The CCFZ Environmental Study carried out by KORDI

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Deep-Sea & Marine Georesources Research Department
Objectives

- To understand the physical, chemical, biological, and geological properties of the northeastern equatorial Pacific:
  - in relation to the natural variation
  - in association with global climatic events (i.e. El Nino & La Nina)

- To use the environmental baseline study to make a strategic plan for Mn nodule mining in the future

- To evaluate and minimize the environmental impact by mining activity
KORDI Environmental surveys

- survey areas
  - 1995~2009: 131.3°W, 10.5°N (KOMO, Long-term Monitoring St.)
  - 2006~2010: KR2 (n=14) and 5 (n=70)

Map showing study area in the northeastern equatorial Pacific.
Background: Surface current system

- South Equatorial Current (SEC): 10°S~3°N
- North Equatorial Counter Current (NECC): 3°N~8°N
- North Equatorial Current (NEC): 8°N~20°N
- Equatorial Under Current (EUC)

Study Area

Typical structure of water column in the northeast Equatorial Pacific.
Background: Global climatic events (El Niño/La Niña in Equatorial Pacific)

El Niño event  La Nina event

Period of Korea Deep-sea Environment Study
Background: Geological Setting
(Sediment types of C-C zone)

Distribution of sea floor sediments and the study area in the northeastern part of the equatorial pacific (KR 1, 2 area: pelagic red clay, KR 3-7 area: biogenic siliceous sediment, 7-0° N: calcareous ooze)
Environmental items (ISA recommended)

<table>
<thead>
<tr>
<th>Group</th>
<th>Environmental items</th>
<th>Methods and Instruments</th>
</tr>
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<tbody>
<tr>
<td>Physical Oceanography</td>
<td>- Surface oceanographic structure</td>
<td>- CTD</td>
</tr>
<tr>
<td></td>
<td>- Current condition</td>
<td>- Current meter and ADCP</td>
</tr>
<tr>
<td></td>
<td>- Particulate matter in discharge depth</td>
<td>- Filteration</td>
</tr>
<tr>
<td></td>
<td>- Satellite-data analysis</td>
<td>- SeaWiFS satellite image</td>
</tr>
<tr>
<td>Chemical Oceanography</td>
<td>- D.O., pH, Inorganic Nutrients</td>
<td>- Titration, pH meter, Nutrients auto analyzer</td>
</tr>
<tr>
<td></td>
<td>- Total organic carbon</td>
<td>- TOC analyzer</td>
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<tr>
<td></td>
<td>- Chemical exchange between the sediment and the water column</td>
<td>- ? Benthic Chamber</td>
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<tr>
<td></td>
<td>- Trace metals in water column</td>
<td>- ICP-MS</td>
</tr>
<tr>
<td>Sediment properties</td>
<td>- Geotechnical properties</td>
<td>- MC, Pycnometer, motorised vane system, automatic grain size analyzer</td>
</tr>
<tr>
<td></td>
<td>- Pore chemistry, Organic carbon</td>
<td>- IC, Elemental analyzer</td>
</tr>
<tr>
<td></td>
<td>- Metal contents of manganese nodule</td>
<td>- ICP-AES</td>
</tr>
<tr>
<td>Biological Communities</td>
<td>- Microorganism at water column and sediments</td>
<td>- Scintillation counter, Microscope, Luminometer</td>
</tr>
<tr>
<td></td>
<td>- Pelagic communities</td>
<td>- Flow cytometric analysis, Microscope, Net, Scintillation counter, Elemental analyzer</td>
</tr>
<tr>
<td></td>
<td>- Benthic fauna</td>
<td>- MC, BC, Microscope, Deep sea camera</td>
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<tr>
<td></td>
<td>- Nodule fauna</td>
<td>- MC, BC, Microscope, Deep sea camera</td>
</tr>
<tr>
<td></td>
<td>- Demersal scavenger</td>
<td>- ? Freefall benthos observation system</td>
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<tr>
<td>Bioturbation</td>
<td>- Benthic impact experiments</td>
<td>- ?</td>
</tr>
<tr>
<td></td>
<td>- Sediments-mixing rate</td>
<td>- MC, BC, $^{210}$Pb</td>
</tr>
<tr>
<td>Sedimentation</td>
<td>- Vertical mass flux</td>
<td>- Sediments Trap</td>
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</table>

