THE CALIFORNIA FISHERY FOR MARKET SQUID (*LOLIGO OPALESCENS*)

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ABSTRACT

The California fishery for market squid (*Loligo opalescens*) was established over 130 years ago in Monterey Bay, central California. The fishery expanded into southern California after the 1950s, but remained relatively minor until the late 1980s, when worldwide demand for all squid species increased. Landings in California prior to 1987 rarely exceeded 20,000 metric tons. Since then, landings have increased fourfold, and squid is now the state's largest fishery in both tons landed and market value. The number of vessels participating in the fishery has also increased from approximately 85 to over 130.

Industry members have questioned whether such high catches are sustainable. Unfortunately, the California Department of Fish and Game has a paucity of data to determine how best to provide for sustainable harvest. Knowledge and experience from other Loliginid fisheries around the world are sought to guide us in developing a state management plan for the market squid.

INTRODUCTION

For several decades the market squid resource was viewed as vastly underutilized, and many suggested that increased harvest could and should be pursued (Frey 1971; Kato and Hardwick 1975; Recksiek and Frey 1978). Today that view may have changed. A fishery supplying dried product to China during the 1880s–1930s has grown into a fishery providing frozen product worldwide. Squid fishing has grown from a Japan-dominated industry to one of more global involvement. Sonu (1993) indicates that the number of nations landing more than 20,000 metric tons (t) of squid species annually increased from two in 1966 to twelve in 1992. The United States is one of those countries, and contributes approximately 3% to the total world squid catch. *Loligo opalescens* figures prominently in that share. Not only does market squid find its way into restaurants and homes in Spain, Greece, and Japan, it has quite a following in China and here in the United States. Price competitiveness and demand have increased its popularity internationally, and creative recipes and healthy eating campaigns have increased its demand domestically.

Rapidly rising catches and vessel participation over the past four years have focused attention on market squid and California's lack of a plan for sustainable management of the resource. To begin the plan-development process, I will briefly cover some life-history characteristics that make *Loligo opalescens* unique, explain the types of gear and methods employed to harvest squid, provide a brief history of squid catches, and give a general overview of changes in the California squid fishery over the past century.

There is a lot we don't know about market squid, making management of the fishery difficult. I intend to lay the groundwork for further discussions of how we might use knowledge and experience from other *Loligo* fisheries and other research to help develop the Department of Fish and Game's management approach. The papers that follow will likely have major influence on where or how the Department applies its future research and management funding for squid off California.

BASIC LIFE HISTORY

Loligo opalescens is one of 30–40 species of squid in the Loliginidae family (Boyle and Boletsky 1996) and is found from central Baja California, Mexico (Fields 1965), to Southeast Alaska (Wing and Mercer 1990; fig. 1). However, it is rarely available in fishable concentrations north of Vancouver Island, British Columbia, Canada. Although market squid appear to be widely dispersed along most of coastal North America, the areas of greatest spawning activity appear to be off central and southern California (Fields 1965; Kato and Hardwick 1975). In California, it is the only squid species consistently taken for commercial purposes.

Market squid are relatively small. Adults measure up to 305 mm (12 in.) total length and weigh between 56 and 84 g (2–3 oz.). They are short-lived, and are believed to complete their entire life cycle in 12–18 months (Spratt 1979). Mature squid form relatively large spawning aggregations in nearshore waters. Market squid egg capsules are found throughout the year in Monterey Bay, but the greatest concentrations are found in early spring through summer (Fields 1965). In southern California, large spawning aggregations can be observed from November through April (Fields 1965). Egg capsules are usually deposited on a sandy substrate, often at the edges of canyons or rocky outcroppings (McGowan 1954). Mass adult mortalities are evident after spawning events, but it is unclear how long squid live after spawning, or

