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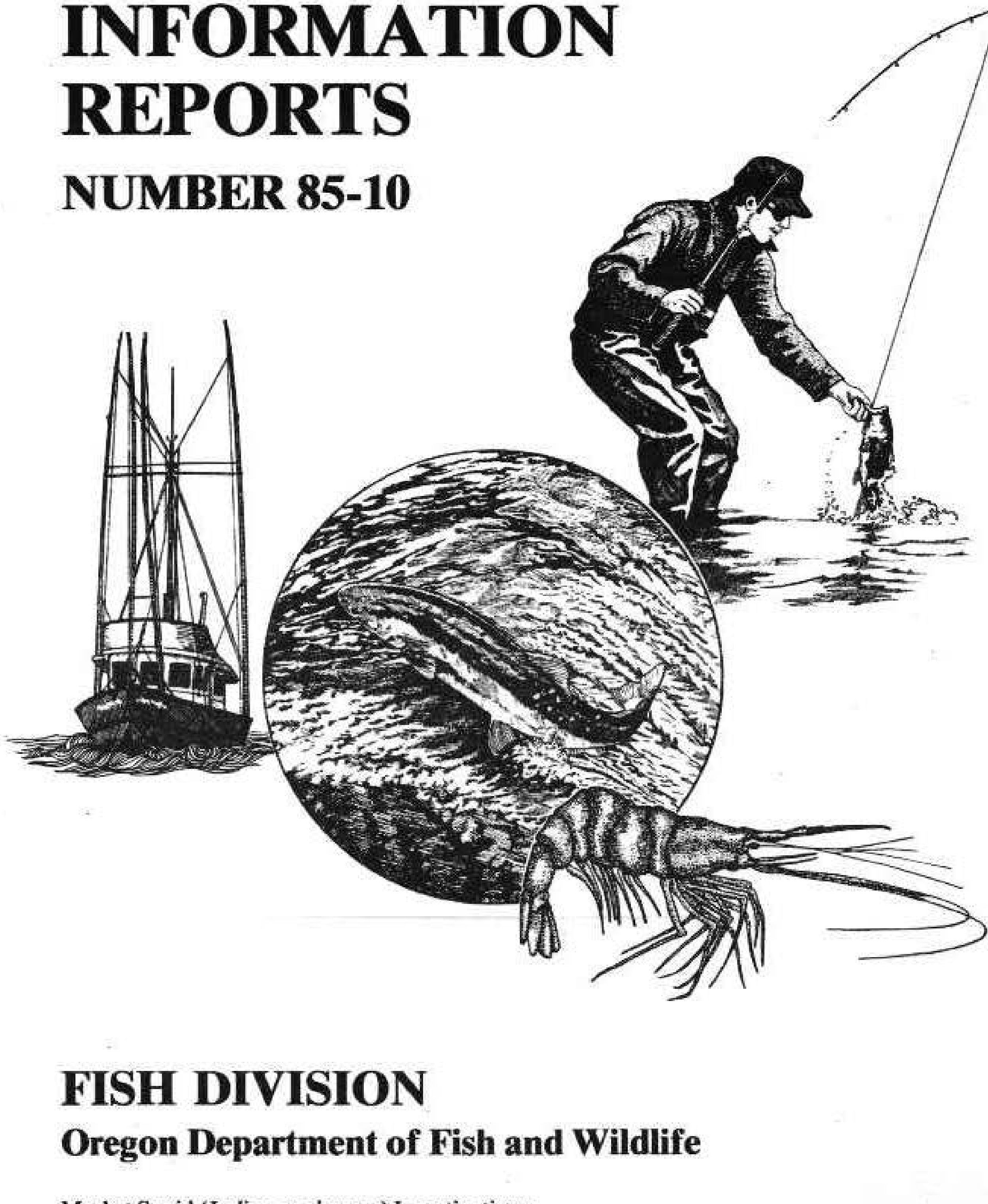

FISH DIVISION

Oregon Department of Fish and Wildlife

Market Squid (*Loligo opalescens*) Investigations
in Oregon, 1983-85

Market Squid (*Loligo opalescens*) Investigations in Oregon, 1983-85

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ABSTRACT

The Oregon fishery for Loligo opalescens is expanding at a rapid rate. Fishing effort and efficiency are increasing; purse seines are used most frequently to catch squid. In 1985 catch per trip averaged 27.0 thousand lb. Six vessels accounted for 77% of the 1.75 million lb landed. Ex-vessel price averaged $350 per ton.

L. opalescens caught off Oregon apparently have different biological characteristics than squid caught in California. Females in an aquarium laid an average of 23 egg capsules per animal. A total of 700 egg capsules collected in the field yielded an average of 98 ± 2 (95% CI) eggs per capsule. The mean dorsal mantle length of L. opalescens sampled diminished with time. Females had longer dorsal mantle lengths than males. The sex ratio of all samples collected is weighted toward males. Storage tests revealed that squid whole weights decline with time when frozen. Length to weight ratios of spawning female squid indicated that three different groups of squid entered the harvest area to spawn.

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INTRODUCTION

In the past several years Oregon fishermen have taken an increasingly greater interest in the market squid (Loligo opalescens). This interest stemmed primarily from a decline in the availability of squid in Monterey, California. In 1982 the west coast harvest of squid was at a 10 year low, and the supply of foreign squid was also low. Consequently the market was strong and ex-vessel price was high; the price paid to fishermen almost doubled in Monterey from 1980 to 1982. The market conditions were thus conducive to the start of an Oregon fishery, and with the observation of squid in large quantities near shore, fishermen geared up to catch the pelagic mollusc. Successful catches increased fishermen interest; fishing effort and landings doubled or tripled each year since the first sizeable landing occurred in 1982.

