Relations of Fluctuations in Standing Crop of Kuruma Prawn among the Fisheries along the Buzen District\(^*\)

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This paper treated relations of fluctuations in the standing crop of kuruma prawn *Penaeus japonicus* among the set net, gillnet and small boat seine fisheries in the fishing area around Minosima, Fukuoka, to clarify their qualitative characters for the purpose of deriving a method for analysing quantitatively such relations in future. A log transformed standing crop index of the prawn was expressed by the moving average of log transformed catch per unit effort of 9 2-days. Among the three fisheries, a relation of long-term changes in their index was not always constant in the season and hence was non-stationary. An analysis of short-term changes in the index gave the following results. The index for the gillnet fishery changed nearly synchronously with that for the set net fishery in a short term but the short-term change in the former seemed to occur somewhat later than one in the other. The index for the small boat seine fishery changed behind that for the set net and gillnet fisheries by 6-9 and 4-6 2-days, respectively, in a short-term. The respective time lags between two of the three fisheries seemed to correspond roughly to the distances between their fishing areas.

The waters around Minosima, Yukuhasi, are one of the most important fishing areas of kuruma prawn *Penaeus japonicus* along the Buzen District, Fukuoka. The main exploited populations of the prawn in the area recruit from Minosima tidal land and migrate into offshore with growth.\(^1,2\) The populations are fished by a set net and a gillnet, called masuami and tateami respectively, in nearshore and by a small boat seine, called ebikogiami, in offshore in the course of their migration, and the distance between the fishing areas in nearshore and offshore is more than 3 km. The preceding paper\(^2\) analysed the daily catch data concerning the kuruma prawn fisheries in the fishing area around Minosima over the period of 1974 to 1978 and gave a method for dividing the variation in catch per unit effort (CPUE) into two components \(\gamma\) and \(\alpha N\), which referred to the variation in the efficiency of fishing gear and availability on a relatively short time scale and to one in CPUE on a long time scale, respectively. \(\alpha N\)'s obtained by the method present similar tendencies among the three fisheries every year as shown later.

For predicting the catch of an exploited migrant fish population in a fishing area after a few weeks, the informations on its catch in somewhat distant areas have been frequently used on the bases of our experiences. Many investigators (for example, Mitani\(^3\) and Kakuda\(^4\)) have already reported qualitatively comparative studies on catch of exploited fish populations between fisheries or among areas but it is likely that there are a few reports on quantitatively comparative ones. Because CPUE is influenced not only by the standing crop of exploited populations but by the efficiency of fishing gear and availability,\(^6\) a relation of CPUE between fisheries or fishing areas may be supposed to be complicated to considerable degree. This paper treated relations of the changes in the standing crop of kuruma prawn among the set net, gillnet and small boat seine fisheries in the fishing area around Minosima and clarified their qualitative characters, for the purpose of deriving a method for analysing quantitatively such relations in future.

Data and Methods

Analyses were made with the statistics of daily kuruma prawn catch and fishing effort in boat-day for the set net, the gillnet and the small boat seine by the commercial fisheries in the fishing area around Minosima from 1974 to 1978, which are the same data as in the preceding paper\(^2\). The gillnet is operated in the nearly same area with that where the set net is set but the area of the

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former is somewhat larger and more offshore than the other. Using the data, CPUE in 2-day period at time $t$, $C(t)$, was calculated for each fishery. For CPUE's at the time of no fishing, was used the geometrical average of CPUE's just prior and posterior to them.

The respective fishing seasons are from late May or early Jun. to mid or late Dec. in the set net fishery, from early or mid Jun. to late Nov. in the gillnet fishery and from early or mid Jun. to the end of Oct. in the small boat seine fishery. Since CPUE for the gillnet fishery decreased markedly near the end of the season in many years in question, this paper analysed standing crop index of the prawn, which will be defined later, for the set net and gillnet fisheries from Jun. to Oct. every year except 1977. For 1977, were analysed the data about the set net and gillnet fisheries from mid Aug. to Nov. since the gillnet fishery had comparatively many days of no fishing and its CPUE was very low till mid Aug. For the small boat seine fishery, this paper dealt with the standing crop index over the period of Jun. to early Oct., 1974–1976, since it had many days of no fishing over the season in 1977 and 1978 and CPUE decreased markedly near the end of the season, or late Oct., in 1974–1976.

