BSPE00507-823-7

참조기 어획고의 변동에 미치는 수온과 염분의 계절 편차의 효과

The effect of seasonal anomalies of seawater temperature and salinity on the fluctuation in yields of small yellow croaker, *Pseudosciaena polyactis*, in the Yellow Sea

1995. 5.

한 국 해 양 연 구 소

제 출 문

한국해양연구소장 귀하

본 보고서를 '참조기 어획고의 변동에 미치는 수온과 염분의 계절 편차의 효과' 의 보고서로 제출합니다.

1995년 5월

한국해양연구소
연구책임자: 김수암

요 약 문

I. 제 목

참조기 어획고의 변동에 미치는 수온과 염분의 계절 편차의 효과

II. 연구개발의 목적 및 중요성

본 연구의 대상인 참조기는 민어과에 속하는 우리나라의 주요 수산어종으로, 1930년대에는 최대 67,000톤이 어획되었으나, 최근에는 어획이 계속 감소하여 10,000톤에도 미치지 못하는 어획을 기록하고 있다. 이러한 감소는 남획에 의한 원인이 가장 커다란 요소로 작용하였겠지만, 해양환경의 변동에 따른 자원량의 증감도 무시하지 못하리라고 생각된다. 따라서 어획 혹은 자원량 감소의 원인을 정확하게 밝히지 못한다면 참조기 어업자원의 관리는 불가능하게 되어, 이 어업은 회복 불가능한 상태로 빠져들게 된다.

본 연구는 참조기 자원의 감소와 해양환경과의 관계가 갖는 상관관계를 찾는데 초점을 모았으며, 이 연구의 결과로서, 어류가 서식하는 환경이 장래의 어군 강세(Year-class strength)를 예측하는데 이용될 수 있다는 가능성을 제시하였다.

III. 연구개발의 내용 및 범위

가. 해양환경요인인 수온과 염분의 장기간 시간변동 양상의 서술.

나. 참조기 어획고의 장기간 계절변동 양상을 서술.

다. 수온과 염분이 어획고에 미치는 효과를 평가.

라. 참조기 어획고의 예측모델 개발.

마. 통계적인 분석결과를 생물학적 의미로 해석.

IV. 연구개발의 결과 및 활용에 대한 건의

황해에서의 참조기 어업의 변동을 연구하기 위하여 1970년부터 1988년까지의 어획량, 해수온, 염분에 대한 자료를 수집하여 시계열 분석과 통계학적인 분석을 실시하였다. 어획고는 뚜렷한 계절적 성향을 보이고 있었으며, 해마다 감소하는 추세가 나타났다. 어획고의 잔차(residual)는 해수온과 염분의 평균의 잔차와 표준편차의 잔차와 상관관계가 나타났으며, 시간지연효과가 분명하게 나타났다. 즉, 참조기의 생산의 계절변동에 가장 큰 영향을 미친 요소는, 1년전 참조기가 서식하던 해수온의 계절변동이며, 염분의 변화는 수온의 효과만큼 크지 않은 것으로 나타났다. 그러므로, 1년전의 안정된 해수온의 조건은 다음해의 참조기 생산을 증가시키는 것으로 추론된다.

이러한 결과를 사용한 예측모델은 실제의 어획상황과 유사하게 나타나고 있으므로, 이 연구를 조금 더 발전시킨다면 1년 후의 참조기 자원량은 비교적 정확하게 예측할 수 있으리라고 생각한다.

목 차

CONTENTS

List fo Figures

List of Tables

The effect of seasonal anomalies of sea water temperature and salinity on the fluctuation in yields of small yellow croaker, *Pseudosciaena polyactis*, in the Yellow Sea

Suam Kim, Sukgeun Jung and Chang Ik Zhang*

Polar Research Center

Korea Ocean Research and Development Institute

Ansan, P.O. Box 29, Seoul, 425-600, Korea

*** Department of Marine Living Resources**

Kunsan National University

Kunsan, 573-360, Korea

Abstract

To extract the effects of the seasonally fluctuating environmental factors on the fish production, the commercial catch data of small yellow croaker and the sea water properties from oceanographic cruises during 1970 through 1988 in the southeastern part of the Yellow Sea were examined by time series analysis. The residuals of the logarithmic catches from the weighted least square regression with year and month were calculated to remove not only the seasonal factor but also the long term trend of catches. Also, the residuals of average and standard deviation (SD) of sea water temperature and salinity for each month were calculated and used for autocorrelation, cross correlation and a regression analysis with autoregressive errors (AREG) by maximum likelihood. The landings showed decreasing pattern through years with conspicuous seasonal cycles in each year as expected. The residuals of bimonthly catches showed not only strong positive autocorrelation but also conspicuous time lagged cross correlation with the residuals of average and SD of temperature and salinity. AREG revealed that the seasonal anomalies of mean temperature were the main effect on the seasonal anomalies in the production of small yellow croaker with one year time lag. The seasonal decrease in SD of temperature seemed to be related to the production, while the effect of salinity was negligible comparing to that of temperature. Therefore, the stable temperature condition of previous years seemed to increase the following year's production of this fish species. With the results from AREG, the forecasted catches from 1989 to 1990 could explain 40% of the variances of the observed landings.

Key words: Yellow Sea, small yellow croaker, time series analysis, cross correlation coefficient, autoregressive regression

1. Introduction

The annual catch of fish species in temperate area shows usually unpredictable pattern, although some seasonality may appear. In some natural conditions, fish catches such as sardine and anchovy fisheries increase or decrease abruptly (Barber and Chavez, 1986; Houde and Rutherford, 1993). In many cases, however, the changes demonstrate smooth-line pattern of fluctuation through years if there was no innovation in fishing technique or economic disaster in fishing industry. The catch itself has a tendency of increase or decrease during a certain time period, and is correlated by those in previous years. In this case, the temporal fish catch seems to have memory, *i.e.*, the catch tends to be high if the previous year's catch is high, and *vice versa*.

Many researchers have speculated the causes of the fluctuation in fish catches with time (Hjort, 1914; Wooster *et al.*, 1983). Aside from human's fishing activities, biological interaction among species as well as environmental changes in ecosystem have an influence on the catch level, which might be regarded as an indication of fish biomass. Owing to the complexity of marine ecosystem, however, it is very difficult to extract the correct causal relationships among biotic and abiotic factors determining the catch and year-class strength of a fish population. Furthermore, the survivorship, growth and reproduction of fish population must have been influenced by some environmental changes such as sea water temperature and salinity. Therefore, the laboratory experiments under controlled condition in which natural fish population live can be tried to prove the causal relationships in the level of individual (Wootton, 1990; Winkle *et al.*, 1993). Also, the abundance of a population in marine ecosystem varies as the probabilities of survival and reproductive success of individual fish. Evidently, environmental factors have an important role in controlling population abundance, although the processes are not clearly explained.

To find causal relationships between fishery statistics and proper seawater properties, the application of correlation procedure might be the first step. This empirical approach with long-term time series statistics enables to forecast stock fluctuation through regression process (Houde and Rutherford, 1993). Forecasts of population fluctuation based on time series have many applications in fish resource management and marine ecology (Mendelssohn and Cury, 1987, 1989; Austin *et al.*, 1993; Carpenter *et al.*, 1994)and the results of these studies can be directly applied to the management of fish stocks (Siddeek and Abdul-Ghaffar, 1987). Austin *et al.*(1986) has well documented the advantage of time series analysis applied in marine ecology. Authors proposed that the insight into the residuals from time series would reveal new patterns which cannot be shown directly by other classical statistical analyses.

