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Long Term Changes Pattern in Marine Ecosystem of Korean Waters

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우리나라 주변 해양생태계의 장기 변동

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Abstract : *Long term changes in winter time(JFM) sea surface temperature(SST) and marine ecosystem of different Korean waters during last five to six decades were illustrated. Fishing intensity with climate-ocean variability(e.g. SST) have been increasing since 1970s in all of the Korean marine waters. Winter SST around Korean waters went to colder regime in early 1980s and after the late 1980s increased gradually. After 1988/89 CRS all of the waterbody started warmer regime and well coincided with the CRS phenomena. Large predatory, small pelagic and crustacean and mollusks abundance were well coincided by the warmer SST regime after 1988/89 CRS and changed the fishery from demersal fishery to pelagic fishery. Ecosystem parameter of Mean Trophic Level(MTL) showed continuous decreasing trend since mid of 1970s which was mostly affected by the increasing of lower trophic level species. Fishing in balance(FIB) index showed increasing pattern since early 1970s to the late of 1970s and from early 1980s it was almost stable until now. Finally wasp-waist population of anchovy and Japanese sardine have a greater impact to the whole MTL since early 1970s.*

Key Words : *Ecosystem structure, Climate regime shift, Pelagic fishery, Demersal fishery, Mean trophic level*

요 약 : 겨울철 해표면 수온 및 한국 주변역 생태계의 장기 변화 특성 및 상관관계를 분석하였다. 기후 및 해양환경의 변화와 동반된 어획강도의 변화는 1970 년대 이후 어획량 증가의 주요 원인으로 나타났다. 한국 주변역의 겨울철 SST는 1980년대 후반 기후체제변환 시점을 중심으로 상대적으로 저수온에서 고수온으로 변화되었다. 평균영양단계(MTL)는 1970년대 중반 이후 지속적으로 감소하기 시작하였으며, 하위영양단계 어류의 어획량 증가가 중요 변수로 작용하였다. 통합생태계 기반 자원평가 방법중 한가지인 FIB 지수는 1970년 초부터 1970년 후반까지 증가하였으며, 이후 일정 수준을 유지하였다. 특히, 중간영양단계에 위치하는 멸치와 정어리의 개체수 변화는 1970년대 초 이후 MTL 변화의 주요 인자로 작용하였다.

핵심용어 : 생태계 구조, 기후체제변환, 부어어업, 저서어업, 평균영양단계

1. Introduction

There are three different ecosystems in Korean marine waters: demersal ecosystem in the Yellow Sea and the East China Sea, the pelagic ecosystem in the Tsushima Warm Current(TWC) from the East China Sea to the East Sea and the demersal ecosystem in the northern part of East Sea(Kim et al., 2007). All of the three dominant ecosystems changing pattern are well coincided both with the fishing intensity and the environment variability. Fishing effort together with long term environmental variation can affect the structure and function of marine communities(ICES, 2000; Pauly et al., 2002, Watters et al., 2003).

Temperature variation which is one of the main factors can alter the physical environment and in the same time alter the trophodynamics of the marine biotic community. Many of the researcher suggested teleconnections between global North Pacific climate-ocean variability like Pacific Decadal Oscillation(PDO), tropical El Niño and the Korean marine water parameters like sea water temperature, mixed layer depth, primary production etc. Lee et al.(2008) suggested strong correlation between water temperature and El Niño events with a time lag of 1.5 and 5.5 years for periods of 3 to 6 years and of decades respectively. Sugimoto et al.(2001) pointed out that mean chlorophyll concentrations

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and zooplankton biomass were much higher during El Niño years and La Niña years in the offshore side of Kuroshio. PDO tend to coincide with anomalously dry weather and cool temperature periods in Korea(Mantua and Hare, 2002) whereas positive Arctic Oscillation(AO) make the Asian monsoon weak and concurrently rise the sea water temperature. Chiba et al.(2005) and Zhang et al.(2000) also documented the impact of climate regime shift in the East Sea and the other marine ecosystem.

The objectives of this study were to identify changes pattern in the three different marine ecosystem related to trophic structure of the species and effect of the wasp-waist population in the trophodynamics.

2. Materials and Methods

2.1 Water temperature

Winter(JFM) sea surface temperatures(SST) of East Sea (36-38^{0}N, 130-131^{0}E), West Sea(35-37^{0}N, 125-126^{0}E) and South Sea(33-34^{0}N, 127-129^{0}E) have been collected from the World Ocean Database(WOD, 2012), National Oceanographic Data Center(NODC), NOAA available at http://www.nodc.noaa.gov/since 1964 to 2009. This data set was used to identify the winter SST patterns in three different Korean marine waters.