In response to the increase in squid landings, we designed a research project to obtain data needed to manage the new fishery. One of the initial goals was to describe the biology and life history of L. opalescens in Oregon waters, and compare the biological characteristics of squid caught here with those doumented for squid caught off Monterey.

L. opalescens have been harvested in California for over 100 years. Numerous fine studies describe the fishery and biology of this species in Monterey (see for example Fields 1950, 1963, 1965; Hurley 1977; Kato and Hardwick 1975; Recksiek and Frey 1978; and Hixon 1983). We felt that if squid off Oregon are comparable to those off Monterey our management program could rely upon population parameters identified and published for the Monterey area.

If squid here turned out to have different biological characteristics, however, new estimates of stock characteristics would be needed. We designed a sampling program to collect data in a way that the results could be directly compared to California data, but that would also allow the formation of a unique Oregon data base. The other primary goals of the research project included an evaluation of harvest rates and fishery impacts. This report summarizes information from three years of fishery observations and biological data collection.

HARVEST ACTIVITIES

Late in 1984, public hearings were held in Astoria, Newport, and Charleston to gather input from fishermen, processors, and other interested people regarding management strategies and regulations for the 1985 fishery. At those meetings we expressed concerns for the resource including the potential for overharvest (especially of one school), the impact of fishing gear on egg capsules, and the potential for incidental catch and gear conflicts. Management objectives outlined for 1985 were:

1) To keep overall removal at a moderate level in the absence of abundance data;
2) To prevent overharvest of one school;
3) To evaluate gear impacts on egg capsules;
4) To identify interfishery and intrafishery gear conflicts;
5) To encourage fishery experimentation and processor involvement.

Alternatives suggested in order to achieve the management objectives and increase our understanding of the resource and fishery included:

1) Limiting the total number of vessels on the squid grounds through the use of closely monitored experimental gear permits;

2) Limiting the rate of removal by enacting daily, weekly, or monthly trip limits; and

3) Allowing processing requirements and limitations to control both the number of vessels fishing for squid and the amount of squid landed each day.

Industry representatives expressed an understanding and agreement with the need for conservation measures. They also felt it was important to build their markets while the California squid production was low and world markets were strong. Processors stated they needed sufficient quantities of squid to establish markets and to operate economically, and suggested that present processing capacities would limit harvest and participation in the fishery.

In late January 1985, the Oregon Fish and Wildlife Commission (OFWC) held a hearing to review the 1984 fishery and set regulations for 1985. In 1984 we learned how the industry would function with tight controls. A limited number of trawl permits, with restrictive time and area limits, were issued and a trip limit was imposed. This encouraged orderly development of the fishery by slowing removal rate, encouraging exploration and experimentation, and increasing the knowledge necessary for management of the resource. In response to public views and staff evaluation of the 1984 fishery, the OFWC felt it desirable in 1985 to see how industry would react to less restrictive controls.

To prevent overharvest of all schools the OFWC set a harvest review point. When 4.5 million lb were landed coastwide, or 3 million lb north or south of Heceta Head, the fishery was to be reviewed. To protect specific schools, the OFWC endorsed the concept of establishing a temporary fishery closure within 5 mi of an area when 1 million pounds were harvested from an individual school. This closure would allow time for the squid in the school to spawn and/or new squid to move into the area. The OFWC directed staff to decide if and when temporary closures would be necessary.

Experimental gear permits continued to be issued in 1985 to allow trawl vessels to fish for squid. This was necessary because under groundfish regulations it is unlawful to fish for ocean foodfish (including squid), with a mesh size of less than three inches. There was no limit on the number of permits issued and they were valid for the entire Oregon coast for the entire year.

Effort

Some fishermen and processors suspected that the 1982 and 1983 occurrence of squid off Oregon was due to a northward displacement, caused by El Nino conditions, of the stock that usually spawns in Monterey Bay, California. Oregon fishermen refrained from purchasing new gear for a fishery that many considered to be temporary. Consequently the first equipment used to catch, unload, and process squid was not specifically designed for squid, but was modified gear used in other fisheries. The modified gear was moderately successful.

In 1984 and 1985 ocean waters cooled and squid returned to Monterey. Squid were still abundant off Oregon, however. As fishermen and processors became more convinced they could profit from the harvest of squid off Oregon, they started using gear designed specifically for squid. The industry is now in transition from the initial exploratory and experimentation stage to a production stage. Fishermen are rapidly learning how to locate and catch squid.

In 1985, 26 permits for fishing with trawl gear were issued; 7 boats with permits made landings. In addition, 9 boats landed squid using gear that did not require a permit. Of the 16 vessels landing squid, 6 vessels accounted for 77% of the landings. Four vessels landed squid as an incidental catch.

In 1984 vessels with lampara landed squid most frequently (41% of the 66 landings), followed by shrimp trawls (35%), and purse seines (24%). At the end of the 1985 season, 58% of the 65 landings came from purse seines, 22% from shrimp trawls, and 20% from lampara. The drop in the number of shrimp trawl landings occurred in part due to an improvement in the 1985 pink shrimp fishery.

