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Studies on Squid Behavior in Relation to Fishing

I. On the handling of squid, *Todarodes pacificus* Steenstrup, for behavioral study

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Abstract

An experimental run was conducted to develop the handling and maintenance techniques for squids, *Todarodes pacificus* Steenstrup as subject for behavioral studies. A 50-liter capacity transport pail was designed to contain an outer intact and an inner perforated plastic bag where two squids were placed with aeration. A polyethylene sheet bumper was fitted to a concrete experimental aquarium ($180 \times 230 \times 115$ cm) with flowing seawater. A 10–day survival test was performed on the squid without feeding and then followed by feeding tests with shrimps and sardines on the remaining squids.

The transport method proved to be efficient with the squids remaining stationary at the bottom of the pail, and the bumper used minimized fin injuries. These results produced a survival of 70% at the end of the 10th day. Feeding tests showed that squids readily take an average of 10 g per day of sardine fillet.

Introduction

The studies on squid, *Todarodes pacificus* Steenstrup, under laboratory conditions have been restricted because of the problem of maintaining the animal in confinement. Among the Cephalopods, this oceanic squid which is migratory[1][2][3] presents greater problems in laboratory maintenance as compared with the demersal *Sepia*. Most of the studies on this species have been on actual field observations, on ecology, distribution, migration and spawning. Various studies have been made on the rearing of other Cephalopod species such as *Sepia*[4][5][6], *Euprymma*[7], *Sepiola*[8], *Loligo*[9][10][11][12], *Doryteuthis*[13][14] and *Sepioteuthis*[14]. However, for this study, only works on Loliginid squids have been cited here in the handling of the oceanic squid because of closer ecological similarities. About *T. pacificus*, Hamabe[15] reported on the spawning of fully matured species in an indoor aquarium. Mikulich and Kozak[16] made studies on the experimental rearing of the same species in large concrete tanks.

To be able to improve squid fishing techniques, the authors find it necessary to study the behavior of the species in laboratory conditions. However, to achieve this, the techniques in the handling and maintenance of the species in confinement have to be developed first. This report mainly presents the handling of the squid from the moment of capture on to the experimental aquarium for behavioral study.

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Materials and Methods

The squid were taken from a 5-ton squid fishing boat operating off Hakodate, Japan. The fishing gear used was a squid handline with multiple jigs operated on an automatic angling machine. Eight double line haulers were fitted on the bulwark i.e. four haulers on each side of the boat which one of the authors had boarded. The fishing operation was done at night starting at sunset until daybreak with the aid of attraction lights. The boats were fitted with two live hatches at midship with a capacity of about 2,000 liters. Exchange of seawater was made through screened holes about 15 cm in diameter one on each side of the hatch below the water line. The squids caught fell on deck after passing through the line rollers. They were picked up manually and placed in the live hatches. The haulers adjacent to the live hatches had their catch slip right into the hatches. The live hatch was taken to be full when the bottom was no longer visible. At this stage, there were about 1,000 squids in both hatches. Dead and moribund squids were periodically removed from the hatches.

The fishing boats returned to port at about six in the morning. Some boats unloaded their catch upon landing for the morning sales, while others unloaded their catch at about eleven in the morning for the noon sales. The latter boats were docked near the entrance of the basin where there is a good exchange of seawater in the live hatches while waiting for the time to unload their catch. The squids used for this study were secured just before the noon sales direct from the fishing boats.

The squids were dip-netted from the live hatches and placed in plastic hand buckets (10-liter capacity) two at a time, then hand carried to a waiting van where five polyethylene transport pails of a 50-liter capacity each were made ready with 40 liters of seawater each. Aeration was provided by an ordinary aquarium air pump. One pail was intentionally not aerated for comparison. Each pail was provided with an outer plastic bag and an inner perforated plastic bag whose bottom was spread wide by a rubber hose shaped into a ring by a wire support. Two squids were placed in the perforated plastic bag. An air stone was placed at the bottom between the walls of the outer and inner plastic bags (Fig. 1). The transportation time from the fish landing to the laboratory was about 15 minutes.