2.2 Ecosystem structure patterns

Annual landings of 62 species from different Korean marine waters has been collected from the Korean Fisheries Yearbook(2011) for total annual landings estimation. They were belongs to the large predatory, small pelagic, demersal and invertebrates species. Common 3 species of large predatory, 9 species of small pelagic, 9 species of demersal and 8 species of crustaceans and mollusks were selected from all 62 species(Table 1) to check long term changing patterns of these four categories species in different ecosystem from 1950 to 2010.

Community indices including mean trophic level(MTL) was identified to demonstrate the long term trophic structure and ecosystem community pattern of Korean marine waters. Trophic level(TL) of the selected 62 species was obtained from the FishBase database(2011), which provides TL estimates from food items for many species(Froese and Pauly, 2000). Time series of MTL was estimated as follows(Pauly et al., 2000; Pinnegar et al., 2003) :

$$MTL = \sum_{i}^{n} \frac{TL_i Y_i}{Y} \qquad (1)$$

where Y_i and Y represent the catch of species item i and the sum of total n (62) items; TL_i is trophic level for species i.

Fishing-in-balance index(FIB) was also estimated to assess whether the fisheries are ecologically balanced or not.

$$\mathrm{FIB} = \log\left(Y_i\left(\frac{1}{\mathrm{TE}}\right)^{\mathrm{TL}_i}\right) - \log\left(Y_0\left(\frac{1}{\mathrm{TE}}\right)^{\mathrm{TL}_0}\right) \qquad (2)$$

where Y_i is landing at year i, TL_i is the MTL of the landing at year i, TE is the trophic efficiency (here set at 0.10), and Y_O and TL_O are the landing and MTL of the first year of the series respectively.

Changes pattern in higher trophic species(TL > 3.5) and lower trophic species(TL < 3.5)(Pauly et al., 2002) also have been identified for the 62 species. Finally abundance of two wasp waist population, anchovy and Japanese sardine were calculated to demonstrate their effect on the total ecosystem.

Table 1. Common species of large predatory, small pelagic, demersal and invertebrates(Crustaceans and mollusks)

Groups	Common Name	Scientific Name
Large Predatory Species	Tuna	*Thunnus albacores*
	Yellowtail	*Seriola lalandi*
	Spanish mackerel	*Scomberomorus sp*
Small Pelagic Species	Anchovy	*Engraulis japonicas*
	Japanese Sardine	*Sardinops melanostictuc*
	Pacific herring	*Clupea pallasii*
	Hickory shad	*Konosirus punctatus*
	Flathead mullet	*Mugil cephalus*
	Chub mackerel	*Scomber japonicas*
	Horse mackerel	*Trachurus japonicus*
	Pacific saury	*Cololabis saira*
	Common squid	*Todarodes pacificus*
Demersal species	Flounder	*Microstomus achne*
	Bastard	*Paralichthys olivaceus*
	Red tongue sole	*Cynoglossus joyneri*
	Pacific cod	*Gadus macrocephalus*
	Walleye pollock	*Theragra chalcogramma*
	Sea bream	*Pagrus major*
	Yellow corvina	*Larimichthys polyactis*
	Yellow croaker	*Larimichthys crocea*
	Hairtail	*Trichiurus lepturs*
Crustacea /Mollusk	Large shrimp	*Fenneropenaeus sp*
	Kuruma shrimp	*Marsupenaeus japonicus*
	Blue crab	*Portunus trituberculatus*
	Large crab	*Chionoecetes opilio*
	Red snow crab	*Chionoecetes japonicus*
	Top shell/whelk	*Trochidae spp.*
	Oyster	*Ostrea spp.*
	Manila clam	*Ruditapes philippinarum*

3. Results and Discussion

3.1 Water temperature

Net SST has been increasing in East China Sea (1.22℃), East Sea (1.09℃) and West Sea (0.67℃) of Korean waters between 1982 and 2006(Belkin, 2009). Winter SST in all of the three different waterbody showed clear and continuous increasing pattern from the late 1980s(Fig. 1). The physical and biological changes occurred by the CRS in 1976 and in 1988/89 in Korean waters were illustrated by Zhang et al.(2000). Mean SST was higher than normal in 1976, the volume transport of the Kuroshio Current was increased and higher seawater and air temperature persisted until 1988. In our results, the winter SST around Korean waters went to the colder regime until 1988/89 CRS and after the late of 1980s relatively higher temperature was clear.

