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Squid Resource Assessment, 1984

SQUID RESOURCE ASSESSMENT

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by

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ABSTRACT

Commercial landings of the market squid (*Loligo opalescens*) increased from 113,000 lb, produced by 7 vessels in 1982 to almost one million lb produced by 13 vessels in 1984. A research project was established to provide information to manage the new fishery. Observers were placed on fishing vessels to identify problems associated with incidental catch of the gear, gear impacts on squid egg capsules, and gear conflicts. Observers saw few problems associated with the level of harvest and activity in 1984.

Samples of 200-250 squid were collected three times a week to obtain estimates of the biological characteristics of spawning squid in Oregon. Results of the analysis indicate that a sample size of 100-150 animals would provide sufficient precision in estimating dorsal mantle lengths. The average dorsal mantle length of squid collected was 110.8 $\pm$ 0.5 mm (95% CI). Females were significantly ($P \leq 0.05$) larger than males. The average dorsal mantle length of samples declined throughout the season. Average sample weights declined then increased in the second area of harvest, suggesting that new groups of squid moved into the area to spawn.

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INTRODUCTION

Oregon fishermen have long known that market squid (Loligo opalescens) congregate to spawn off the Oregon coast, but only recently have attempted to fish for squid. Interest in the fishery and effort expended have markedly increased in the past three years. Landings have tripled each year since 113,000 lb were landed in 1982.

We currently know relatively little about Loligo opalescens off Oregon. We suspect the market squid is abundant here, is broadly distributed, and is a common food item of many fish, bird, and mammal species. It is also a valued food item in many countries and is used extensively for bait in our area. We anticipate it will be increasingly sought after.

In an effort to provide information to manage the new squid fishery we designed a research project to obtain the data needed to develop a sound management plan. The primary goals of the research project are:

1. To collect and consolidate existing information pertaining to squid life history and management;
2. To develop a squid information retrieval and data analysis system;
3. To evaluate the selectivity, efficiency, and impact of gear used to harvest squid; and
4. To collect, analyze, and summarize data from commercial harvest and research cruises to describe the biology and life history of Loligo opalescens in Oregon waters.

FY 84 Objectives

Initially we planned to learn about the squid fishery in Oregon and about squid fisheries around the world. We devoted the first year of the study to identifying information gaps, to identifying problems in the fishery, and to learning about the biology of squid in our area. Accordingly, our objectives for FY 84 were:

1. To conduct a literature review;
2. To set up a vessel logbook program;
3. To set up an information and retrieval system;
4. To collect harvest data to obtain catch, effort, and by-catch estimates; and
5. To collect biological data to define stock characteristics.

Accomplishments in FY 84

We accomplished an initial objective of collecting existing information about squid. We acquired information by writing to federal agencies and other states and countries, by sponsoring a workshop to discuss squid research on the west coast, by obtaining references from publications, and by conducting computerized literature searches through the Oregon State University and National Marine Fisheries Service libraries. We also worked on a data retrieval and analysis system for handling research and fishery information. We expect to continue to improve our squid data access and analysis techniques throughout the course of this project.

We instituted a vessel logbook program and established an observer program to monitor the fishery at sea. We observed fishing activity of 70% of the vessels participating in the 1984 fishery, and observed 24% of the landings. We collected biological samples from the commercial landings and collected samples directly at sea in the observer program.

We participated in research cruises conducted by Oregon State University (OSU) and Southwest Oregon Community College (SWOCC). OSU researchers evaluated the use of hydroacoustic techniques as a method to assess squid abundance. SWOCC researchers attempted to collect squid for market analysis and development. We collected and analyzed biological samples from those cruises. We plan to continue hydroacoustic work with OSU in 1985 and will analyze samples collected by SWOCC.

HARVEST RESULTS

Experimental gear permits were issued in 1984 to allow trawlers to fish for squid. We allocated 5 nearshore permits for fishing with trawl gear inside of 50 fm in each of the four major areas of the coast. The permits were valid for three week time periods and were renewable if the fishermen either searched for squid for a minimum of 20 hr during the permit period or landed 2000 lb of squid. Additionally, we issued permits for midwater trawling for the entire coast outside of 50 fm. Only three vessels searched for squid in deep water and did not land squid.

During the course of the year nearshore permits were issued to 26 vessels. Additionally, six vessels fished for squid with gear that did not require a permit, and we had verbal interest but no participation from twelve other skippers. The permit system did not prevent any fisherman from fishing for squid at some time during the year, except that it did prevent some skippers from fishing when they wanted to. The permit system allowed us to achieve our objective of limiting the number of vessels fishing at any one time to a level that could reasonably accommodate our observer program. Although over 40 vessels expressed interest in the squid fishery, only 13 vessels actually landed squid.

In 1984 squid were commercially harvested from March 9 through July 26. This represents a considerable expansion of time of harvest relative to the late April through early June landings in 1982 and 1983. Two areas produced virtually all of the squid landed in 1984. One area north of Yaquina Head produced about 590,000 lb of squid in March and early April, and an area near Heceta Head produced about 360,000 lb in May and June.

Squid or squid eggs were also observed in other locations along the coast (Fig. 1). We received reports of squid eggs on crab pots off Cape Blanco in February and off Cape Lookout in April, we observed juvenile squid in samples collected off Bandon in late July, and heard of squid eggs on the beach near Brookings after a storm in September, and in drag nets off Yaquina Head in October. Additionally, a few crabbers reported eggs on their pots in early December. This leads us to suspect we have squid spawning off our coast much of the year.

Harvest from the first area was characterized by an initial discovery and low removal rates by vessels with lampara gear, then by a higher exploitation rate caused by increased availability of spawning squid to the gear, increased knowledge about fishing techniques, and an influx of shrimp trawlers and one purse seine vessel. Eight vessels landed squid 35 times, averaging 16,721 lb per landing. Vessels using lampara nets accounted for 19 of the 35 landings; vessels using shrimp trawls landed squid 14 times. Two landings came from purse seiners.

A trip limit of 20,000 lb per day was enacted after average landings increased from 12,282 to 33,640 lb. The trip limit was intended to slow the

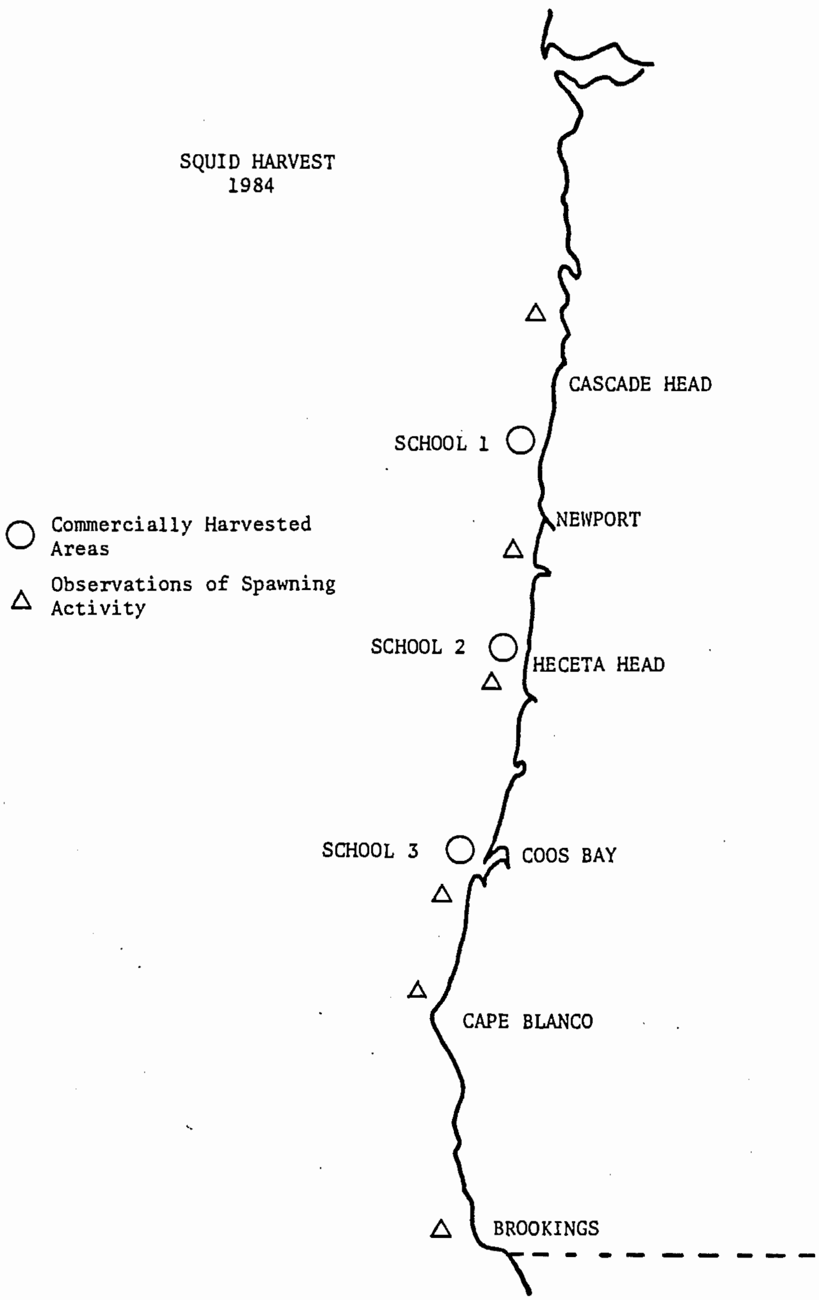

Figure 1. Locations of commercial harvest and observations of spawning activity of *Loligo opalescens* in 1984.

fishing activity in an effort to continue an orderly development of the fishery. The ex-vessel price varied during this period from a high of $600-$700 per ton when squid were heavier than 10/lb, to a low of $240-$300 per ton when mantle quality was poor and count per pound was high (Fig. 2). The higher price was paid for food grade squid caught early in the season; the price dropped as the fleet brought bait grade squid in for processing.

In the second area of harvest, as in the first area, the largest harvest occurred when the squid were well into the spawning phase and were more available to the gear. Six vessels landed squid 32 times, averaging 11,289 lb per landing. The trip limit was dropped in the middle of the harvest of the second area, but did not influence the landings, as processor requirements had a greater influence on harvest at this time.

The ex-vessel price during the second period of harvest ranged from a high of $400-$500 per ton to a low of $200-$240 per ton, again due to a decrease in mantle quality and an increase in count per pound. Most of the squid harvested from the second area were small and only marketed as bait. Processors had to sort squid if they wanted food grade, as only a small percentage were larger than 10/lb. Processors indicated that they would purchase large quantities of food grade squid, but were not eager to buy bait grade squid. Storage and interest costs were high and processors were reluctant to risk storing the bait for the sablefish and Dungeness crab fisheries. Consequently, the total harvest of squid this year was limited more by the size of squid and processing limitations than by the availability or abundance of squid.

