



# **Food web structure in the continental shelf and slope waters of the Korean peninsula: Stable isotope approach and prospects for future research**

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# Tables of Contents

## 1. Background

End-to-end food web study and methodological issues

## 2. Materials & Methods

Stable isotope analyses and survey in Korean waters

## 3. Results: data set from Korean waters

Isotopic composition of producers and predators

## 4. Summary & future work



# 1. Background

## PICES Annual Meetings

### PICES 16th Annual Meeting

*Oct 26 - Nov 5, 2007, Victoria, BC,  
Canada*

*The changing North Pacific: Previous  
patterns, future projections, and  
ecosystem impacts*

### PICES 15th Annual Meeting

*Oct 13-22, 2006, Yokohama, Japan  
Boundary current ecosystems*

### PICES 14th Annual Meeting

*Sep 29 - Oct 9, 2005, Vladivostok,  
Russia  
"Mechanisms of climate and human  
impacts on ecosystems in marginal seas  
and shelf regions"*

### PICES 13th Annual Meeting

*Oct 14-24, 2004, Honolulu, HI, USA  
"Beyond the continental slope -  
complexity and variability in the open  
North Pacific Ocean"*

### PICES 12th Annual Meeting

*Oct 10-18, 2003, Seoul, Korea  
"Human dimensions of ecosystem  
variability"*

## Why end-to-end food web study ?

### PICES/GLOBEC Symposium on

*Climate variability and ecosystem impacts on the North Pacific:  
A basin-scale synthesis*

## Background

### General Information

Atmospheric forcing, ocean structure, and ecosystem structure and population dynamics vary on many spatial and temporal scales. Dominant temporal scales are diel, seasonal, interannual and longer. In the past ten to fifteen years, marine scientists have begun to document evidence that basin-wide or large-scale changes might be significant forcing for decadal to millennium-scale changes in marine ecosystems. In 1994, the PICES Climate Change and Carrying Capacity (CCCC) Program, a regional program of the IGBP/SCOR/IOC GLOBEC International, was developed to provide a framework for examining climate-ecosystem linkages, mostly on regional scales, but with plans for broader-scale, basin-wide synthesis, in the North Pacific.

The primary scientific objective of this symposium is to present a synthesis of the effects of seasonal to multi-decadal variability on the structure and function of the North Pacific that goes beyond the analysis and understanding developed from studies of a single trophic level, process or region-a True Synthesis.

### Dates and Venue

The symposium will be held April 19-21, 2006, at the Ala Moana Hotel, Honolulu, U.S.A.



Integrated Marine Biogeochemistry and Ecosystem Research



# IMBER Update

Issue No. 10 - June 2008

**Editorial:** [CLIMECO - Climate driving of marine ecosystem changes...Training for young marine scientists](#)

[Climate driving of marine ecosystem changes: a perspective on physical-biological coupling](#)

## Science Highlight:

[Modeling of the ecosystem of the bay of Brest: importance of benthic-pelagic coupling](#)

[Regulation of carbon export by short-term variability in organic matter recycling within the upper twilight zone](#)

**IMBER activities:** [IMBER SSC meeting report](#), [IMBER IMBIZO](#), [new IMBER SSC members](#)

**IMBER special sessions at meetings:** [IGBP Congress](#), [IMBER/SOLAS open session at EGU](#)

## IMBER-sponsored meetings :

[ICED Southern Ocean food web modeling workshop](#)

[Surface Ocean CO<sub>2</sub> Atlas kickoff meeting](#)

[Austral Summer Institute VIII](#)

[Symposium on "Coping with global changes in marine social-ecological systems"](#)

**Endorsed projects:** [Research activities of the China IMBER project](#), [Global experiments carried out on the Galathea Expedition](#), [Pressure effects On marine prokaryoTES](#)

**New European project:** [EPOCA](#)

**IMBER-related meetings and conferences** [click here](#)

**News** [click here](#)

# IMBER special sessions IGBP Congress

## Session A3: End to end food webs in marine ecosystems

Co-convenors: **Dr Coleen Moloney** (IMBER) and **Prof. Astrid Jarre** (GLOBEC)

The consequences of global change for plant and animal communities can be direct and/or indirect. Indirect effects are likely to be complex, with many possible responses and different degrees of response to different combinations of factors. Perturbations can propagate both up and down a food web hierarchy, affecting living organisms and feeding back to biogeochemical cycles. Marine food webs should be considered from end to end (from viruses to top predators) as integrated systems within changing physical and chemical environments. Although marine food webs are essentially continuous systems, research has been fragmented among different scientific communities, tending to focus on either the low trophic levels (phytoplankton and the microbial food web), intermediate trophic levels (zooplankton and fish), or high trophic levels (top predators). Through studying end to end marine food webs, it should be possible to quantify the flows of energy and cycling of materials in marine ecosystems on global scales, to characterize ecosystem responses to external forcing, and to understand the causes and consequences of changes in biodiversity. This session was organised to provide an opportunity to share information about processes involved in end to end marine food webs, and to raise issues that should be considered in future research activities.



# 1. Background *How end-to-end food web study ?*

*Trends in Ecology and Evolution* Vol.23 No.6

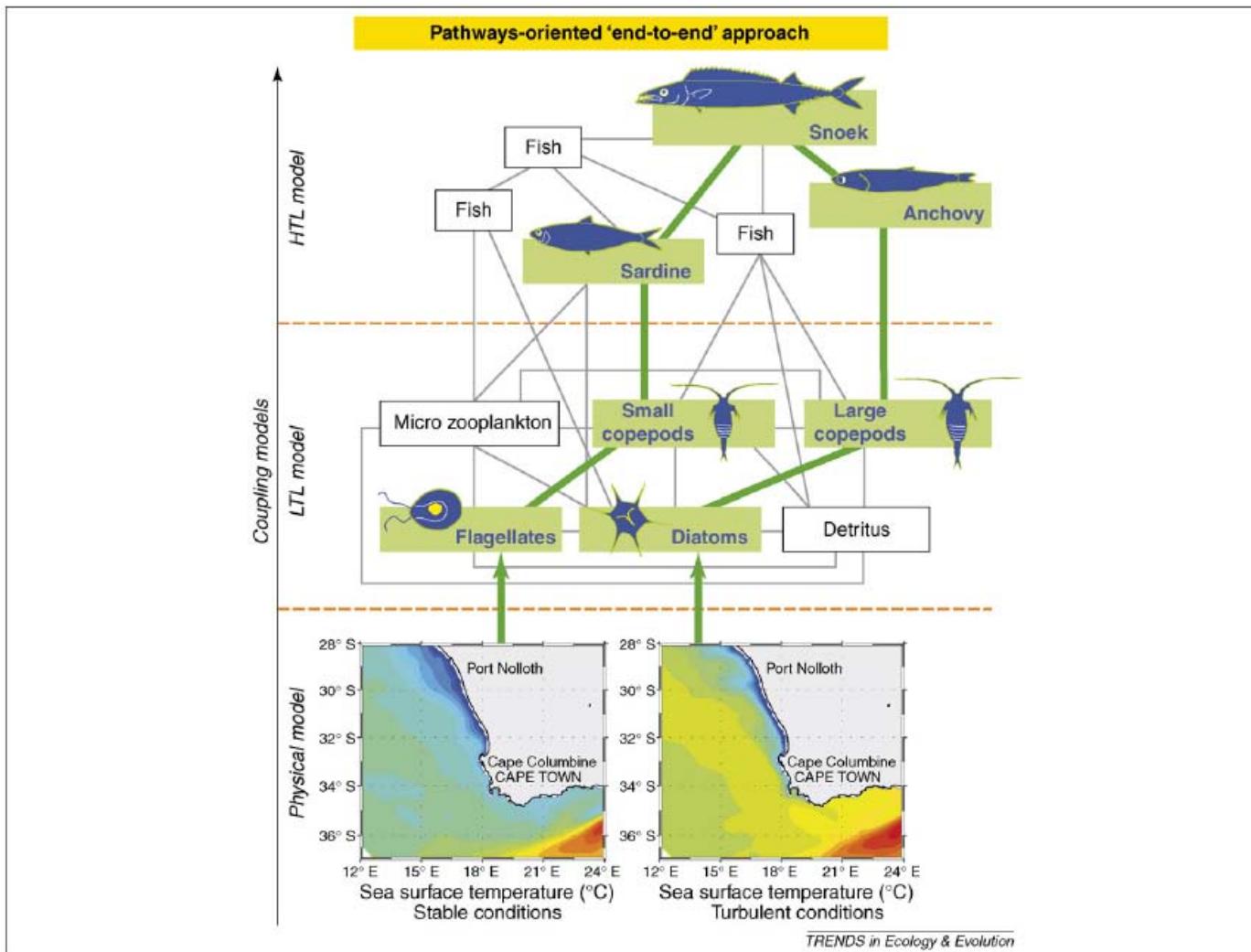
Review

Cell  
PRESS

## Ecosystem oceanography for global change in fisheries

Philippe Maurice Cury<sup>1</sup>, Yunne-Jai Shin<sup>1</sup>, Benjamin Planque<sup>2</sup>, Joël Marcel Durant<sup>3</sup>, Jean-Marc Fromentin<sup>4</sup>, Stephanie Kramer-Schadt<sup>5</sup>, Nils Christian Stenseth<sup>3,6</sup>, Morgane Travers<sup>1</sup> and Volker Grimm<sup>7</sup>

Overexploitation and climate change are increasingly causing unanticipated changes in marine ecosystems, such as higher variability in fish recruitment and shifts in species dominance. An ecosystem-based approach to fisheries attempts to address these effects by integrating populations, food webs and fish habitats at different scales. Ecosystem models represent indispensable tools to achieve this objective. However, a balanced research strategy is needed to avoid overly complex models. Ecosystem oceanography represents such a balanced strategy that relates ecosystem components and their interactions to climate change and exploitation. It aims at developing realistic and robust models at different levels of organisation and addressing specific questions in a global change context while systematically exploring the ever-increasing amount of biological and environmental data.



**Figure 2.** End-to-end models can be built by coupling three types of models: high trophic level (HTL) models, low trophic level (LTL) models and physical models (output of physical model from [62]). The boxes represent key species or groups of species, the lines represent the trophic interactions (pathways) and the arrows represent the forcing of hydrodynamic models on the LTL model. The pathways-oriented approach acknowledges the role of biodiversity in the emergence of alternative trophic pathways. Depending on the climate and fishing forcings, the dominance of trophic pathways alternates, for example, 'sardine' or 'anchovy' regimes can alternate in upwelling ecosystems as illustrated here. By carefully selecting the species to represent using empirical and retrospective analyses, this pathways-oriented approach could help predict drastic ecosystem responses to changes in climate and fishing.

