNA



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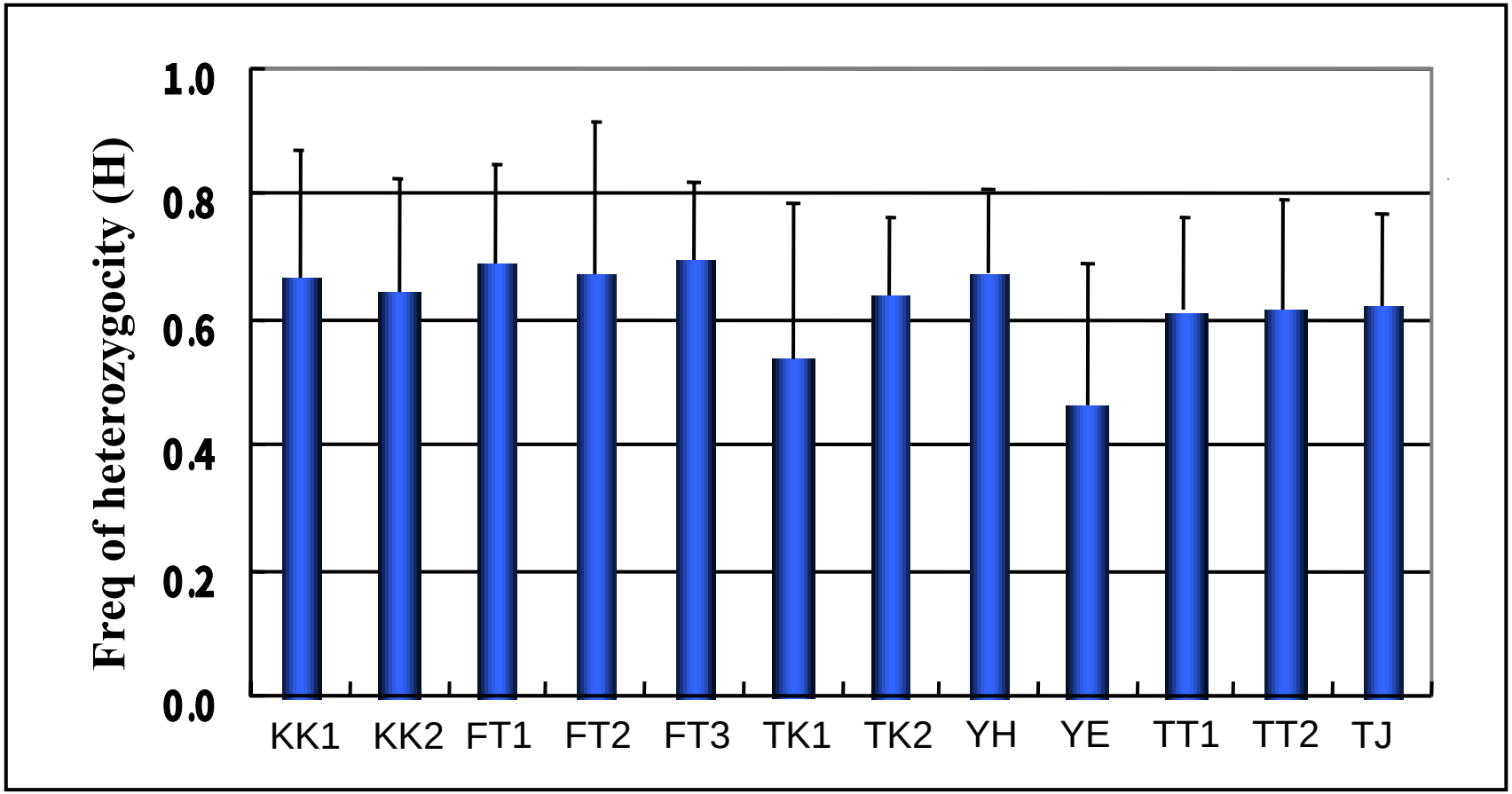
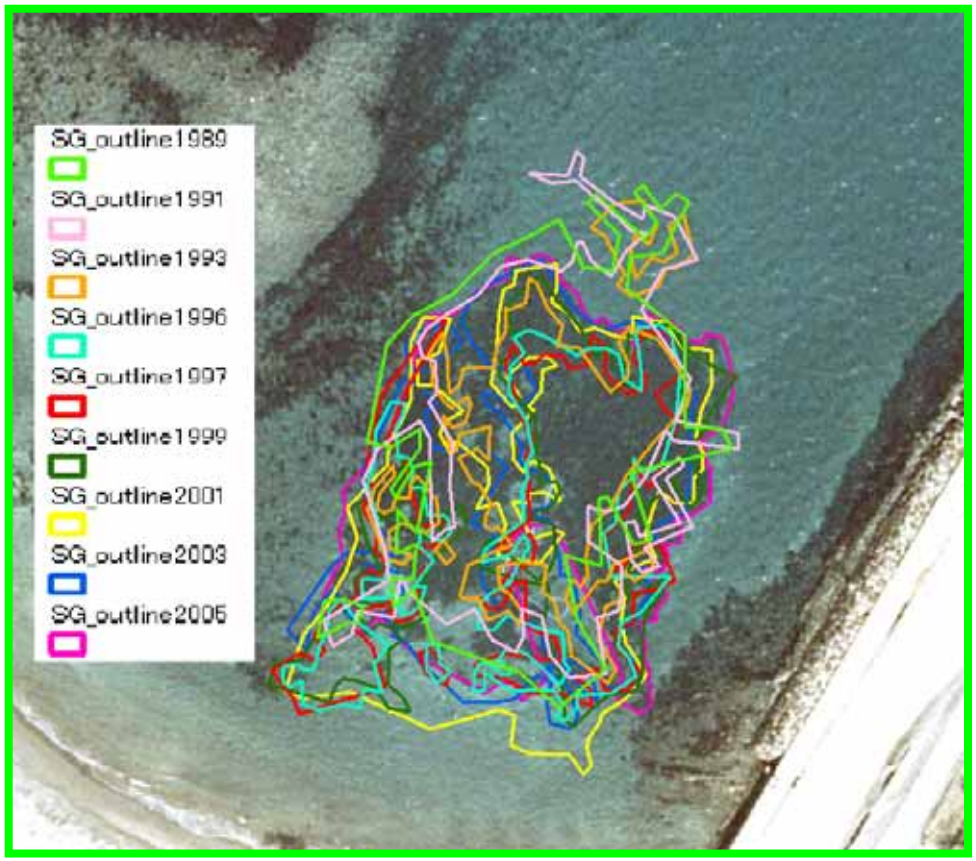


