Effects of nutrient transport through the Korea Strait on the seasonal and interannual variability in the East Sea ecosystem

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Long-Term Mean Chlorophyll-a

East Sea

Mean Chlorophyll a

Korea Strait
(Yoo & Park, 2009)
Nutrient Supply through the Korea Strait

(Onitsuka et al 2007)

EK: upwelling along the East coast of Korea
WC: Western Channel of Korea Strait
EC: Eastern Channel of Korea Strait
Nutrient Transport through the KS


Tsushima current

Kuroshio current

Nutrient poor

East Sea
Nutrient Transport through the KS

**Tsushima intermediate water** supplies nutrient to the SCM layer

vertical cross sections of fluorescence (Aug 2008)

Roh et al. (2012)

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**Large amount of nutrient**

Morimoto et al. (2009)

**DIN : Dissolved inorganic Nitrogen**

**DIP : Dissolved inorganic phosphorus**

total 3.59 kmol/s

total 0.29 kmol/s

SCM layer : Subsurface Chlorophyll Maximum layer

DIN Transport

DIP Transport
Objective

To investigate how the nutrient transport through the KS affects the low trophic ES ecosystem.
Hypothesis:
Nutrient transport through the KS contributes to the seasonal and interannual variations of the ES ecosystem.

3 numerical experiments with different nutrient transport
1) nutrient flux with seasonal variation only
2) no nutrient flux
3) nutrient flux with seasonal/interannual variations

Methodology:
A 3D physical-biological coupled model

Assumption:
No other nutrient supplies (from atmosphere, river discharge etc)
### 3D Physical–Biological Coupled Model

**ROMS** + Low trophic biological model

**NPZD model**

\[
\frac{\partial N}{\partial t} + \mathbf{u} \cdot \nabla N = D + \gamma_n GZ - UP + \frac{\partial}{\partial z} \left( k_v \frac{\partial N}{\partial z} \right),
\]

\[
\frac{\partial P}{\partial t} + \mathbf{u} \cdot \nabla P = UP - GZ - \sigma_d P + \frac{\partial}{\partial z} \left( k_v \frac{\partial P}{\partial z} \right),
\]

\[
\frac{\partial Z}{\partial t} + \mathbf{u} \cdot \nabla Z = \left( 1 - \gamma_n \right) GZ - \zeta d Z + \frac{\partial}{\partial z} \left( k_v \frac{\partial Z}{\partial z} \right),
\]

\[
\frac{\partial D}{\partial t} + \mathbf{u} \cdot \nabla D = \sigma_d P - \zeta d Z - D + \omega_d \frac{\partial D}{\partial z} + \frac{\partial}{\partial z} \left( k_v \frac{\partial D}{\partial z} \right)
\]

**Nitrogen cycle**

Powell et al. (2006)

\[
G = R_m \left( 1 - e^{-\Delta P} \right),
\]

\[
I = I_0 \exp \left( k \zeta + k_p \int_0^z P(z') dz' \right),
\]

\[
U = \frac{V_m N}{k_N + N} \frac{\alpha I}{\sqrt{V_m^2 + \alpha^2 I^2}}
\]

