

# A Review of Cuttlefish Basket Trap Fishery

Naohiko WATANUKI<sup>1)</sup> and Gunzo KAWAMURA<sup>2)</sup>

## Abstract

While cuttlefish basket trap fishery is a traditional fishing activity with a long history, there has never been an article which comprehensively assesses this type of fishery. The present review compiles existing knowledge on cuttlefish trap fishery and the findings of interviews conducted with fishermen by the authors. It mainly covers such issues as the history of cuttlefish trap fishery, relationship between traps and the catch, structure of traps, characteristics of fishing grounds and trap operating methods. In addition, the spawning habits of cuttlefish, which are closely related to trap fishery, are briefly described and the credibility of various theories on the catching process (especially the motivation of cuttlefish to enter a trap) is examined. The review concludes that because of the virtual absence of research on cuttlefish trap fishery, behavioral research is extremely necessary to establish fishery oriented resource management.

Key words: Cuttlefish basket trap, Traditional fishery, Spawning habits, Catching process, Resource management

## Introduction

Cuttlefishes (Sepiidae) are widely found in warm waters in the world. Cuttlefish basket trap has long been employed in Japan in areas around the Inland Sea and along the coast of Kyushu Island, on the Atlantic coast in Europe, and by countries around the Mediterranean Sea. In recent years, it has spread to African and Southeast Asian countries for the capture of cuttlefish for domestic consumption and export. Despite the increasing popularity of cuttlefish trap fishery, however, no article has so far been published which presents a comprehensive assessment of this type of fishery. This paper reviews existing knowledge on the history and present state of cuttlefish trap fishery in Japan and the findings of interviews conducted with fishermen by the authors. Overseas examples are also introduced where deemed necessary. Moreover, general knowledge and pending research issues are explained in relation to the catching process which poses a challenging issue for research on cuttlefish trap fishery.

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1) United Graduate School of Agricultural Sciences, Kagoshima University, 1-21-24 Korimoto, Kagoshima, 890-0065 Japan.

Present address : Overseas Agro-Fisheries Consultants Co., Ltd., Shuwa Daini Toranomom Bldg. 2F, 1-21-19 Toranomom, Minato, Tokyo 105-0001, Japan.

2) Faculty of Fisheries, Kagoshima University, 4-50-20 Shimoarata, Kagoshima, 890-0056, Japan.

## 1. History and present state of cuttlefish trap fishery

### 1.1. History

Among the various cuttlefish fishing methods, trap fishery has been the most popular method since olden times. According to The History of Japanese Fisheries (Ministry of Agriculture and Commerce, 1983), cuttlefish trap fishery for *Sepia esculenta* was conducted in the 1660's in the Ariake Sound off the coast of Toguchi, Uto City in Kumamoto Prefecture, Japan. In the Inland Sea along Ehime Prefecture, trap fishery commenced around 1890 to 1990, gradually spreading to neighboring areas. Full-scale cuttlefish trap fishery began around 1940 with an increase of the fishing boats engaged in this form of fishery. Meanwhile, similar fishery is said to have commenced around 1925 along the Fukuoka coast of the Inland Sea (Inland Sea Fisheries Development Council, 1978). Cuttlefish trap fishery was particularly popular at Shakuda and was ranked third in terms of the number of fishermen after small-scale trawl net fishery and set net fishery (Fukuoka Prefectural Buzen Fisheries Experimental Station, 1956).

At the Bay of Tsuruga in Fukui Prefecture, Japan, cuttlefish trap fishery started in 1935. Chicken cages were initially used with fish heads being placed inside as the bait but only clumps of cuttlefish eggs were found spawned outside the traps. The use of spawning substrate inside the traps led to the actual capture of cuttlefish (National Federation of Fisheries Cooperative Associations, 1979a; Hokkai Suisan Shinbun, 1979).

Cuttlefish trap fishery became popular in the 1940's along the Korean Peninsula (YAMAMOTO, 1942) and the Sea of Izumi as well as the Sea of Harima in Hyogo Prefecture (UCHIHASHI and YAMAGUCHI, 1943). The Kata Fisheries Cooperative Association in Wakayama Prefecture learned the necessary techniques around 1947 from the Fuke Fisheries Cooperative Association in Osaka Prefecture (National Federation of Fisheries Cooperative Associations, 1979a).