Progress in Oceanography 75 (2007) 751–770

## Towards end-to-end models for investigating the effects of climate and fishing in marine ecosystems

M. Travers <sup>a,\*</sup>, Y.-J. Shin <sup>a</sup>, S. Jennings <sup>b</sup>, P. Cury <sup>a</sup>

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Available online 9 August 2007

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### Abstract

End-to-end models that represent ecosystem components from primary producers to top predators, linked through trophic interactions and affected by the abiotic environment, are expected to provide valuable tools for assessing the effects of climate change and fishing on ecosystem dynamics. Here, we review the main process-based approaches used for marine ecosystem modelling, focusing on the extent of the food web modelled, the forcing factors considered, the trophic processes represented, as well as the potential use and further development of the models. We consider models of a subset of the food web, models which represent the first attempts to couple low and high trophic levels, integrated models of the whole ecosystem, and size spectrum models. Comparisons within and among these groups of models highlight the preferential use of functional groups at low trophic levels and species at higher trophic levels and the different ways in which the models account for abiotic processes. The model comparisons also highlight the importance of choosing an appropriate spatial dimension for representing organism dynamics. Many of the reviewed models could be extended by adding components and by ensuring that the full life cycles of species components are represented, but end-to-end models should provide full coverage of ecosystem components, the integration of physical and biological processes at different scales and two-way interactions between ecosystem components. We suggest that this is best achieved by coupling models, but there are very few existing cases where the coupling supports true two-way interaction. The advantages of coupling models are that the extent of discretization and representation can be targeted to the part of the food web being considered, making their development time- and cost-effective. Processes such as predation can be coupled to allow the propagation of forcing factors effects up and down the food web. However, there needs to be a stronger focus on enabling two-way interaction, carefully selecting the key functional groups and species, reconciling different time and space scales and the methods of converting between energy, nutrients and mass.



## 1. Background *Prolematics*

- For more precise and believable assessment, better understanding trophic interactions between ecosystem components from primary producers to top predators is needed
- While numerical models tended to limit the study area to the pelagic components, biodiversity and biomasses are still high in bottom/deep waters
- Knowledge on trophic interactions in benthic food webs and among bentho-pelagos is very limited
- Stable isotope techniques can provide more direct and straightforward tool to investigate end-to-end food web structures including all trophic components

## Stable isotope approach: an alternative method

There is considerable interest in using stable isotopes, particularly those of nitrogen and carbon, to evaluate the structure and dynamics of ecological communities (e.g., Peterson and Fry 1987, Kling et al. 1992, France 1995, Vander Zanden et al. 1999, Post et al. 2000).

### The unit of stable isotope measures:

#### Natural abundances of C & N isotopes:

Nitrogen       $^{14}\text{N}$  : 99.63%     $^{15}\text{N}$  : 0.37%

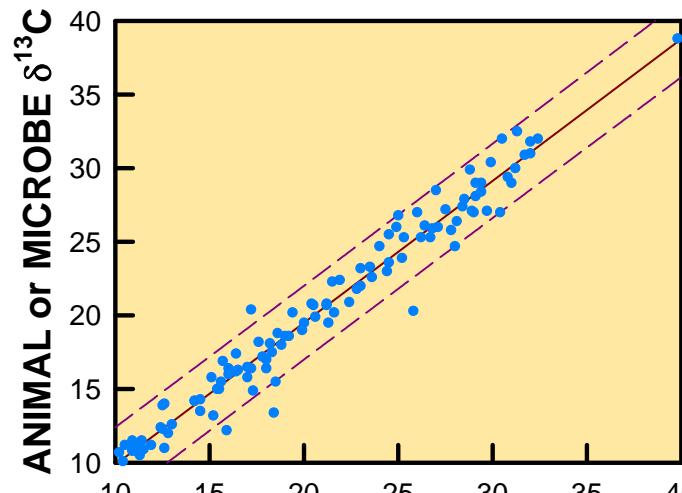
Carbon         $^{12}\text{C}$  : 98.89%     $^{13}\text{C}$  : 1.11%

#### $\delta$ notation:

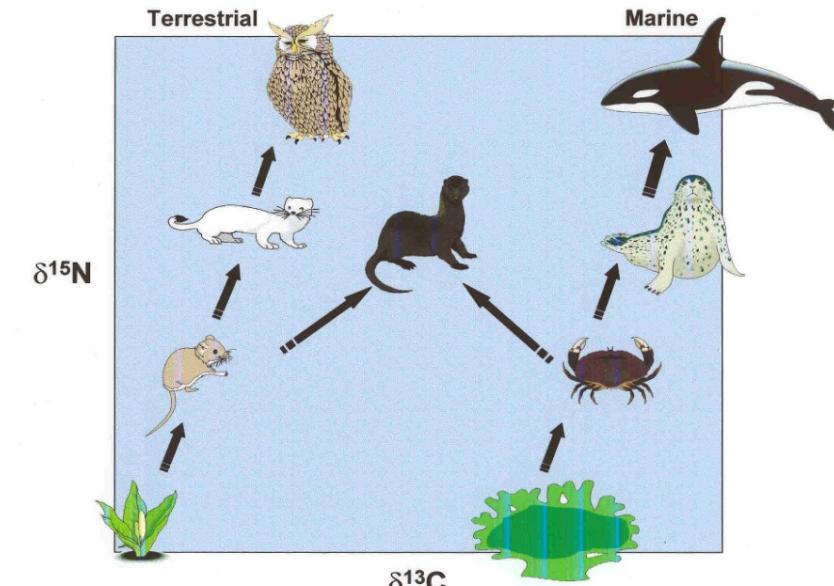
$$\delta = \frac{R_{sample} - R_{standard}}{R_{standard}} \times 1000 [\text{\textperthousand}]$$

$R$  =  $^{13}\text{C}/^{12}\text{C}$  or  $^{15}\text{N}/^{14}\text{N}$  (Standards : **PDB** for C & **atmospheric N<sub>2</sub>** for N)

# You are what you eat...

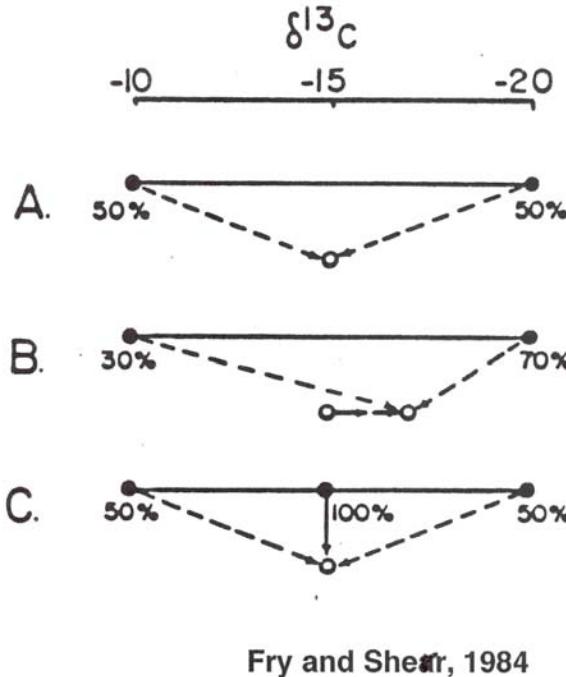


(After Fry & Sherr 1984)



The ratio of stable isotopes of nitrogen ( $\delta^{15}\text{N}$ ) can be used to estimate trophic position because the  $\delta^{15}\text{N}$  of a consumer is typically enriched by 3–4‰ relative to its diet (DeNiro and Epstein 1981, Minagawa and Wada 1984, Peterson and Fry 1987). In contrast, the ratio of carbon isotopes ( $\delta^{13}\text{C}$ ) changes little as carbon moves through food webs (Rounick and Winterbourn 1986, Peterson and Fry 1987, France and Peters 1997) and, therefore, typically can be used to evaluate the ultimate sources of carbon for an organism when the isotopic signature of the sources are different.

## Trophic sources: allocation of dietary source importance



Oecologia (2003) 136:261–269  
DOI 10.1007/s00442-003-1218-3

Donald L. Phillips · Jillian W. Gregg

## Source partitioning using stable isotopes: coping with too many sources

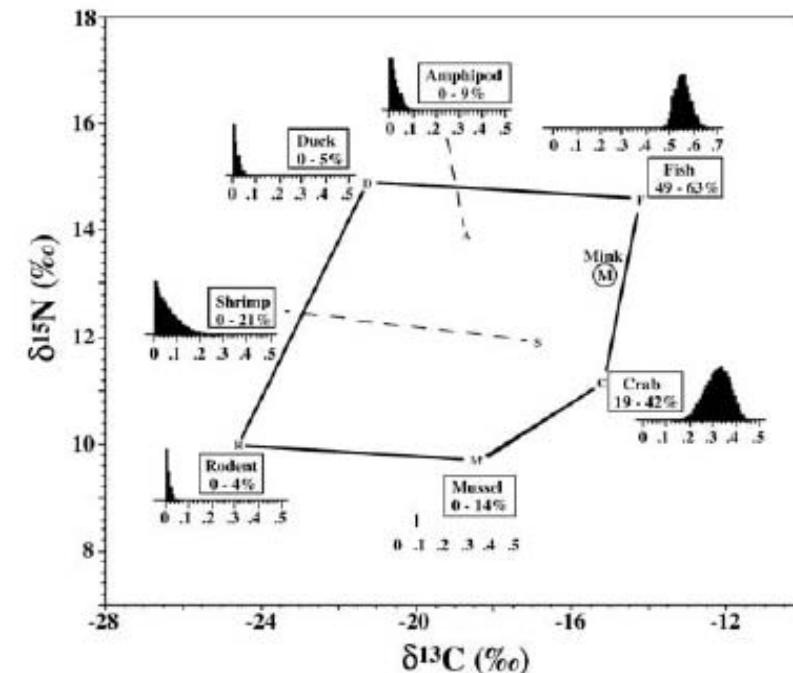


Fig. 4 Mixing polygon for  $\delta^{13}\text{C}$  and  $\delta^{15}\text{N}$  signatures of seven food sources for spring coastal mink in SE Alaska (after correcting for trophic fractionation). Histograms show the distribution of feasible contributions from each source to the mink diet (M). Values shown in the boxes are 1–99 percentile ranges for these distributions

Software: IsoSource



## Trophic position

Journal of Marine Systems 72 (2008) 17–34

### Benthic community and food web structure on the continental shelf of the Bay of Biscay (North Eastern Atlantic) revealed by stable isotopes analysis

François Le Loc'h<sup>a,b,\*</sup>, Christian Hily<sup>b</sup>, Jacques Grall<sup>b,c</sup>

As  $\delta^{15}\text{N}$  values provide an indication of the trophic position of a consumer, the following formula was used to estimate trophic level:

$$\text{Trophic Level} = (\delta^{15}\text{N}_{\text{consumer}} - \delta^{15}\text{N}_{\text{mean POM}}) / 3.4 + 1$$

where 3.4‰ is the assumed  $^{15}\text{N}$  trophic enrichment factor according to [Minagawa and Wada \(1984\)](#). In a benthic ecosystem such as the Grande Vasière (depth > 100 m), no primary production can occur on the bottom; consequently, the only organic material available for benthic primary consumers is assumed to be the POM sedimenting from upper water layers and therefore this is designated as the first trophic level.



