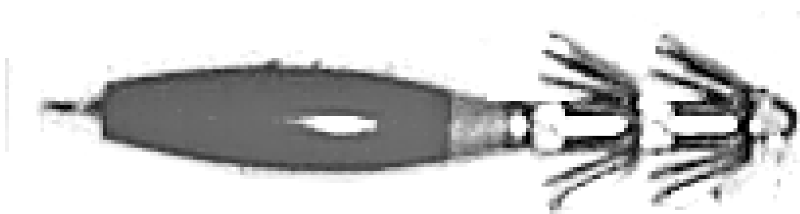
Oceanic Squid Fishery Development



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Coonamessett Farm

CONTENTS

II. ABSTRACT

The commercial fishing vessel Perseverance, operating out of Fairhaven, Massachusetts, conducted nine exploratory fishing trips for unexploited oceanic squid resources east of the continental shelf waters of New England and the Mid-Atlantic. The vessel was outfitted with lights and electronic jigging machines. The objective was to determine the economic feasibility of a commercial fishery on oceanic squid, using existing large offshore vessels, by assessing species availability, distribution, and economic return. The results indicate a potential resource of neon flying squid, *Ommnestrephes bartramii*, may exist in the region.

III. EXECUTIVE SUMMARY

The New England sea scallop vessel, F/V Perseverance, was converted to conduct exploratory squid jigging operations. This conversion consisted of installing a light platform with an array of lights, a small electric generating system, and four jigging machines. Two of the machines were fully automatic and two were manual. A total of 65 jigging stations were occupied between September and November, 1996. On 80% of the stations occupied under good observing conditions off the shelf/slope, the oceanic neon flying squid, *Ommnestrephes bartramii*, was observed or caught. A total of 141 neon flying squid were caught and specimens sent to the NMFS Systematics lab at the Smithsonian and to potential buyers. A detailed literature search was conducted on the neon flying squid but little was found about its distribution and ecology in the Northwest Atlantic. Even though the catches made during this project would seem too low to predict commercial potential, there were quite a few of these squid observed. Surveys earlier in the season and at greater depths should be undertaken.

IV. PURPOSE

A. Identification of problem

Groundfish and scallop resources on the continental shelf of New England and the Mid-Atlantic are heavily fished and have reached the point of being severely over-exploited. Stocks have been reduced to such extent that most offshore groundfish and scallop vessel operations are on the verge of economic collapse. Individuals that comprise the groundfish and scallop fishing industry are desperately seeking alternative fisheries.

Many of the vessels in these fisheries are large (> 30 meters LOA) and use towed bottom gear. It is highly likely that existing continental shelf resources can not support all these vessels due to their number, their harvesting efficiency, and their impact on habitat. Alternative gears and fisheries need to be found for these large vessels if they are to remain fishing in a sustainable manner. Jigging for oceanic cephalopods may be one of these alternatives. The pattern of moving larger boats into offshore fisheries (ie, oceanic cephalopods), reserving coastal waters for smaller boats, was successfully pioneered in Japan (Court, 1980).

Cephalopod resources represent a significant portion of the world's fish catch (Coelho, 1985). There has been an increase in interest to harvest cephalopods as human food due to the general decline in finfish and crustacean catches worldwide. It is also interesting to note that cephalopods are very useful in experimental biology (Hanlon, 1988). Ninety-nine percent of the world's catch of cephalopods come from the continental shelves. Various researchers have tried to estimate the potential of oceanic cephalopod resources found off the shelf areas and have produced crude estimates from 5-30 million tons (Coelho, 1985).

There is little existing information about the commercial potential of the oceanic squid resources in the Northwest Atlantic. This project began to explore the potential for developing these resources in an ecologically sound and responsible manner. Success in this venture will help to diversify the fishing industry and increase total resource yields with the resulting economic and social benefits.

One of the largest obstacles to the wise development of the oceanic squid resources is our almost total lack of knowledge concerning what species might be commercially available, and how to appropriately conduct the harvest. Squid fishery development in the Northwest Atlantic has focused on long-finned (*Loligo*) and short-finned (*Illex*) species. There is now some concern that the fisheries on these species, mostly conducted by trawl vessels, may be at their long-term potential yield levels (NMFS, 1993; 1994). There are also those that believe trawls are not the best gear type to harvest these species (Court, 1980; Roper and Rathjen, 1991).

There is some limited information on the distribution of oceanic squids based on research focused on *Illex*. Dawe and Stephen (1988) conducted four years of squid survey work in the Gulf Stream system east of 60 degrees W in February-March. More than 25% of their mid-water trawl squid catch were species other than *Illex*. Long and Rathjen (1980) reported on experimental jigging for *Illex* squid along the Northeast outer continental shelf. Whenever their vessel drifted into deep water their catch of *Ommastrephes* increased. *Ommastrephes* has also been reported in the diet of swordfish (Toll and Hess, 1981).

Thus, while *Loligo* and *Illex* stocks are the most abundant closest to the coast, there are other squid stocks of unknown potential off the continental shelf of the eastern United States. The following is a brief synopsis of what species might be available in this area based on the FAO Species Catalogue, Vol. 3 Cephalopods of The World and other sources.

Ancistrocheirus lesueurii (Sharpear enope squid):

This robust squid (39 cm mantle length) is distributed worldwide in temperate open ocean waters. It is believed to have fishery potential because of its size.