This form of fishery, which was popular in western Japan, spread to a much wider area in the 1950's, including the Kanto and Chubu Regions. Important fishing grounds were developed in the Bay of Tokyo and Bay of Mikawa, both of which were quite near to major consumption areas (YASUDA, 1951; KOIDO *et al.*, 1956; ISHIKAWA and IWAI, 1958).

In more recent years, the trap fishery has been attempted in areas where cuttlefish resources have not been fully utilized in view of (i) the simplicity of operation, (ii) excellent marketability of cuttlefish and (iii) possibility of combining it with other forms of fishery (set net fishery and jig fishery) (Kanagawa Prefectural Fisheries Experimental Station, 1977; Kagoshima Prefectural Takayamacho Fisheries Cooperative Association, 1995). However, the extensive land reclamation along the Japanese coastline, environmental deterioration of bay areas, excessive fishing and competition with other forms of fishery have led to a noticeable decline of the cuttlefish catch (National Federation of Fisheries Cooperative Associations, 1979a; Inland Sea Fisheries Coordination Office, 1982; Ehime Prefectural Government, 1995) and restrictions in terms of the fishing season, fishing grounds and number of traps have been introduced (National Federation of Fisheries Cooperative Associations, 1979b; Kyoto Prefectural Fisheries Office, 1986; KAWAMURA,

1990). At the same time, efforts have been made by Japanese fishermen to hatch the eggs spawned on traps and to develop spawning grounds to breed and protect cuttlefish resources (Kyoto Prefectural Kurita Fisheries Promotion Association, 1981; Hyogo Prefectural Kitanada Fisheries Cooperative Association, 1982; HAMAMATSU, 1990; SHIODA *et al.*, 1992).

### **1.2. Relationship between traps and catch**

The entry of cuttlefish *S. esculenta* to a trap is generally explained in the following manner. Spawning substrate is placed inside a trap to take advantage of the habit of cuttlefish of approaching the coast to spawn eggs on seaweed and submerged wood, etc. in the early spring. Cuttlefish are attracted by this spawning substrate and the trap is lifted when cuttlefish spawn inside the trap (YAMAMOTO, 1942, TAKEUCHI, 1981, BRANDT, 1984, RATHJEN and VOSS, 1987, NATSUKARI, 1991). This explanation of the entry of cuttlefish to a trap for spawning is shared by overseas researchers for *S. officinalis* (BAKHAYOKHO, 1983) and *S. pharaonis* (BOONGERD and CHITRAPONG, 1986). Because of the increasing use of traps with spawning substrate attached to the outside, it is suggested that cuttlefish accidentally enter the trap when spawning outside the trap or that cuttlefish seek a safe haven inside the trap because of the appearance of another cuttlefish. However, these explanations have no scientific grounds and the actual catching process has not yet been clearly explained.

There are reports that traps only catch mature cuttlefish as the spawning substrate does not attract immature cuttlefish (KITAHAIRA *et al.*, 1976) and that the catch of cuttlefish is affected by the sexual attraction between male and female cuttlefish (Yamaguchi Prefectural Mure Fisheries Cooperative Association, 1958; National Federation of Fisheries Cooperative Associations, 1979a; KAWAMURA, 1990). Other reports suggest that traps are excellent fishing gear which are capable of effectively utilizing adult cuttlefish which die after spawning and sustaining resources at the same time because of their special feature (Uchihashi and Yamaguchi, 1943; Hokkai Suisan Shinbun, 1979; Inland Sea Fisheries Coordination Office, 1982). According to these reports, the cuttlefish inside a trap have fully completed spawning before the trap is lifted and the spawning substrate with eggs can be thrown back into the sea after fishing or may be left on the seabed for some time to allow the eggs to hatch.

There is a report which casts doubt on the claim made by other reports that cuttlefish traps assist the protection and propagation of cuttlefish (Aichi Prefectural Fisheries Experimental Station, 1950). It is argued that even though traps are almost an ideal way of catching cuttlefish by allowing spawning at an artificially created spawning ground before actual capture, the cuttlefish so captured still retain many eggs. It is, therefore, necessary to introduce a new method which facilitates the spawning of more eggs. The same report also urges cooperation and awareness on the part of fishermen as many appear to remove the trap from the sea before the spawned eggs have hatched.