We observed a change in fishing gear used this season. Over the course of the year we saw a shift in harvest by vessels using lampara nets to a

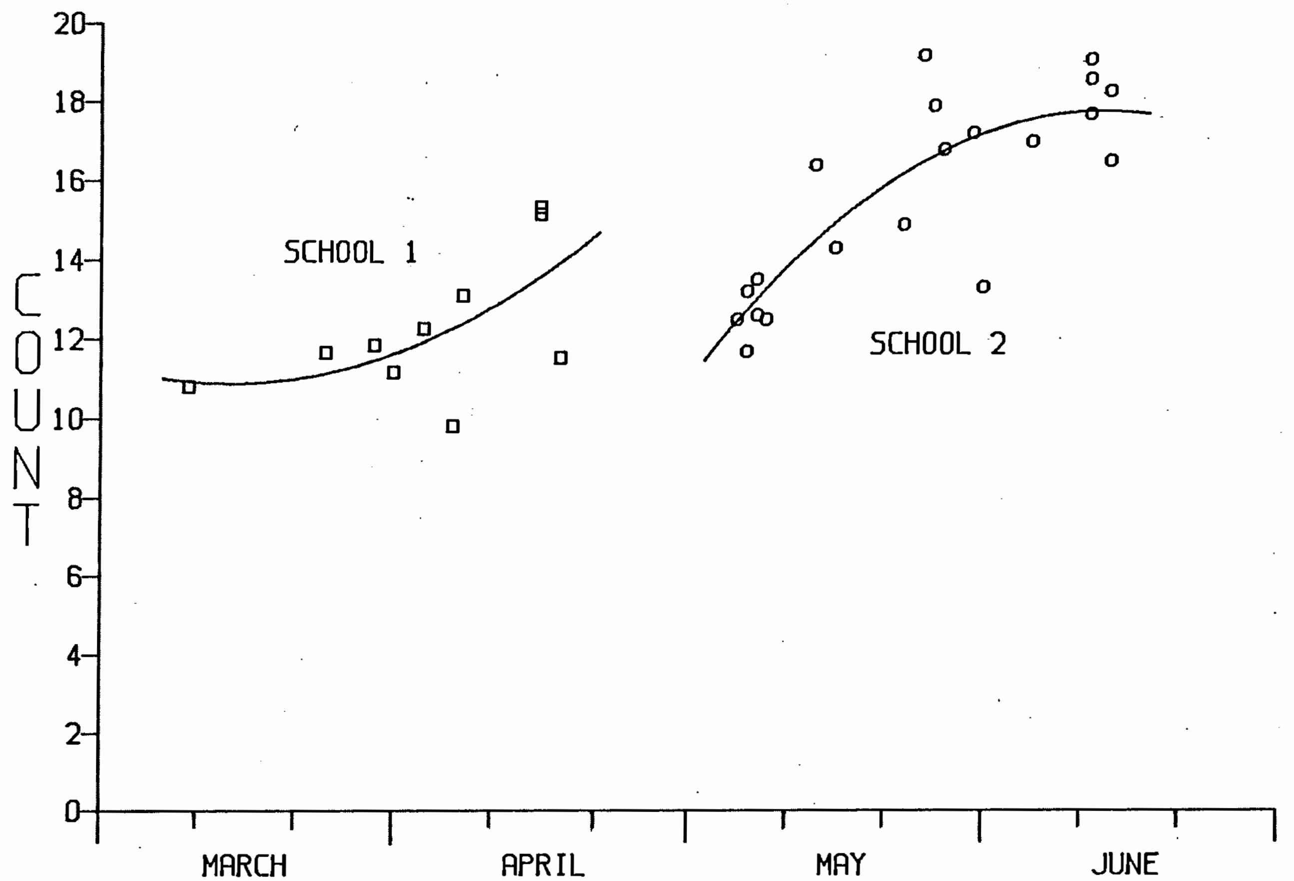

Figure 2. Average count per pound of squid landed from schools 1 and 2, 1984.

harvest with purse seines and shrimp trawls. Of the nearly one million pounds of squid landed at the end of the season, 38% were harvested with shrimp trawl nets, 33% with lampara nets, and 29% with purse seines. Less than 1% of squid harvested this year were taken using brail nets or jigs.

Observer Program

We placed personnel on vessels using lampara nets, purse seines, and trawl nets to observe fishing activity. Our objectives were to document any gear conflicts between trawlers (mobile gear) and seiners (stationary gear), to document any gear conflicts between the squid fleet and other fisheries (primarily the crab fishery), and to identify problems associated with incidental catch of the gear or negative impacts on squid egg capsules.

Our concern about intrafishery gear conflicts is one of space limitation. If too many vessels attempt to fish in the same small area in which squid are spawning, squid may be stirred up or dispersed to the point that they are more difficult to harvest. Vessels may also not have room to fish if too many boats are on the grounds. Our concerns about interfishery conflicts are primarily that squid fishing activities will interfere with commercial crabbing operations since they often occur in the same area. Of concern also is the possibility that squid nets will catch salmon or rockfish in large numbers.

We observed 24% of the total number of landings representing 26% of the landings by weight. We were able to observe fishing activity at least once on 70% of the vessels landing squid. We most frequently observed the fishing activity of vessels using purse seines and shrimp trawls; gear with the greatest potential for environmental damage (Table 1).

Table 1. Summary of 1984 squid observer program.

School	Number of Landings	Number of Landings Observed	%	Pounds Landed	Pounds Observed	%	Number of Vessels	Number of Vessels Observed	%
1	35	8	23	585,241	137,999	24	8	6	75
2	31	8	26	359,512	106,962	30	5	3	60
Total	66	16	24	944,753	244,961	26	10	7	70

Observed 24% of landings by number
26% of landings by pounds
70% of vessels landing squid

Observations by Gear Type

Gear	Number of Landings	Number of Landings Observed	%	Pounds Landed	Pounds Observed	%	Number of Vessels	Number of Vessels Observed	%
Lampara	27	3	11	314,424	17,622	6	2	2	100
Purse	16	6	38	269,512	73,187	27	4	2	50
Shrimp Trawl	23	7	30	358,817	130,269	36	6	4	67

This year we saw few problems associated either with gear conflicts or with incidental catch. The limited number of trawl vessels permitted in an area helped reduce the intrafishery conflicts. There were a maximum of eight vessels fishing in an area at any one time. Our observers and several skippers felt, however, that there would have been more conflicts for space on the fishing grounds if more vessels had been in the area. Similarly, we heard reports of only one conflict between squid fishermen and crab fishermen, but believe a potential exists for greater conflict.

The trawl and purse seine gear occasionally brought up squid egg capsules, but not in large quantities. We are optimistic that the gear has minimum negative effects, but will be attempting to further document gear impacts in 1985.

Only a small incidental catch occurred on vessels fishing on known concentrations of squid. The by-catch of vessels targeting on squid included small volumes of species of smelt, herring, anchovy, whiting, and flatfish. We occasionally saw Dungeness crab, rockfish, and salmon caught as well. This year we observed about 400 lb of rockfish, and two juvenile and three adult salmon caught incidentally to harvesting squid. The potential catch of other species still concerns us; however, since we observed over 1000 lb of black rockfish caught incidentally in one tow in 1983.

BIOLOGICAL RESULTS

Sampling Methods

During the commercial season, we attempted to collect three samples of squid each week, spread out over the entire week if possible, each sample from a boat using a different type of gear. The samples were usually collected at the processing plant during the unloading process or after the boats were unloaded. We collected a total of 200-250 squid from several totes and from different locations within a tote to ensure a well mixed sample.

A few samples were collected while on board vessels at sea. At sea, squid were again taken randomly from several hauls or from the hold to ensure a well mixed sample. If the vessel used more than one type of gear, we sampled the catch of each gear type before the catches were mixed together. We also collected additional information to use in our analysis such as boat length, date of landing, type of gear used, time of harvest (day or night), area of harvest by Pacific Marine Fisheries Commission statistical block number, and depth of harvest.

The samples were brought back to the laboratory and refrigerated until they could be processed, usually by the next day. Most samples were processed within 1-3 days of collection. Although we attempted to process all samples quickly to avoid introducing bias into our results, a few samples that could not be worked up immediately were frozen. Next year we will test for any changes in physical characteristics due to freezing or prolonged refrigeration.

In the laboratory, the squid were cut lengthwise on the ventral side of the mantle in order to determine sex and maturity stage using the method described in Kashiwada and Recksiek (1978). This method of determining gonad condition proved to be quite satisfactory except we had some difficulty in distinguishing between conditions 2 and 4 in the males. We sometimes had difficulty deciding whether we saw only few spermatophores because they were just beginning to form or because the spermatophoric sac was spent. This may continue to be a problem as Fields (1965) suggested spermatophores are always present in the Needhams sac of mature males. Additionally, if the sample had been frozen, it was difficult to distinguish whether the spermatophores were loosely packed and/or degenerating because of spawning (conditions 3 and 4) or because they had been frozen and thawed. We also encountered difficulty visually determining sex and maturity stage of small (<50 mm mantle length) animals.

In distinguishing between conditions 3 and 4 in the females, we further defined the criterion, "eggs large but few in number and opaque," used by Kashiwada and Recksiek (1978). We assigned an individual to condition 4 if more than two-thirds of the gonad was spent. If less than two-thirds was spent we labeled it condition 3. We did not measure nidamental glands to distinguish conditions 1, 2, and 3 in the females, but will do so next year when needed.

We measured whole weight to the nearest whole gram and then eviscerated the animal. Mantle length was recorded from the posterior body tip along the dorsal side to the anterior most point with the pen intact to help prevent stretching. We recorded mantle weight after the mantle was measured. The pen was sometimes included in the weighing of the mantle but since we weighed to the nearest gram, we considered the pen weight to be negligible.

After processing the sample, the data were entered into a microcomputer and summarized by length, whole weight, and mantle weight, by sex and gonad condition. We collected and analyzed the data by gear type, time of day, location, and depth. We do not yet have enough data points to differentiate sample characteristics by gear or time of day, but plan to continue to separate data collected next year.

At the end of the season we conducted a statistical test to determine the adequacy of this year's sample size. We plotted a curve expressing the relationship between the 95% confidence interval (CI) expressed as a percent of the mean mantle length, and the sample size as described in Beidler and Nickelson (1980). We used the formula:

$$95\%\ CI = \frac{t_5\ CV}{\sqrt{N}}$$

where

CV = coefficient of variation

N = number in sample

t_5 = Student's t value associated with N-1 degrees of freedom.

The slope of the power curve generated (Fig. 3) flattens at a sample size of 100-150 animals, indicating we can reduce our sample size without significantly reducing the level of precision in estimating mean length. For samples with 200-250 individuals, the 95% CI averaged ± 1.3% of the sample mean. Decreasing the size of those samples to 100-150 animals would have reduced the precision of the estimate to an average of ± 1.5% of the sample mean. We believe the advantages of a smaller sample size outweigh the small reduction in precision of the estimate. Using a smaller sample size next year will allow us to increase the number of samples we collect so we can compare morphometric characteristics of squid caught by different gear types.

RESULTS

This year we sampled more than 6,450 squid, primarily from three spawning schools[1]/. The squid were all harvested from water less than 20 fm deep

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[1]/ In this report we use the term school to distinguish groups of spawning squid separated by time and space. We use this term loosely, however, because we do not know yet exactly what constitutes truly separate schools. We do not know, for example, if two groups of squid spawning in the same general area, one right after another, are two distinct and different schools coming from different areas, or just two "spawning waves" of one school.

