Progresses and achievements of GLOBEC research projects in JAPAN

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Primary goal for GLOBEC

To advance our understanding of the structure and functioning of the global ocean ecosystem, its major subsystems, and its response to physical forcing so that a capability can be developed to forecast the responses of the marine ecosystem to global change.

Four serial research programs related to GLOBEC led by Fisheries Research Agency (FRA)

- Objectives
- Main achievements
- Relationship with the international programs
Bio-Cosmos Project  (1989 - 92, 93 - 95, 96 - 98)
(Pelagic Fish Management)
To elucidate the mechanism causing the variability of the
Japanese sardine (Sardinops melanostictus) population

1984 - 1989 SARP (Sardine/Anchovy Recruitment Program)
1989 - 2nd SARP
1992 - International GLOBEC
1994, 1996 - GLOBEC-SPACC

VENFISH Project  (1997- 2001)
(Comprehensive study of the Variation of the oceanic ENvironment and
FISH populations in the North-western Pacific)
To develop ecosystem model based on the bottom-up control processes from the phytoplankton production to the recruitment of Pacific saury (Cololabis saira) and walleye pollock (Theragra chalcogramma)
FRECS Project  (2000 - 2006)
(Fluctuation of Recruitment of fish eggs and larvae by changes of spawning grounds and transport patterns in the East China Sea)

To understand the mechanisms of environmental impacts on the spawning grounds of jack mackerel (Trachurus japonicus) and Japanese common squid (Todarodes pacificus), and their linkages to recruitment

2000 - “Ocean Futures” activity
Draft Framework for Future Research on Biological and Chemical Aspects of Global Change

DEEP Project  (2002- 2006)
(Deep-sea Ecosystem and Exploitation Program)

To understand the meso- or bathypelagic ecosystem structure and dynamics, relationship between the pelagic fish community and the meso- or bathypelagic ecosystem
History and progress of the Bio-Cosmos Project

1st period (1989 - 1992)
- Verification of three hypotheses
- Accumulation of basic information

2nd period (1993 - 1995)
- Comparative study among three locations
- Focusing on the stage from post larvae to YOY stage

3rd period (1996 - 1998)
- Focusing on the sardine population along the Pacific Coast
- Modeling of the population dynamics based on the information of physical conditions

Decrease of Sardine population

Shift to the GLOBEC-like project
Japanese sardine population

- Oyashio and Kuroshio
- Egg, Yolksac, Feeding, Age 1
- Graph showing catch, abundance, and growth
- Data from Watanabe et al., 1995
Regime shift

Sea surface temperature anomaly in February
(Noto & Yasuda, 1999)
Mortality coefficient (M) was calculated from the regression formula; \( N_1 = N_0 \cdot e^{-M} \), where \( N_0 \) is the number of larvae and \( N_1 \) is the number of one year old fish.

(Noto & Yasuda, 1999)
Arrow diagram of simulation model

Survival rate

Juveniles

Mature time

Adults

Mortality

(Natural, catch)

Food availability

Recruit

Food density

Nursery area

Egg

Time series

Food density

Egg production

SST

A. mortality

Threshold

MAX.

Recruit

Food availability

SST

Egg production

Food density

SST

(Wada et al.)

\[ \text{Egg production} = a \times \left( \text{Food dens}^2 \times \text{Nursery area} \right) \]
Results of positive feedback simulation model

(Wada et al.)
Juvenile sardine eats large zooplankton (size range from 0.6 to 1.6 mm) selectively after their metamorphosis, however the optimum prey concentration is low in the KEX region.

Size fraction change of food organisms might be the key factor relating to the alternation of fish species from sardine to anchovy.

Bottom-up process should be studied from the viewpoint of the food organisms for fish from juvenile to YOY.
VENFISH Project

To make clear the influence of the oceanic environment, phytoplankton and zooplankton to the resources variation of Pacific saury (*Cololabis saira*) and walleye pollock (*Theragra chalcogramma*) and develop the forecasting ecosystem models through food chain.
Vertical migration of four copepods in the Oyashio and Okhotsk area

**Oyashio**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>0-20m</th>
<th>20-50m</th>
<th>&gt;50m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. <em>flemingeri</em></td>
<td>E. <em>bungii</em> (C1-C3)</td>
<td>N. <em>cristatus</em></td>
</tr>
</tbody>
</table>

**Okhotsk**

<table>
<thead>
<tr>
<th>Depth (m)</th>
<th>0-20m</th>
<th>20-50m</th>
<th>50-100m</th>
<th>&gt;100m</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N. <em>flemingeri</em></td>
<td>E. <em>bungii</em> (C1-C3)</td>
<td>N. <em>cristatus</em></td>
<td>E. <em>bungii</em> (C3-C6)</td>
</tr>
</tbody>
</table>

*Neocalanus plumchrus*

(Tsuda et al.)
three zooplankton
small
large
predatory

(Itoh et al.)
Life History of Pacific Saury with Oceanographic Features

- Spawning ground in winter
- Spawning ground in spring & autumn
- Feeding ground in summer
- Fishing ground in autumn
- Mixed water region
- Kuroshio Extension

(Itoh et al.)
Result from NEMRO.FISH

Pacific Saury Bioenergetics Model

\[
\frac{dW}{W \cdot dt} = \left[ C - (R + S + F + E + P) \right] \cdot \frac{CAL_z}{CAL_f}
\]

- change of weight
- C: consumption
- R: respiration (loses through metabolism)
- S: specific dynamic action (digesting food)
- P: egg production
- E: excretion
- F: egestion

Wet weight of saury

Graph showing wet weight of saury from 2001/1/1 to 2004/12/31.

