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# AVAILABILITY AND POPULATION STRUCTURE OF SPOTTED MACKEREL, *SCOMBER AUSTRALASICUS*, IN THE ADJACENT WATERS OF TAIWAN

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## ABSTRACT

To clarify the population structure and catch variation of spotted mackerel *Scomber australasicus* Cuvier and Valenciennes in the adjacent waters of Taiwan, catch statistics of large purse seiners operating in the waters of northeastern (NE) and southwestern (SW) Taiwan was collected and size composition of the catch was measured from 1981 to 1987. The catch variation was related to the water temperature of fishing areas. In addition, the translocation of the spotted mackerel population between NE and SW areas was discussed.

Large purse seining has replaced the handlining and became the main fishing method for mackerel in Taiwan since 1977. The fishing grounds were concentrated in the waters around Penchiahsu and Fishing Island (NE Taiwan) in autumn and winter and adjacent to Prata Island (SW Taiwan) during spring.

Common mackerel, *Scomber japonica* and spotted mackerel, *S. australasicus* were the dominant species about 70-90% of the catch of the large purse seiner.

Common mackerel was caught in the NE area only and their size distributed mainly at 20-30 cm in fork length (FL), the size of immature fish and sizes over 30 cm FL were not common. Spotted mackerels were found in both NE and SW areas and size comprised almost all of the range aged from one to five-year-old.

Spotted mackerel migrated from the north to the NE area for overwintering and to the SW area for spring spawning.

The water temperature in the NE fishing ground in winter 1983 was higher than the optimum temperature (20-22°C) for catching mackerel; thus, the fishing area shifted to the north of Taiwan and the mackerel catch significantly decreased in 1983.

## INTRODUCTION

Two species of mackerels, common mackerel *Scomber japonica* Houttuyn and spotted mackerel *S. australasicus* Cuvier and Valenciennes, were found in the waters off Taiwan. Of these, spotted mackerel was the overwhelming majority in production (Chang and Lee 1971). The annual landings were approximately 10,000 to 30,000 tons. Before 1977, most of the mackerels were caught by handliners. Afterwards the handliners have been replaced mostly by large purse seiners. Also, the mackerel fishing area has extended to the offshore waters of northeastern (NE) and southwestern (SW) Taiwan.

The population biology of spotted mackerel, e.g. maturity and spawning (Chang and Wang 1970; 1971), age and growth (Ku and Tzeng 1985), stock identification (Chang and Chen 1976) and tagging experiment (Chang and Wu 1977a) have been well documented. But, the distribution and movement of the spotted mackerel in the Taiwan adjacent waters were lacking, because the handliner's fishing ground was restricted around inshore waters and the catch statistics was not available. Based on the current catch and effort data of purse seiner, the distribution is very likely delineative.

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Moreover, the distribution, migration, and catch of mackerels correlated to water temperature (Cho 1981; Tzeng 1986). The spotted mackerel migrated from the East China Sea into the waters of NE Taiwan in winter (Tsujita and Kondo 1957). Thus, the monthly catch of mackerel in the NE area increased when water temperature began to decrease from autumn, and the seasonal catch reached a monthly peak in winter (Tzeng 1986). As a consequence, the relationship between the catch of mackerel in the NE area and the water temperature was analyzed, and the possible interpretation of the decline of catch in 1983 was addressed.

## MATERIAL AND METHOD

The catch and effort data of large purse seiners had been collected consecutively from 1981 to 1987. The magnitude of the catch of each haul was recorded by locations (longitude and latitude) and by species. Based on these data, the catch per unit effort (CPUE) was calculated by each $30' \times 30'$ statistical quadrant to express the stock density; and the spatial variation of CPUE could be used to investigate the distribution of mackerel.

The size compositions of both common and spotted mackerels were measured respectively from the landings of large purse seiners at Su-Ao fish market from July 1981 to October 1987. Age composition of catch was back-calculated from incorporation of the growth curve (Ku and Tzeng 1985) and the size composition trend.

Surface water temperature was measured at fishing areas by using a digital thermometer in each net casting. Then, the monthly mean temperature was calculated and related to the monthly catch of the mackerel. In addition, mean, standard deviation, maximum and minimum catches per haul were also calculated at 0.5°C interval of surface water temperature to understand the optimum temperature for catching mackerel.

## RESULTS

### 1. Mackerel fisheries in Taiwan

The development of mackerel fisheries in Taiwan could be understood from the fluctuation of annual mackerel landings in the past two decades. As shown in Fig. 1, from 1963 to 1977, handline and small purse seine were the main fishing methods for mackerel, the total catch was about 10,000 tons in 1963 and increased to about 30,000 tons in 1970. After 1971, the total catch declined abruptly until the efficient large purse seiner was introduced into Taiwan in 1977. The catch increased rapidly to a historically high level in 1979, and the number of large purse seiner increased to four sets. The total annual catch by large purse seiner (Fig. 2) has been about 20,000 tons since 1979 (excluded 1983). The large purse seine has become the main fishing method for the mackerel in recent years.

### 2. Species composition of catch

The monthly and yearly variations of species composition in large purse seiners' catch at the waters near Penchiahsu-Fishing Island (NE Taiwan) and Prata Island (SW Taiwan) were shown in Figs. 3 and 4. Mackerels were the dominant species in the catch of large purse seiner, approximately 50–70% in spring-summer and 70–90% in autumn-winter.

Regionally, the mackerels comprised approximately 70% of the large purse seiner's catch in the NE area from 1981 to 1986. On the other hand, it varied greatly from 100% in 1982 to 40% in 1984 in the SW area. Of the mackerels, two species, common and spotted mackerel, are dominant and mix in the catch; however, the spotted mackerel apparently was an overwhelming majority in production.