# USING STABLE ISOTOPES TO ESTIMATE TROPHIC POSITION: MODELS, METHODS, AND ASSUMPTIONS

DAVID M. POST<sup>1,2,3</sup>

When comparing among ecosystems, the  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  of an organism alone provides little information about its absolute trophic position or ultimate source of carbon. This is because there is considerable variation among ecosystems in the  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  of the base of the food web from which organisms draw their nitrogen and carbon ( $\delta^{15}\text{N}_{\text{base}}$ ,  $\delta^{13}\text{C}_{\text{base}}$ ; Rounick and Winterbourn 1986, Zohary et al. 1994, Cabana and Rasmussen 1996, MacLeod and Barton 1998, Kitchell et al. 1999, Vander Zanden and Rasmussen 1999; France, *in press*). Without suitable estimates of  $\delta^{15}\text{N}_{\text{base}}$  and  $\delta^{13}\text{C}_{\text{base}}$  in each system, there is no way to determine if variation in the  $\delta^{15}\text{N}$  and  $\delta^{13}\text{C}$  of an organism reflects changes in food web structure and carbon flow, or just a variation in the  $\delta^{15}\text{N}_{\text{base}}$  and  $\delta^{13}\text{C}_{\text{base}}$ . Obtaining the isotopic baseline required to estimate trophic position is one of the most difficult problems facing the application of stable isotope techniques to multiple-system food web studies.

Using primary consumers as the baseline trophic level, consumer trophic position can be calculated using the formula

## Trophic position<sub>consumer</sub>

$$= (\delta^{15}\text{N}_{\text{consumer}} - \delta^{15}\text{N}_{\text{baseline}})/3.4 + 2$$

Two primary consumers, surface-grazing snails and filter-feeding mussels, capture the spatial and temporal variation at the base of aquatic food webs.

Snails reflect the isotopic signature of the base of the benthic food web and mussels reflect the isotope signature of the pelagic food web. They provide a **good isotopic baseline** for estimating **trophic position of secondary or higher trophic level consumers**.

According to the approach of Vander Zanden and Vadeboncoeur (2002) and Sherwood and Rose (2005), we use  $\delta^{13}\text{C}$  values as an indicator of food origin. The reliance on benthic affinity prey (RBAP) of upper consumer species was estimated using the formula:

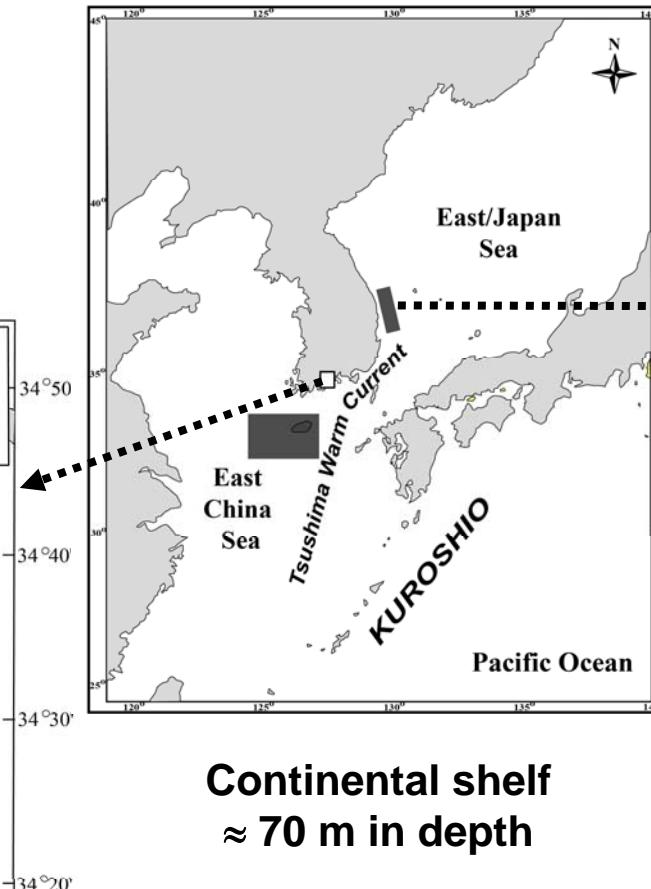
$$\begin{aligned} \text{RBAP} = & \left( X + \left( \delta^{13}\text{C}_{\text{Consumer II}} - \delta^{13}\text{C}_{\text{Consumer I Pelagic affinity baseline}} \right) \right) \\ & / \left( \delta^{13}\text{C}_{\text{Consumer I Benthic affinity baseline}} - \delta^{13}\text{C}_{\text{Consumer I Pelagic affinity baseline}} \right) \\ & \times 100 \end{aligned}$$

where  $\delta^{13}\text{C}_{\text{Consumer I Benthic affinity baseline}}$  and  $\delta^{13}\text{C}_{\text{Consumer I Pelagic affinity baseline}}$  are the mean  $\delta^{13}\text{C}$  of the benthic and pelagic primary consumer used as baseline. Here, zooplankton is considered as the pelagic primary consumer baseline and the bivalve *Nucula sulcata* and the gastropod *Scaphander lignarius* as the benthic primary consumer baseline (see Table 4).  $\delta^{13}\text{C}_{\text{Consumer II}}$  is the  $\delta^{13}\text{C}$  of the secondary consumer considered. As primary consumers are used as baseline, RBAP is calculated for consumers with TL higher than 2.

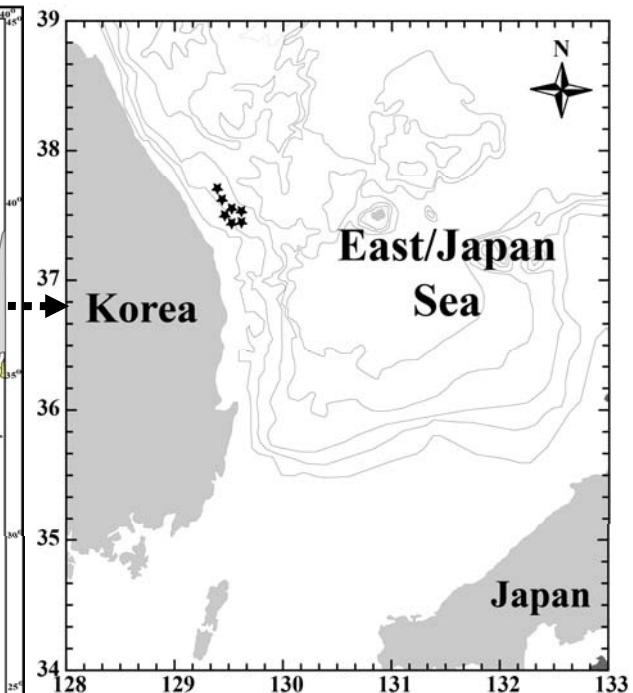
## 2. Materials & Methods Sampling sites - Korean waters



