THE CALIFORNIA SQUID FISHERY

by

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1. INTRODUCTION

Numerous species of squid are found in the California Current system, but only the common market squid, Loligo opalescens (Berry, 1911) is the object of a fishery. A few tons of the jumbo squid, Dosidicus gigas (d'Orbigny, 1835) have been landed from time to time but never in sufficient quantity to support a sustained fishery (Croker, 1936). Most other species are either too small or not readily available to the fisheries. It should be noted, however, that exploratory fishing efforts have never been directed by U.S. fisheries toward locating and attempting to fish squid on the high seas off the west coast. An exploratory cruise conducted by a Japanese vessel in 1971 failed to catch substantial quantities of squid between British Columbia and California; however, the vessel made good catches (probably D. gigas) off the southern tip of Baja California, Mexico (Anon., 1971). This report deals only with the fishery for Loligo opalescens in California.

Loligo opalescens (Fig. 1) is a small squid. In commercial landings at Monterey, California, males averaged 150 mm in mantle length and weighed 70 g, while females were 140 mm and 50 g (Fields, 1965). Maximum mantle length was about 190 mm for males and 180 mm for females (Ibid.). Nearly all squid taken by the commercial fishery are mature and are caught during the spawning season.

2. LIFE HISTORY

2.1 Reproduction

Adults of L. opalescens congregate in vast numbers in shallow waters to spawn. McGowan (1954) directly observed spawning on sandy bottom with rocky outcroppings, primarily at depths of 15 m and down to at least 35 m. The egg capsules were laid in clusters, the largest of which was about 12 m in diameter. Most clusters are considerably smaller, however. Only a few animals are known to feed on egg capsules of L. opalescens. Patiria (MacGinitie and MacGinitie, 1949) and possibly other starfish may feed on the eggs, and the junior author has observed large numbers of white sea urchin Lytechinus sp. aggregated around and over clusters of squid eggs. In an aquarium each of several females deposited overnight an average of 20 capsules, each containing 180 to 300 eggs (Fields, 1965). Larval squid hatch at 2.5 mm mantle length after 3 to 4 weeks at 16°C (Fields, 1965) and 4 to 5 weeks at 13.6°C (McGowan, 1954). Mass mortality occurs after spawning, as evidenced by large numbers of dead squid (Fig. 2) on the bottom in spawning areas (McGowan, 1954). Whether or not all squid die after a single spawning season is not known.

2.2 Growth and Longevity

Loligo opalescens has been reared from eggs in a laboratory tank for periods up to 100 days (Ann Hurley, National Marine Fisheries Service, La Jolla, pers. comm.). Growth rate was slow for the rearing period, averaging about 2.5 mm/month mantle length. Whether this growth rate truly reflects natural growth in the wild remains to be seen, but it seems rather low. Fields (1965) estimated longevity of about three years, with a growth rate of 4 mm/month using monthly modal progression of the length-frequency distribution, but his conclusion was based primarily on spawning animals caught by the Monterey commercial fishery. Such squid would presumably be expending more energy on reproductive processes than body growth. Field's data on juveniles showed a similar growth rate, but his modal progressions followed squid spawned in different years, and caught at several localities by different methods.

Recent evidence suggests that squid may exhibit daily growth increments in the statolith (Brothers *et al.*, in press). The number of growth increments in the form of fine lines or lamallae showed good correspondence to actual age of squid reared in the laboratory (Edward Brothers, Inter-American Tropical Tuna Commission, La Jolla, California, pers. comm.). In wild squid ranging in size from 110 to 160 mm mantle length, the number of lamallae numbered 320 to 450. If the lamallae truly represent daily growth increments, they suggest a longevity of about one to one and a half years (Jerome Spratt, California Dept. of Fish and Game, Monterey, California, pers. comm.).

2.3 Distribution and Migration

Adults of *L. opalescens* are found from British Columbia (Fields, 1965) to central Baja California, Mexico. Spawning concentrations or egg masses have been occasionally reported from British Columbia, Puget Sound, and Punta Eugenia (Lat. 27°51'N), Baja California (Okutani and McGowan, 1969), but the main spawning grounds are apparently at Monterey and at the Channel Islands off southern California. Large spawning aggregations are also known to occur in many areas along the mainland coast from San Diego to Monterey, California (Ally, Evans and Thompson, 1975). The months of heaviest concentration at the Channel Islands are December to March, and off Monterey, May to July. A minor peak in availability of spawning squid, reflected in catch statistics, used to occur regularly in November at Monterey (Fields, 1950), but recently this peak has not been evident consistently.

Larval distribution of squid has been examined in detail by Okutani and McGowan (1969). They found larvae of *L. opalescens* in nearshore waters from the southern tip of Baja California to San Francisco, with greatest numbers occurring between Pt. Conception and southern Baja California in winter and spring. However, considering the heavy annual concentration of spawning activity at Monterey in spring and summer, one would expect to find correspondingly high concentrations of larvae during this period off central California. Perhaps sampling patterns or some other factors led to underestimation of relative abundance north of Pt. Conception.

Information on distribution of juvenile stages is scanty. Juvenile *L. opalescens* are found in many inshore localities along the central and southern California coast, but large concentrations are rarely encountered. This may simply be due to lack of sampling effort and inadequacy of fishing and sampling gear for catching juvenile squid.

Depth distribution of *L. opalescens* has not been investigated extensively. Although it is clear that the greatest concentrations of spawning squid occur in shallow water, egg masses and adult squid have also been taken by bottom trawl in depths of 180 m. Squid of various sizes from juveniles to adults have been observed near the surface at Monterey feeding on aggregations of euphausids, and in turn being consumed by birds (G.V. Morejohn, Moss Landing, California, pers. comm.).

Movements and migratory patterns of *L. opalescens* are unknown. Okutani and McGowan (1969) found a progressive northward movement in number and frequency of occurrence of larvae, starting in winter from southern Baja California. This does not necessarily mean that adults or subadults migrate in similar fashion. Widespread spawning, both in time and geography, makes it difficult to interpret observed distributional patterns, particularly because adults presumably die after spawning. Further, lack of knowledge about homing behaviour and population structure hampers our ability to gain an insight into migratory patterns.

2.4 Sex Ratio

Fields (1965) concluded from extensive sampling through several years of commercial landings at Monterey that the sex ratio of L. opalescens was essentially 1:1. Large imbalances in sex ratio, with either males or females predominating, often occurred with particular schools of squid, however. His samples were primarily taken from squid fishing vessels, but he also examined squid caught incidentally in other fisheries. Unfortunately, Fields lumps several years of data and does not give sex ratios by seasons or smaller entities. Ronald Evans (Moss Landing Marine Laboratories, Moss Landing, California, pers. comm.), found males predominating with 56 percent of the total in the 1974 Monterey catch. In the 1974 southern California catch, he found 59 percent males. Samples from the two areas may not be comparable because of different fishing methods. Light-attraction methods used in southern California may be selective for males (J.R.R. Ally, California Department of Fish and Game, Long Beach, California, pers. comm.). Interestingly, McGowan (1954) found 63 percent males when he sampled dead and dying squid during a period of spawning activity.