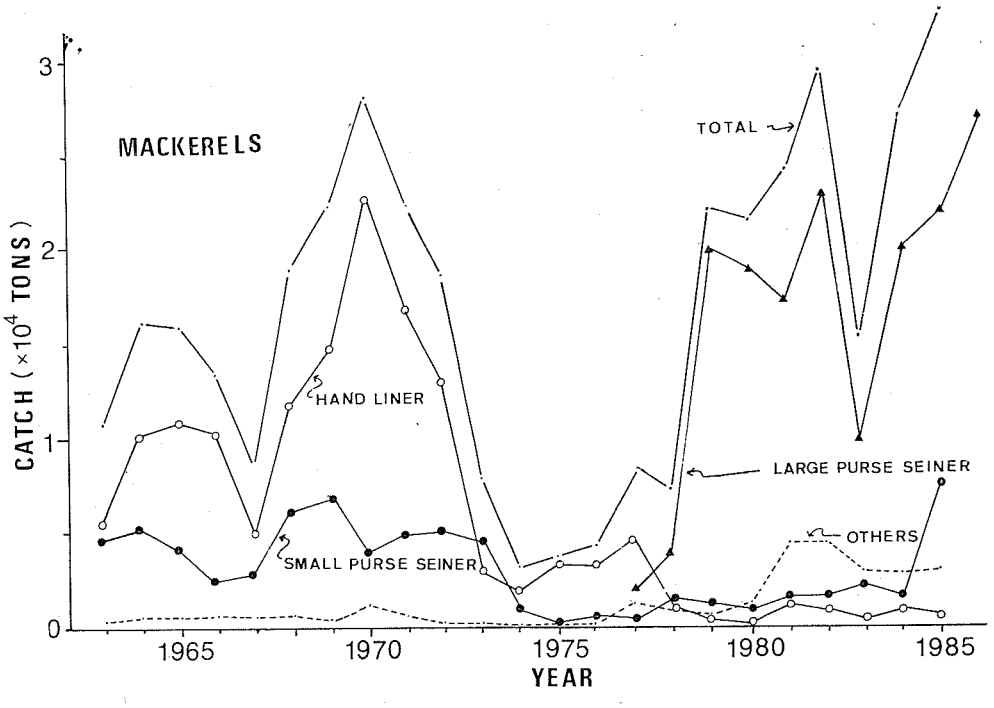


Fig. 1. Annual catch of mackerels of each type of fisheries in Taiwan.

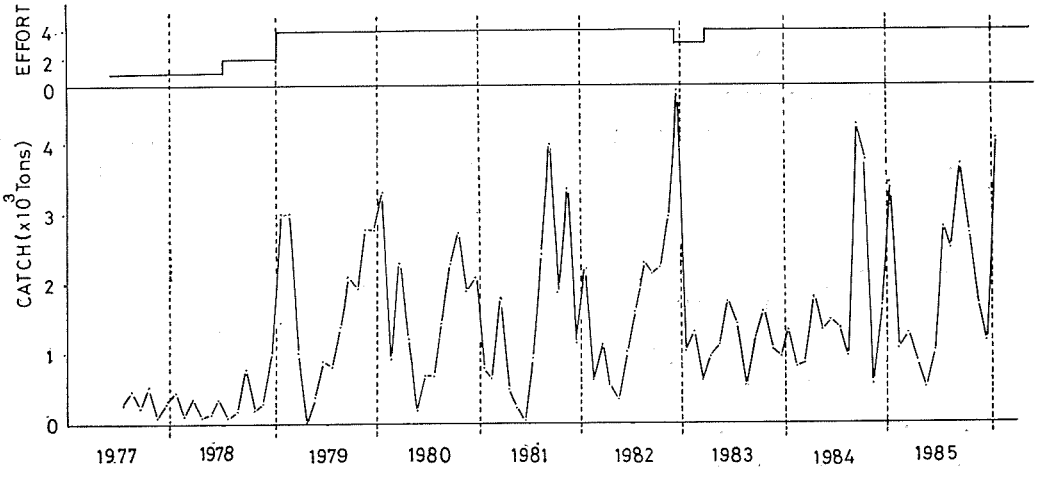


Fig. 2. Monthly changes of the catch of mackerels and scads from large purse seiners in the adjacent waters of Taiwan, July 1977-Jan. 1986. Effort indicate the number of large purse seiners.

### 3. Length and age compositions

The seasonal variations of length frequency distribution and age composition of the catch of spotted mackerel, *Scomber australasicus* in both NE and SW areas were shown in Figs. 5 and 6 respectively. There were two dominant modes in the length frequency distribution of spotted mackerel, 20–25 cm and 30–35 cm in fork length (FL), found in the

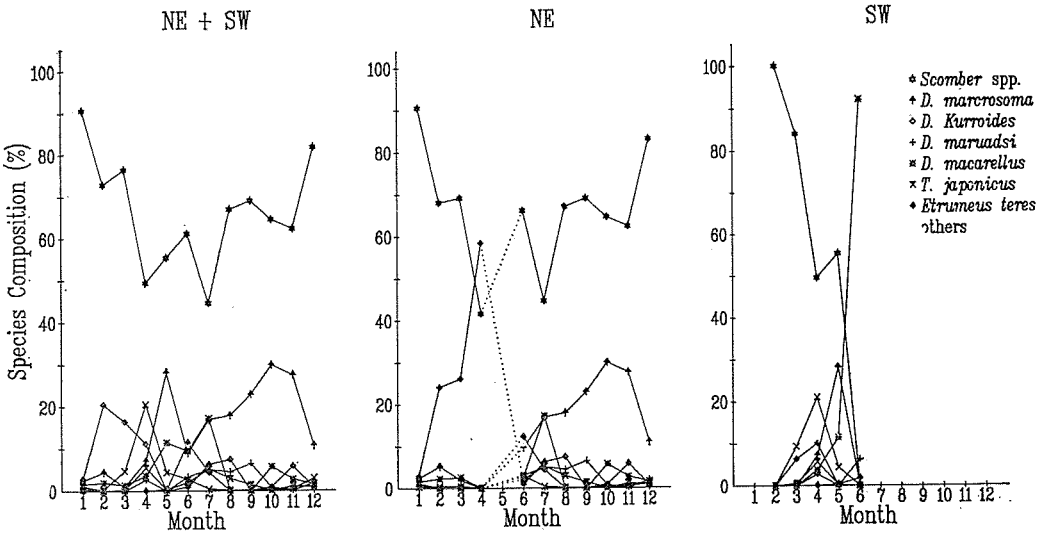


Fig. 3. Monthly variations of species composition of the catch of large purse seiners in the northeastern (NE) and southwestern (SW) waters off Taiwan.

