Climate-driven ecosystem shifts in Korean waters during the past 40 years

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Objective of Study

• The reported past regime shifts in the North Pacific

• How did the ecosystems of the Korean waters responded to these basin-wide regime shifts?

• Regional differences
  – Japan/East Sea: deep basin
  – Korea Strait: intermediate
  – Yellow Sea: shallow
Study Area for Env, Zooplankton and Fish
Latitude: 32-39°N
Longitude: 124-133°E
Time-series Data

• Korea Meteorological Administration
  – Air surface temperature 1968-2009

• MIFAFF-NFRDI
  – Depth-specific T, S, DO (0~100 m) 1968-2010
  – Meso- and Macro-zooplankton 1965-2006
  – Fisheries Data 1968-2010

• Seoul National University
  – Volume Transport of TWC and KSBCW 1968-2007
Methods

• **Canonical Correspondence Analysis**
  – To summarize annual changes in fish community structure
  – Biomass composition of major fisheries species
  – Environmental variables
    • Only those of $p<0.05$ were selected to display in the biplot

• **Regime-shift detection**
  – STARS 2
  – Bayesian Markov-chain switching model
Annual Catch from Korean Sea Waters by Species (marine capture fisheries, metric tons, 1968-2008)
Correspondence Analysis on Biomass composition of Fishes
Correspondence Analysis
on species composition of Korean fishery catch

Temperature and salinity in the mixed layer were correlated significantly.
## Canonical Correspondence Analysis 2

Means for the entire Korean water Monthly ENSO index

<table>
<thead>
<tr>
<th>Variable</th>
<th>Corr. With Dim1</th>
<th>p-value</th>
<th>Variable</th>
<th>Corr with Dim2</th>
<th>p-value</th>
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</thead>
<tbody>
<tr>
<td>Air Temp</td>
<td>-0.53</td>
<td>0.000289</td>
<td>disoxy 100 m</td>
<td>0.54</td>
<td>0.000413</td>
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<tr>
<td>Salin 0 m</td>
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<tr>
<td>Wtemp 10 m</td>
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<td>ENSO May</td>
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<td>SST</td>
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<td>0.00131</td>
<td>Air Temp.</td>
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<td>Salin 10 m</td>
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<td>Salin 20 m</td>
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<td>0.003756</td>
<td>SST</td>
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<td>Salin 30 m</td>
<td>0.39</td>
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<td>Salin 50 m</td>
<td>0.32</td>
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<td>disoxy 75 m</td>
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<td>ENSO Mar</td>
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<td>dosat 30 m</td>
<td>0.32</td>
<td>0.047241</td>
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</table>
Dim 1 Stars2

1976

1988

1995
Dim 1
Bayesian Markov switching models

1976 1991
Bayesian Markov switching models

1976
1983
1991
Detected Shifts

<table>
<thead>
<tr>
<th>STARS 2</th>
<th>Bayesian Markov</th>
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<tr>
<td>1976-1977</td>
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<tr>
<td>1983</td>
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<tr>
<td>1988</td>
<td>1991</td>
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<tr>
<td>1991</td>
<td></td>
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<tr>
<td>1995</td>
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</tbody>
</table>

- The 1983 shift seems to be related with the strong 1983 ENSO.
- The 1991 shift seems to be related with the 1989 shift, considering a time lag of 2 yr for recruitment and fishermen’s preparation for catching new target species.
A shift in the time-series of air surface temperature in the Korean peninsula 1989
No detectable shift in depth-specific water temperatures in the JES
Shifts in depth-specific water temperatures in the Korea Strait

0 m

1988 2007

30 m

1988 2000
Shifts in depth-specific salinity in the Korea Strait

0 m

1998

30 m

2002
Shifts in Dissolved Oxygen in the Korea Strait
Meso- and macro-zooplankton biomass 1965-2006, from KODC
Meso-zooplankton Averaged biomass (1965-2006)

Mesh size = 330 micron
Zooplankton mean biomass in the Japan/East Sea

Shifts in the mean for biomass, 1977-2006
Probability = 0.1, cutoff length = 10, Huber parameter = 1

1992, 2001
Mean numerical density of major zooplankton groups in the JES: 1999 shift
Summary of responses of Korean marine ecosystems to the past regime shifts and El Niño events
(Kang et al. Submitted to Progress in Oceanography)

<table>
<thead>
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<td>X</td>
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<td>O</td>
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<tr>
<td></td>
<td>SJES</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td><strong>Salinity</strong></td>
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<td>X</td>
<td>O</td>
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<td>SJES</td>
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<tr>
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<td>O</td>
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<td>SJES</td>
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<td>X</td>
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</tr>
<tr>
<td></td>
<td>NJES</td>
<td>–</td>
<td>–</td>
<td>–</td>
<td>X</td>
</tr>
<tr>
<td><strong>Zooplankton community structure</strong></td>
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<td>–</td>
<td>–</td>
<td>–</td>
<td>O</td>
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<tr>
<td></td>
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<td>O</td>
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<tr>
<td></td>
<td>SJES</td>
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<td>X</td>
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<tr>
<td></td>
<td>NJES</td>
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<td>–</td>
<td>–</td>
<td>X</td>
</tr>
<tr>
<td><strong>Fish</strong></td>
<td>Korean waters</td>
<td>O</td>
<td>O</td>
<td>O</td>
<td>X</td>
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<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>2</strong></td>
<td><strong>4</strong></td>
<td><strong>9</strong></td>
<td><strong>13</strong></td>
</tr>
</tbody>
</table>

Symbols: X = Not detected, O = Detected, – = Data unavailable
Landings of Pacific cod and Herring in Korea
1971-2000

Cod

Herring

1998
Cod, Mean catch level (1994-2008) based on location reports from fishing boats

East Sea

Yellow Sea

Ko

Main Spawning ground (Jinhae Bay)

Winter migration

Spring migration

; Χατχη βψ γιλλνετ ισ υνδερρεπρεσεντεδ.
Southward Expansion of Pacific cod to Jeju Island

Caught on September 9, 2011
Length = 32~35 cm (2 yrs old)
Linear Trend of Change in Water Temperature at 75 m (1968-2006)
Water temperatures at 100-m depth in the Korea Strait
Volume Transport by the Tsushima Warm Current (1962-2008)

TWC volume transport
Courtesy of Hanna Na, Seoul National University

Shifts in the mean for VTSLD, 1962-2007
Probability = 0.1, cutoff length = 10, Huber parameter = 1

1984, 2002
KSBC (Estimated relative volume transport of bottom cold water from the Japan/East Sea)
Courtesy of Hanna Na, Seoul National University

Shifts in the mean for ksbcwd12, 1968–2008

1993
Tsushima Warm Current (TWC) vs. Korea Strait Bottom Cold Water (KSBW)
Conclusions

• Responses to the reported regime shifts can vary depending on region and depth, and which variables you choose.
• In Korean waters, the shift in 1998 was the most evident, followed by 1989.
• Although the CCA did not detect the 1998 shift in fish community structure, the recent increase of cod and herring catch supports the idea of the 1998 shift, related with strengthened TWC.
Future Works

• Develop a robust shift detection method that can incorporate and reflect spatial variability in hydrographic conditions

• Improve reliability in estimation of volume transports of the TWC and KSBCW by applying general circulation models