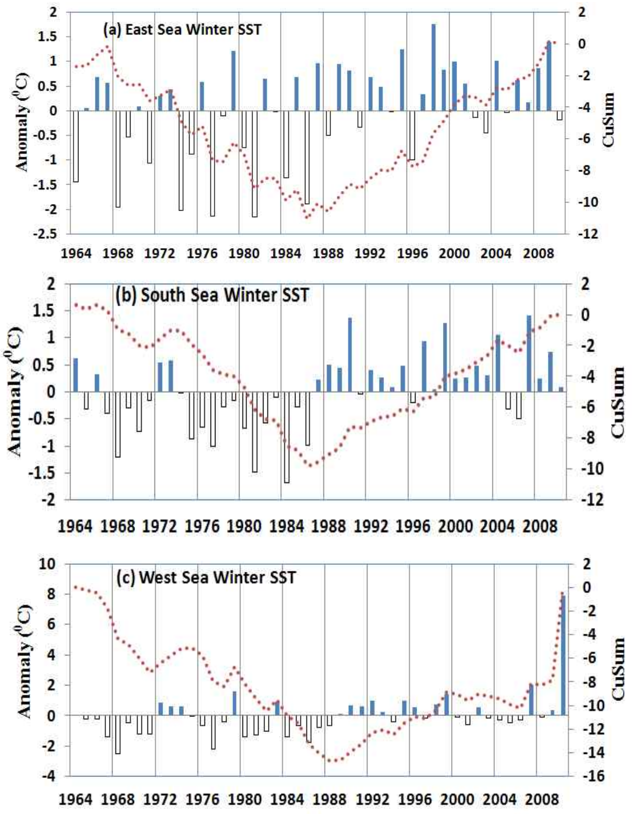

Fig. 1. Water SST (dotted line indicates cumulative sums and bar indicates anomalies of SST) changes pattern in different Korean waters (a) East Sea (b) South Sea (c) West Sea.

3.2 Ecosystem structure patterns

Total catch(Fig. 2(a)) of Korean marine waters has been increasing since mid of 1970s with the development of fishing gear and fishing methods and with the increasing of fishing vessels(FAO, 1998). The average catch is 804,896 MT from 1950 to 2010. From early 1980s to early 1990s, the higher catches were occurred and the highest catch was 1,282,936 MT in 1984. From early 2000s to end of 2000, total catch is almost stable though the average catches from middle of 1980s to end of the 2000s is still in decreasing mode.

In the mean time there are many changes occurred inside the total landings; shift catches from higher valued fish to lower valued smaller fishes, from large demersal species to smaller pelagic fishes, alteration between cold water species to warm water species. These all of the changing patterns did not happen only for the fishing but also climate-ocean variability plays a vital role. Almost all dominant commercial species were severely affected with different oceanic variability. After 1976 CRS, ecosystem of Korean water body was manifested by increasing of mixed layer depth(MLD) which results the lower primary production in spring and higher in autumn and also affect the fish biomass like lower Pacific saury biomass and higher Japanese sardine biomass(Zhang et al., 2000). After 1988 CRS, the recruitment, biomass and production of Japanese sardine collapsed and Chub mackerel, the warm water pelagic fish substantially increased with the higher sea water. Chavez et al.(2003) reported that change from a cool ‘anchovy regime’ to a warm ‘sardine regime’ in the 1970s and a shift back to an anchovy regime occurred in the mid to late 1990s in the entire Pacific Ocean. However, in Korean South Sea, Japanese Sardine regime occurred mostly between early 1980s to late 1980s and at that time anchovy catch was lower; shift back of anchovy regime occurred just after collapse of Japanese sardine in late 1980s(Fig. 5). During early 1980s the SST of South Sea in winter was lower but at that period Japanese sardine high stock level occurred which may be coincided with the 1976 CRS which had effect on increasing of autumn productivity. Walleye pollock one of the major demersal fishes in the East Sea was in higher catches during middle of 1970s to middle of 1980s and abruptly changed in lowest catches in late of 1980s which also may be affected by the higher temperature in 1988/89 CRS in the East Sea.

Changes pattern of most common three large predatory species showed an increasing pattern(Fig. 2(b)) from the middle of the 1980s and continuously increasing up to 2010 with exception in lower catch around early of 1990s. This increasing pattern is well matched with the increasing pattern in sea water temperature in the South Sea and in the East Sea and also support the northern shift of the warm water species from the tropical and subtropical regions. Though it would be good sign for the commercial fishery it must hamper the normal ecosystem patterns.