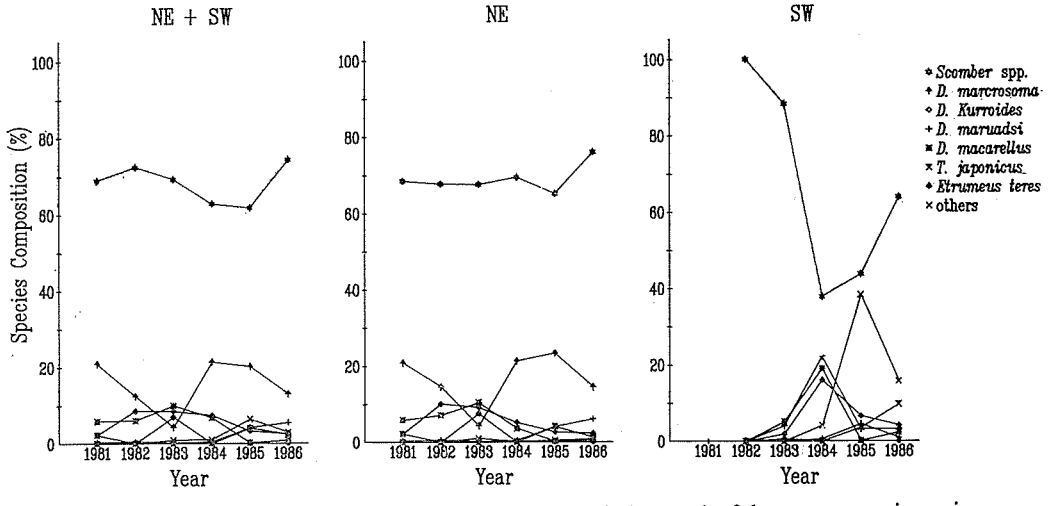


Fig. 4. Yearly variations of species composition of the catch of large purse seiners in the northeastern (NE) and southwestern (SW) waters off Taiwan, 1981-1986.

NE area (Fig. 7). The spotted mackerel of 20-25 cm FL aged one year in the NE area occurred from autumn through winter, and grew to 25-30 cm FL in the following year. The spotted mackerel of 30-35 cm FL, aged 3- and 4-year-old fish, were found through most of the year. In general, the age composition of spotted mackerel in the NE area constituted of multiple ages, no dominant year class was found in the investigated years, 1981-87.

The fishing season for spotted mackerels in the SW area was mainly concentrated during spring and early summer from February to May. The length frequency of spotted mackerel was mainly the major mode of 35 cm FL aged 3- and 5-year-old for most years and a minor mode of 30 cm FL aged 2- and 3-year-old for 1985 and 1987 (Fig. 6). It

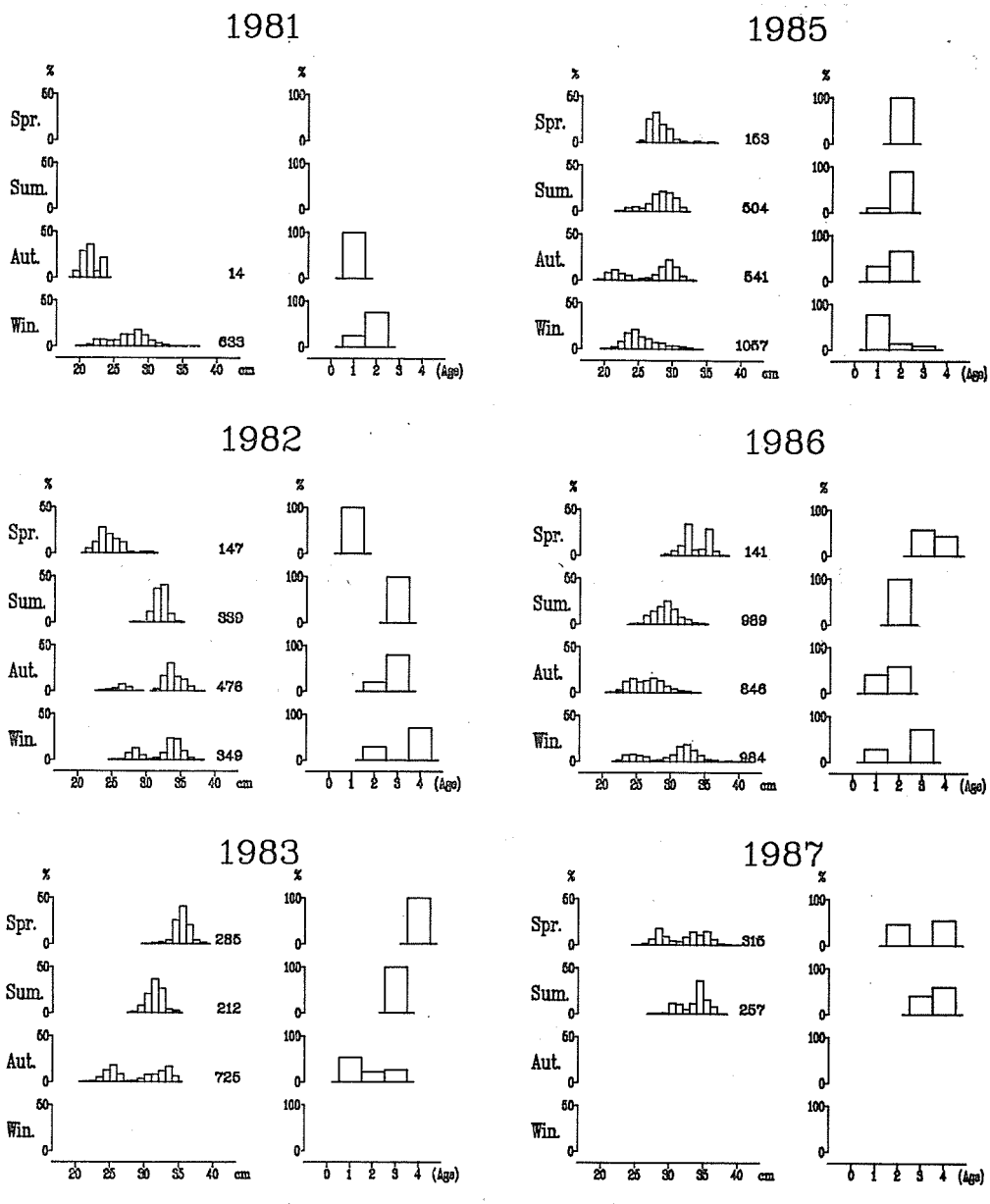


Fig. 5. Seasonal variations of fork length frequency distribution and age composition of spotted mackerel *S. australasicus* in the waters of northeastern Taiwan, 1981–87. Numerals in the diagram indicate sample size.

indicated that the spawner of spotted mackerel in the SW area constituted mainly of 4- and 5-year-old fish.