Remote sensing analysis on long-term changes in seagrass beds



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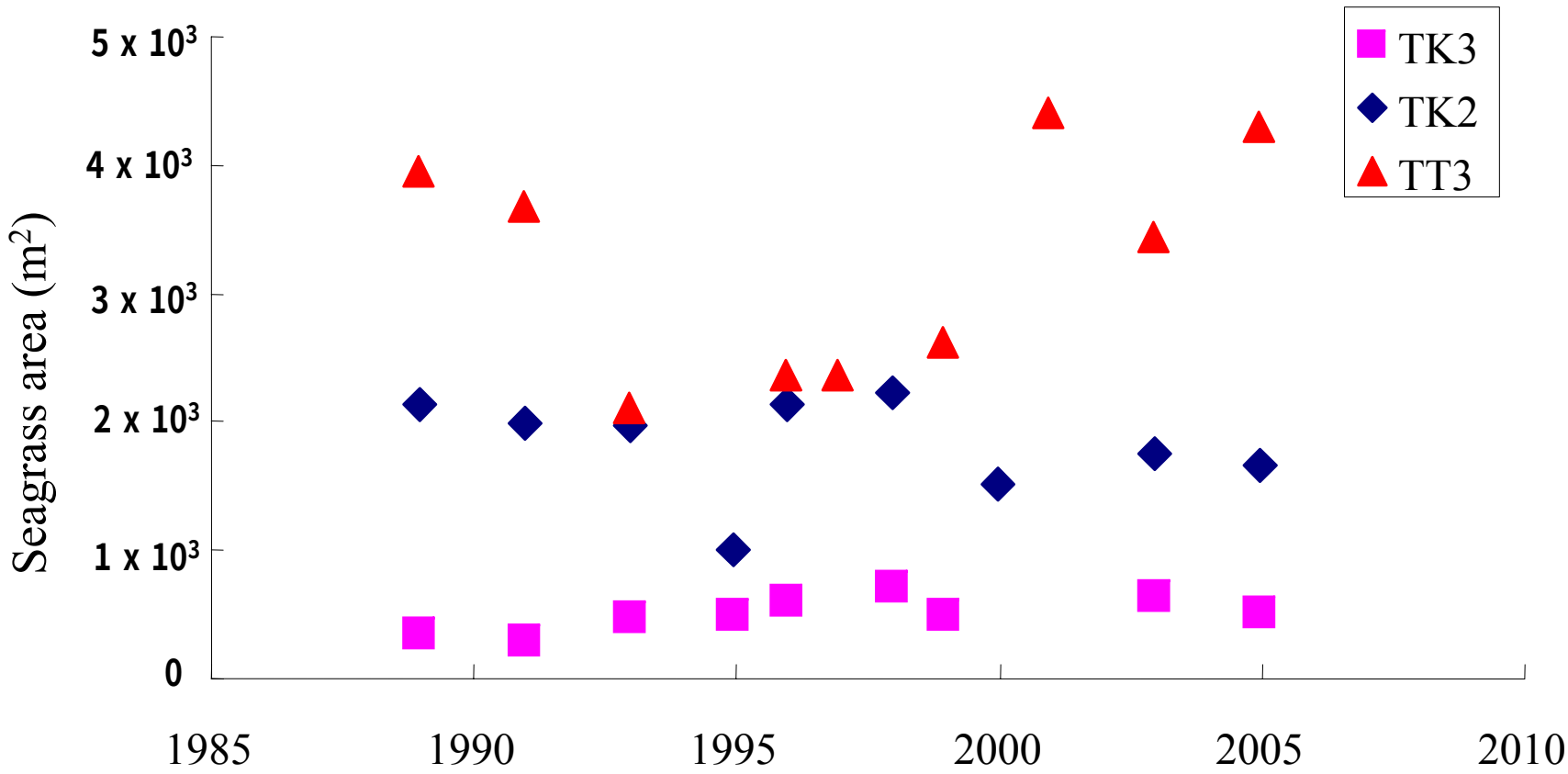
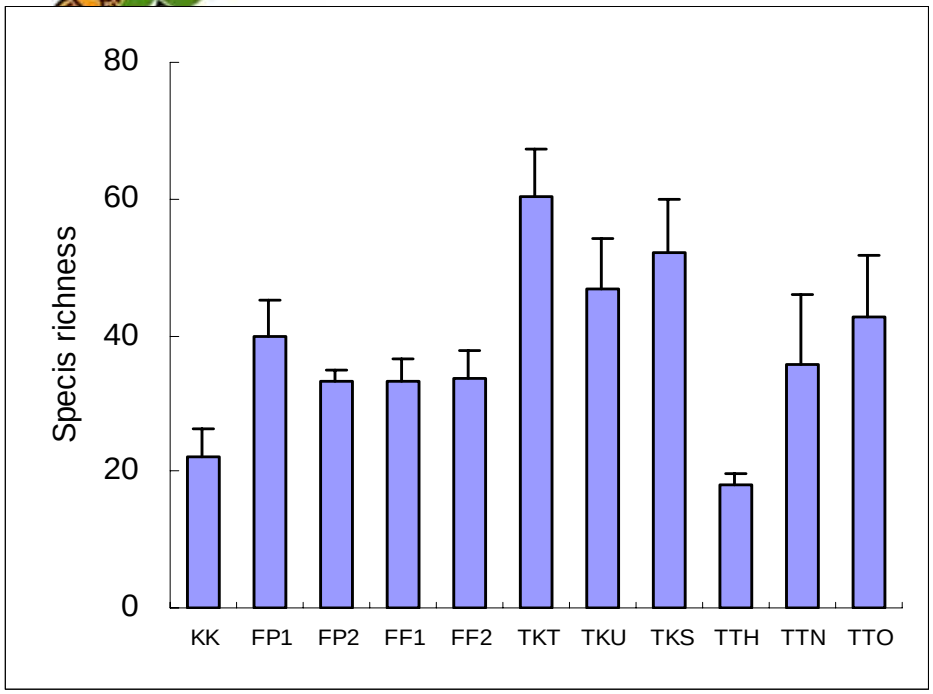
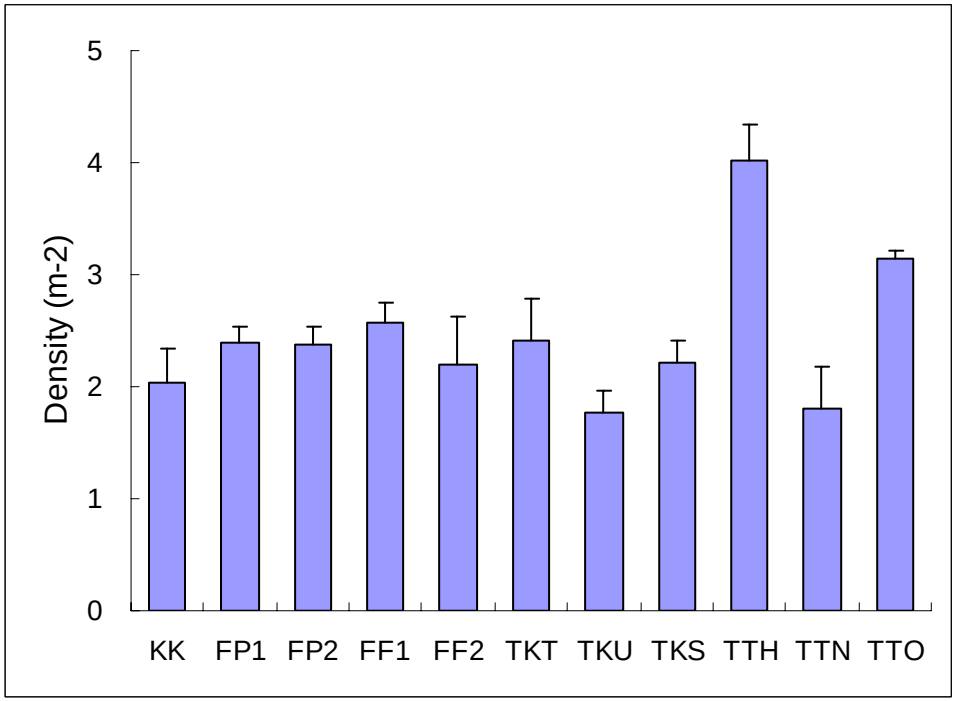