Detail sampling protocols were described at Chapter 10, Data Standards utilized in the environmental studies of KORDI.
In: Standardization of environmental data and information-Development of guidelines (ISA, 2002)
Gaps in Environmental measurements

- Chemical exchange between the water and sediment
- Community composition of demersal scavenger
- Benthic impact experiments
- 3-D numerical modeling of discharge plume
- Genetic screening of benthic fauna
International Collaborative Efforts

- The bi-annual meeting of Korea-China cooperation to exchange information and results

- The cross participation of researchers in environmental surveys with France (2004-2005)

- University of Hawaii (Dr. Paul Wessel) - the generation research of Hawaii-Emperor Bend (2009 - )
Standardization Effort

- We made efforts for standardization of inorganic nutrients analysis through the cross check analysis with Australia.

- All environmental sampling and analysis are based on standardization of environmental data and followed the recommendation and documents provided by ISA.
Results
Physical properties - Latitudinal

- South Equatorial Current (SEC) : 10°S~3°N
- North Equatorial Counter Current (NECC) : 3°N~8°N
- North Equatorial Current (NEC) : 8°N~20°N


Physical properties - Longitudinal

- Vertical distribution of temp., salinity and density along the longitude (2004)

Vertical structure of water mass in the mixed layer and deep water (from West to East)
Physical properties - bottom current

- Long-term monitoring results of the bottom current (Jul. 2008 to Jul. 2009)

Summarize of the bottom current velocities and main directions

<table>
<thead>
<tr>
<th>Water Depth/Altitude (m)</th>
<th>Current velocity</th>
<th>Progressive vector current velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Average (cm/s)</td>
<td>Maximum (cm/s)</td>
</tr>
<tr>
<td>1,254 / 3,765</td>
<td>4.4</td>
<td>15.3</td>
</tr>
<tr>
<td>5,004 / 15</td>
<td>3.5</td>
<td>10.6</td>
</tr>
</tbody>
</table>

Stick plots of current velocity (15 m above the bottom)
Progressive vector diagram of current velocity (15 m above the bottom)
Chemical properties – DO & TOC

- Vertical distribution of dissolved oxygen (DO) and total organic carbon (TOC)

Typical structure of water column in the northeast Equatorial Pacific.

Vertical distribution of DO in study area shows general pattern of open ocean

Vertical structure of TOC in study area (ROM = 0.7 mg/L)
**Chemical properties - Nutrients**

- **Vertical distribution of inorganic nutrients (2007)**
  - (nitrate+nitrite, phosphate, silicate)

Vertical distribution of inorganic nutrient in study area shows general pattern of open ocean. The green color bar indicate a permanent thermocline.
Spatial distribution of nutrients

- **Vertical distributions of nutrients**

**South** → **North**

Convergence

Divergence

- **Nitrate + Nitrite**

**South** → **North**

Convergence

**Nitrate + Nitrite**

- **Phosphate**

**South** → **North**

- **Silicate**

**South** → **North**

- **Silicate**

**West** → **East**

- **Nitrate + Nitrite**

**2003**

**Si**

**2004**

**Si**

**2005**

**Si**


Interannual variation of nutrients

- long-term variation of nutrients

Annual variation of nutrients concentration at KOMO (1995 – 2007)
**Pelagic ecosystem — Chl a**

- **Distribution and abundance of Chl-a (primary producer)**

  **Latitudinal vertical distribution of Chl-a in surface mixed-layer (2003)**

  **Longitudinal vertical distribution of Chl-a in surface mixed-layer (2004)**

  **Latitudinal distribution of primary production (2003)**

  **Longitudinal distribution of primary production (2004)**
Interannual variation of Chl $a$

- Distribution and abundance of Chl-$a$ (primary producer)