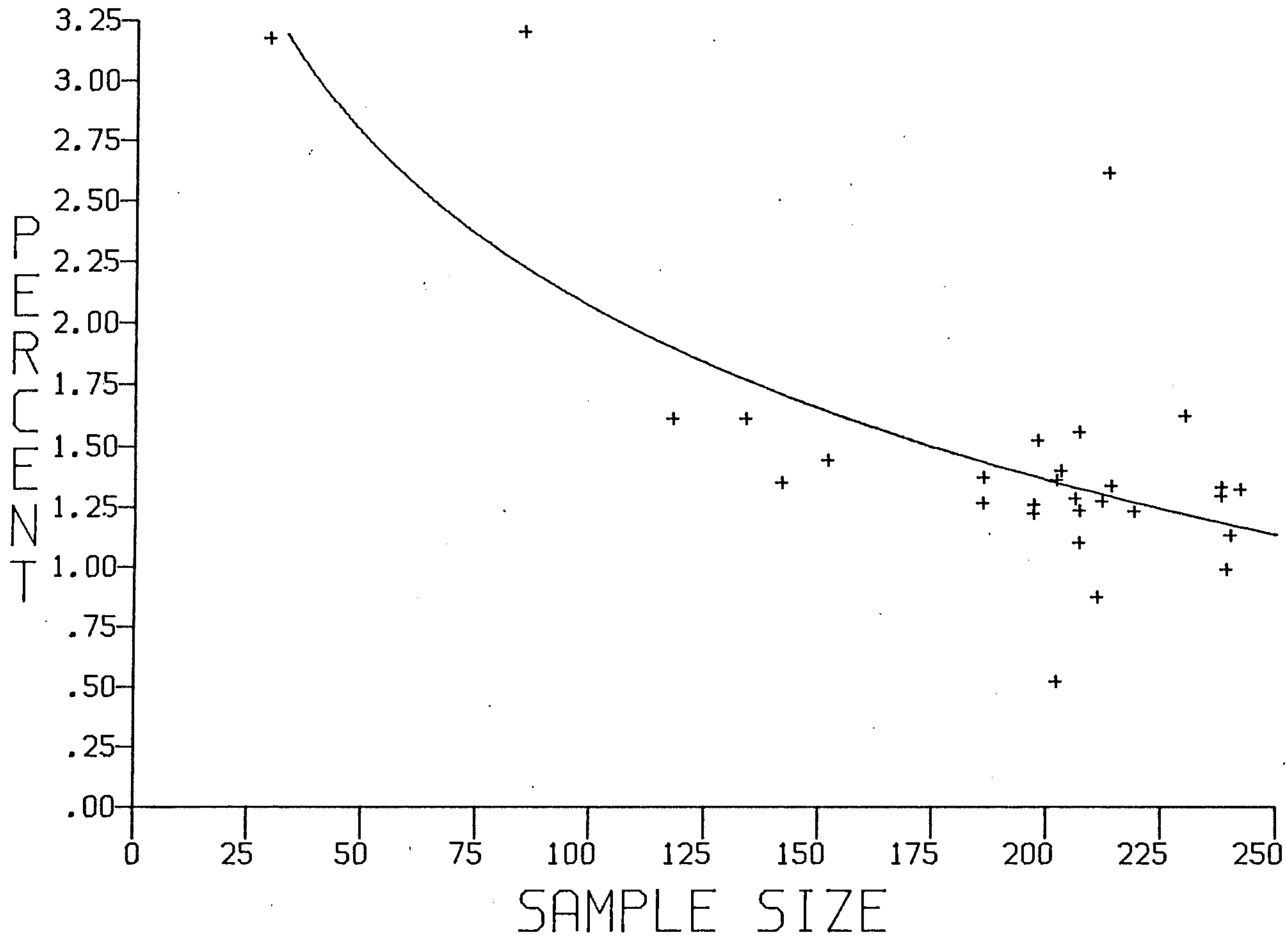

Figure 3. Relationship between the 95% confidence interval expressed as a percent of the mean and the size of samples of squid collected in 1984.

except one sample of spawning adults came from 55 fm of water. We obtained frequent large samples from the first two schools and obtained small samples from the sparse commercial landings from the third area of harvest.

We calculated chi square values to test the assumptions that the commercial gear caught males and females equally, and that all gear types caught the same ratio of males to females. We first calculated chi square values for each gear type to test the null hypothesis that the sample sex ratios were 50:50. We pooled values from samples from all schools but discarded those samples at the end of each school which were heavily weighted toward males, presumably caused by females dying first. The sex ratios of samples collected from vessels using lampara and shrimp trawl nets were not significantly different ($P > 0.05$) than 50:50. The sex ratio of all squid collected by purse seine was significantly different ($P \leq 0.05$) than 50:50.

We next compared the sex ratios by gear type to the actual sex ratio of all the samples combined (58% males, 42% females). A chi square test indicated that the sex ratios of samples collected from purse seines and shrimp trawls were not significantly different ($P > 0.05$) than the observed overall ratio, but that the sex ratio of all squid collected with lampara nets was significantly different ($P \leq 0.05$) than the observed overall sex ratio.

The chi square tests suggest there is a difference in selectivity of different gear types. We do not currently have enough data points for each gear type to identify the differences between gear. Next year we plan to collect samples in a manner that will facilitate comparisons of gear.

The average dorsal mantle length of all animals collected was 110.8 ± 0.5 mm (95% CI); mantle length ranged from 30-181 mm. Average lengths of male and female squid were 111.9 ± 0.5 mm and 114.4 ± 0.5 mm, respectively. The smallest male squid we measured in spawning condition (condition 3) had a dorsal mantle length of 78 mm. The smallest female squid (condition 3) measured 84 mm in mantle length. The smallest spawned (condition 4) animals for both males and females had mantle lengths of 76 mm. These values are in the range of minimum values presented by Fields (1965) for California squid.

Samples from the first school contained squid with the largest mean length (120.9 $\pm$ 0.5 mm) and from the third school had the smallest mean length (85.1 $\pm$ 1.4 mm) (Table 2). In almost all samples the average dorsal mantle length of females was significantly ($P \leq 0.01$) greater than of males. This was unexpected, as Fields (1965) suggested that male squid in Monterey were larger than females. Squid mantle lengths were evenly distributed around a frequency mode of 115 mm (Fig. 4) except that the third school contained squid skewed to the small side of the distribution. The third school contained juvenile and adult squid resulting in a bimodal distribution of mantle lengths. The smallest mantle lengths we measured (30-50 mm) from the third school represent 4-6 month old squid, depending upon the growth curve used (Fields 1965; Spratt 1978; Yang et al. 1980).

The squid collected from the third school came from hour-long tows with a trawl net. Some of the samples almost entirely consisted of either juvenile or adult squid, while others were mixed. This leads us to suspect that the adults and juveniles were segregated in different schools which were sampled separately in some cases and in close succession in other tows. Hurley (1978) suggested that squid in a laboratory situation segregate by size classes. Her work enforces our idea that the juvenile and adult squid we sampled were segregated.

Table 2. Mean mantle length (mm ± 95% CI) of *L. opalescens* by area through time, 1984.

Area 1				Area 2				Area 3			
Date	Gear	Length (mm)	(N)	Date	Gear	Length (mm)	(N)	Date	Gear	Length (mm)	(N)
3-9	L	121.7 ± 2.0	(230)	5-4	P	119.1 ± 1.6	(241)	5-6	S	86.0 ± 3.9	(76)
3-23	L	118.6 ± 1.8	(170)	5-5	P	119.2 ± 1.5	(219)	7-25	S	80.8 ± 2.6	(129)
3-28	L	123.3 ± 3.2	(212)	5-5	S	115.1 ± 1.8	(207)	7-27	S	78.1 ± 2.0	(190)
3-30	L	125.0 ± 1.1	(211)	5-6	P	118.1 ± 1.5	(186)	8-4	S	76.2 ± 3.3	(63)
4-2	P	119.0 ± 1.5	(189)	5-6	L	115.3 ± 1.6	(202)	8-8	S	108.6 ± 3.3	(24)
4-5	S	120.7 ± 1.6	(142)	5-7	L	116.9 ± 1.7	(152)	8-11	S	103.4 ± 1.9	(98)
4-6	L	120.9 ± 1.2	(237)	5-12	S	115.5 ± 1.3	(240)				
4-14	S	120.2 ± 0.6	(202)	5-14	P	115.6 ± 1.6	(186)				
4-14	S	119.7 ± 1.4	(196)	5-21	P	114.9 ± 1.5	(212)				
				5-23	J	115.9 ± 1.9	(118)				
				5-24	S	111.5 ± 3.6	(84)				
				5-25	P	111.9 ± 1.7	(197)				
				5-28	S	108.9 ± 1.5	(238)				
				5-29	B	114.7 ± 1.9	(134)				
				6-3	P	108.6 ± 1.5	(214)				
				6-9	S	106.6 ± 1.3	(207)				
				6-9	S	107.0 ± 1.4	(206)				
				6-9	P	109.8 ± 1.2	(207)				
				6-11	S	105.3 ± 1.4	(238)				
				6-11	P	111.4 ± 1.6	(203)				
Overall		120.9 ± 0.5	(1789)			113.0 ± 0.4	(3891)			85.1 ± 1.4	(580)

Gear:
- B = Brail Net
- J = Jig
- L = Lampara Net
- P = Purse Seine
- S = Shrimp Trawl

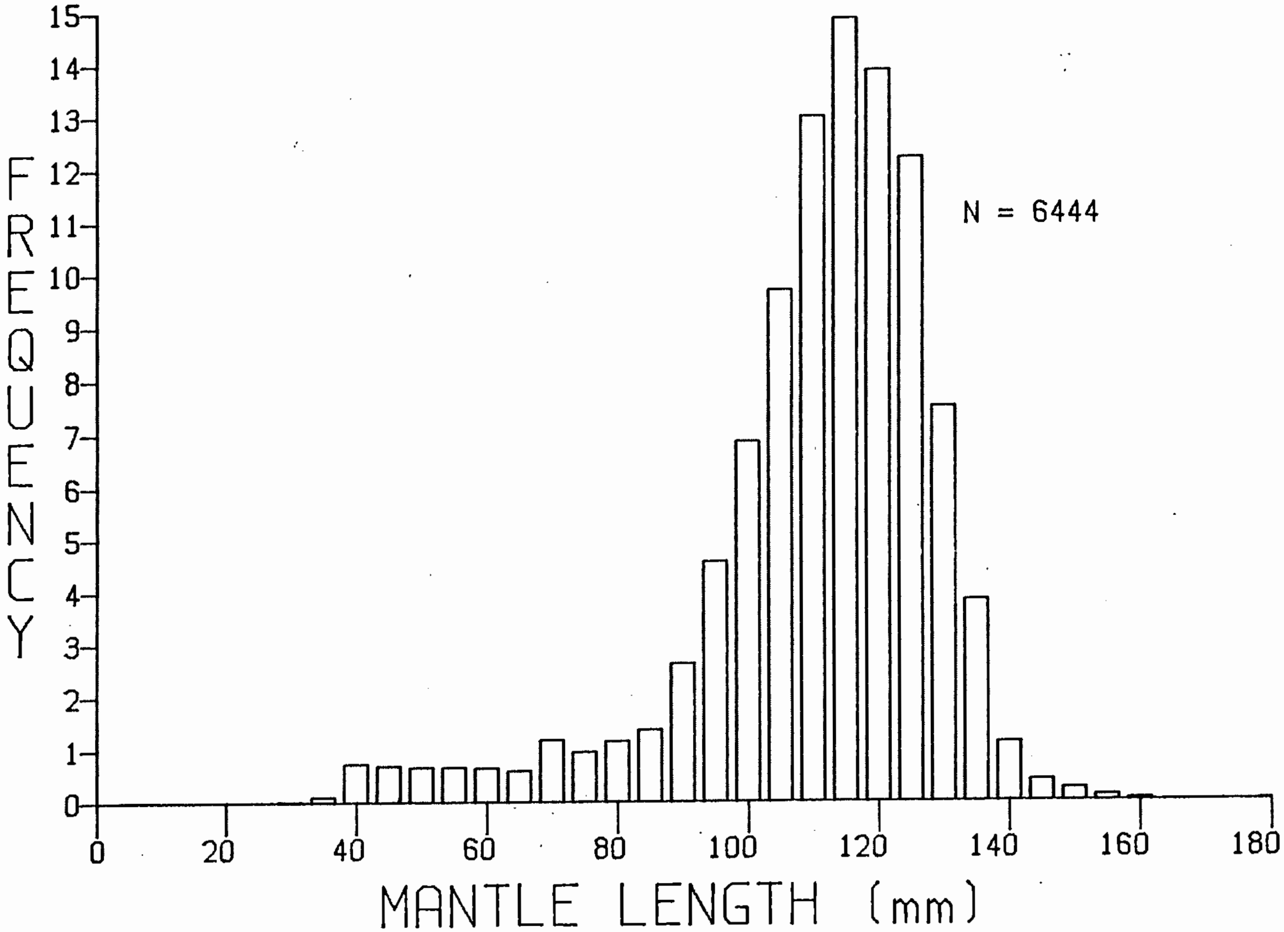

Figure 4. Length frequency (%) of all Loligo opalescens sampled in 1984.