**Coastal system**  
 $\approx 20$  m in depth

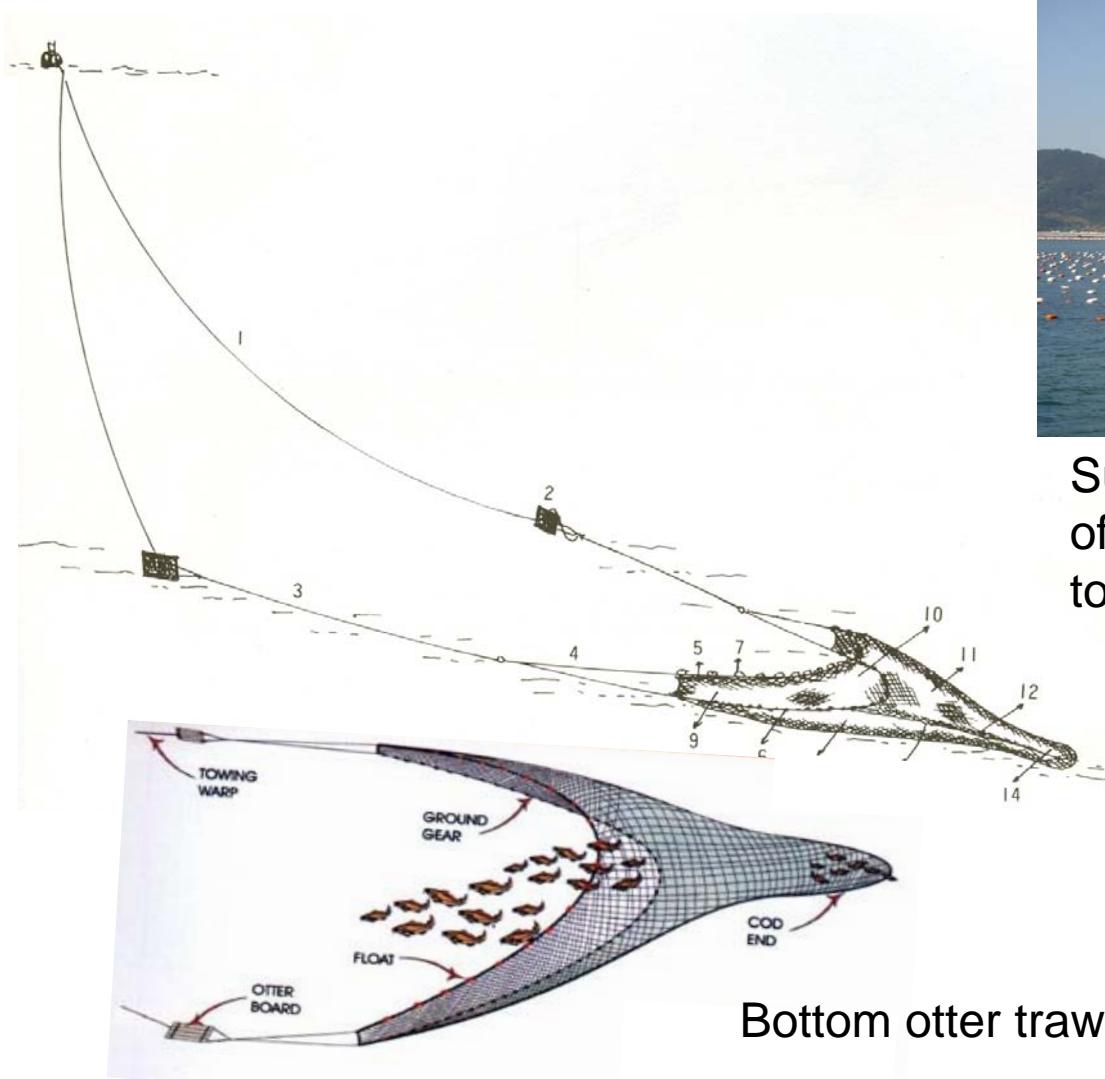


**Continental shelf**  
 $\approx 70$  m in depth



**Continental slope**  
500 to 1000 m in depth

## 2. Materials & Methods Sampling gear



Suspended cultures  
of oysters & sea squirts  
to capture pelagic baseline

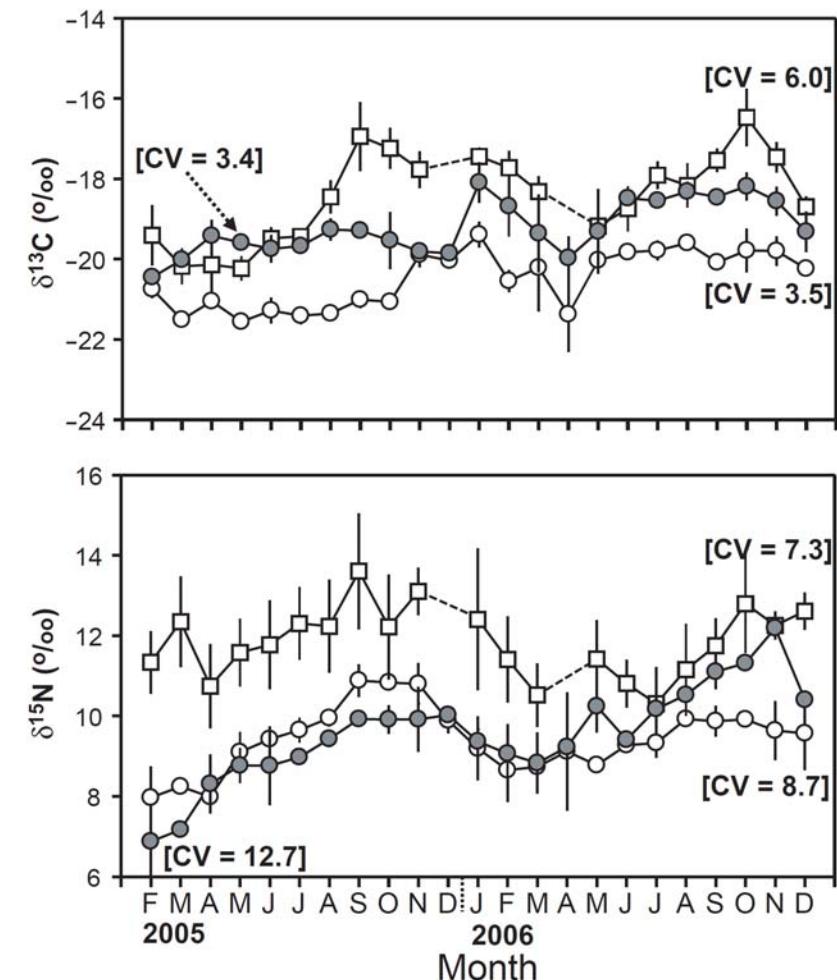
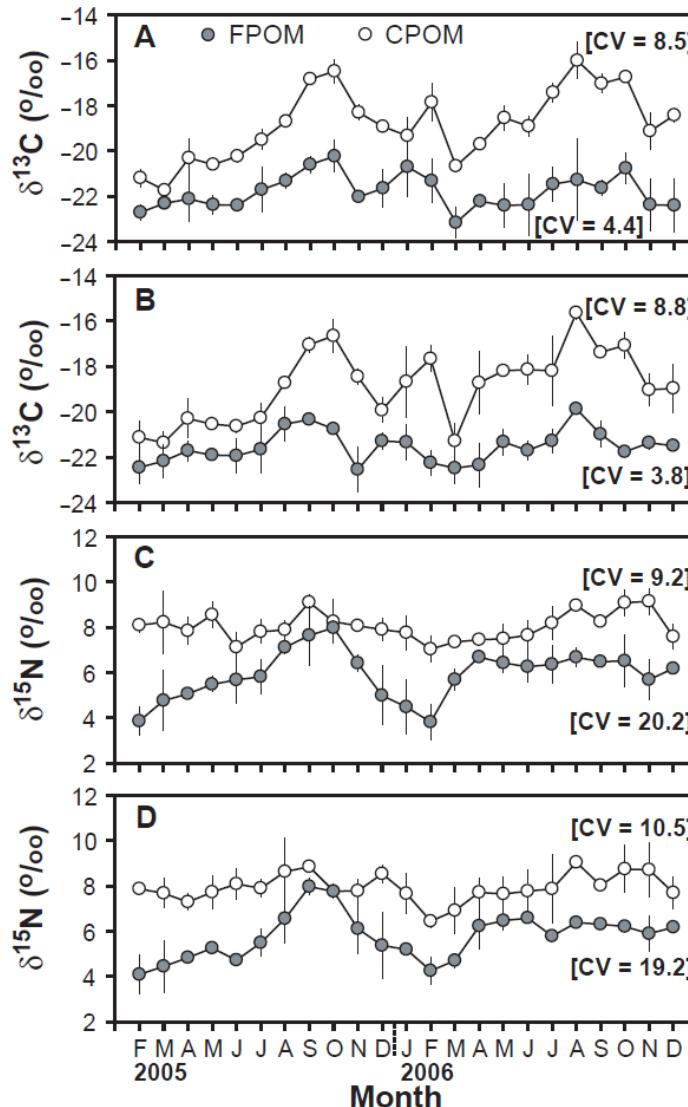
Bottom otter trawl

### 3. Results: data set from Korean waters

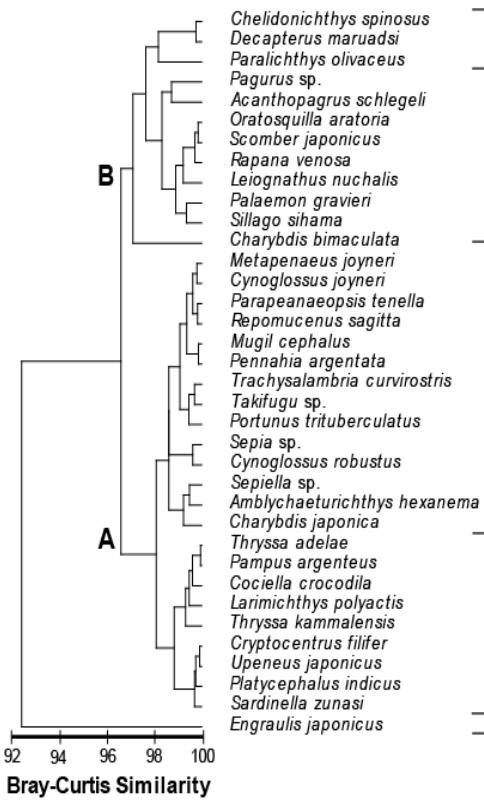
#### 3-1. Coastal systems: suspended POM & pelagic baselines

