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Winter Warming and Long-term Variation in Catch of Yellowtail (*Seriola quinqueradiata*) in the South Sea, Korea

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The relationships among long-term climate variation at the southern part of the Korean peninsula, oceanic conditions in the South Sea, Korea, and variation in the winter catch of yellowtail (*Seriola quinqueradiata*) were analyzed using 32 years of time-series data from 1971～2002. In the early 1990s, winter climatic conditions at the southern part of Korean peninsula shifted from a cool to a warm regime with higher air temperature, relative weak wind speed, and lower relative humidity. Also, the winter water temperature at 50 m depth became consistently higher in the South Sea. The annual winter catch of yellowtail in the South Sea increased dramatically in the early 1990s, as did that of anchovy, which is the major food organism for yellowtail. From the results of correlation analysis, we found that the winter catch of yellowtail was more closely related to the increasing of air temperature, water temperature and anchovy catch.

Key words : yellowtail, South Sea, winter, climatic conditions, warm regime

Introduction

With the changes in marine ecosystems caused by rapidly changing climate regimes, the major fishing countries of the world have continued to monitor long-term alterations in nearby marine ecosystems in order to predict trends in the variations (Graham, 1995; Montevecchi and Myers, 1997; Planque and Taylor, 1998). Recently, some changes in marine ecosystems caused by climate changes have been observed around the Korean peninsula, especially in the South Sea and Japan /East Sea (Kang *et al.*, 2000; Kim and Kang, 2000; Park *et al.*, 2000; Zhang *et al.*, 2000; Kang *et al.*, 2002; Ginger and Kang, 2003).

Yellowtail (*Seriola quinqueradiata*), which populates Korean waters, is a commercially important migratory fish caught mostly around the coast in winter (NFRDI, 1998). In Japan, which is adjacent to Korea, numerous studies have examined yellowtail ecology (Okata, 1976; Murayama, 1992a), resource variation (Kobata, 1986; Hara, 1990a, b; Hara and Murayama, 1992; Murayama and Kitahara, 1992), migration (Tanaka, 1972; Murayama, 1992b), and fishing conditions and distributions (Uchino, 1977; Hiyama, 1998). In Korea, Kim *et al.* (2002a, b) examined fluctuations in the catch and distribution of yellowtail in Korean waters and the formation of the fishing ground around Jeju Island, while Han and Lee (1974) examined the migration of yellowtail shoals to the Japan/East Sea. However, despite the fact that yellowtail plays an important economic role for fishers in the area, there have been no recent studies of the long-term variation in

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yellowtail catch in relation to environmental changes, such as changes in the climate and ocean conditions.

Therefore, this study investigated seasonal variation in the catch of yellowtail, for which a major fishing ground exists in the South Sea of Korea in winter, using long-term data, and examined the relationship between long-term environmental changes and the variation in the winter catch of yellowtail.

Materials and Methods

1. Weather conditions

The variation in weather conditions at the southern part of Korea was examined using long-term time-series data for air temperature, wind speed, relative humidity, and sea level pressure from four regions: Mokpo, Yeosu, Busan, and Jeju (Fig. 1). These data were collected over 32 years, from 1971～2002, by the Korea Meteorological Administration (KMA). Each meteorological factor anomaly was used the value which an average of the regional monthly mean minus the monthly actual value from the KMA data from 1971～2000.

2. Oceanic conditions

Variation in the long-term oceanic conditions of the South Sea were examined using bimonthly observational water temperature data at a depth of 50 m, which is a major swimming zone for yellowtail, at 53 stations along eight observational lines (Line 203, 204, 205, 206, 207, 208, 209, and 314; Fig. 1). These data were collected over 32 years (1971～2002) by the National Fisheries Research & Development Institute (NFRDI). The water temperature anomaly was used the value which an average of the normal value at each point, from 1966～1995, from data of sea conditions in Korean Waters (NFRDI, 1997) minus the monthly actual value at each station.

3. Catch data

Published catch data for yellowtail and anchovy, which is a major food resource for yellowtail, were obtained from the Korean Ministry of Maritime Affairs and Fisheries (MOMAF). Yearly and monthly catch data from 1971～2002 for four regions at the southern part of Korea, *i.e.*, Jeollanam-do, Gyeongsangnam-do, Busan, and Jeju, were used for this study. Yellowtail data were derived from the total fishing catch, while anchovy data were derived from powered anchovy drag net, drift gill net, and set net catches.

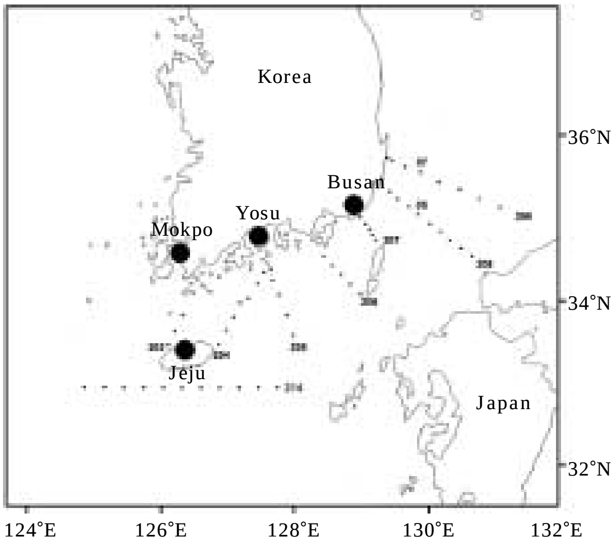

Fig. 1. Map showing the meteorological data observation area (black circle) by KMA (Korea Meteorological Administration) and water temperature observation stations (dotted points) by NFRDI (National Fisheries Research & Development Institute) in the South Sea of Korea from 1971 to 2002.