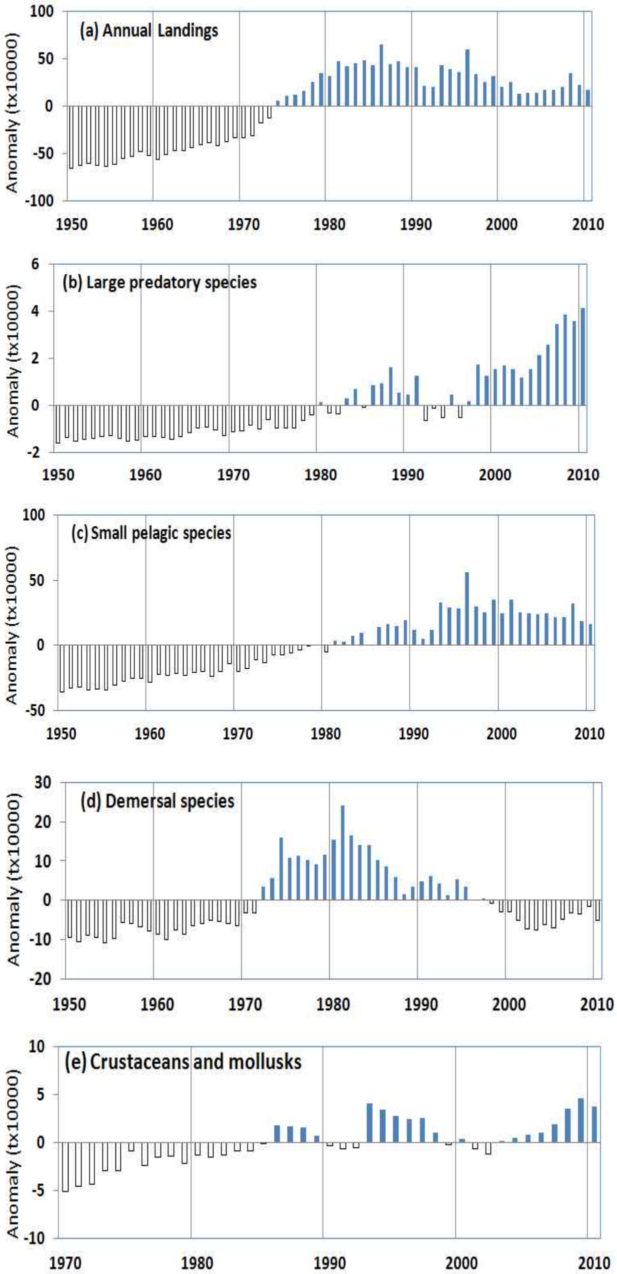

Fig. 2. Annual landings in Korean waters: (a) total 62 species, (b) large predatory(3 species), (c) small pelagic(9 species), (d) demersals(9 species), (e) crustaceans and mollusks(8 species).

Major small pelagic species which are mostly inhabitant in the South Sea and in the East Sea also showed increasing pattern(Fig. 2(c)) from its average value at the beginning of the 1980s though from the late 1990s, catch pattern again moved back to decreasing pattern slightly. In case of dominant demersal species, which are mostly inhabitant in the West Sea and East Sea(Walley pollock, Pacific cod) showed higher catches between the early 1970s to late of 1990s(Fig. 2(d)). Decreasing pattern from the late 1990s is well matched with the increasing pattern of the small pelagic species though they are may be inhabit in different habitat. Zhang and Kim(1999) also pointed out the reduction in number of the demersal species between 1967 to 1980/81 survey. Major crustaceans and mollusks showed higher abundance since late of 1980s with two lower abundance periods at early 1990s and early 2000s(Fig. 2 (e)).

MTL significantly decreased since middle of 1970s and constantly in decreasing pattern which coincide with the higher abundance of lower trophic level species(Anchovy, herring)(Fig. 3(a)). The percentage of the landings of species of TL < 3.5 increased since early of 1970s and species of TL > 3.5 decreased in the same period(Fig. 4).

The FIB index showed a steady upward trend from 1950 to middle of 1970s and from early 1980s to 2010, it seemed to be stable(Fig. 3(b)). Steady upward suggesting that the fishery was expanding with higher level of catch and long term stability of this index refers that the whole fishery was in balance.