While the use of a large number of traps has traditionally been quite difficult because of restrictions imposed by the trap shape and loading capacity of small wooden fishing boats,

the introduction of larger fishing boats, the progress of mechanization characterized by the use of a line hauler and the introduction of smaller traps in recent years have made it possible to use a large number of traps at the same time. As trap fishery aims at catching cuttlefish immediately before spawning, another report points out the importance of production control for the conservation of cuttlefish resources (National Federation of Fisheries Cooperative Associations, 1979b).

### 1.3. Structure of traps

Many different traps exist in terms of the shape, size, entrance configuration and spawning substrate even though they all aim at catching cuttlefish. There are also historical variations.

The trap used to catch *S. esculenta* by fishermen in Kumamoto Prefecture in the 1910's was a hemispherical basket made of bamboo and rope. Branches of myrica were placed on the basket which was carefully lifted when cuttlefish were believed to be spawning (Ministry of Agriculture and Commerce, 1983). The local cuttlefish trap in Kumamoto Prefecture was improved to a turtle-shaped folding trap in the 1950's via a cylindrical trap (National Federation of Fisheries Cooperative Associations, 1979b; Kyushu Fisheries Coordination Office, 1990). This folding type trap has a steel framework which is covered by blue cremona netting and has an entrance funnel at one side. Branches of thick stemmed bamboo (*Phyllostachys pubescens*) or Japanese bush clover (*Lespedeza bicolor*) are attached to the trap around the entrance funnel as spawning substrate. The assumed advantages of this trap are said to be (i) multiple loadability on a fishing boat, (ii) good stability on the seabed and (iii) easy storage during the off-season.

In Kagoshima Prefecture, a bamboo shoot-shaped trap made from bamboo was firstly used. Following a series of improvements, a cylindrical trap and folding trap are currently used (National Federation of Fisheries Cooperative Associations, 1979b). The materials used to make cuttlefish traps for application at a shallow depth are determined based on durability and underwater weight which prevent the traps from falling sideways due to heavy sea conditions. The results of a test conducted by the Kagoshima prefectural government on prospective trap frame materials indicate that a bamboo frame and stainless steel frame have a life of approximately one year and more than four years respectively (Kagoshima Prefectural Government, 1979). However, the instability of a stainless steel frame, due to its light underwater weight and high cost, makes it unsuitable for actual use. Fishermen in Izumi, Kagoshima Prefecture use bamboo or PVC piping for the upper frame and iron bars for the lower frame so that their cylindrical traps stand properly upright when placed on the seabed.

The same fishermen believe that cuttlefish dislike pale colors and, therefore, they paint the entire frame red (KAWAMURA, 1990). The test results on the color of netting in Kagoshima reveal that a dark brown has the largest catch, followed by black, orange or blue, illustrating the good performance of darker colors (Kagoshima Prefectural Government, 1979). The Yamaguchi Prefectural Mure Fisheries Cooperative Association (1958) has tested different types and colors of netting and report that blue vinylon netting

results in a better catch than white, catechu or coal tar dyed cotton netting. In addition, blue vinylon netting is found to be more economical than others. Cuttlefish are believed to be color blind, however, these test results should not be taken as indicating the effect of the netting color on the catch.

The same cooperative association has also tested different entrance shapes for a cylindrical trap. The largest catch was recorded by a funnel-shaped entrance of which the base of the side net was extensively cut while long cylindrical entrances tended to have a smaller catch. The report also states that the supply of new spawning substrate with leaves during the fishing season levels out discrepancies in the entry of cuttlefish to different traps.

In Shimane Prefecture, spawning substrate has historically been placed inside the trap. Following improvement test results indicating a similar catch when spawning substrate is externally attached to the ceiling of the trap and / or to the side of the entrance funnel, it is argued that the latter method with easier replacement of the spawning substrate is more advantageous in terms of actual operation (Shimane Prefectural Government, 1996). Many fishermen in Kumamoto Prefecture and Kagoshima Prefecture also believe that the external attachment of spawning substrate to the trap results in a better catch based on their own experience. In Fukuoka Prefecture, spawning substrate may be attached outside the trap (ARIMA *et al.*, 1963; Fukuoka Prefectural Buzen Fisheries Experimental Station, 1979) or may not be used at all. At Kushikino in Kagoshima Prefecture, cylindrical traps without spawning substrate are traditionally used as the existence of spawning substrate is assumed not to affect the entry of cuttlefish to traps. In fact, there is no operational data which determines the impact of spawning substrate on the catch.