FPOM  
 $< 20 \mu\text{m}$

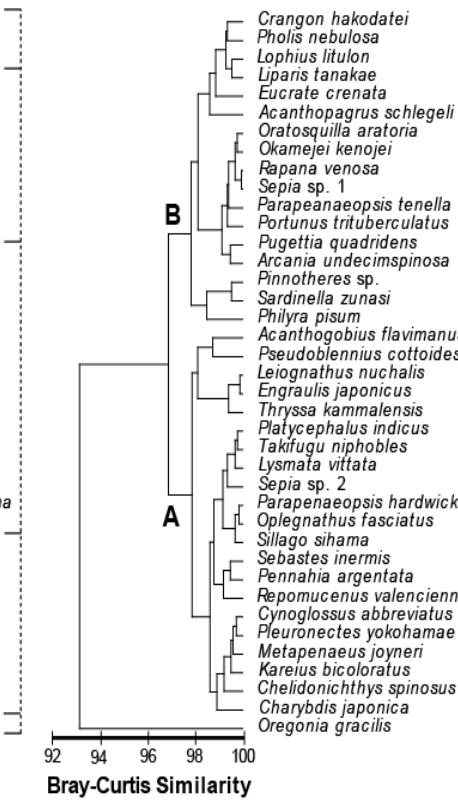
CPOM  
 $\geq 20 \mu\text{m}$



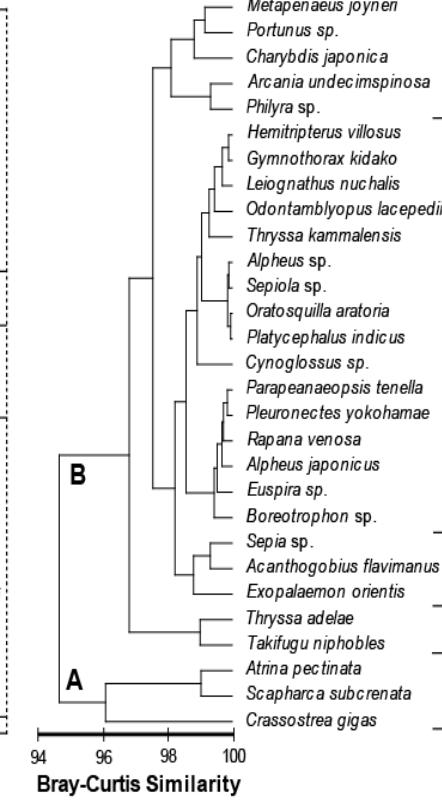
(a) September 2005



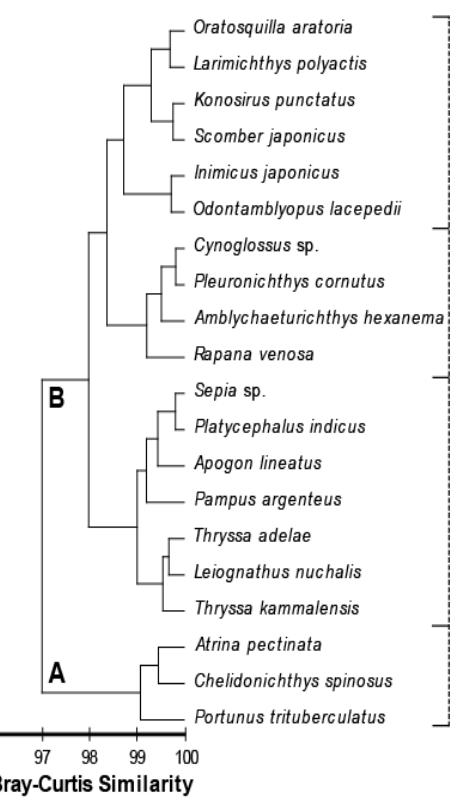
(b) December 2005

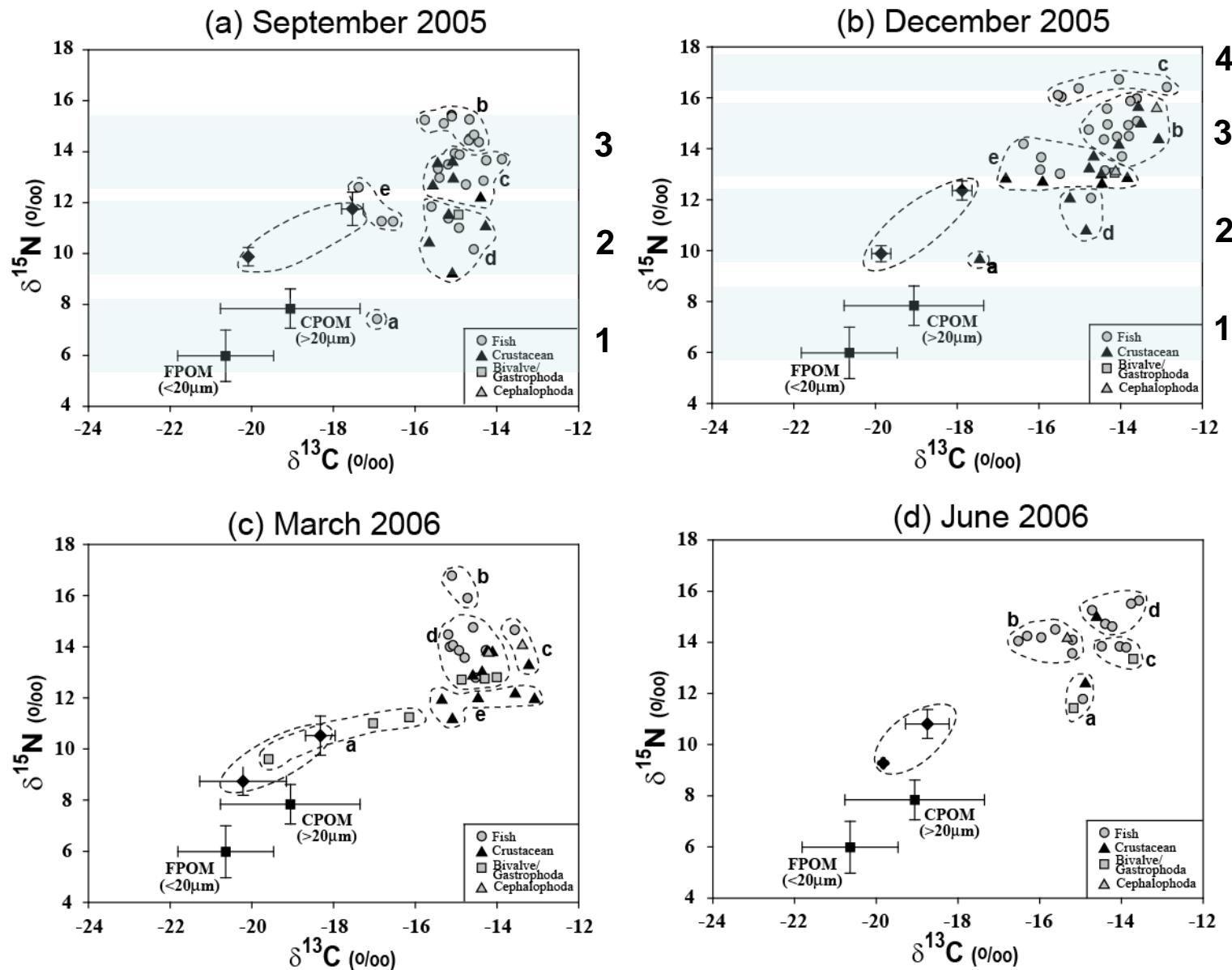


(c) March 2006

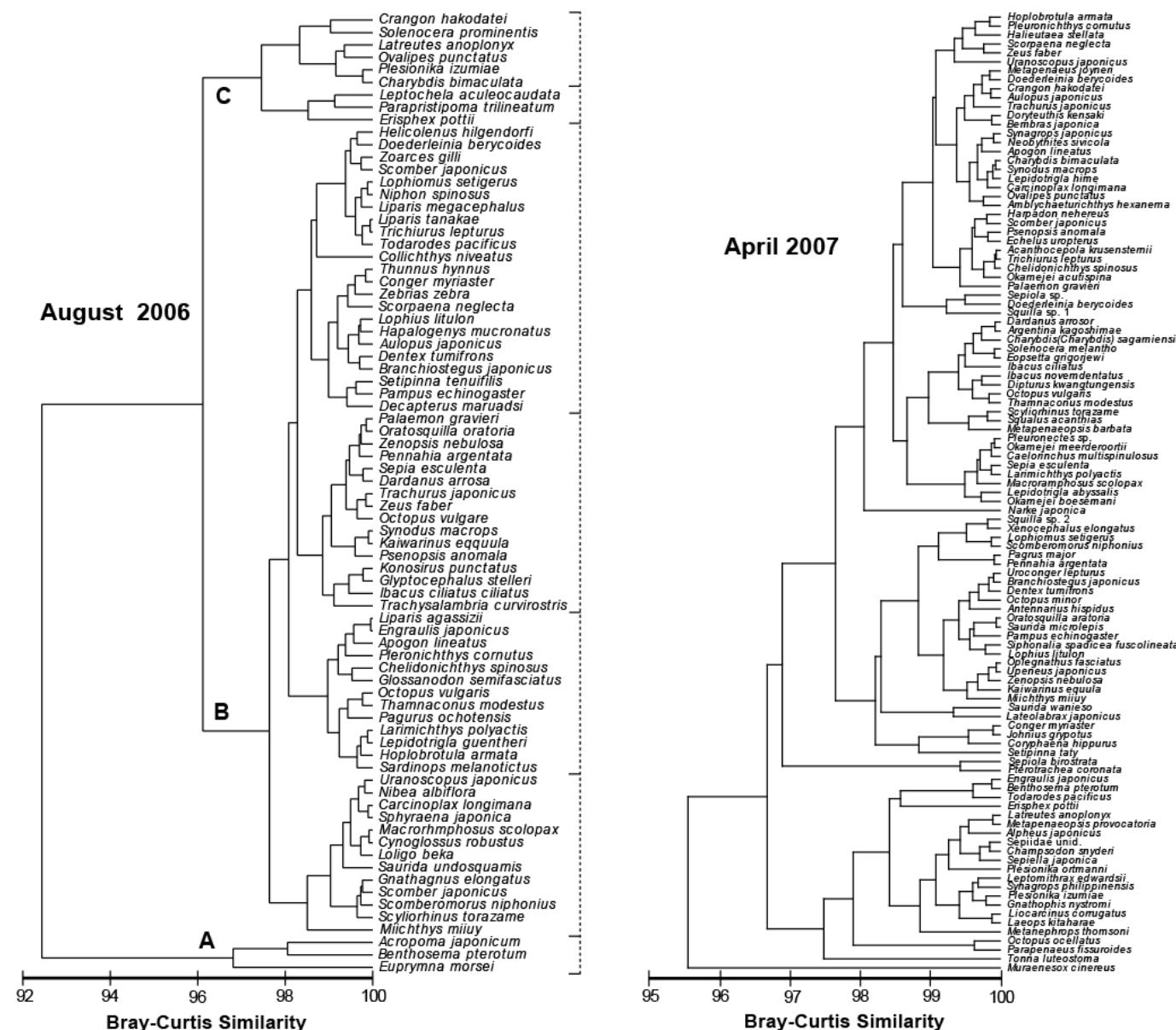


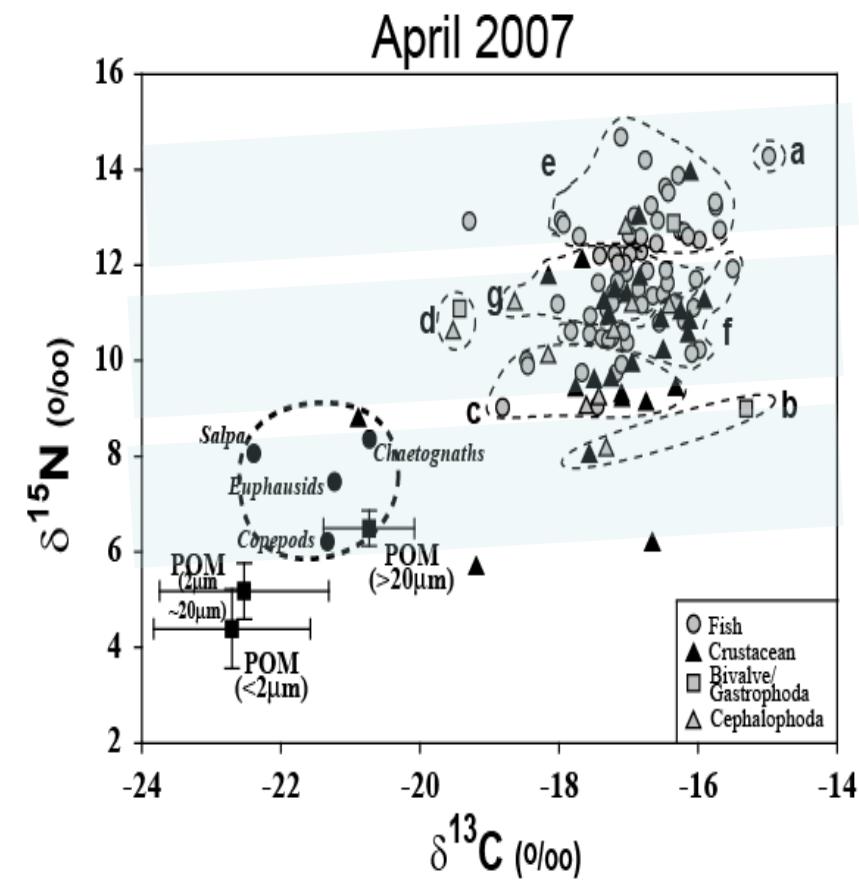
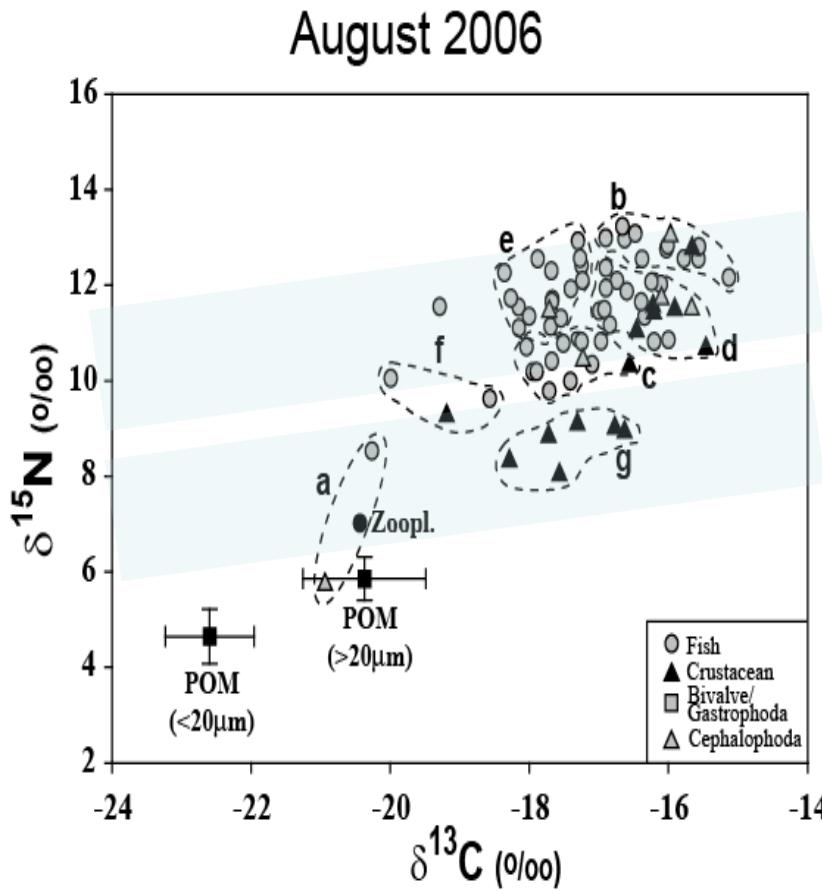
(d) June 2006