Ancistroteuthis lichtensteini (Angel squid):

Maximum mantle length of 30 cm. Its distribution is poorly known. However, Dawe and Stephen (1988) found this species to be abundant in their mid-water trawl samples, in both shelf and slope water south of the Grand Banks. The size and firm consistency of the flesh of this squid make it a potential fishery target.

Onychoteuthis banksi (Common clubhook squid):

Maximum mantle length of 30 cm. The quality of the flesh is judged to be good as human food. It is widely distributed worldwide in warm and temperate oceanic waters.

Histioteuthis bonnellii (Umbrella squid):

Maximum mantle length of 33 cm. This species may have some fishery potential but the flesh contains ammonia ions requiring additional treatment. The species may school.

Ommastrephes bartrami (Neon flying squid):

Maximum mantle length of 50 cm. This squid is distributed worldwide in temperate waters. Dawes and Stephens (1988) reported its presence in mid-water trawl hauls during their survey. The Japanese have developed a fishery in the Pacific on this species that landed 180,000 tons in 1980. This squid is caught using jigs and marketed fresh and frozen. Okutani (1977) reports on large concentrations occurring in mixed water areas in the Pacific; similar oceanographic conditions exist in the Northwestern Atlantic.

Ommastrephes caroli (Webbed flying squid):

Maximum mantle length of 70 cm. This species is available in the western North Atlantic. In Madeira it is fished for human food and bait. Its size and muscular consistency make it a desirable squid for harvest. Recent work suggests that this is not a separate species but adult neon flying squid (M. Vecchione, pc).

Ommastrephes pteropus (Orangeback flying squid):

Maximum mantle length of 40 cm. This species exist in warm-temperate waters but the actual distribution limits are unknown. Clarke (1966) stated that where this species did occur it was present in large numbers. Rathjen (1974) thought this species to hold significant potential for a jig fishery. The flesh is of excellent quality for human consumption. This squid is also desirable for the tournament fishing bait market. Prices in excess of $6.00 per pound were obtained (Voss and Brakoniecki, 1985).

Thysanoteuthis rhombus (Diamondback squid):

Maximum mantle length of 100 cm. A large species presumed to occur worldwide in warm temperate seas. A night jig fishery exists for this species in Japan.

These oceanic squid species can be caught with drift gill nets, mid-water trawls, and jigging gear. Jigging methods, while sometimes less productive than the others, were utilized in this project because they are known to be clean and selective, ie, no bycatch. Jigging is size selective and does not damage the captured animal. Jig caught squid thus fetch a higher price (Court, 1980). When jigging, the capture rate is even and steady preventing any pile-up on deck thus quality is maintained. Jigging is habitat friendly. There is some indication that jigging may be the most productive technique for oceanic squids (Roper and Rathjen, 1991).

Jigging has been utilized in the Northeast for *Illex* and *Loligo*. In Newfoundland, jigging for *Illex* squid has been conducted for over a century near shore. In the 1960's, the traditional hand jig was replaced by the semi-automatic Japanese drum jigger (Hurley, 1980) in the fishery. In the USA Northeast, there have been a number of projects to test squid jigging in inshore waters using lights (Allen and Tabor, 1974; Amaral and Carr, 1980; Long and Rathjen, 1980; DSI, 1982) with mixed results. However, the Japanese and others successfully fish oceanic squid with the gear and procedures we used (Okutani, 1977; Murata, 1990).

B. Project objectives

The primary mission of the project was to conduct exploratory fishing for oceanic squid off the continental shelf of Southern New England and the Mid-Atlantic. The following specific objectives were accomplished by the project:

1. The project identified potential commercial oceanic squid resources both by researching the literature from earlier explorations in the Northwest Atlantic region, and examining fisheries in similar areas around the world.

2. Jigging gear and operational strategies were identified by researching the literature and contacting equipment suppliers. This included determining requirements for vessel mounted hydro-acoustic equipment, automatic jigging machines, electrical lighting, sea-anchors, mizzen sail, and environmental sensors (eg, XBT units).

3. The F/V Perseverance was outfitted to conduct oceanic squid jigging operations. Two automated and two manual jigging machines were acquired. Electrical lighting was installed and a towed temperature sensor purchased.

4. Jigging operations were conducted beyond the edge of the continental shelf where oceanic squid might occur. These operations included hydro-acoustic transects, night jigging, and catch handling. Detailed catch and environmental records were maintained.

5. The limited catch was distributed to potential buyers for evaluation. Vessel expense records were kept for economic evaluation. Scientific samples were collected and preserved for taxonomic studies.

V. APPROACH

A. Work performed

1. Preliminary data collection

This stage of the project entailed a literature search to determine the most likely squid species to target and fishing methods to utilize. As the project progressed the main species caught turned at to be *Ommastrephes bartrami.* The literature search then concentrated on finding whatever information was available on this species relevant to its natural habits. Information on jigging equipment and procedures was solicited from fishing gear suppliers, equipment manufacturers, and others.

The exploratory fishing and survey strategy was discussed with Dr. Thomas Azarovitz, chief of the NMFS Northeast Fisheries Science Center Survey Investigation. Very little exists on how to conduct a scientific survey for squid using jigging techniques so the agreed upon approach was to first try to find squid concentrations and proceed from that point.

2. Gear and equipment acquisition

Two fully automatic jigging machines, manufactured by Polarteknikk A/S, Norway, were ordered and received. The machines arrived fully rigged for squid fishing with a dozen jigs per line. In addition, two manually operated jigging machines were purchased. Plans included purchasing two more automated machines from a different source if squid catches warranted the expense. The automatic machines cost much more than anticipated due to taxes and tariffs.