**Annual variation of SeaWiFS satellite image showing surface Chl-$a$ in the eastern Pacific (1998-2006)**

**Monthly surface chl-$a$ variation at the KOMO station (1998-2007)**

**SeaWiFS satellite image showing surface Chl-$a$ in the eastern Pacific (2007, 2008)**
Pelagic ecosystem - zooplankton

- Composition and abundance of zooplankton (2005)

Latitudinal distribution of mesozooplankton abundance in surface mixed layer and lower layer

Percentage of taxonomic groups in mesozooplankton at surface mixed layer and lower layer
Benthic ecosystem - meiofauna

- Species composition and abundance of meiofauna (2003)

Latitudinal abundance of dominant meiofauna groups

Comparison of abundance of total meiofauna in the KR5 area

Major meiofauna taxa in the KR5 area (A: *Desmoscolex* sp. (Nematodes), B: *Tricoma* sp. (Nematodes), C: Harpacticoid copepods, D: Tardigrada)
Benthic ecosystem - macrofauna

- **Species composition and abundance of macrofauna (2003)**

  ![Graph showing latitudinal abundance of dominant macrofauna groups](graph.png)

  - Actinaria
  - Foraminifera
  - Deep-sea cucumber
  - Isopoda
  - Polychaeta
  - Macrura
  - Ophiuroidea
  - Ostracoda
  - Sea Anemone

- **According to these biological results, the distribution of zooplankton and benthos is mainly affected by their food source (the surface primary production).**
Photographic examination - megafauna

The photographs of megafauna obtained by deep-sea camera (2008)

Observation of species in the substrate at each photographing line

<table>
<thead>
<tr>
<th>Species and Lines in KR5</th>
<th>DSC08-01</th>
<th>DSC08-02</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sea cucumber</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Sea anemone</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Sea star</td>
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<td>*</td>
</tr>
<tr>
<td>Sea pen</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Fish</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Bivalve</td>
<td>*</td>
<td>-</td>
</tr>
<tr>
<td>Crustacean</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Faecal cast</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Phytodetritus</td>
<td>*</td>
<td>*</td>
</tr>
<tr>
<td>Burrow openings</td>
<td>*</td>
<td>*</td>
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<tr>
<td>Locomotion trace</td>
<td>*</td>
<td>*</td>
</tr>
</tbody>
</table>

[Images of various species shown as thumbnails]
Sediment properties

Sediment type characteristics in relation to latitude (2003)

Latitudinal variation of sediment types in the study area

Comparison of CaCO$_3$ variation between core RC11-210 (western Pacific) and PC98N6 (CCZ)
Particle Mass flux

- Long-term monitoring (at KOMO St.) of the particle mass flux using sediment trap (2003-2009)

- The monthly variation of total mass flux (grey bar) was well matched with Chl-a concentration (green circle), and the mass flux also showed a seasonal variation.

- The moderate El Niño was accompanied by a significant reduction in total mass flux, and the opposite trend was observed for the moderate La Niña.
Plume impact experiment

- Microcosm experiments to evaluate the impact of discharge plume on SCM water (2008)

Results of microcosm experiment

Mesocosm & Microcosm (100L)

Effects of discharge plume on Nitrate, Chl, ATP, and POC of SCM water (F-con; control, SED-1: 1/10000, SED-2: 1/5000, SED-3: 1/3300 dilution)
Seasonal and interannual variation of physico-chemical properties have been detected in our study area.

Strong spatial heterogeneity of pelagic and benthic community were found and benthic production were well coupled with pelagic production.

Particle mass flux was well correlated with surface primary production, particularly during episodic events.

No clear impact of plume discharge was detected on pelagic ecosystem (SCM) through micro-scale experiment. May be due to experimental design we used or/and targeted water sample (SCM).

From this study, 57 papers (SCI:16 and Local:41) have been published.
Future works

- Continuation of Environmental baseline study focused in Claimed Areas (KR 2, 5) with long-term monitoring (KOMO)
- Pelagic & Benthic impact experiments
- Genetic analysis of benthic fauna
- International collaborations needed to fill the gaps
Thank you