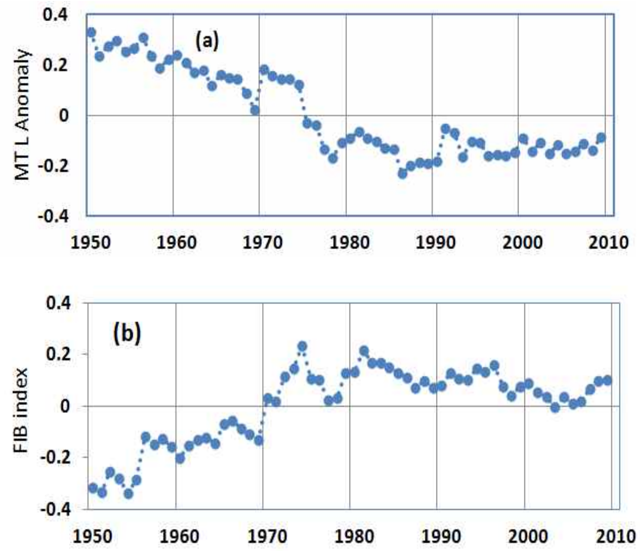

Fig. 3. Changes pattern of ecosystem components: (a) MTL (b) FIB index.

In many highly productive ecosystems in the world, there tend to be a crucial intermediate trophic level occupied by small, plankton-feeding pelagic species that typically dominated by only one, or at most a few species(Bakun, 1996). These small pelagic fishes exert a major control on the trophic dynamics of marine ecosystems and constitute mid trophic-level ‘wasp-waist’ population(Cury et al., 2000). In korean waters there is two wasp-waist population, anchovy and the Japanese sardine. Anchovy is playing a dominant role in the South Sea since 1970s with its substantial increasing pattern whereas the other species Pacific sardine played vital role from the early 1980s to the late 1980s(Fig. 5). These wasp-waist population is important because they are sometimes food for the upper trophic level species and sometimes for the lower trophic level species; so lower abundance of this species would have bad impact in the wasp-waist ecosystem.

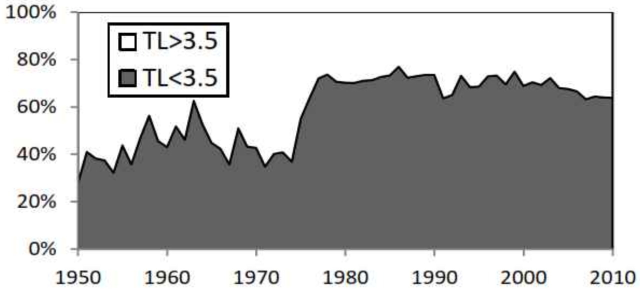

Fig. 4. Annual landings discriminated by trophic level(TL): TL > 3.5 and TL < 3.5.

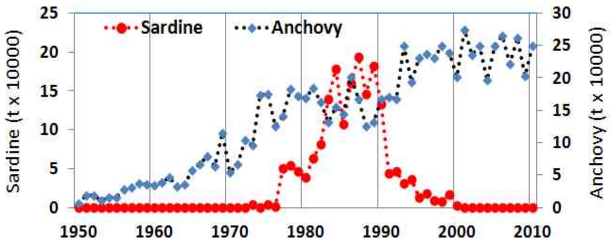

Fig. 5. Wasp-waist population(Anchovy and Pacific sardine) changing pattern in Korean waters.

4. Summary

Present state of the different marine ecosystem of Korean waterbody is not stable in the last 5-6 decades. There were two identified climate regime shift altered the entire ecosystem with temperature variability until late 1980s played vital role to form different dominant pattern of marine species community. From the late 1980s all of the waterbody is exhibiting warmer than their previous average state. This warmer environment enhances the large pelagic warm water species both in number and abundance. With the increasing trend of water temperature, it is to be assumed that several warm water species would be dominant in most of the ecosystem of Korean waters. In the same time cold water demersal fishery would not be able to recover their abundance in the previous state. Small pelagic species will also play dominant role all of the ecosystems though it difficult to predict future abundance of all of the species with the environmental variability with control fishing intensity. Dominant collapse species population should be precisely identified with their distribution, migration and recruitment patterns. The fishing effort which was deployed at the highest catch period of the collapse species would also be identified though it is very difficult to separate environmental effect and fishing effect to the marine population. Teleconnections with local climate-ocean variability with northwest Pacific climate-ocean variability also should be identified very precisely though there several researches have been already done with different results.

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