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Studies on Squid Behavior in Relation to Fishing II. On the survival of squid, *Todarodes pacificus* Steenstrup, in experimental aquarium

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Abstract

A 10-day survival test was conducted on 10 autumn captured squid, *Todarodes pacificus* Steenstrup, duplicating the previous test on the summer captured squid. A 90% survival was attained with all of the transport pails aerated. This is an improvement over the 70% survival for the summer captured squid where one transport pail was not aerated. Feeding tests were conducted on the remaining squid that survived the 10-day survival test. It was possible to train the squid to feed on sardine fillet attached either to a monofilament nylon line or to a commercial plastic jig with the hooks removed. The squid feeding on sardine fillet survived for a maximum of 50 days with 50% surviving at the end of one month for the summer captured squid. Mortality was high with the autumn captured squid which may have been caused by the spreading of a skin infection. The last squid was discarded on the 25th day of confinement.

With the squid regularly feeding on sardine fillet using the methods mentioned above, it is then possible to design a shape discrimination test with the use of baits presented in different forms as positive or negative stimulations. The attained survival period allows enough time to conduct shape discrimination tests on the animal.

Introduction

This basic study on the survival of the squid, *Todarodes pacificus* Steenstrup, is a direct continuation of a previous work[1] on the handling of the same species from the fishing boat on to the experimental aquarium. Reference should be made to that paper for descriptions on the handling procedure and the set up of the experimental aquarium. This study presents the survival of the squid for 10 days without feeding and then followed by the survival with feeding. Feeding was closely observed with the objective of formulating experimental procedures for future behavioral studies on the light intensity and wavelength discrimination by the squid.

The *T. pacificus* being an active feeder, in nature, feeds on small fishes, planktonic crustaceans and some macroplanktons[2)3)4)]. Cannibalism has also been reported for this species; however, cannibalism alone can not maintain the squid as experienced by LaRoe[5)] for loliginid squids reared in aquariums. The feeding of squid in laboratory conditions has been concentrated on using live baits[5)6)7)]. This would be the ideal form of food for the animal; however, this imposes a great problem of the continued supply of live baits especially when using small fishes. Furthermore, LaRoe[5)] and Neill[7)] found out that small live fishes

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could be very elusive, and the stress of making several unsuccessful attacks could even kill the squid. Attempts have been made in this study in using the readily accessible sardine in the fresh or frozen form as food for maintaining *T. pacificus* in laboratory conditions. In the Hokkaido area, Japan, small fishes including sardine and mackerel compose the main diet of *T. pacificus*.[4)]

Materials and Methods

The seven summer captured squid of the previous study[1)] that survived the 10-day survival test without feeding, were further used for observations on feeding behavior using sardine fillet. On September 24, 1976, a second batch of 10 squid with mantle lengths ranging from 20 to 23 cm, were obtained from squid fishing boats and transported to the laboratory with all the transport pails aerated. This batch (autumn captured squid) was also subjected to a 10-day survival test without feeding duplicating the previous work on the summer captured squid. Then the squid that survived this test were fed with sardine fillet and observed for feeding behavior.

The squid were fed with sardine fillet of 3 to 5 g each, using three different types of feeding method;

Free sinking bait. The bait, sardine fillet, was merely thrown on to the water surface. The bait reaching the bottom of the tank were removed by using fish clips.

Bait attached to line. The bait was tied loosely to a light green monofilament nylon (0.5 mm dia). This bait when introduced into the tank sunk slowly and when reaching the bottom of the tank, was retrived quitely so as not to excite the squid. Later in the experiment, the bait was allowed to sink to about 50 cm from the surface and there remained stationary for a period of between 2 to 5 minutes before it was retrived when not taken.

Bait attached to jig. The bait was attached to a white plastic commercial jig (50 mm long, 17 mm dia) replacing the hooks. This was also allowed to sink to about 50 cm from the surface and there remained stationary for a period of between 2 to 5 minutes before it was removed when not taken.

The summer captured squid were subjected to feeding tests using all of the above methods; while the autumn captured squid at the start of the feeding tests were trained to take baits attached to line and then to baits attached to jig. The seawater temperature for the duration of the tests ranged from 19.5° to 22°C (summer) and 16° to 19°C (autumn).

Results and Discussions

The 10-day survival test.

