INTRODUCTION

It is said that spawning is the motivation for the entry of the cuttlefish Sepia esculenta into basket traps, but no specific evidence has supported this belief. In the present study, the behavior of cuttlefish near basket traps was observed in order to analyze the capture process of basket traps. This finding negates the conventional idea that the entry of cuttlefish into traps is motivated by spawning. Cuttlefish entered and exited from the trap in a straight movement with the arms first, as in feeding. No cuttlefish touched the trap during these movements, which means that the reaction of cuttlefish to traps is mediated by vision. Cuttlefish inside the trap moved very slowly, not evasively, and they remained inside for at least 2 days. This behavior indicates the existence of an attractive stimulus within the trap. In laboratory tanks, individuals repeatedly entered the trap. Because the average length of stay of six cuttlefish in the trap in the first entry (6 h 18 min) was less than in the sixth entry (8 h 19 min), exploratory behavior cannot explain the behavior of cuttlefish entering basket traps.

KEY WORDS: basket trap, behavior, capture process, cuttlefish, spawning.

MATERIALS AND METHODS

Field observation

Field observation was conducted for 37 days from 19 March to 24 May 1991 in the spawning season of cuttlefish S. esculenta. The observation site was in front of a floating jetty at the Kumamoto Prefectural Fisheries Research Center in Oyano Town, Amakusa District, western Kyushu, Japan, and adjacent to the basket trap grounds for cuttlefish (Fig. 1). The seabed is sandy and the water depth is about 7 m at high tide. Cuttlefish are known to come to the site every year as eggs are found attached to ropes suspended from the jetty.

The only examples of field observation of the behavior of cephalopods vis-à-vis fishing gear are reports on the Japanese common squid Todarodes pacificus and neon flying squid Ommastrephes bartramii, observed by scuba divers or through the window of a research vessel. The installation of underwater observation equipment for a long period of time on the seabed where basket traps are operated is essential for studying the behavior of demersal cuttlefish. However, this method has not been tried because of the various difficulties involved in such a method. In the laboratory, the spawning behavior of cuttlefish has been reported, but not the behavior of cuttlefish vis-à-vis fishing gear.

SUMMARY: The behavior of the cuttlefish Sepia esculenta near basket traps was observed in the field and in the laboratory in order to analyze the capture process of basket traps. In the field, cuttlefish spawned both during the day and the night and mainly outside the traps. This finding negates the conventional idea that the entry of cuttlefish into traps is motivated by spawning. Cuttlefish entered and exited from the trap in a straight movement with the arms first, as in feeding. No cuttlefish touched the trap during these movements, which means that the reaction of cuttlefish to traps is mediated by vision. Cuttlefish inside the trap moved very slowly, not evasively, and they remained inside for at least 2 days. This behavior indicates the existence of an attractive stimulus within the trap. In laboratory tanks, individuals repeatedly entered the trap. Because the average length of stay of six cuttlefish in the trap in the first entry (6 h 18 min) was less than in the sixth entry (8 h 19 min), exploratory behavior cannot explain the behavior of cuttlefish entering basket traps.
Determination of maturity and calculation of gonad index (GI) followed the methods used by Watanuki et al.9 During the observation period, the traps were inspected twice a day (07.00 and 19.00 h) and the number of laid eggs were counted except when cuttlefish were in the traps. Newly spawned eggs were easily identifiable from old eggs because they were softer and the appearance of the sand attached to the egg surface was fresher.

The maximum tidal difference during the observation period was 4 m and the highest current (measured by the Dutchman log method) was 0.5 knots. The surface water temperature was 13.1–20.1°C.

Tank observation

A behavioral observation was conducted in a 15-ton white rectangular water tank (5x3 m; water depth of 0.8 m) at the Kumamoto Prefectural Fisheries Research Center from 31 April to 21 May 1993 during the spawning season of this cuttlefish. A foldable-type trap (Fig. 3) with its funnel section removed was placed in the center of the tank. The seawater in the tank was constantly changed and the water temperature in the tank varied between 13.7 and 17.9°C. The live cuttlefish specimens used in the present study were caught in basket traps off the coast of Oyano Town by the Oyano Fisheries Co-operative Association and transported by land to the Research Center. Three females (mantle length: 135–165 mm) and three males (mantle length: 142–176 mm) were tested individually seven times to see whether the cuttlefish entered traps repeatedly. In principle, the observation period in each test was 20 min. Once an individual entered the trap, observation continued until it exited the trap.

Two cuttlefish were captured 3–4 days after the first entry into the traps, and examined for species identification, mantle length, weight, sex and maturity. Determination of maturity and calculation of gonad index (GI) followed the methods used by Watanuki et al.9 During the observation period, the traps were inspected twice a day (07.00 and 19.00 h) and the number of laid eggs were counted except when cuttlefish were in the traps. Newly spawned eggs were easily identifiable from old eggs because they were softer and the appearance of the sand attached to the egg surface was fresher.