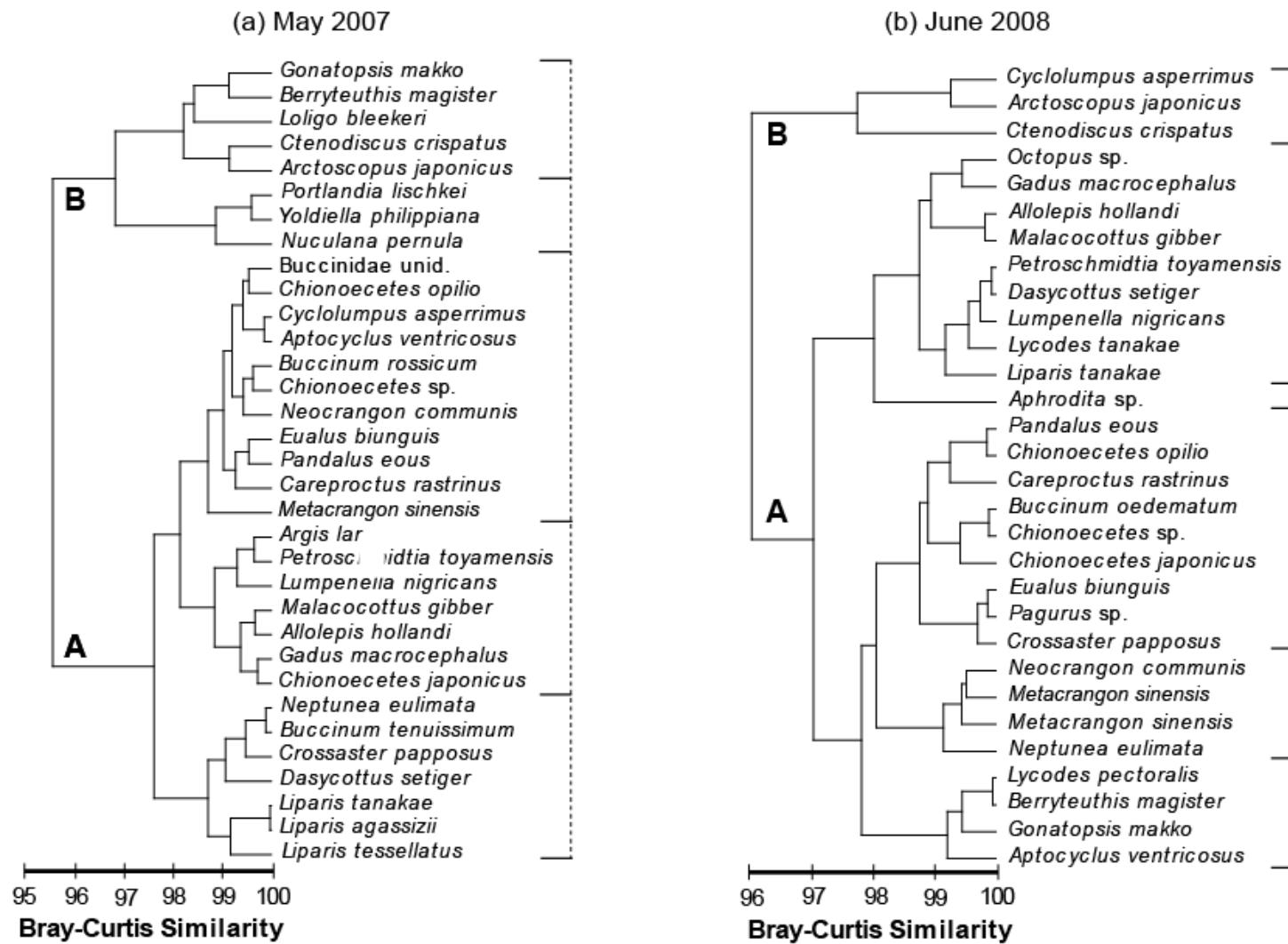


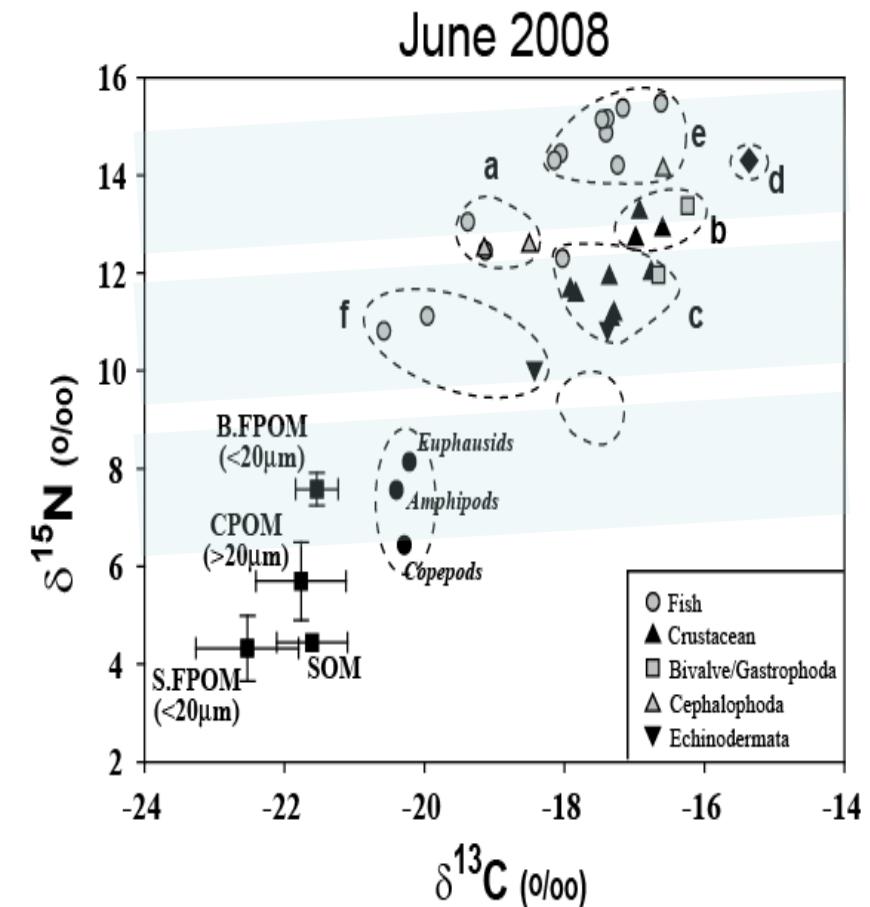
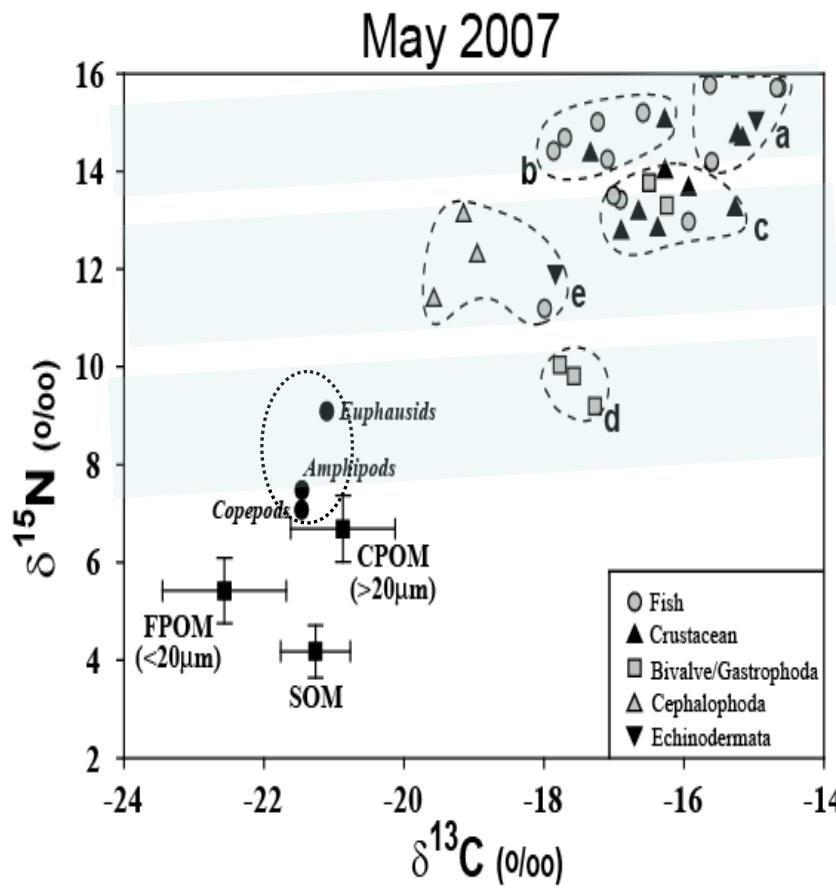
### 3-3. Continental shelf