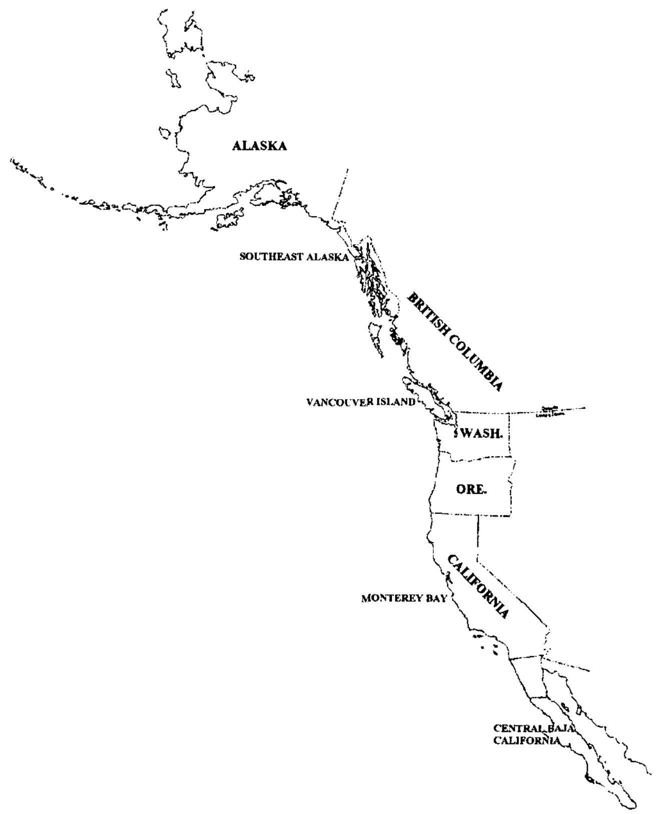

Figure 1. Geographic range of market squid (*Loligo opalescens*).

how many times a squid may spawn (McGowan 1954).

Young squid hatch between 3 and 5 weeks after the egg capsule is deposited, and development is highly correlated with water temperature (McGowan 1954; Fields 1965). Although young squid have been noted in the area of spawning grounds, large concentrations of juveniles have not been found (Okutani and McGowan 1969; Recksiek and Kashiwada 1979). Likewise, distribution information about nonspawning adults is scant, although some information does exist from research cruises (Mais 1974; Ally et al. 1975) and commercial trawler landings. Because *L. opalescens* are highly phototropic (Fields 1965), the fishery often uses lights to attract spawning aggregations.

HISTORY OF THE FISHERY AND GEAR

The Chinese were the first to harvest squid off North America, in Monterey Bay, California. In the late 1800s they used small skiffs, lit torches to attract the squid to the surface, and deployed purse seines to capture the squid (Scofield 1924; Kato and Hardwick 1975; Recksiek and Frey 1978; Dickerson and Leos 1992). They dried their catch and shipped most of it to China, although some was probably consumed locally and in nearby San Francisco (Scofield 1924). In 1905, Italian immigrants introduced the lampara net into the fishery and outcompeted the Chinese, who settled into the processing and exporting business (Scofield 1924; Kato and Hardwick 1975; Recksiek and Frey 1978; Dickerson and Leos 1992).

Both the purse seine and lampara net are round haul nets. The webbing of the nets is laid out to encircle a school of squid (Fields 1965; Kato and Hardwick 1975). A purse seine net has metal rings sewn along its bottom edge, and a cable is passed through the rings. When the cable is drawn tight, the net "purses" (Fields 1965). The lampara net does not have rings, but rather tapered "wings" of webbing on both sides so the body of the net tends to form a bag. When the wings of the net are drawn simultaneously toward the vessel, the bottom of the net essentially closes together and the fish are herded toward the bag portion of the net (Kato and Hardwick 1975). Until the 1970s a small brail net was used to lift squid out of the main net, a couple of hundred pounds at a time, and into the vessel's hold. Now a centrifugal pump is lowered into the bagged school of squid, and water and squid are pumped through a separator and into the hold of the fishing vessel (described in Kato and Hardwick 1975).

Lights, as an attractant, have been allowed and disallowed many times since the fishery began in Monterey (Dickerson and Leos 1992). Lights have never been prohibited in southern California and presently are allowed, with few restrictions, everywhere in the state. Using lights to attract spawning aggregations of squid to the surface of the water column is effective because of the animal's phototropism. Lights are used for both round haul nets and brail fishing (Kato and Hardwick 1975).

