Estimation of the larval drift of the Japanese spiny lobster in the vicinity of the Goto Islands

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Contents

Abstract

For the last 40 years, the annual catch of the Japanese spiny lobster has remained steady at about 1,200 metric tons. Thus, constant larval recruitment is required to maintain a steady stock abundance of the spiny lobster in Japanese coastal areas. To estimate the coastal areas over which the phyllosoma of the Japanese spiny lobster (mainly *Panulirus japonicus*) are transported from or returned to its hatching areas, a field experiment was carried out with drift cards. This field study consisted of releasing 6,000 drift cards during the spiny lobster hatching season (June 26 - July 31, 1992) in units of 1,000 cards per week from the southeast region of the Fukuejima Island, which is in the Goto Islands. The results from this study are summarized as follows: 1) It was difficult for the drift cards to be transported by the currents to the Japan Sea. Therefore, the waters around the Goto Islands are a good habitat for phyllosoma of the Japanese spiny lobster because the prevailing current system makes transport into the less desirable habitat of the Japan Sea unlikely. 2) The current systems were likely to cause the drift cards to remain in the vicinity of the Goto Islands. Therefore, it is suggested that the lobster stock is locally retained in that area. 3) The drift cards tended to be transported along the Pacific coast of southern Japan. This then suggests that the vicinity of the Goto Islands is also an important spawning and hatching area for the Pacific stock.

1. Introduction

The geographical distribution of the Japanese spiny lobster,

Panulirus japonicus, extends from Taiwan Island to the Boso Peninsula along the coast of the East China Sea and the Pacific coast of western and southern Japan (Sekiguchi, 1988a). Sekiguchi (1988a, 1988b) also pointed out that the Japanese spiny lobster does not inhabit the Japan Sea, and suggested that this absence results from water temperatures that decrease below 10 °C in winter. However, it is generally believed that the Tsushima Warm Current, which flows from the southwest to the northeast in the East China Sea, transports the phyllosoma of the Japanese spiny lobster to the Japan Sea from their hatching grounds. Yet the phyllosoma of the Japanese spiny lobster have not been collected in the Japan Sea and few have been collected in the Pacific Ocean off southern Japan, in spite of many net sampling studies (Sekiguchi, 1988b).

Along the Pacific coast of southern Japan, the Kuroshio is the most important current influencing the drift of the larvae of the Japanese spiny lobster. The phyllosoma must be transported by this current from the upstream regions to the downstream regions. Also, it is known that a weak southward flow exists in west of Kyushu. These currents have been observed in the surface currents patterns measured with a GEK (Kobayashi, 1987), in the subsurface currents observed with current meters and in simulated circulation patterns obtained with a numerical circulation model (Odamaki, 1982). The southerly flow in west of Kyushu eventually joins with the flow of the Kuroshio. Therefore, the true upstream source region for phyllosoma of the Japanese spiny lobster is the area around the Goto Islands, which is known to have a large population of the spiny lobster.

For the last 40 years, the annual catch of the Japanese spiny

lobster has been steady at about 1,200 metric tons. Therefore, constant larval recruitment is required to maintain steady stock abundance in Japanese coastal areas. Understanding the processes of constant larval recruitment requires knowledge of the transport pathways around the Goto Islands. Thus, a field study that used drift cards simulating the phyllosoma of the Japanese spiny lobster was carried out to determine larval loss and retention around the Goto Islands.

A similar drift cards experiment was carried out in south of South Africa in order to estimate the transport of the phyllosoma of the spiny lobster, *Hoamrus capensis*, from its upstream hatching grounds (Hayakawa, 1985). The drift cards showed clearly that the phyllosoma of *Hoamrus capensis* were retained in the coastal areas by wind and current effects (Hayakawa, 1985). Drift cards experiments are a straightforward approach for estimating the region over which floating material, including planktonic marine organisms, can drift. However, we do not know the exact trajectories of the drift cards. In this study, drift cards experiment was used to estimate the areas over which the phyllosoma of the Japanese spiny lobster, which is seldom collected in nets, could have been transported from or returned to its hatching grounds.

