Marine Ecosystem Studies of Today and Tomorrow with emphasis on the western North Pacific Ocean.

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At present, the tentative goal of global environmental studies is to provide clear-cut scientific scenarios to solve various kinds of environmental problems within the next 50 to 100 years under the reliable database and simulation studies. Integrative studies involving observation, modeling and simulation may be connected to social management systems of the Plan-Do-Check-Action.

PART 1. What kinds of ecosystem models are we developing?

PART 2. What is Stable Isotope techniques?

Distributions of δ15N-δ13C in marine ecosystems

ii. Application of SI techniques in future studies.

- Biome or Vegetation types or ISOSCAPE (Isotope Landscape)
- L. Baikal & W. N. Pacific: Fish Scaleδ exhibits Synchronous Oscillation
- AMINO ACID Trophic Level → MEMURO.FISH + ECOSIM
  - Boreal area. → Growth rate (μ) could be estimated from δ13C(phyto-)
Our Ecosystem Change Program, FRCGC has been developing several kinds of global ecosystem simulation models as indicated in this slide.

Terrestrial Ecosystem (30 Vegetation Types)
Sim-CYCLE for global carbon dynamics,
Sim-CYCLE-MATSIRO-AGCM
Spatially Explicit Individual Based
-Dynamic Global Vegetation Model

Marine Ecosystem (No Biome)
NEMURO model for a plankton dynamics
NEMURO.FISH model
Oceanic GCM for carbon dynamics (OFES)

Remote sensing for PAR, NDVI, 3D-forest model and pCO2 to refine above models in two systems.

What is our Research Purposes?
The major, mid-term goal of the Ecosystem Change Research Program (ECRP) is to develop the biosphere sub-model for the integrated model of global change.
In this context, our efforts have been focused on modeling of biogeochemical carbon cycles in both terrestrial and oceanic ecosystems.

PAR, Temp. Precip.
PART 2. Nitrogen and carbon isotope ratios in the biosphere — From molecule to ecosystem

1) What is the SI method?
2) Distribution in plant kingdom.
3) Isotopic map and human food web analysis.
4) Possible application for assessing the ecosystem models

Definition of parameters

\[ \delta^{\%o} = \left( \frac{R_{\text{sample}}}{R_{\text{standard}}} - 1 \right) \times 1000 \]

\( R : \) \(^{15}\text{N}/^{14}\text{N} \) or \(^{13}\text{C}/^{12}\text{C} \)

standard: \( \text{N}_2 \text{ air} \) or PDB
Empirical law of SI distribution

1) Plant $\delta^{13}C$ is determined by the dynamics of CO2 fixation during photosynthesis. C3 & C4 plant exhibit different 13C content.

2) Food chain

$$\delta^{15}N(\text{animal}) = 3.3 \times (T \times L - 1) + \delta^{15}N(\text{plant})$$

TL: Trophic level

3) Increase in $^{15}N$ in an ecosystem is caused by evaporation of $NH_3$ and denitrification ($NO_3 \rightarrow N_2$).

**Trophic effect during a feeding process**

A schematic illustration for analysis of a food web by a stable isotopic method.
1) A simple Example

Examples of human Food habit

δ¹⁵N-δ¹³C Sl-map of human hair

![Graphical representation of δ¹⁵N-δ¹³C in human hair with various data points and labels.]

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OAA

PGA

25 kg

C₄

C₃plant

C₄plant

10⁴ ~ 10⁵

[Japanese text on the left side of the page, partially translated below]

末梢微量化

(Peripheral quantitative microanalysis)

1.1: American adults

1.2: Japanese adults

1.3: Swedish adults

1.4: Indian adults

1.5: Chinese adults

1.6: Indonesian adults

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[Further detailed analysis and data points on the graph]
TOPICS

- Topic 1.
  Is $\delta^{15}$N-$\delta^{13}$C SI-map of phytoplankton useful to classify biome in the open ocean?
    1) Satellite Biome
    2) Stable Isotopes: ISOSCAPE or Isotope Landscape!

- Topic 2.
  Does synchronous oscillation of biological activities occur between L. Baikal and marine ecosystems in the western North Pacific?

- Topic 3.
  Newly developed SI method for Amino acid Trophic Level is useful to validate NEMURO.FISH model & ECOSIM.