Results for the summer captured squid have been reported in a previous paper[1)]. Except for the repeated hitting and tracing of the bumper of the experimental aquarium which was observed during the previous test for the two squid transported in an unaerated transport pail, the behavior of the autumn captured squid during the transport and at the moment of introduction into the experimental aquarium

did not differ from that of the summer captured squid. For this test, the repeated hitting and tracing of the bumper was observed for one squid only after a lapse of five days in confinement. This squid was the subject of attack by other squid keeping it to the walls and corners of the aquarium. On the 7th day, this squid was found with cuts on the right lobe of its fin.

As experimental animals, efforts were made in selecting squid with the least injury from the live hatches of the fishing boats. With the overcrowding in the live hatches, it was very difficult to get squid with intact fins. The skin of the squid which is delicate is easily damaged; and those squid hitting the walls and corners of the live hatches easily had the skin at the tip of their fins peeled off. In the experimental aquarium, this became clear with the bare area of the fin turning creamy white like open sores on the 5th day of confinement. Observations during the succeeding days showed that the injuries had spread to the entire margin of the fin. On the 9th day of confinement, five squid developed well pronounced fin wounds.

One squid was found dead in the drainage canal of the laboratory adjacent to the aquarium on the second day of confinement. This squid must have jumped out of the aquarium through the covers during the night. By mistake, the covers were left overnight without the usual weights on them. The bumpers here were raised to about 20 cm from the water surface; however, this did not prevent the squid from jumping out of the aquarium. This type of death was also observed in the previous test for one squid which also occurred during the night. To prevent this, additional aquarium lights may be necessary.

During the rest of the 10-day survival test, no squid died although there was marked skin infection in most squid. The survival here at 90% is an improvement over the previous test. This improvement must have been due to the aeration of all the transport pails. Those that were transported in an unaerated transport pail in the previous test did not survive the 10-day period, and were found most of the time hitting the corners of the bumper during their confinement. It is then necessary even for a short period of transport (15 minutes for these tests) to aerate the transport pails. Oxygen release tablets (O-TABS) have been found effective in improving survival for short periods in transporting *Loligo pealei*[8)9)]. This oxygen generating device eliminates the use of messy air hose with its connections in conventional aquarium air pumps during transport.

For the short transport period in these tests, the change of seawater in the transport pails was not deemed necessary since the squid did not release ink during the transport. LaRoe[5)], for transporting loliginid squids, had to change the water when there was a copious discharge of ink into the transport pail.

Using the above handling technique, a 100% survival upon reaching the laboratory was attained for both summer and autumn tests. For longer periods of transport, keeping the seawater temperature in the transport pail constant would be necessary especially during summer. With the healthy condition of the squid maintained during transport, a 100% survival for a period of 10 days in experimental aquariums without feeding could easily be attained since the mortality for the autumn captured squid was purely accidental and could be eliminated in future tests.

The survival with feeding.

Summer captured squid. The feeding test using free sinking bait as reported earlier, showed that the baits were readily taken as they were sinking at about mid-depth. Since the missed baits settling on the bottom of the aquarium were never taken, they had to be removed to prevent fouling in the aquarium. However, the process of removing the missed baits using the fish clips excited the squid as they would flush darkly and jetted away. Neill[7] in maintaining *Loligo vulgaris*, noted that squid after a few days in the aquarium were not excited by tank-cleaning and by the removal of uneaten food provided nothing was removed too violently or close to them. For *T. pacificus*, the introduction alone of the fish clips into the aquarium was enough to excite them. With the use of baits attached to line, the removal of missed baits was made easy by merely pulling up the line quitely without disturbing the squid.

Feeding was then shifted to using baits attached to line after six days of feeding with free sinking baits. It was interesting to note that after an attack was made, most of the time the squid would try to pull away the seized bait attached to the line, and the resistance excerted with the other end of the line held fast, may simulate a "live condition" of the bait. Bradbury and Aldrich[10] in keeping the short-finned squid, *Illex illecebrosus illecebrosus*, in round tanks (app 1,000 liters cap) for three weeks, used whole fish (*Mallotus villosus*) also suspended in the tank by means of a monofilament line as bait.

Commercial jigs colored red or green attached to line with their hooks removed were introduced into the tank before the regular feeding with baits attached to line had begun. The jigs upon introduction were at once taken and held for about 10 seconds. This then gave way to the possibility of training the squid to take baits attached to jig. The squid were continuously fed daily with sardine fillet attached to lines at about 10 g per squid for one week before transferring to feeding with baits attached to jig.