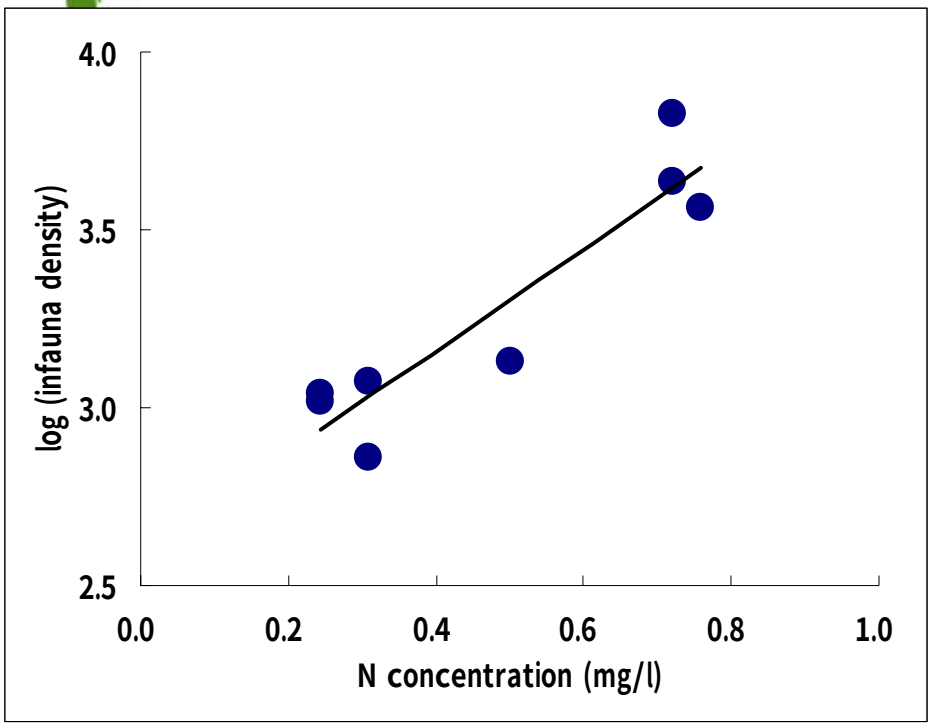
Analyses on animal community

Analyses on animal community

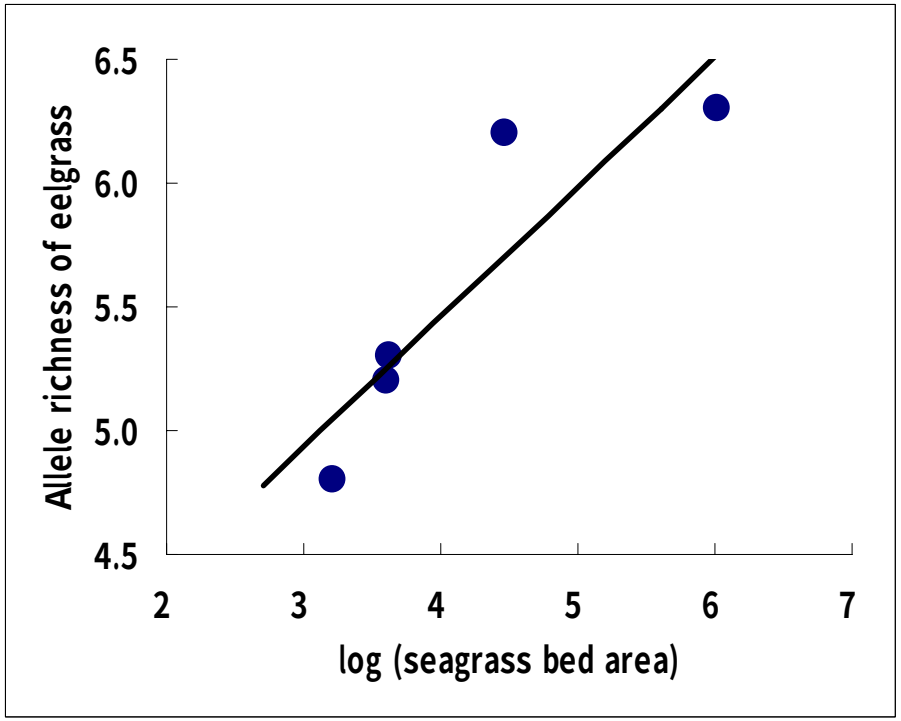




Relationships among environmental factors, biodiversity and ecosystem functions

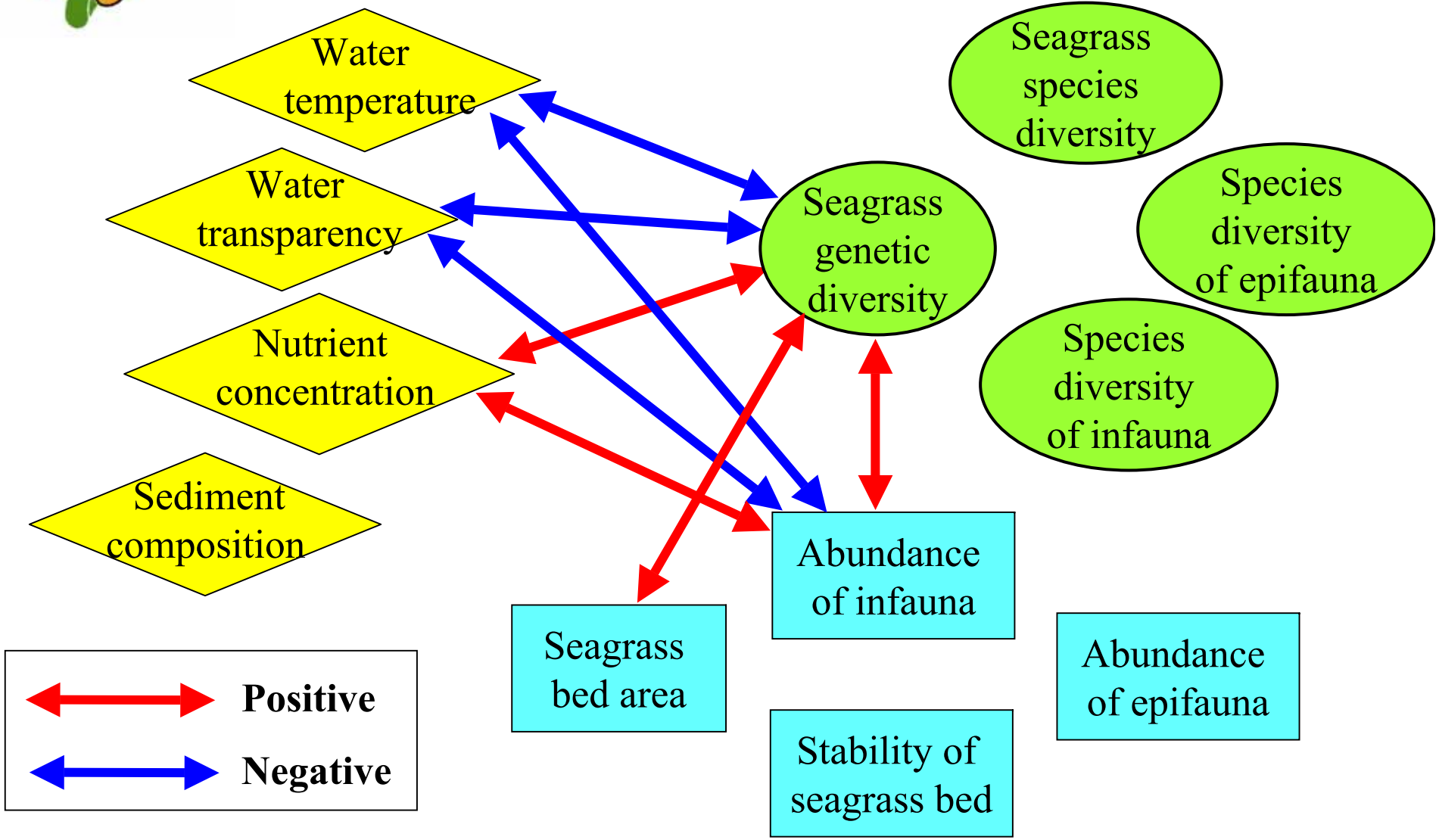


Positive correlation between nutrient concentration and density of benthic animals (r=0.921, p=0.001)



Positive correlation between seagrass bed area and genetic diversity of eelgrass (r=0.892, p=0.042)

Relationships among environmental factors, biodiversity and ecosystem functions