The third school contained the lightest squid as well as the shortest. Average whole weights and mantle weights decreased within each school and decreased over the course of the season, from a high of 37.2 ± 0.5 gm (whole weight) to a low of 15.4 ± 0.7 gm (Table 3). The overall mean whole weights and mantle weights (with 95% CI) of squid sampled were 29.9 ± 0.3 gm and 13.9 ± 0.1 gm, respectively.

Within each school (Table 4), and overall (Fig. 5, 6), lengths and weights increased between conditions 1-3 then dropped in condition 4 (spawned animals). Males gained weight faster than females. The ratio of mantle weight to length also showed an increase for the first three conditions then a drop for condition 4 (Fig. 7). It appeared that the decrease in weight of the females began slightly before the decrease in weights of the males (Fig. 8).

DISCUSSION

The collection of data for this year represents one point in time, so we are not ready to draw many definite conclusions from our results. We did notice some interesting trends, however, and offer several possible explanations for observed changes in the measured parameters. We expected to see some variation in morphometric characteristics between schools, but anticipated that squid lengths and weights would generally increase during the season as happens in the California fishery (Fields 1965). We were surprised to find instead just the opposite occurred; average whole weight, mantle weight, and dorsal mantle length exhibited a general decrease over time (Fig. 9, 10). Also, the decrease in mean length was due to a gradual decline in mean size and not to an influx of juvenile squid (Fig. 11).

Table 3. Mean whole weight and meat weight (gm ± 95% CI) of <u>L. opalescens</u> by area through time, 1984. (N)

	Area 1			Area 2			Area 3	
Date	Whole weight	Meat weight	Date	Whole weight	Meat weight	Date	Whole weight	Meat weight
3-9	42.0 ± 2.0 (230)		5-4	36.3 ± 1.1 (240)	17.2 ± 0.6 (240)	5-6	14.6 ± 2.0 (76)	8.0 ± 1.3 (76)
3-23	39.0 ± 1.7 (169)	18.4 ± 0.8 (170)	5-5	38.8 ± 1.2 (219)	17.7 ± 0.7 (219)	7-25	14.8 ± 1.4 (129)	8.0 ± 0.7 (129)
3-28	38.4 ± 1.3 (213)	19.0 ± 0.7 (213)	5-5	34.3 ± 1.5 (207)	15.6 ± 0.7 (207)	7-27	12.1 ± 0.9 (189)	6.8 ± 0.5 (189)
3-30	40.7 ± 1.2 (211)	18.7 ± 0.6 (211)	5-6	36.1 ± 1.3 (186)	16.9 ± 0.7 (186)	8-4	13.2 ± 1.4 (63)	7.7 ± 0.8 (63)
4-2	37.1 ± 1.3 (197)	17.2 ± 0.7 (197)	5-6	33.6 ± 1.3 (202)	14.9 ± 0.7 (202)	8-8	28.0 ± 2.1 (24)	14.8 ± 1.2 (24)
4-5	46.3 ± 2.1 (142)	20.1 ± 1.0 (142)	5-7	36.4 ± 1.5 (152)	16.7 ± 0.7 (152)	8-11	21.5 ± 1.0 (98)	10.9 ± 0.6 (98)
4-6	34.7 ± 1.0 (239)	15.2 ± 0.5 (233)	5-12	27.7 ± 1.0 (240)	13.0 ± 0.5 (240)			
4-14	29.7 ± 1.2 (202)	12.9 ± 0.5 (202)	5-14	31.9 ± 1.4 (186)	15.3 ± 0.7 (186)			
4-14	30.0 ± 1.2 (197)	13.7 ± 0.6 (197)	5-21	30.5 ± 1.2 (211)	14.1 ± 0.6 (211)			
			5-23	23.7 ± 1.2 (118)	10.0 ± 0.6 (118)			
			5-24	25.4 ± 1.8 (85)	10.4 ± 0.9 (85)			
			5-25	27.1 ± 1.2 (198)	13.4 ± 0.7 (198)			
			5-28	26.4 ± 0.9 (238)	12.8 ± 0.5 (238)			
			5-29	34.2 ± 1.4 (134)	17.1 ± 0.7 (134)			
			6-3	26.7 ± 1.1 (213)	12.7 ± 0.5 (214)			
			6-9	23.8 ± 0.7 (207)	11.6 ± 0.4 (207)			
			6-9	25.7 ± 1.0 (206)	12.6 ± 0.5 (206)			
			6-9	24.5 ± 0.9 (207)	11.8 ± 0.5 (207)			
			6-11	24.8 ± 0.9 (238)	12.2 ± 0.5 (238)			
			6-11	27.6 ± 1.2 (203)	14.1 ± 0.6 (203)			
Overall	37.2 ± 0.5 (1800)	16.7 ± 0.3 (1565)		29.9 ± 0.3 (3890)	14.1 ± 0.2 (3891)		15.4 ± 0.7 (579)	8.3 ± 0.3 (579)

Table 4. Mean mantle length (mm ± 95% CI), whole weight (gm ± 95% CI) and meat weight (gm ± 95% CI) of squid by sex and maturity condition, 1984. (N)

		Length	Whole Weight	Meat Weight
Males	Condition 1	75.1 ± 1.7 (121)	10.8 ± 0.7 (120)	6.0 ± 0.4 (120)
	2	116.2 ± 1.5 (459)	36.4 ± 1.3 (4600	17.4 ± 0.7 (321)
	3	116.6 ± 0.7 (1345)	37.0 ± 0.6 (1345)	17.8 ± 0.3 (1324)
	4	109.7 ± 0.6 (1669)	27.2 ± 0.4 (1668)	12.9 ± 0.2 (1669)
Females	Condition 1	70.4 ± 1.6 (132)	8.8 ± 0.5 (132)	5.2 ± 0.3 (132)
	2	86.0 ± 3.1 (34)	15.2 ± 1.7 (34)	8.9 ± 0.8 (34)
	3	119.2 ± 0.5 (1155)	37.0 ± 0.4 (1162)	15.9 ± 0.2 (1087)
	4	115.4 ± 0.5 (1302)	26.0 ± 0.3 (1305)	12.3 ± 0.2 (1305)

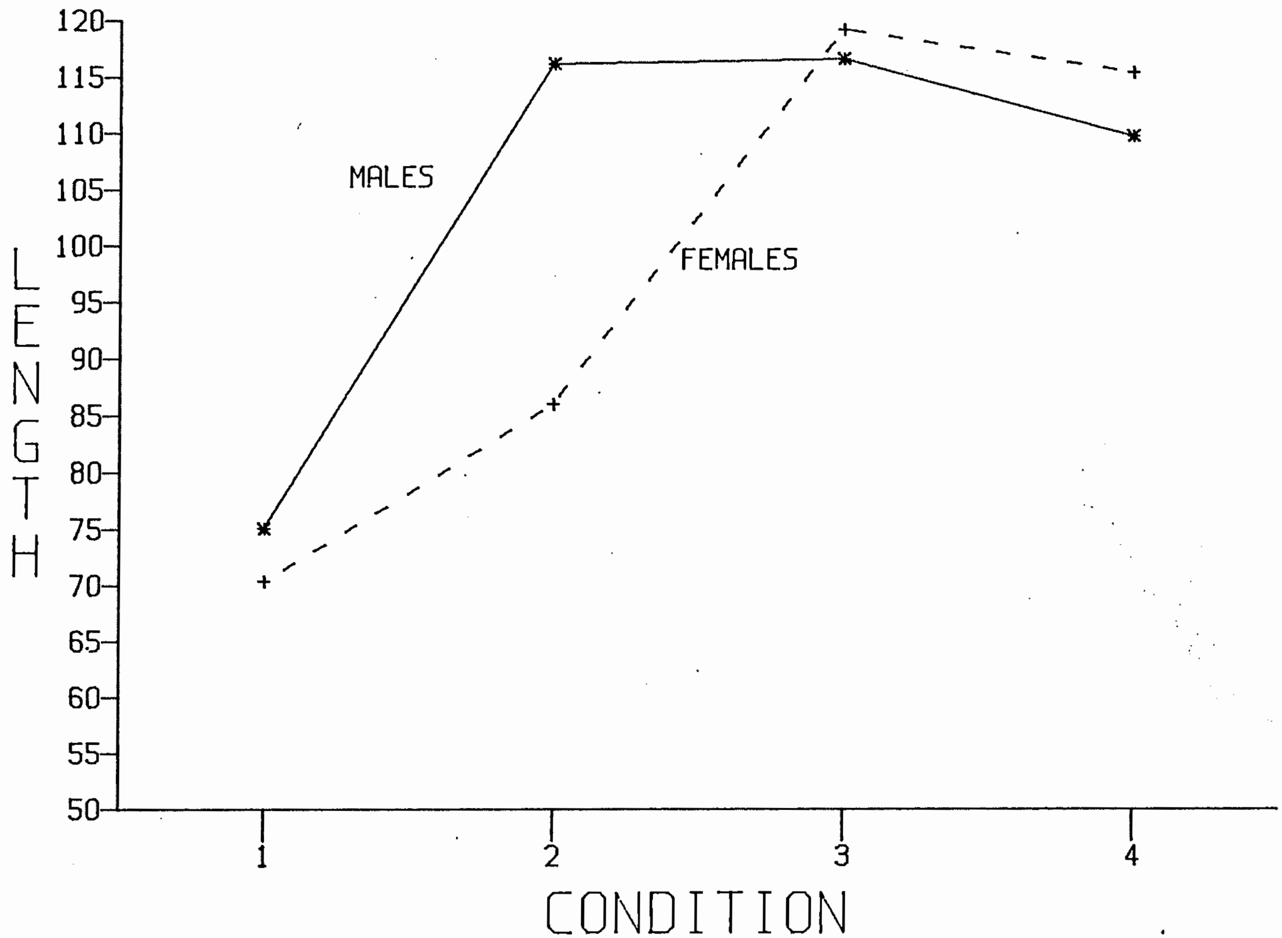

Figure 5. Average dorsal mantle length (mm) by maturity condition and sex for squid sampled from the 1984 commercial fishery.

