A discarding problem of mantis shrimp in Tokyo Bay

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SUMMARY: In the present study, we studied a small trawlnet fishery in Tokyo Bay which mainly targeted mantis shrimp (Oratosquilla oratonia) and discarded many small mantis shrimp. We surveyed the numbers and body length of discarded and landed mantis shrimp aboard a small trawnet boat once a month from January 1993 to December 2000. Body length (BL) of the mantis shrimp caught by this boat ranged from 8 to 13 cm, and those less than 10 cm in BL were discarded because they are commercially unmarketable. The number of discarded mantis shrimp markedly increased in summer, reaching a high of more than a million per month. The high numbers of discarded small mantis shrimp in summer are due to 2 main factors: 1) fishermen often use nets with small mesh sizes, in order to catch other species; 2) around May, they begin catching small mantis shrimp that were spawned the year before and are still commercially unmarketable.

KEY WORDS: discarding, mantis shrimp, small trawlnet fishery, Tokyo Bay

INTRODUCTION

In this study, we investigated a small trawlnet fishery in Tokyo Bay which mainly targeted mantis shrimp and discarded a great number of mantis shrimp (Fig. 1). Mantis shrimp accounts for around 70% of total annual value of landed species (average, 8.4×10^8 yen). The fishery takes more than 50 species, including conger eel, marbled sole and kuruma shrimp. It is operated under 2 regulation systems: a limit on the quantity of landed mantis shrimp per boat-day; and a regulation stating that fishermen cannot fish for 3 consecutive days. This fishery discards great numbers of animals of many species, including many small mantis shrimp of commercially unmarketable size.1) Mantis shrimp is the main target species in this fishery. We conducted this study in order to find the reason why this fishery discards so many mantis shrimp. Based on the information obtained in this study, we propose policies for managing the mantis shrimp population.

MATERIALS AND METHODS

We surveyed body length and numbers of mantis shrimp landed and discarded on a small trawlnet fishing boat once a month from January 1993 to December 2000. We measured body length of landed and discarded mantis shrimp at intervals of 5 mm. In addition, we performed an experiment on the mortality of discarded mantis shrimp, beginning in January 1996. About 30 discarded mantis shrimp sampled at random were put into an aeration tank (20 L) filled with sea water, and the dead mantis shrimp were counted after 2 hours. The mortality rate, \( \mu \), was calculated as follows:

\[
\mu = \frac{\text{number of dead shrimp}}{\text{total number of shrimp used in experiment}} \approx 30.
\]

We defined the selection rate, \( S_h \), of fishermen for mantis shrimp of body length 1 as follows:

\[
S_1 = \frac{L_1}{C_1},
\]

where \( L_1 \) and \( C_1 \) are the numbers of landed and caught mantis shrimp of body length 1, respectively. We calculated the discard rate, \( d_m \), as follows:

\[
d_m = \frac{D_m'}{L_m' + D_m'},
\]

where \( L_m' \) and \( D_m' \) are the numbers of mantis shrimp landed and discarded during month \( m \), respectively.

Fig. 1 Location of fishing ground in Tokyo Bay. The hatched area shows the main fishing ground.
We estimated the monthly total number of mantis shrimp discarded at this fishery, using the estimated discard rate and the total number of mantis shrimp landed each month. Using the above definition of discard rate, the total number of discarded mantis shrimp, $D_{t,m}$, for month $m$ was calculated as follows:

$$D_{t,m} = L_{t,m} \frac{d_{t,m}}{1 - d_{t,m}},$$

where $d_{t,m}$ and $L_{t,m}$ are the discard rate and the total number of landed mantis shrimp in month $m$, respectively. $L_{t,m}$ can be calculated from the data on monthly numbers of landed mantis shrimp by market size categories from 1993 to 2000. By setting $d_{t,m}$ equal to $d_{m}$, we can estimate the total number of discarded mantis shrimp for each month with this equation.

**RESULTS**

Figure 2 shows body length distribution of mantis shrimp landed each month from January 1996 to December 1999.

![Fig. 2 Body length distribution of mantis shrimp per haul by month from January 1996 to December 1999.](image)

Mantis shrimp have a relatively long spawning season, lasting from April to October, and they are about 7 cm long at 1 year of age. Given these facts, we can assume that mantis shrimp with a BL of about 5 cm caught in October 1996 were spawned in that year. As seen in Fig. 2, beginning in May 1997, fishermen caught many small mantis shrimp that were spawned in 1996. As a result, most of the mantis shrimp caught in May and June 1997 were discarded because they were commercially unmarketable. In July and August 1997, fishermen landed many large mantis shrimp that were spawned in 1996. After November, most of the mantis shrimp landed were spawned in 1996; landed mantis shrimp averaged 11 cm in length in November.

We then examined the discard rate for mantis shrimp from January 1993 to December 2000. In Fig. 3, the discard rate is plotted against time (monthly intervals), from January 1993 to December 2000. The discard rate ranged from 0.3 to 0.7, and exceeded 0.5 in 36 out of the 75 months that comprised the survey period.

The year 1999 was the only one in which the average discard rate significantly differed from those of the other years.

![Fig. 3 Monthly changes in the discard rate from 1993 to 2000. The dotted line indicates months when the survey was not performed.](image)

In every year except 1995, the discard rate showed a distinct pattern of seasonal fluctuation, in which the discard rate tended to be relatively high around May to August and relatively low during the other months. In 1995, the discard rate tended to decrease over time from January to December. This is thought to have resulted from a small number of mantis shrimp having been spawned in 1994, a theory supported by the fact that the monthly numbers of landed mantis shrimp were relatively low in 1996, as seen in Fig. 5.