Small yellow croaker, *Pseudosciana polyactis*, is a traditionally important commercial fish species in Korea (Chyung, 1977). The annual catches of small yellow croaker revealed conspicuous fluctuations of a range from 7,000 to 80,000 mt during the period of 1926-1988. The annual catches have declined since 1980's and the catch of 1985 marked the lowest as about 7,000 tones (Baik *et al.*, 1992; Zhang *et al.*, 1992a). The monthly catches of small yellow croaker showed strong seasonality like those of other marine organisms in the Yellow Sea and the East China Sea (Zhang *et al.*, 1988).

Small yellow croaker has been known as a remarkable migratory species. They used to migrate out of the Yellow Sea to the East China Sea in winter season and move into the Yellow Sea to spawn in spring (Zhang *et al.*, 1988). The spawning season begins from April through June with a peak in May in the Yellow Sea (Park, 1981), and fishing fleets usually chase the school of spawners. However, spawning schools were rarely found in the Yellow Sea recently due to the diminished stock size. Accordingly, the main fishing ground moved southward from the middle part of the Yellow Sea to southwestern area off Cheju Island after 1980's. More recently, the fishing ground moved further southward to the East China Sea and the fish catch has been continuously decreased although the fishing effort has been increased (Yeon and Park, 1991; Baek *et al*, 1992).

Some researches have focused on biology and ecology of this fish species (Shin, 1975; Hwang, 1977; Hwang and Choi, 1980; Park, 1981; Yeon and Park, 1991; Baik *et al.*, 1992; Hue *et al.*, 1992). And some scientists on fisheries management have suggested that the fishing effort should be reduced to half of current level to restore the shrunken fish catches (Zhang *et al.*, 1992a, 1992b, and 1992c). However, there has never been process-oriented research clarifying the causal relationship between the yellow croaker fishery and their environments. Therefore, in this study, some physical parameters which might cause the fluctuation of fish catch would be identified. Also, based on those results, real and predicted catches were compared to evaluate the validity of our model using time series analyses.

2. Data

The catch statistics of small yellow croaker from commercial fisheries have been filed at the National Fisheries Research and Development Agency of Korea (NFRDA) since 1926. The monthly catches appeared to have strong seasonal cycles in a year, although annual catches had a tendency of decrease through years. This seasonal pattern of catch is resulted from the aggregation of small yellow croaker due to the schedule of spawning migration of the fish in the Yellow Sea. For the statistical analysis in this study, a set of bimonthly (February, April, June, August, October, and December) catch data during 1970-1988 was chosen to match with environmental data, and means and standard deviations (SD) of the selected months were calculated for the 19 years. The bimonthly fish catch were then transformed into logarithmic scale for the time series analysis.

NFRDA has conducted several routine oceanographic surveys in a year in the Yellow Sea since 1962 and published raw data of seawater properties in the Serial Oceanographic Station Data of NFRDA. In many surveys, about 60 stations occupied the southeastern part of the Yellow Sea located between 124°-128° E and 33°-36° N where the small yellow croaker fishery operated (Fig. 1). Because the number of observation for temperature and salinity was too few for odd months, only observations in even months were selected. Some physical properties such as sea water temperature and salinity were measured at the depths upto 100 m or near bottom. The bimonthly means and SDs of sea water temperature and salinity at standard depths (0, 10, 20, 30, 50, 75 m and near bottom) at each station were calculated for the 19 years. Because no information on sea water temperature and salinity was available for December 1987, the monthly mean and SD were interpolated by taking the mean value of those for December of 1986 and 1988.

3. Analytical methods

Surveys were not conducted consistently through years, so that some data at the sampling stations and/or depths were often missing. Because of the differences in sampling location and time, it was necessary to make unbiased values of bimonthly means and SDs. To remove the biases owing to unequal sampling, all parameters were adjusted by inputting some independent variables (*i.e.*, geographic locations of sampling stations and sampling depths and sampling months) in weighted least square regression analysis (WLS), which resulted in the estimation of residuals. These residuals can be denoted as "seasonal anomaly" and can be assumed to be unbiased for months, distribution of stations and depths, or even for the number of sampling. The main independent variable was month which had been transformed into five dummy month variables whose value is 0 or 1. For temperature and salinity data, mean latitude and longitude of each month were also used as an independent variable to minimize the biases from unequal observation stations.

The seasonal anomalies of bimonthly sea water temperature, salinity and fish catches were then examined by autocorrelation (ACF) and cross correlation(CCF) to see the environment's time-lag effects on fish catches with an interval of 2 months from 0 to 6 year time lags. ACFs and CCFs at each standard depth were compared to see how long the effects persisted and at which depth the effect was most pronounced. After comparing the CCFs at each standard depth, the depth at which the overall environmental effect on fish catch was most pronounced was selected for autoregressive regression with first order errors (AREG) to forecast fish catches.

Seasonal anomalies of temperature and salinity at the selected depth were used as leading indicators for small yellow croaker catches in AREG. Leading indicators were the four parameters (means and SDs of temperature and salinity) with only 1, 2, and 3 year time lags. The other time lags were discarded in AREG because seasonal anomalies of environments usually have significant ACF until 1 year. Another reason was to simplify the AREG model for prediction by reducing the number of leading indicators (independent variables). From the results of AREG, the seasonal anomalies in fish catches for the following 2 years were forecasted. These forecasted seasonal anomalies were then added to the forecasted seasonal mean fish catches from WLS to predict the following 2 years' fish catch. The real and predicted fish catches were compared to see whether this model is useful to forecast the fish catches.

4. Results

The annual catches of small yellow croaker from the southeastern part of the Yellow Sea showed a long-term declining trend during the 1970-1988 period (Fig. 2). In the early 1970s, the annual catch of this fish was around 30,000 mt, but it has been gradually decreased to 10,000 mt in late 1980s. The WLS indicated that the slope value for year was -.0663, which could be interpreted as about 6% reduction in catch per year.

Regardless the long-term trend in catch, bimonthly catches of small yellow croaker showed a clear seasonality in a year. In general, catches were high in winter and early spring (*i.e.*, December and April), but decreased drastically by the early summer. After then, as season progressed, the catches steadily increased. Mean catch values showed that the catch in April was at least 6 times higher than that in June (Table 1).

The water column was well mixed between December and April, so that water property was homogeneous from surface to bottom (Fig. 3). The vertical profiles of monthly mean temperature and salinity for each depth, however, showed a large variation at the upper layer (0-50 m) from June to October, forming thermoclines at a depth of 50-60 m. At the surface, temperature changed from 10°C in February to 26°C in August (Fig. 3a), and salinity from 33.8 ppt to 31.5 ppt (Fig. 3b). But there was no big change below 50 m. At the lower layer(50-75 m), temperature and salinity remained stable, ranging 10-15°C, and 33.5-34.0 ppt, respectively.