4. Seasonal classification

The seasonal classification of yellowtail and anchovy catch and environmental factors were as follows: spring, from March to May; summer, from June to August; autumn, from September to November; and winter, from December to February. Mean values was used for this study. For water temperature, which was observed every other month, winter values were represented by the mean of data from February and December.

5. Statistical analysis

Correlation analysis was performed to examine the relationship between the catch of yellowtail and environmental factors in the South Sea in winter. Owing to differences in the units of measurement, all data were standardized prior to analysis using the formula $(X_i - X)/\mathrm{SD}$, where X_i is observational data for variable i, and X and SD are the mean and standard deviation, respectively (Johnson and Wichern, 1988).

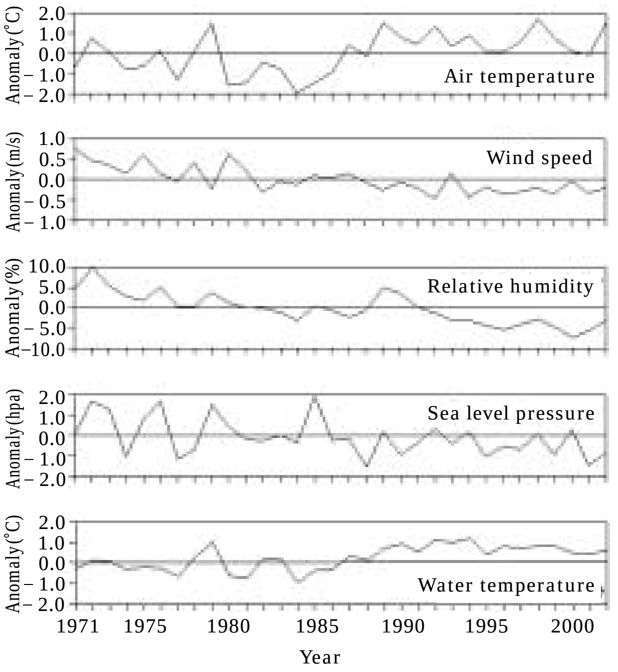

Fig. 2. Annual changes of meteorological factor anomalies in the southern part of Korea and water temperature anomaly at a depth of 50 m in winter in the South Sea of Korea from 1971 to 2002.

Results

1. Annual changes in winter environmental factor anomalies

Fig. 2 shows the long-term variations in climatic factor anomalies, such as air temperature, wind speed, relative humidity, and sea level pressure, at the southern part of Korea, and the winter water temperature anomaly at a depth of 50 m in the South Sea.

The air temperature anomaly ranged from −2.0°C (1984) to 1.7°C (1998). Temperatures for most years until the mid-1980s were lower than that of an average year by 0.5~2.0°C; after this time, the temperature began to increase. After the late 1980s, air temperatures were consistently higher than average.

Variation in the wind speed anomaly ranged from −0.5 $m\ s^{-1}$ (1992) to 0.7 $m\ s^{-1}$ (1971). Until the late 1980s, the wind speed was similar to or greater than that of an average year. However, after the 1990s, the wind speed was consistently lower, and the winter wind speed tended to decrease steadily.

Variation in the winter relative humidity anomaly ranged from −7.2% (2000) to 10.0% (1972). Until the early 1990s, the relative humidity was similar to or greater than that of an average year. After the early 1990s, the relative humidity was consistently lower.

Variation in the sea level pressure anomaly ranged from −1.5 hpa (1988) to 1.9 hpa (1985). Until the late 1970s, the variation in sea level pressure was irregular; after the 1980s, the sea level pressure was similar to or lower than that of an average year, except in 1985.

Variation in the winter water temperature anomaly at a depth of 50 m ranged from −1.0°C (1984) to 1.2°C (1994). From the late 1980s to 2002, water temperatures were consistently higher than average by 0.5~1.0°C. The water temperature anomaly varied similarly to the air temperature anomaly. Thus, winter at the southern part of Korea gradually became warmer beginning around the 1990s, as did water temperature in the South Sea.

2. Horizontal distribution of the winter water temperature anomaly in the South Sea

Fig. 3 shows the horizontal distribution of the winter water temperature anomaly at a depth of 50 m in the South Sea over time. In the 1970s, the water temperature anomaly ranged from −2.4 to 1.5°C throughout the whole South Sea, and, in most areas, it was similar to or lower than that of an average year. In 1974, a cold water zone, with a temperature 1~2°C lower than average, formed in the middle of the South Sea.

In the 1980s, the water temperature anomaly ranged from −2.7 to 2.4°C. Particularly in 1980 and 1984, water masses that were lower in temperature than average by 2°C were found in the middle of the South Sea and northwest of Jeju Island, respectively. In contrast, in 1988, a water mass that was higher in temperature than average by 1~2°C was found east of Jeju Island.