A three cylinder Deutz generator (25 Kw) was purchased and installed in the aft Lazerate to power the squid lights. The generator was rubber-mounted, sized small, and situated aft to minimize noise; an important aspect of squid jigging. The installation was a large job requiring significant welding, wiring, etc. Three mercury vapor and three metal halide lights (1000 watts each) were purchased and installed. Originally, 1500 watt lights were planned but these are not available. These new lights augmented the existing sodium vapor lamps (two at 500 watts) and eight quartz lamps (500 watts). A special removable platform was built just aft of amidships to hold four of the new lights to allow for easy access and adjustment. The remaining two lights were mounted on the gallows frames aft. Two types of lights were chosen because different wave lengths have different impacts on squid behavior.

3. Vessel Outfitting

Our efforts focused on changing over the F/V Perseverance from a scallop rig to a vessel capable of jigging. The F/V Perseverance has a 96 ft LOA, 25 ft beam, 14 ft draft. The vessel is powered by a Cat 3512 with 1055 BHP; carries 12,000 gallons of fuel; has 13 berths; and a trip duration of 25 days. The vessel has two 50 KW generators that provide 3 phase 120/208 volt power. The vessel has a Furuno model FCV 121 color video sounder. The sounder has 1 kw output but can be easily upgraded to 5 kw for use with frequencies of 50 and 200 kHz. During this project the sounder used a frequency of 28 kHz.

At the start of the project, the F/V Perseverance was outfitted with four jigging machines from two suppliers (two manual and two electric driven). Four machines is about ten percent of the number fished by a similar sized Japanese squid vessel, but were enough to make an economic evaluation of the commercial potential if squid concentrations were located. Installation of the automatic machines required welding a pipe stanchion to the deck to hold the main unit, and welding a bracket to the rail to hold the fishing unit. Power was provided by heavy extension cords with watertight connectors. The manual machines required a rail bracket to which to be clamped. Plans for a sea anchor and mizzen sail were developed but the need for this equipment never materialized. Freezer chests were placed on the vessel to hold the anticipated catch.

4. Exploratory Fishing

The F/V Perseverance commenced a series of nine trips starting on September 9, 1996 and ending on November 23, 1996. The fishing and survey strategy, developed with the cooperation of NMFS, was followed. Offshore areas, from south of Georges Bank to Cape Hatteras were surveyed. Satellite imagery, provided by the NOAA Ocean Products Center, was used to identify areas of high productivity where squid concentrations were expected to occur (Voss and Brakoniechki, 1985; Murata, 1990). Hydroacoustic transects were conducted between stations (Flores, 1972). A towed temperature system was used to assist in the search for various squid species based on known temperature preferences.

Upon arrival on a station, the vessels main engine and generator was secured and the auxiliary generator started. All lights were then turned on and observations for squid commenced. The two automatic jigging machines were placed into operation with ten jigs on each line. Normal fishing depth was set at 20 meters though deeper depths (<50 meters) were tried. The manual machines were operated only when squid were present and being caught. The echo sounder was in continuous operation on station to observe vertical movement of any biomass/target under the vessel. Catch records were kept. Landed squid were measured for mantle length and then saved for either identification or marketing efforts. On some stations the squid were weighed using an electronic scale but vessel movements made this an imprecise exercise. Environmental/meteorological data were recorded at each station. A surface temperature was taken using a thermometer with an attached bucket that was cast over the side. Wind speed, wind direction, sea state, cloud cover, moon stage, and other factors affecting visibility were logged.

5. Marketing

A & A Seafood, Ltd, an American firm that exports to Japan was contacted and they set up a meeting with a Japanese buyer. Price categories and markets were discussed. Small quantities of high quality product, specially handled would command a premium price on the Japanese market. High catches resulting in less quality handling would be sold to the Korean market. Only small catches were made (<60 squid/station). The catch was placed in plastic bags, boxed, and then frozen. The catch was distributed to various potential buyers and scientists.

6. Report Preparation

Quarterly reports and this detailed final report were prepared on all facets of the project including gear, equipment, exploratory survey efforts, catch data, marketing, etc. An economic evaluation was also performed to identify the costs associated with this type of enterprise. Several news stories were written on the project.

B. Project management

Captain Kenneth Thuestad, part owner of K and T Fishing Corporation, has twenty years of fishing experience on both coasts. Captain Thuestad was in charge of the project. He ordered all the equipment, arranged for all the installations, and conducted the at-sea operations.

Mr. Ronald Smolowitz assisted on the technical aspects of the project. He has more than twenty years of experience in exploratory fishing, fishing gear design, and fishing operations. Mr. Smolowitz was responsible for conducting the literature search, analyzing the results of the fishing operations, and writing the project reports.