Because adult small yellow croaker is known to live in near bottom (Chyung, 1977), the data at 75 m depths, which were approximately equivalent to the data at the bottom layer, were used in AREG to explain the time lagged effects of seasonal anomalies of temperature and salinity on the seasonal anomalies of fish catches. Actually, when we applied 75 m data to AREG, the forecasting results from this layer data were the most pronounced among other depth data. The seasonal pattern of change at 75 m was totally different from that in the surface layer. The temperature at 75 m was higher in October and December, and lower in February and April. The water masses were saline during February through June, but less saline in August and October.

Bimonthly means and SDs of sea water temperature and salinity also showed strong seasonality (Table 1). Unlike fish catches, there were no clear long-term trend of decreasing or increasing through years. Bimonthly mean salinity was higher from February to April, and decreased continuously after June to show the lowest value in October. Also, SD of temperature was highest in October and lowest in June, while SD of salinity was higher in December and February and lower in June, August and December. Seasonal anomalies of mean temperature, mean salinity, and their SDs at 75 m were demonstrated in Fig. 4.

Seasonal anomalies of bimonthly sea water temperature, salinity, and fish catch were then examined by ACF and CCF, to see the environment's time-lag effect on the seasonal anomalies of fish catch. In the results of CCFs from all standard depth data, the overall environmental effect of temperature and salinity appeared to be most pronounced at 75 m depth, especially with 1 year time lag (Fig. 5).

Seasonal anomalies of fish catches showed strong ACF for 1 year (not shown), but CCF of seasonal anomalies of mean temperature at 75 m depth with the seasonal anomalies of fish catches was significant for 8-14 months time-lag. Also, anomalies of SD of temperature and catch were significant with time-lag of 6-12 months. In the case of mean salinity, however, CCFs were not significant for nearly all of the time lag periods, except that SD of salinity showed strong CCF at the first 2 months' time-lag point.

The environmental leading indicators at 75 m depth explained 37% (r^2=0.37) of the fluctuations of seasonal fish catch anomalies in AREG from 1970 to 1988 (Table 2). However, AREG could not fit well the extreme cases of fish catches' seasonal anomaly (Fig. 3). AREG revealed that the most important leading indicators which effected on the seasonal anomalies in the catches of small yellow croaker were the anomalies of mean temperature and SD of temperature one year before the catch. In the case of salinity, only SD in two years before the catch was significant at α=10% . Consequently, it seemed that temperature was more important leading indicator than salinity for the catches. From the slope coefficients in AREG, the abnormally higher temperature seemed to cause the increase in the fish catches upto following 2 years. In contrast, abnormally higher salinity seemed to decrease the fish catches for the following two years but it's effect was not conspicuous comparing to temperature.

Based on the results from AREG with 1970-1988 data, seasonal fish catches were forecasted for the following 2 years. In general, the predicted catch curve matched real data very well (Fig. 6). The prediction curve illustrated the same pattern as the real data plotted. The observed and predicted catch values were relatively accurate in the beginning of the prediction period, but the prediction seemed to underestimate the real data thereafter. The prediction of fish catches which was made from 1989 to 1990 by this model explained 40.1% of the variance of log-transformed fish catch, while the fitted catch by this model from WLS and AREG explained 74% of the variance from 1970 to 1988 ($r^2 = 0.40$ and 0.74, respectively).

5. Discussion

Short-term forecasting of fish catch is of practical importance in fisheries management. Ecosystem models and multi-species models as well as traditional single species models fall short of predicting power needed for practical management of fisheries resources due to the lack of sufficient data or information for the required parameters. However, univariate time series analysis extracts the information on the stochastic variability from the time series itself and makes estimates of the future stochastic variability. Therefore, the analysis could be used for short-term forecasting with minimum data requirements (Yoo and Zhang, 1993). Prediction of fish catch has been tried by many authors, and Autoregressive Integrated Moving Average (ARIMA) is quite often used. One of the advantages of ARIMA applied in fishery science is that it does not require the bulks of environmental data, but only the series of fish catch. KORDI(1991) applied ARIMA for the small yellow croaker fisheries in the Yellow Sea, and concluded that ARIMA was efficient to predict the catches but it underestimated observed catches. However, KORDI(1991) could not explain the mechanism regulating fish catches.

Zhang *et al.* (1992b) speculated that the density independent process might control the small yellow croaker stock off Korea. This means that the stock could be sensitive to the changes in extrinsic environmental factors such as temperature and salinity. From our research, the results of the AREG modeling showed a good agreement ($r^2 = 0.401$ and 0.74) between the forecasts and the actual catches. Also, the seasonal anomalies of temperature and salinity usually effected on small yellow croaker fishery with time-lag of mostly one or two years in CCF. According to Zhang *et al.*(1992b), the majority of fish caught were one- or two-year olds (Fig. 7) and the mean age was 1.6 year. Based on these facts, it could be inferred that the environmental conditions of the habitat of small yellow croaker at the spawning season control the strength of recruitment of this fish stock.

We do not know the critical period in the life history of small yellow croaker and the processes how physical conditions act on the mortality of eggs and larvae. The information on biological factors are indispensable to reveal the mechanism. However, information on biological factors, *i.e.*, the ecology of eggs and larvae of small yellow croaker, was not available in this study. Furthermore, the age structure and migration route of the stocks of small yellow croaker was not considered at all. To delineate the causes of small yellow croaker catches more accurately, the process-oriented approach is required. Also, to predict more powerfully the future catches, time series analyses based on the age specific population parameters may be needed to collaborate information on environmental factors and individual fishes.

In this study, fish catches and environmental factors were filtered to remove the effect of season and observation biases. The residuals showed significant time lagged correlation between fish catches and environmental factors. These results will not be extracted from the classical regression or correlation analysis since the variables are dependent on time axis and there was no long-term trend of change in temperature or salinity, but fish catch, on the contrast, demonstrated long term decrease. Many authors suggested that overfishing is one of the main causes on the long-term decrease in small yellow croaker catches (Yeon and Park, 1991; Zhang *et al.*, 1992a, 1992c; Baik *et al.*, 1992). This study also showed that long-term trend of decrease in catches but the cause of catch decrease was not analyzed.

Some authors have studied the effect of ENSO (El Nino Southern Oscillation) on the fish production. The El Nino was prominent in 1984 and the effect of temperature anomaly on marine ecosystem was reviewed by Barber and Chavez(1986). They concluded that ENSO decreased the production of several major fish production off Peru by modifying the distribution of thermocline and nutricline. In the case of this study area, the anomaly of temperature was conspicuously low between 1982 and 1986 (Fig. 3), and the fish catch anomaly was also decreased continuously after 1982 showing that the lowest was found in 1986 and catch restored to normal status after 1987 (Fig. 2). Although we cannot confirm whether one of the causes of the lower anomaly of temperature and fish catch of small yellow croaker was ENSO, CCF and AREG showed that the lower temperature anomaly found during the ENSO period depressed the anomaly of fish catch one or two years later.

5. References

Austin, H.M., D. A. Evans, and B. L. Norcross. 1986. Time series analyses as a means of examining long term biological data sets. IEEE OCEANS 1986 Conf. Proc., Wash., D.C., Sept. 23-25, 1986. pp. 946-952.