In both Wakayama Prefecture (National Federation of Fisheries Cooperative Associations, 1979a) and Ehime Prefecture (KANEDA, 1977), semi-circular cuttlefish traps are used. While it is easy to make this type of trap, it is not widely used outside these two prefectures because of the difficulty of piling them up onboard a fishing boat. This trap has an entrance funnel at each end and is fixed to the seabed by a bunch of strong tree branches which are placed upright at the center point just inside each entrance funnel. Wooden and bamboo frames are being increasingly replaced by steel frames which are usually fabricated by an ironworks at the request of fishermen.

In Osaka Prefecture, once an advanced area in the use of semi-circular traps, rectangular parallel piped traps are currently used. The frame is made of iron bars and is covered by synthetic netting. Each trap has two entrance funnels and spawning substrate is placed inside the trap. At Matsuura in Nagasaki Prefecture, semi-circular traps with a frame combining wood and bamboo are popularly used.

In Fukui Prefecture, as cylindrical and rectangular parallel piped traps are believed to be unsteady on the seabed, thereby liable to shifting in stormy weather, a pyramidal bamboo frame is used. This frame eradicates the troublesome work of bending the frame materials and is easy to assemble and disassemble. It is claimed that even a large quantity of such traps can be easily stored in a warehouse after use (Hokkai Suisan Shinbun, 1979). One caution in regard to this trap is the necessity to ensure sufficient internal space as a small trap can cause damage to or even the death of cuttlefish because of frequent contact with

the netting. The most important point of this trap to improve the entry rate of cuttlefish is said to be the shape of the entrance funnel. A long funnel makes it difficult for cuttlefish to enter the trap and the recommended position of the entrance funnel is approximately one-third of the trap height. When placing spawning substrate made of branches of Japanese box wood inside the four supporting posts, care is required to create space below the overhanging spawning substrate. The reason for this arrangement is that a large internal space makes it less likely that the cuttlefish inside the trap will be eaten by octopus (Hokkai Suisan Shinbun, 1979).

Looking overseas, cylindrical traps have been widely used along the coast of the Korean Peninsula. Traps consisting of side and bottom nets without a square net and flat traps using only a bottom net have also been used (YAMAMOTO, 1942).

Cuttlefish, squid and octopus fisheries have been very popular in Mediterranean countries since olden times and traps were frequently used to capture cuttlefish at Catania in Sicily in the 1920's. These conical traps had an entrance funnel at the circular end. It was believed that small branches of mastic placed inside the trap would attract cuttlefish because of their resin-like scent. Presumably as a greater attraction, a lure cuttlefish was sometimes also placed inside the trap (OHSHIMA, 1928).

In Europe and Africa, cylindrical and rectangular parallel-piped traps have been widely used in recent years (BOUCAUD-CAMOU, 1990; BAKHAYOKHO and ITO, 1991). In Senegal around 1975, horizontal drum-shaped traps for sea bream were also used to capture cuttlefish but rectangular parallel-piped traps were introduced around 1977. Although the latter have the advantages of being easily made and easy to handle at sea, they have many shortcomings in that the manual retrieval of the captured cuttlefish through the entrance funnel often injures the hands of fishermen and that only a limited number of traps can be operated by a small fishing boat. To amend these shortcomings, JOCV (Japan Overseas Cooperation Volunteers) members have been trying to spread the use of folding traps.

#### ***1.4. Characteristics of fishing grounds for cuttlefish trap fishery***

A cuttlefish trap has the advantage of being usable on the undulating seabed where trawling nets cannot be used. The characteristics of fishing grounds vary from one region to another. In general, fishing grounds are formed in a shallow water area of 10 - 30 m in depth in an inner bay where the current speed is very slow (National Federation of Fisheries Cooperative Associations, 1979a; Inland Sea Fisheries Coordination Office, 1982; Kumamoto Prefectural Government, 1983). However, there are places in which cuttlefish trap fishery is conducted in much deeper water (70 - 80 m) as in the case of the Kushi District, Oyano in Kumamoto Prefecture.