One of the experimental aquariums of the Hakodate Fisheries Experimental Station was made available for this study. It was a rectangular concrete tank with inside dimensions of 180 cm by 230 cm; 100 cm at the shallow side and 130 cm at the deep side. Seawater supply was provided by an inflow pipe at the shallow side of the tank. The mouth of the inflow pipe was submerged 2 cm below the water line. The seawater flow rate was maintained at about 10 liters per minute. An overflow drain located near the corner of the deep side of the tank kept the seawater volume at approximately 4,000 liters.

The tank was provided with a polyethylene sheet bumper system as shown in Fig. 2. This system was based mainly on the bumper system developed by Summers, et al.[11] for maintaining *Loligo pealei*. For this study, polyvinylchloride (PVC) pipes were used instead of the conventional floats to hold the sheet away from the tank walls. The PVC pipes with an outside diameter of 5 cm were

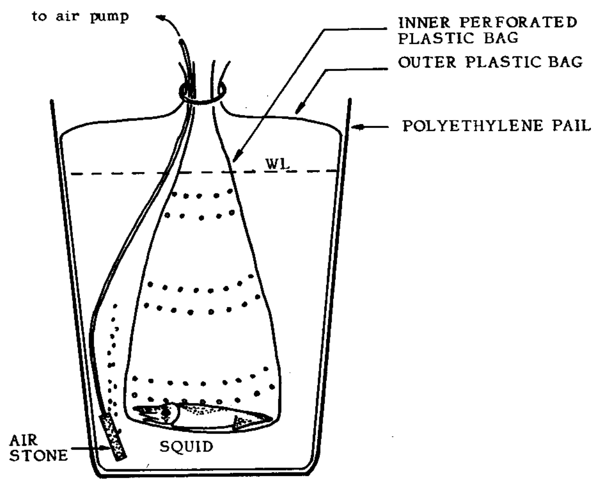

Fig. 1. Transport system for squid, *Todarodes pacificus* Steenstrup.

mounted around the edge of the tank. The sheet was clipped to these pipes and hung vertically producing a distance of about 5 cm from the tank wall. The lower end of the sheet was clipped to smaller PVC pipes of 2 cm diameter. These pipes filled with pebbles and closed at both ends served well as sinkers. The corners of the pipes at the top were provided with plastic covers to prevent the squid from jumping out.

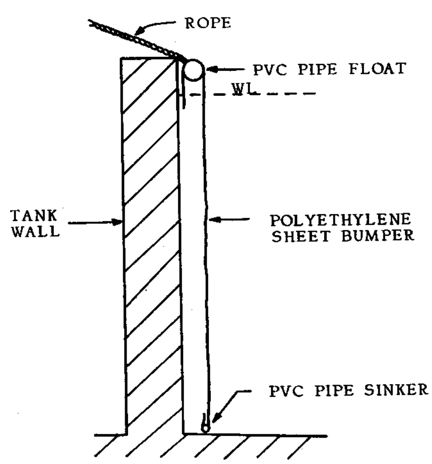

Fig. 2. Experimental tank arrangement of bumper system.

The tank was constantly covered with translucent corrugated polypropylene sheets 1 mm thick. During the day, natural light was introduced into the tank through the skylight of the laboratory about 5 m above the tanks. The window about a meter away from the shallow side of the tank was covered with a thick cloth. Later in the experiment, a black plastic sheet was hung about 2 meters from the top of the tank to remove roof reflection on the water surface during observations. At night a 40-watt fluorescent light was provided from 1800hrs to 0600hrs. The lamp was hung about a meter away from the deep side wall and a meter high over the tank edge. This arrangement produced a shaded portion at the deep side of the tank.

An experimental run was started on August 13, 1976 by placing a group of 10 squids in the tank; they were observed for up to ten days for survival. Squids were observed twice daily at nine in the morning and six in the evening. Dead squids were removed and their mantle length (ML) and weight measured and pertinent observations recorded at each observation. The seawater temperature was recorded during each tank observation and oxygen and pH analyses were made once for the entire run. To simplify the experimental design, the squids were not fed intentionally for the survival test of ten days. After this period, the squids were fed using shrimps and sardines to obtain data for future reference on the maintenance of squid over an extended period of time.