**Topography**: ETOPO5

**Horizontal resolution**: 1/6°

**Vertical layers**: 30 layers

**Table 1. Parameter Values**

<table>
<thead>
<tr>
<th>Parameter Name</th>
<th>Symbol</th>
<th>Value</th>
<th>Dimension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Light extinction coefficient</td>
<td>(k_e)</td>
<td>0.067</td>
<td>m⁻¹</td>
</tr>
<tr>
<td>Self-shading coefficient</td>
<td>(k_p)</td>
<td>0.0095</td>
<td>m² mmol-N⁻¹</td>
</tr>
<tr>
<td>Initial slope of P-I curve</td>
<td>(\alpha)</td>
<td>0.025</td>
<td>m² W⁻¹</td>
</tr>
<tr>
<td>Surface irradiance</td>
<td>(I_0)</td>
<td>158.075</td>
<td>W m⁻²</td>
</tr>
<tr>
<td>Nitrate uptake rate</td>
<td>(V_m)</td>
<td>1.5</td>
<td>d⁻¹</td>
</tr>
<tr>
<td>Uptake half saturation</td>
<td>(k_N)</td>
<td>1.0</td>
<td>mmol-N m⁻³</td>
</tr>
<tr>
<td>Phytoplankton senescence</td>
<td>(\omega_d)</td>
<td>0.1</td>
<td>d⁻¹</td>
</tr>
<tr>
<td>Zooplankton grazing rate</td>
<td>(R_m)</td>
<td>0.52</td>
<td>d⁻¹</td>
</tr>
<tr>
<td>(llev constant)</td>
<td>(\alpha_L)</td>
<td>0.06</td>
<td>m³ mmol-N⁻¹</td>
</tr>
<tr>
<td>Excretion efficiency</td>
<td>(\gamma_x)</td>
<td>0.5</td>
<td>d⁻¹</td>
</tr>
<tr>
<td>Zooplankton mortality</td>
<td>(\omega_z)</td>
<td>0.145</td>
<td>d⁻¹</td>
</tr>
<tr>
<td>Remineralization</td>
<td>(\delta)</td>
<td>1.03</td>
<td>d⁻¹</td>
</tr>
<tr>
<td>Detrital sinking rate</td>
<td>(w_d)</td>
<td>8.0</td>
<td>m d⁻¹</td>
</tr>
</tbody>
</table>
## Experiment Results

1) nutrient flux with seasonal variation only
2) no nutrient flux
3) nutrient flux with seasonal/interannual variations

<table>
<thead>
<tr>
<th></th>
<th>(seasonally varying) Nutrient flux</th>
<th>No flux</th>
</tr>
</thead>
</table>
| **Initial condition** | N : WOA2005  
P, Z, D : 1.0 mmolN/m³ |         |
| **Biological boundary condition (at KS)** | N : WOA2009  
P : SeaWiFS chlorophyll (50%)*  
Z, D : SeaWiFS chlorophyll (20%)*  
*corresponding to the ratio with chl-a | closed  
(boundary value = inner value) |
| **Spin-up**       | 10 years                                          |         |
| **Forcing**       | ECMWF interim (climatology, bulk formula)         |         |
Surface Chl-a (mg/m³) in Spring and Fall

**nutrient flux**

- **spring**
  - Positive effect decreased gradually toward the northern ES in the spring bloom season

- **fall**
  - Affected in the entire southern part of the subpolar front in fall bloom season

**no flux**

**nutrient flux – no flux**

- Almost zero

- 0.4 m/s

- Subpolar front
nutrient concentration (mmolN/m$^3$) along the 130°E in Feb

- nutrient transport through the KS only
- nutrient through the KS + other supplies
Annual Mean Chl-a (mg/m³) in Surface & Subsurface Layers

**Surface**
- 0-5m
- Spring bloom
- Fall bloom

**Subsurface**
- 20-40m
- SCM

**Nutrient Flux**
- No flux
- Nutrient flux – no flux

**Spring Bloom**
- 51%

**Fall Bloom**
- 35%
- 53%
Experiment Results

1) nutrient flux with seasonal variation only
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2004-2012 Nutrient flux anomalies

- 0–150 m integrated (whole water column)
- 20–40 m integrated (subsurface layer)
Correlations of Nutrient flux (kmol/s) Anomalies with Chl–a (mg/m³) Anomalies

- 0-150m integrated nutrient flux ano.
- 20-40m integrated nutrient flux ano.
- Surface 0-5m chl.-a ano.
- Subsurface 20-40m chl.-a ano.

Annual mean Chl-a no flux almost zero = Nutrient flux only
Summary

The effect of nutrient transport through the Korea Strait …

Annual mean chl–a

Spring bloom  Fall bloom  surface  subsurface

35%  51%  53%
The downstream areas of the Tsushima current show good correlation of nutrient flux with chlorophyll-\(\text{a}\) concentration.

The interannual variation of nutrient transport through the KS affects the variation of the chlorophyll-\(\text{a}\) concentration with time-lag.
• Low resolution-1/6
  – EKWC overshooting
  – UWE, upwelling
• NPZD model ...
  – Only one compartment of Phyto. & Zoo.
  – T dependency (photosynthesis, grazing etc.) ignored
  – biological BC & parameters poorly known
Thank you very much