The seabed of fishing grounds consists of either sand or muddy sand with shells sometimes being mixed with the sand. An area around a reef or artificial fish reef is said to provide excellent fishing grounds. When the seabed consists of mud, the catch is poor because the trap sinks into the seabed (KAWAMURA, 1990). Moreover, the wisdom of fishermen says that an area rich with seaweed should be avoided and no catch can be expected if a trap is placed more than 10 m from the path of cuttlefish.

Although much of the relationship between the behavioral patterns of cuttlefish during the spawning season and fishing grounds is unknown, fishermen in Kagawa Prefecture believe that a group of spawning cuttlefish moves further offshore during the second half of the fishing season (National Federation of Fisheries Cooperative Associations, 1979a). In Kumamoto Prefecture, two groups of cuttlefish, i.e. locally spawned and grown cuttlefish and migrating cuttlefish which approach the coast from the open sea for spawning, exist (Kumamoto Prefectural Government, 1983). Traps are set in the same places for the duration of a single fishing season and the number of traps set is increased or decreased depending on the level of the catch (National Federation of Fisheries Cooperative Associations, 1979b). In Kagoshima Prefecture, given the fact that the level of the catch declines at previous fishing grounds, cuttlefish which have arrived at spawning grounds are believed to hardly move from these grounds after spawning. Accordingly, local fishermen take extra care not to repeatedly fish at the same fishing grounds (KAWAMURA, 1990).

### **1.5. Operating method of cuttlefish traps**

Fishing using cuttlefish traps involves one or two fishermen onboard a 2- 3 ton powered fishing boat. A main line and branch lines are attached to the traps and a single operator installs between 100 and 1,000 traps at the fishing grounds. The length of the main line between the traps should be slightly longer than the water depth in order that the next trap remains on the seabed when a trap is lifted to the boat. It is said that if the next trap is suspended in mid-water when the trap before it is lifted, the cuttlefish will leave the trap.

Fishermen usually leave the port in the morning, lift their traps to collect the cuttlefish inside and return the traps to the sea. The traps are regularly brought back to the beach for washing, drying and repair. The spawning substrate is changed when it becomes old although substrate with cuttlefish eggs continues to be used as it is.

The catch is improved if a female cuttlefish is placed inside a trap as a lure. In Nagasaki Prefecture, the lure cuttlefish is hung from the ceiling of the trap by a hook to prevent its escape.

It is often the case that cuttlefish enter the trap first, followed by an octopus which feeds on the cuttlefish. A lower entrance position improves the chance of the mixed capture of cuttlefish and octopus. When spawning substrate is attached, the inside of the trap is darkened like a fish basket, increasing the likelihood of the mixture capture of common sea bass (*Lateolabrax japonicus*), black sea bream (*Acanthopagrus schlegeli*), red sea bream (*Pagrus major*), black rockfish (*Sebastes inermis*), greenling (*Hexagrammos otakii*), filefish (*Monacanthus cirrhifer*), flatfish and bartailed flathead (*Platycephalus indicus*), etc.

Most fishermen believe that they can lift their traps at any time of the day as the cuttlefish inside the traps will not leave the traps. However, if the traps are left for more than three days, the netting becomes dirty, reducing the prospect of a good catch. Particularly at the time of the spring tide, the cuttlefish are said to be damaged as they often hit the netting. While lifting the traps every five or six days is acceptable in the early fishing season, the

frequency should preferably be increased to daily during the high season.

The opinions of fishermen on the relationship between atmospheric weather conditions as well as sea phenomena and the catch are summarized that the catch is better with fair weather than cloudy weather, with a calm lull than stormy weather and at the neap tide than the spring tide.

Various voluntary movements have been recently formed in many parts of Japan in relation to the protection, culture and effective utilization of cuttlefish resources (National Federation of Fisheries Cooperative Associations, 1979a; Hokkai Suisan Shinbun, 1979; KAWAMURA, 1990), illustrating the awareness of fishermen that fishery oriented resource management must be established with the departure from the past exhaustive fishery.

## **2. Catching process of cuttlefish trap**

### **2.1. Ecology and behavior of cuttlefish**

The most important factor in regard to the establishment of fishery oriented resource management is knowledge of the catching process, i.e. the reaction of the target animals to a particular fishing gear.

The cuttlefish trap is considered passive fishing gear which skillfully uses the behavior of cuttlefish during the spawning season. In order to examine its catching process, existing knowledge of the ecology and behavior of cuttlefish should prove useful.