2. Annual changes of the spiny lobster catch in Japan

The annual changes in the catch of spiny lobster in Japan and the top 6 Prefectures from 1970 to 2009 are shown in Fig. 1. The catch data were derived from the statistical tables compiled by the Ministry of Agriculture, Forestry and Fisheries of Japan. It is well

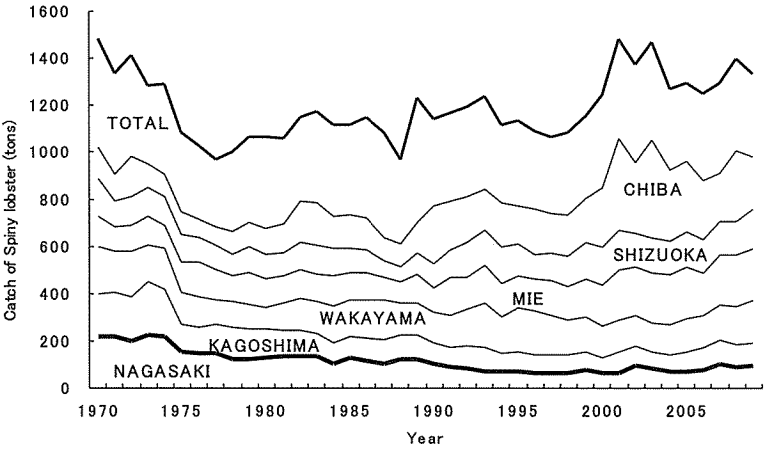

Fig. 1. The annual changes in the spiny lobster catch in Japan and the top 6 Prefectures from 1970 to 2009. These data were derived from the statistical tables compiled by the Ministry of Agriculture, Forestry and Fisheries of Japan. The locations of the 6 Prefectures are shown in Fig. 2.

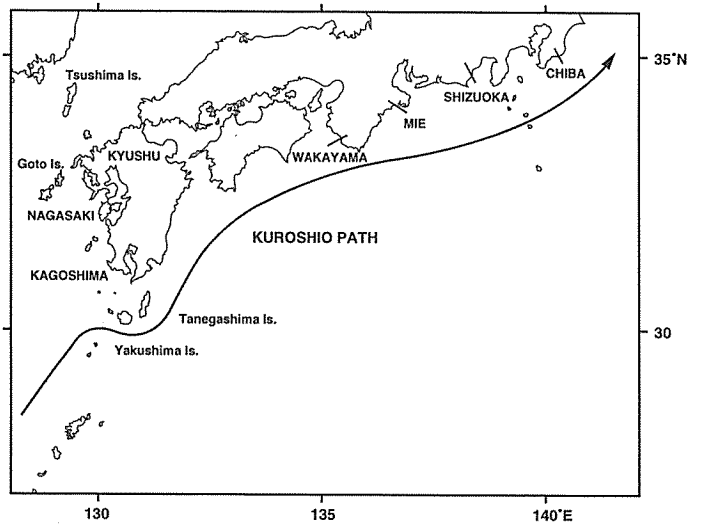

Fig. 2. Geographical location of the regions in the southern and western parts of Japan. A schematic view of the path of the Kuroshio is also shown.

documented that the spiny lobster catch is primarily composed of *Panulirus japonicus* (Sekiguchi, 1988a). It is assumed that fishing efforts have been essentially constant for the past 40 years; hence changes in catch reflect variability in the Japanese spiny lobster stock. As mentioned above and illustrated in Fig. 1, about 1,200 metric tons of the Japanese spiny lobster have been caught steadily per year for the last 40 years. The yearly catch values also show that variability in the landings is less in the upstream regions (e.g. Nagasaki) than in the downstream regions (e.g. Chiba). The regions and their location relative to the Kuroshio are shown in Fig. 2.

The annual changes in the spiny lobster catch from 1981 to 1996 in Nagasaki Prefecture, which is located in the upstream region, are shown in Fig. 3. These catch data were provided by the Fisheries Office of the Goto Branch, Nagasaki Prefecture. The species of spiny