An index of the standing crop of the prawn, $\alpha(t)N(t)$, was determined as a first approximation by Eq. (1) which had been derived in the preceding paper,

$$\log \alpha(t)N(t) = \frac{1}{2T+1} \sum_{t-2}^{t} \log C(t+i), \quad (1)$$

where $\alpha(t)$ is a relatively long-term component of the variation in catchability coefficient and availability at $t$, $N(t)$ standing crop at $t$ in the area where the member of the population has a chance of being fished and $T$ a positive number whose estimate was given $T=2$ 2-days by a spectral analysis on log $C$. Here, it should be noticed that $\alpha(t)$ in Eq. (1) is always not constant because there is a possibility that catchability coefficient and availability change on an intermediate or long time scale with changes in environmental conditions such as water temperature etc. and the ecology of the species.

![Fig. 1. Typical examples of fluctuation in the standing crop index of kuruma prawn, $\alpha(t)N(t)$, calculated by using $T=2$ 2-days. Open and solid circles show the dates of full and new moons, respectively.](image-url)
Results

Using Eq. (1) and \( T=2 \) 2-days, \( a(t)N(t) \) was calculated as a first approximation of the standing crop index from CPUE in 2-day period for the set net and gillnet fisheries from 1974 to 1978 and for the small boat seine fishery from 1974 to 1976. Fig. 1 shows the fluctuations in \( a(t)N(t) \) for the set net fishery of 1975 and 1977 and for the gillnet fishery of 1977 and 1978 as typical examples. \( a(t)N(t) \) in Fig. 1 keeps relatively constant levels on a long time scale in these fisheries but sometimes shows cyclical patterns with the period of about 7–15 2-days. Since it was reported that the activity, or movement and migration, of shrimp in genus \textit{Penaeus} was affected by relative change in salinity occurring with tidal change\(^{1, 8})\), the dates of full and new moons are shown by open and solid circles, respectively, in Fig. 1 to clarify the characters of the fluctuations in \( a(t)N(t) \) on an intermediate time scale. As seen from Fig. 1, not a few peaks of \( a(t)N(t) \) appear prior or posterior to full or new moon. Accordingly, there remains a possibility that the strength of tidal change has the influence on \( a \) which is a parameter representing the efficiency of gear and availability. For the purpose of eliminating the component of variation in \( a \) resulting from one in the strength of tidal change, therefore, \( a(t)N(t) \) was calculated for the set net and gillnet fisheries of 1974 to 1978 and for the small boat seine fishery of 1974 to 1976 using Eq. (1) and \( T=4 \) 2-days again. The results thus obtained were shown by open circle (set net), solid circle (gillnet) and solid line (small boat seine) in Fig. 2.

In Fig. 2, though \( a(t)N(t) \)'s show different

![Graph showing standing crop indices of kuruma prawn](Image)

Fig. 2. The standing crop indices of kuruma prawn, \( a(t)N(t) \), in the set net (open circle), gillnet (solid circle) and small boat seine (solid line) fisheries. The index was calculated by using \( T=4 \) 2-days.
tendencies from year to year, their tendencies can be largely grouped to two patterns independently of the fisheries, 1974, 1976 and 1975, 1977, 1978. That is, in 1974 and 1976, \( a(t)N(t) \) increases steeply from Jun. to early or mid Jul. when it reaches a peak, then decreases rapidly till early Aug., and then hereafter keeps a relatively constant, low level. On the other hand, \( a(t)N(t) \) holds comparatively constant level, fluctuating more or less, through the whole season in the other years though its levels are different year to year. The two patterns suggest that every fishery in the area chiefly takes two main populations of the prawn which recruit in early summer and autumn, respectively, and that the long-term tendencies of \( a(t)N(t) \) depend chiefly on the difference in their sizes.

Here, let's denote \( a(t)N(t) \)'s of the set net, gillnet and small boat seine fisheries by \( X(t) \), \( Y(t) \) and \( Z(t) \), respectively, for brevity. A comparison of \( X(t) \), \( Y(t) \) and \( Z(t) \) in Fig. 2 indicates that their changes seem to be apparently proportional to one another in a short term but to show different tendencies in a long term. In 1975, for example, the relative changes in \( X(t) \), \( Y(t) \) and \( Z(t) \) are considerably similar to one another in a short term with some exceptions although the change in \( Z(t) \) occurs somewhat behind the others. In a long term, however, \( X(t) \) keeps a nearly constant level throughout the fishing season while \( Y(t) \) increases gradually over the period of Jun. to early Oct., fluctuating more or less, and \( Z(t) \) seems to change rather in a mode like \( Y(t) \) than \( X(t) \). The above mentions will be quantitatively shown in the following.