The subjects of past research on the ecology and behavior of *S. esculenta* include the spawning season, spawning grounds and fecundity (YAMAMOTO, 1942; YASUDA, 1951; KOIDO *et al.*, 1956; TOMIYAMA, 1957, Chiba Prefectural Inner Bay Fisheries Experimental Station, 1962; ARIMA *et al.*, 1964; CHOE, 1966a; Kumamoto Prefectural Government, 1983), selection of the spawning substrate (UCHIHASHI and YAMAGUCHI, 1943; MAEKAWA, 1961; SHIODA *et al.*, 1992; FUJITA *et al.*, 1997), breeding behavior under rearing conditions (ARAKAWA, 1960; KATAOKA, 1960; SUZUKI, 1962; SOICHI, 1983), feeding, swimming and aggregations of young (OHSHIMA and CHOE, 1961; ARIMA *et al.*, 1964; CHOE, 1966a), change of color patterns of young (YAMAMOTO, 1941), migration, movements and formation of fishing grounds (KOIDO *et al.*, 1956; TOMIYAMA, 1957; ISHIKAWA and IWAI, 1958), growth, maturity and life span (YASUDA, 1951; TOMIYAMA, 1957; YAGI, 1960ab; NATSUKARI *et al.*, 1991), cuttlebone and locular index (YAMAMOTO, 1945; YASUDA, 1951; KOIDO *et al.*, 1956; TOMIYAMA, 1957; YAGI, 1960; CHOE, 1962; NATSUKARI *et al.*, 1991), exhaustion process of the gonad (HAMADA, 1963), seeding production and culture techniques (Chiba Prefectural Inner Bay Fisheries Experimental Station, 1962; CHOE and OHSHIMA, 1963; ARIMA *et al.*, 1964; CHOE, 1966a; Osaka Prefectural Fisheries Experimental Station, 1969), feeding habits (OKADA and OHTAKI, 1955; KOIDO *et al.*, 1956; TOMIYAMA, 1957; NATSUKARI and TASHIRO, 1991), efficiency of food conversion (CHOE, 1966b), age determination (CHOE, 1963; NATSUKARI and TASHIRO, 1991), stock assessment (Kumamoto Prefectural Government, 1983) and tagging methods (WATANUKI and IWASHITA, 1993). The ecological aspects of the research



subjects listed above were also reviewed (KUBO, 1966; OKUTANI, 1979; ARAYA, 1988; NATSUKARI and TASHIRO, 1991; Marine Ecology Research Institute, 1991). In regard to the physiological aspects of the reception of stimulus, which forms the basis for the behavior of cuttlefish, reports on the structure of the eye and retina (HARA, 1968) and visual pigment (KITO *et al.*, 1979) have been published. In contrast, there have been few reports on cuttlefish fishery and past reports have only dealt with the current state of fishery and protection / propagation measures for cuttlefish resources (KAWAMURA, 1990; NATSUKARI, 1991; NATSUKARI and TASHIRO, 1991), set net selectivity based on color (MIYAMOTO and SHIODA, 1954), effects of artificial fish shelter (MACHIDA *et al.*, 1979), marine environment and fishing ground fluctuations (BAIK and PARK, 1985), catch composition of traps (WATANUKI *et al.*, 1993), catching effectiveness of traps (WATANUKI *et al.*, 1994) and relationship between the catch and currents (YAMAGUCHI *et al.*, 1998).

Below, the spawning habits of cuttlefish are briefly explained in relation to cuttlefish trap fishery and the possible connection between various circumstantial evidence provided by past research and the catching process of cuttlefish traps is discussed.

## **2.2. Spawning habits of cuttlefish**

The season for cuttlefish trap fishery almost coincides with the spawning season. The actual spawning season is from December to May in the Yatsushiro Sea (KAWAMURA, 1990), from January to June in the Ariake Sound (Kumamoto Prefectural Government, 1983), from April to July in the Inland Sea (TOMIYAMA, 1957) and Bay of Mikawa (YASUDA, 1951) and from March to June in the Bay of Tokyo (KOIDO *et al.*, 1956). The spawning season around Kyushu Island is believed to commence three or four months earlier than in the coastal area of Honshu Island.