(Itoh et al.)
Trophodynamic model of walleye pollock

(Yamamura et al.)
Synthesis of the VENFISH project

• Accumulation of biological and ecological information of the Oyashio region
• Establishment of bottom-up model from nutrients to zooplankton (NEMRO model).
• Increasing biological information on Pacific saury.
• Recognizing importance of meso- and bathypelagic ecosystem closed up as the carnivores and competitor to pelagic fish.
FRECS Project

To understand the mechanisms of environmental impacts on the spawning grounds and their linkages to recruitment; the mechanisms by which eggs and larvae are injected into the Tsushima and Kuroshio Currents and are carried to coastal areas; and factors affecting survival during growth processes. Target species are **jack mackerel** (*Trachurus japonicus*) and the Japanese common squid (*Todarodes pacificus*).
Transportation of jack mackerel larvae and juveniles from southern area of East China Sea

(Sassa et al.)
High resolution 3 dimensional advection process simulation model

Ocean general circulation model:
Three dimensional primitive model (C-HOPE)
Observed data assimilated to the satellite altimetry data (Jason-1) by the Adjoint method (TAMC)

Time of simulation

(K. Komatsu)
Result

Simulation (20m)
Current: 2001/02/21/0:00

Observation
(K. Komatsu)
Advection experiment of pseudo-jack mackerel eggs (from 15th Feb 2001)

0-6 days: Low temp.

7-16 days: Insufficient food

17-30 days: (K. Komatsu)

(Sassa et al. 2002)
Deep-Sea Ecosystem and Exploitation Programme
To understand the meso- or bathypelagic ecosystem structure and dynamics, relationship between the pelagic fish community and the meso- or bathypelagic ecosystem.

**DEEP project**

- Physical oceanography at deep sea
- Vertical migration of zooplankton
- Energy transfer
- Meso- & bathy-pelagic fish community, jellatinous plankton
- Pelagic fish resources
- Food competition
Deep-Sea Ecosystem and Exploitation Programme (DEEP)

Research ID & their flux study
Structure and movement of intermediate water

Particle flow model experiment

Low potential vorticity water moves southward to transition region or the Kuroshio Extension.

High potential vorticity water moves
1) southward to transition region
2) back to the subarctic circulation.
Transportation by physical process and biological pump

Annual carbon flux by Copepods in various depth layers toward southwestward crossing OICE-line (× 10^{10} gC)

<table>
<thead>
<tr>
<th>Layer</th>
<th><em>N. cristatus</em></th>
<th><em>N. flemingeri</em></th>
<th><em>N. plumchrus</em></th>
<th><em>E. bungii</em></th>
</tr>
</thead>
<tbody>
<tr>
<td>0–50m</td>
<td>8.2</td>
<td>4.5</td>
<td>8.0</td>
<td>7.9</td>
</tr>
<tr>
<td>50–150m</td>
<td>5.8</td>
<td>0.1</td>
<td>0.3</td>
<td>2.3</td>
</tr>
<tr>
<td>150–300m</td>
<td>1.9</td>
<td>1.6</td>
<td>0.6</td>
<td>3.0</td>
</tr>
<tr>
<td>300–500m</td>
<td>3.6</td>
<td>2.0</td>
<td>0.7</td>
<td>7.5</td>
</tr>
<tr>
<td>Total</td>
<td>19.5</td>
<td>8.3</td>
<td>9.6</td>
<td>20.7</td>
</tr>
</tbody>
</table>

Total 580,000 ton carbon was transported by the four Copepod species in the Low potential vorticity Oyashio water southwestward crossing OICE-line for one year from 2001 spring to 2002 winter.
Organic materials transported to meso- or bathypelagic layer

Plankton feeders in the meso- or bathypelagic layer

Fecal pellet feeder

Biomass and vertical distribution of *Oithona similis*

Biomass, vertical distribution, and feeding ecology of jellatinous plankton

Biomass, daily vertical migration, feeding ecology of meso- or bathypelagic decapoda
VPR was modified for measuring meso- and bathypelagic jellatinus plankton biomass
Feeding ecology of small pelagic fishes and mesopelagic fishes

- Myctophum nitidulum
- Diaphus perspicillatus
- M. asperum
- Symbolophorus evermanni
- Ceratoscopelus warmingi
- Anchovy
- Sardine
- Scomber

- Clausocalanus
- Eucalanus
- Neocalanus
- Ceratoscopelus
- Paracalanus
- Euphausiacea
- Symbolophorus
- Pleurocapna
- Corycaeus
- Oncaea
- Microsetella
- Ostracoda