In the set net and gillnet fisheries from the first of Jun. to the first of Nov., was divided the fishing season into three sub-seasons, i.e. the first of Jun. to the 20-th of Jul., the 21-th of Jul. to the 8-th of Sept. and the 9-th of Sept. to the first of Nov., and the averages of \( X(t) \) and \( Y(t) \), \( \bar{X} \) and \( \bar{Y} \), were calculated for each sub-season every year from 1974 to 1978 except the early sub-season of 1977. \( \bar{Y} \) is plotted against \( \bar{X} \) for each sub-season in Fig. 3, in which the plots are approximately represented by linear regressions. As clear from Fig. 3, the slopes of the lines increase with the sub-season. This implies that a relation of \( Y(t) \) to \( X(t) \) does not always remain constant in the season.

To examine a relation of short-term variations in \( X(t) \) and \( Y(t) \), we calculated the cross corre-
lation coefficients of the deviations of \(X(t)\) and \(Y(t)\) from the respective trends, \(\Delta X(t)\) and \(\Delta Y(t)\). It was assumed that their trends were represented by linear regressions whose coefficients were determined at 1% level of significance. Fig. 4 presents the cross correlation coefficients of \(\Delta Y(t)\) on \(\Delta X(t)\) for each year from 1974 to 1978. The coefficients in Fig. 4 have a peak at the time lags of 0 2-day in 1974, 1 2-day in 1975 and 1977, 5 2-days in 1978 and 6 2-days in 1976, respectively. Considering that the coefficients thus obtained are affected by the method for determining the trends, it is interpreted from the above results that \(Y(t)\) changes nearly synchronously with \(X(t)\) but the change of the former seems to be somewhat later than one of the other in a short term every year.

Attempts are made to examine a relation of \(Z(t)\) to \(X(t)\) over the period of Jun. to early Oct., 1974–1976. The season was divided into two sub-seasons, Jun. to the 7-th of Aug. and the 8-th of Aug. to early Oct., and the averages of \(X(t)\) and \(Z(t)\), \(\bar{X}\) and \(\bar{Z}\), were obtained for sub-season every year. The relations of \(\bar{Z}\) to \(\bar{X}\) are shown for each sub-season in Fig. 5, in which the plots are approximated by linear regressions. Fig. 5 indicates that the slopes of the lines are higher in the late than early sub-season as in the relation of \(\bar{Y}\) to \(\bar{X}\). Fig. 6 shows the cross correlation coefficients of \(\Delta Z(t)\) on \(\Delta X(t)\), \(\Delta X(t)\) and \(\Delta Z(t)\) referring to the deviations of \(X(t)\) and \(Z(t)\) from their trends. In Fig. 6, the peaks of the coefficients appear at the time lags of 7, 6 and 9 2-days, respectively, for 1974, 1975 and 1976 and have relatively high values. It follows, therefore, that \(Z(t)\) changes behind \(X(t)\) by several 2-days in a short term but the tendencies of their long-term change differ from each other.

Let's carry out the same analyses on the data of the gillnet and small boat seine fisheries in 1974–1976. As in the set net and small boat seine fisheries, letting two sub-seasons be Jun. to the 7-th of Aug. and the 8-th of Aug. to early Oct., the averages of \(X(t)\) and \(Z(t)\), \(\bar{X}\) and \(\bar{Z}\), were calculated for each sub-season every year. \(\bar{Z}\) was plotted against \(\bar{X}\) for each sub-season in Fig. 7, where the plots were approximated by thin line (early sub-season), dashed line (late sub-season) and thick line (whole season). Fig. 7 indicates that there is no difference in the slope of the line between early and late sub-seasons, that is, there is little difference in the tendencies of the long-term changes in \(Y(t)\) and \(Z(t)\) at least in 1974–1976. Fig. 8 shows the cross correlation coefficients of \(\Delta Z(t)\) on \(\Delta Y(t)\) for each year from 1974 to 1976. The coefficients have relatively high peaks which appear at the time lags of 6, 4 and 6 2-days, respectively, in 1974, 1975 and 1976. Thus Figs. 7 and 8 suggest that \(Y(t)\) and \(Z(t)\) change in the similar manner in a long term but the short-term change in the latter is later than one in the former by 4–6 2-days.
Fig. 7. Z plotted against Y, Y and Z referring to the average standing crop indices of kuruma prawn for each sub-season in the gillnet and small boat seine fisheries, respectively, every year from 1974 to 1976. Marks show sub-season and thin, dashed and thick lines are the regression lines for the early and late sub-seasons and the whole season, respectively.