In southern California, lights and brail nets were used almost exclusively until the late 1970s (Dewees and Price 1982). Squid were attracted to the surface by high-intensity lights and the brail net was used to scoop the squid aboard; no other net was used (Kato and Hardwick 1975; Dickerson and Leos 1992). Vessels using this method were referred to as "scoop" or "brail" boats. These boats tended to be smaller and required smaller crews than the purse seine or lampara vessels (Kato and Hardwick 1975).

Around 1977 there was a definite shift in fishing gear from brail vessels to purse seine vessels in southern California (fig. 2). Today nearly all of the squid are landed by purse seine nets. Members of the squid industry have indicated that economics forced that change. Tuna and "wetfish"[1] vessels were looking to participate in more

[1]The term *wetfish* was historically used to describe how a group of small pelagic species (i.e., anchovies, Pacific sardines, mackerels, etc.) was processed at canneries. The species were placed in cans in a "wet," or fresh, condition and then cooked (Frey 1971; Klingbeil 1992). Vessels harvesting such species are typically referred to as the wetfish fleet.

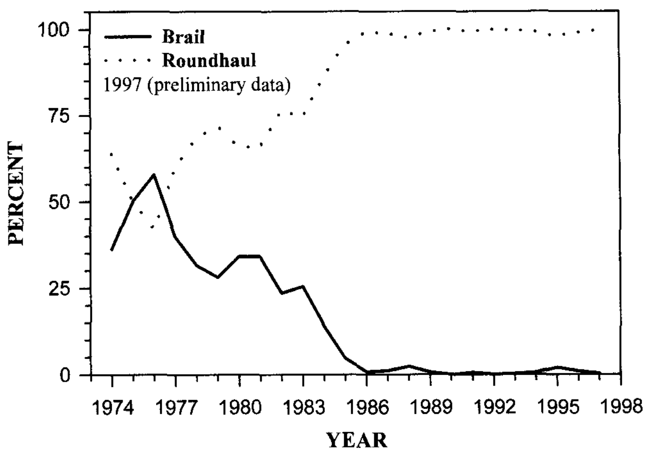

Figure 2. Proportion of squid landings taken with round haul gear (lampara and purse seines) and brail gear, by calendar year.

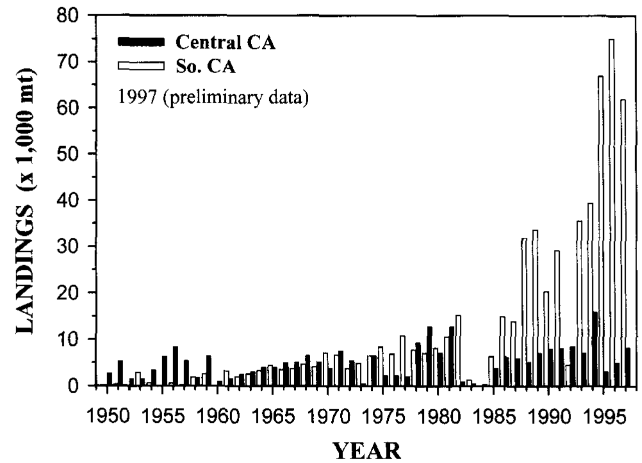

Figure 3. California squid landings (metric tons) by region and calendar year.

lucrative fisheries closer to home. In addition, brail vessels had difficulty competing because seiners could meet the market demand more efficiently. With the current market demand so strong, there appears to be room for every type of gear, but brail vessels haven't reentered the fishery in appreciable numbers.

CATCHES AND FISHERY DYNAMICS

Until the mid-1920s annual squid landings rarely exceeded 270 t (Scofield 1924). A healthy export market to China existed from 1923 to 1932, and catches increased to an average of 1,900 t annually. When the export market collapsed because of adverse financial conditions, most squid were used domestically, and catches averaged about 365 t for the next decade (Fields 1965; Frey 1971; Dickerson and Leos 1992). The central California coast, specifically Monterey Bay, produced nearly all the market squid catches until the early 1950s.