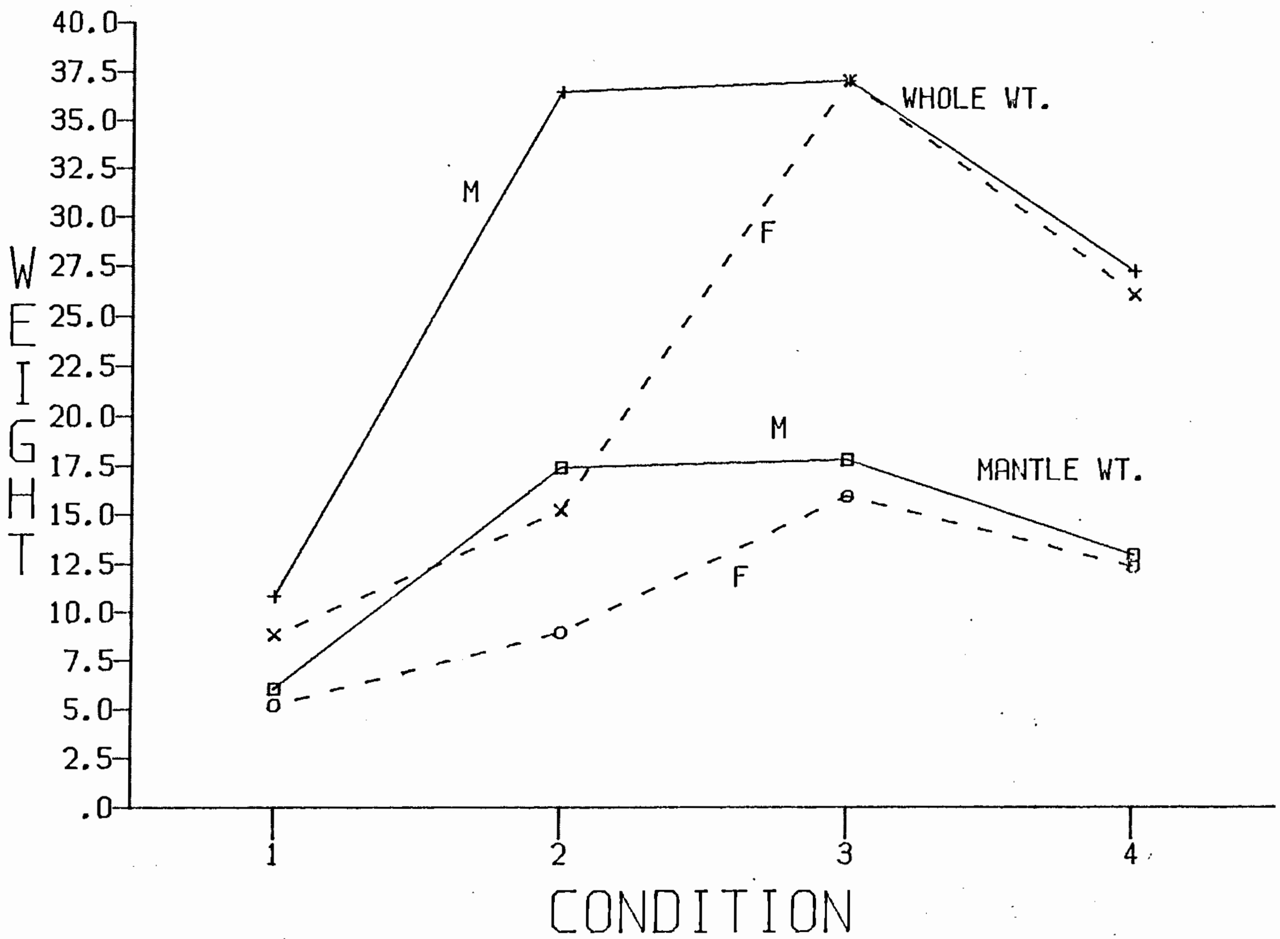

Figure 6. Average whole weight (gm) and mantle weight (gm) by maturity condition and sex for squid sampled from the 1984 commercial fishery.

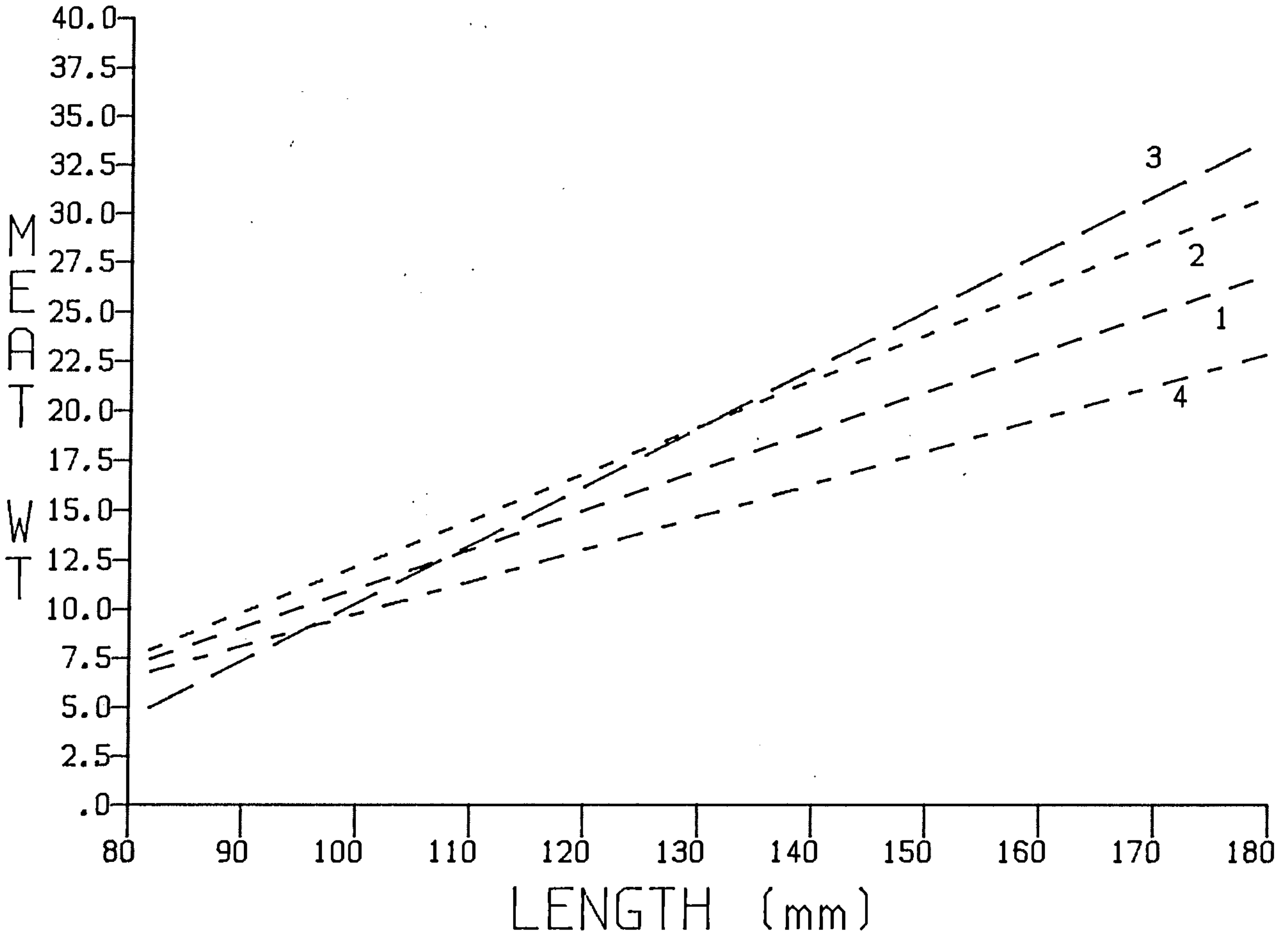

Figure 7. 1984 average meat weight (gm) to length relationships of female squid by maturity conditions 1-4.

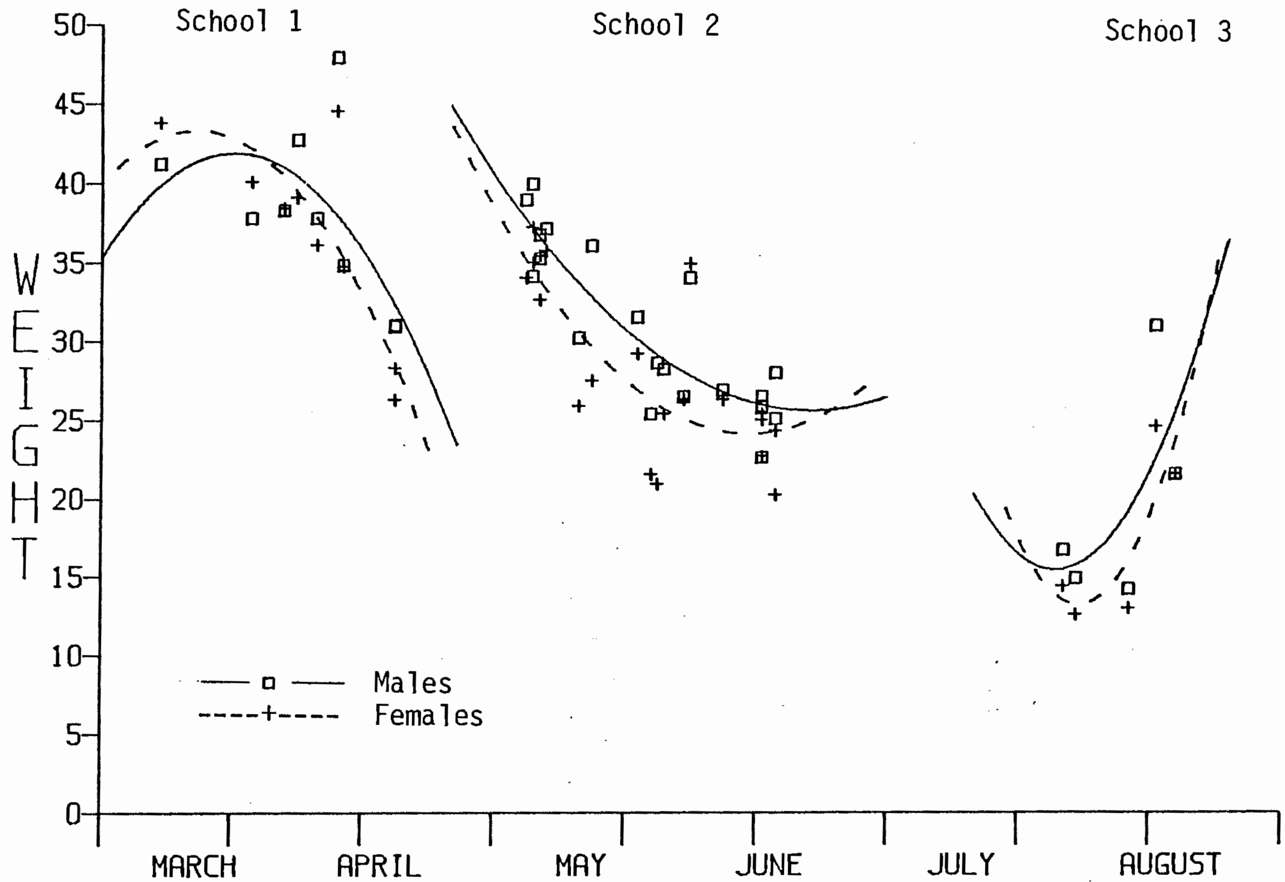

Figure 8. Average whole weight (gm) of squid by sex, for samples from each school in 1984.