K and T Fishing Corporation and its consultant have discussed this project and were assisted by NMFS Northeast Science Center on important aspects of this project as follows:

Survey strategy	- Steve Murawski Population Dynamics Program
Data recording	- Tom Azarovitz and John Galbraith Resource Survey Program
Economic evaluation	- Phil Logan Fisheries Economics Program
Taxonomy	- Mike Vecchione National Systematics Lab Washington, DC 20560

K and T Fishing Corporation worked closely with the following companies and institutions for gear design and acquisition;

DNG Electronics K.E. Johannesson 354-6-11122
IS 602
Akureyri, Iceland

Oilwind International Lars Pedersen 206-285-1296
1900 Westlake Ave. N.
Seattle, WA 98109

IMP Fishing Gear Jeff Moulton 508-993-0010
44 South St
New Bedford, MA 02740

VI. FINDINGS

A. Neon flying squid, *Ommastrephes bartramii*

During this project we occupied a total of 65 stations from September 10, 1996 through November 22, 1996. Table One presents the station data.The area surveyed stretched from south and east of Georges Bank to Cape Hatteras. Stations were mostly chosen at random; not by hydroacoustic targets or oceanographic data. Oceanic squid were observed on 34 of the stations and caught on 19 of those where observed. Poor jigging conditions due to bright moonlight occurred on 7 stations where squid were observed but not caught. Only 8 stations in deep water where oceanic squid should of been observed, and observation conditions were satisfactory, had no squid visually observed or caught. The remaining stations, 23 in number, were conducted in shallow (<1000m) water (14 stations) either for gear testing purposes or avoiding bad offshore weather. The remaining 9 offshore stations had bad weather and thus poor observation conditions. Figures One and Two present the geographic distribution of where the squid were caught. In summation, oceanic squid were observed present on 34 of 42 randomly chosen offshore stations where observation conditions were satisfactory for a total of 81%. In our opinion this is remarkably high and could indicate a large biomass. However, we did not come across, or possibly did not recognize, any biomass concentration in this first exploratory effort.

During the project a total of 141 squid were caught (Table Two and Figure Three). Samples representing different sizes and locations were sent to Dr. Mike Vecchione at the National Systematics Lab for positive identification. The results indicate that all squid caught were neon flying squid, *Ommastrephes bartramii*. Tissue samples were taken for DNA analysis to determine if this is the same species found in the Pacific. There were squid present that were not caught. Some of these squid were identified as orangeback squid, *Ommastrephes pteropus*, by the phosphorescent oval spot on their back. Others remained unidentified. Atlantic saury and other species of beaked fishes were sighted frequently during the night stations.

Once confirmation was received that the squid we were catching was the neon flying squid we concentrated the literature search on this species. What follows are our findings, based on this search, which should be of use to fishery development efforts in the future:

Distribution

Neon flying squid are widely distributed in both the Atlantic and Pacific oceans throughout subtropical and temperate waters. In the North Pacific these squid are found in large numbers along the subarctic boundary in summer and fall. Population densities are high in the waters west of 165 E and east of 170 E (Araya, 1983). The migration of the western most population follows the movement of the Kuroshio branch current northward in spring and summer. In the late fall the squid in this North Pacific population migrate south to spawn though little is known about the location of the spawning grounds. In the North Pacific the best fishing occurs in surface water temperatures ranging from 15-16 degrees C in May to July and 13-18 degrees C in August through January; highest densities are associated with thermal fronts of 15-18 degrees C in August/September (Gong et al, 1985). Higher densities of squid seem to be associated with higher horizontal gradients of surface temperature. There are also one or more populations of neon flying squid spread across the southern oceans and spawning swarms have been observed in several locations (Korzun et al., 1979).

In a fishing survey for neon flying squid 12 to 200 miles off the coast of Washington and Oregon in August of 1990, squid were located along a warm water front near a cold water upwelling (Nakamura and Siriraksophon, 1992). Surface water temperatures ranged from 12.8 to 19.4 degrees C. Squid were caught at jigging depths of 50 to 150 meters though squid catches were highest from a depth of 120 meters where temperatures ranged from 7.5 to 8.3 degrees C. This temperature range is interesting since the FAO Species Catalogue (Roper et al., 1984) states that this species avoids waters of less than 10 degrees C. Squid were not caught in waters shallower than 600 meters during this west coast survey.

Araya (1983) reported that during the Japanese fishing season the vertical distribution of the squid was related to the depth of the 10 degree C isotherm; catches seldom occurring below this isotherm. In the Japanese fishery this isotherm during the season can be as deep as 150 m but more commonly is less than 70 m. However, high yields from the surface drift net fishery indicate that at night the squid are usually at depths less than 10 m. Smaller individuals, <18 cm mantle length, may occupy surface layers day and night (Murata, 1990).

Virtually nothing is known about the distribution of neon flying squid in the North Atlantic. There is even some question on species identification between *O. Bartrami* and the European or webbed flying squid, *O. Caroli* (Murata, 1990) which would affect distribution maps. Zuev et al. (1976) place the northern border of the North Atlantic population along the southern slope of the Grand banks to the Faroe Islands and into the western and southern sections of the North Sea. The southern border is placed from the Florida Strait across to West Africa. They place the reproductive range in the western part of the Atlantic at 25 to 35 degrees N and remark that spawning occurs year round with a peak in spring and summer. They further state that only large immature females reach the British Isles and North Sea, mainly during fall and winter. Dawe and Stephen (1988) found that the north wall of the Gulf Stream serves as a northern boundary to tropical squid species. Their sampling with mid-water trawls to a maximum depth of 60 meters in February/March east of 60 degrees W and north of 40 degree N caught only 5 neon flying squid.

Life History

The neon flying squid grows from 30-50 cm in mantle length and weighs from 1-4 kg. They mainly feed on small fish such as the lanternfishes and saury and small squid. In turn they are eaten by large pelagic fish and marine mammals. Oceanic squid have been found to be, at times, an important prey item of swordfish (Scott and Tibbo, 1968; Toll and Hess, 1981; Bello, 1991).