2.5 Feeding Relationships

Fields (1965) found differential feeding patterns in spawning and nonspawning schools of squid. Female squid sampled from the commercial catch at Monterey nearly always had empty stomachs, while 37 percent of males had some food. The bulk of this food consisted of squid, presumably L. opalescens. Stomach samples taken from nonspawning squid caught incidentally with fish in roundhaul nets revealed entirely different patterns. Both males and females had food in the stomachs, and crustaceans (euphausid and mysid shrimp) and fish were predominant. Anatole Loukashkin (California Academy of Sciences, San Francisco, California, pers. comm.) found about equal amounts of fish and crustacean remains in the stomachs of squid caught by jigging. Stomachs from spawning schools were usually empty.

Loligo opalescens is undoubtedly a major food item for the whole spectrum of carnivores occurring in the California Current system. Predators include birds, sharks, bony fishes, and marine mammals.

2.6 Populations and Abundance

Studies on population structure of Loligo opalescens have only recently been initiated. A recent study disclosed statistically significant differences in some morphological characteristics between squid from southern and central California (Ronald Evans, Moss Landing Marine Laboratories, Moss Landing, California, pers. comm.). Southern California squid were longer, had thicker mantles, and had longer and wider fins. Curiously, the Monterey squid weighed slightly more than southern California squid. Another study, involving electrophoretic techniques on enzyme and blood protein distribution, suggests the existence of more than one population of squid (Jay Christofferson, California State College, Stanislaus, California, pers. comm.).

No good estimate of the abundance of L. opalescens is available at present. Various estimates of the potential annual yield have been given, ranging from over 100 000 tons (Voss, 1973) to 300 000 tons (Gulland, 1971). The latter figure seems high, but may include other squids found in the California Current system. The highest annual catch, 19 012 tons, was taken in 1946.

3. THE FISHERY

The squid fishery in California is essentially two fisheries, one centred at Monterey and the other in southern California at the Channel Islands (Fig. 3). Fishing methods, price, and seasons are different in the two areas.

Earliest accounts of the Monterey squid fishery go back to the late eighteen hundreds, when immigrant Chinese fishermen harvested squid at Monterey Bay (Collins, 1892). Squid were attracted to a lighted torch hung from a small skiff. When sufficient numbers had accumulated two vessels surrounded them with a purse seine 55 m long and 5.5 m deep (Ibid.). In 1905 immigrant Italian fishermen introduced the lampara net at Monterey, and this gear has predominated there to the present time.

The fishery started somewhat later in southern California, beginning in earnest in 1953 when over 2 450 tons were harvested. Previous to that year the high catch was under 350 tons.

Historical catch data (Fig. 4) show the Monterey fishery (which includes landings at Moss Landing, located about 30 km north of Monterey) predominating until the early sixties, when the southern California catch started to increase. In recent years the southern catch has even exceeded the Monterey catch (e.g., 1965, 1970, 1973, 1974). The ex-vessel price (Fig. 5) has always remained higher at Monterey, however. A considerable price differential exists between prices paid by freezers and by canners of squid, with the former paying 1.5 to 4 times more than the latter. Monterey processors have always paid more than southern California processors, both for freezer and canning squid. Reasons for this are vague but apparently are related to quality of squid, union activity, and market conditions.

Usually, squid are sold to freezer plants because of the higher price, and canners receive the excess beyond processing capacity of the freezer plants. Thus, in times of high availability, more squid is canned, and the average value of squid is consequently lower. The freezer plants usually apportion the amount they can handle to several vessels. A few vessels in southern California fish exclusively for canners, electing to fish for a lower price to be assured of a larger market.

The bulk of the California squid catch is canned or frozen and exported to Europe. Lesser amounts are exported to Latin American countries and to the Orient, particularly the Philippine islands. Domestic consumption is mostly in frozen form, and a considerable amount of frozen squid is also used as bait in both commercial and recreational fisheries.

Several fishing methods are employed to capture squid in the California fishery. The methods are dictated by fishing regulations, economics, behaviour of the squid, and fortuitous encounters by fishing vessels that are searching for other species.

The fishing seasons in the two areas are different, with landings peaking in winter in southern California and early summer in Monterey (Fig. 6). A secondary peak used to occur in Monterey in November (Fields, 1965), but this peak has been small in the average catch for the last 20 years. In southern California, fishing generally starts in December at the lower Channel Islands of Santa Catalina and San Clemente Islands. Nearly all squid landed are caught by light-attraction methods, but some are also caught by purse seine. As the season progresses, the squid appear to move northward, and catches from Santa Cruz Island and off Port Hueneme increase. Purse-seining activity also increases, particularly after the closure of the anchovy (*Engraulis mordax*) reduction season in the middle of May.

3.1 The Southern California Fishery

Squid is usually located with the aid of depth sounders. Both flasher type and paper recorder sounders are used, and many makes and models are represented in the fishery. Frequencies of the depth sounders vary from 38 to 125 kHz. At present there appears to be no preference for any single type or frequency of echo sounder, but most are relatively inexpensive sets that operate at 50 kHz. At least two vessels employ sonar to good advantage.

The model used by both, Wesmar SS-150[1/], operates at a frequency of 160 kHz and is reported to be quite effective in locating schools of squid. However, positive identification as to species is not usually made from echo sounder marks alone. In order to confirm identification, fishermen often employ bare treble hooks to snag animals located by echo sounders. Some fishermen appear to be able to distinguish squid from fish (usually anchovy or jack mackerel) by the general form of the school as revealed by the depth sounder, and through the school's behaviour under attracting lamps.

At night bioluminescence also aids in the detection of squid schools. Another indication of squid is the presence of predators - pilot whales (Globicephala macrorhynca), sea birds, and occasionally, sea lions (Zalophus californianus).

Scouting usually commences before dark and continues into the night until squid are found. Most searching is concentrated near shore in depths of 20 to 70 m. No searching is done in deeper waters where squid are undoubtedly present, because fishing operations are limited to depths in which the vessels can anchor. Further, when squid are too deep they will not respond to the attraction system employed by the southern California fishery. Most fishing is done over depths of 24 to 33 m (J.R.R. Ally, California Department of Fish and Game, Long Beach, California, pers. comm.).

Once a promising school is found, the vessel is anchored in the area of heaviest concentration (except when purse seining, which will be discussed later). At dark, attracting lamps are turned on. The lamps consist of two or more 1 500 Watt incandescent lamps placed high above on the mast (Fig. 7). Other types of lamps, such as quartz-halogen and mercury vapour, have occasionally been used, but most fishermen prefer the incandescent lamp. Concentrating lamps, usually of similar intensity, are situated about two metres above the water. These lamps are also turned on at the same time. After a period of time, which depends on the behaviour of the school, the squid come to the surface. School size varies from a few tons to over 100 tons (Fig. 8). The squid swim in a circle, usually heading aft outboard, turning at the edge of the lighted area, and passing alongside the ship on both sides directly under the concentrating lamps. Squid normally swim with a heading into the current toward the lamp. Thus, when current and wind directions are markedly different, the vessel is placed under power to maintain the bow headed into the current. A power-assisted brail is the principal fishing gear used in southern California (Fig. 9). The hoop of a typical brail is about 1.1 to 1.5 m in diameter, and the netting, constructed of 2.5 cm stretched mesh, is about 150 to 200 meshes deep. Small purse rings are sewn in at the bottom of the net to facilitate quick opening and closing of the brail. During operation, one man guides the brail into the water holding a handle 3 m long. The same man holds on to the chain purse line. The brail is lowered and raised by a second man with a hydraulic or mechanical winch. As the brail is manoeuvred into the water ahead of the swimming squid, a third man pulls the brail toward the stern of the vessel, through the concentration of squid. At the end of a sweep, the winch man lifts the brail out of the water and lets the net rest on the gunwhale or deck for several seconds to drain most of the water (Fig. 10). The brail is again raised until it is poised over the fish hold, and the bottom is opened. The brails hold about 250 to 500 kg of squid. A variation called the "Canadian" or "sock" brail is sometimes used. This brail has a net depth of about 6 m and does not have purse rings. During operation, the brail is passed several times through the school of squid. To bring the catch aboard, the hoop is placed on the opening of the fish hold, and the end of the brail is lifted upward by means of a line passing through a block on the mast. Although most vessels carry three crew members, two-person operations are not uncommon, and in one case a single man uses a power-assisted brail effectively, although the amount he can catch is limited.