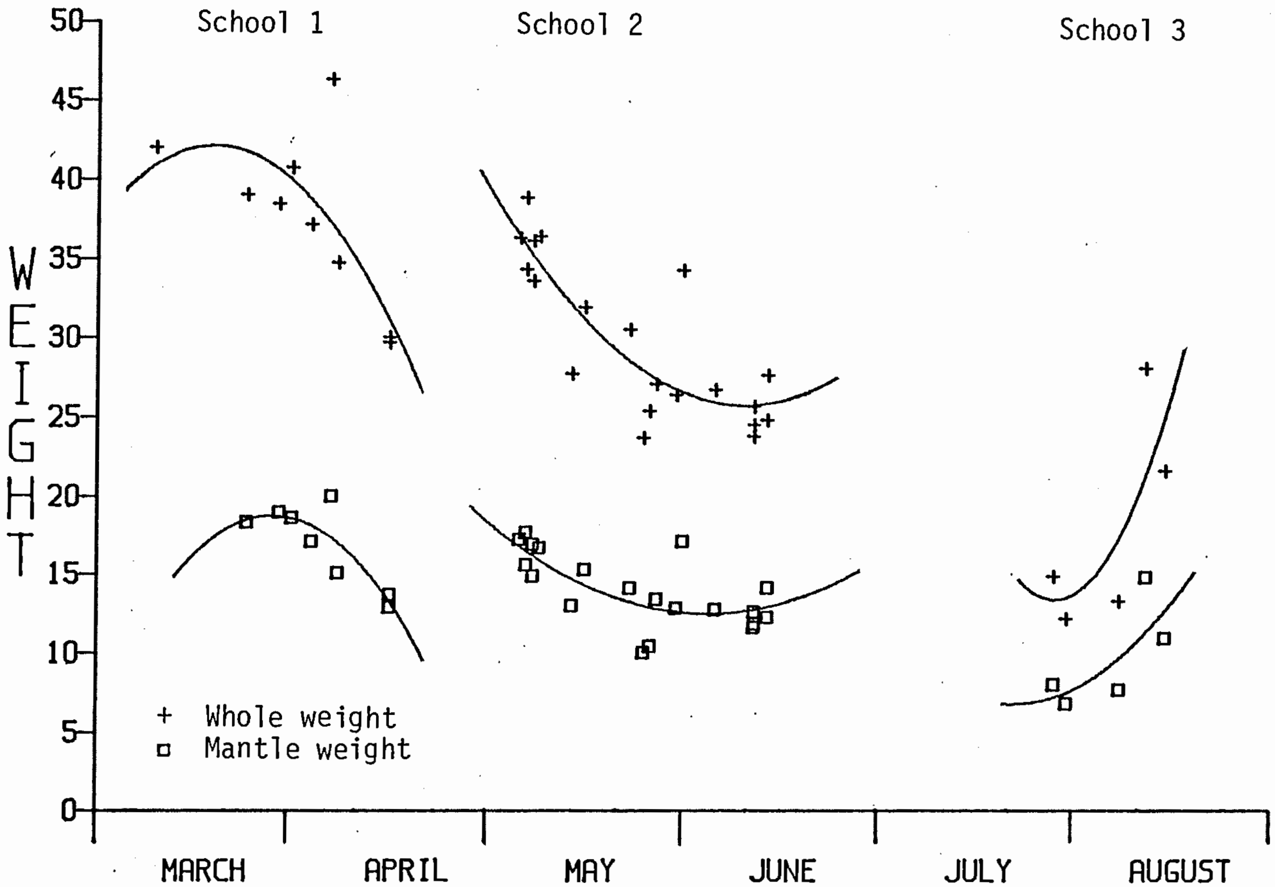

Figure 9. Average whole weight (gm) and mantle weight (gm) for samples from each school of squid, 1984.

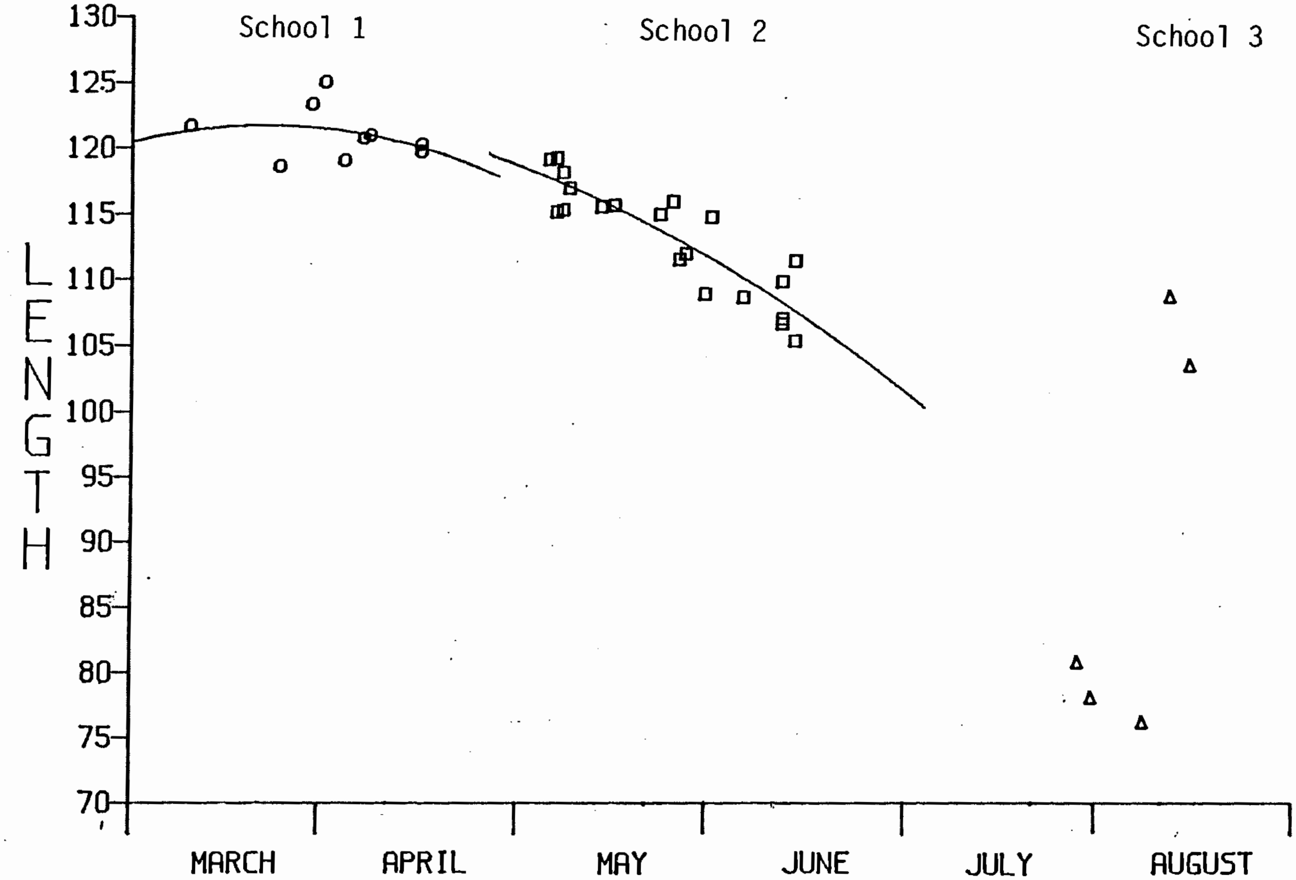

Figure 10. Average mantle length (mm) of squid sampled from each school, 1984.

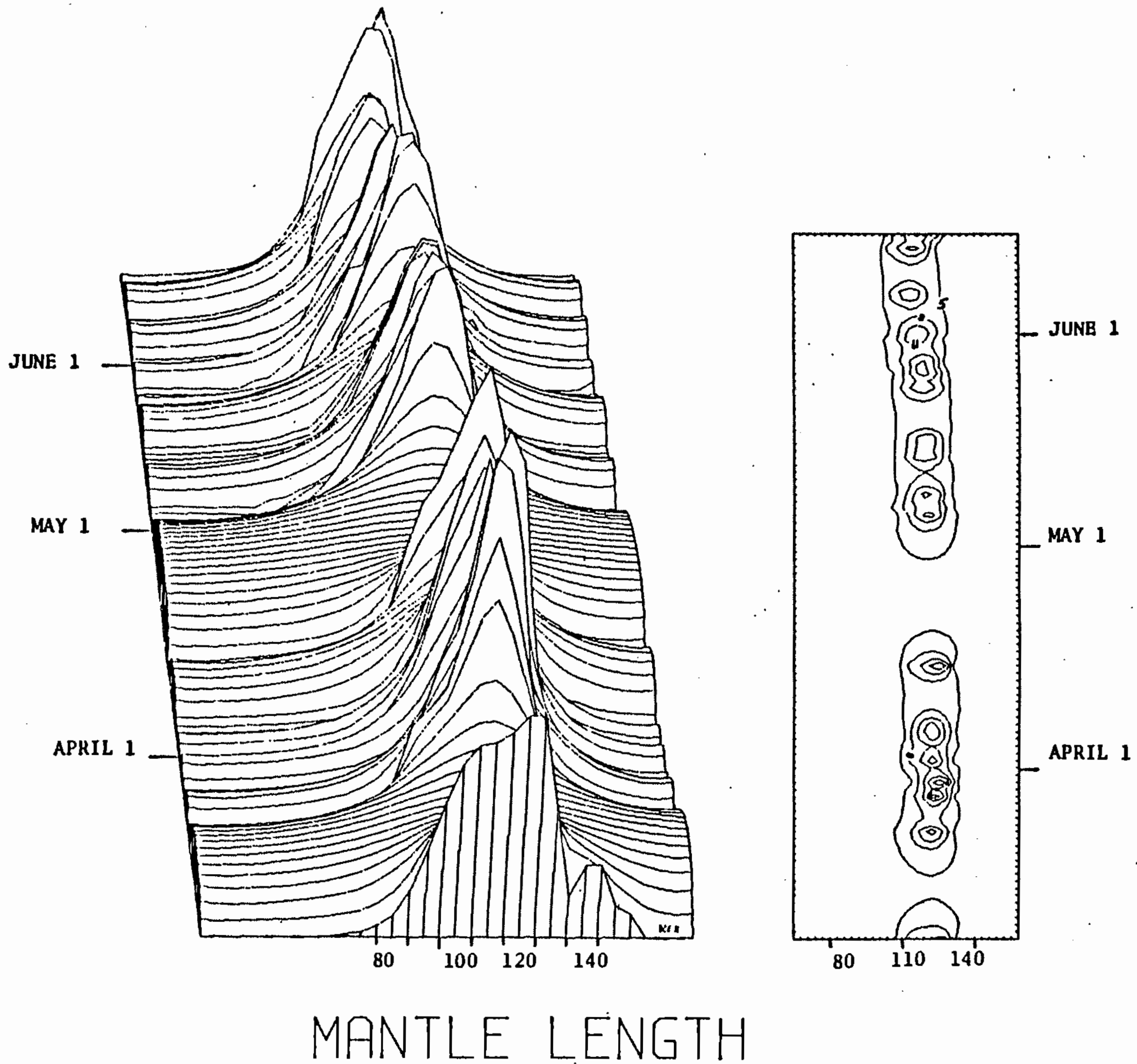

Figure 11. Length frequency of squid sampled in 1984 displayed in a relief diagram and a contour plot. The isopleths in the contour plot are expressed in frequency intervals of 3%.

The size decrease was especially surprising since fishermen tell us that squid are usually larger off Coos Bay in July than off Newport in May. At this point in time we do not know if the size decrease through time is due to differences in regional growth and maturity pattern, due to stock differences, or due to unusual environmental conditions, perhaps caused by the 1983 El Nino phenomenon.

Fields (1965) and Karpov and Cailliet (1978) suggested that squid feed sparingly while in spawning aggregations. Although we did not record stomach contents, we did notice very few squid with any amount of material in their stomachs[2/]. A decrease in feeding and a high level of activity during spawning would result in a net energy loss and explain the observed decreases in weights (Table 3).