Neon flying squid mature late; males at mantle lengths of 30 cm, females at lengths of 40-50 cm (Zuev et al., 1776). In general the neon flying squid reproduce in tropical latitudes, January through May, and then migrate into cooler waters feeding along thermal fronts. The North Pacific population of neon flying squid may consist of two groups; a northwestern and a central Pacific sub-population based on two distinct spawning grounds (Murata et al, 1980). However, Gong et al. (1985) believe that the spawning grounds may in fact be quite large extending across the western and central Pacific.

In the North Pacific newly hatched neon flying squid have been found in the vicinity of the Hawaiian Archipelago from mid-January through early April during the 1991-93 spawning seasons (Bower, 1996). Some hatching took place over 600 kilometers from the islands indicating proximity to a land mass is not a prerequisite for spawning. Virtually nothing is known about the life history of neon flying squid in the North Atlantic. Zuef et al. (1976) refer to spawning concentrations in the North Atlantic in the vicinity of Madeira and the Azores.

There is still a high degree of uncertainty of how long a neon flying squid may live. There are definitely different size groups in the population that travel at different rates of speed and/or migrate at different times. Most live only one year but some may survive into the second year. Murata (1990) has divided the North Pacific neon flying squid population into four size groups; extra large (LL), large (L), small (S), and extra small (SS). The last three groupings may be from spawnings 2-3 months apart. The LL group may be SS group members from the previous year. Another theory has the groups developing at different rates due to environmental/feeding conditions.

A very interesting behavioral observation was made during one of our night stations. At least six neon flying squid were observed swimming inter-dispersed within a fish school; the fish were an unidentified herring-like species. The squid were not feeding at the time and moved in unison with the fish. Dolphins were swimming and possibly feeding nearby. The squid were about 20 cm in mantle length; this size range later identified as being that of juveniles.

There is some life history/ecological information available important to jigging operations. It has been reported that some species of oceanic squid do not take artificial bait (jigs) when they are feeding on abundant concentrations of euphausids (Lipinski and Wrzesinksi, 1982). Bernard (1981) found few euphausids present in 200 stomachs he examined of neon flying squid taken off Vancouver Island, B.C. However, Murata (1990) reports on research that indicates the juvenile squid, 15-19 cm, do feed on planktonic crustaceans. Lipinski and Wrzesinksi (1982) conducted manual jigging in the South Atlantic in September of 1978 and found that neon flying squid did not form well-defined concentrations but traveled near the light/shadow line in small schools (up to 60 individuals). Murata (1990) sites evidence that the squid primarily feed during the day.

Jigging methods

The origin of jigging probably goes back into antiquity in many parts of the world. The Japanese squid jigging fishery began in the Heian Era about 1000 A.D. (Murata, 1990). He reports that by the 1600's annual jig caught squid catches were about 45,000 mt and grew to 450,000 mt by the 1970's. Hand jigging, with up to 12 jigs per man, was replaced by machine jigging (50-80 hooks/man) by the 1960's. A total of 40% of the world's catch of squid is taken by jigs (Roper and Rathjen, 1991).

Traditionally jigs were made of horn or lead (Okutani, 1977). Today, the most common type of squid jig consists of rings of barbless stainless steel prongs attached to a plastic base or stem. From one to three rings can be attached in line with each other to the stem. The barbless prongs measure from 10-20 mm and the stems are about 40-60 mm. There are also bright metal and phosphorescent stems, some measuring longer than 300 mm in length. The jigs we used had plastic stems with a flexible vinyl connection to the stainless steel barbs. The stems were 60 mm in length and the barbs were 15 mm long. We used jigs that had one to three rings of barbs, but mostly doubles. Colors were red, green, and white. Red has been reported to outfish other colors, especially white, in the Newfoundland *illex* fishery (Aldrich, 1991).

In the Japanese jig fishery about thirty jigs are attached to the angling line spaced about one meter apart (Ogura, 1983). We copied this arrangement in our project but only used 10-12 jigs per line. Ogura points out that some fishermen change the size of their jigs to match seasonal changes in size and habits of squid. He indicates that red and green are the preferred jig colors and that fishermen sometimes attach cyalume lightsticks to the jigging line. We purchased lightsticks of different colors and attached them at times to our lines as well. However, experiments with placing lightsticks in drift gill nets provide little evidence that the lights are an effective attractant (Bernard, 1980). The Japanese fishery uses sinkers of 750 g (10 ton vessel class) to 1000 g (99 ton vessel class).

The Japanese automatic jigging machine has one or two jigging lines and a vessel can have upwards of fifty machines. The largest vessels are 50-70 meters long, can freeze and hold 1000 tons of product, and utilize up to 70 double reel computerized machines to land 35 tons/day in certain squid fisheries (Roper and Rathjen, 1991). Incandescent lights (200 v, 3-4 kW) were most commonly used and a large vessel may have fifty lamps (150-300 kW total). Halogen lamps are now more common as they are smaller and more economical. The lights are positioned so that the jigs pass through the boundary between light and shadow. Double rows of lights yield better catches than a single row of lamps. Large jigging vessels use sea anchors and spanker sails to maintain position against wind and current (Ogura, 1983).