Purse seines seem to be becoming the gear of preference for harvesting squid. At the beginning of the season one local vessel and one boat from Puget Sound used purse seines, but several local boats switched to purse seines in the middle of the season. By season's end almost half of the boats in the fishery used purse seines. Typical purse seines were 150-200 fm long by 10-15 fm deep and were set and retrieved by either a drum or power driven block. Hydraulically operated brail nets were used on most boats to transfer the product to the boat once squid were bagged. Two boats used a wet pump by placing the pump directly into the squid in the net. During the unloading process at the docks a hydraulically powered brail net was usually employed. One plant made use of a dry pump used for unloading pink shrimp.

Harvest

The amount of squid landed nearly tripled each year between 1982 and 1984, then doubled in 1985 to 1.75 million lb (Table 1). In 1985, squid were commercially harvested from April 10 through May 21. This six-week period was

Table 1. Annual harvest of *L. opalescens* off Oregon by area, 1982-1985.

Area	1982	1983	1984	1985
A			585,241	
B	N/A	N/A	361,262	1,750,441
C				
D				
Total*	113,138	297,410	946,725	1,751,773

* Includes incidental catches from other areas.

a much shorter time period than in 1984 but is similar to the fishing periods of 1982 and 1983. One area near Heceta Head (Figure 1) produced 99.9% of the total harvest. This was the same location of harvest of school 2 in 1984 (Figure 2). Incidental catches by vessels with trawl gear occurred north of Coos Bay in April and July, off Cape Blanco and Brookings in April, and off Cascade Head in May.

The 1985 harvest was characterized by a rapid removal rate as news of the discovery of the squid school spread through the industry. Catch per trip averaged 20.3 thousand lb in the first week and 24.8 thousand lb in the second week (Table 2). Harvest rates peaked in the third and fourth weeks, when over 1 million lb were landed and catch per trip averaged 28.6 thousand lb. Almost one third of the total harvest was landed during the fourth week. Cumulative landings through the fourth week accounted for 80% of total landings.

Harvest rates slowed after the fourth week when processors enacted trip limits after the product grade increased from 8 to 9-10 squid per lb (Figure 3). Typical trip limits were 10-20,000 lb for food grade and 3-5,000 lb for bait grade squid. By the end of the season, 16 vessels made 65 landings, averaging 27.0 thousand lb per landing.

In 1984 the harvest by the three major gear types was fairly equal. In 1985 the arrival of seiners from Washington and the switch of some local boats to purse seines enabled vessels with purse seines to harvest 66% of the total pounds landed. Lampara nets and shrimp trawls harvested 16% and 19%, respectively.

Ex-vessel price followed the same trend as last year. An initial high price of approximately $500-600 per ton dropped to a low of $200-300 per ton by the end of the season with a seasonal average of $350 per ton. As in 1984,