On the other hand, the length frequency distribution of common mackerel, *S. japonica* was also investigated. Common mackerel was not found in the SW area. The length frequency distribution of common mackerel in the NE area mainly constituted of 20–30 cm FL. Common mackerel with length over 30 cm FL were not found frequently in this area (Fig. 7).

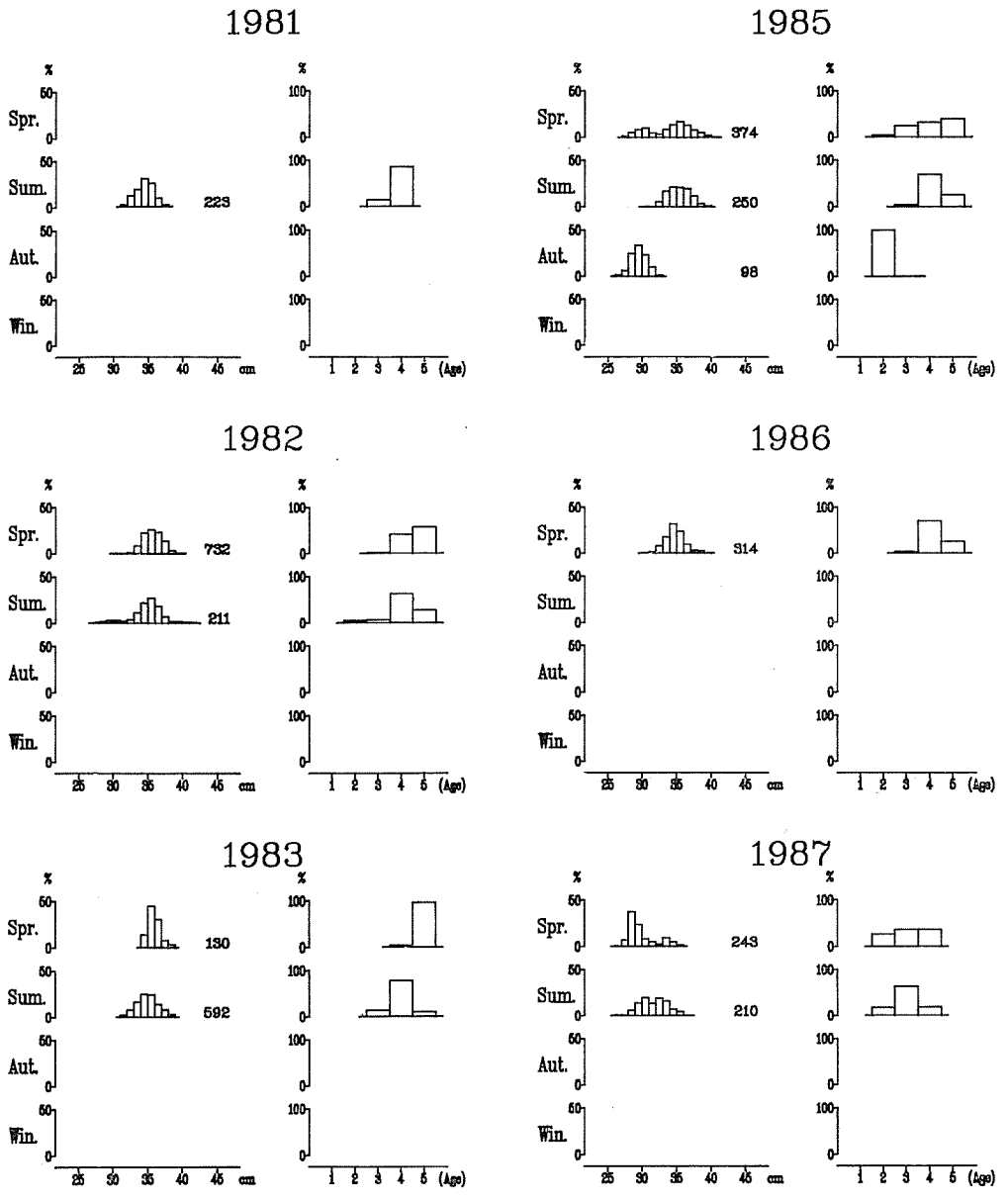


Fig. 6. Seasonal variation of fork length frequency distribution and age composition of spotted mackerel *S. australasicus* in the waters off southwestern Taiwan, 1981-87.

**4. Seasonal variability of distribution**

The seasonal migration and distribution of mackerel in the adjacent waters of Taiwan was investigated from the seasonal variations of stock density estimated from large purse seiners' catch at the NE and SW fishing areas (Fig. 8). At the NE area the high density distributed from 25°30′ to 27°30′ in autumn, then shifted southward to the north and northeastern coastal waters of Taiwan in winter. At the SW area, the mackerel occurrd in winter and spring, but higher in spring; however, the mackerel has never found in Taiwan Strait between mainland China and Taiwan.