From the 1990s on, the water temperature anomaly ranged from −2.6 to 2.7°C. Except for cold water zones that were lower in temperature than average by 2°C that formed in 1998 and 2000, water masses with temperatures 1~2°C higher than average were widely distributed in most areas, unlike in the 1970s and 1980s. Examination of winter oceanic conditions in the South Sea over time showed that high-temperature

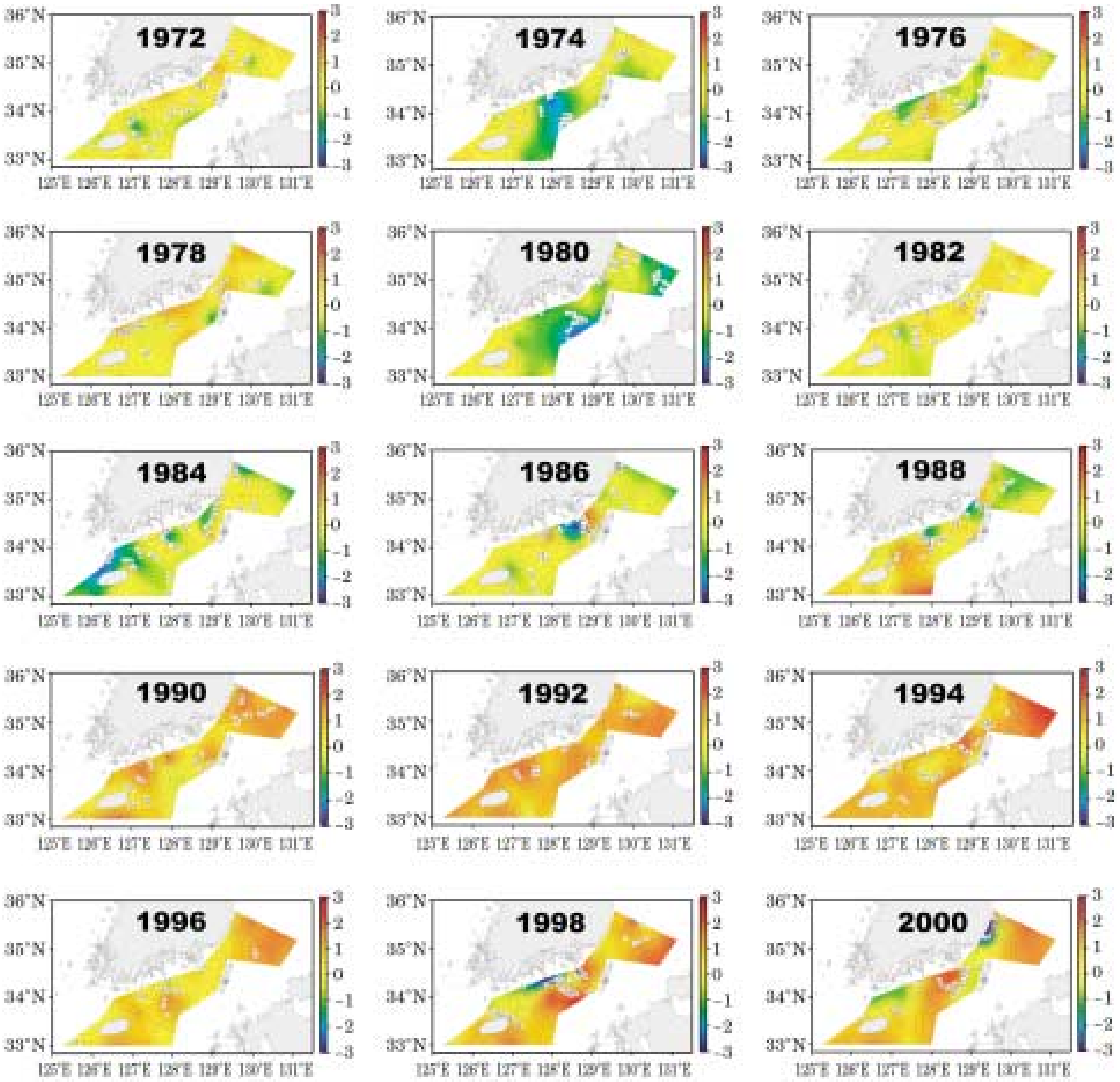

Fig. 3. Biennial variation in the horizontal distribution of water temperature anomaly at a depth of 50 m in winter in the South Sea.

water masses appeared mostly in the 1990s, in comparison with the 1970s and 1980s.

3. Annual changes in yellowtail catch

Fig. 4 shows the annual variation in yellowtail catch in Korea, including the South Sea, over 32 years, from 1971～2002. The mean catch of yellowtail in Korea over the 32 years was 3,848 M/T. In 1971, the mean yellowtail catch was 761 M/T; this increased steadily during the 1980s and reached 6,218 M/T in 1989. However, a large decrease in yellowtail catch began in 1990, with only 2,233 M/T caught in 1992. After this, the catch increased to 9,620 M/T, the maximum catch, in 1998.

Variation in the yellowtail catch in the South Sea was similar to that in Korea. The catch from the South Sea accounted for at least 65.5% of the total catch of yellowtail in Korea during the period of investigation. These results indicate that the catch of yellowtail began to increase markedly from the late 1990s, and yellowtail was mostly fished from the South Sea.