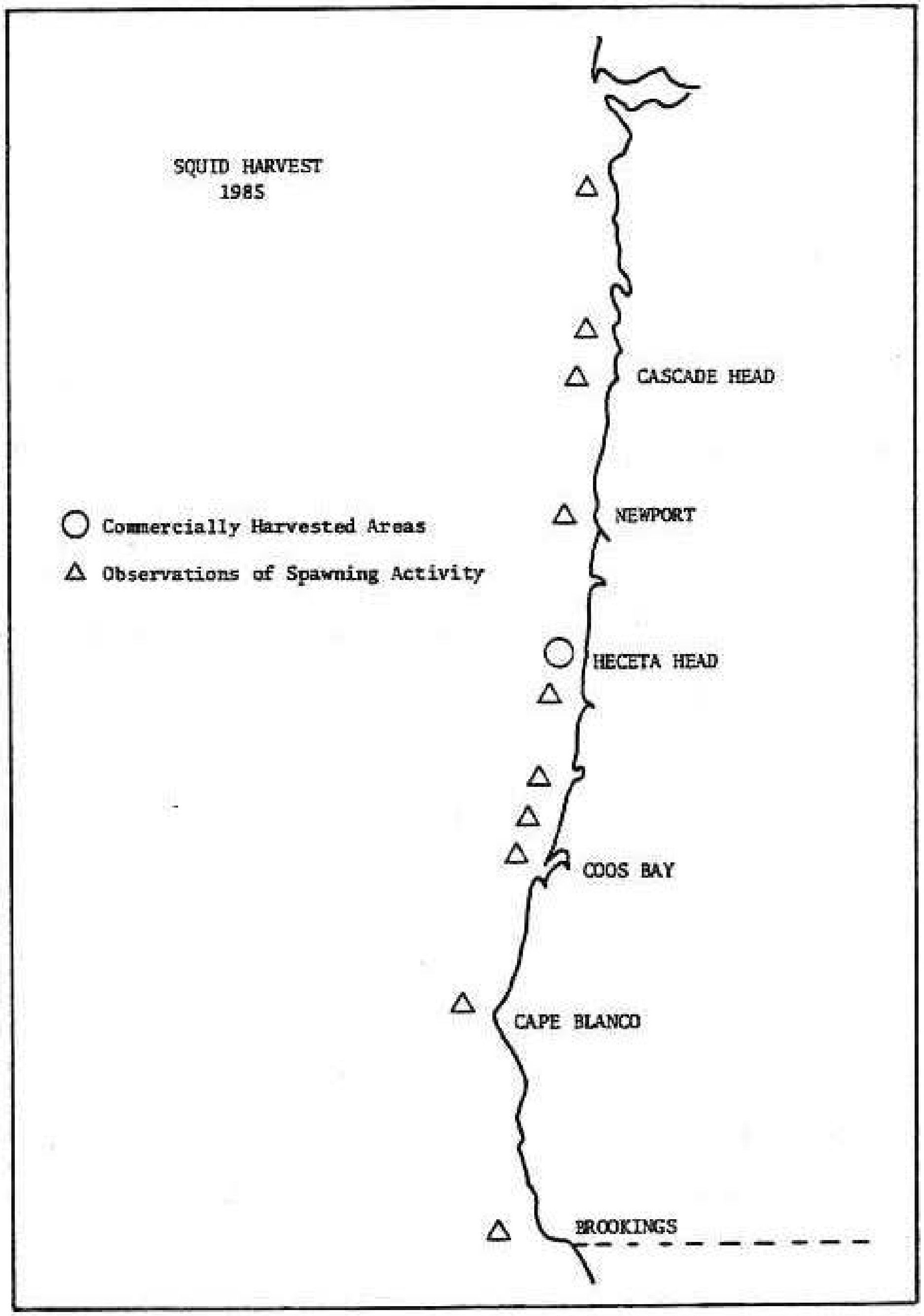

Figure 1. Locations of commercial harvest and observations of spawning activity of L. opalescens in 1985.

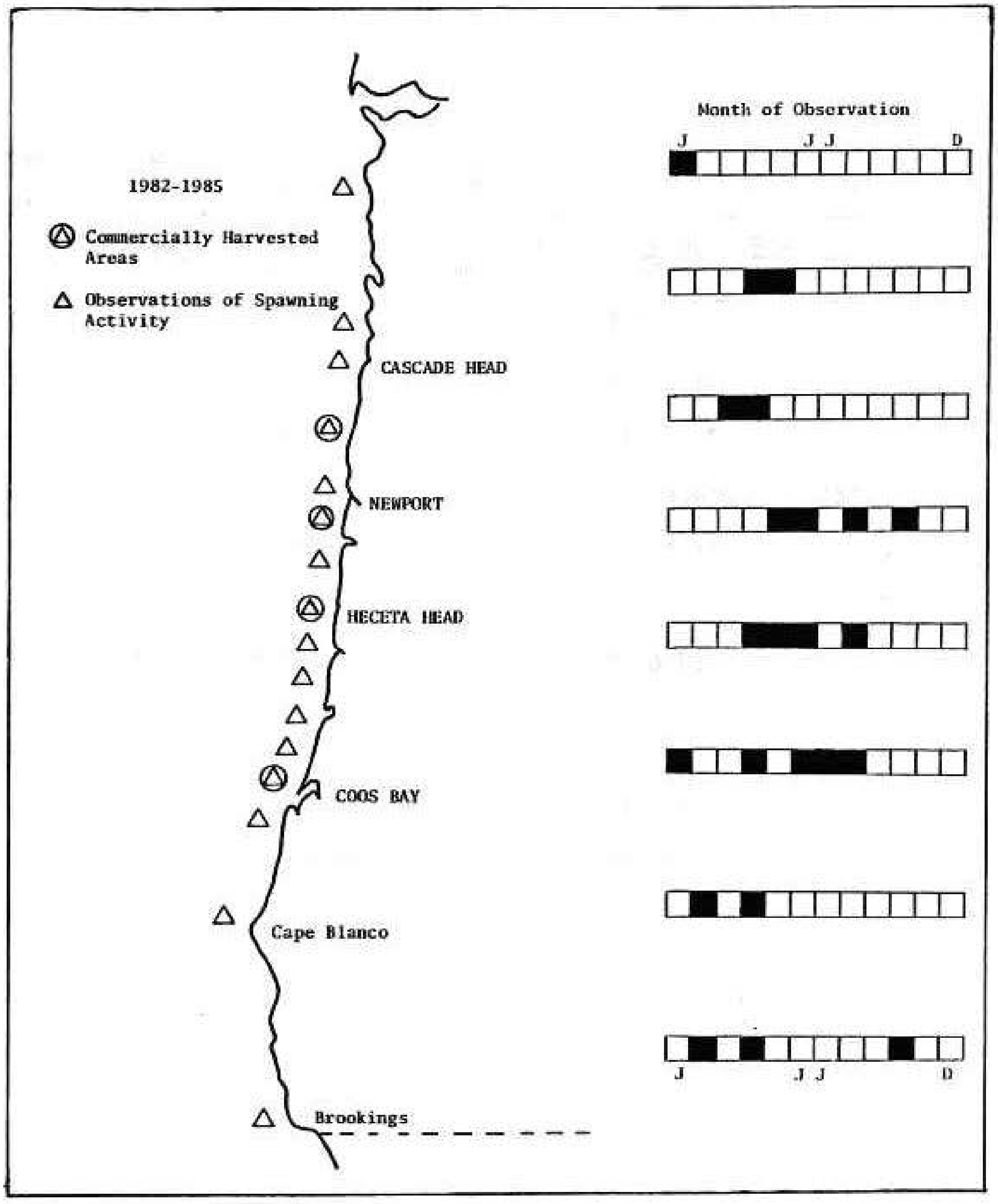

Figure 2. Locations of commercial harvest and observations of spawning activity of L. opalescens, by month, 1982-1985.

Table 2. Pounds landed (in thousands of lb), number of trips, and mean pounds per trip of L. opalescens, by week, by gear, 1985.

