Studies on Long-term Changes in the Abundance of Coastal Fisheries Resources in Relation to Environmental Conditions in the Japanese and Korean Waters

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Ocean conditions are key determinants of abundance of fisheries resources. Growing human pressures, including climate changes, have broad implications for changes in abiotic factors and ecological states of marine ecosystems. The Japanese and Korean coastal waters are one of the regions under severe human pressures. These regions are composed of diverse fish species, and ecosystem regime shifts occurred as a result of climatic regime shifts, showing long-term changes in the fish community structure. The purpose of the present study is to diagnose mechanisms of the long-term changes in abundance of coastal fisheries resources such as cod and anchovy in relation to environmental changes in the Japanese and Korean coastal waters.

Ecological relationship between environmental factors and Pacific cod (*Gadus macrocephalus*) catch in the southern Japan / East Sea (Chapter 2)

The habitat characteristics of Pacific cod (*Gadus macrocephalus*) and the ecological relationship between Pacific cod catch and environmental parameters in the southern Japan / East Sea (JES) were investigated. Pacific cod are sexually matured at age of 4–5. The highest catch of Pacific cod off the eastern Korean Peninsula occurred in seawater temperature range of 0–4℃ and salinity range of 33.8–34.2 PSU at 100 m. The Cross-Correlation Function analysis showed that there was a significant negative correlation between Pacific cod catch and February seawater temperature at 75 m nearby spawning area with a time-lag of 5 years in Korean waters (r=-0.360, p<0.05). The annual catch of Pacific cod also had the significant correlation (p<0.05) with zooplankton biomass in coastal nursery areas with a time-lag: i.e., the highest correlations, r=0.432 and r=0.452, for total zooplankton biomass in June of 5 years ago, and for euphausiids abundance in February of 4 years ago from the period when Pacific cod was caught, respectively. Furthermore, total catches of Pacific cod in the southern JES (i.e., sum of Korean and Japanese catches) were negatively correlated with winter Arctic Oscillation Index, and the highest negative correlation (r=-0.364, p<0.05) was shown with a time-lag of 4 years. Considering sexual maturation at ages 4 to 5, such statistical analyses imply that biotic and abiotic environmental factors during the early life stages of Pacific cod have a significant influence on recruitment after 4–5 years of spawning.

Response of fish community structure to climate and human-induced changes inferred from fishery landings in Omura Bay (Chapter 3)

Variations in the fish community structure in Omura Bay, an enclosed bay in the East China Sea, were investigated using long-term fishery landing data over the past five decades (1965–2006). We confirmed that the fish community structure in Omura Bay showed three conspicuous regimes during the study period. Anchovies dominated in the pelagic domain with abundant and various demersal fish species in the first phase (1965–1978). Demersal fish declined remarkably with the dominance of sardines in the pelagic domain during the second phase (1979–1987), and fish community was simplified with the return of anchovies and no recovery of demersal fish in the third phase (1988–2006). These changes were significantly related with periodic large-scale

climate changes and cumulative regional-scale human impacts. The replacement of sardine/anchovy caused by a climate regime shift in the North Pacific contributed to the fish community regime shifts in Omura Bay. Moreover, habitat degradation such as depletion of dissolved oxygen combined with climate-induced changes in food web systems resulted in a rapid reduction in demersal fish. Contraction of the habitat volume due to an increase in oxygen restricted water simplified the fish community structure and eventually reduced fishery landings in Omura Bay. These findings demonstrate that long-term fish community responses to large-scale climate changes and regional-scale human impacts can be observed in a coastal enclosed bay, providing useful information for fisheries management in areas with climate and human-induced changes.

Temporal changes in the eggs and larval abundance of Japanese anchovy, *Engraulis japonicus*, in Omura Bay (Chapter 4)

During the last two decades, most of the fishery landings in Omura Bay were composed of the low level of anchovy catch. To reveal the possible cause of decrease in anchovy catch in Omura Bay in recent years, temporal changes in the eggs and larval abundance of Japanese anchovy, *Engraulis japonicus*, in relation to oceanographic conditions were investigated through ichthyoplankton surveys and environmental observations during the period from April 2010 to October 2012. Anchovy mainly spawned in June and the beginning of July, and spatiotemporal distribution of eggs was characterized by a high concentration of chlorophyll a and copepod nauplii. However, despite the high density of eggs in June, the larval density was higher in May than in June, though the data were very limited, this suggests that spawning in June–July may not be the best for survival. According to the previous study, the highest density of anchovy eggs was observed in May from 1967 to 1970, whereas in June and July from 2010 to 2012 in the present study. The shift in spawning timing could make anchovy larvae deviate from the suitable thermal condition (22℃), and encounter oxygen restricted water that is pervasive in this bay in summer. The unfavorable conditions in recent years could eventually contribute to decrease in anchovy production in Omura Bay.

In conclusion, the effects of change in oceanic conditions on abundance of fish species and communities in the Japanese and Korean coastal waters were examined in the present study. Both large-scale climatic changes and regional-scale human impacts were associated with long-term species- and community-level changes. As demonstrated in long-term changes in fish community structure in Omura Bay and cod population in the southern JES, climate-induced change in oceanographic conditions plays an underlying role in change in fish recruitment as well as shifts in species composition such as sardine/anchovy replacement. Moreover, deterioration of regional habitat conditions could have a significant impact on changes in fish community and fishery production in nearshore regions. While the effect of land-based anthropogenic drivers is tenuous in the east coast of Korea Peninsula, Omura Bay is under the severe human pressures. The results of this study illustrate that variation in fish abundance is fundamentally modulated with climate-induced changes, and long-term changes in fish species and communities in the nearshore regions where human pressures are high respond obviously to coupled climate-human impacts.