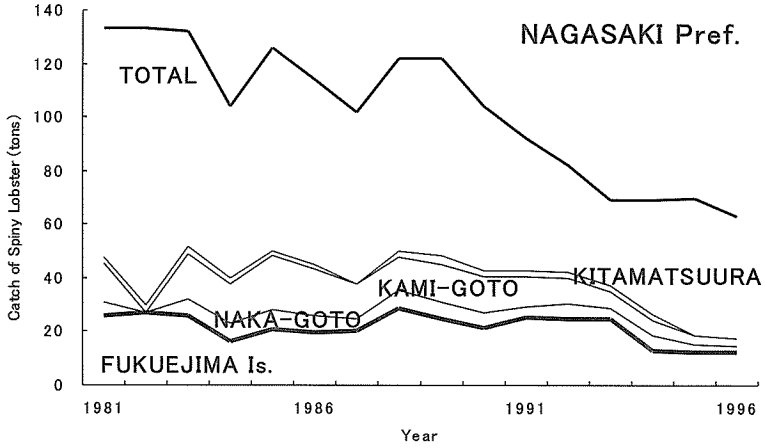

Fig. 3. The annual changes in the spiny lobster catch in the Goto Islands from 1981 to 1996. These data were provided by the Fisheries Office of the Goto Branch, Nagasaki Prefecture. The locations of the local area in the Goto Islands are shown in Fig. 4.

lobster that accounts for most of these catches is also primarily *Panulirus japonicus* (Sekiguchi, 1988a). The catch in the Goto Islands comprises about 40% of the total catch for each year. Further, about half of the spiny lobster that is caught near the Goto Islands has been landed near the Fukuejima Island (Fig. 3). Therefore, it is likely that the stock abundance of the Japanese spiny lobster near the Fukuejima Island is large. Consequently, the region around the Fukuejima Island was selected as the site for drift card study.

3. Drift card release experiment

During the hatching season of the Japanese spiny lobster, 1,000 drift cards were released per week (June 26, July 3, 11, 18, 25, 31, 1992) from 5 fixed points (200 cards per point) for a total of 6,000

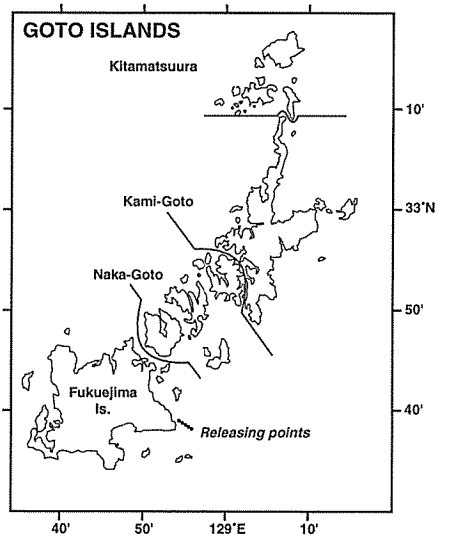

Fig. 4. Geographical location of the Goto Islands, and the 5 points at which the drift cards were released.

drift cards. The 5 release points were located about 2km off Sakiyama in southeast of the Fukuejima Island and were about 1km apart (Fig. 4). The drift card used in this study (type ORI-SK) was made of synthetic paper (type FPG300, specific gravity: 0.77) with a weight (small clip: about 1g).

Although it is known that the phyllosoma of spiny lobster undergo daily vertical migration (Phillips, 1981), it was assumed that the drift cards approximated the transport of the phyllosoma by the currents.

4. Drift card collection

From day 1 to day 337 after release, 122 drift cards have been collected, which gives a return rate of 2.03%. Most of the drift cards were collected on the shore, but 8 cards were picked up in the water by fishing nets.

The distance over which the drift cards moved was approximated with a straight-line from the release point to the collection point. The relationships between the number of days and the straight-line distance of the drift cards for the region north of the Goto Islands including the coast of the Japan Sea, the coasts of the Goto Islands and the region of the East China Sea and the Pacific Ocean are shown in Fig. 5-7, respectively. The symbols of F921-F926 in Fig. 5-7 indicate the release date of drift cards (June 26, July 3, 11, 18, 25, 31, 1992), respectively. After 1 day, drift cards were collected at the Fukuejima Island, which was 10 km from the release point. After 75 days drift cards were collected off Choushi on the Boso Peninsula, which was 1,420 km from the release point. Also, one drift card was collected after 214 days at the coast of the Fukuejima Island, which