The Japanese work together to locate fishing grounds. A vessel proceeding to the grounds will call the Information Service Center to get the location based on the most recent fishing and oceanographic conditions. Each vessel maintains water temperature records and uses echo sounder data to pick its fishing spot. Radio communications between vessels is also essential in determining fishing locations. The echo sounder traces are used to determine jigging depth, usually 70 meters or more. Squid can be identified while steaming slowly during the day as clumps of dots and crescent shaped traces on machines with frequencies between 75-200 kHz using narrow beam and minimum pulse length (Bernard, 1980). We attempted this procedure, with 28 kHz, but found too many unidentifiable targets having similar characteristics to squid targets.

Jigging Surveys

The development of a fishery on neon flying squid will require a means to survey the squid population over time to assess its size and distribution. The Japanese have been conducting jigging surveys since 1971 on neon fling squid as well as several other species (Murata, 1983). While they have had some success determining the abundance of Japanese common squid, *Todarodes pacificus,* they have had less success with neon flying squid. This may be due to the fact that their surveys did not cover the entire range of this species. We could not get more recent information on squid survey techniques currently used in Japan.

The Japanese survey strategy consists of a grid survey carried out twice a year, in spring and fall. The survey is conducted by 6-12 research vessels over a period of 5-10 days. Each vessel would spend 2-10 hours at each grid point using automatic jigging machines and lights. Jigging depths were primarily between 50 and 70 meters. The catch index was expressed in terms of number caught per jigging machine hour despite differences in lamp power and number of machines per vessel (Murata, 1983).

Murata believes jigging is the best method for surveying neon flying squid but does point out that the smallest and largest of the species are not easily caught by standard jigs. There are also times that squid are present in drift net catches late in the season but are not taken by jigs; possibly related to feeding behavior. Canadian efforts at surveying oceanic squid stocks using nets and trawls revealed small numbers of squid at many stations (Bernard, 1980). It wasn't until they used jigs that commercial concentrations were identified.

Processing and Marketing

Bodies, referred to as tubes, in the Japanese high sea fishery, are commonly placed in aluminum trays and plate frozen in 13 kg blocks (Bernard, 1981) and 20 kg blocks (Yatsu, 1990). These blocks are water-glazed and stored at -40 degrees C. Heads with attached tentacles are frozen in the same manner but sell at a lower price. The frozen squid are made into processed dried and seasoned products when landed. A recent higher priced product, hiraki, is the mantle without the internal organs and slit at the ventral midline. This is frozen onboard and saves freezer space compared to the round product (Yatsu, 1990).

Closer to shore squid can be held on ice for up to two days without losing much color. Contact with the ice must be avoided to prevent color loss since color is the primary means of evaluating squid quality. We placed fresh caught squid in plastic bags and held them in an ice chest for up to four days. Ronald Smolowitz brought one of these squid home and held it refrigerated for two additional days. The squid was then prepared by slicing the mantle, which was 6 mm thick, into strips about 25 mm wide and 50 mm long. The strips were dipped in a light batter and fried in a wok for about 30 seconds. The squid was remarkably tender and had a delicious not-too-sweet flavor. The one squid fed four adults who rated the culinary quality superior to fresh sea scallops.

Mr. Osamu Onoui, of Rocky Neck Seafoods, was contacted about the squid and was very interested in using the squid for shishimi. Samples were given to David Pelliter, A & A Seafood Limited, New Bedford, MA who sells to the Japanese Seafood Exchange in Tokyo. The samples were shipped fresh, individually wrapped in plastic and held on ice, to Japan. We have not yet received an evaluation of this product. Other samples were given to Fred Durham, Fairway Fish Company, New Bedford, MA. These samples were frozen. They indicated that they would purchase a significant quantity if available at $3.75/lb.

B. Equipment Evaluation

The first commercially available automatic jigging machines reached the market in the 1960's. These machines were heavy and bulky. By the 1970's these machines were replaced by a second generation of smaller and lighter machines with enhanced electronic displays but these machines still had problems with watertight integrity. The 1980's brought microchip technology to the jigging machine. The machines were smaller, less expensive, and had more features. The electronics were contained on one small board. The newest machines replace the board with a single microchip. The machines are completely watertight and use o-rings to encase the electric motor. The machines we used, produced by Polarteknikk of Norway, have a coated aluminum housing with a thickness of 5 mm that provides ample strength and shock resistance. The machine has a motor driven reel that is loaded with a heavy monofilament drive line. This line connects to a reel on the rail mounted fishing spool and transmits the rotational motion to the fishing unit.

Some of the features are as follows:

a) Sensitivity: The machine can sense when a squid is on the jig. The sensors are fully adjustable to set the weight to determine when to haul back. the haul back rate is adjustable and the display panel indicates haul back procedure with a green light.

b) Coupling: The jigging machine's motor and reel are connected by an electro-mechanical clutch that is fully adjustable.

c) Brakes: The units have fully adjustable brakes to set tension (free fall) when setting out line.

d) Jig length: The jigging machine has four options for jigging length; 2.8 meters, 1.8 meters, 1.3 meters, and no jigging.

e) Jig range: The jigging machine has a monofilament fishing line 250 meters long. The machine can be set to stop and jig at various points as the line is hauled back to the surface. The machine can be set to jig at depths from 1 to 50 meter intervals. For example, the machine can set out 250 meters of fishing line and then haul back stopping at 50 meter intervals to jig at pre-set lengths.