4. Seasonal variation in yellowtail catch in the South Sea

Fig. 5 and 6 show the variation in the yellowtail catch and the proportion of the yellowtail catch from the South Sea by season from 1971～2002, respectively. During the period examined, the mean winter catch, at 1,212 M/T, was higher than the catches of the other seasons. The winter catch was as low as 500 M/T until the early 1980s, showed a rapid increase from the mid-1980s, and was high, over 3,000 M/T, after the late 1990s. The spring and autumn catches showed similar trends, with mean catches of 436 and 787 M/T, respectively. Both spring and autumn catches were high in the late 1980s and 1990s. After the early 2000s, however, both spring and autumn catches tended to decrease. Among the seasons, the mean summer catch was the lowest, at 276 M/T. The summer catch was as low as 500 M/T during the period of investigation, with a slight increase in the 1988 and 1993.

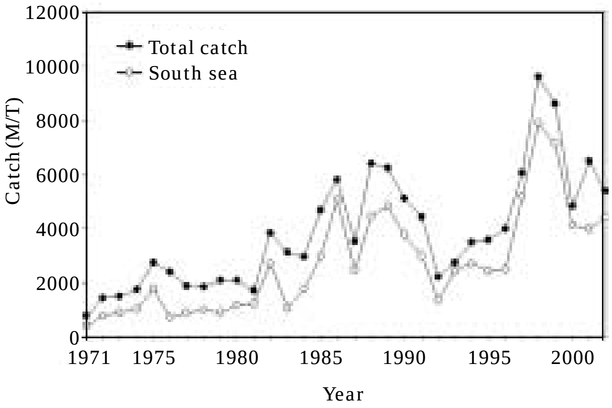

Fig. 4. Fluctuations in annual catch of yellow tail in Korea from 1971 to 2002.

The proportion of the yellowtail catch from the South Sea differed between winter and the other seasons, for which the catch decreased over time (Fig. 6). The winter proportion of yellowtail catch from the South Sea increased rapidly from 31.5% in the 1970s, to 50.3% in the 1990s, and to as much as 72.5% in the early 2000s.

5. Annual variation in winter anchovy catch in the South Sea

Fig. 7 shows the annual variation in the winter

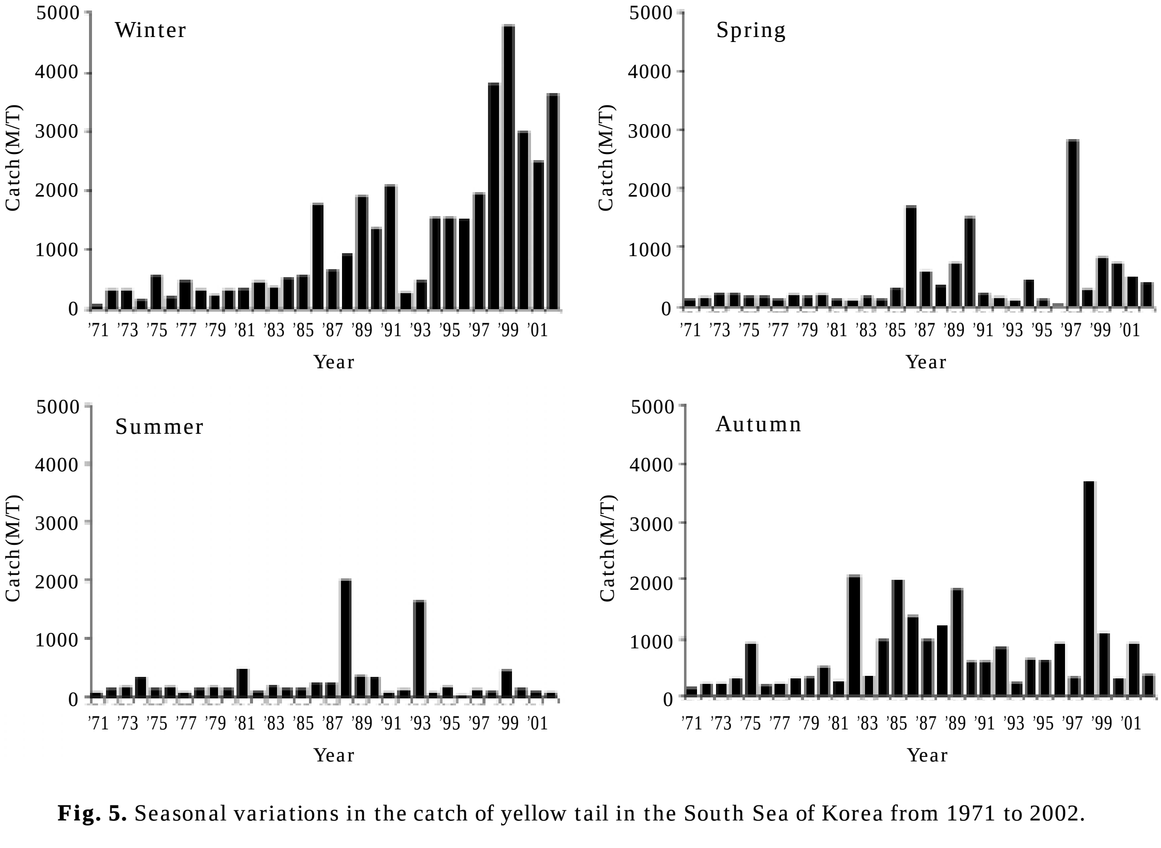

Fig. 5. Seasonal variations in the catch of yellow tail in the South Sea of Korea from 1971 to 2002.

catch of anchovy in the South Sea. In general, the winter anchovy catch remained near approximately 20,000 M/T until the early 1990s, rapidly increased after the mid-1990s, and reached about 40,000 M/T in the early 2000s. In 2002, the winter catch of anchovy reached a maximum of 55,889 M/T.