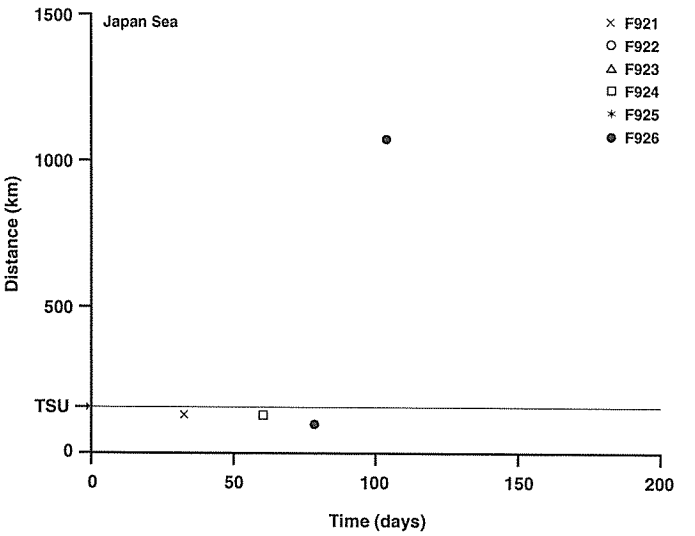

Fig. 5. The relationship between time and the straight-line distance traveled by the drift cards in the region north of the Goto Islands, including the coasts of the Japan Sea. "TSU" indicates the distance from release point to the south end of the Tsushima Island. The symbols of F921-F926 indicate the release date of drift cards in Fig. 9, respectively.

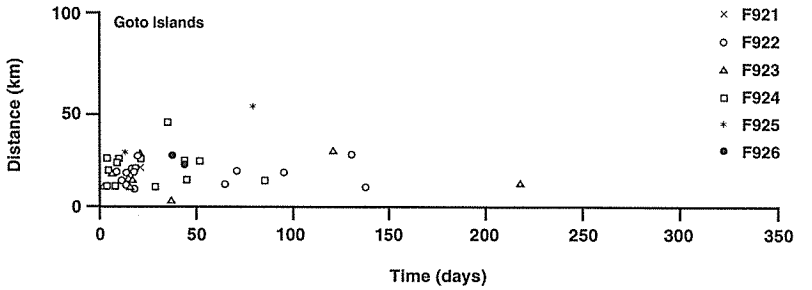

Fig. 6. The relationship between time and the straight-line distance traveled by the drift cards along the coat of the Goto Islands. The symbols of F921-F926 indicate the release date of drift cards in Fig. 9, respectively.

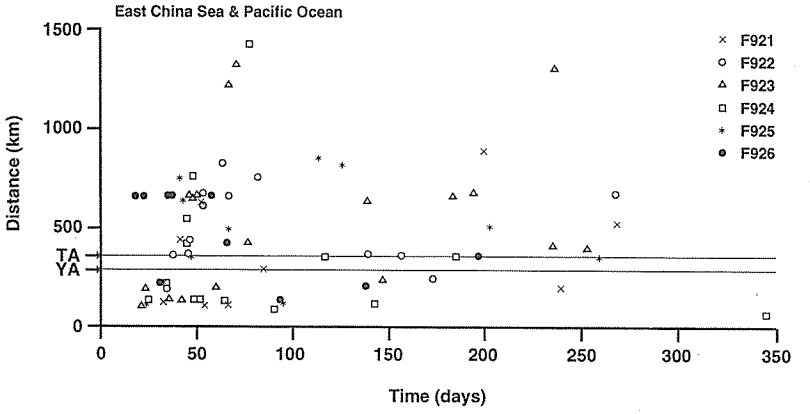

Fig. 7. The relationship between time and the straight-line distance traveled by the drift cards in the region of the East China Sea and the Pacific Ocean. "TA" and "YA" indicate the distance from release point to the north end of the Tanegashima Island and the Yakushima Island, respectively. The symbols of F921-F926 indicate the release date of drift cards in Fig. 9, respectively.

is only 11km from the release point. Hence, the drift cards covered a large area and showed considerable variability in transit times.

Overall, about 40% of the total cards were collected along coasts bordering the Pacific Ocean and about 30% were picked up at the

Table 1. Number of collected drift cards and its ratio for each area.

Collection points	Number of collected drift cards	Ratio (%)
northward of the Goto Islands, including the coasts of the Japan Sea	4	3.3
coasts of the Goto Islands	43	35.2
(coasts of the Fukuejima Island)	(36)	(29.5)
coasts of the East China Sea	22	18.0
waters of the East China Sea	4	3.3
coasts of the Pacific Ocean	49	40.2
Total	122	100.0