Austin, H., D.S. Haven and M.S. Moustafa. 1993. The relationship between trends in a condition index of the American oyster, *Crassostrea virginica*, and environmental parameters in three Virginia estuaries. Estuaries, 16: 362-374.

Baik, C.I. J.H. Park and K.D. Cho. 1992. The variations of fishing conditions of yellow croaker *Pseudosciaena polyactis* Bleeker in relation to the oceanographic conditions of Korean waters. Bull. Natl. Fish. Res. Dev. Agency, 46: 69-80

Barber, R.T. and F.P. Chavez. 1986. Ocean variability in relation to living resources during the 1982-83 El Nino. Nature. vol. 319, no. 6051, pp. 279-285.

Carpenter, S.R., K.L. Cottingham, and C.A. Stow. 1994. Fitting predator-prey models to time series with observation errors. Ecology, 75: 1254-1264.

Chyung, M.K. 1977. The fishes of Korea (Korean *ed.*). Il Ji Sa Publishing Co., Seoul. pp. 351-352.

Hjort, J. 1914. Fluctuations in the great fisheries of northern Europe. Rapp. Proc. Verb., 20: 1-13.

Houde, E.D. and E.S. Rutherford. 1993. Recent trends in estuarine fisheries:

predictions of fish production and yield. Estuaries, 16: 161-178.

Hue, H.K, G.L. Hwang, Y.C. Lee, and C.S. Chang. 1992. Preliminary analysis of molecular biological methods for stock identification of small yellow croaker (*Pseudosciaena polyactis*) in the Yellow Sea. Bull. Korean Fish. Soc., 25: 474-484

Hwang, B.N. 1977. Stock assessment of yellow croaker in the Yellow Sea and the East China Sea. Bull. Fish. Res. Dev. Agency, 17: 87-97.

Hwang, B.N. and S.H. Choi. 1980. Age and growth of yellow croaker, *Psudosciaena manchurica* Jordan *et* Thompson, in the Yellow Sea and the East China Sea. Bull. Fish. Res. Dev. Agency, 23: 171-178.

KORDI. 1991. Studies on models for fisheries resource assessment and management and their softwares. 211 p.

Mendelssohn, R. and P. Cury. 1987. Fluctuations of a fortnightly abundance index of the Ivorian coastal pelagic species and associated environmental conditions. Can. J. Fish. Aquat. Sci., 44:. 408-421.

Mendelssohn, R. and P. Cury. 1989. Temporal and spatial dynamics of a costal pelagic species, *Sardinella maderensis* off the Ivory Coast. Can. J. Fish. Aquat. Sci., 46: 1686-1697.

Park, C.S. 1981. Maturity and spawning of yellow croaker, *Pseudosciaena manchurica*(Jordan *et* Thompson), in the western waters of Korea. Bull. Fish. Res. Dev. Agency, 27: 93-101.

Shin, S.T. 1975. Stock assessment of yellow croaker in the Yellow Sea and East China Sea. Bull. Korean Fish. Soc., 8: 11-19.

Siddeek, M.S.M. and A.R. Abdul-Ghaffar. 1987. The effects of the one month delay in opening the shrimp fishing season of *Penaeus semisulcatus* in 1986 in Kuwait waters. Kuwait Bull. Mar. Sci., 10: 81-96.

Winkle, W.V., K.A. Rose and R.C. Chambers. 1993. Individual-based approach to fish population dynamics: an overview. Trans. Amer. Fish. Soc., 122: 397-403.

Wooster, W.S., K. Bans and D.R. Gunderson. 1983. On the development of strategies for the study of ocean fish interactions. In W.S. Wooster (*ed.*). From year to year. Washington Sea Grant Publication, Univ. of Washington, Seattle, WA.

Wootton, R.J. 1990. Ecology of teleost fishes. Chapman and Hall. 404 p.

Yeon, I.J. and C.S. Park. 1991. Changes in distributional area on the stock fluctuation of yellow croaker, *Pseudosciaena polyactis* Bleeker. Bull. Natl. Fish. Res. Dev. Agency, 45: 85-100

Yoo, S. and C.I. Zhang. 1993. Forecasting of hairtail (*Trichiurus lepturus*) landings in Korean waters by time series analysis. Bull. Korean Fish. Soc., 26: 363-368.

Zhang, C.I., J.M. Kim and H.T. Huh. 1988. Current status of fisheries resources and their rational management in the Yellow and East China Seas. Proc. of Symp. on Dev. of Mar. Res. & Int. Coop. in the Yellow Sea & the East China Sea, 71-96.

Zhang, C.I., Y.M. Kim, S.J. Yook, C.S. Park, S.A. Kim, C.K. Kim, S.B. Yoon. 1992. Estimation of population ecological characteristics of small yellow croaker, *Pseudosciaena polyactis* off Korea. Bull. Korean Fish. Soc., 25: 29-36

Zhang, C.I., Y.M. Kim, S.J. Yook, C.K. Kim, S.M. Ahn. 1992. A study on fluctuations in biomass of small yellow croaker, *Pseudosciaena polyactis*, off Korea. Bull. Korean Fish. Soc., 25: 37-44

Zhang, C.I., Kim, S, and Yoon, S.B. 1992. Stock assessment and management implications of small yellow croaker in Korean waters. Bull. Korean Fish. Soc., 25: 282-290

Table 1. Bimonthly mean and SD of fish catch of small yellow croaker, and temperature and salinity of their habitat environment in the Yellow Sea. N* denotes the number of total observations of temperature and salinity.

Month	Fish catch (mt)	Temperature Mean	Temperature SD	Salinity Mean	Salinity SD	N
FEB	1,760	11.77	3.28	33.98	0.69	656
APR	3,493	11.53	3.15	33.97	0.67	655
JUN	555	12.43	2.88	33.84	0.62	652
AUG	1,370	13.13	3.22	33.60	0.60	665
OCT	2,441	14.29	3.82	33.59	0.55	674
DEC	3,198	15.09	3.29	33.77	0.69	618

Table 2. The results of weighted least square regression analysis of small yellow croaker catch in the Yellow Sea for 1970-1988. The slopes are relative values to June.

Independent variable	Slope	Standard error	t-value	significance
Year	-0.066271	0.010770	-6.153	0.0000
FEB	1.261258	0.200754	6.283	0.0000
APR	1.842154	0.209904	8.776	0.0000
AUG	0.899978	0.227938	3.948	0.0001
OCT	1.629967	0.207965	7.838	0.0000
DEC	1.817922	0.213849	8.501	0.0000
(constant)	6.664380	0.185810	35.867	0.0000
r^2	0.57580			

Table 3. Parameter estimates, Standard error (SE), and the level of significance of the model by AREG to forecast catches of small yellow croaker in the Yellow Sea.

Parameter	Period 1970-1988		
	Estimate	Standard error	Significance
AR(1)	0.204	0.116	NS
AVGT18	-0.013	0.071	NS
AVGS18	-0.422	0.341	NS
STDT18	-0.061	0.102	NS
STDS18	0.028	0.395	NS
AVGT12	0.129	0.073	NS
AVGS12	-0.308	0.375	NS
STDT12	-0.187	0.099	0.0638
STDS12	-0.061	0.407	NS
AVGT06	0.207	0.071	0.0043
AVGS06	0.191	0.386	NS
STDT06	-0.227	0.098	0.0233
STDS06	0.624	0.404	NS

Remarks: AVG = Mean, STD = standard deviation, T = temperature, S = salinity, NS = Not significant at alpha=10 %, and Two digits in parameter names denote time lag (6 = 1 year).

