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Effects of the 1988/89 climatic regime shift on the structure and function of the southwestern Japan/East Sea ecosystem

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Abstract

In this study we compared the structure of the ecosystem and the role of major species before and after 1988/89 climatic regime shift (CRS) in the southwestern Japan/East Sea. The 1988/89 CRS event changed the biomass and production of fisheries resources in the southwestern Japan/East Sea. Total biomass of all species groups in the ecosystem increased by 59% after the CRS. These results indicate that there were substantial changes in the function of major species in the southwestern Japan/East Sea ecosystem. The relative contribution of walleye pollock, at trophic level (TL) III, to the total flow of energy decreased drastically from 33.0% in the pre-CRS period to 4.3% in the post-CRS period, while that of common squid, at the same TL, doubled from 34.2% to 72.2% during the periods.

Keywords: Climatic regime shift (CRS); Mass-balance model; Trophic level; Ecosystem structure; Biomass; Production

1. Introduction

Regime shifts involving entire biological communities occur worldwide (Lluch-Belda et al., 1992). In the western North Pacific environmental conditions shifted from a warm regime, that began in the late 1940s, to a cool regime in late 1970s, then back to a warm regime in 1980s (Minobe, 1997). These changes affected the dynamics of the marine ecosystem and fisheries resources in Korean waters during the late 1970s and 1980s (Zhang et al., 2000). The global-scale CRS resulted in alterations of the oceanic environment that were followed by temporal and spatial changes in marine ecosystems and fisheries resources in the North Pacific (Francis et al., 1998; McFarlane et al., 2000; Clark and Hare, 2002) and North Sea (Holliday and Reid, 2001).

Annual variations in the catches of major fisheries appear to coincide with these regime shifts. In particular, in the northwestern Pacific, common squid catches decreased during the early 1980s and increased during the late 1980s (Minobe, 1997). Also, winter-spawning areas of common squid in the East China Sea contracted when adult stocks decreased during cool regimes (1984–1988). Conversely, autumn and winter-spawning areas expanded into the Japan/East Sea when adult stocks increased during warm regimes (Sakurai et al., 2000, 2002). During the same time period, walleye pollock catches were opposite to that of the common squid. The change of dominant species in the Japan/East Sea during mid-1970s and 1980s, from common squid to walleye

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pollock, then back to common squid in the late 1980s, corresponds with an alternating change between warm and cold regimes.

Common squid and walleye pollock are caught by two different fisheries, that interact with the marine ecosystem in very different ways. Common squid are captured mostly by the Korean offshore jigging fishery, whereas walleye pollock are taken by a combination of fisheries, mainly otter trawl but also with longlines and drift gill nets. Also, the main fishing seasons differ: common squid are caught from September to December and walleye pollock are caught from February to April. Catch biomass in the independent fishing activities for the two species may be influenced mainly by their stock abundance in the Japan/East Sea.

The late 1980's CRS altered the strength of the North Pacific high pressure system. This change influenced the Kuroshio Current and affected the structure and function of the southwestern Japan/East Sea ecosystem (Zhang et al., 2000). The seawater temperature anomaly at the 50 m depth layer shifted from negative to positive after 1988 (Kang et al., 2002). The composition of major zooplankton assemblages changed and zooplankton biomass started to increase in the late 1980s. The distributional area of subtropical zooplankton such as salps overlapped with that of small pelagic fish. The increase in recruitment and biomass of small pelagic fish, especially chub mackerel, was attributed to the increase in the availability of their prey organisms in the ecosystem (Zhang et al., 2004).

The objective of this study is to examine the changes in the structure of the ecosystem and role of major species before and after 1988/89 CRS in the southwestern Japan/East Sea.

2. Data and methods

2.1. Ecological and catch data

Essential biological information about marine species inhabiting the Japan/East Sea ecosystem was investigated through previous research and literature (Chyung, 1977; NFRDI, 1994a,b; Park and Choi, 1997; NFRDI, 1999, 2000a,b). Time-series of catch data from the Korean Ministry of Maritime Affairs and Fisheries database were analyzed (MOMAF, 1978–2000). The times of two CRS events were examined according to two periods: before the CRS (pre-1988) and after the CRS (post-CRS). Average catches for both time periods were calculated per unit area from annual catch data. The catch for each group was calculated as the sum of the average catch of each species within each group. The catch of minke whales from Gong (1981, 1988) was assigned to the baleen whales group.

2.2. Self-organizing mapping (SOM)

A neural network is a system composed of many simple processing elements operating in parallel whose function is determined by network structure, connection strengths, and the processing performed at computing elements or nodes. Artificial neural networks (ANNs) are non-linear mapping structures based on the function of the human brain. An ANN is a 'black box' approach, that has a great capacity for predictive modeling, i.e. all the characters describing an unknown situation must be presented to the trained ANN, and the identification (prediction) is then given (Lek and Guegan, 1999).

A self-organizing mapping (SOM), one of neural network pattern recognition techniques, was applied in this study to classify groups with 103 marine species in the Japan/East Sea including, 50 fishes, 6 birds, 10 mammals, 4 cephalopods, 20 benthic animals, 4 zooplanktons and 9 algae. Seven variables used were (1) mobility (weak or immobile, swimming, flying), (2) body size (small, medium, large, great large), (3) bone type (softbone, hardbone, mollusk, carapace, others), (4) habitat depth (epipelagic, pelagic, semi-demersal, demersal), (5) body shape (spindle, flat, streamlined, others), (6) habitat type (surface, bottom, sand/mud, rock, sand/rock, sandy bottom, nektonic, others), and (7) feeding type (filter feeding, beak/tooth, nonfeed, others). Note that zooplankton and phytoplankton were not included in this analysis.

2.3. Ecosystem analysis

The structure of the Japan/East Sea ecosystem and the ecotrophic relationships among organisms were examined using a mass-balance model (Ecopath) for the periods of before and after the 1988 CRS.

The Ecopath model is based on two master equations (Christensen et al., 2000). The first Ecopath equation, the mass-balance equation, describes how the production term for each group (i) can be split into components. This is implemented using the equation,

$$P_i = Y_i + B_i \cdot M2_i + E_i + \mathrm{BA}_i + P_i \cdot (1 - EE_i) \quad (1)$$

or

$$B_i \cdot (P/B)_i \cdot EE_i - \sum_{j=1}^{m} B_j \cdot (Q/B)_j \cdot DC_{ji} - Y_i - E_i - \mathrm{BA}_i = 0 \quad (2)$$