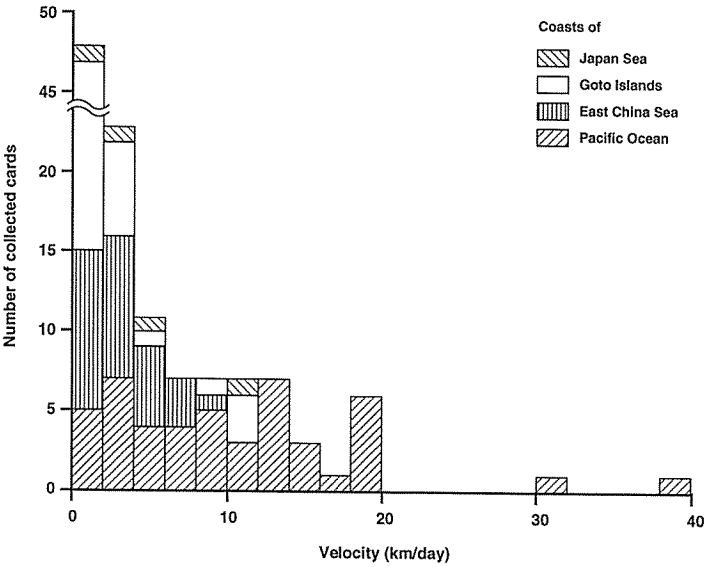

Fig. 8. The velocity frequency distribution calculated for the drift cards that were recovered.

Fukuejima Island (Table 1). In contrast, only 3.3% of the total were collected northward of the Goto Islands including the coast of the Japan Sea. The farthest collection point in the Japan Sea was 1,087 km from the release point, with the card recovered 104 days after release. Most of the drift cards tended to be transported towards the Pacific coasts or to remain in the vicinity of the Goto Islands. Transport of drift cards towards the coasts surrounding the Japan Sea was infrequent.

Transport velocities for the drift cards were calculated using the drift time and straight-line movement distance (Fig. 8). The transport velocities ranged from 0.1 km/day to 39 km/day. Overall, the cards collected in the vicinity of the Goto Islands and along the coasts of

the East China Sea tended to move slower than those along the Pacific coasts.

5. Conclusions and discussion

The drift cards were released at weekly intervals over a five-week period. The frequency of recovery of the drift cards for each release interval is shown in Fig. 9. The tendency for the drift cards to be transported to the Pacific coasts was the same for each weekly interval. However, many of the cards released from July 3 to 18 were found on the shore of the Goto Islands a few days after release (Fig. 9). The reason for this pattern in drift cards recovery was investigated by looking at the changes in the sea surface temperature distributions over five day intervals, from late June to early August in the East China Sea (Fig. 10). These distributions show that the warm tongue approached the Goto Islands from southwest in early July. Therefore, it is possible that the many cards recovered on the shore of the Goto Islands at this time, were transported there as the Tsushima Warm Current approached the Goto Islands temporarily in early July.

The results of the drift cards experiment suggest that floating material tends to remain in the vicinity of the Goto Islands and to be transported to the Pacific Ocean. There is little tendency for material to be transported to the Japan Sea. These results allow the following conclusions to be drawn about transport of the phyllosoma of the Japanese spiny lobster that are released near the southern Goto Islands;

1. It is difficult for the phyllosoma to be transported to the

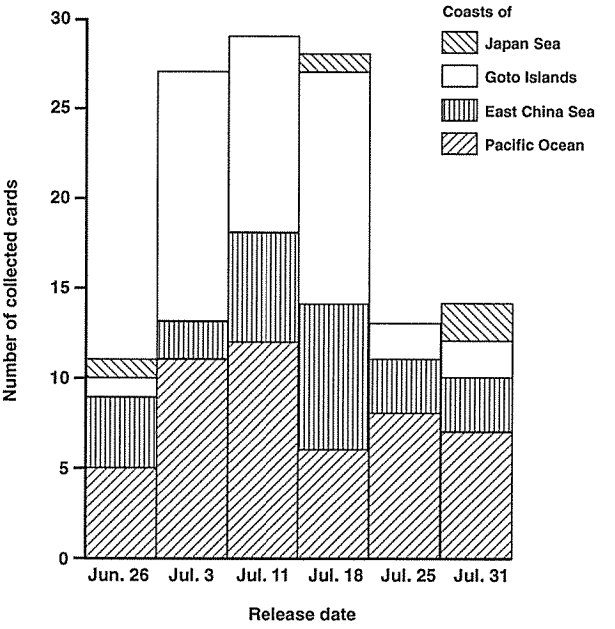

Fig. 9. The frequency distribution of the recovered drift cards for each release interval.

Japan Sea. Therefore, the larval loss of the Japanese spiny lobster in the water of the Japan Sea must be very small.