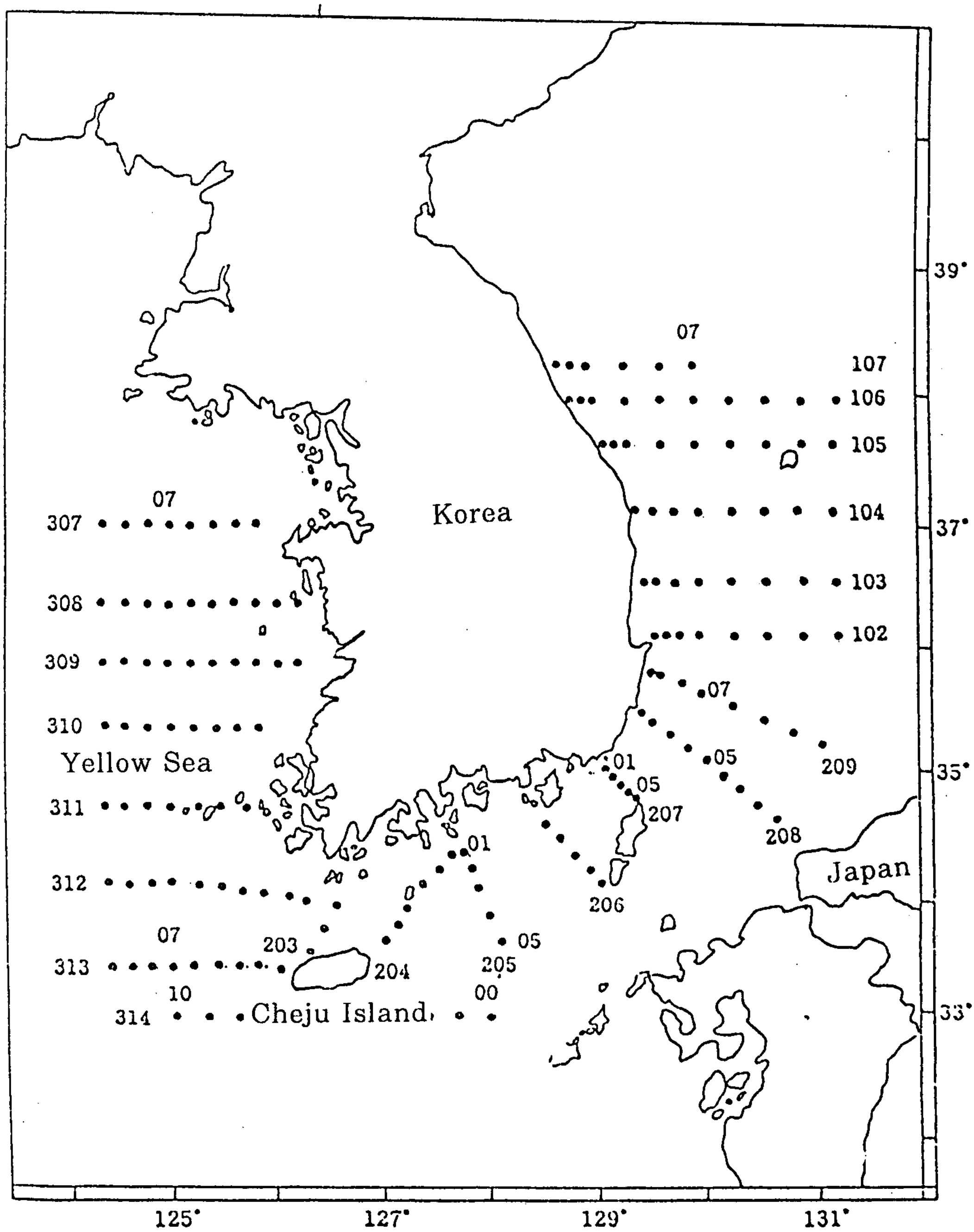


Fig. 1. Location of the serial oceanographic stations off Korea Peninsula conducted by NFRDA.

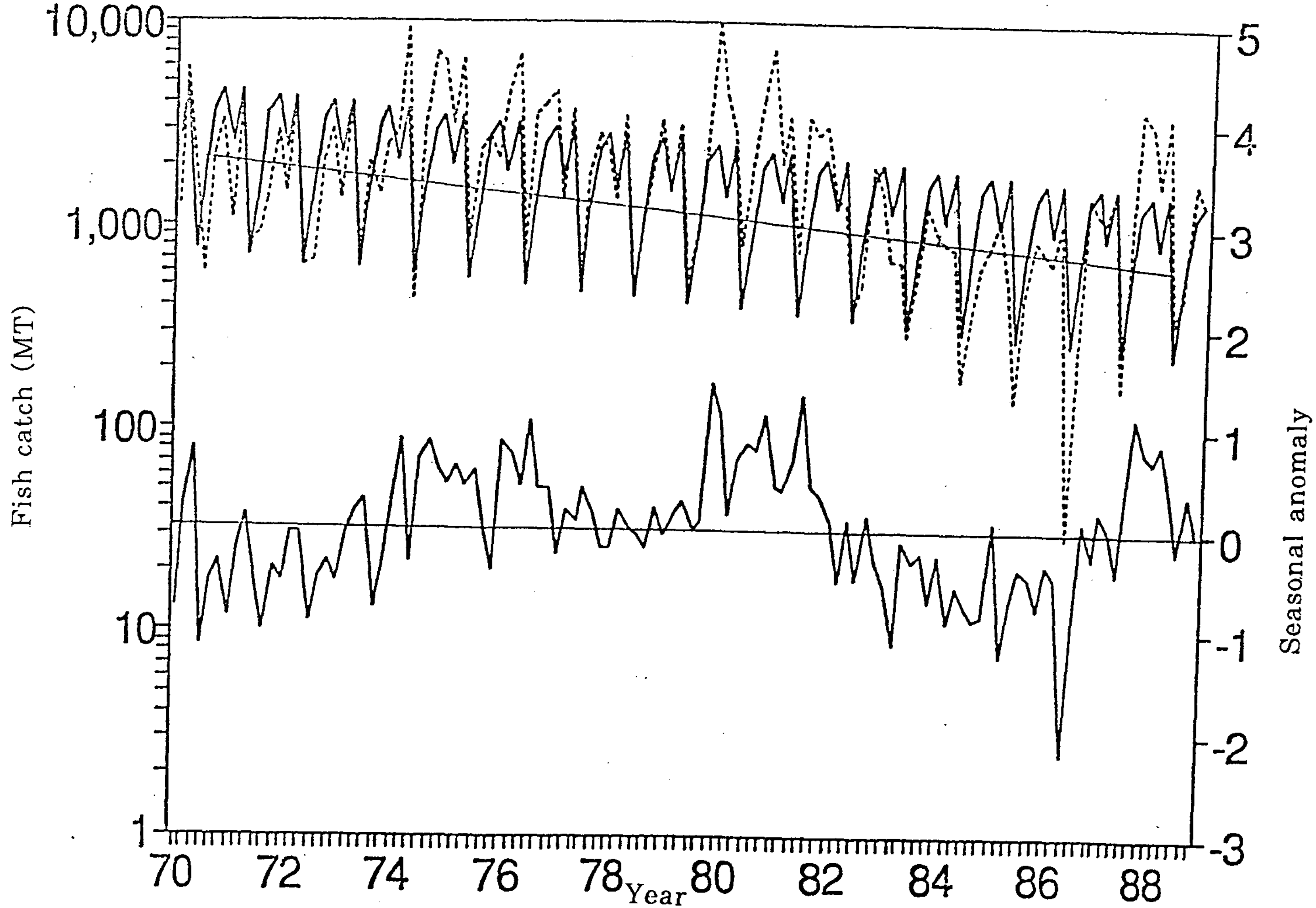
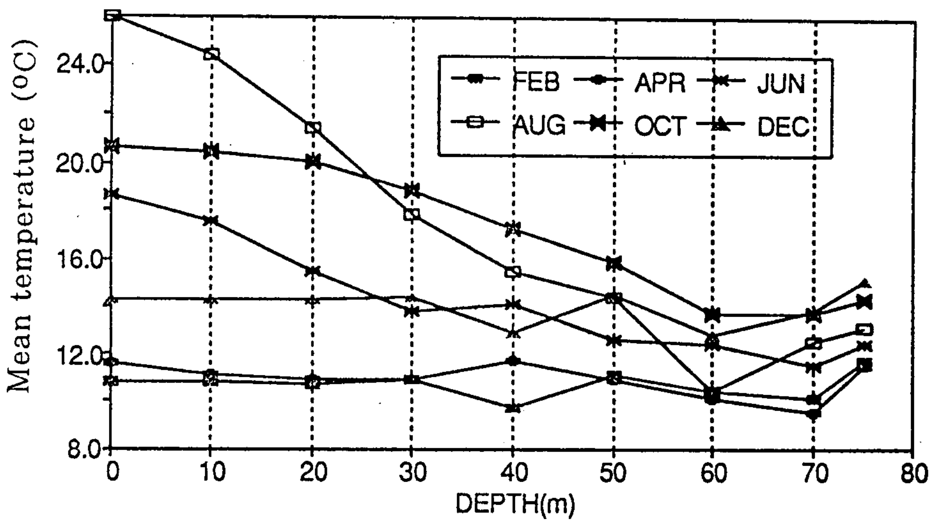