When the spawning season arrives, cuttlefish move from deep offshore areas of 50 - 60 m in depth to shallow coastal areas of 2 - 36 m in depth. There are many materials which can be used as spawning substrate for cuttlefish, including cuttlefish traps, netting, rope, cage, laver bed, sunken wood, aquatic plants, seaweed, Coelenterata and tube of lobworms (*Neanthes japonica*) (YAMAMOTO, 1942, UCHIHASHI and YAMAGUCHI, 1943, YASUDA, 1951, KOIDO *et al.*, 1956, TOMIYAMA, 1957, MAEKAWA, 1961, Chiba Prefectural Inner Bay Fisheries Experimental Station, 1962, ARIMA *et al.*, 1964, CHOE, 1966a, Kumamoto Prefectural Government, 1983, POPER *et al.*, 1984, SHIODA *et al.*, 1992, FUJITA *et al.*, 1997).

Compared to *S. latimanus* (OKUTANI, 1978; CORNER and MOORE, 1980; OKA, 1991) and oval squid *Sepioteuthis lessoniana* (TSUCHIYA, 1981; SEGAWA, 1987; UETA *et al.*, 1992), *S. esculenta* do not select spawning substrate as rigorously but are said to dislike soft materials (FUJITA *et al.*, 1997). In this sense, the branches used for cuttlefish traps appear to meet the requirements of spawning substrate as they are hard and thin, allowing cuttlefish to use the arms to place eggs in them.

Attempts to culture cuttlefish reveal that cuttlefish perform courting and mating rituals prior to spawning. Males are more active in these rituals, changing the body color of the mantle and the base of the fins when approaching females with Arm I being raised upward.

Females sometimes adopt the same body stance in response to courting by males. When mating, the male and female keep their heads in close contact with their arms entangled and remain still in this position for several minutes. During this time, the male uses a hectocotylyzed arm to insert its spermatophores inside the body of the female to complete the mating process (ARAKAWA, 1960; KATAOKA, 1960; SUZUKI, 1962; SOICHI, 1983). During the busy mating season, the same individuals may repeat this mating process several times a day with different individuals of the opposite sex. Females appear to select the males. Some males appear to be accepted by all females while other males are not. Preliminary mating between males is also observed (ARAKAWA, 1960).

Cuttlefish are ready to spawn immediately after mating (OKUTANI, 1979). A female approaches the spawning substrate of her choice, sprays water on the substrate using the funnel and places her eggs one at a time by inserting an arm deep inside the substrate. Throughout this process, a male is said to accompany the spawning female (ARAKAWA, 1960; KATAOKA, 1960; SUZUKI, 1962; SOICHI, 1983). The use of a female cuttlefish inside a trap as a lure, exploiting a series of behavioral characteristics of cuttlefish from courting to mating, is said to substantially increase the catch (KAWAMURA, 1990).

The eggs of cuttlefish have the shape of a Western pear. They have a milky white color and the surface is covered by sand granules or mud from the seabed (OKUTANI, 1986; KUBODERA, 1989). One female individual has some 2,500 eggs. Instead of spawning all of the eggs at once, several tens of eggs are spawned at a time (KUBODERA, 1989). Spawning is conducted more at night than during the day (YAMAMOTO, 1942). Cuttlefish are said to be nocturnal and bury themselves inside bedding materials during the day (OKUTANI, 1987).

The eggs of cuttlefish hatch approximately one month after being laid in an ambient water temperature of 20°C (KUBODERA, 1989). The young which hatch in the summer move offshore in autumn when they are grown. After winter, the mature cuttlefish return to the coastal area for spawning in spring. They die after the completion of spawning. Accordingly, the life of cuttlefish is estimated to be one year (ARAYA, 1988; OKUTANI, 1979).

### ***2.3. Relationship between traps and catching process***

A survey of catch composition is a useful means of inferring the behavior of cuttlefish in relation to traps. The survey findings regarding the sex ratio, sexual maturity, fecundity and evidence of mating on cuttlefish caught by traps can determine whether or not traps are fishing gear which catch females in a selective manner, at what stage of the process of sexual maturity cuttlefish are caught in traps and whether or not cuttlefish conduct spawning and / or mating inside traps.