During the experimental fishing the jigging machines were set to operate between 5 and 50 meters. Our observations indicated that most of the time the squid were caught near the surface so most of our fishing was in the top 20 meters of the water column. Our operating experience with these machines was mostly positive. The machines were easy to use, even with instructions written in Norwegian. The machines required no maintenance during the entire project period. The squid catching process was automatic and the machines could normally be left unattended; the squid catch landing in fish boxes placed on deck under the chutes. The only negative experiences occured in rough weather with heavy vessel rolling. The drive line to the fishing reel would jump off the pulley and get caught in the reel shaft stopping the machine. This would require un-fouling the line which could take up to five minutes. Our inexperience in this procedure sometimes cost us entire strings of jigs.

Since we only fished off one side of the vessel we did not feel it necessary to maintain the vessel head to windward. Consequently, we decided we did not need to go through the process of setting and hauling a sea anchor. We tried to get in two to three different stations each night so we wanted to avoid wasting time if it was at all possible. We did drift at times to leeward with speeds of up to one knot however most of our drifting was due to currents.

Temperature is a controlling factor in squid distribution. Initially we planned to purchase an Expendable Bathythermograph System (XBT) to be able to determine temperature at various depths while on station or underway between stations. We hesitated because of the expense of the unit and probes. The initial literature search indicated that surface temperatures would be more important than vertical temperature profiles. We decided to initially make use of ocean frontal analysis from private sector forecast services and surface temperature charts available through the NOAA CoastWatch program. We tried to borrow an XBT unit from various NOAA funded programs, to augment the surface temperature data, but none were available for loan to a commercial fishing vessel.

It soon became evident that a continuous surface temperature reading while underway would be useful to augment the satellite data since the area we were operating in was very dynamic. Cloud cover during the fall season obscured many of the satelite pictures. The situation was further complicated by the fact that there were few stable water masses/ ocean fronts during 1996. A degree of stability is required to allow the cycle of nutrients/forage/target species to develop in a particular spot. We decided to purchase a Cannon Speed-N-Temp system to help position ourselves in the water masses observed by satelite. The system consists of a lower unit that is attached to a downrigger weight that acoustically transmits water temperature, speed, depth, and light intensity data up to a hull mounted transducer. The hull mounted transducer unit also provides a surface temperature reading.

C. Economic Potential

The neon flying squid in the North Pacific have been caught by the Japanese jigging fleet since 1974 (Araya, 1983). The catch by jigging was 17,000 mt in 1974 and grew to about 100,000 mt by 1978. The North Pacific jigging fishery begins in July, peaks from August to October, and rapidly declines in November. In 1978/79 the average nightly catch of a medium scale jigging boat was 1400 kg which represents about 2500 individual squid. Thus a vessel with 50 jigging lines in the water catches 50 squid/line/night on average. Jigging efficiency of a vessel increases with the number of jigging machines (Araya, 1983). Populations of squid may be more clustered closer to shore due to more complex thermal regimes compared to mid-ocean areas (Bernard, 1981) which certainly would impact catch rates.

On our best station, 1-7, we caught 60 squid using two lines over a four hour period. We did not arrive on that station until 0245 in the morning so it is likely that our catch rate would of been much higher for the night if we started earlier that evening. The total weight of this squid catch was about 17 kg (38 lbs). If we were fishing at a commercial scale using 50 lines this catch would of been almost 1000 lbs. Using a price of $3.75 that Fairway Seafood offered for frozen product this would amount to $3,750 dollars for one night fishing. This is admittedly our best catch rate however we were very inexperienced in our fishing methods. Almost one third of the squid, usually the larger ones, fell off the jigs and were not even landed. Solving this problem could conceivably double our catch weight.

The cost of fishing these squid is a function of how fast one can locate the fishing site. The Japanese work together very closely in this regard. We will assume for the purposes of this analysis that on a seven day trip our model squid jigging vessel would have the equivalent of three good nights fishing thus landing 3000 lbs of frozen squid worth $11,250 ex-vessel. Fresh shishimi grade squid would fetch a much higher price but could only be from the final fishing night. Our vessel will be a typical large New England scalloper/trawler but will only operate with a four man crew (we were able to operate with two men) and get in three trips per month. The following are our projected monthly expenses:

Mortgage	$ 6,500
Insurance	$ 6,000

Repairs	$ 4,500
Fuel	$11,000
Gear, supplies, ice	$ 5,000
Total Monthly cost:	$33,000 for a trip cost of $11,000

This very preliminary examination indicates that an oceanic squid fishery would barely cover existing expenses of a large New England vessel let alone pay the captain and crew. However, we may be greatly underestimating the potential catch based on our initial fishing attempts. In addition a vessel designed strictly for jigging would have substantially less fixed and variable costs compared to a multi-purpose vessel. The most expensive capital cost would be the purchase of jigging machines. Twenty-five double drum machines would probably cost about $100,000. Installing 25 kW of lighting would cost an additional $30,000.

There is another possible scenario for an oceanic squid fishery. Offshore pelagic longliners lay too at night while tending their gear. If these vessels equipped themselves with a few jigging machines they would be able to catch their own fresh bait. There is reason to believe that their target species of large pelagics may be co-located with the squid at certain times. When we discussed this idea with several longliners they did acknowledge that at times squid are plentiful around their vessels at night.