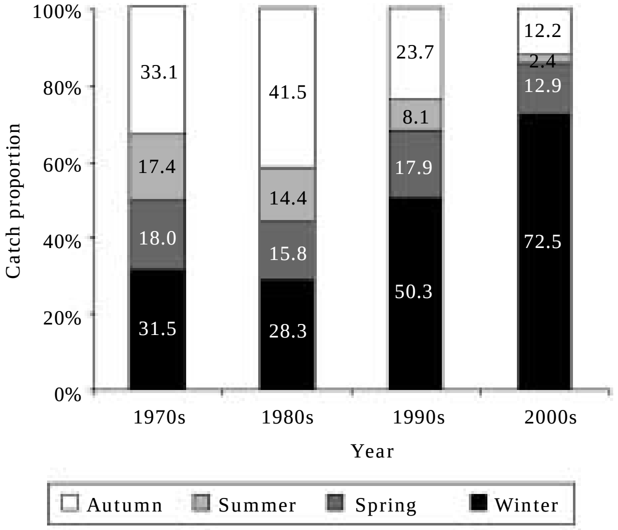

Fig. 6. Seasonal variations in catch proportion of yellow tail in the South Sea of Korea from 1971 to 2002.

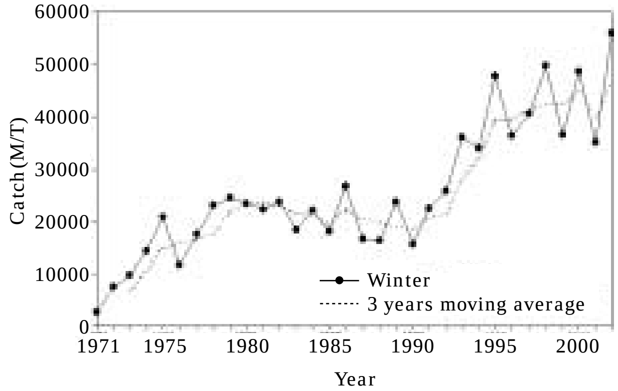

Fig. 7. Annual change of the winter anchovy catch in the South Sea of Korea from 1971 to 2002.

6. Correlation analysis

Table 1 gives the correlation coefficients between the winter catch of yellowtail in the South Sea and environmental factors including meteorological variable anomalies, and the winter anchovy catch. The winter catch of yellowtail showed significant positive correlation with anchovy catch (r=0.741, $P<0.01$), air temperature (r=0.468, $P<0.01$) and water temperature (r=0.433, $P<0.05$).

On the other hand, the winter catch of yellowtail showed significant negative correlation with wind speed (r= − 0.512, $P<0.01$), relative humidity (r= − 0.548, $P<0.01$) and sea level pressure (r= − 0.364, $P<0.05$).

Discussion

According to the report of the Intergovernmental Panel on Climate Change (IPCC), global warming has accelerated as the average global temperature has increased by about 0.6°C since 1860 (IPCC, 2001). The signs of global warming are distinct, as atmospheric and water temperatures around Korea have increased since the 1990s (Hahn, 1994; Choi *et al.*, 2003; Kwon *et al.*, 2003). Climate changes have caused variation in the stocks and catches of commercial fisheries worldwide. Beamish and Bouillon (1993) investigated the correspondence between long-term patterns in the Aleutian Low Pressure system and trends in salmon catches and found that both the climate and the marine environment may play an important role in salmon production. Hollowed *et al.* (1998) also reported increasing trends in

Table 1. Results of correlation analysis for the winter yellowtail catch (Y) and environmental variables (X)

	Y	X_1	X_2	X_3	X_4	X_5	X_6
X_1	+0.741**	+1.000					
X_2	+0.468**	+0.392*	+1.000				
X_3	−0.512**	−0.554**	−0.462**	+1.000			
X_4	−0.548**	−0.771**	+0.008	+0.545**	+1.000		
X_5	−0.364*	−0.355*	+0.026	+0.359*	+0.546**	+1.000	
X_6	+0.433*	+0.471**	+0.873**	−0.591**	−0.262	−0.106	+1.000

Y, catch of yellow tail; X_1, catch of anchovy; X_2, anomaly of air temperature; X_3, anomaly of wind speed; X_4, anomaly of relative humidity; X_5, anomaly of sea level pressure; X_6, anomaly of water temperature.

*, significant at 5% level; **, significant at 1% level.

total salmon catches, primarily as a result of increased salmon production in Alaska after the intensification of the Aleutian Low Pressure system. Klyashtorin (1998) examined the relationships between long-term dynamics of catches of major commercial fish species and indices such as the northern hemisphere surface air temperature anomaly, the Aleutian Low Pressure Index (ALPI), and the Atmospheric Circulation Index (ACI) in the Atlantic and Pacific, and found that the ACI was more closely related to long-term fluctuations in the major commercial fish stocks than were the other indices. In addition, in Korean waters, the variation in commercial fisheries catches was caused by climatic changes such as the warming that occurred after the late 1980s or early 1990s around the Korean peninsula. Kang *et al*. (2002) and Kang and Kim (2002) reported that squid has replaced saury, cod, and walleye pollock as the major fishery in the Japan /East Sea since the late 1980s and that the catch of mackerel increased in the early 1990s. Also, anchovy, mackerel, and jack mackerel catches increased, while sardine and filefish catches decreased in the northern East China Sea in the 1990s (Kim and Kang, 2000; Zhang *et al*., 2000). These phenomena indicate that environmental changes, such as climate change, have led to significant changes in oceanic ecosystems, including changes in both higher trophic levels and primary producers.