### 3-3. Continental slope







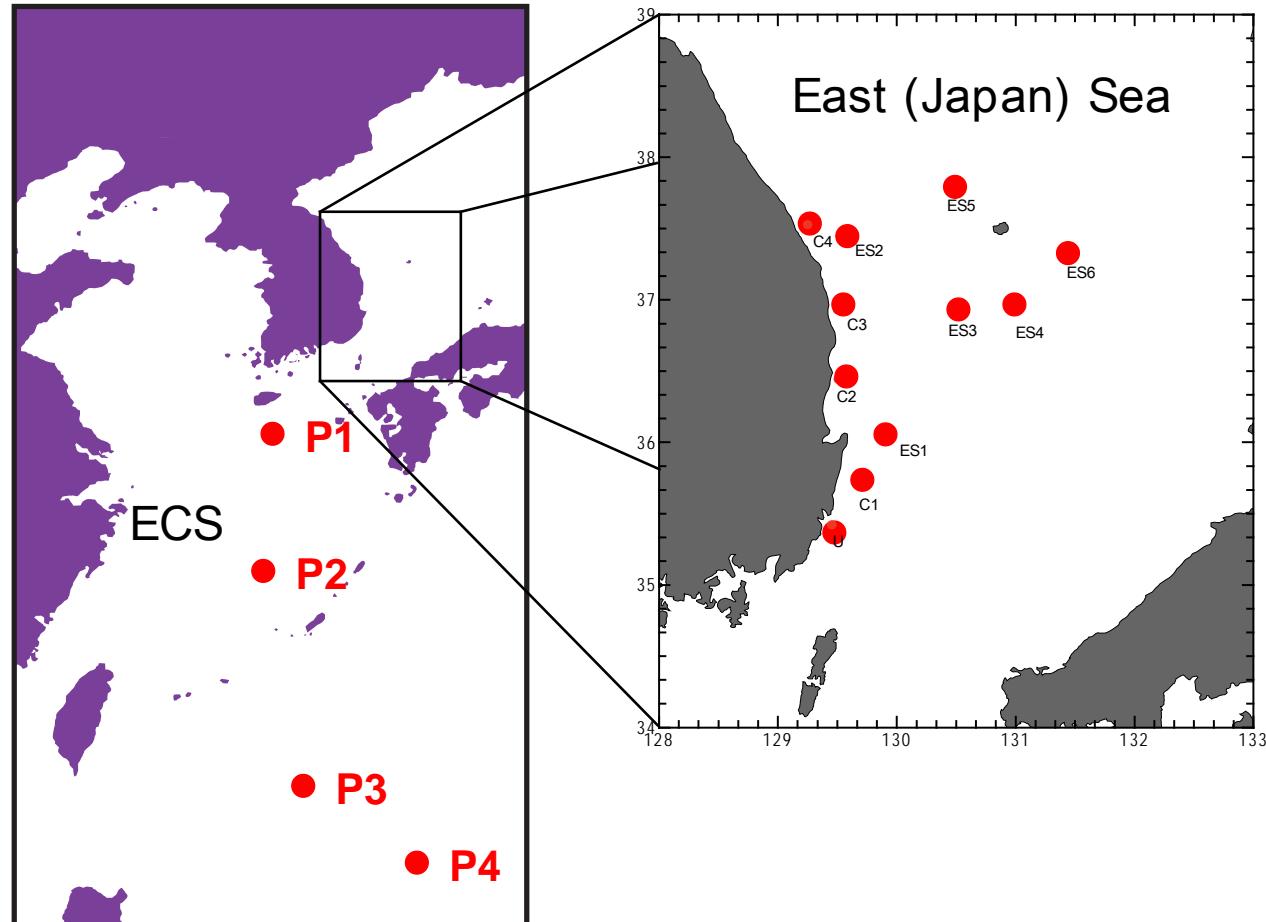
## 4. Summary & future work

- Direct trophic linkage between pelagic producers and benthopelagos is limited to very few species
- This suggests that end-to-end food web dynamics due to climate changes may not be fully understood in overall ecosystem components by using the previously applied ecosystem models
- Stable isotopes can be an alternative method as powerful tool to assess ecosystem dynamics
- Further research is needed to understand interactions between surface primary production and deep-sea/benthic systems due to climate change as follows:

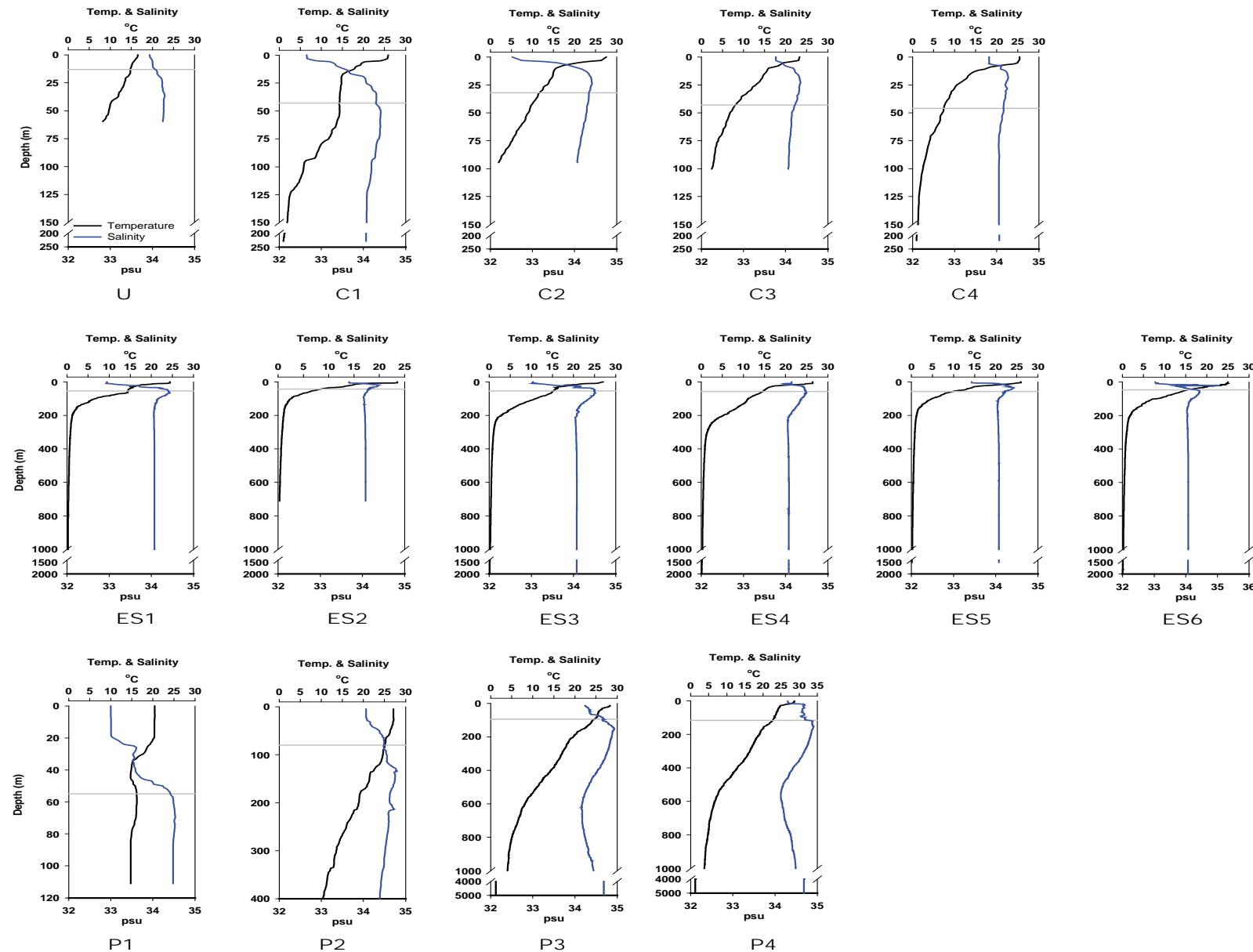
## 4. Future work

### Primary productivity vs water column structure

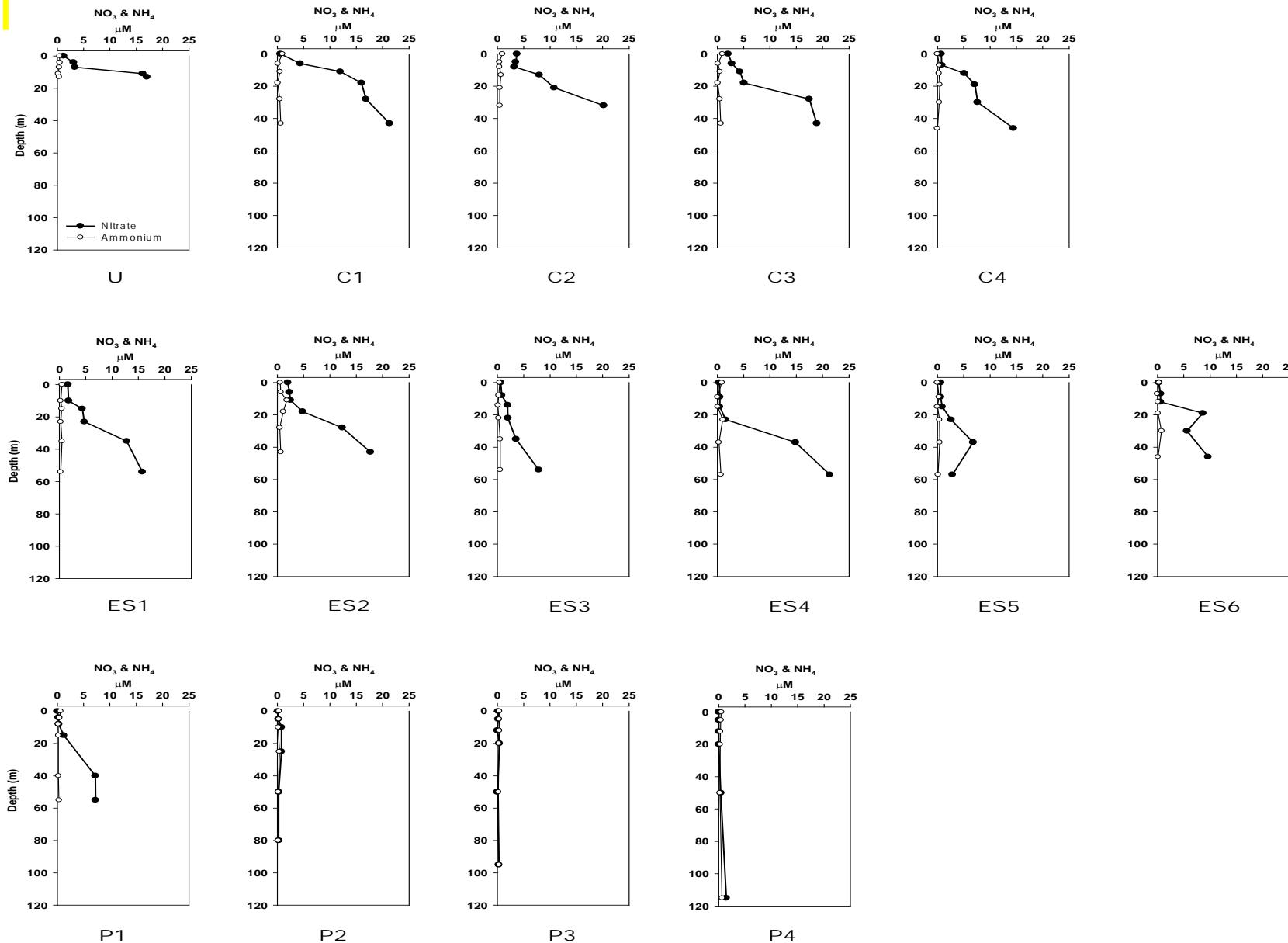
Sampling sites for primary, new and regenerated production measurement