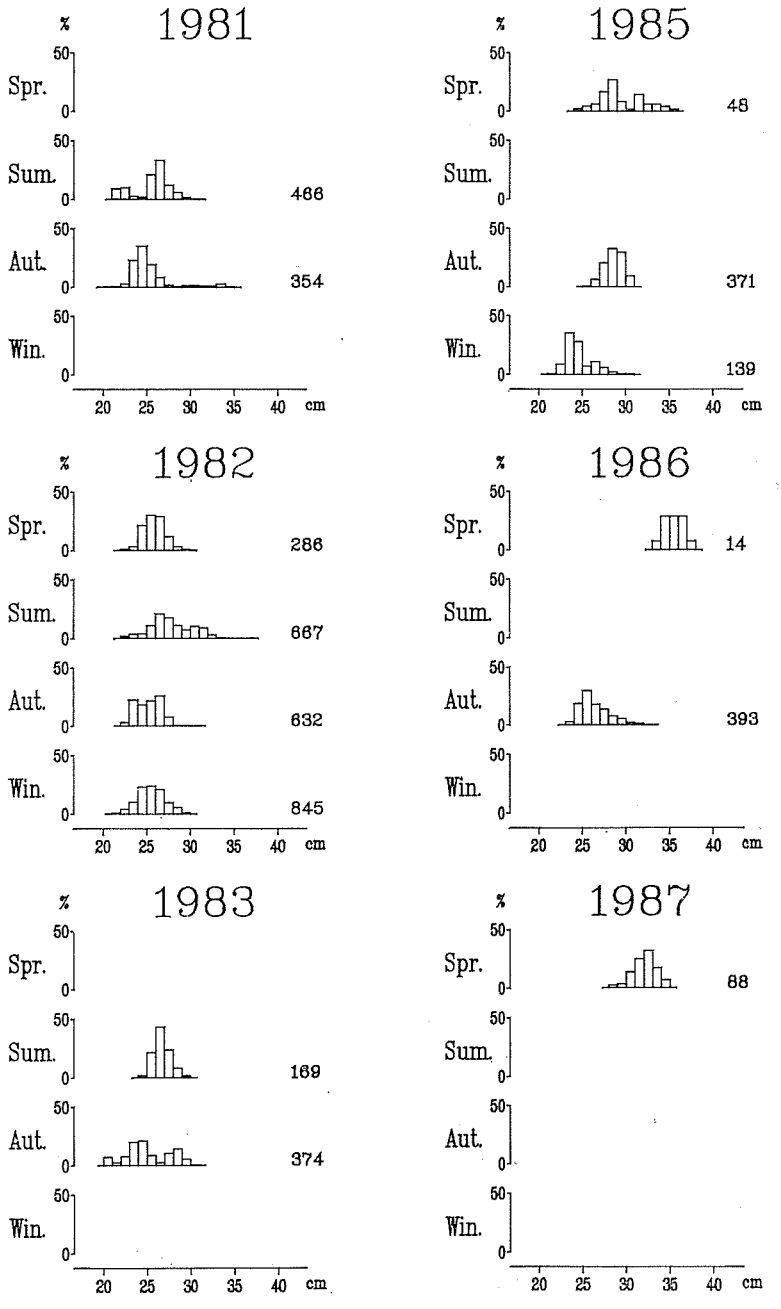


Fig. 7. Seasonal variation of fork length frequency distribution of common mackerel, *S. japonica* in the waters off northeastern Taiwan, 1981-87.