In this study, the winter air temperature at the southern part of Korea increased from the average by about 0.7°C since the 1990s, accompanied by lower wind speeds and drier weather. In addition, winter water temperature at a depth of 50 m in the South Sea increased by about 0.7°C since the 1990s, similar to air temperature. In particular, the variation in the winter air temperature anomaly is similar to and correlated with that of water ($r = 0.873$, $P < 0.01$, Table 1). Therefore, meteorological changes at the southern part of Korea are closely related to variations in oceanic conditions in the South Sea in winter, indicating that global warming has occurred at the southern part of Korea since the 1990s, resulting in continuous dryness caused by decreases in relative humidity, weaker seasonal winds, and increases in winter air temperature.

Yellowtail is a migratory fish that forms a major fishing ground in the southwestern South Sea area centered on Jeju Island in winter; it therefore was caught mostly in winter (NFRDI, 1998; Kim *et al*., 2002b). The total catch of yellowtail in Korea increased from the late 1990s. In particular, the winter catch showed a rapid increase after the late 1990s compared with that of other seasons. Thus, we conclude that the distinctive increase in the winter yellowtail catch since the 1990s is closely related to global warming, which caused variation in meteorological and oceanic conditions in the South Sea area. Generally, the migration of yellowtail, which is a warm-water species, depends on the formation of warm water masses. Hara (1990a, b) reported that yellowtail populations, residence time, and the period of fishery formation increased with increases in warm water masses caused by an inflow of the Tsushima Warm Current into the west coast of Japan. In the South Sea of Korea, water masses with higher than average temperatures have occurred since the 1990s. Considering that most yellowtail fishing grounds are formed in the South Sea in winter, warmer water masses in this area may have played an important role in increasing the yellowtail fishery-forming period compared with that in the 1970s and 1980s, resulting in improved yellowtail production in winter.

Small pelagic fishes such as anchovy, sardine, common mackerel, and horse mackerel are major food resources for yellowtail, which is a high trophic-level piscipredator. Yellowtail is not very selective in its prey choice (Kubo, 1966; NFRDI, 1998). The anchovy catch has steadily increased since the 1990s; this fish has a simple age structure, grows rapidly in its early stages, and tends to form large groups. Its recruitment and food resources are considerably affected by various environmental factors. Anchovy lives near the sea surface, is a warm-water fish, and is very sensitive to variations in the climate (Kawasaki, 1993; Watanabe *et al*., 1995; Kim, 2003). Ginger and Kang (2003) reported that the climate regime shift that occurred in the late 1980s around the Korean peninsula caused an increase in copepod biomass, which is a major food resource for anchovy (Arthur, 1976; Hirakawa *et al*., 1997) in the South Sea of Korea. Thus it is supposed that changes in the marine environment in this area, such as the increase in winter water temperature since the 1990s caused by global warming, favorably affected anchovy populations and led to the improvement of anchovy production. In addition, the winter catches of anchovy and yellowtail in the South Sea were highly positively correlated (r=0.741, $P < 0.01$, Table 1). Therefore, an increase in anchovy caused by winter warming may lead to the provision of favorable food resources for yellowtail that migrate to the South Sea in winter and may have contributed to the increase in this yellowtail population.

Meteorological factors affect the formation of the yellowtail fishing ground; in particular, fishing ground formation is closely related to low pressure systems passing through the fishing ground (Mitani, 1954; Mori, 1964; Kubo, 1966). Using data for set net catches of yellowtail, Mori (1964) proposed that meteorological factors strongly affect the migration and existence of yellowtail. Mitani (1954) also reported that the number of yellowtail increased several days before or after a low pressure system passed through the fishing ground. We found that the atmospheric pressure has consistently been lower than average since the mid-1980s. Low pressure in winter may indirectly affect the yellowtail population migrating to the coast, resulting in the improvement of the yellowtail catch, but the correlation between these factors is still unknown. Therefore, it is necessary to thoroughly examine the effect of atmospheric pressure on fishing ground formation in yellowtail.

Future studies should develop this forecasting model by adding appropriate environmental factors that are closely related to the ecology of yellowtail, as well as factors such as changes in fishing fleet operations in the coastal area and catch per unit effort (CPUE) since the 1970s, for greater precision.

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References

Arthur, D.K. 1976. Food and feeding of larvae of three fishes occurring in the California Current, *Sardinops sagax*, *Engraulis mordax* and *Trachurus symmerticus*. Fish. Bull., 74 : 517～530.

Beamish, R.J. and D.R. Bouillon. 1993. Pacific salmon production trends in relation to climate. Can. J. Fish. Aquat. Sci., 50 : 1002～1016.

Choi, Y., K.Y. Nam, H.S. Jung and W.T. Kwon. 2003. Estimating and correcting urban bias in surface temperature time series of Korea. Inter. J. Climato., 23 : 577～591.