Week	Pounds landed (trips)			Total		
	Lampara	Purse	Trawl	Pounds	Trips	lb/trip
1	33.5 (2)	47.8 (2)	0	81.3	4	20.3
2	83.1 (5)	238.0 (5)	0.8 (3)	321.9	13	24.8
3	114.3 (4)	171.5 (7)	197.7 (5)	483.5	16	30.2
4	42.8 (2)	344.6 (12)	130.5 (5)	517.9	19	27.3
5	0	258.4 (8)	0	258.4	8	32.3
6	0	0	0	0	0	0
7	0	87.6 (4)	0	87.6	4	21.9
18	0	0	1.1 (1)	1.1	1	1.1
Total	237.7 (13)	1,148.0 (38)	330.1 (14)	1,751.8	65	27.0

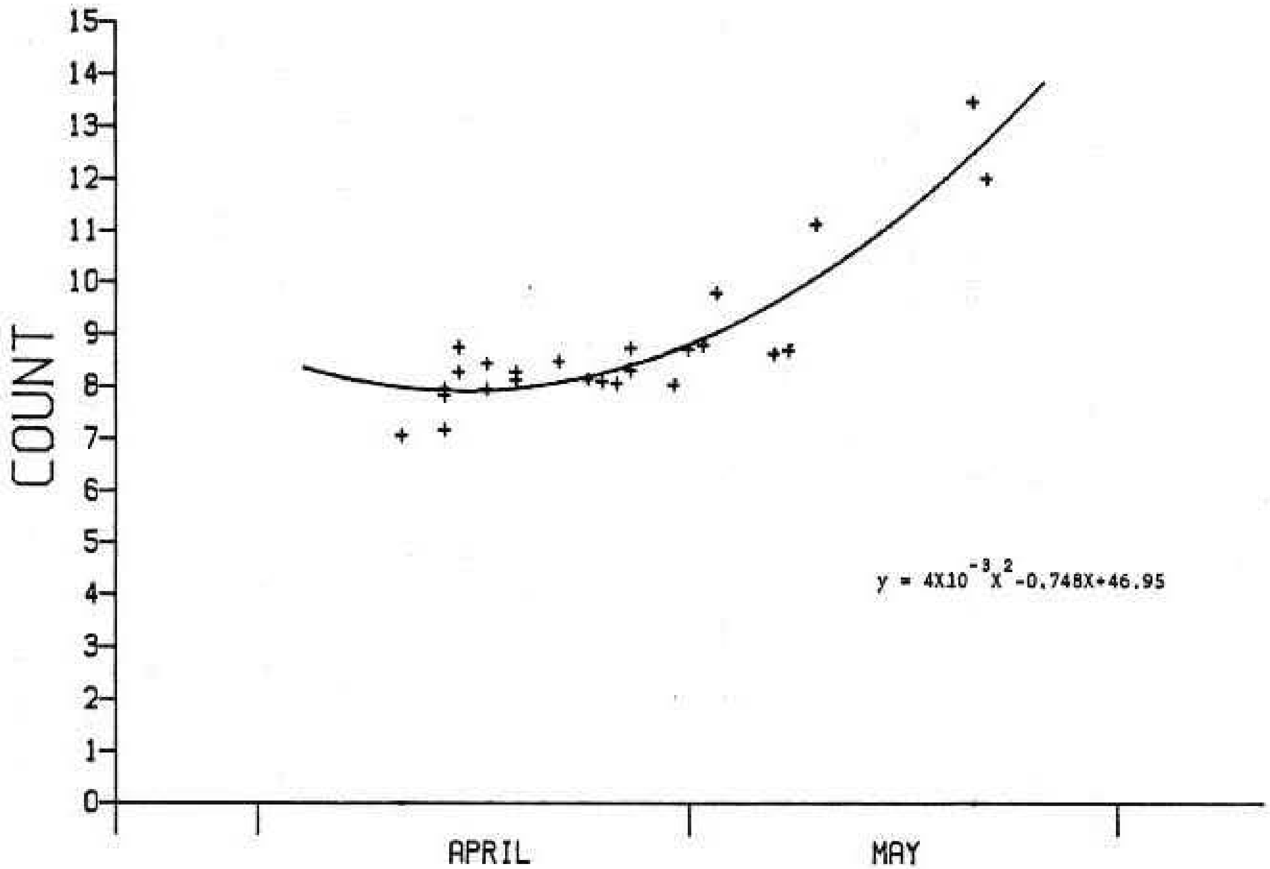

Figure 3. Average count per pound of squid landed in 1985.

prices dropped with a decrease in mantle quality. Processors were willing to buy quantities of food grade squid but were reluctant to buy bait grade squid due to high storage costs.

Observer Program

The 1985 objectives of the observer program were similar to those in 1984: to document any gear conflicts between different types of squid gear, to document any gear conflicts between the squid fishery and other fisheries, and to identify problems associated with gear impacts on squid egg capsules or incidental catch. Commercial fishery observers viewed catches of 11% of the number of landings representing 11% of the harvest by weight. All observations were made on vessels using purse seines. We were able to observe fishing activity at least once on 38% of the vessels using purse seines equaling 19% of all vessels landing squid.

As with last year, few problems arose associated with gear conflicts or incidental catch. The fewer number of trawl vessels involved in the 1985 fishery helped reduce some of the intrafishery conflicts that occurred in 1984. Also, observers noted that the number of boats in any one area at the same time was less in 1985 than in 1984. There were a couple of instances where salmon trollers, anchored at night in the area of the squid school, caused some potential conflicts for space. A potential conflict remains between squid fishermen and crab fishermen, as we witnessed squid nets being wrapped around crab pots. Few conflicts developed this year because squid fishermen usually released crab pots that were caught in their nets.