- Topic 4.
  Does $\delta^{13}$C inform you growth rate of phytoplankton in the ocean?
Topic 1. Possible BIOME on the del15N-13C map

\[ \alpha = 1.002 \]

Diatom 1\text{permil}, -25\text{permil}

Coccolithophorids

Pico-phytoplankton

6<\text{permil}, -20\text{permil}

\text{-2 permil, -13 permil}
$\delta^{15}N, \delta^{13}C (// \mu)$ can inform a growth rate constant of phytoplankton!

$N_t = N_0 \exp (\mu t)$ The higher the algal growth rate, the higher the $\delta^{13}C$ value.
Topic 2. Does synchronous oscillation of biological activities occur between L. Baikal and marine ecosystems in the western North Pacific? YES!
Decrease in $\delta^{13}C$ is similar.
Chikaraishi et al. suggested that glutamic acid is systematically enriched in 15N toward the upper levels of the food chain (8.0 ± 1.2‰ at each trophic step) as a result of metabolic processes; in contrast, phenylalanine shows little enrichment in 15N because of the absence of nitrogen-involving reactions in its dominant metabolic processes. Therefore, trophic level is estimated based on the δ15N values of glutamic acid and phenylalanine via the following equation, termed the “Amino acid Trophic Level (ATL):”

\[ \text{MEMURO.FISH} \rightarrow \text{saury and herring} + \text{ECOSIM} \]

where δ15N\text{Glu} and δ15N\text{Phe} are the nitrogen isotopic compositions of glutamic acid and phenylalanine, respectively.

(submitted to *Limnology and Oceanography* Yuichiro Kashiyama\textsuperscript{1}, Nanako O. Ogawa\textsuperscript{1}, Yoshito Chikaraishi\textsuperscript{1}, Napussakorn Kashiyama\textsuperscript{1}, Saburo Sakai\textsuperscript{1}, Kazushige Tanabe\textsuperscript{2}, and Naohiko Ohkouchi\textsuperscript{1}(2007)

\textsuperscript{1}Japan Agency for Marine-Earth Science and Technology)
Topic 4. Possible Idea!!

$\delta^{15}\text{N}, \delta^{13}\text{C}$ (// $\mu$) can inform a growth rate constant of phytoplankton!

Estimation of SST, chl.a, Nitrate by using satellite data (T. Saino, Sasaoka et al.,)

$\mu$ could be estimated by $\delta^{13}\text{C}$ of phytoplankton or Possibly SST

Validation is conducted by using a new buoy system for NPP (in situ quantum irradiance spectra) in Euphotic Zone. T. Saino

Dynamics of plankton biomass at intervals of Day-Night cycle
**Conclusion**

**Topic 1.**
Is $\delta^{15}$N-$\delta^{13}$C SI-map of phytoplankton useful to classify biome in the open ocean? 
**POSSIBLE!**

1) Satellite Biome  
2) Stable Isotopes: ISOSCAPE or Isotope Landscape!

**Topic 2.**
Does synchronous oscillation of biological activities occur between L. Baikal and marine ecosystems in the western North Pacific?  
**YES!**

**Topic 3.**
Newly developed SI method for Amino acid Trophic Level is useful to validate NEMURO.FISH model & ECOSIM.  
**YES!**

**Topic 4.**
Does $\delta^{13}$C inform you growth rate of phytoplankton in the ocean?  
**POSSIBLE!**
Finally a new framework of environmental studies is required to deepen the interactive cycles between nature and humanity.

Integrative studies of the observation, modeling and simulation are possibly connected to social management systems of the Plan-Do-Check-Action as indicated.
Introduction

50 years` progress of ecosystem studies is summarized with emphasis on the various kinds of international cooperative research programs under global environmental issues. These programs are IBP, MAB, IGBP, DIVERSITAS and HDP. At the beginning of 21st century, integration of WCRP, IGBP and IHDP are highly required to provide significant practical solution and scenarios to social sciences and public involvement.
PART 1

Introduction of our Program

Several process model have been integrated to several dynamic models of biophilic elements in the fields of biogeochemistry and ecosystem ecology. Based on these data base, our Ecosystem Change Research Program, FRCGC has been developing several kinds of global ecosystem models as indicated in the following slides.

What is our Research Purposes?
The major, mid-term goal of the Ecosystem Change Research Program (ECRP) is to develop the biosphere sub-model for the integrated model of global change. In this context, our efforts have been focused on modeling of biogeochemical carbon cycles in both terrestrial and oceanic ecosystems.