The sex ratio (females / males) of cuttlefish caught by traps in the Bay of Mikawa shows a female dominant figure of 2.8 in mid-April which gradually declines thereafter to 0.84 in early to mid-May. However, sailing drag seine consistently catches more females than males (YASUDA, 1951). These findings suggest that traps are not selective fishing gear to predominantly catch females and there are factors other than spawning involved in the

catching process. YASUDA (1951) states that cuttlefish enter a trap for spawning or mating and that the reason why more males are caught by traps in the late fishing season is unknown.

According to the results of a comparative analysis of the biological characteristics of cuttlefish caught by traps, jigs and trammel nets in the Ariake Sound off the coast of Kumamoto Prefecture, the ratio of females is significantly large in the case of traps but a large number of males is also caught together with immature or unmated females. There is no noticeable difference between the three types of fishing gear in regard to the sex ratio or maturity, negating the contention that traps are more selective than other types of fishing gear to catch spawning individuals (WATANUKI *et al.*, 1993).

In the Inland Sea off the coast of YAMAGUCHI Prefecture, clumps of cuttlefish eggs begin to be attached to traps in early April. The females caught by traps show traces of mating and appear to be ready to spawn. The average number of eggs found inside females caught in May, the height of the spawning season, is 1,518 which is some 1,000 less than the average number of eggs found in females caught in October through February. This difference is explained by the fact that spawning is not completed on a single occasion but on several occasions (TOMIYAMA, 1957). There is no firm evidence to indicate the spawning of females inside traps. It may be possible to infer the behavior of cuttlefish based on the clumps of eggs attached to traps. In this case, it is essential to scrutinize whether these clumps are actually placed inside the traps. The type of trap which is becoming increasingly popular throughout Japan has spawning substrate attached to the outside of the trap, therefore enabling cuttlefish to spawn without entering the trap. While there is a persistent theory that the entry of cuttlefish to traps is motivated by spawning using the attachment of clumps of eggs on traps as evidence, more attention should be paid to detailed studies on the situation surrounding spawning and the composition of the catch.

At the Bay of Urago of Oki Island, a large number of weakened cuttlefish can be observed drifting through the bay at the end of the fishing season. Comparison of the biological measurement of these drifting cuttlefish with actively swimming cuttlefish caught by various types of fishing gear reveals that, regardless of sex, the drifting cuttlefish have a lower body weight, liver weight and gonad weight. This observation suggests that individuals which have engaged in reproductive activities suffer a weight loss of the liver and gonad due to energy consumption and have been weakened to eventual death (HAMADA, 1963). If the same phenomenon is observed with the weight of the gonad of cuttlefish caught by traps, it can be ascertained that cuttlefish conduct spawning and / or mating inside traps.

The results of the survey on cuttlefish caught by traps in the Buzen Sea did not show a decrease of the weight of the ovary with the progress of the fishing season. On the contrary, a tendency for the weight of the ovary to increase was observed as the fishing season progressed despite the fact that the size of cuttlefish gradually declined from the early fishing season when large individuals with a large quantity of eggs inside the ovary were caught (ARIMA *et al.*, 1964). This observation may imply that cuttlefish do not spawn inside traps and that cuttlefish caught in traps constitute a reserve group for spawning outside traps. At the same time, as the attachment of eggs to traps can be interpreted that

caught cuttlefish and spawning cuttlefish form different groups, further studies are required.

KATAOKA (1960) reports that when male and female cuttlefish are placed in a tank, the female engages in mating several time before spawning all of her eggs. Nevertheless, it has not yet been established if cuttlefish actually engage in multiple mating in the sea. If a male escorts a spawning female into a trap for multiple mating as in the case of the tank experiment, a pair of male and female cuttlefish must be caught. No report to this effect has yet been published. As reported by YASUDA (1951), it may be the case that females and males are not necessarily together in the spawning season as the observed dominancy of one sex over another fluctuates during this season.

It may also be the case that the low density of cuttlefish in the natural environment makes it difficult to find a partner. The placement of a lure in a trap may, therefore, be an effective fishing method which exploits the mutual attraction between male and female individuals.

The existing knowledge regarding cuttlefish trap fishery introduced and explained so far is still extremely insufficient, particularly in relation to the ecology and behavior of cuttlefish. It is also stated that the various theories put forward to explain the catching process, especially the motivation of cuttlefish to enter a trap, have no reliable grounds. Behavioral research on the catching process of cuttlefish traps must be given the highest priority with a view to firmly establishing fishery oriented resource management.

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