Fig. 2. Annual catches (---) of small yellow croaker from the southeastern part of the Yellow Sea during 1970-1988. Normalized fish catch (strait line in the upper part of panel) by weighted least square regression analysis and seasonal anomaly (lower part) are shown in the box.

(a)



(b)

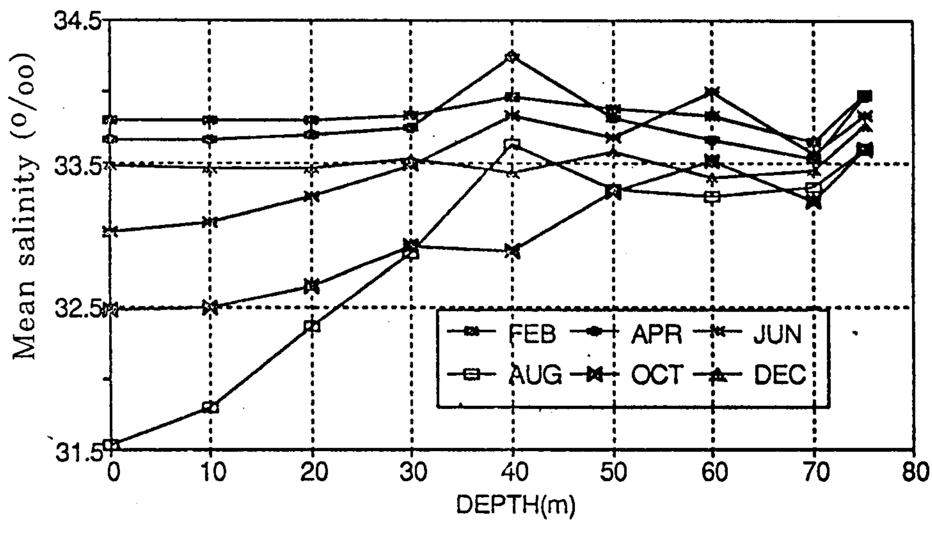
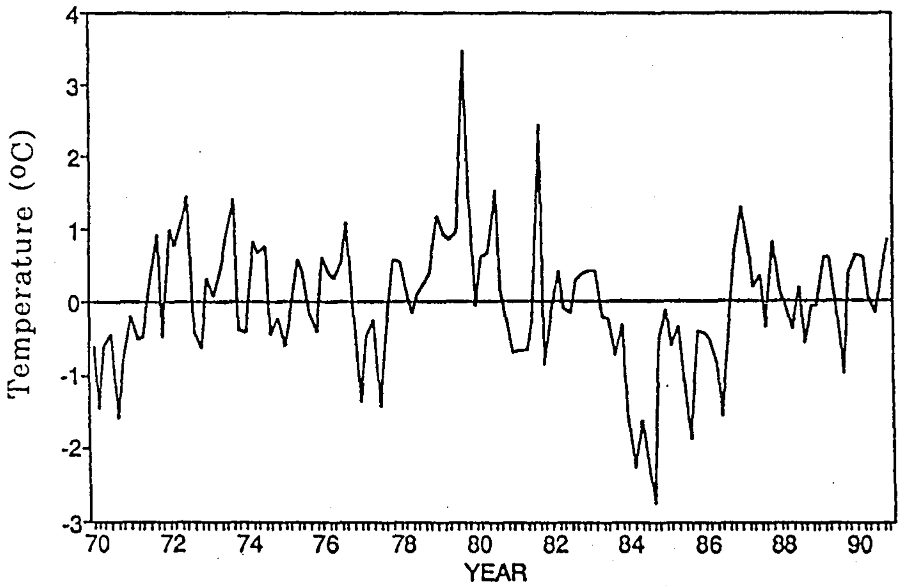


Fig. 3. Vertical profiles of (a) bimonthly mean temperature (°C) and (b) salinity (o/oo) in the southeast Yellow Sea from 1970 to 1988.