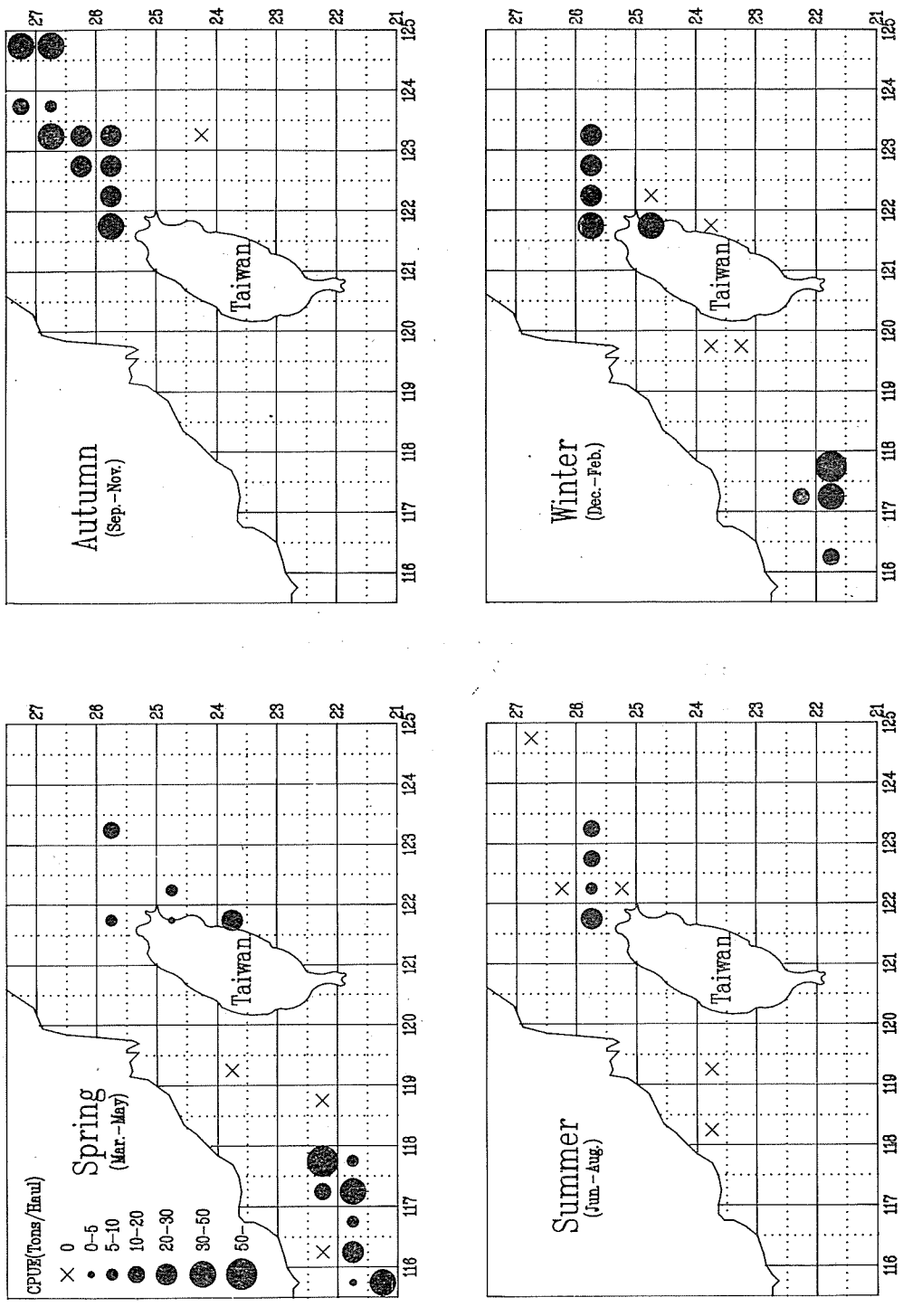


Fig. 8. Seasonal variation of density distribution of mackerels in the adjacent waters of Taiwan.

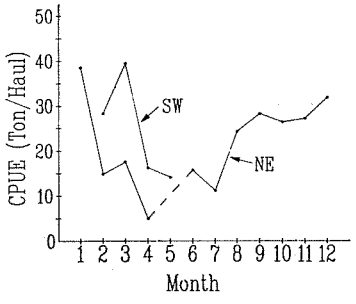


Fig. 9. Monthly changes of the CPUE of mackerels in the northeastern (NE) and southwestern (SW) waters off Taiwan.

The spawning season of mackerel in both NE and SW areas was from February to April (Chang and Wang 1970; Ku and Tzeng 1985). Therefore, the SW area seemed to be the main spawning ground for the mackerel and only small shoals were found in the NE area. On the other hand, the monthly variation of CPUE at both SW and NE areas also showed similar tendency (Fig. 9). CPUE increased from August and peaked in January at the NE area. But, CPUE decreased at the NE area and increased at the SW areas from February. CPUE became low at both NE and SW areas after March. Therefore, it was considered that mackerel migrated from north to the waters of northeastern Taiwan to overwinter and then migrated to the waters of southwestern Taiwan to spawn in spring.

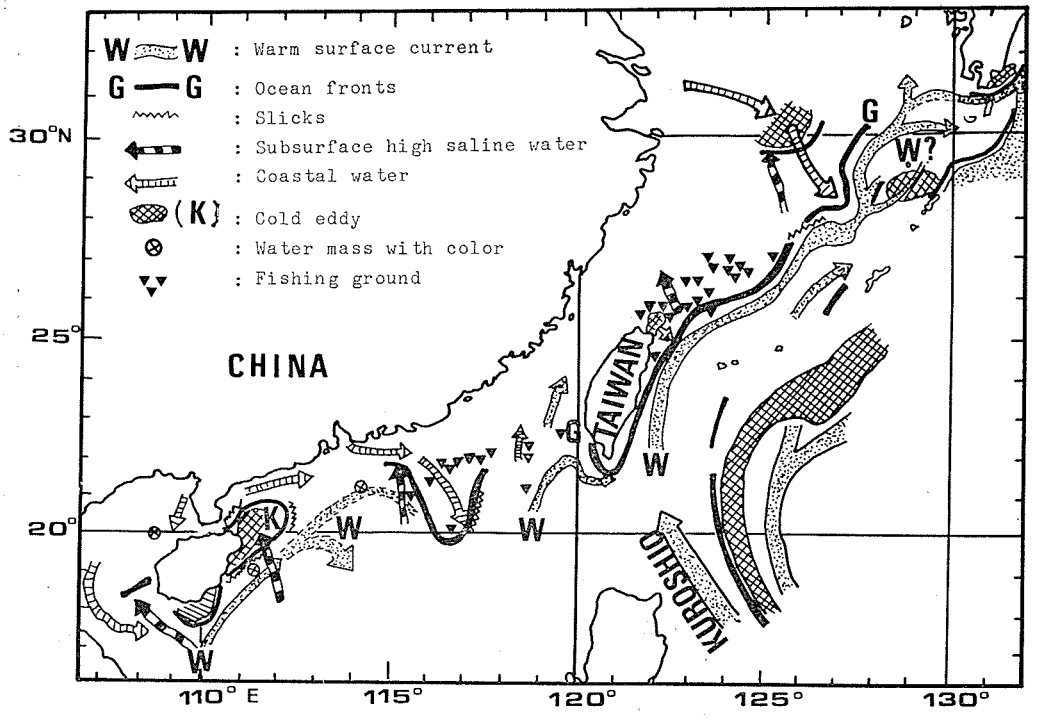


Fig. 10. The fishing grounds of mackerels caught by Taiwanese large purse seiners and the Uda's (1960) generalized oceanographic features in the adjacent waters of Taiwan.

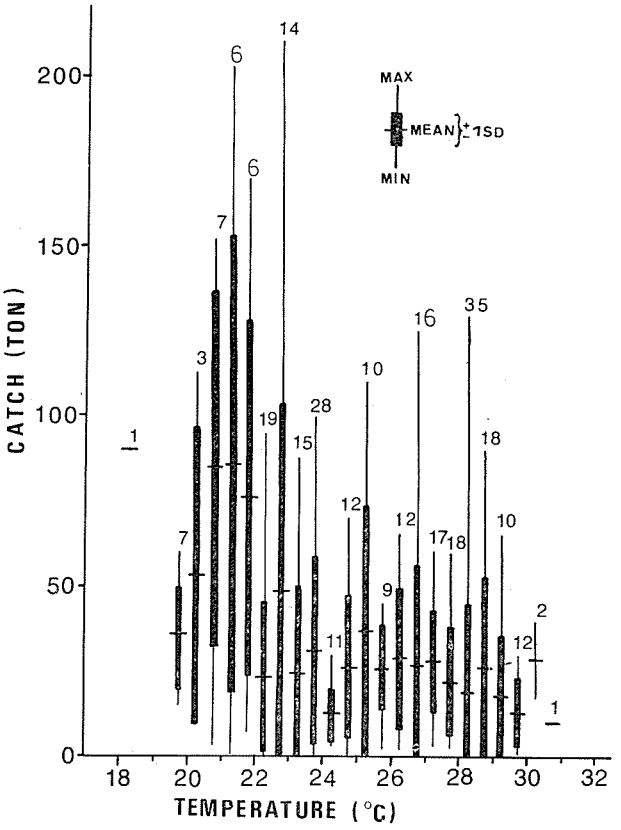


Fig. 11. The relationship between sea surface temperature and the catch of mackerels in the waters off northeastern Taiwan.