Squid are usually oblivious to brailing activity; thus operations often continue until the hold or the market order is filled. Occasionally commotion at the surface will cause squid to dive, halting fishing operations. Active predators such as dogfish sharks (Squalus

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1/ Mention of commercial products by name does not constitute or imply endorsement by the National Marine Fisheries Service or California Department of Fish and Game acanthias), pilot whales, sea lions, and diving birds can cause the squid to sound, while slow-moving blue sharks (Prionace glauca) cause little alarm to the school except when large numbers of sharks are present. Thus, fishermen are obliged to continuously chase predators away from the immediate area.

When a school of squid behaves erratically, it becomes impossible to use a large brail, because the disturbance causes the squid to sound. In such cases, fishermen often resort to the use of hand-operated brails, gently dipping a few kilogrammes per scoop.

In the southern California fishery the primary fishing method is the power-assisted brail, used in conjunction with attracting lamps. A unique method of catching squid with a hydraulic centrifugal pump and the traditional light attraction system was developed by one of the authors and a commercial fisherman (Kato, 1970). The pump, a Marco Model U-230 Capsulpump (Fig. 11) was designed to handle fish, but we found it also useful for catching squid. At a total static head of 5.2 m and hydraulic fluid flow of 75.7 l/min (under a pressure of 84 kg/cm^2 or 1 200 psi), the pump will discharge about 400 tons of water per hour through a discharge hose with a diameter of 203 mm. A 20 Hp electric motor supplies sufficient power for the hydraulic system.

After many trials an effective system was developed which utilized a floating wooden funnel (Fig. 12). The funnel measured about 2 m wide, 1.5 m high, and 2 m long. A small 500 Watt quartz-halogen underwater lamp was placed at the interior end of the funnel where two vertical bars were also installed to prevent sharks from being sucked into the pump. Floats were used to keep the funnel at the surface. A small boom was sufficient to handle the gear which weighed about 200 kg. A rubber fish hose led from the pump to the gunwhale, where a steel elbow was used to prevent kinking. Another section of rubber hose led from the elbow to a steel separator, which removed water over the side. The separator was lined with galvanized cloth, 9.5 mm square mesh.

Through continued experimentation the commercial fisherman, Madison Dee May, improved the system to correct some flaws. He found that the lower wing of the funnel could be constructed of 50 mm (stretched mesh) netting and the upper wing left open, without lowering the catch rate (Fig. 13). This funnel measured about 1.25 m square at the opening, tapering to 0.32 m square at the pump. The length was about 1.20 m. This innovation aided in preventing the funnel from moving back and forth violently when wave action was high and reportedly was effective in winds up to 25 knots (Madison May, San Pedro, California, pers. comm.). Further, the open top wing eliminated the need for an underwater lamp within the funnel. It should be noted that squid actually swim into the funnel, and strong suction is not necessary for the pump system to be effective. Indeed, when squid lie almost motionless at the surface, as sometimes they are wont to do, the squid pump is quite ineffective. May also suspected that water splashing over the side of the vessel from the separator scared some schools of squid. The black, foamy water apparently disturbed the squid or blocked out the light. To resolve this problem, he designed and built a separator which was completely enclosed. Two hoses leading from holes fed by a trough carried the water from the separator to a depth of 2 m under the surface. Surface foam was thus largely eliminated. To facilitate handling and eliminate need for a connecting elbow, the pump was turned 90° from its normal vertical position and the intake attached directly to the funnel.

To date only one fisherman has successfully used the pump system. One other vessel was equipped with a pumping system, but for various reasons it was not successful in catching squid. Others have indicated their intention of installing a pump, but none has done so yet.

Probably the greatest advantage of the squid pump over the brailing method is the possibility of reducing the crew size, and the dramatic reduction of physical labour. The pump can fish for sustained periods without rest, unlike crew members. When squid are active, the pump can easily outfish the brail. However, when squid lie nearly motionless at the surface, brailing is faster. At times when squid concentration is low, the pump can fish continuously, resulting in a substantial catch after several hours, while brailers usually will not attempt to fish until a good concentration of squid has accumulated. A major disadvantage of the pump is that two to five percent (depending on the pumping speed) of the heads of squid are torn loose.

It is difficult to compare the effectiveness of the two methods of fishing, because we lack information concerning important variables such as vessel capacity, market limits, fishing effort, and skill of individual fishermen. During the 1973/74 season the fishing vessel, PACIFIC TROJAN, which used a fish pump as well as the brailing method, caught 719 tons of squid in 43 delivery days (i.e., days when catches were landed) for an average of 16.7 tons per day. The range in catch per night varied from under a ton to 54 tons. PACIFIC TROJAN'S catch amounted to 14 percent of the total catch taken during that period by 20 to 25 vessels. Thus, other factors aside, pumping was relatively efficient. Generally, squid were pumped aboard for relatively short periods, with catches commonly reaching 15 tons per hour. This amount was sometimes brought aboard in ten minutes. Catches of 75 to 85 tons have been made with the pump in one night's fishing by PACIFIC TROJAN in previous years.

Cost of the pump, including hydraulic hoses and fish hoses, is presently about U.S.$ 5 000. Construction of a separator, chutes, and a funnel costs around U.S.$ 1 000.

Southern California has yet another method for catching squid, i.e., purse seining. No special seines are used for catching squid, but the anchovy and jack mackerel seines are also used for catching squid when the opportunity arises. Typically, the seines are 460 to 550 m long and 64 to 73 m deep. The anchovy net has a stretched mesh of 17 mm and the mackerel net of 35 mm (Anthony Pisano, Manager, Fishermen's Cooperative Association of San Pedro, pers. comm.). Like brail fishermen, purse seiners use bioluminescence, predators, and depth sounders to locate squid. Most of the vessels are equipped with sonar which adds a further dimension to their searching capabilities. Most fishing is done at night although day fishing is not rare. Fishing operations follow the same procedure used in most single boat purse seining operations. Sometimes squid are attracted to the surface with lights from the vessel. Then a skiff bearing a small portable lamp is used to hold the squid while the vessel extinguishes other lights and makes a set around the skiff. This method is not preferred because of the large number of predators, particularly sharks, attracted to the scene. When these animals are caught in the seine it is difficult to transfer the catch into the hold, a task often accomplished with a 300 mm Marco Capsulpump. Further, sharks outside the net often bite and tear the bag of the net during the transferring operation. During most years low market demand and small shoreside handling and processing capacity discourage the use of purse seines, which are capable of catching large quantities of squid. Late in the fishing season, from April through July, landings by seiners increase, while landings by brailers decrease. It is not clear why this situation occurs. One factor is reduced fishing effort by brailers because of the beginning of the albacore (<u>Thunnus alalunga</u>) season in summer. Most squid brailers turn to albacore as soon as this tuna, which is the principal source of their income, appearsoff the west coast. Further, as squid move progressively northward late in the season, the market and landing facilities become too distant for most of the brail fleet, which is comprised of smaller vessels. Because of the length of time it takes to make a round trip from the fishing grounds to port, fishing can be conducted only on alternate nights, and since these vessels can only carry 15 to 30 tons of squid, the fishery is uneconomical. It is also held that squid are not strongly phototropic during the summer months. On the other hand, purse seiners find anchovy fishing declining in late spring, and after mid-May, the season is closed. Thus they turn to other fisheries, including squid.