Incidental catches of other species again were small on vessels fishing on known concentrations of squid. The bycatch included a few mackerel, flatfish, skate, and crab species. One catch from a purse seine was released because of a high bycatch of smelt and anchovies. We observed the catch of one juvenile salmon, one adult salmon, and one adult steelhead. Once a seal was encircled by a purse seine but escaped the net unharmed.

Squid or squid eggs were also observed in other locations along the coast. Squid eggs were reported on crab gear south of Tillamook Head, and off Coos Bay in January, off Brookings in February, and in drag nets between Coos Bay and the Siuslaw River in July and August. Squid were observed by rockfish fishermen south of Tillamook Bay in May and off Heceta Head and Yaquina Head in late July. Tuna fishermen reported large quantities of schooling squid about 200 miles off the Columbia River but these were most likely a different species.

Squid and eggs were observed in similar times and locations as in past years (Figure 2), reinforcing our belief that squid are spawning off the coast much of the year. The lack of observations in some areas is probably due more to the fact that few people are looking for or noticing squid rather than the absence of squid.

BIOLOGICAL STUDIES

Sampling Methods

The sampling methods used in 1985 were similar to those used in the 1984 sampling season (Starr and McCrae 1984). During the commercial season we attempted to collect three samples a week from each major gear type. The samples were usually collected at the processing plant during the unloading process. A few were collected while on board vessels at sea. Samples were randomly collected from different totes on the dock or from several tows to ensure a mixed sample. Each sample contained 100-150 squid, a sample size determined to be adequate from the 1984 data.

The samples were brought to the laboratory and refrigerated until they could be processed, usually by the next day. Whole weight, dorsal mantle length (DML), mantle weight, and sex were recorded as described in our 1984 report. State of maturity was also recorded, using the criteria described in Kashiwada and Recksiek (1978). Maturity stages were based on length of the testes or nidamental gland and fullness of the spermataphoric sac or ovary. The four conditions ranged from condition 1--immature, condition 2--intermediate, condition 3--mature, and condition 4--spent squid.

We continued to have some difficulty in distinguishing between conditions 2 and 4 in the males. It was sometimes difficult to determine whether individuals contained few spermatophores because they were just beginning to form or because the animal had spawned. Also, if the sample had been frozen, it was difficult to determine 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 continued to have difficulty visually determining sex and maturity stage of small (<50 mm DML) animals.

In addition to the morphometric data, vessel name, date of landing, type of gear used, time (day or night), area, and depth of harvest were recorded. Area of harvest was recorded by Pacific Marine Fisheries Commission statistical block number. Area A refers to block 1226, Area B is block 1206, Area C is block 1143, and Area D is block 1216. Stomach samples were taken for species composition analysis by Oregon State University researchers.

Storage Test Results

Most samples were processed the same day they were collected. A few were held in a cooler for a day or two and a few were frozen when processing could not take place immediately. In addition, samples collected at other ports were frozen and processed at a later time. We conducted storage tests on five samples to determine if whole weight measurements were biased due to prolonged storage or freezing, and to provide information to processors concerning changes in their products due to storage.

Six samples of 150-225 squid were each divided into three groups and individual squid were weighed immediately. Five samples were then stored for various lengths of time and weighed again at a later date. One sample was measured for the second time immediately after the first measurements as a control to test for any differences due to handling.

Three samples were placed in the cooler, one each for 24 h, 48 h, and 72 h. One sample was frozen for one month, and an additional sample was frozen for two months. Students "t" tests were conducted on the changes of average whole weights. None of the changes in average whole weights in the cooler and control samples were significant at the 95% level (Table 3). The amount of change that did occur was similar between the control and cooler samples; we believe the changes in the cooler sub-sample weights were due to loss of moisture because of handling. The average weight loss for the three cooler samples was 2.6% and for the control sample was 2.8%

Samples stored in the freezer did lose significant amounts of weight relative to the control sample. The average loss in mean whole weight of the two samples stored in the freezer was 9.3%. In the one month sample, two of the three sub-samples lost weight that was significant at the 95% level, and the third sub-sample had a significant weight loss at the 90% level. In the two-

Table 3. Mean whole weight (gm) and mean loss of whole weight (%) by storage method, 1985.

Storage method		First weighing replicate 1	First weighing replicate 2	First weighing replicate 3	Second weighing replicate 1	Second weighing replicate 2	Second weighing replicate 3	Average loss
Control	n	50	50	50	50	50	50	
	ave	50.6	53.0	47.8	49.0	51.4	46.6	
	% loss	3.0	3.0	2.4				2.8
Cooler 24 hr	n	75	75	75	75	75	75	
	ave	54.2	51.4	53.2	52.3	50.3	52.3	
	% loss	3.6	2.0	1.9				2.5
Cooler 48 hr	n	70	70	70	70	70	70	
	ave	47.2	44.6	47.4	45.8	43.2	45.7	
	% loss	2.9	3.3	3.6				3.3
Cooler 72 hr	n	60	60	60	60	60	60	
	ave	55.4	54.7	53.0	53.2	54.4	52.0	
	% loss	3.9	0.6	1.9				2.1
Freezer 1 month	n	60	60	55	60	60	54	
	ave	61.8	62.3	63.3	55.6	55.1	56.8	
	% loss	10.0	11.6	10.2				10.6
Freezer 2 months	n	70	70	70	70	70	70	
	ave	50.9	53.8	56.5	46.3	49.6	52.7	
	% loss	9.0	7.8	6.8				7.9

month freezer sample, one sub-sample displayed a significant loss in mean whole weight at the 95% level and the other two sub-samples showed a significant loss at the 90% level.