Our purpose: Development of Global Carbon Model

Comprehensive ESM (MIROC・KISSME) · An integrated Earth system model (ESM) has been developed by coupling biogeochemical sub-system models to an AOGCM (MIROC). A result from the ESM contributed to the IPCC AR4 (2007) for the assessment of feedbacks between climate change and carbon cycle.
**Topic 4. $\delta^{15}N, \delta^{13}C$ can provide growth rate constant of phytoplankton**

\[
\begin{align*}
\frac{d[CO_{2\text{air}}]}{dt} &= k_1 [CO_{\text{air}}] - (k_1^- + k_2) [CO_{2\text{air}}] = 0 \quad \text{(Steady State)} \\
[CO_{2\text{in}}] &= \frac{k_1}{k_1^- + k_2} [CO_{2\text{air}}] \\
CO_2 &\rightarrow PGA = 1 + \Delta k_1 + (\Delta k_2 - \Delta k_1^-)X \quad (2) \\
X &= \frac{k_1^-}{k_1^- + k_2} = \frac{[CO_{2\text{air}}]}{[CO_{2\text{in}}]} \\
\Delta k_1 &= \frac{12}{13} k - 1, \quad k_1 = k_1^- \\
\Delta k_1^- &= \Delta k_1 = 0.0044, \quad \Delta k_2 = 0.030
\end{align*}
\]

In case we can measure the difference in $\delta^{13}C$ between CO$_{2\text{air}}$ and plant leaf ($\alpha$ CO$_2$→PGA), we can calculate the value X. Then [CO$_{2\text{in}}$] can be also calculated by using the X in Equation 1.

\[
\delta^{13}C_{CO_{2\text{air}}} = -7\%, \quad [CO_{2\text{air}}] = 340\text{ppm}
\]

<table>
<thead>
<tr>
<th>Plant</th>
<th>$\alpha$</th>
<th>X</th>
<th>PCO$_{2\text{in}}$</th>
<th>$\delta^{13}C$ CO$_{2\text{in}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>-27</td>
<td>1.020</td>
<td>0.61</td>
<td>201</td>
<td>3%</td>
</tr>
<tr>
<td>-20</td>
<td>1.013</td>
<td>0.34</td>
<td>111</td>
<td>10%</td>
</tr>
<tr>
<td>-37</td>
<td>1.030</td>
<td>1.0</td>
<td>330</td>
<td>-7%</td>
</tr>
<tr>
<td>-11</td>
<td>1.004</td>
<td>0</td>
<td>0</td>
<td>-11%</td>
</tr>
</tbody>
</table>

**The variation of $\delta^{13}C$ between forest height levels.**

**Reaction dynamics in the phytosynthetic CO$_2$-fixation by C3 plants.**
Relationship between the nitrogen-isotope fractionation factor in nitrate assimilation ($\alpha$) and growth constant ($\mu$) of *Phaeodactylum tricornutum*. (From Wada, E. and Hattori, A., *Geomicrobiol. J.*, 1, 97, 1978. With permission.)

\[ N = N_0 e^{\mu t} \]

0.69  \( \tau = 1 \text{日} \)
0.5  \( \tau = 1.5 \text{日} \)

**Steady state kinetics**

\[
S_0 \xrightleftharpoons[k_0]{k_i} S_i \\
S_i + E \xrightleftharpoons[k_i]{k_2} ES \\
ES + AH_2 \rightarrow E + A + P
\]

\[
\alpha = 1 + \Delta k_0^+ + (\Delta k_0^+ - \Delta k_0^-)X + (\Delta k_0^+ - \Delta k_0^-)XY,
\]

where

\[
\Delta k = k_{14}/k_{15} - 1, X = \frac{k_0^- [Si]}{k_0^+ [So]} and Y = \frac{k_i^- [ES]}{k_i^+ [Si][E]}
\]

The cleavage of the N-O bond in nitrate and the transport of nitrate across the cell membrane might from, respectively, primary and secondary key steps where nitrogen isotope fractionation takes place. Then Equation 69 reduces to

\[
(\alpha - 1) = \Delta k_0^+ + (\Delta k_2 Y - \Delta k_0^-)X
\]
δ15N-δ13C SI-map of plants

The highest

The lowest
1) Off Kuril

2) SST stratification starts in May.

3) Daytime Zoo

4) Uptake on NITRATE: 1.005