A unique method is sometimes used by one vessel for capturing squid and maintaining them alive for bait. Hatches have been cut into the sides of the vessel below the waterline. Each hatch leads to a divided compartment. When squid are crowded alongside the vessel underneath a concentrating lamp, the hatch is opened, causing the squid to be sucked into the vessel's hold together with the rushingwater. The light is then moved in front of another hatch and the procedure repeated. Squid caught and kept in these hatches remain viable for several days, and are sold primarily to recreational fishermen for bait.

Squid fishing vessels in southern California are of many varieties. Except for the purse seiners, all are combination vessels, used primarily in trolling or pole and line fishing for albacore tuna during summer and autumn. These vessels range in overall length from 10 to 28 m, with gross tonnages of 15 to 100 tons. Most vessels are equipped with hydraulic power and electric (AC) generators. Although nearly all vessels are equipped with refrigeration, usually a spray-brine system, squid are not refrigerated. Catches are hauled to fish plants immediately after fishing is terminated each night. About 15 vessels (excluding purse seiners) participate in the fishery regularly, while a few others engage in the squid fishery occasionally.

During unloading, the fish hold is flooded with water, and a small brail is used to transfer fish from the hold into metal tubs containing slush ice. In some cases pumps and moving belts are used to unload squid directly to a cannery or into transport trucks.

3.2 Monterey Fishery

The squid fishing method in Monterey Bay is determined primarily by California State fishing regulations. Purse seining was outlawed in 1953 because of possible effects on squid eggs. Spawning squid occur in shallow waters in the fishing grounds in Monterey Bay, and the lead line of purse seines drags across the ocean floor, uprooting the sessile egg masses. Another law which limits fishing methods, introduced in 1959, is the ban on the use of lights to attract squid. Thus brailing and pumping methods are effectively excluded. Reasons given for the passage of this law are many and varied, and there seems little chance of repealing or modifying it in the near future, despite recommendations to that effect by the California Department of Fish and Game. One reason given is that fishermen felt they needed protection from plant operators who in the past were able to catch substantial quantities of squid without vessels by employing lights and dip nets at their piers and floating unloading platforms. Fishermen also felt that bright lights disrupted spawning activity, and processors thought that light-attracted squid were lower in quality.

Squid at Monterey are caught with a roundhaul net called a lampara. Specifications for large and small lamparas are given by Scofield (1951) who defines a lampara as a roundhaul net with "...a large central bunt and relatively short wings of larger mesh. The two wings are pulled simultaneously." Lampara nets have been used to catch squid in Monterey Bay since 1905 when it replaced the purse seine that had been used by Chinese fishermen since at least 1863 (Fields, 1950). Some purse seines were used during the late forties but were outlawed in 1953. The bunt of the present-day lamparas has a mesh size of 32 mm (stretched). The corkline is usually 55 to 73 m long over the bunt. The leadline is usually less than 36 m long (sometimes as short as 12 m) below the bunt. The corkline of each wing is 145 to 190 m long. The leadline is usually 10 percent shorter so that it precedes the corkline as the net is hauled (Fig. 14), minimizing chances of squid escaping downward. Adjacent to the bunt the mesh size in the wings is 100 mm stretched and increases toward the wingtips to 150 to 230 mm. The wings of some nets taper to a point; others are cut nearly square. They are usually about 55 m deep where they join the bunt. The entire net is usually made of netting twine R 610 tex or R 700 tex (American number 8 or 9), but lighter netting yarns are sometimes used in portions of the wings. Further details on construction of lampara nets are given by Higgens and Holmes (1921), Scofield (1951), and FAO (1972).

Fishermen began replacing and repairing their cotton nets with Marlon (mixed polymeric) in the early fifties. In spite of its greater bulk, this Japanese synthetic netting material was favoured over nylon (polyamide) because of its softness, superior knot-holding qualities, and lower cost. Presently fishermen use nylon because its price has come down.

Most depth sounders used to locate squid in the Monterey area are of the flasher type. Frequencies are similar to those used in southern California. At least one fisherman tried to use sonar, but the wakes created by ten to 20 boats scouting an area of less than one square mile created so much interference that he was unable to locate squid. Squid are commonly located by searching for bioluminescense created by plankton when disturbed by schools of moving animals. The top of a school of squid tends to remain deeper than that of many other species located by luminescense, and the luminescense is more diffused by the thicker layer of water between the squid and the fisherman's eye. Spawning schools of squid also tend to swim in one direction, unlike some fishes.

As in southern California, the presence of predators indicates presence of squid. Predators used to locate squid schools at Monterey include marine birds, California sea lions (Zalophus californianus), and since about 1970, sea otters (Enhydra lutris).

In most years extensive scouting is normally not required during the height of the season. The fleet simply proceeds to the end of the breakwater of the Monterey boat harbour, and vessels manoeuvre for positions within the few hundred square metres in which squid are densest. There is much exchanging of oaths, and the question of where to set the net is often decided on the basis of where the safety of the crew, vessel and net is most secure. When species composition of schools is questionable, it is common practice to allow the first vessel to complete a set before the other vessels begin theirs. Vessels usually leave port around midnight except in periods of low availability when vessels embark shortly after dusk. Scouting is conducted outside the edge of an existing kelp bed which is in 20 m of water. Greatest depth scouted is around 60 m. The lampara nets generally fish to a depth of 35 to 55 m.