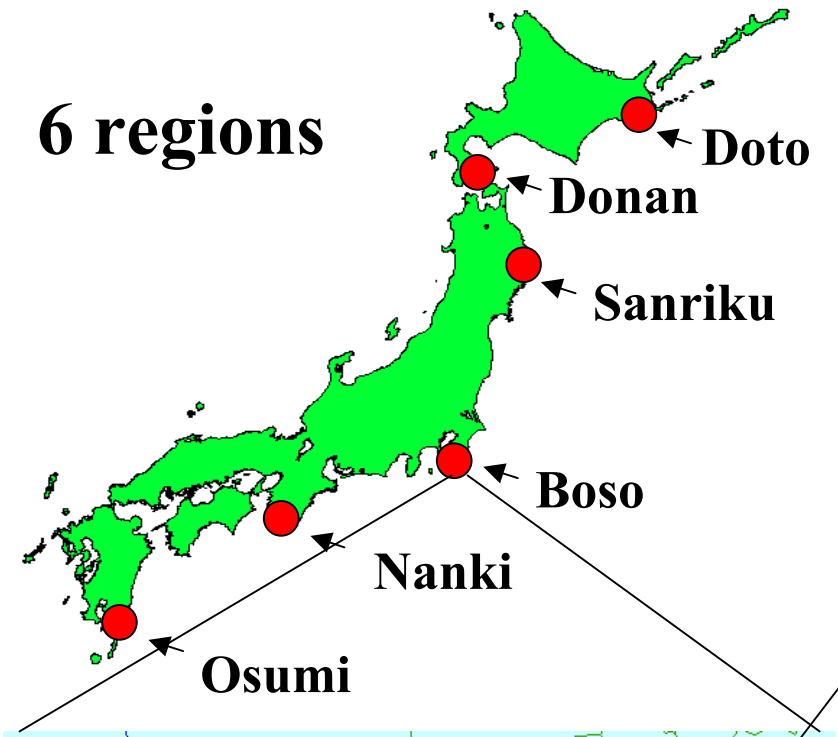
What is rocky intertidal community?

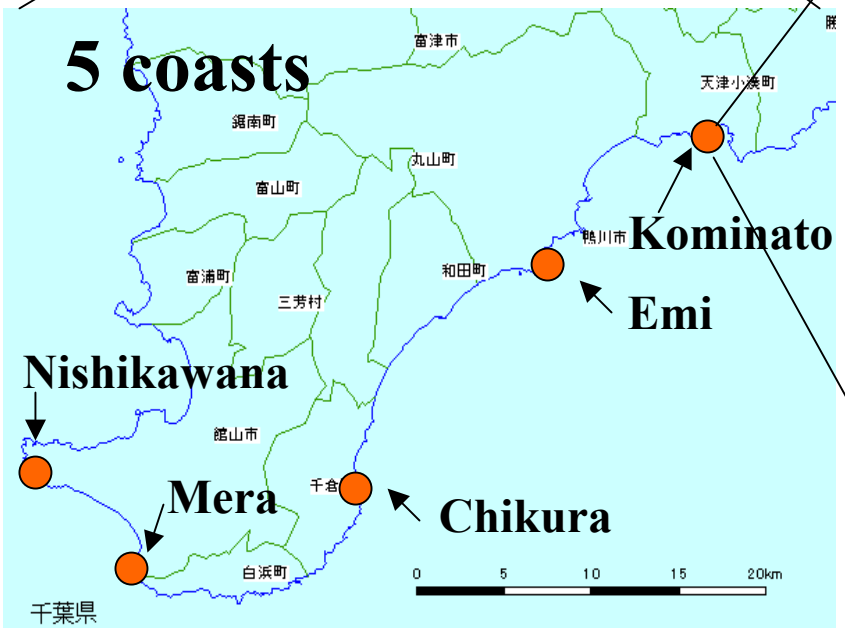
- Community on marine hard bottom which is exposed to severe stress when emerged at low tide
- Strong environmental gradient creates characteristic zonation pattern of organisms.
- Species interactions were strongly influenced by competition over space.
- Known as ideal system for experimental studies on population and community ecology (such as classic studies by Joseph Connell and Robert T. Paine)