Fig. 8. Cross correlation coefficients of \( \Delta Z \) on \( \Delta Y \), \( \Delta Y \) and \( \Delta Z \) referring to the deviations of \( Y \) and \( Z \) from their trends, respectively. Marks show year.

Next, let's treat the values of the intercept of the regression lines on the ordinate axis in Figs. 3, 5 and 7. The absolute values of their estimates are low as shown in these figures and all the estimates are insignificant at 5% level.

Discussion

The preceding section determined the index of the standing crop of kuruma prawn, \( \alpha(t) N(t) \), in the fishing area around Minosima from 1974 to 1976 or 1978 using the data concerning the catch by the set net, gillnet and small boat seine fisheries and clarified the qualitative characters on the relations of \( \alpha(t) N(t) \)'s between two of the three fisheries. In the set net and gillnet fisheries, a relation of their \( \alpha(t) N(t) \)'s was not always constant throughout the season, while in a short term, \( \alpha(t) N(t) \) for the gillnet fishery changed nearly synchronously with that for the set net fishery but the change in the former seemed to occur somewhat later than one in the other. A relation of \( \alpha(t) N(t) \)'s between the set net and small boat seine fisheries showed the nearly same tendency with one between the set net and gillnet fisheries except \( \alpha(t) N(t) \) for the latter changing behind that for the former by 6-9 2-days. In the gillnet and small boat seine fisheries, \( \alpha(t) N(t) \)'s relatively changed in the comparatively similar manner in a long term but the short-term change in \( \alpha(t) N(t) \) of the latter was later than one of the former by 4-6 2-days.

In the above results, it should be noticed that the cross correlation coefficients calculated here are affected by the method for determining the trends. Comparing the time lags estimated from the coefficients, however, the respective time lags between two of the three fisheries seem to correspond roughly to the distances between their fishing areas. This supports the following results obtained in the preceding paper as far as the
short-term changes in $a(t)N(t)$ are concerned. The main exploited prawn populations recruit from Minosima tideland and are fished by the set net, gillnet and small boat seine fisheries in the course of their migration to offshore.

The tendencies of the long-term changes in $a(t)N(t)$ were different between the set net, and gillnet and small boat seine fisheries but were little different between the gillnet and small boat seine fisheries. It may be supposed, however, that there is not great difference in the changes of relations of $Y(t)$ to $X(t)$, $Z(t)$ to $X(t)$ and $Z(t)$ to $Y(t)$ with $t$ among years at least from 1974 to 1976 or 1978. For the averages of $a(t)N(t)$ in each sub-season showed approximately linear relations between two of the three fisheries and were nearly proportional to each other as seen from Figs. 3, 5 and 7. Considering a system for expressing the relation of $a(t)N(t)$'s between two arbitrary fisheries, therefore, it is predicted that the system is non-stationary at least between these net, and gillnet and small boat seine fisheries but the yearly variation of it is relatively small.

Next, an attempt will be made to discuss a non-stationary process of the considered systems. As mentioned previously, the long-term tendencies of the changes in $a(t)N(t)$ are different between the set net and gillnet fisheries in spite of their operation in the nearly same area and are little different between the gillnet and small boat seine fisheries operating in the areas distant from each other. Consequently, it is unlikely that the systems are pronouncedly affected by the immigration of the prawn populations arising in other tidelands, and hence are made non-stationary, even if they immigrate more or less practically. Accordingly, the non-stationary process of the systems is supposed to be ascribable chiefly to the changes in $a$ and/or fishing effort with time.

HASEGAWA et al.9) showed the change in catchability coefficient per unit effort with time in the kuruma prawn fishery by the gillnet in Ōmi Bay and interpreted that it resulted from the change of fishing intensity, or fishing effort per unit area, subject to the change in the area of the fishing ground occurring with the dispersion of the prawn. There is, however, a possibility that the catchability is different among some main prawn populations since they subsequently appeared in the length compositions of kuruma prawn catch8). Moreover, it can be supposed to change with water temperature as well because it has the influence on the activity of the species10).

The fishing effort is very variable in the gillnet and small boat seine fisheries, its change frequently corresponding to the abundance of the prawn in the area. In the small boat seine fishery, especially, availability to the prawn is variable even though the effort is constant, since it aims at a variety of species. We can not decide the factors which mainly make the systems non-stationary and so need to collect the informations not only on the ecology of the species but on the fishing operations. For treating a quantitative relation of the abundances of the prawn population between two fisheries in future, at the same time, it is necessary to study a reasonable method for making the systems stationary.

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References