Seasonal fluctuation in the discard rate is due mainly to the following facts. Around May, the fishermen begin landing small mantis shrimp that were spawned the year before, all of which are discarded in May. Over the following months, the discard rate of mantis shrimp spawned the year before gradually decreases as they grow in body size. Thus, in summer, the discard rate depends on the number of mantis shrimp that were spawned the year before.

Figure 4 shows average annual selection rates for body length of mantis shrimp. Within each year, selection rate increased with increasing body length.

The minimum length at which $S_t = 1$ tended to decrease gradually over time from 1993 to 2000. This tendency suggests that this fishery has gradually
become more dependent on relatively small mantis shrimp over the years. In 1993, the average selection rate was 0 for body length of less than 10 cm, and was 1 for body length of more than 13.5 cm. In 2000, the rate was 0 for body length of less than 10 cm, and was 1 for body length of more than 11 cm.

Figure 4 Yearly profile of average selection rates of fishermen for body size from 1993 to 2000. Vertical lines indicate the rough body length ranges for the 4 market size categories.

Figure 5 shows the plot of the total number of landed mantis shrimp against time (monthly intervals). The monthly total number of mantis shrimp ranged from $3 \times 10^5$ to $2.1 \times 10^6$. Although there were no statistically significant yearly changes in the monthly total numbers of landed mantis shrimp, the numbers for the peak months of each year showed a decreasing tendency, suggesting that the available mantis shrimp per boat-day in the peak month has fallen below the allowed amount.

As with the discard rate (described above), we observed a seasonal fluctuation in the monthly total number of landed mantis shrimp, with the exception of the period from December 1995 to December 1996. The monthly total number of landed mantis shrimp was high around July and low in winter, with the exception of December 1995. This finding is consistent with the above explanation of the monthly changes in length distribution of landed mantis shrimp.

Figure 6 shows the plot of the monthly total number of discarded mantis shrimp against time (monthly intervals).

The monthly total number of discarded mantis shrimp ranged from $1.1 \times 10^5$ to $2.8 \times 10^7$. As with the discard rate (described above), the year 1999 was the only one in which the total number of discarded shrimp significantly differed from those of the other years. Also, the total number of discarded mantis shrimp showed a seasonal fluctuation that was similar to the seasonal pattern observed for the discard rate. In fact, in most years, the peak month for total number of discarded mantis shrimp coincided with the peak month for the discard rate. This suggests that the seasonal fluctuation in the total number of discarded mantis shrimp was caused by the factors that were responsible for the seasonal fluctuation in the discard rate.

Figure 7 shows the plot of the mortality rate of discarded mantis shrimp against time (monthly intervals).

The mortality rate of discarded mantis shrimp was highest (0.40 - 1.00) from July to September, except July 1998, and lower (0.00 - 0.27) during the other months.

**DISCUSSION**

The fishery we studied discarded many mantis shrimp every year. The small size of the discarded
mantis shrimp (which made them commercially unmarketable) indicates that they were spawned from May to August the year before. The results indicate that a somewhat small number of discarded mantis shrimp die after release from June to September. The available evidence indicates that current methods of catching mantis shrimp are not cost-effective, especially in summer.

In addition, the fishery we studied has gradually increased its dependence on relatively small mantis shrimp, as seen from the trend in yearly selection rate for BL. This phenomenon can also be seen in trends in yearly market size category composition of mantis shrimp (Table 1).

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Table 1 Yearly changes in the size category compositions of landed mantis shrimp from 1980 to 2000.

Given the current fishing regulations, and the fact that fishermen usually try to fill their landing with the largest mantis shrimp possible, the above findings indicate that the population of large mantis shrimp has been decreasing in recent years. Although a decrease in the population of large shrimp does not always reliably indicate a decrease in general population size 4), the present findings indicate that the general population of mantis shrimp should be closely monitored.

The reason fishermen land small mantis shrimp, that are commercially unmarketable, is that they usually use nets of small mesh size, in order to selectively catch conger eel of narrow body girth. The value of the annual catch of conger eel is much lower (average, about 22 million yen) than that of mantis shrimp (average, about 634 million yen). The numbers and mortality rates of discarded mantis shrimp, that we calculated, indicate that the annual number of mantis shrimp, that die after release, is more than one million. As seen in Fig. 2, mantis shrimp that have a BL of about 8 cm around May have a BL of about 11 cm in October.

We estimated the number of mantis shrimp of marketable size that would have been caught after October if fishermen had not caught small mantis shrimp from June to September. We used the figure of one million mantis shrimp, the estimated annual number of dead discarded shrimp calculated above, starting at the beginning of June. We assumed that the natural mortality and exploitation rates per month are $6.0 \times 10^{-2}$ 5) and $3.0 \times 10^{-1}$, respectively. The estimation we obtained for the number of extra mantis shrimp that would be caught was at least 600 000. Given that the mean price of a mantis shrimp is 52 yen, the value of the extra mantis shrimp caught would be 31 million yen. That is greater than the value of the average annual catch of conger eel.

We propose a more cost-effective method for exploiting mantis shrimp. Fishermen should not target conger eel, and should enlarge the mesh size of their nets so that they do not catch shrimp less than 10 cm in BL. Closing fisheries for a few months every summer would also increase the cost-effectiveness of mantis shrimp fishing. In the future, we will use simulation to study the economic effects of these proposed management policies.

REFERENCES