Fishing for squid began in southern California as demand for seafood increased after World War II. Landings were evenly divided between central California and southern California from 1960 until the early 1980s (fig. 3). Since the late 1980s, southern California has far outpaced central California in landings. Annual landings of squid in central California have averaged around 6,000 t since 1950. In contrast, southern California landings have increased from an annual average of 9,000 t during the 1970s and early 1980s to over 41,000 t in the past ten years (fig. 3).

Squid fishermen were paid less than $14 per t in the early 1900s (Scofield 1924). After canning and freezing became the method of preserving squid, fishermen were paid differently depending on which method was to be employed. As late as 1981 fishermen were getting between $105 and $253 per t, depending on how the squid was to be processed (DeWees and Price 1982). Now most squid is frozen and exported. It is used primarily for human consumption, to a lesser extent as animal feed, and as bait in both recreational and commercial fisheries. Most recently, squid has averaged $294 per t, but the price varies throughout the season and geographic location of landing. When supply did not meet the demand, the ex-vessel value rose as high as $452 per t.

FACTORS AFFECTING CATCHES

Within the last few years, market squid has become the number one fishery in California in both tons landed and value (table 1). Two major factors have influenced

TABLE 1
Top Three California Fisheries in Metric Tons and Ex-vessel Value

Metric tons		U.S. dollars (millions)	
1992			
Mackerel	19,733	Red urchin	29.2
Pacific sardine	17,914	Dungeness crab	10.7
Red urchin	14,649	Rockfishes	10.3
1993			
Squid	42,630	Red urchin	26.7
Pacific sardine	15,329	Dungeness crab	13.2
Mackerel	13,469	*Squid*	10.5
1994			
Squid	55,374	Red urchin	25.3
Mackerel	12,698	Dungeness crab	18.5
Pacific sardine	11,610	*Squid*	16.2
1995			
Squid	69,841	Red urchin	22.5
Pacific sardine	40,635	*Squid*	21.8
Mackerel	10,340	Dungeness crab	14.6
1996			
Squid	80,272	*Squid*	33.3
Pacific sardine	32,517	Red urchin	18.7
Mackerel	11,791	Dungeness crab	17.2

Source: California Department of Fish and Game Commercial Fisheries Information System database.

these steeply rising numbers. Most obvious is the increase in market demand, which is fueled by the expanding global economy and the unavailability of export squid species from the Falkland Islands, Japan, and New Zealand (Sonu 1993). Exports of market squid from California to various nations have changed significantly since 1991 (table 2). The greatest changes have been a decrease of exports to Japan and an increase of exports to Europe and Asia. Over 60% of exported frozen squid goes to Asia, and China buys most of it (93%). We assume that the demand will continue as long as market squid prices in California remain competitive to foreign importers.

TABLE 2
California Exports of Market Squid to Various Countries

1991	
Japan	37%
Europe	29%
Philippines	15%
Other Asia	<1%
All others	~18%
Metric tons exported	12,546
1992	
Japan	16%
Europe	41%
Philippines	21%
Other Asia	5%
All others	17%
Metric tons exported	13,468
1993	
Japan	25%
Europe	53%
Philippines	2%
Other Asia	5%
All others	15%
Metric tons exported	9,003
1994	
Japan	16%
Europe	54%
Philippines	7%
Other Asia	10%
All others	13%
Metric tons exported	24,406
1995	
Japan	11%
Europe	28%
Philippines	6%
Other Asia	51%
All others	4%
Metric tons exported	38,353
1996	
Japan	12%
Europe	16%
Philippines	<1%
Other Asia	67%
All others	~4%
Metric tons exported	51,669
1997	
Japan	5%
Europe	34%
Philippines	4%
Other Asia	53%
All others	4%
Metric tons exported	59,933

National Marine Fisheries Service statistics. Assumes all squid exported through California ports is *Loligo opalescens*.

The second factor affecting squid landings is an increase in fishing effort in southern California. Dickerson and Leos (1992) stated that the expansion of fishing effort to previously underutilized squid spawning habitat has definitely affected catches. If squid availability and demand are high, the southern California fleet does well. The Monterey fishing fleet catches seem to be more stable even when demand is high. This may be because of the limited fishable habitat for squid in central California. Although it is assumed that squid spawn all along the coast, much of the central California coast is rocky, is fully exposed to weather patterns, and has a narrow continental shelf. The topography and weather patterns in southern California, especially the northern Channel Islands, allow for substantially more fishable spawning habitat. Thus when global demand increased (as it did in the last ten years) and squid were available, more of the southern California squid spawning habitat was exploited, and catches increased.