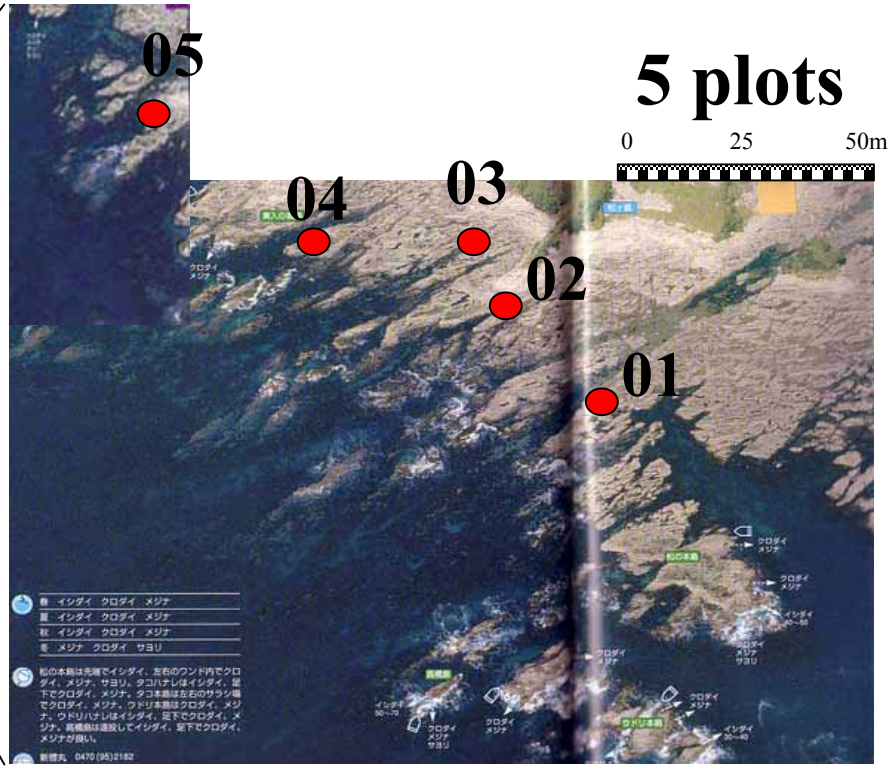
国土地理院承認 平13総複 第367号

Hierarchical census along the Pacific coast of Japan

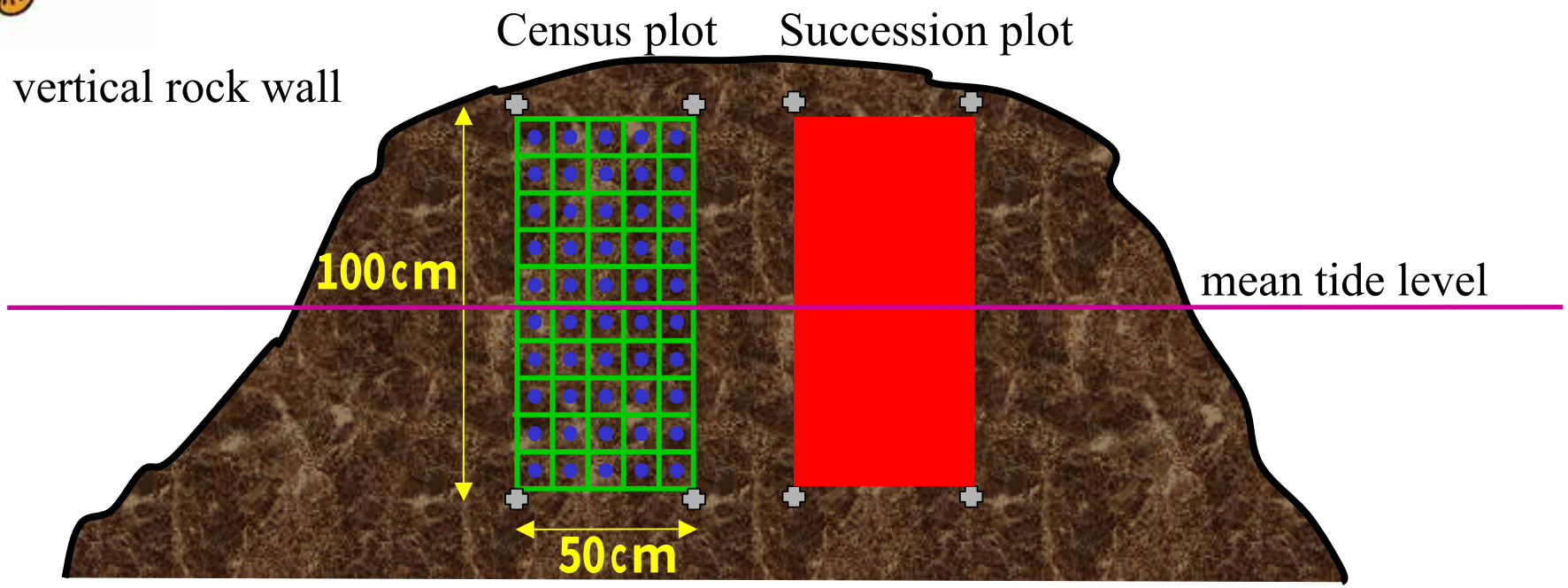
6 regions * 5 coasts * 5 plots
=150 plots