When a school of squid has been located, a small skiff, carrying the end of one towline attached to a wing, is released from the stern of the vessel. The remainder of the net, along with a length of towline, is pulled over the stern as the vessel makes a counterclockwise encircling manoeuvre, returning to the skiff. Sections of the bunt are usually manually thrown overboard to allow it to sink deeper. In a few cases, a skiff is not used; in its place a large lighted buoy with the end of one towline tied on is used. After the towline is retrieved from the skiff or float, both ends of the net are hauled simultaneously with the aid of powered net haulers or gurdies (Figs. 15 and 16). Most gurdies are made from automobile differentials and the net rollers constructed of automobile tires. Although a few gurdies are powered mechanically by the main engine, most are powered hydraulically. The lead lines close as the wings are drawn together, and the squid are thus trapped. While the wings are being hauled, a submerged flashing light is often hung from the vessel to deter squid from escaping between the wings. Loud hammering on the deck or gunwhale also serves the same purpose. The boom is used to bring in the bunt of the net by strapping. A winch aids in cinching up the strapping slings. If the skiff is powered, it is sometimes used to tow the fishing vessel away from the net during hauling operations. In most cases, however, the captain sets the net so that the vessel is downwind during retrieval, and towing is unnecessary. The bag of the net is held open with a wooden or metal boom (tangón) and by the skiff. Brailing squid from the net into the fish hold requires at least five men. Two men in the skiff dip the brail into the bag to fill it with squid. A man on the winch hoists the brail, and two men pull it toward the vessel while the men in the skiff push the handle. After excess water is drained off, the net is poised over the fish hold and the purse line slackened to allow the squid to fall into the hold. Loose netting is hauled by hand during the brailing operation as the weight in the bag diminishes. When transferring the catch from the net into a barge or lighter, the brail is handled from the main vessel and pushed over the net to the lighter. Most brailing is done with the sock brail, which is operated from the main vessel, similar to the method used in Southern California.

In a typical set, about 1.5 minutes are required to set the net around a school of squid. The towlines and wings are hauled aboard in about five minutes. The net is dried up by strapping in 40 minutes. Brailing requires about 2.5 minutes per ton of squid.

About 12 to 16 vessels regularly participate in the Monterey squid fishery. They range from 8 to 16 m in length and 8 to 52 tons in gross tonnage. The smaller vessels tow lighters which can carry about 25 tons of squid (Fig. 17). Most vessels have hydraulic power to operate gurdies, but do not have electric (AC) generators. None of the fish holds are refrigerated. When squid are unavailable, these vessels fish primarily for Pacific herring (Clupea harengus pallasi) and anchovy. Crew complement varies from 6 to 10 men.

The catch is landed at Monterey or at Moss Landing, located about 30 km to the north. Unloading is carried out by brailing from the hold into a chute under the pier. The chute leads to a wire conveyer belt (Fig. 18) which dewaters the squid and carries them into a weighing hopper on top of the pier. From the scale, the squid is fed by conveyer into a waiting truck which carries the squid to the processing plant.

4. COMPARISON OF FISHING METHODS

In the California squid fishery, choice of fishing methods is dictated by several factors, not all of which bear upon efficiency. Price, market demand, and processing capacity, as well as fishing regulations and traditions, are factors which determine choice of fishing methods. At Monterey methods necessitating large crew complements are feasible because of the high price paid for squid. On the other hand, despite lower prices, southern California fishermen can profitably brail 10 to 20 tons of squid per day because of the small crew required. It is not clear why these brailers have not converted to pumps. Certainly many of the vessels are capable of using a pump, but there has been a strong opposition to change. Reasons given for this opposition are the low price paid for squid, small market orders, cost of the required equipment, and doubt of the efficacy of the pump system (despite the obvious success of the lone fisherman using the pumping method). Moreover, many of the vessels maintain a crew of three men when fishing for other species, and rather than replacing one man with a pump, the captains prefer to keep the crew intact. This is because squid is usually not the principal target species for the vessels.

Purse seines are also effective, but low market demand, small processing capacity, and existence of alternate fisheries which are more attractive restrict their use. Thus catches by purse seine in southern California are usually restricted to late in the season, when squid from other sources are scarce and other fisheries are not profitable. Small catches of squid are not economical for purse seiners because of the low price and large crew complement. Mixed catches are ordinarily not possible because fish holds are not adequately separated.

The lampara net is certainly effective in catching squid in shallow water. Its only disadvantage is the large crew size required, particularly during the brailing operation. Mechanical aids, such as a pump for transferring fish into the hold, could make it possible to increase efficiency. As previously mentioned, fishing regulations prohibit the use of purse seines or attracting light in Monterey Bay.

5. FUTURE OF THE FISHERY

Although many questions regarding the populations of Loligo opalescens and the maximum sustainable yield are unanswered, it is clear that the annual catch off California can be increased substantially, if the economic conditions warrant. The chief constraint to growth of the fishery is market demand. Given a consistent and higher demand, more squid could undoubtedly be taken by the existing fleet at the traditional fishing grounds during most years. Additionally, new fishing grounds and alternative fishing methods could be developed to further increase the catch. The wide area between the southern and northern fishing grounds has remained unexploited, although squid are known to be present in substantial quantities. Probably the greatest constraint against a real expansion is that normally supply at traditional fishing grounds exceeds market demand. In years of low availability at the normal fishing grounds, lack of suitable unloading facilities hampers expansion into other areas. It should be emphasized, however, that there are no data showing that squid are available at other areas when they are scarce at the primary fishing grounds; indeed, experiences of both fishermen and researchers seem to indicate that in poor fishing years abundance of squid is low throughout California. To open up new areas which are far from existing ports, squid will have to be refrigerated or new unloading facilities constructed. A possible solution to the latter problem is the use of large diameter fish pumps, which could be used both for fishing and for offloading.

Research is needed on economics, population dynamics, distribution, and life history of Loligo opalescens in order to expand the fishery with due regard to optimum sustainable yield, economic ramifications, and the ecosystem. Areas of particular importance for management in which knowledge is lacking are possible existence of distinct groups and age composition of the catch.

Regarding fishing methods, experiments are needed to determine optimum types and intensities of lamps, with the goal of better manipulating the behaviour of squid. Alternate fishing methods - such as bottom and mid-water trawling - may prove to be fruitful in some areas or seasons, particularly with the nonspawning squid.

The fishery at Monterey can certainly be made more efficient, but existing social and economic conditions presently deter attempts at modernizing gear and methods. Light-attraction methods need to be tried to determine if quality of squid differs from lampara-caught animals. Considerable labour savings could be achieved by using pumps instead of brailing squid out of the net into the hold. However, most of the vessels are probably too small to justify installation of a pump g system.

Research presently being done by California Department of Fish and Game and the Moss Landing Marine Laboratories should provide many of the answers needed to enable a rational expansion of the California squid fishery. These studies are conducted under the auspices of the Sea Grant Program, funded by the National Oceanic and Atmospheric Administration and by the State of California.

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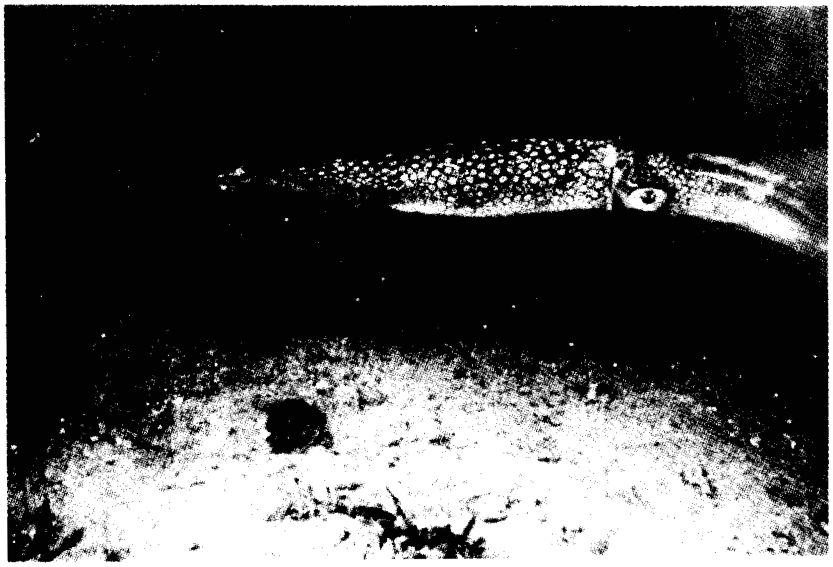