Climatological changes can also affect squid catches (Dickerson and Leos 1992). In the Monterey area, warmer than normal water temperatures appear to have a positive effect on catches 18 months later (McInnis and Broenkow 1978). El Niño events, however, seem to have the opposite effect. Squid landings in California decreased during the two major El Niño events since 1950 (fig. 4). Other, less strong, El Niño years, such as 1973–74 and 1992–93, show some apparent effect on squid catches as well. A strong El Niño developed in the equatorial

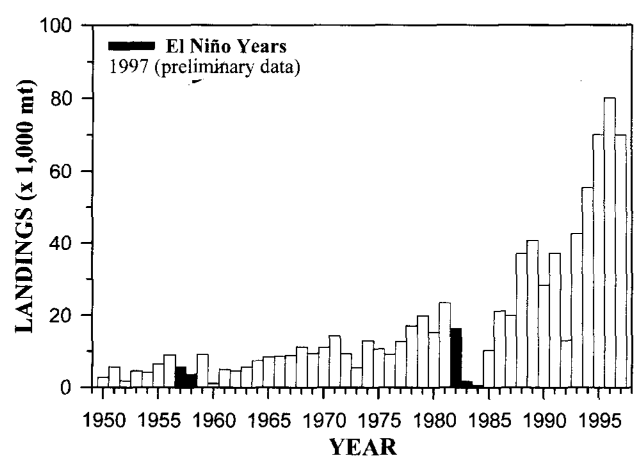

Figure 4. Statewide squid landings (metric tons), with major El Niño events indicated.

Pacific during 1997, and we believe that winter squid catches in southern California will be negatively affected, as in the past.

VESSEL PARTICIPATION

During the 1970s and 1980s, an average of 85 vessels were active in the squid fishery (fig. 5). Since 1993 the number of vessels landing over 0.5 t of squid has increased to nearly 135. The past four years of unmet demand and easily available squid have attracted many to the fishery. Some of the recent increase has come from out-of-state vessels (fig. 5), but many new entrants are from within California. The vessels from out of state have been salmon and herring seiners active at other times of the year in Alaska and Washington fisheries.

Many of the newly arrived vessels are of recent vintage and have sophisticated electronics and refrigerated fishholds. They are typically 17.7 m (58 ft.) long and of steel construction, with a fish capacity of 55 t. Many vessels in the California fleet have upgraded during the past 15 years, but many remain from the wetfish and tuna fishery of the 1950s and 1960s. They tend to be 24.4 m (80 ft.) long, with fishholds of 68–108 t, many of which are not refrigerated. Some processors prefer loads of squid that have been kept refrigerated because they hold up better in transport and provide for a better-quality product. Consequently, this has resulted in a keen level of competition between owners of older or unrefrigerated vessels and owners of more updated vessels.

Participation in the squid fishery has also grown because it has been relatively free of regulation. Because many fisheries (i.e., nearshore gillnetting, salmon, herring) have become more restrictive, and access to them has become tightly controlled, an opportunity to enter an open and profitable fishery is viewed by many as the chance of a lifetime. There are some minor area closures in effect along Santa Catalina Island and a weekend closure in Monterey Bay, but all that is needed to participate in this fishery are a California commercial fishing license and boat registration.

Many participants in California's squid fishery operate on a "statewide" basis. Although Monterey vessels tended to fish only in Monterey Bay in earlier years, the offset fishing "seasons" have made it attractive for them to fish southern California waters also.