- Jellatinus
- House
- Ostracoda

- Oithona
- Candacia
- Fishes – incl. scales & fins
## Food consumed by mesopelagic fishes

### Daily ratio of lantern fishes (%WW m\(^{-2}\) d\(^{-1}\))

<table>
<thead>
<tr>
<th>Location</th>
<th>Food Chain</th>
<th>Daily Ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Oyashio area</strong></td>
<td><strong>Metridia</strong> → <strong>D. theta</strong></td>
<td>0.017</td>
</tr>
<tr>
<td></td>
<td><strong>Metridia</strong> → <strong>S. leucopsarus</strong></td>
<td>0.015</td>
</tr>
<tr>
<td></td>
<td><strong>Euphausiids</strong> → <strong>L. jordani</strong> (night, surface)</td>
<td>0.058</td>
</tr>
<tr>
<td></td>
<td><strong>Mysid</strong> → <strong>L. jordani</strong> (day, deep)</td>
<td>0.039</td>
</tr>
<tr>
<td><strong>Oyashio-Kuroshio transition area</strong></td>
<td><strong>Metridia</strong> → <strong>D. theta</strong></td>
<td>0.008</td>
</tr>
<tr>
<td></td>
<td><strong>Metridia</strong> → <strong>S. leucopsarus</strong></td>
<td>0.034</td>
</tr>
<tr>
<td></td>
<td><strong>N. cristatus</strong> → <strong>S. nannochir</strong></td>
<td>0.001</td>
</tr>
<tr>
<td></td>
<td><strong>Euphausiids</strong> → <strong>L. jordani</strong> (night, surface)</td>
<td>0.046</td>
</tr>
</tbody>
</table>
Acoustic survey for mesopelagic fishes

Acoustic parameters of lantern fishes

Estimated biomass of *Stenobrachius leucopsarus* in Bering sea

<table>
<thead>
<tr>
<th>Area</th>
<th>(km²)</th>
<th>Biomass (g/m²)</th>
<th>Total weight (10⁴ ton ± SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>27,902</td>
<td>55.5</td>
<td>156.3 ± 7.8</td>
</tr>
<tr>
<td>2</td>
<td>10,433</td>
<td>70.0</td>
<td>73.7 ± 2.2</td>
</tr>
<tr>
<td>3</td>
<td>4,045</td>
<td>78.5</td>
<td>32.1 ± 2.5</td>
</tr>
<tr>
<td>4</td>
<td>1,413</td>
<td>132.6</td>
<td>18.9 ± 2.5</td>
</tr>
<tr>
<td>Total</td>
<td>43,793</td>
<td>64.1</td>
<td>281.0</td>
</tr>
</tbody>
</table>

Weight in average 10.1 (g/ind.)

![Graph showing TS (dB) vs. Log (SL, cm) with regression lines and intercepts]
Real-time data exchange network via internet

Internet satellite “ETS-VIII” system

1.5 Mbps coverage area
Population fluctuation of Japanese sardine

Stock \( \sim 10^{12} \text{ gC} \)
Feeding \( 2.4 \times 10^{12} \text{ gC/ 4 months} \)

Population fluctuation of Japanese sardine affects meso- or bathypelagic ecosystem

Fluctuation of meso- or bathypelagic fish population affects the pelagic fish population

Oyashio area & Oyashio-Kuroshio Transition area

Meso-pelagic fish
Estimated feeding \( 5.1 \times 10^{12} \text{ gC} \)
National committee of Japan-GLOBEC
Chaired by Yasunori Sakurai (Hokkaido Univ.)
http://j-globec.fish.hokudai.ac.jp/MainGate-e.htm
On-going projects

**Diagnostics of Marine Ecosystem and Forecasting**  
Michio Kishi (Hokkaido Univ.)  
(2004-2009)

**Japanese Fisheries Oceanography Data Base**  
( [http://jfodb.dc.affrc.go.jp/kaiyodb.pub](http://jfodb.dc.affrc.go.jp/kaiyodb.pub) )  
Data published in gray documents by Japanese Fisheries Agency  
(from 1920’ to present)

**The Odate Project**  
Long-term variations of zooplankton community in the Western North Pacific  
Using “Odate collection” collected >20000 samples from 1949  
Result will be presented by Chiba et al. and Tadokoro et al.  
10:30- and 10:50- on 21 Oct, S9
Population dynamics model of two copepod species, *Paracalanus* sp. (upper) and *Calanus pacificus* (lower), in the Kuroshio-Oyashio transition region.

Left case (small spring bloom): *Paracalanus* increases but *Calanus* does not respond.

Right case (large spring bloom): Both *Calanus* and *Paracalanus* increase
• Biological and ecological information of the Japanese sardine have been accumulated.
• Importance of biological monitoring was recognized in order to verify the models constructed in this project.
• Construction of ocean fluctuation model is needed to predict the future of pelagic fish populations.
• Biological research on the other pelagic fishes should be accelerated based on the knowledge of Japanese sardine.
• Research activities on bottom-up process should be succeeded to the coming project.