(a)



(b)

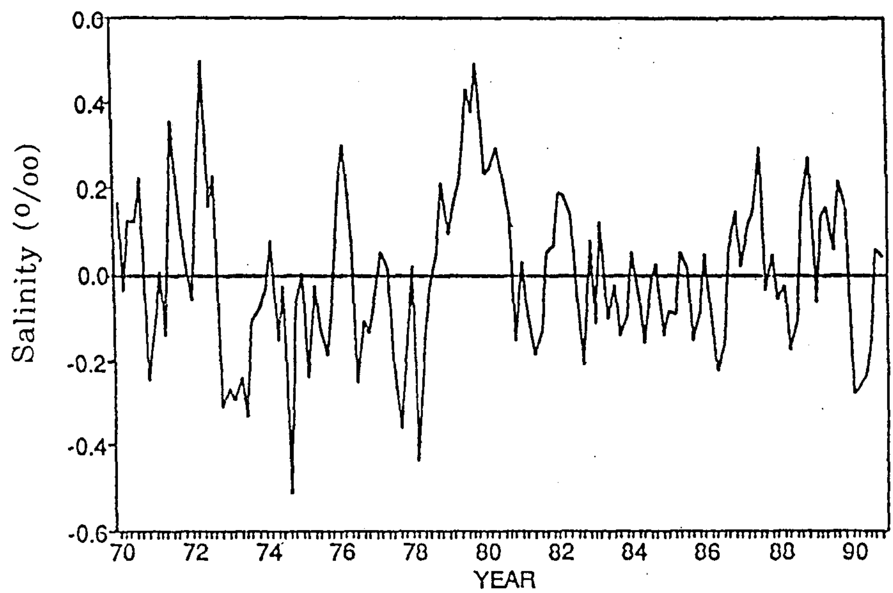
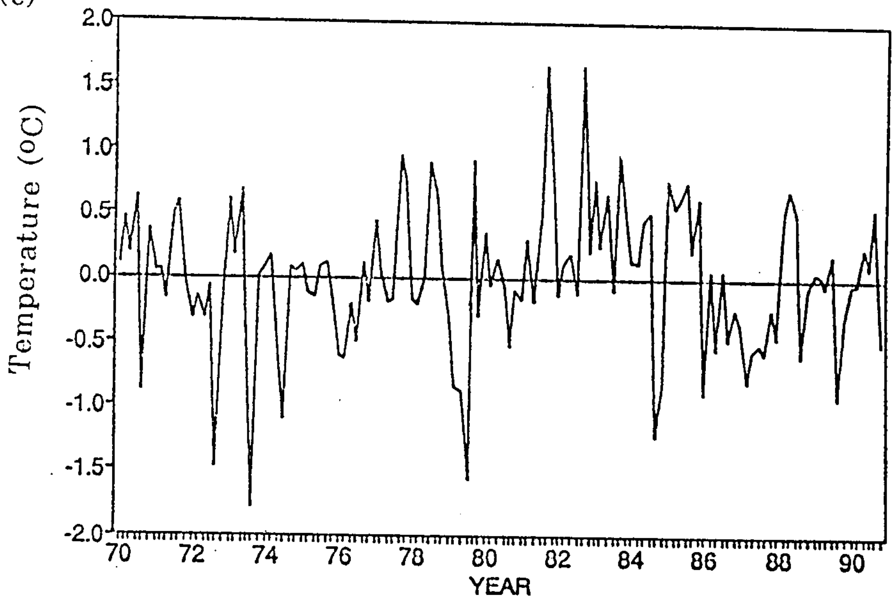
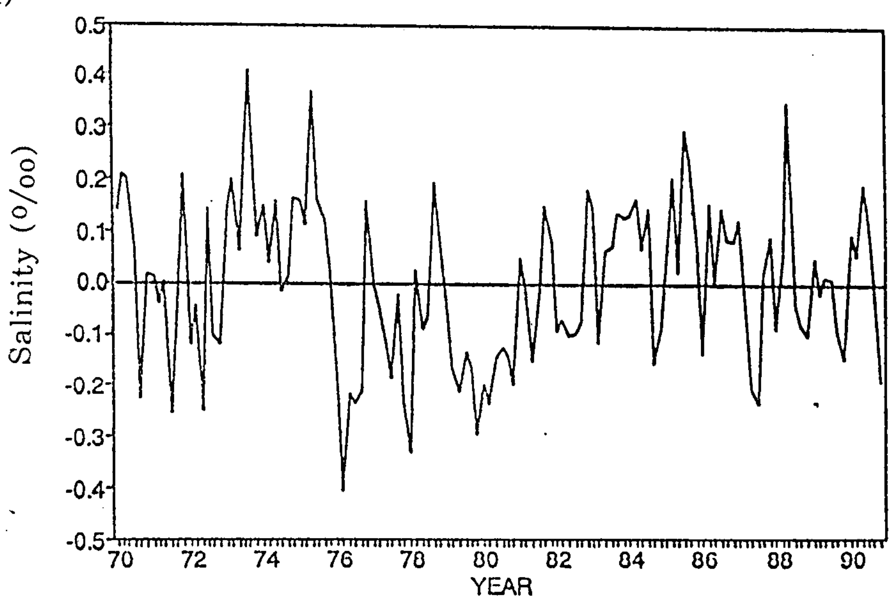


Fig. 4. Anomalies of (a) mean temperature, (b) mean salinity, (c) standard deviation of temperature, and (d) standard deviation of salinity at 75 m depth in the southeast Yellow Sea from 1970 to 1988.

(c)



(d)



(continued)
Fig. 4. Anomalies of (a) mean temperature, (b) mean salinity, (c) standard deviation of temperature, and (d) standard deviation of salinity at 75 m depth in the southeast Yellow Sea from 1970 to 1988.