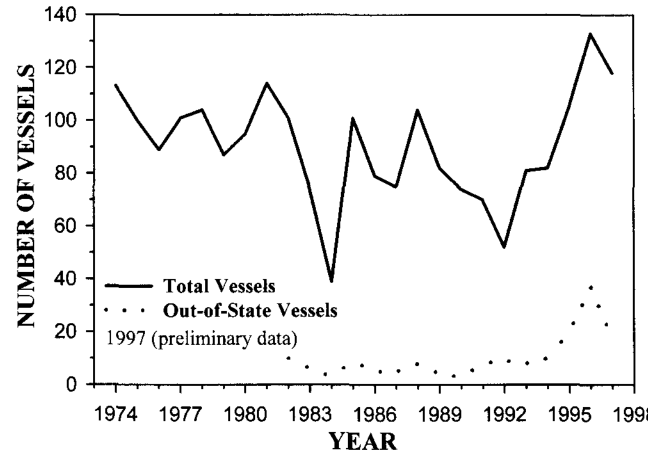

Figure 5. Number of vessels landing more than 0.5 metric tons in California, by calendar year.

SUMMARY

Until recently the fishery for squid has grown at moderate levels. During the mid-1970s some fishing industry members from Monterey voiced concerns that spawning aggregations were being fished very near shore, that squid were low in the food chain, and that we knew next to nothing about them. With monies collected from a special tax levied on the wetfish fleet (begun in the 1940s) to study wetfish, the Department directed some of those funds and some Sea Grant funds to researching squid (H. Frey, San Pedro, Calif., pers. comm., Feb. 1998). A major research cooperative was developed by the Department and Moss Landing Marine Laboratories to answer questions about age and growth, maturity and fecundity, spawning habits and habitats, assessment techniques, population structure, environmental influences, and harvest impacts on squid and its prey and predators. These are necessary bits of scientific information upon which management decisions are made.

Results from some of the research form the basis upon which we presently weigh the "status" of the market squid resource. The studies found that squid are abundant in the waters of the California Current and are a major food source for other marine animals. It was found that squid spawn during only one spawning period. Ageing of statoliths indicates that squid live less than two years.

Other results, however, were not conclusive. Specifically, studies were unable to identify more than one population of squid along the West Coast even though there is a temporal and geographic separation between "fishable" spawning aggregations. There appeared to be a correlation between squid availability and oceanographic conditions, but the results were geographically limited. Some acoustic techniques held promise for assessing squid biomass but needed additional testing (Recksiek and Frey 1978).

In a proactive management move, a draft management plan was prepared by biologists involved in squid research for presentation to and consideration by the newly formed Pacific Fishery Management Council. The council felt that there was no need to federally manage squid, because most of the fishing occurred in state waters, and only during occasional warm-water events like El Niño was there a fishery for squid in Oregon and Washington. Interest in expanded squid exploitation wasn't quick to develop; the fishery appeared to be healthy; and the fishing industry convinced the California legislature to rescind the extra research tax on wetfish (H. Frey, pers. comm., Feb. 1998). Continued interest in squid research was put on the back burner and has remained there until just recently. It is important to note, however, that Recksiek and Frey (1978) concluded that if squid-importing countries began to accept smaller frozen squid, then there appeared to be considerable potential for an expanded fishery for *L. opalescens*. In less than two decades their predictions and vision have become a reality.

So where are we now? We have a major fishery for a species that appears to have unlimited market demand. We have a rapidly increasing squid fishing fleet and a fishery that is technically unmanaged. And we are still asking some of the same questions we asked in the mid-1970s. Is there only one population of squid on the West Coast? How large is the population? Where do squid spawn? What influences population changes or availability? How does exploitation affect the stock(s)? How important is squid in the food web, and how do we factor that into management? How are we to best manage this fishery for sustainable use?

In presenting the lead paper for this symposium, my objective is to set the stage for the papers that follow. The Department's overall goal is to develop a management protocol that will consider this squid fishery from an ecosystem perspective and provide for a sustained fishery. How we are to achieve this objective will likely depend on the information provided in the following papers and the discussions that ensue. We are fortunate to have information about Loliginid fisheries from around the world presented at this 48th CalCOFI Conference.

ACKNOWLEDGMENTS

I thank the members of the squid fishing industry for openly discussing the fishery with me and allowing me to observe their fishing operations. I thank the California Seafood Council for its generous support. I thank Mary Larson and John Ugoretz for producing the graphics used in this paper and other presentations about the squid fishery throughout the year. I also thank Rick Klingbeil for his editorial comments, as well as those anonymous reviewers who give freely of their time and talents to make all of us better communicators.

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