Data from samples collected at the same time as the freezer samples indicated that the two-month freezer sample contained a higher percentage of spawned individuals than the one-month freezer sample. Giese (1979) stated there are differences in biochemical levels of body components between gravid and spent squid. This may account for some of the difference in the average loss of weight between the two freezer samples (10.6% for the one-month sample and 7.9% for the two-month sample).

There does not appear to be any change in the whole weight of squid due to storage in a cooler for a short period of time. Thus there is no bias in our estimates of whole weight. There is a loss of weight due to freezing. This is contrary to the findings of Evans (1976) who found no significant difference between weights of fresh and frozen samples. The loss in weight we measured in the freezer samples is probably a little greater than the loss processors would notice because they often soak the product before freezing. Next year we plan to redesign the tests to account for processor methods of storage and to reduce the handling factor.

Fecundity Estimates

Female fecundity is an especially important parameter used to help model population reproductive potential. Modeling the stock dynamics of Oregon squid would be simpler if the fecundity of L. opalescens here and in California were similar; estimates could be used that are already well described and documented. We designed an initial sampling project to ascertain if Oregon and California squid are indeed similar.

Egg counts came from capsules that were laid in an aquarium and capsules that were caught in the nets of commercial purse seines during harvest. Live squid were captured on May 21, 1985 and reared in the Oregon State University Hatfield Marine Science Center circular display tank for two weeks. The squid were fed crangonid shrimp and small fish; they displayed the courting and mating behavior described by Hurley (1977) and Fields (1965). Males darted toward and away from the females until the females were receptive. The male then grasped the female at the anterior portion of the mantle cavity. The male removed spermatophoric sacs with his left ventral arm and placed them in the female's mantle cavity. This activity continued for several days before spawning. The females spawned the night before a full moon and died within a few days after spawning. Egg capsules were stored in aquaria for two to three weeks before the eggs were counted.

Egg capsules were measured from the posterior end of the egg capsule to the anterior end of the first egg. The attached filament of the egg was not measured. After measuring the length of the egg capsule we cut the capsules longitudinally, gently spread the capsule membrane apart and removed the eggs. Only eyed embryos were counted to avoid double counting eggs that happened to split into several pieces in the process.

The seven females that spawned in the aquarium produced a total of 184 egg capsules, for an average of 23 egg capsules per female. This average falls into the range of values presented by Fields (1965). The average number of eggs per capsule falls well below those values reported by Fields (1965), however. We counted an average of 106 $\pm$ 4 (95% CI) eggs in the capsules of squid that spawned in the aquarium, or one-fourth to one-half the value reported by Fields.

The number of eggs per capsule counted from field collections was similarly much lower than the average reported in the literature. Four separate samples of a total of 700 egg capsules yielded an average of 98 ± 2 (95% CI) eggs per capsule (Table 4). Interestingly, the average number of eggs per capsule collected from the field was lower than the average obtained from capsules laid in the laboratory; Hixon (1983) predicted the opposite would occur. Another interesting aspect of these data is that the number of eggs per capsule increased over the three weeks that encompass the data collection.

Morphometric Results

This year, we sampled more than 3,600 squid, primarily from one spawning school. Squid from the main school were harvested from water less than 20 fm deep. A couple of the incidental samples were from deeper water tows.

Sex ratio varied from sample to sample (Figure 4) as it did in 1984, with an overall ratio of 54:46, males to females. The sex ratio in 1984 was 57:43 (Table 5).

The average dorsal mantle length of all animals collected in 1985 was 128.4 ± 0.5 mm (95% CI); mantle length ranged from 66-170 mm. Average lengths of male and female squid were 128.5 ± 0.8 mm and 128.5 ± 1.3 mm, respectively. The smallest male squid we measured in spawning condition (condition 3) had a DML of 85 mm. The smallest condition 3 female squid measured 101 mm in mantle length. The smallest spawned (condition 4) animals for males and females had mantle lengths of 87 mm and 96 mm, respectively. These values are still in the range presented by Fields (1965) for California squid and were larger than

Table 4. Mean length and number of eggs per squid egg capsule by sample, 1985.

Sample		Field Samples 1	2	3	4	Total	Aquarium Sample	Overall Total
Date		4-25-85	4-26-85	5-2-85	5-16-85		6-2-85	
Capsule length	Ave.	52.9	77.3	80.8	81.2	75.0	90.6	78.8
	N	94	171	139	141	545	173	718
	95% C.I.	2.2	1.2	3.0	2.5	1.5	2.5	1.4
Number of eggs	Ave.	91.8	92.1	102.5	108.4	97.7	106.2	99.4
	N	200	200	150	150	700	177	877
	95% C.I.	4.0	2.6	5.7	4.6	2.1	3.6	1.9