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RESULTS

Field observation

While clear pictures were obtained during the daytime with good underwater visibility, observation at night was sometimes obscured by suspended particles, black rockfish *Sebastes inermis*, Japanese horse mackerel *Trachurus japonicus*, and other fish that appeared near the light source. As the camera lacked a zoom mechanism, it was impossible to clearly see some of the fish species sighted or to establish changes in the color patterns on the mantles of the cuttlefish. During the observation period of 37 days, the cuttlefish were videotaped on five occasions. As the size of the cuttlefish clearly differed each time, it was judged that five different individuals of cuttlefish were observed. Behaviors such as spawning, feeding, entry into and exit from traps were recorded on videotapes (Table 1).

Spawning by four solitary females was observed outside the traps. Spawning was observed both during the day and night, and it was found that more eggs were spawned at night. The bush clover branches always had more eggs than the bamboo branches. The total egg count in the spawning substrate was 110 for the bush clover and 68 for the bamboo. Six eggs were found on the net (Table 2).

The process of cuttlefish spawning is as follows:

1. Approached the branches, stopped, and kept a distance of 50 cm to 1 m from the spawning substrate.
2. Gathered seabed sand and held it with the arms.
3. Left the seabed and changed the mantle color from dark brown to white.
4. Moved in a straight line and arms in front towards the branches with eggs. When a part of the bunch of branches was full of eggs, the cuttlefish moved to another part of the branches with fewer eggs.
5. Spurted water on spawning area of the branches two to four times, without touching the branches.
6. Balancing the body with the fins, it inserted and squeezed the arms among the base of the branches.
7. Rested on the seabed and stayed still after spawning.
8. Started to gather sand again to cover the egg for subsequent spawning.

This entire process took some 4–6 min. The females repeated egg-laying from 23 to 65 times. After spawning, two females entered the trap and the other two swam away. The activities of the two females in the trap could not be observed in detail as the camera view was blocked by the trap netting and branches.

Entry of three cuttlefish into the cylindrical trap was observed, and as in spawning and feeding, all entered the trap in a straight movement with the arms first. They stopped momentarily at the trap entrance and moved inside at a speed of 5 cm/s via the central part of the entrance.

Four behavioral patterns were observed in the trap for the five females (Table 1). After spawning onto the branches outside the trap, the female did not enter the trap (cuttlefish 3 and 4). After spawning onto the

<table>
<thead>
<tr>
<th>Cuttlefish</th>
<th>Date of recording</th>
<th>Spawning Time</th>
<th>Feeding Type of bait</th>
<th>Entry and exit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>19 March</td>
<td>19.20–18.00</td>
<td>Fish</td>
<td>22.40</td>
</tr>
<tr>
<td>2</td>
<td>22 March</td>
<td>14.20–18.00</td>
<td>Fish</td>
<td>18.12</td>
</tr>
<tr>
<td>3</td>
<td>14 April</td>
<td>02.00–02.12</td>
<td>Benthos</td>
<td>14.07 (25 March)</td>
</tr>
<tr>
<td>4</td>
<td>22 April</td>
<td>10.10–12.03</td>
<td></td>
<td>12.23</td>
</tr>
<tr>
<td>5</td>
<td>12 March</td>
<td>10.10–12.03</td>
<td></td>
<td>12.23</td>
</tr>
</tbody>
</table>

Table 1 Video recording findings of five cuttlefish

<table>
<thead>
<tr>
<th>Date and time of observation</th>
<th>Clover branch</th>
<th>Bamboo branch</th>
<th>Netting of trap</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>22 March 07.00</td>
<td>9</td>
<td>4</td>
<td>0</td>
<td>13</td>
</tr>
<tr>
<td>25 March 19.00</td>
<td>26</td>
<td>12</td>
<td>0</td>
<td>38</td>
</tr>
<tr>
<td>14 April 07.00</td>
<td>34</td>
<td>31</td>
<td>0</td>
<td>65</td>
</tr>
<tr>
<td>19 April 07.00</td>
<td>26</td>
<td>13</td>
<td>6</td>
<td>45</td>
</tr>
<tr>
<td>25 April 19.00</td>
<td>15</td>
<td>8</td>
<td>0</td>
<td>23</td>
</tr>
<tr>
<td>Total</td>
<td>110</td>
<td>68</td>
<td>6</td>
<td>184</td>
</tr>
</tbody>
</table>
branches outside the trap, the female entered the trap and continued spawning (cuttlefish 2). After spawning onto the branches outside the trap, the female entered the trap without spawning in the trap (cuttlefish 5; captured 3 days after entry; mantle length of 143 mm; GI: 44.32). The female showed no spawning onto the branches outside the trap or inside the trap after entry (cuttlefish 1; captured 2 days after entry; mantle length of 152 mm; GI: 47.38).

Because the behavior of the cuttlefish in the trap varied from one female to another, no universal relationship between entry to the trap and spawning was established. Two captured females were mature and fully mature amber-colored eggs were found in their ovaries and oviducts.

The movement of all three cuttlefish observed inside the trap was very slow with no evasive behavior. Once the cuttlefish entered the trap, they remained inside for at least 2 days. One cuttlefish was observed leaving the trap and it slowly moved out of the trap with the arms first, then disappeared from view.