Figure 1.- Loligo opalescens. Photo credit: D. Gotshall

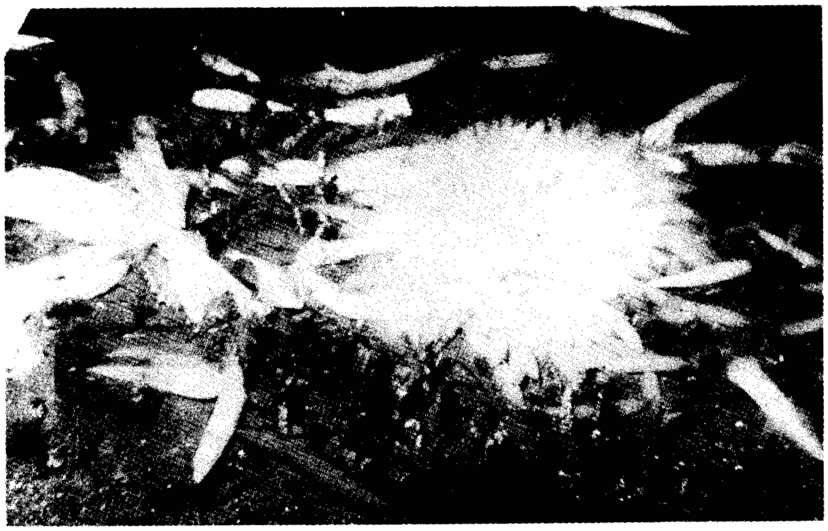

Figure 2. Aftermath of a period of spawning activity. Dead squid are shown around a cluster of eggs. Photo credit: E. S. Hobson.

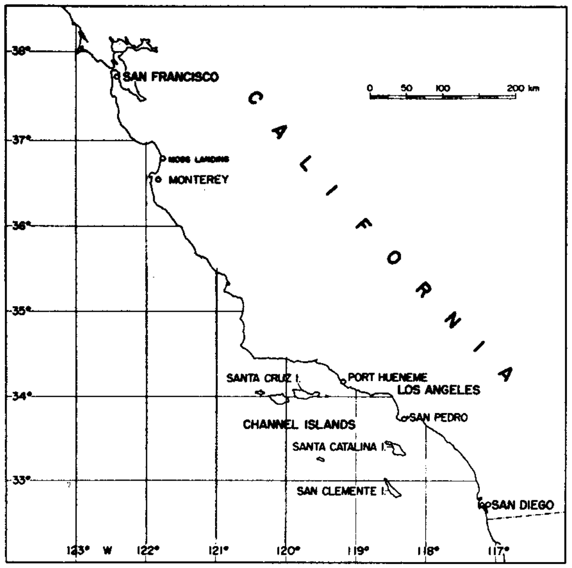

Figure 3.- Map of central and southern California. Major fishing grounds are located at Monterey and the Channel Islands.

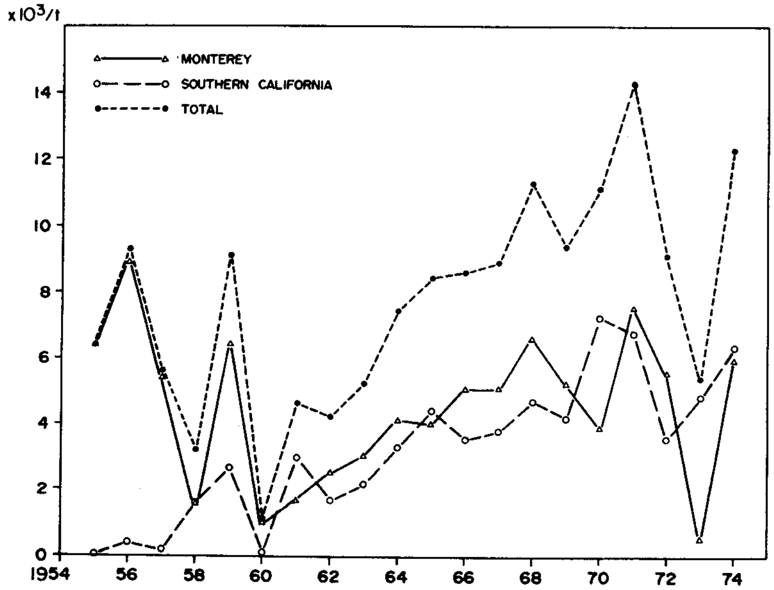

Figure 4.- Annual landings of squid at the Monterey area and southern California, 1955-1974. Data are from the Statistics Division, California Department of Fish and Game, Long Beach, California.

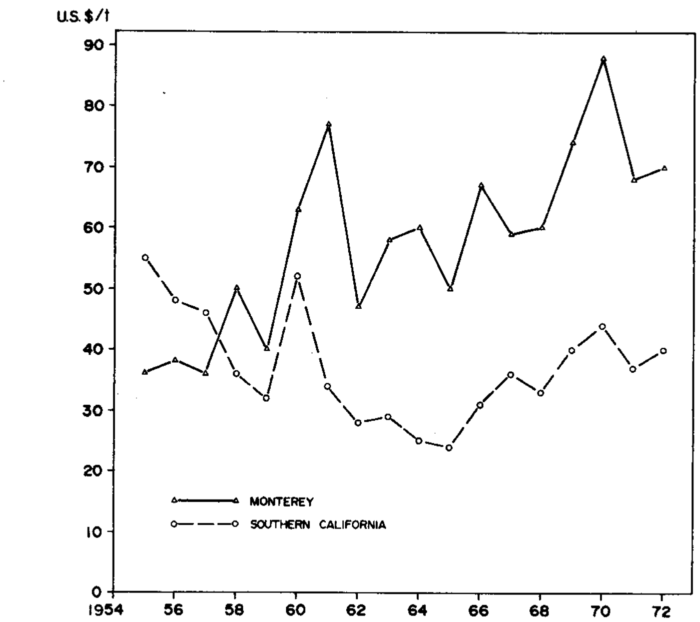

Figure 5.- Value per metric ton of squid landed at the Monterey area and southern California, 1955-1972. Data are from the Statistics Division, California Department of Fish and Game, Long Beach, California.