Results

On board the fishing boat. The squid coming on board were dark in color and released ink immediately upon being placed in the live hatch. In the same manner, the squid would release ink when placed in the transport pail after catching. However, if the squid released ink when first introduced into the live hatch, it would no longer do so when transferred to the transport pail. So when the squids were dip-netted from the live hatches for transport at the fish landing, no ink was released. Tests conducted on board the fishing boat showed that the squid when placed directly into the transport pail upon capture with no seawater exchange and aeration and there releasing ink, would survive only for about an hour. Those that were allowed to "calm down" in the live hatch and there releasing ink, were still alive after three hours of observation in the transport pail even without aeration and seawater exchange. The squids here stayed stationary most of the time at the bottom of the pail. The squids in the live hatch moved very actively hitting the walls with their fins. Repeated hitting of the corners of the live hatch was observed for most of the captured squids.

Transport. The squid when placed in the perforated plastic bag of the transport pail, at once descended to the bottom and there remained stationary for the entire duration of transport. Air bubbles coming out of the air stone placed at the bottom of the transport pail between the inner and outer bags did not seem to disturb the squids as they remained stationary at the bottom. The body coloration did not change. The closed outer bag prevented the splashing of seawater and effectively dampened the water movement during transport. The outer bag became inflated as aeration was continued.

Experimental tank. Upon reaching the Hakodate Fisheries Experimental Station, the squids were at once placed in the experimental tank. The squids immediately became pale upon introduction into the tank except for a dark stripe at the center of the entire length of the dorsal portion of the mantle. The squid swam independently from each other about the central area of the tank near the surface level. At times squids would hit the bumper sheet. Surfacing of squids (fin breaking the water surface) and attacks on suspended particles were observed occasionally.

The two squids identified as squids (A) and (B), transported in the unaerated transport pail were observed to be tracing the bumper at near surface and would hit repeatedly the bumper corners with their fins. This was not observed in the rest of the squids. These two squids were then the subject of attack by other squids keeping them to the sides and corners of the tank. Squid (A), the smallest in the group (ML 152 mm) died on the 3rd day. Squid (B) with ML 180 mm and whose right tentacle was half cut, died on the 7th day. Squid (B) and the rest of the squids were of the same size. Both dead squids were found at the bottom of the tank during the morning observations. No cannibalism was observed.

There was no distinct swimming layer from the second day onwards. Surfacing also was no longer observed. Only the squids subject to attack by other squids were found tracing the walls and repeatedly hitting the corners. No squid was observed stationary as was observed during transport. The body coloration would darken when disturbed by tapping the water surface or when attacked. It was also noted that the body coloration would darken when attacking another squid or a bait. The squids being attacked at the tank corner, at times would jet back fast breaking the water surface only to hit the corner plastic cover and fall back into the water. A squid (C) managed to jump high and landed on top of the cover and was found dead on the morning of the 8th day. This could be taken as an accidental death. The top of the wall at the deep side of the tank was observed wet with water splashes from the 4th day onwards. This must have been caused by squids trying to escape their attackers.

Among the remaining seven squids, there were two that were the subject of attacks by other squids. One was found stationary at the bottom near the outlet with its arms spread out and when disturbed by a scoop net, the body coloration would turn dark and it would move away only to be sought after by other squids. The following attacks would drive the squid to the corners. This squid which was marked (D) was later found again stationary at the bottom near the outlet. At this position, no attack was observed.

On the 9th day a siphon (plastic tubing) was introduced in the tank to clean the water near the surface. Upon introduction, it was attacked and when placed deeper, another attack was made. This then excited the whole group and the squids were attacking each other head on, which was different from when attacking a weak squid; they then hit the fin or the posterior portion of the body. With this observation, the siphon was removed from the tank. On the following day, one squid was found with a deep cut at the left posterior portion of its fin. The survival of this experimental run at the end of the 10th day was at 70%.