Field census



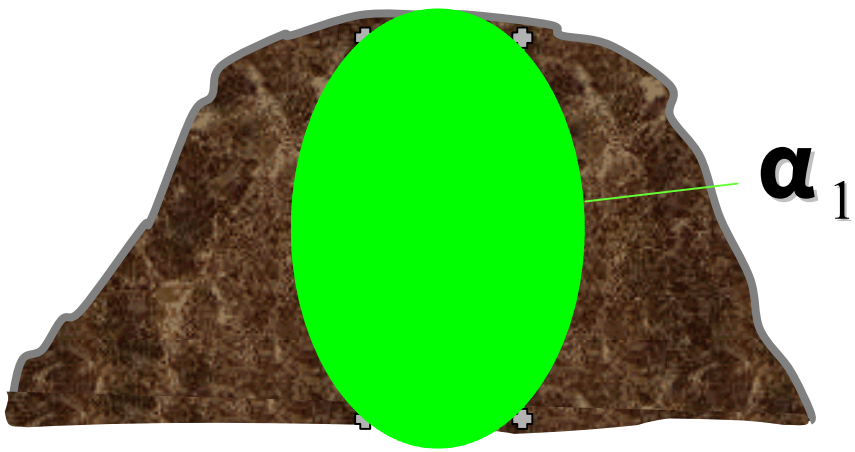
Simultaneous monitoring at all sites since 2002

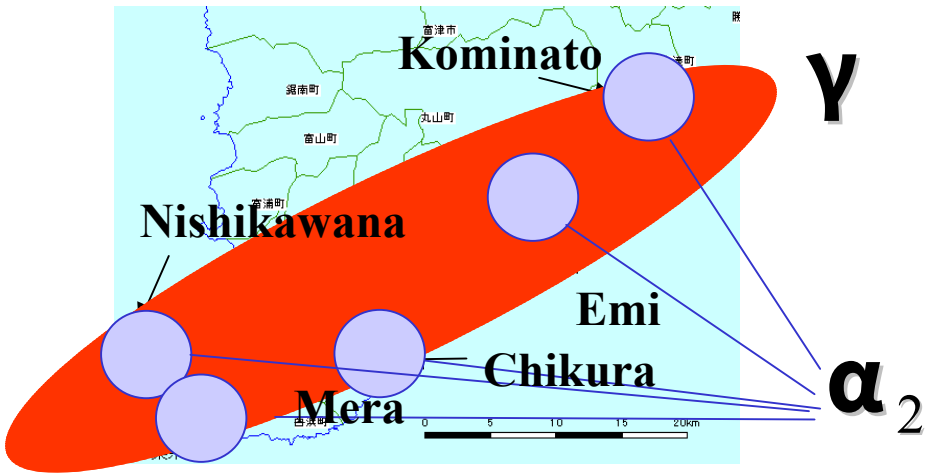
- Monitoring of environment (temperature, nutrient, chlorophyll *a* concentration, wave exposure, geology and geography of rocks)
- Measurement of BD and EF (see next page)

Biodiversity at different spatial scales

Species richness of sessile organisms appeared at census plots between 2002 and 2005

α_1 : plot species richness
α_2 : coastal species richness
γ : regional species richness





Ecosystem functions

1: Coverage

- indicator of biomass and productivity
  (average between 2002 and 2005)