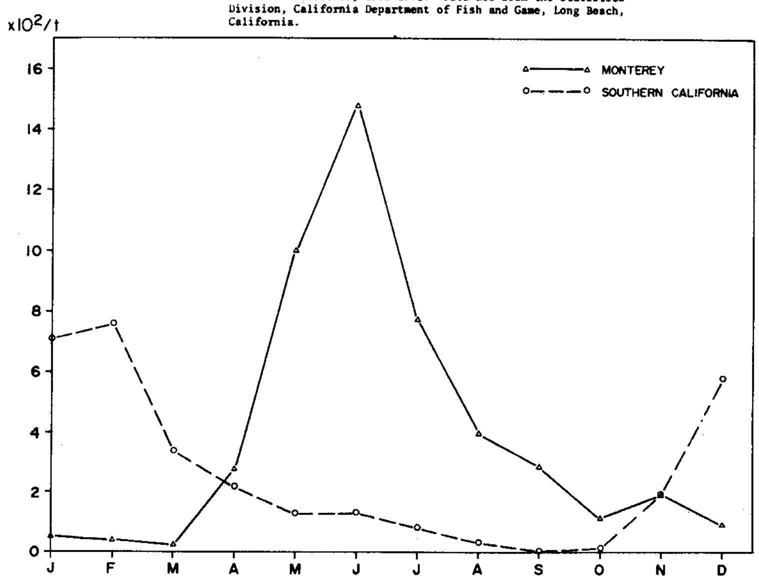

Figure 6.- Average monthly landings of squid at the Monterey area and southern California, 1955-1974. Data are from the Statistics Division, California Department of Fish and Game, Long Beach, California.

Figure 7.- Typical squid brailing vessel. Two lamps near the top of the mast are the attracting lamps.

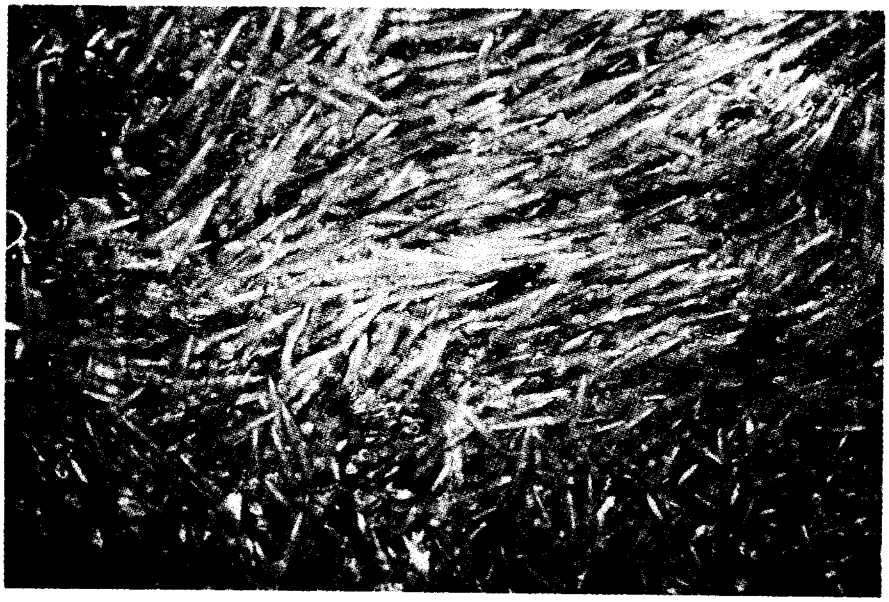

Figure 8.- A school of squid attracted to the surface and gathered under the concentrating lamp.

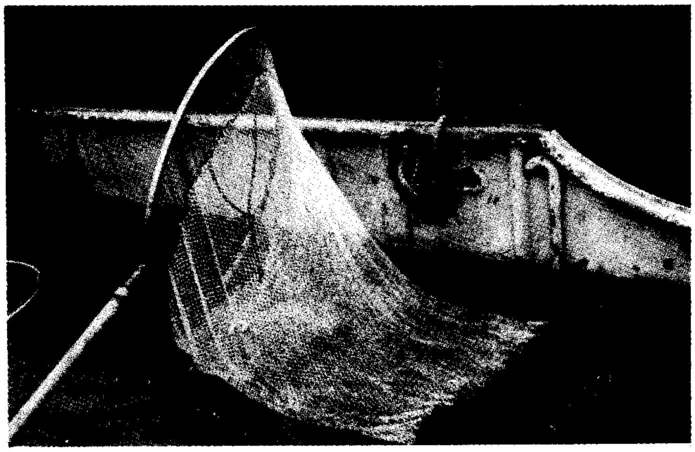

Figure 9.- A typical squid brail with a hoop diameter of about one meter. Note the purse rings at the bottom.

Figure 10.- Brailing squid. The brail is laid on deck to remove excess water before the squid are released into the fish hold.

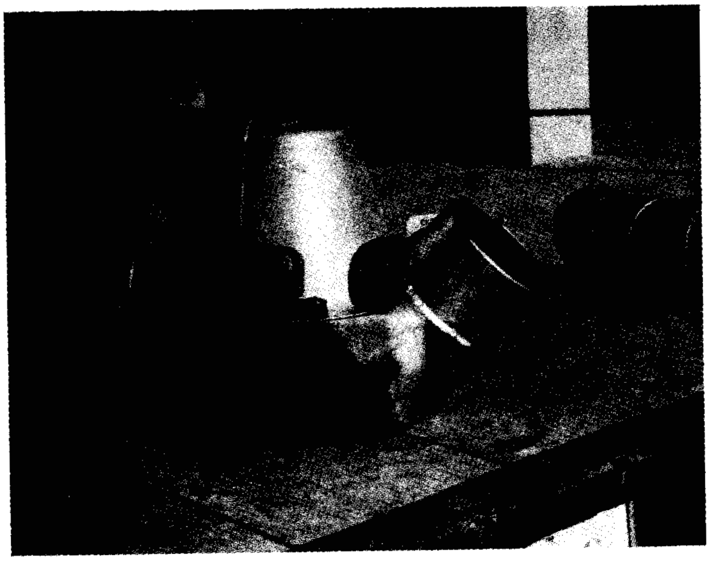

Figure 11.- Marco Model U-230 Capsulpump, side view. The entrance, not shown, is on the bottom.

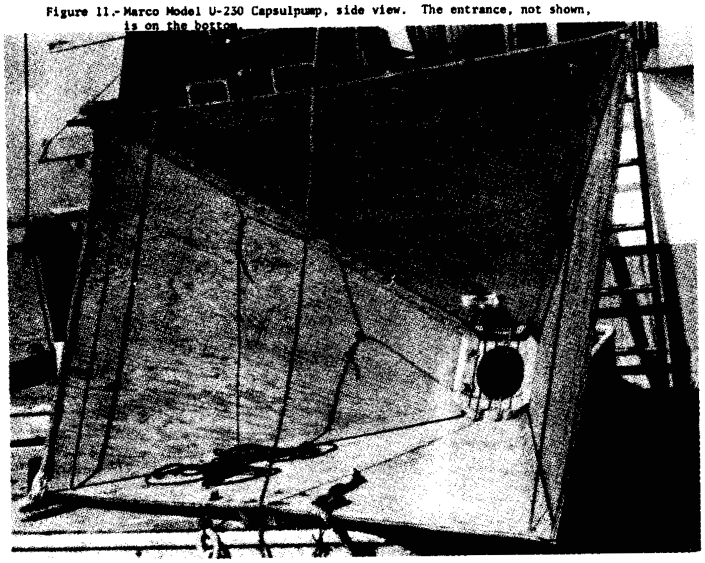

Figure 12.- Early funnel design constructed of wood and including a quartz-halogen underwater lamp.