On the 11th day, feeding was started on the remaining seven squids using cut shrimp flesh of about 2 cm a piece. The bait was thrown on to the water surface; it sank slowly and was taken as it was sinking at about mid depth. The first bait taken then excited the whole group resulting to squids attacking each other head on. This type of attack would find squids clenched to each other for about ten seconds. Pieces of flesh cut off were seen after such an attack. Seeing this behavior, more baits were hurriedly introduced. This led the squids to turn their attention to the baits instead of attacking each other. Subsequent feedings were done by throwing in about ten pieces of bait which would give each squid its own piece. After this, the bait was introduced piece by piece. A squid can hold as much as four pieces of cut shrimp between its arms. An entire piece is not at once swallowed but is cut to smaller pieces before swallowing. Feeding was stopped when pieces of bait were missed and reached the tank bottom. It was observed that the bait at the bottom was never taken. About 100 g of bait were taken during the first feeding. Shrimps were used for three days and then followed by sardines.

The feeding was done daily during the morning observation. Upon removal of the tank covers, the squids would gather about the deep side of the tank where the feeding was done regularly. Sardine fillet about 3 to 5 g a piece were readily taken. An average of 10 g of bait per squid was taken daily. Sardines were chosen as the regular bait because of its availability and price. Experiments on feeding behavior are still going on and the results will be presented in future reports. The seawater temperature during the experimental run ranged from 19° to 20°C. The oxygen content was at 4.78 ml/l and pH at 8.16.

Discussions

The problem of transporting squids in containers where the seawater exchange was not possible is centered on the ink released by the squids during the transport. This has been solved in our study by allowing the squid to release ink and to "calm down" in the live hatch of the fishing boat before the transport. The transport in perforated plastic bags was satisfactory as the system produced minimum movement and thereby prevented injury to the squids. Chanley[12)] developed this system for *Loligo pealei* without the outer plastic bag and used oxygen tabs for aeration instead of the conventional air pump. His results were also satisfactory with his species surviving for several hours. The fact that no ink was released during the transport suggests that the squid was not exposed to any mechanical shock in the process. The squids dip-netted from the live hatch and placed in the bare polethylene pail half filled with seawater released ink while trying to jet out of the pail. The inflated outer plastic bag resulted in improved utilization of the air introduced into the pail and at the same time effectively dampened the water movement. Summers[10)] used 40-liter polyethylene containers on fishing vessels; these were filled to the top, fitted with tight lids and aerated with oxygen tabs. Matsumoto[13)] placed two squids in a double sheet plastic bag half filled with seawater, aerated and contained in corrugated boxes for transporting *Doryteuthis bleekeri*.

The bumper system in the experimental tank minimized fin injuries on the squids. At the start of the experimental run, six squids already had the tips of their fins bare without skin. The damage occurred during their confinement in the live hatches of the fishing boat. The squids were not observed hitting the bumper near the bottom. This behavior erazed the possibility of the squid going under the bumper as experienced by Summers, et al.[11)]. The accidental death of one squid (C) suggests that the bumper should be raised higher. For the present study, the edge of the bumper was only about 10 cm above the water surface.

The 70% survival of this experimental run reflects the efficiency of the transport system and of the experimental tank arrangement. This survival may still be improved by the selection of intact animals from the live hatches. Hamabe[15)] was able to keep fully matured *T. pacificus* alive for about 4 or 5 days without feeding in glass aquariums (30×19×45 cm and 54×51×41 cm) for his successful spawning experiments. However, behavioral studies on squids require the maintenance of the animals in confinement over an extended period of time. Mikulich and Kozak[16)] using large concrete tanks (5×5×1.6 m) reported survival times of squids with mantle lengths ranging from 9.3 to 25.9 cm, from

25 to 35 days with feeding. It was a relief to note that the squids studied here were taking sardine fillet regularly thus simplifying laboratory procedures.

The results of this first experimental run make it possible to continue the test on the same species at different age levels, and then proceed further with the study of the behavior of the squids, with the objective of improving existing squid fishing methods and gear. The authors wish to acknowledge sincerely the kind cooperation of Dr. Ryogo Yuuki, Director, Hokkaido Hakodate Fisheries Experimental Station for the use of the experimental aquarium.

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