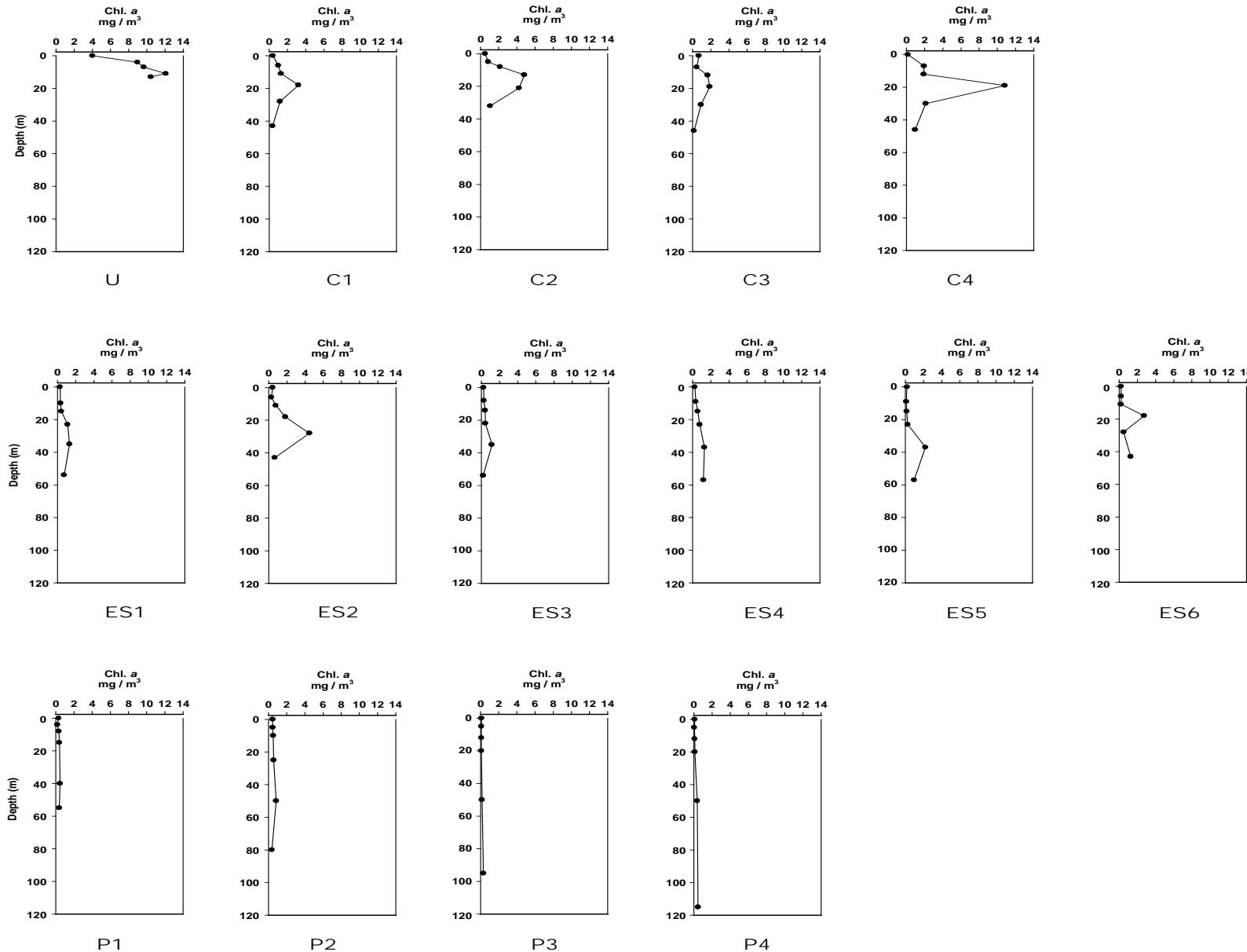
## 4-1. Temperature & salinity



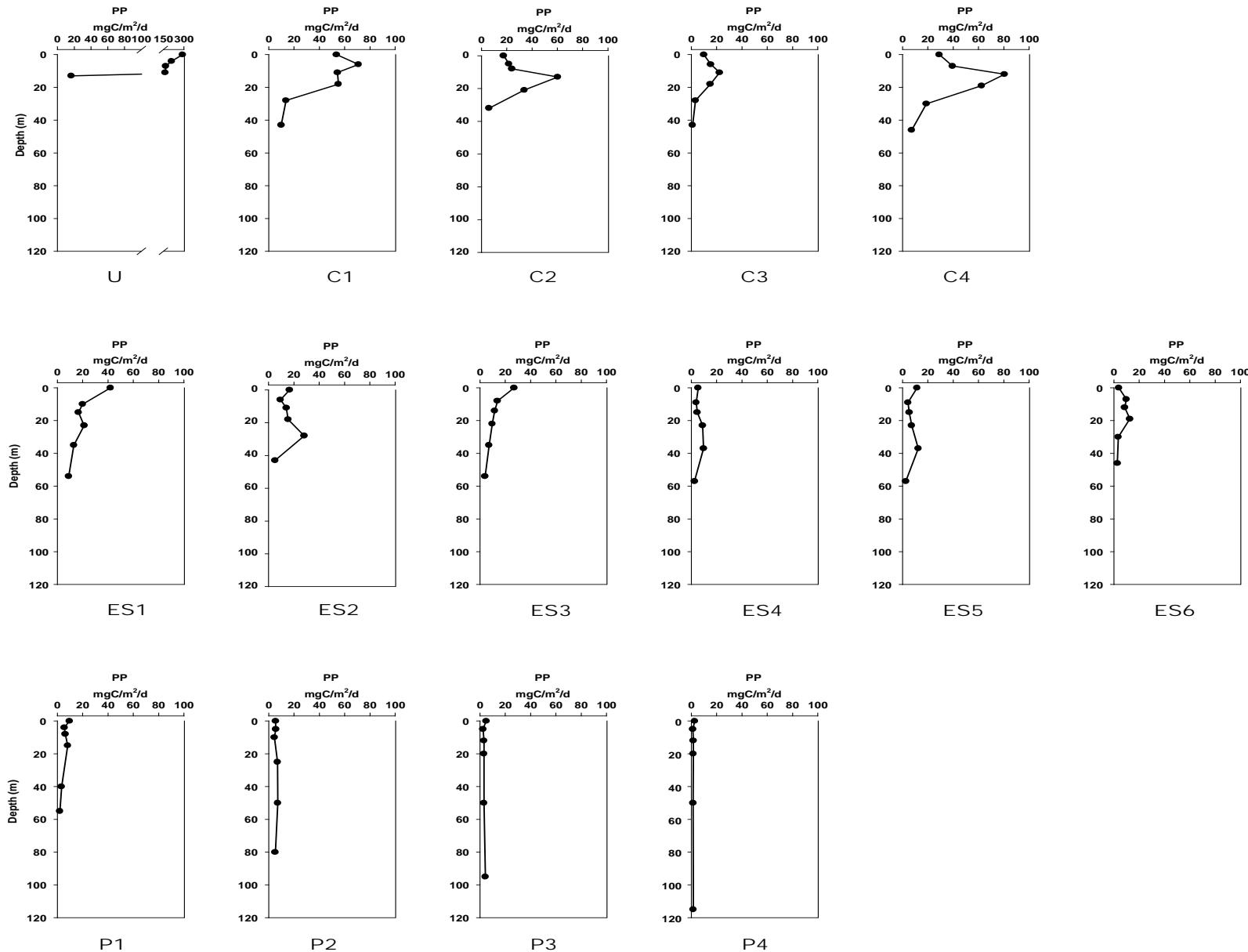
## 4-2. Nitrate & ammonia



### 4-3. Chlorophyll a

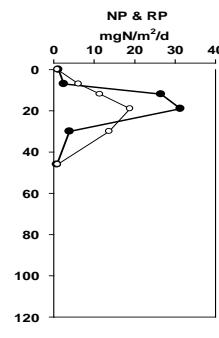
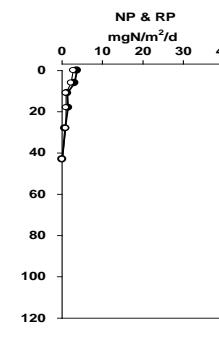
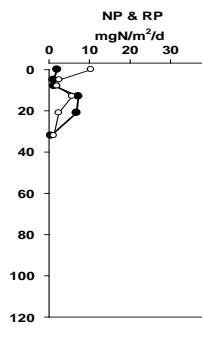
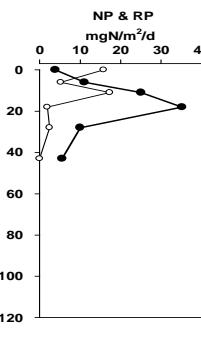
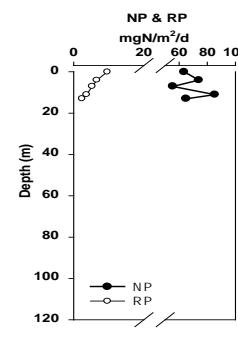


## 4-4. Primary productivity

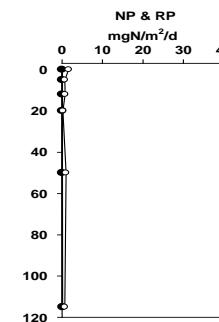
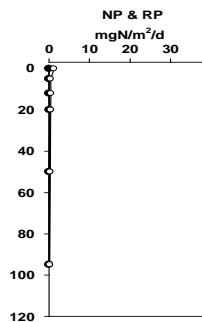
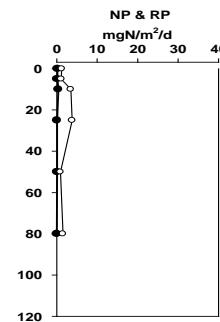
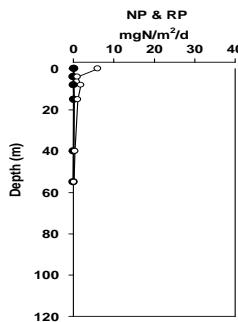
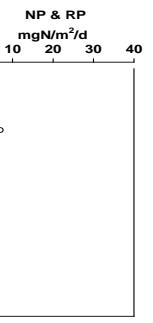
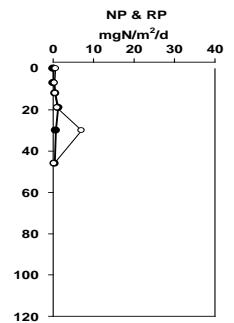
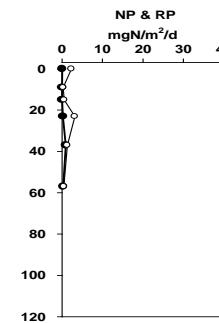
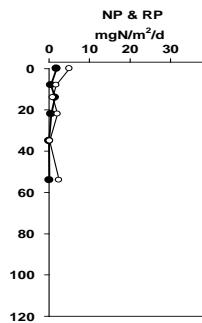
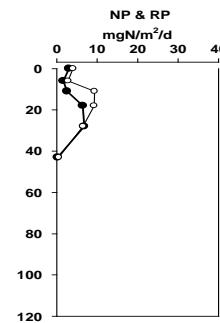
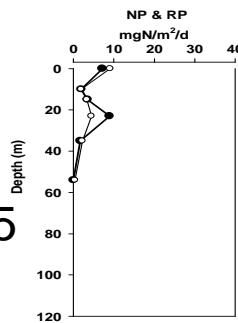


## 4-5. Nitrate uptake & ammonia uptake rates

*f*-ratio  
0.8 to 0.9



*f*-ratio  
0.45 to 0.55



*f*-ratio  
0.05 to 0.08

## Primary production controlled by water column stratification

Warming of the surface



Deepened surface mixed layer

Increased vertical stratification

**Direct effect:**  
biological disturbance  
from surface  
probably to benthic systems

Oligotrophic: lowered nutritional condition

Lowered surface productivity

Reducing the supply of organic matter to sediments

Decreased benthic metabolism and secondary production

**Reduction of benthic organisms,**  
The reduction of microbial biomass (bacteria and meiofauna etc.)  
results in a reduction of suitable organic food sources

Overall deep-sea response to climate change  
can have **indirect effects** on the deep-sea ecosystems  
through altered biogeochemical cycles





# Thank you very much !!!



Integrated Marine Biogeosciences and  
Ecosystem Research