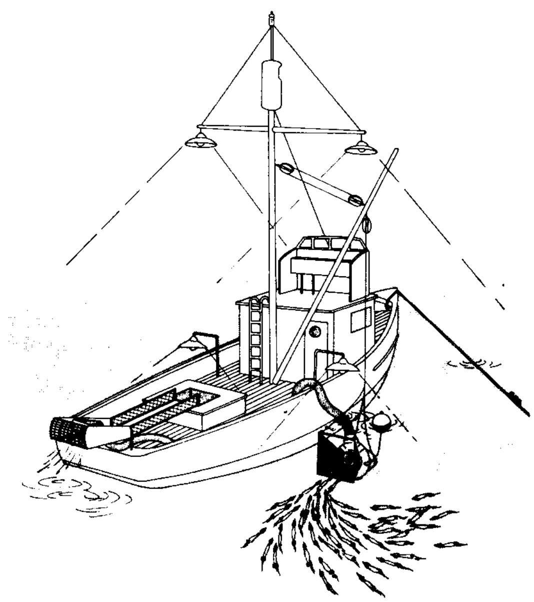

Figure 13.- Diagram of squid pumping system. Squid pass through the funnel and pump to a hose which leads to a dewatering screen.

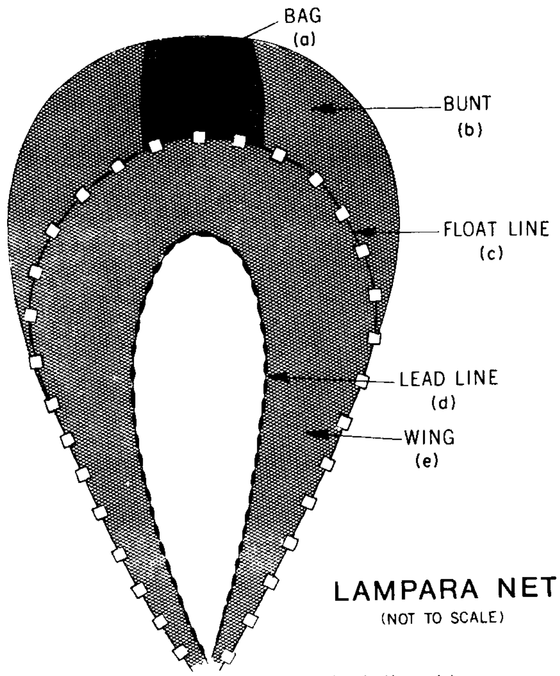

Figure 14.- Overhead view of lampara net in a hauling position.

Figure 15.- Gurdies used at Monterey for hauling wings of lampara net. These gurdies are placed amidship.

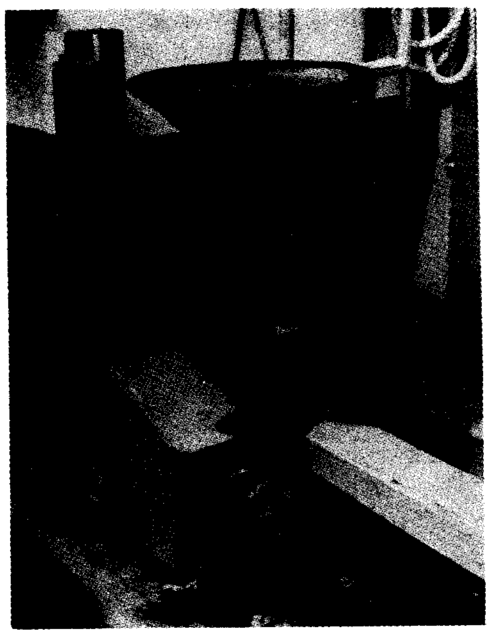

Figure 16.- Single gurdy used to pull one wing. A second gurdy, not shown, is situated near the stern of the vessel. Although most gurdies are hydraulically powered, this particular gurdy is mechanically powered.

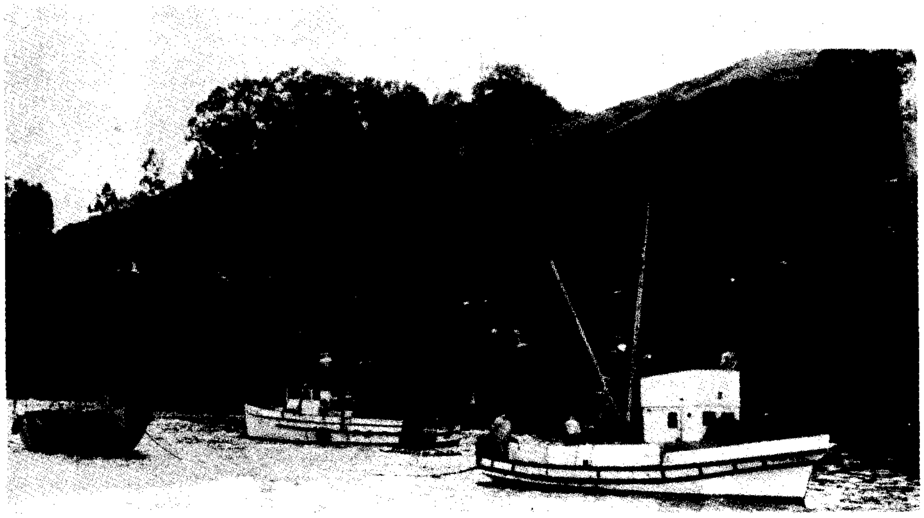

Figure 17.- Monterey lampara vessels in set. The vessel in the right foreground uses a lighter (left) to store the catch. The vessel in the background is strapping and hauling the bunt with the boom. Photo credit: J. Spratt.

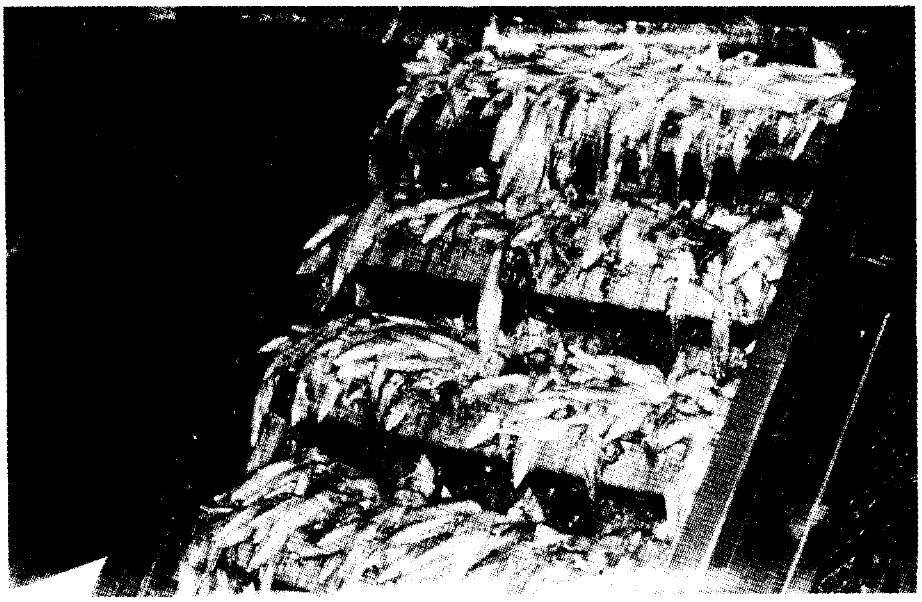

Figure 18.- Conveyer belt full of squid leading to a weighing hopper.