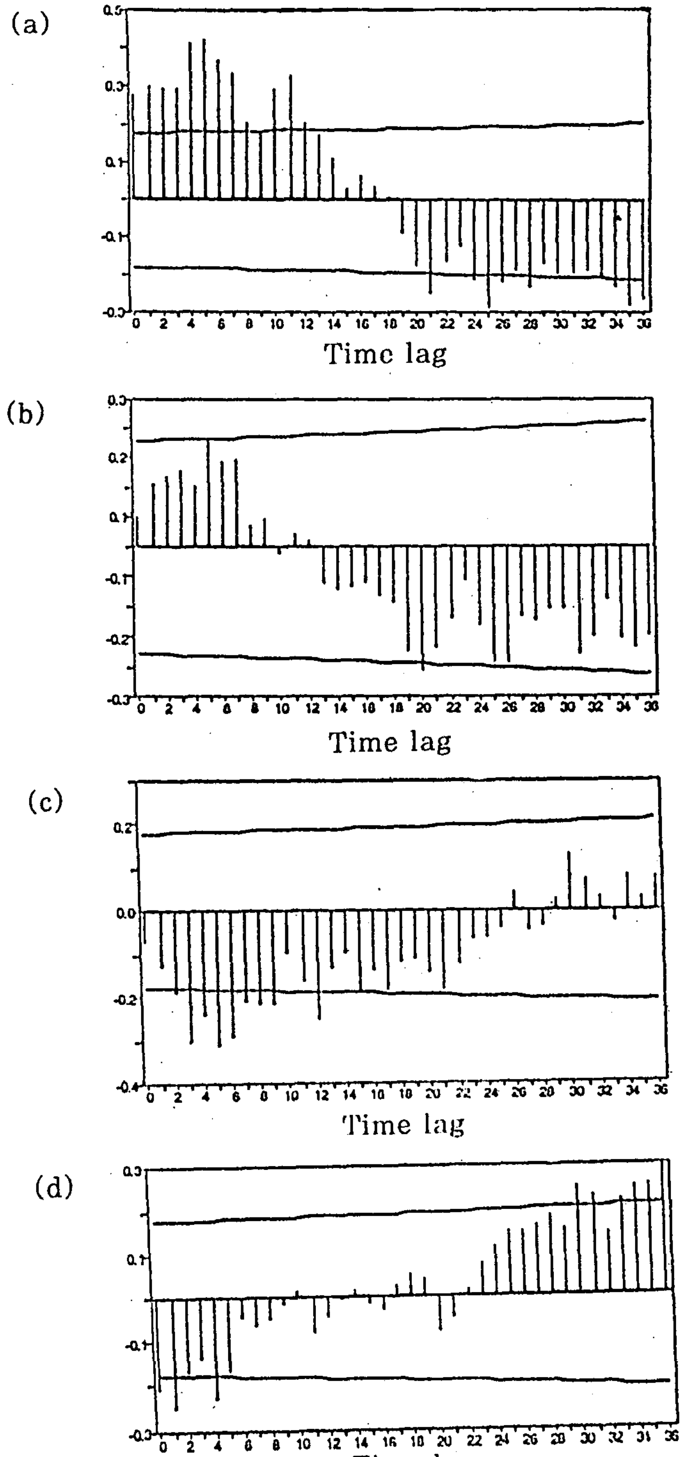


Fig. 5. CCF between water properties residual at 75 m and catch residual: (a) mean temperature and catch residuals, (b) mean salinty and catch residuals, (c) standard deviation of temperature and catch residuals, and (d) standard deviation of salinity and catch residuals. One unit of tick in time lag indicates 2 months, and two horizontal lines in each box are the limits of 95% of confidence interval.

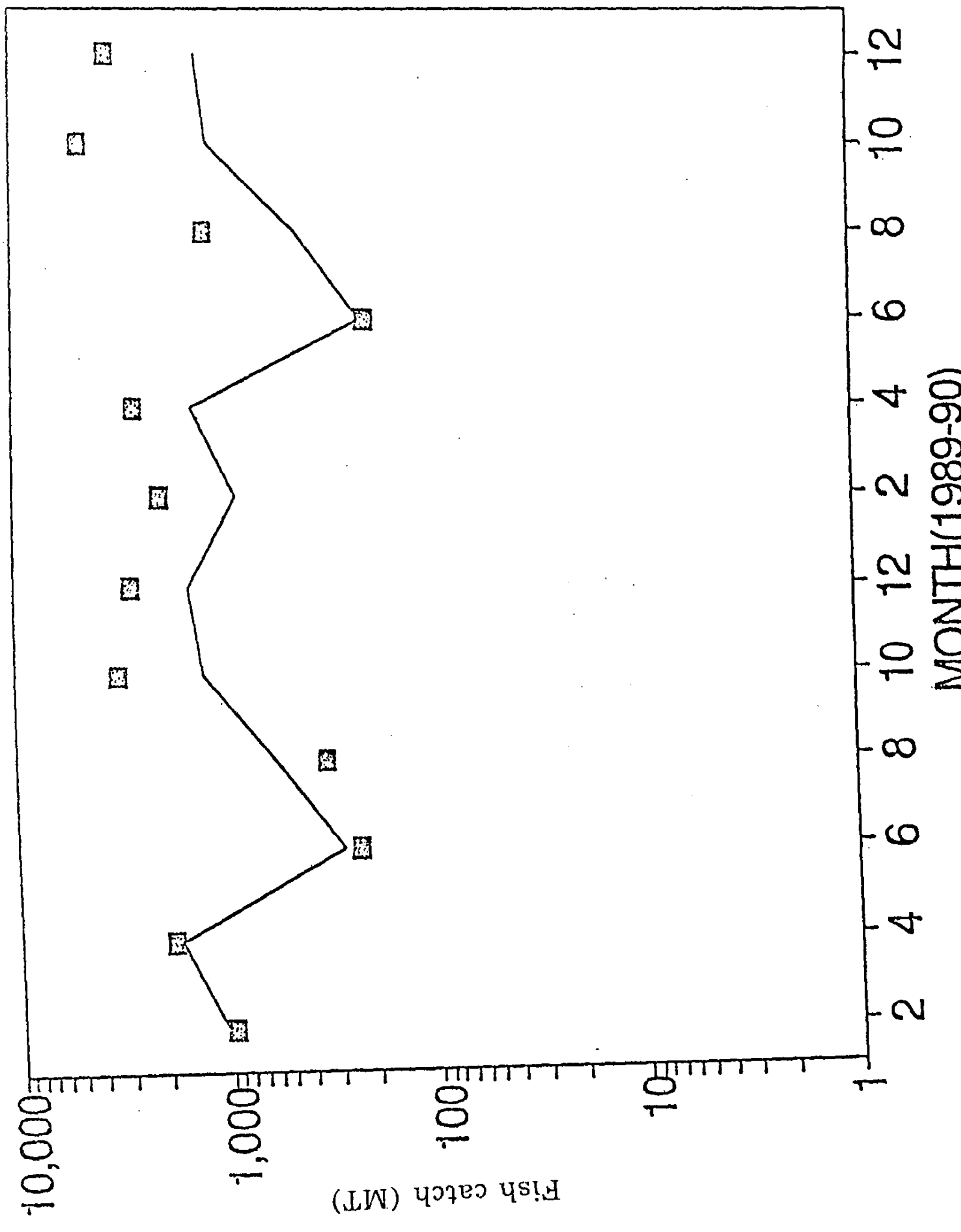


Fig. 6. Real catch (black rectangle) and forecasted catch (line) of small yellow croaker in 1989 and 1990.

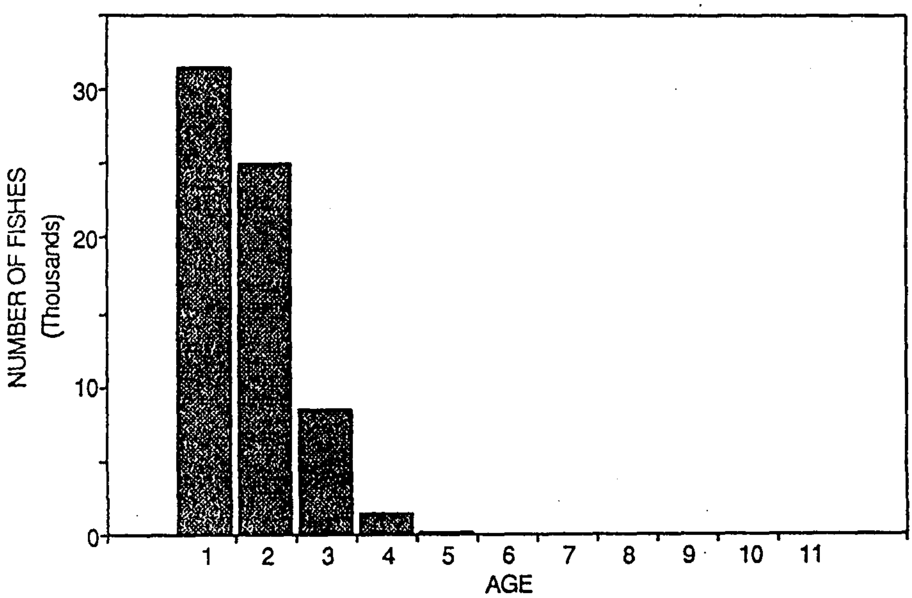


Fig. 7. Age composition in number of catches of small yellow croaker off Korea in 1988.