Fields (1965) also noted a 24% decrease in mantle thickness in males and a 42% decrease in females following spawning. Although we did not measure mantle thickness we qualitatively noticed a pronounced decrease in mantle thickness and firmness in condition 4 squid as compared to squid in condition 3. When we compared mantle weight to mantle length for each condition, condition 4 squid were lighter at a given length than squid in conditions 1-3, substantiating our observation that spawned squid had thinner mantles (Fig. 7).

Female squid showed a greater loss in weight than males (Fig. 6). This is probably because the eggs in the female make up a larger proportion of the whole weight than the spermatophores do in the males. According to Fields (1965) mature reproductive organs comprise between 25-50% of the total body

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2/ An interesting exception to our observations of squid stomachs is that all (29 individuals) of the spawning squid we collected from 55 fm contained full stomachs.

weight of females prior to spawning, and reproductive organ weights decline by over 80% after spawning. Conversely male reproductive organs comprise only 5-12% of the total body weight, and the weight of the reproductive system declines by only 38% after spawning.

The earlier decrease in weight of females relative to males (Fig. 8) may indicate that as a group females spawned sooner, stopped eating sooner, or were on the spawning grounds longer. We also noticed a shift in the sex ratio from near parity in the early samples from a school to considerably more males near the end of the spawning activities, suggesting that females die first.

Since there is a loss of weight and decrease in firmness in the mantle after spawning, squid are more desirable as a food item to the industry before spawning. Therefore, it would be beneficial to determine how close the majority of individuals in a school are to spawning. Changes in the sex ratio of a sample, an increase in the percentage of spawned individuals (condition 4), and decreases in the mantle weight to length ratios may prove useful as indicators of the progression of spawning activities of a given school.

In the second area of harvest the mean length of the samples decreased through time, but the mean weight decreased for a while, then increased (Fig. 9, 10). An increase in mean weight for a smaller mantle size indicates that squid in an earlier spawning condition moved into the area. To verify that this was the case, we divided the mantle weight by the mantle length for each squid, then plotted the average ratio for each sample (Fig. 12). The mantle weight to mantle length ratio also decreased for a while, then increased. These results corroborate the assumption that squid in an earlier spawning condition moved into area 2 during the time of harvest.

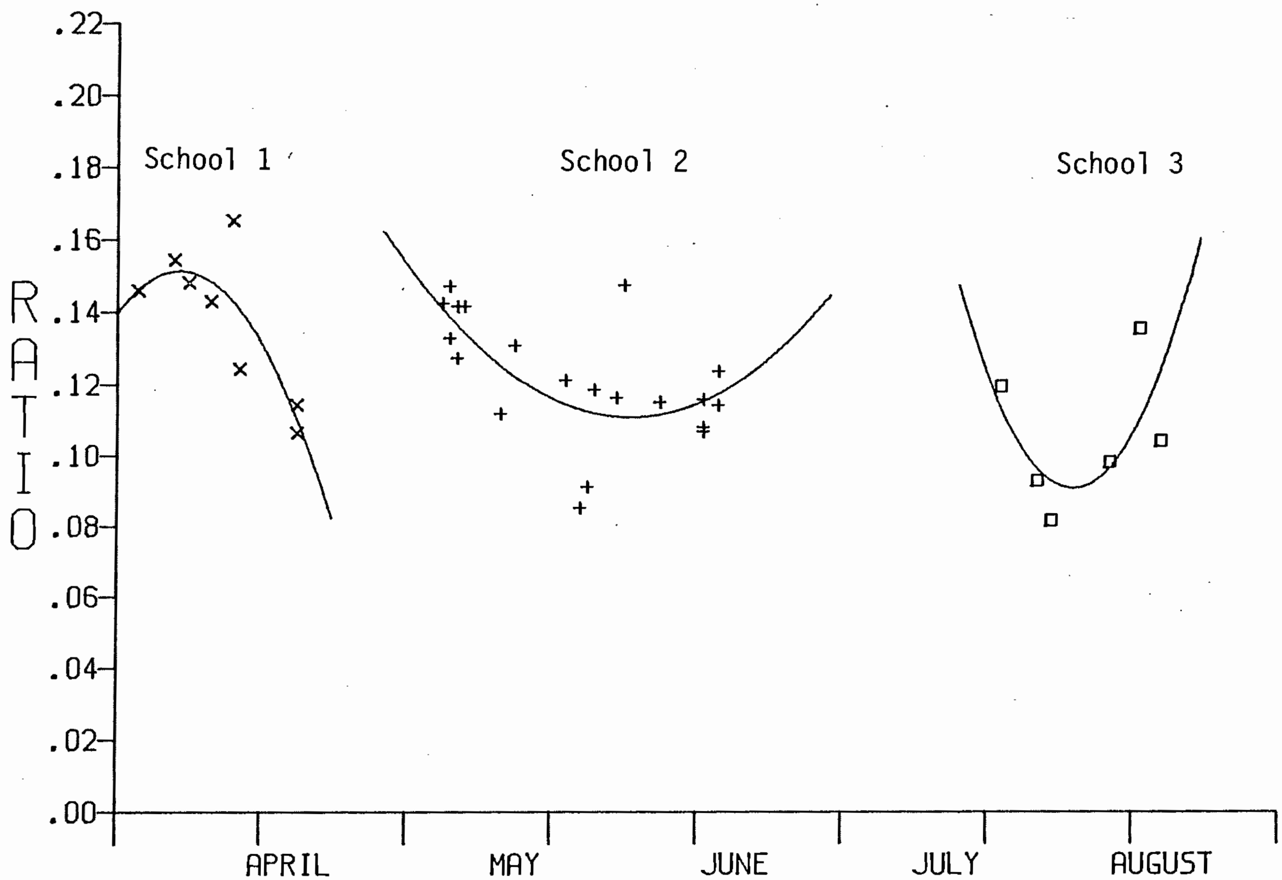

Figure 12. Average ratio of mantle weight (gm) to dorsal mantle length (mm) of samples collected from each school in 1984.

The data indicate that new squid moved into the area, but how many groups of squid arrived to spawn? This is a critical question to answer to help us estimate squid abundance. This year we helped OSU conduct experiments to develop hydroacoustic techniques to estimate squid biomass. Next year we propose to use the gear developed in FY 84 to estimate squid abundance in several major spawning schools. We need to know if and when new groups of squid move into an area to help us design sampling schemes and evaluate our data.

We used the amount of spawned females in our samples as an indicator to determine how many groups of squid came in to spawn. The percentage of spawning animals (condition 4) in each sample was initially very low within a school. As spawning activities progressed, the percentage rapidly increased until 100% of the individuals sampled had spawned (Fig. 13). The data suggest the time from onset of spawning in the population until the time virtually all of the squid have spawned is very short, on the order of 12-15 days. We assumed, based on the shape of the percent spawned females curve derived from the first school harvested this year (Fig. 13), that squid made a consistent and fairly rapid transition from condition 2 or 3 to condition 4. The curve of percent spawned females for the second area of harvest (Fig. 14) displays several alterations from a consistent pattern, however.

To try to explain the observed pattern, we plotted the shape of the curve of percent spawned females in the first school, then assumed an influx of two other schools with the same shape, but offset in time. This gave us a hypothetical curve of percent spawned females in the population (Fig. 15). We then compared the hypothetical curve to the observed curve of spawned females (Fig. 14). The hypothetical curve provided a reasonably good fit to the observed situation.

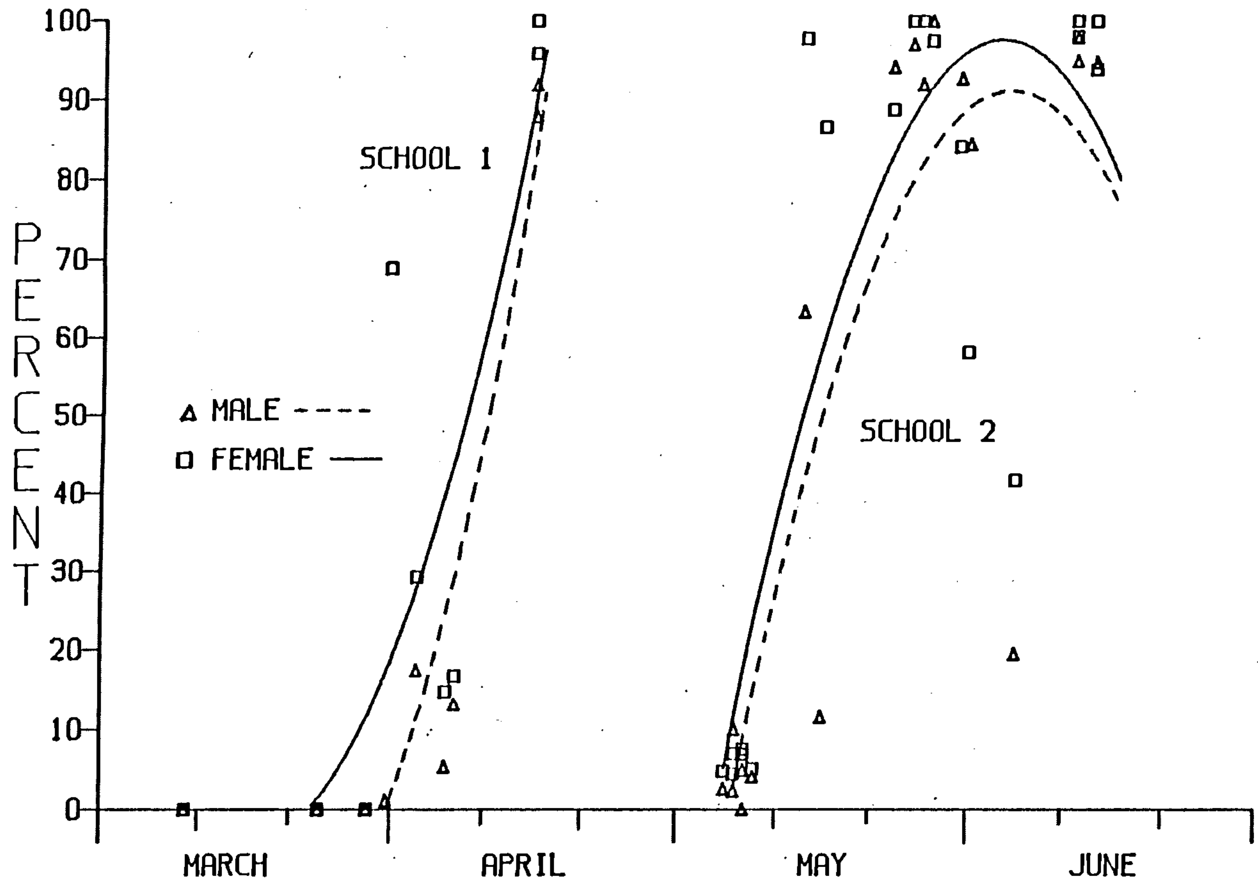

Figure 13. Percent spawned males and females from samples collected in 1984.