2. The current system is likely the mechanism that retains the phyllosoma in the vicinity of the Goto Islands. The time scale associated with the drift cards that moved ashore in the Goto Islands supports this conclusion. This could result in the native stock of the Japanese spiny lobster being retained in this area.

3. There is a high possibility that the current system transports spiny lobster phyllosoma to the Pacific coasts where they then settle. This then suggests that the waters near the Goto Islands are an important spawning and hatching ground for the Pacific spiny lobster

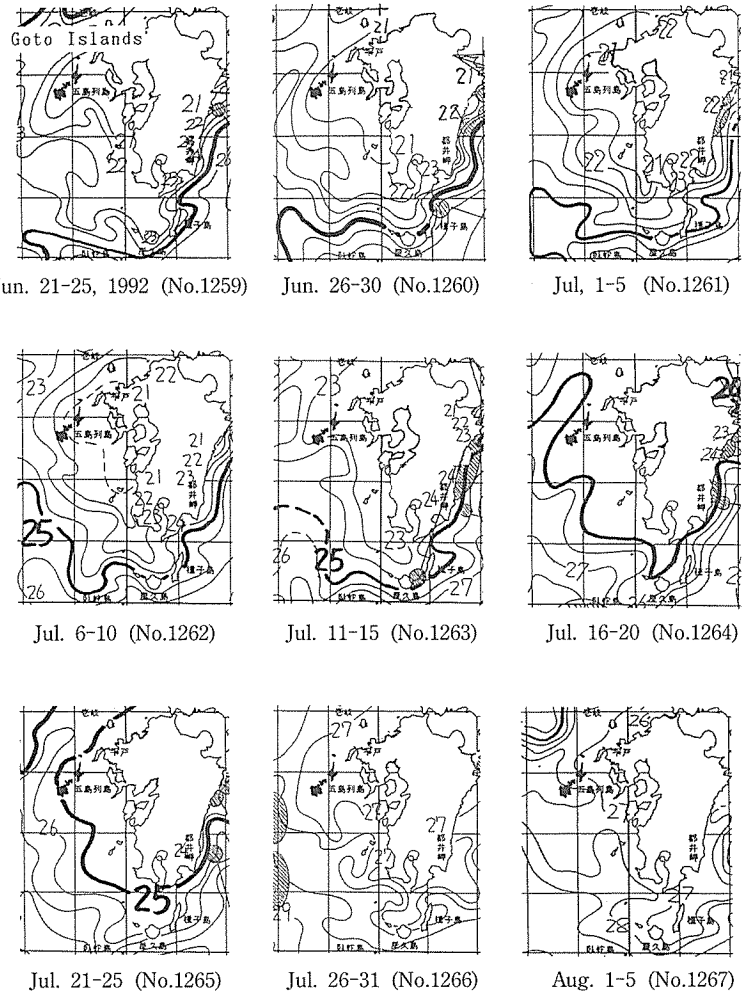

Fig. 10. The changes in the sea surface temperature distribution over 5 day intervals in the East China Sea (After the Japan Fisheries Information Service Center, 1992). Numerals indicate the water temperature (°C). The Goto Islands painted with ink are located in the upper left side for each map.

stock.

Ohshima (1976) speculated that the coasts of the East China Sea were important spawning grounds for the Japanese spiny lobster stock, including the Pacific stock. He also noted the large stock of the Japanese spiny lobster in the waters in west of Kyushu. The results of this study support this speculation and suggest the importance of the current system in retention of spiny lobster phyllosoma. Nonaka (1982) also pointed out that the catch of the Japanese spiny lobster in Nagasaki Prefecture was not correlated with the spiny lobster catch from the Pacific coast. This provides further support for the suggestion that the spiny lobster stock in Nagasaki, especially in the vicinity of the Goto Islands, is locally retained.

In the culture experiment, it was shown that the shortest stage duration for phyllosoma of *Panulirus japonicus* was 307 days (Yamakawa *et al.*, 1989). The drift cards were recovered from 1 to 261 days after release, although one card was picked up in the East China Sea 337 days after release. The times for the drift cards to move ashore are short relative to the stage duration of phyllosoma. However, it is known that the phyllosoma undergo daily vertical migration, which may extend their transport time.

Future work should focus on tracking the pathways of floating material with instruments such as ARGOS drifters. Also, studies on the effect of low temperatures on the physiology of the spiny lobster phyllosoma would help in understanding if this animal can survive during the winter in the East China Sea.

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