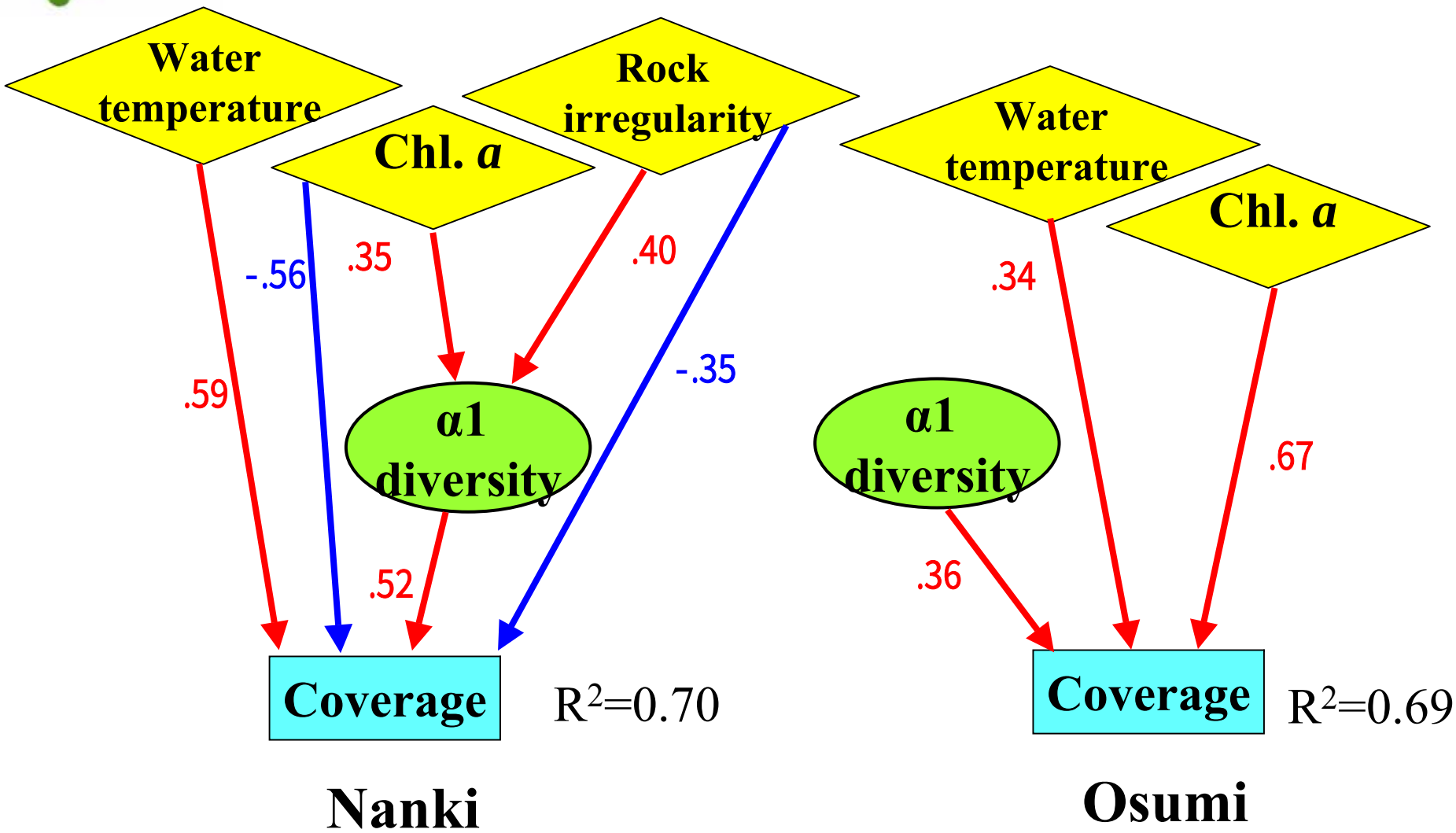
2: Temporal variation in coverage

- indicator of stability
  (C.V. of coverage between 2002 and 2005)

3: Recovery speed from disturbance

- indicator of resilience
  (coverage of the succession plot in 2004, i.e, one year after the removal of organisms)

Results of path analysis



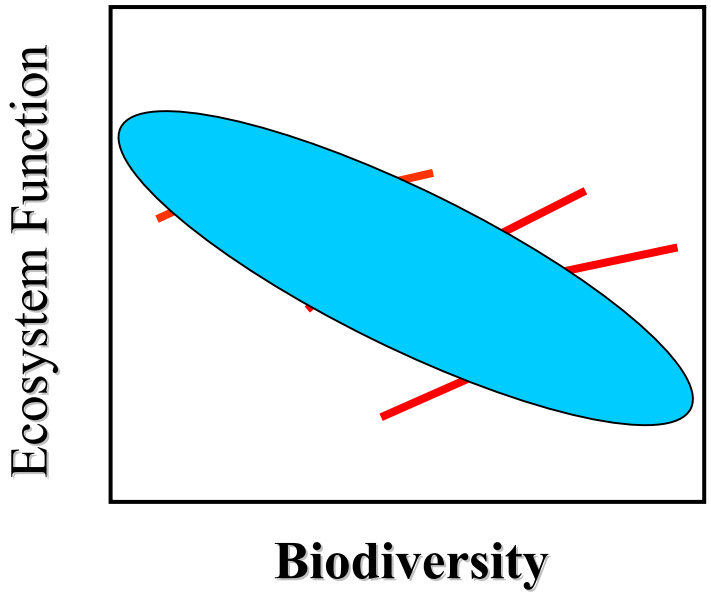
BD-EF relationship at different scales

EF	Coverage			Stability			Resilience		
BD	α1	α2	γ	α1	α2	γ	α1	α2	γ
All	0	-	-	0	0	0	0	-	-
Doto	0	0		0	+		0	0	
Donan	0	0		0	+		+	0	
Sanriku	0	0		0	0		0	+	
Boso	0	0		0	0		0	0	
Nanki	+	+		-	0		+	+	
Osumi	+	0		0	0		+	0	

Discussion from the rocky shore study

Plot diversity (α_1) affects ecosystem functions more frequently than coastal diversity (α_2).

Effects of BD on EF were negative by analysis using data from all regions, but positive for each region.



Conclusion

- Biodiversity measured at different spatial and biological levels is related to functions of coastal ecosystem.

- The observed BD-EF relationship varied among regions and among measures of biodiversity, suggesting importance of considering spatial scale of observation and the effects of environmental gradient.

- Combined approaches using long-term monitoring data and experimental approaches are promising to elucidate **causal mechanisms** for the observed relationships, which is necessary for planning adaptive management strategy for conservation of coastal ecosystem.

Acknowledgements

Seagrass team: T. Yamakita, K. Yamada, N. Whanpetch, M. Hori, Y. Tanaka, N. Tanaka, M. Ishii, A. Kondoh,

Rocky intertidal team : T. Noda, T. Yamamoto, M. Hori, T. Okuda, M. Tsujino, T. Hagino, N. Ito, T. Maruyama