VII. EVALUATION

This project had several goals and objectives that evolved around ascertaining the potential of an oceanic squid fishery in the Northwest Atlantic. The first goal was to conduct a literature search of the scientific literature to determine what was known about oceanic squid that would pertain to starting a fishery in the Northwest Atlantic. Over 60 references were found that had pertinent information about the species that might be available and means to conduct a jig fishery on them. However, our literature search and phone calls found virtually nothing on the life history, distribution, and ecology of oceanic squid in the Northwest Atlantic. The fact is little is known. Most of the literature on the operational aspects of fishing for oceanic squid is in Japanese. Our project was not prepared to acquire and translate this literature. We did contact several Japanese experts on oceanic squid but they said they did not have much to offer us in the way of information. What we did determine is that the fishing strategy for the squid in our area may be very different than that used for the offshore squid in the Pacific.

We talked to quite a few fishing gear suppliers to determine the best source of squid jigging equipment. There was no supplier of Japanese squid jigging machines or jigs. Several companies contacted their Japanese suppliers but no responses were forthcoming. We did have four possible sources of jigging machines from Europe and chose to go with a Norwegian machine as the company was very helpful. The prices were all about the same from the various manufacturers, however, export/import fees and taxes brought the prices of the single drum machines up to over $4000.00. We decided to only buy two automatic machines to get the project going and to delay further machine purchase decisions. Our budget would only of allowed for the purchase of two additional automatic machines. We did purchase to manual machines for under $1000 each to see if these would be adequate.

As stated previously we were quite satisfied with the automatic jigging machine operation. The manual machines were next to useless; heavy seas broke one off the rail and it was lost. The manual operation is too time consuming and inefficient. The machines were not effective in catching squid. Interestingly, using a rod and reel to cast a jig out from the vessel, did attract and catch squid but of course this is labor intensive as well. We feel an American manufacturer can produce these machines, if there was a demand, for under $2000 each. It is just a question of designing the single control microchip which may even be available on the market. The motor and hardware components are off-the-shelf devices. We met our objective of acquiring good jigging gear and operating the gear successfully at sea.

We successfully modified the scallop vessel used in a manner that allowed the vessel to be rigged and de-rigged for squid jigging in one day or less. We accomplished this by building a bolt-on light platform that attached to the vessel's fixed booms and struts. The platform held the extra lighting and allowed for easy access for adjustment. We only used about 10 kW of lighting since we had only two machines located close together on one side of the vessel. We installed an additional 25 kW of generating capacity to augment the existing 50 kW the vessel had with its two generators. The new generator was air cooled and shock mounted. This allowed us to operate on station without any overboard discharges of cooling water and a low noise/vibration level. We tried various arrangements of lights, including switching lights on and off at different times, but it is hard to come to any conclusions about the effectiveness of these trials. The largest problem we had with the lighting was that we totally underestimated the cost of installing the generator and hooking up the lights. We did not originally plan on the separate generator but it was highly recommended by a number of people we talked to for the reasons previously stated. Future projects should not underestimate the cost of this aspect of jigging operations.

We gathered information about sea anchors and prices for building a mizzen sail. The sea anchors and sail would of been needed to hold the vessels head to wind. However, since we were only using two machines off one side of the vessel it became obvious on our first trip that there would not be a need for this equipment hence we have no evaluation of sea anchors or sails.

The most significant problem we had was weather, primarily due to the fact that we started late in the season. The literature lead us to believe that fishing would be best between August and December. This would coincide with the least productive scallop fishing. Since our objective was to find alternatives for scallop vessels to pursue, when not using their limited and decreasing scallop days-at-sea allocations, a late fall squid fishery would be ideal. Our best catches were in September, the start of our field work. This would indicate that if we started a month earlier we may of had better fishing results. Storm after storm prevented us from getting far offshore during the latter part of the project. This left gaping holes in our efforts to plot squid distribution. Even under the best of circumstances there is not enough time for one vessel to conduct a squid survey over a vast area. The Japanese have learned this lesson and use multiple vessels to do this type of work. Even so, we have collected more information on oceanic squid distribution in our area then previously existed from all previous efforts.

Hydroacoustic transects were of limited value during this project with the standard equipment that we had onboard. The area that we surveyed is very rich in marine life and there were many targets on the sounder. We lacked the experience to discriminate between targets to determine what may of been oceanic squid. Over time, it would probably become possible to recognize squid targets with experience and thus hydroacoustic methods would be of some value in searching for squid. Surface water temperature and oceanic front information may also become useful in the search for squid but much more will have to be learned about the specific distribution of these squid in our area with relation to these factors.

The limited catch of squid that we had available for market samples did allow us to determine several important facts. It is evident from comments that these squid were highly desirable and that they would have an ex-vessel price over $3.00 per pound frozen. All indications are that a price of $6.00 per pound would be paid for a fresh high quality shishimi grade product. The size of frozen and fresh markets locally is unknown but in our opinion the potential is large; this squid is excellent.

Conclusion

We achieved all the goals and objectives that we set out to achieve but in many cases we did not accomplish as much as we would of liked. We have established neon flying squid are present in our waters and might be present in numbers that could support a commercial fishery. We established that they can be caught by jigs but have a way to go to become proficient at the methodology. We now have a much better idea on the actual costs to rig up and go jig for oceanic squid. We failed to delineate their distribution throughout the planned survey area due to weather problems. We also suspect that we missed the peak abundance period which we now, based on our experience, hypothesize to be earlier by several months than our survey period.

The above information provides a good lead on what work needs to be accomplished in the future. One or more vessels need to be outfitted with automatic jigging machines and begin a survey routine starting in June. More effort needs to be placed in trying to determine the vertical position (position in the water column) of these squid and the relationship to temperature and temperature gradients (fronts). It is possible that these squid may be vulnerable to squid jigs during the day at depth if concentrations can be found.

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