Ginger, A.R. and Y.S. Kang. 2003. A comparison of three marine ecosystems surrounding the Korean peninsula: Responses to climate change. Pro. Oceanogr., 59 : 357～379.

Graham, N.E. 1995. Simulation of recent global temperature trend. Science, 267 : 666～671.

Hahn, S.D. 1994. SST warming of Korea coastal waters during 1881～1990. KODC Newsletter, 24 : 29～38. (in Korean)

Han, H.S. and B.H. Lee. 1974. On Shoals of the Yellowtail (*Seriola quinqueradiata* T. & S.) migrating to the East Sea of Korea. Bull. Natl. Fish. Res. Dev. Agency, 12 : 27～36. (in Korean)

Hara, N. 1990a. An Abundance Index of Yellowtail Immigrating into the Sea of Japan and Its Yearly Variation. Nippon Suisan Gakkaishi, 56 : 19～24. (in Japanese)

Hara, N. 1990b. Yearly Fluctuations of Yellowtail Catch in Set Net Fishery along the Coastal Area of the Sea of Japan. Nippon Suisan Gakkaishi, 56 : 25～30. (in Japanese)

Hara, N. and T. Murayama. 1992. Long-term Fluctuations in Abundance of the Yellowtail Immigrants in the Coastal Areas of Japan. Nippon Suisan Gakkaishi, 58 : 2219～2227. (in Japanese)

Hirakawa, K., T. Goto and M. Hirai. 1997. Diet composition and prey size of larval anchovy, Engraulis japonicus, in Toyama bay, Southern Japan Sea. Bull. Jap. Sea Natl. Fish. Res. Inst., 47 : 67～78.

Hiyama, Y. 1998. Spatial and temporal variability in fork length of young yellowtail in the Japan Sea. Bull. Jap. Sea Natl. Fish. Res. Inst., 48 : 27～35.

Hollowed, A.B., S.R. Hare and W.S. Wooster. 1998. Pacific basin climatic variability and patterns of northeast Pacific marine fish production. Holloway, G., P. Muller and D. Henderson (Eds), Biotic impacts of extratropical climate variability in the Pacific (pp. 89～104). Proceedings ‘Aha Huliko’ a Hawaiian winter workshops, University of Hawaii at Manoa, January 25～29, 1998.

IPCC. 2001. Climate Change 2001: The Scientific Basis. Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel on Climate Change. Houghton, J.T., Y. Ding, D.J. Griggs, N. Nogurer, P.J. van der Linden, X. Dai, K. Maskell and C.A. Johnson (Eds), Cambridge University Press, Cambridge, United Kingdom, 881pp.

Johnson, R.A. and D.W. Wichern. 1988. Applied multivariate statistical analysis. Prentice Hall, London, 594pp.

Kang, Y.S., J.Y. Kim, H.G. Kim and J.H. Park. 2002. Long-term changes in zooplankton and its relationship with squid, *Todarodes pacificus*, catch in Japan/East Sea. Fish. Oceanogr., 11 : 337～346.

Kang, Y.S., S.A. Kim and S.W. Bae. 2000. Changes in ecosystem components induced by climate variability off the eastern coast of the Korean Peninsula during 1960～1990. Pro. Oceanogr., 47 : 205～222.

Kang, Y.Q. and S.A. Kim. 2002. Zooplankton in the Korean waters. In: D. Lee (Ed), Ecology of Korea. Bumwoo Publishing Co. Seoul, Korea, pp. 331～343. (in Korean)

Kawasaki, T. 1993. Recovery and collapse of the far eastern sardine. Fish. Oceanogr., 2 : 244～253.

Kim, J.T., H.G. Rho and S.H. Kim. 2002a. Studies on the Forming Mechanism of The Fishing Ground of Yellow tail, *Seriola quinqueradiata*, in the Adjacent Sea of Jeju Island. Bull. Kor. Soc. Fish. Tech., 38 : 20～35. (in Korean)

Kim, J.T., H.G. Rho, S.H. Kim, J.C. Ko, Y.H. Ahn and C.M. Choi. 2002b. Characteristics of Catch Fluctuation and Distribution of Yellow tail, *Seriola quinqueradiata*, TEMMINCK et SCHLEGEL, in Korean Waters. Bull. Kor. Soc. Fish. Tech., 38 : 11～19. (in Korean)

Kim, S.A. 2003. Changes in fisheries resources in relation to variability of oceanic environments. J. Kor. Soc. Fish. Res., 6 : 11～20. (in Korean)

Kim, S.A. and S.Y. Kang. 2000. Ecological variation and El Niño effects off the southern coast of the Korean Peninsula during the last three decades. Fish. Oceanogr., 9 : 239～247.

Klyashtorin, L.B. 1998. Long-term climate change and main commercial fish production in the Altlantic and Pacific. Fish. Res., 37 : 115～125.

Kobata, T. 1986. On the Tendency of Long-Term Decreasing Catch of Adult Yellowtail, *Seriola quinqueradiata* in Its Pacific Sub-population. Bull. Jap. Soc. Sci. Fish., 57 : 1181～1187. (in Japanese)

Kwon, W.T., Y. Choi, J.H. Oh and H.J. Baek. 2003. Understanding of regional climate change in Korea. In : The first symposium on climate change, oceanography and fisheries, Nat. Fish. Res. & Dev. Ins. Busan, pp. 17～20.