**5. Fluctuation of catch and water temperature**

The oceanographic conditions were mapped at Taiwanese purse seiners' fishing area (Fig. 10), and it was discovered that the mackerel fishing areas were located at the regime of cold and low saline coastal waters rather than warm and high saline Kuroshio waters. Moreover, Fig. 11 indicated that the catch of mackerel was strongly related to water temperature, and the temperature for the optimum catch of mackerel was found to be between 20–22°C at the NE area. The catch declined obviously when the temperature was above 23°C.

Accordingly, the relations of CPUE of mackerel with the water temperature (Fig. 12) might depict the vagaries of 1983 dramatic catch reduction. Figs. 12 and 13 showed that in 1983 the water temperature being higher than optimum (22°C) resulted in the retardation of southward migration of mackerel in autumn-winter.

## DISCUSSION AND CONCLUSION

The distribution of common mackerel and spotted mackerel were overlapped in the East China Sea. But their habitats were slightly separated, common mackerel was more abundant in the north and spotted mackerel in the south (Tsujita and Kondo 1957). In the adjacent waters of Taiwan, common mackerel was occasionally caught with spotted mackerel at the NE but not at the SW area. However, this phenomenon was reverse in

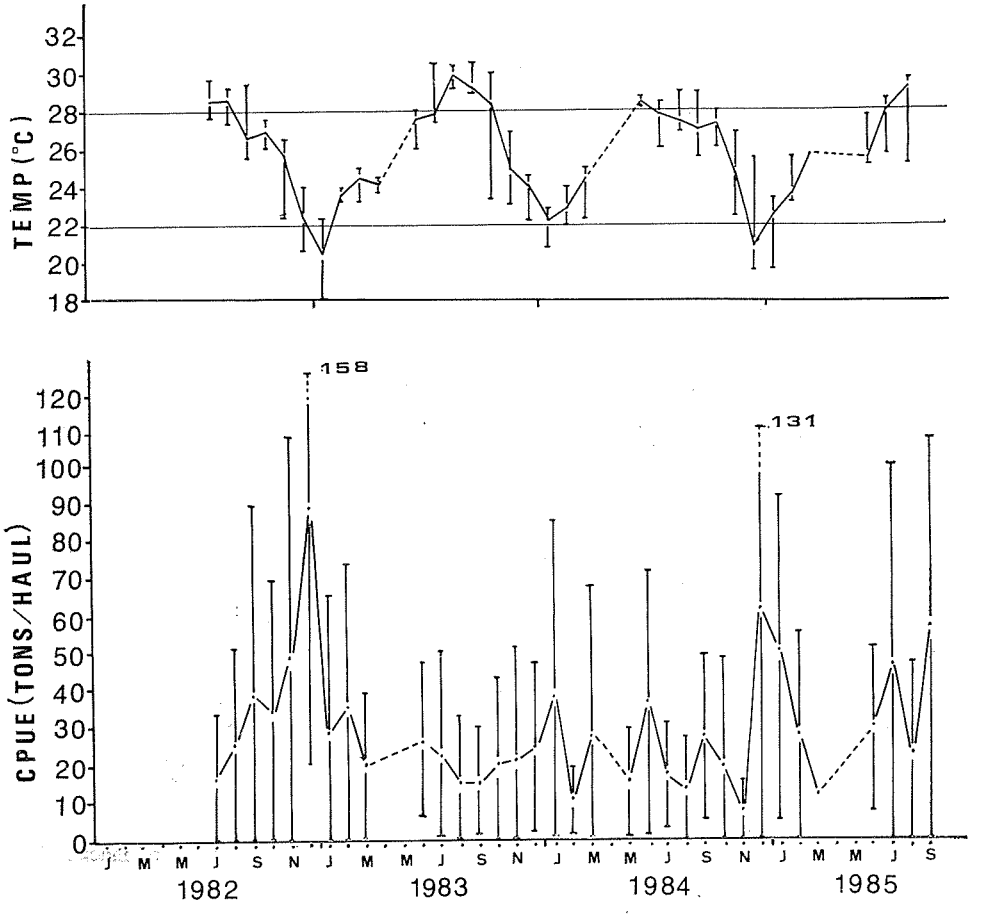


Fig. 12. Monthly variations of water temperature (mean ± 1SD) and the CPUE of mackerels (mean and max and min values) in the waters off northeastern Taiwan, 1982-85.

Japan; common mackerel was the main population in the coastal waters of Japan, a small part of immature spotted mackerel was found occasionally (Kawasaki 1966; Tzeng *et al.* 1980). Therefore, the spotted mackerel was the main harvesting population by purse seiners in the adjacent waters of Taiwan.

The population structure of spotted mackerel in the adjacent waters of Taiwan have not been clarified yet, especially those in the SW area which has been a newly exploited fishing ground since the time of large purse seiner introduction into Taiwan in 1977. Almost the same time a different stock of spotted mackerel had been claimed in the adjacent waters of NE and SW Taiwan (Chang and Chen 1976; Chang and Wu 1977b). Tsujita and Kondo (1957) indicated that spotted mackerel migrated seasonally in the East China Sea; they migrated southward for overwintering and spawning during winter and spring, and northward for feeding in summer. The present study revealed that spotted mackerel in the adjacent waters of Taiwan was likely the same population in the East China Sea, since a lot of spotted mackerel migrated to the NE area of Taiwan (Penchiahsu-Fishing Island) during autumn and winter (Fig. 8), and the tagged mackerel released in