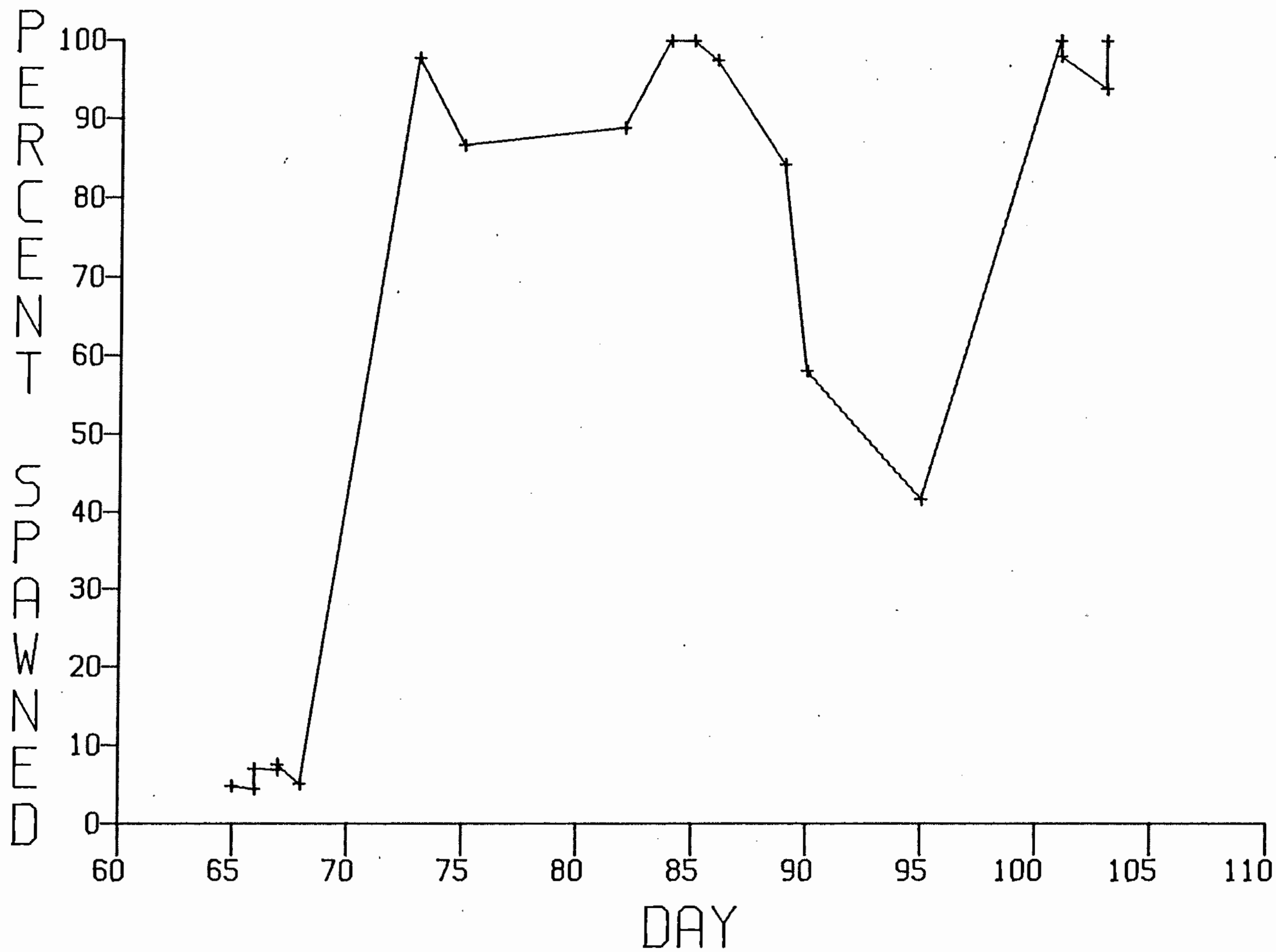

Figure 14. Observed percent of spawned female squid from school 2, over the duration of harvest of school 2, 1984.

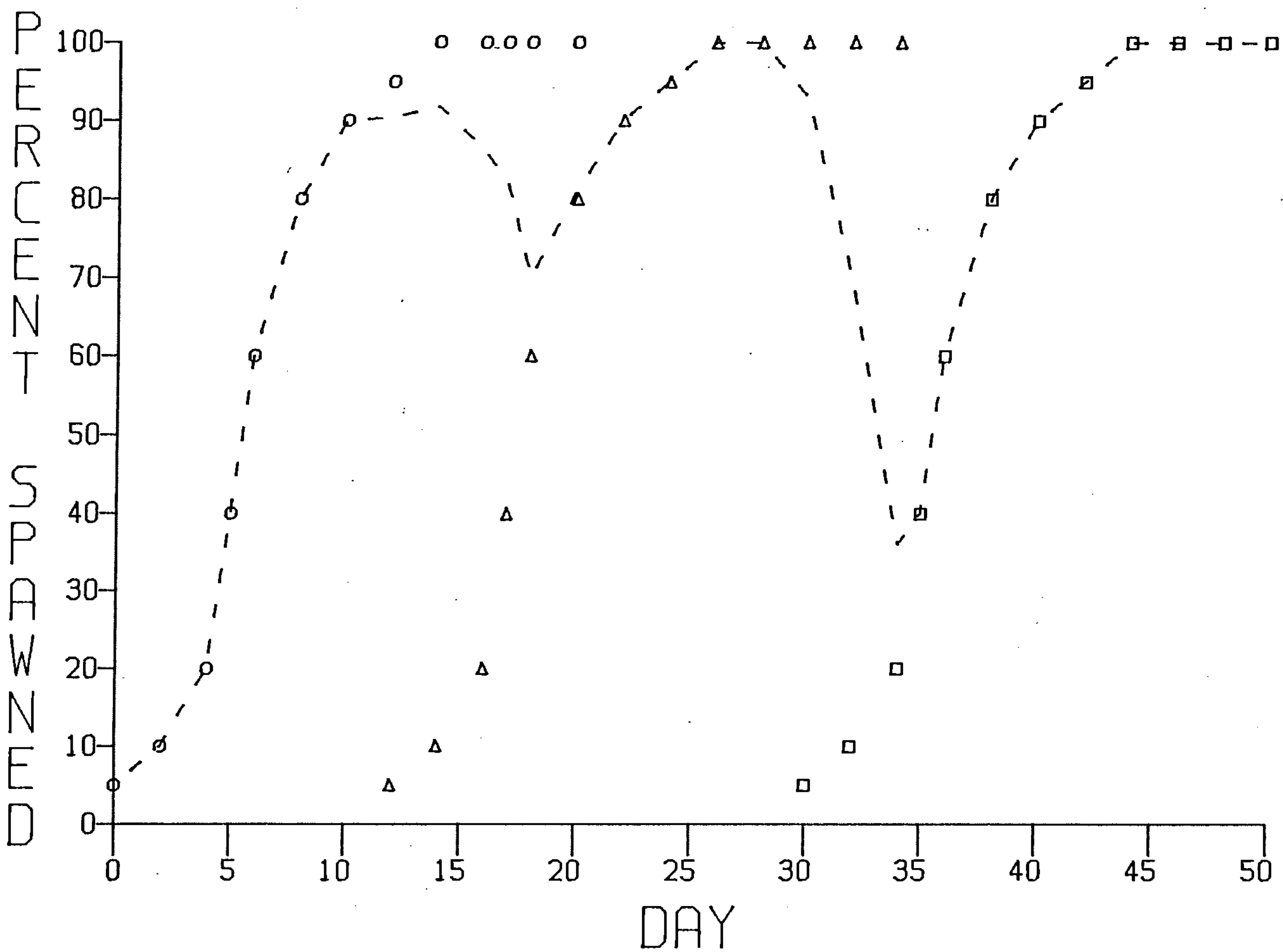

Figure 15. Hypothetical curve of percent spawned female squid over time showing an influx of three groups of animals.

We next analyzed the mean lengths of condition 4 squid to verify the hypothesis that new squid moved into the second area of harvest. We used the Newman-Keuls multiple comparison test (Zar 1974) to test for differences in the samples. The results indicated that three groups of squid did enter the area during the time of harvest. The three groups of squid had significantly ($P \leq 0.05$) different mantle lengths suggesting again that they were of different ages or had come from areas with different growing conditions. Regression lines of sample weight to length ratios for the three groups of squid (Fig. 16) showed three different rates of decrease in mantle weight due to spawning. We expect to be able to use this type of analysis next year to help us estimate squid abundance in an area.

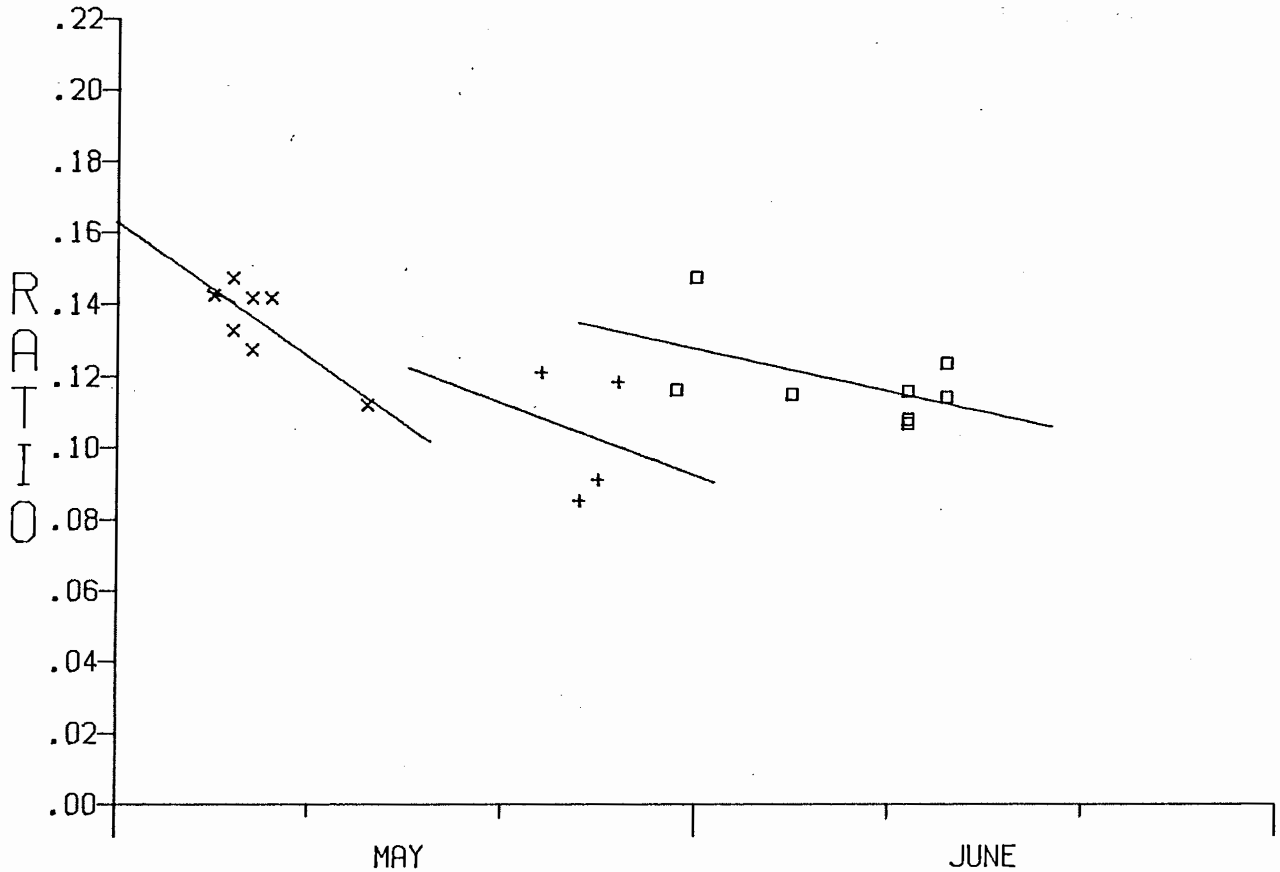

Figure 16. Average ratios of mantle weight to dorsal mantle length for samples collected from school 2 in 1984, showing three groups of squid in the sample area.

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