Kubo, I. 1966. Special Fishery Resources. Chapter 9 Yellow-tail. Kouseisha-kouseikaku Press, Tokyo, pp. 346～387. (in Japanese)

Mitani, F. 1954. Studies on the Fishing Conditions of Some Usefull Fishes in the Western Region of Wakasa Bay-I. Relation between the Catch of the Yellow-tail, *Seriola quinqueradiata* (Temminck et Schlegel), and the Meteorological Factors. Bull. Jap. Soc. Sci. Fish., 20 : 89～95. (in Japanese)

Montevecchi, W.A. and R.A. Myers. 1997. Centurial and decadal oceanographic influences on changes in northern gannet populations and diets in the north-west Atlantic : Implications for climate change. ICES J. Mar. Sci., 54 : 608～614.

Mori, I. 1964. On the secular variation of catch of the Yellow-tail, *Seriola quinqueradiata* T. and S., in the Meshima fishing ground (fixed net) of the East China Sea. Bull. Jap. Soc. Sci. Fish., 30 : 1～5. (in Japanese)

Murayama, T. 1992a. Growth of the Yellowtail, *Seriola quinqueradiata* in the Japan Sea Coast in Recent Years. Nippon Suisan Gakkaishi, 58 : 601～609. (in Japanese)

Murayama. T. 1992b. Migration of Young Yellowtail in the Japan Sea, Estimated from Tagging Experiments. Nippon Suisan Gakkaishi, 58 : 417～426. (in Japanese)

Murayama, T. and T. Kitahara. 1992. Long-term Trends in Abundance of the Yellowtail, *Seriola quinqueradiata* Immigrants in the Coastal Areas of Japan. Nippon Suisan Gakkaishi, 58 : 409～416. (in Japanese)

National Fisheries Research and Development Institute. 1998. Ecology and fishing grounds of major fish species in the Korean coastal and offshore area. Ye-Moon Publication Co., 304pp. (in Korean)

National Fisheries Research and Development Institute. 1997. Climatic Atlas of T, S, DO in Korean Waters (1966～1995). Ye-Moon Publication Co., 268pp. (in Korean)

Okata, A. 1976. Ecological Studies on the Biological Production of Young Amberfish Community in the Sendai Bay-III. Movement of the Young Amberfish. Bull. Jap. Soc, Sci. Fish., 42 : 1101～1113.

Park, J.H., K.S. Hwang and Y.S. Kang. 2000. Variation of Fishing Condition and the Winter Warming in Korean Waters. J. Kor. Soc. Fish. Res., 3 : 77～87.

Planque, B. and A.H. Taylor. 1998. Long-term changes in zooplankton and the climate of the North Atlantic. ICES J. Mar. Sci., 55 : 644～654.

Tanaka, S. 1972. Migration of Yellowtails along the Pacific Coast of Japan Observed by Tagging Experiments-I. Results from Release and Recapture Data. Bull. Jap. Soc. Sci. Fish., 38 : 29～32. (in Japanese)

Uchino, K. 1977. Studies on Fishing Condition of Amberfish in the Wakasa Bay-I. Movement of the Juvenile Amberfish (Mojako), inferred from the Results of Tagging Experiments. Bull. Jap. Soc. Fish. Oceanogr., 31 : 1～6. (in Japanese)

Watanabe, Y., H. Zeromu and R. Kimura. 1995. Population decline of the Japanese sardine, *Sardinops melanostictus*, owing to recruitment failures. Can. J. Fish. Aquat. Sci., 52 : 1609～1616.

Zhang, C.I., J.B. Lee, S.A. Kim and J.H. Oh. 2000. Climatic regime shifts and their impacts on marine ecosystem and fisheries resources in Korean waters. Pro. Oceanogr., 47 : 171～190.

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겨울철 온난화와 남해 방어 어획량의 장기변동

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1971～2002년까지의 지난 32년간 장기간 시계열 자료를 통하여 겨울철 남해의 방어 어획량 변동양상을 계절별로 구분하여 조사하고, 이와 더불어 겨울철 한국 남부의 기상상황 및 남해의 해황 변화도 조사하여 장기간의 환경변화와 방어의 어획량 변동 사이의 대응관계에 대해서 살펴보았다. 겨울철 우리나라 남부의 기상변동을 살펴본 결과 1990년대에 들어서 기온이 상승하고 상대습도는 낮아지며 풍속이 많이 약화되는 특징들을 보이는 등 전체적으로 온난화 경향을 나타내고 있었고, 겨울철 남해의 50 m 수층 수온도 이 시기부터 뚜렷이 상승하고 있었다. 이와 관련하여 남해의 방어 어획량 변동양상을 계절별로 구분하여 조사한 결과 타 계절에 비해 특히 겨울철 생산량이 1990년대에 들어서부터 점차 증가하고 있었으며 방어의 주먹이원의 하나인 멸치의 어획량도 이 시기부터 증가하고 있었다. 이번 연구에서 조사한 기상 요인들을 포함한 환경 요인들과 겨울철 남해 방어 어획량 자료를 이용하여 상관분석을 실시한 결과 겨울철 방어 어획량의 증가는 겨울철 기온과 수온의 증가 그리고 멸치 어획량의 증가와 매우 밀접하게 연관되어 있다는 것을 알 수 있었다.