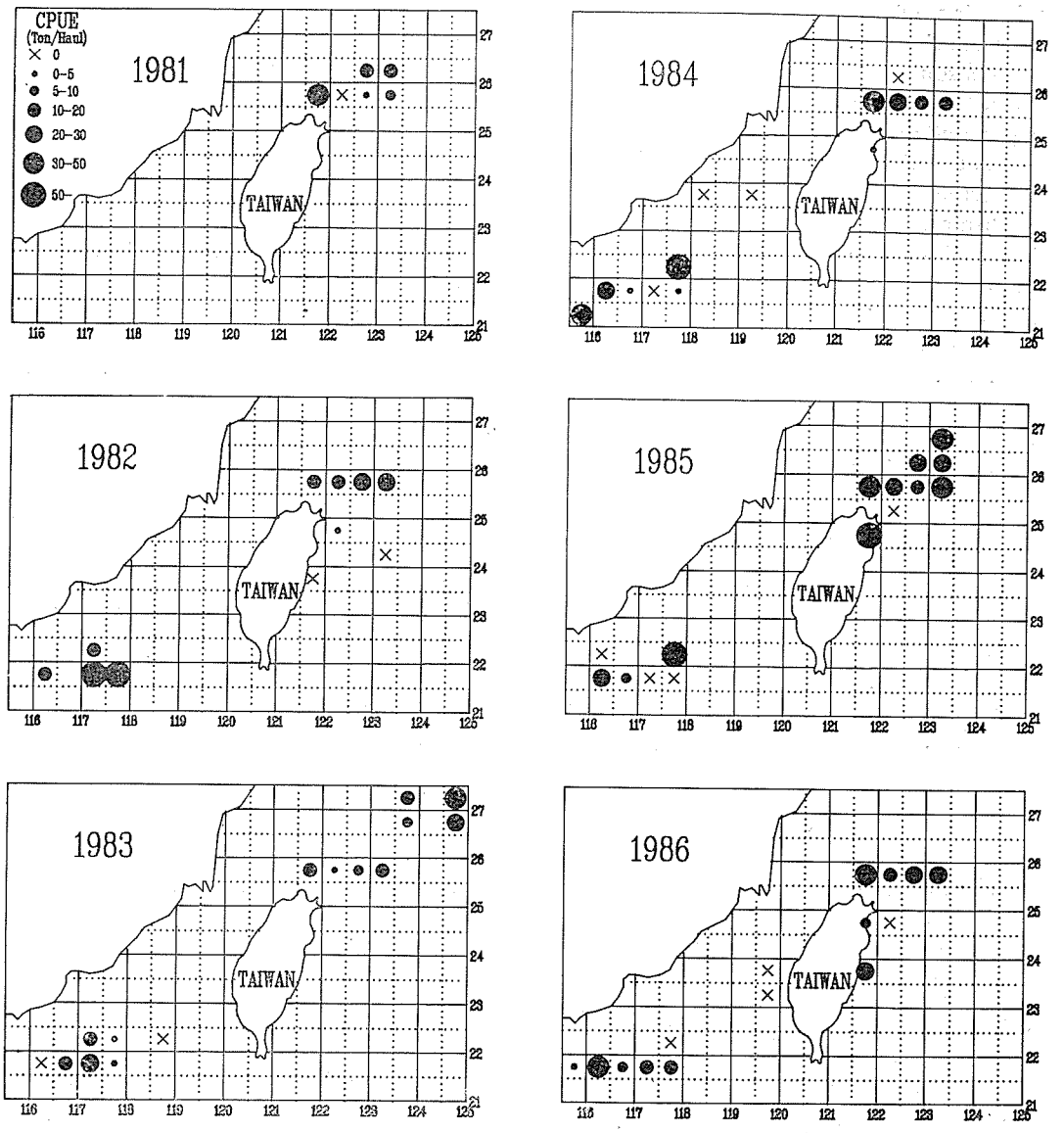


Fig. 13. Yearly variation of density distribution of mackerels in the adjacent waters of Taiwan, 1981-86.

the NE area of Taiwan during autumn and winter had been recaptured in the East China Sea (Chang and Wu 1977a). The spotted mackerel migrated from the East China Sea into the NE area of Taiwan might be for overwinter. The spawning season of spotted mackerel was from February to April (Chang and Wang 1970; Ku and Tzeng 1985). During the spawning season, spotted mackerel was found to be more abundant in the SW area than in the NE area. Therefore, it is inferable that potted mackerel migrated southward to SW area of Taiwan to spawn. In summer, spotted mackerel diffusion from both SW and NE areas might indicate that they migrated northward. In general, the seasonal

migration of mackerel was following the seasonal change of oceanographic condition (Kawasaki 1966). The oceanographic condition in the NE and SW areas (Chu 1970; Williamson 1970) seemed to be corresponding the presumed seasonal migration of the spotted mackerel. However, in order to delimit their migratory path, an intensively tagging study has to be proposed.

The activity of Tawanese large purse seiners were restricted on the adjacent waters of northeastern and southwestern Taiwan. Therefore, any fluctuation of oceanographic conditions, which could influence the distribution and migration of spotted mackerel, have directly influenced the fluctuation of the catch of purse seiner (Cho 1981). Spotted meckerel migrated from the East China Sea southward to the NE area of Taiwan behind the decrease of water temperature in winter. The water temperature in the fishing ground of the area in 1983 was higher than the temperature of the optimum catch for mackerel (Fig. 11). May be due to the high temperature in the NE area in 1983, the southward migration of spotted mackerel in the East China Sea was retarded. Thus, the fishing grounds of mackerel shifted away from the traditional flshing grounds northward to 27°N (Fig. 12). So the catch of mackerel in the adjacent waters of Taiwan in 1983 obviously decreased (Fig. 2). Therefore, the availability of the mackerel in the adjacent waters of Taiwan was obviously affected by oceanographic condition.

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# 淡水河口 *Encrasicholina punctifer* 及 *Stolephorus insularis* 仔稚魚之攝食策略－I. 個體發生過程之食性轉換及其與形態之相關

陳 楊 宗・曾 萬 年

# Feeding Strategy of *Encrasicholina punctifer* and *Stolephorus insularis* Larvae in the Estuary of Tanshui River, Taiwan—I. Ontogenetic Dietary Shifts and Morphological Correlation

Yarng-Tzung Chern and Wann-Nian Tzeng

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