With only four squid remaining in the aquarium, four jigs were prepared with sardine fillet looped at the lower portion of the jig. The first set of four jigs was taken in about 15 seconds after introduction. The following sets took some time before they were taken with a maximum of five-minute presentation. It was observed that when one squid took a jig, the rest would follow. With the bait eaten off the jig, the squid would still hold on to the jig trying to eat it by turning to all parts.

The training however was disrupted by a typhoon that struck the area causing the water in the aquarium to be very turbid, and making feeding difficult. In this laboratory, the pumped seawater was brought up to a settling tank and from there the water was sent to the aquarium by gravity. When the water cleared off after five days, there were only two squid alive with one of them weak. Irratic feeding behavior followed with only one squid feeding well on baits attached to line. When the weak squid died, a final attempt was made on the last remaining squid on feeding with baits attached to jig. For a period of one week, the squid took an average of three baits daily weighing about 10 g. After this, the squid was feeding irratically, becoming weaker and then died on the 50th day of

confinement.

The mortality (3 squid) during the first 10-day period with feeding must have been those squid that did not revive from the 10-day survival test without feeding. Future experiments will be conducted using squid not subjected to this 10-day test with the hope of keeping the animal alive longer in confinement. Those squid that were feeding at an average of 10 g per day survived for another 10-day period. Then the heavy rain caused the water in the aquariums to be very turbid making feeding difficult for five days. The squid that survived this produced a maximum survival of 50 days. For future experiments, necessary filters will have to be installed to insure clean clear water throughout the study. It is however encouraging to note that even with the crude laboratory facilities, an unprecedented survival period was attained for this species.

Autumn captured squid. The remaining nine squid were divided into two groups placing them in separate aquariums of the same size (A and B) for the feeding test. Initially, aquarium (A) had one squid, while aquarium (B) had eight. Feeding with bait attached to line on the 11th day of confinement showed that in aquarium (B), only five squid were feeding; while in aquarium (A), the newly transferred squid, excited and flushing darkly, did not feed. On the second day of feeding, this squid took eight pieces of bait. However, on the third day where only two pieces of bait were taken, this squid was again repeatedly hitting the bumper and flushing darkly. With the hope of calming down this squid, another squid from aquarium (B) was introduced. The introduction found the color of the initial squid turned to normal (pale), and the repeated hitting of the bumper was no longer observed. It seems that keeping squid singly in confinement is not favorable. Neill[7] observed that for *Loligo vulgaris*, single squid did not feed reliably and pairs or groups were better.

Feeding in aquarium (A) was closely observed taking note of the number of baits a squid would take during each feeding session. For a period of one week, the squid here were taking a minimum of three pieces of baits attached to monofilament nylon line per feeding session. Knowing that the squid would also attack baits attached to jig regularly, they were then available for the shape discrimination test. In aquarium (B), the condition of the squid was deteriorating rapidly with the spreading skin infection. The feeding here was below the minimum level of three pieces of baits per squid per feeding session.

On the first 10-day period of confinement with feeding, six squid in aquarium (B) died, and the remaining three squid for both aquariums did not survive the second 10-day period with the last squid discarded on the 25th day of confinement. The probable cause of the high mortality in the autumn captured squid would be the fin sores. A method will have to be developed to control fin infections which may occur in future experiments.

For both the summer and the autumn captured squid, death was hastened in confinement where the weak squid were being attacked by other squid forcing them to the corners and then seeking refuge at the bottom of the aquarium where no attack was made. Again, the attacks gave the weak squid less chances of feeding. LaRoe[5] observed young loliginid squids lying on the bottom of the aquarium as a result of the weakening process of starvation; and that in this condition, the squid

dies after several hours.

Finally, the different types of feeding tests imposed on the squid must have caused some amount of strain on them. However, this is justified with the information gained on the feeding behavior of the squid, i.e., the squid will take regularly sardine fillet attached to line and attached to jig. This makes possible the future shape discrimination test on this species where the bait attached to line will be used as the positive stimulation and the bait attached to jig or a bare jig as the negative stimulation.

It was generally observed that the summer captured squid fed more aggressively than the autumn captured squid. This suggests that younger squid are better experimental subjects for shape discrimination tests where baits are used as forms of stimulations. The authors wish to acknowledge sincerely the kind cooperation of Dr. Ryogo Yuuki, Director, Hokkaido Hakodate Fisheries Experimental Station for the continued use of the experimental aquariums.

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