Feeding was observed four times at night outside the trap between spawnings. When the bait was in the middle water layer, the cuttlefish rose from the bottom after recognizing the bait. The cuttlefish turned towards the bait, then moved straight to the bait and attacked it by quickly stretching its tentacles. This attack on the bait was repeated three times at 20–30 s intervals. However, when the live bait was on the bottom, the cuttlefish stayed on the bottom and tried to catch the bait by quickly stretching its tentacles.

**Table 3** Repeated entry of cuttlefish into a cylindrical trap in a tank

<table>
<thead>
<tr>
<th>Specimen no.</th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
<th>4th</th>
<th>5th</th>
<th>6th</th>
<th>7th</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>×</td>
</tr>
<tr>
<td></td>
<td>○</td>
<td>×</td>
<td>×</td>
<td>×</td>
<td>○</td>
<td>*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>×</td>
<td></td>
</tr>
<tr>
<td>Male</td>
<td>○</td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>○</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td>○</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>○</td>
<td>○</td>
<td>×</td>
<td>○</td>
<td>×</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

○, Entry into a trap; ×, no entry; *, weak and inactive.

Tank observation

Both female and male cuttlefish repeatedly entered the trap. One female cuttlefish entered the trap only twice, but another male entered the trap six times (Table 3).

The length of stay in the trap in the first entry (average = 6 h 18 min, range = 4 h 40 min–8 h 0 min) was less than in the subsequent second entry (average = 9 h 33 min, range = 7 h 30 min–11 h 22 min), third entry (average = 7 h 45 min, range = 5 h 37 min–9 h 0 min), fourth entry (average = 8 h 52 min, range = 7 h 26 min–10 h 21 min), fifth entry (average = 8 h 10 min, range = 6 h 32 min–9 h 48 min) and sixth entry (average = 8 h 19 min, range = 6 h 19 min–10 h 6 min). The length of stay in the trap did not show a noticeable difference between females and males.

**DISCUSSION**

The key findings of the field and tank observation of the behavior of the cuttlefish in the present study are that: (i) feeding, spawning and entry into traps took place at any time of day or night; (ii) entry to and exit from the trap was done in a straight movement with the arms first, without touching the trap; (iii) individual cuttlefish repeatedly entered the trap, (iv) once inside the trap, the cuttlefish stayed there for a long time; and (v) spawning inside the trap was rare.

The first key finding indicates that the cuttlefish are active during both day and night. Denton and Gilpin-Brown suggest that the European common cuttlefish *S. officinalis* is nocturnal because the shell’s buoyancy changes according to different light conditions between day and night. A similar suggestion that *S. officinalis* is nocturnal was made by Castro and Guerra based on the stomach contents. *Sepia esculenta* is also said to be nocturnal. However, the field observation for the present study found that cuttlefish spawn and enter traps day and night. Our study using artificial lighting for video recording purposes at night could have restricted the movement at night; however, it is highly unlikely that the endogenous nocturnal habits were enhanced by such lighting. Jig fisheries operate from early in the morning until noon and basket traps are lifted to empty the catch twice a day (i.e. in the morning and late afternoon), during the peak period of trap fisheries. These fishery practices make it difficult to ascertain that cuttlefish are nocturnal.

The second key finding implies that the tactile sense is not related to the entry to or exit from the trap by cuttlefish. The entry of cuttlefish into the trap without touching the trap means that cuttlefish visually recognize the frame of the entrance, and that the behavior towards the trap is mediated by vision. For *S. officinalis*, Messenger explains that the sense of vision is involved in feeding because the visual axis is in line with the direction of the bait immediately before capture. Similarly for *S. esculenta*, if the stretching direction of the arms is in line with the visual axis, it should be possible to visually recognize the trap entrance and accurately measure the distance to the trap. Similar behavior was observed among males and immature cuttlefish entering traps. The body position taken by the
cuttlefish when entering the trap allows for sudden escape from the trap. The fastest movement is achieved in the direction of jet propulsion when the funnel is parallel to the body axis.

The common explanation for the third key finding (i.e. repeated entry into the basket), is that such behavior is motivated by spawning,\textsuperscript{1–3} although actual spawning in the trap has not been confirmed. The present field observation for the five females showed that spawning of cuttlefish mainly took place outside the trap and only one female spawned eggs inside the trap. Another female failed to spawn even outside the trap. These facts negate the conventional idea that the entry of cuttlefish into traps is motivated by spawning.

Entry into traps must be prompted by some type of stimulus within the trap. Although the experimental traps, with an inner opening of 14–15 cm, enabled cuttlefish free entry and exit from the trap, all cuttlefish remained in the trap for long periods of time which indicates the existence of an attractive stimulus within the trap. Kawamura and Tamura report that the entry of fish to a trap is closely related to exploratory behavior.\textsuperscript{16} If the entry of cuttlefish to a trap is related to this exploratory behavior, the novelty value of the trap should be lost through repeated entries, as a result, shortening their stay in the trap in the sixth entry compared with the first entry. The laboratory test results do not support this theory and, therefore, exploratory behavior cannot explain the behavior of cuttlefish of entering the trap. It is necessary to find another motivation.

REFERENCES