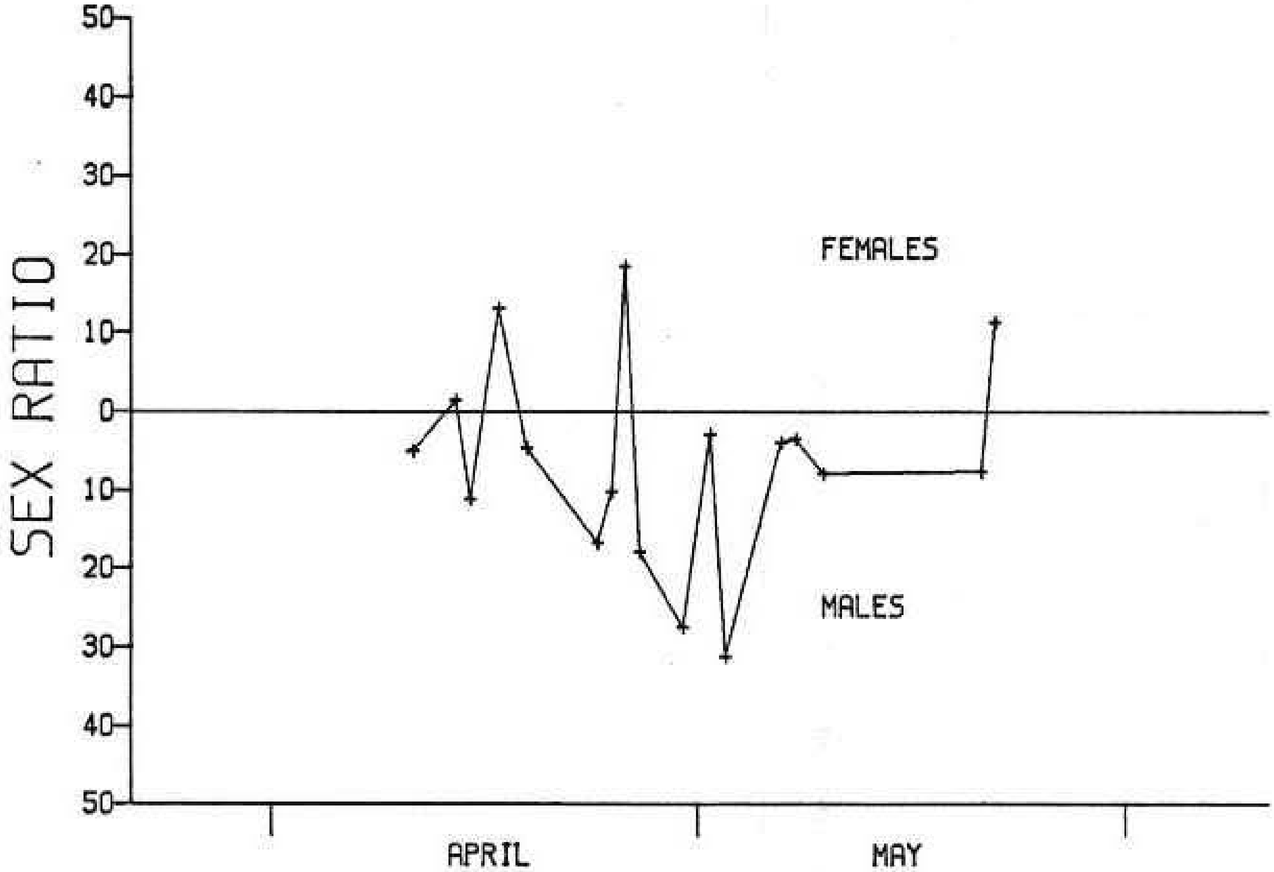

Figure 4. Sex ratio (%) of L. opalescens sampled in 1985 (standardized to purse seine gear only).

Table 5. Total sex ratio (%) of L. opalescens by year, by area, 1983-1985 (N).

	1983		1984		1985		Total	
	M	F	M	F	M	F	M	F
Area A	-	-	57	43(1801)	-	-	57	43(1801)
Area B	-	-	59	41(3894)	56	44(3214)	58	42(7108)
Area C	-	-	51	49 (552)	9	91 (106)	45	55 (658)
Area D	73	27(589)	-	-	-	-	73	27 (589)
TOTAL*	71	29(1290	57	43(6643)	54	46(3652)	58	42(11585)

* Includes incidental catches from other areas.

the minimum sizes encountered in 1984. The average length of squid from the main spawning area was slightly larger than the overall average because many of the incidental samples contained very small squid (Table 6). The average DML of squid from the main spawning area was 130.2 $\pm$ 0.5 mm (95% CI), with a range of 67-170 mm. The average lengths for males and females were 129 $\pm$ 0.7 mm and 130.5 $\pm$ 0.5 mm, respectively.

In 1985 squid mantle lengths were distributed around a frequency mode of 135 mm (Figure 5). The mode was at a greater length interval than samples collected in the past (a mode of 115 mm in 1984 and 120 mm for all years combined). As would be expected with larger mantle lengths, in 1985 mean whole weights and mantle weights were heavier than 1984. The overall average whole weight and mantle weight was 50.6 $\pm$ 0.6 gm (95% CI) and 24.6 $\pm$ 0.3 gm, respectively (Table 6) as compared to the 1984 average whole weight of 29.9 $\pm$ 0.3 gm and average mantle weight of 13.9 $\pm$ 0.1 gm. Average mantle length, whole weight, mantle weight, and ratio of mantle weight to length followed the same general decrease over the season as in 1984 (Figures 6-9).

Following the same pattern as last year, mean lengths and weights increased between conditions 1-3 then dropped in condition 4 (spawned animals) (Figures 10 and 11). The ratio of mantle weight to length in 1984 and 1985 increased for the first three conditions then dropped for condition 4 (Figure 12). The difference in the average ratio of mantle weight to length between condition 3 and condition 4 was significant at the 95% level.

DISCUSSION

The location and timing of commercial harvest of squid in 1985 was again largely influenced by variables other than squid distribution and abundance.

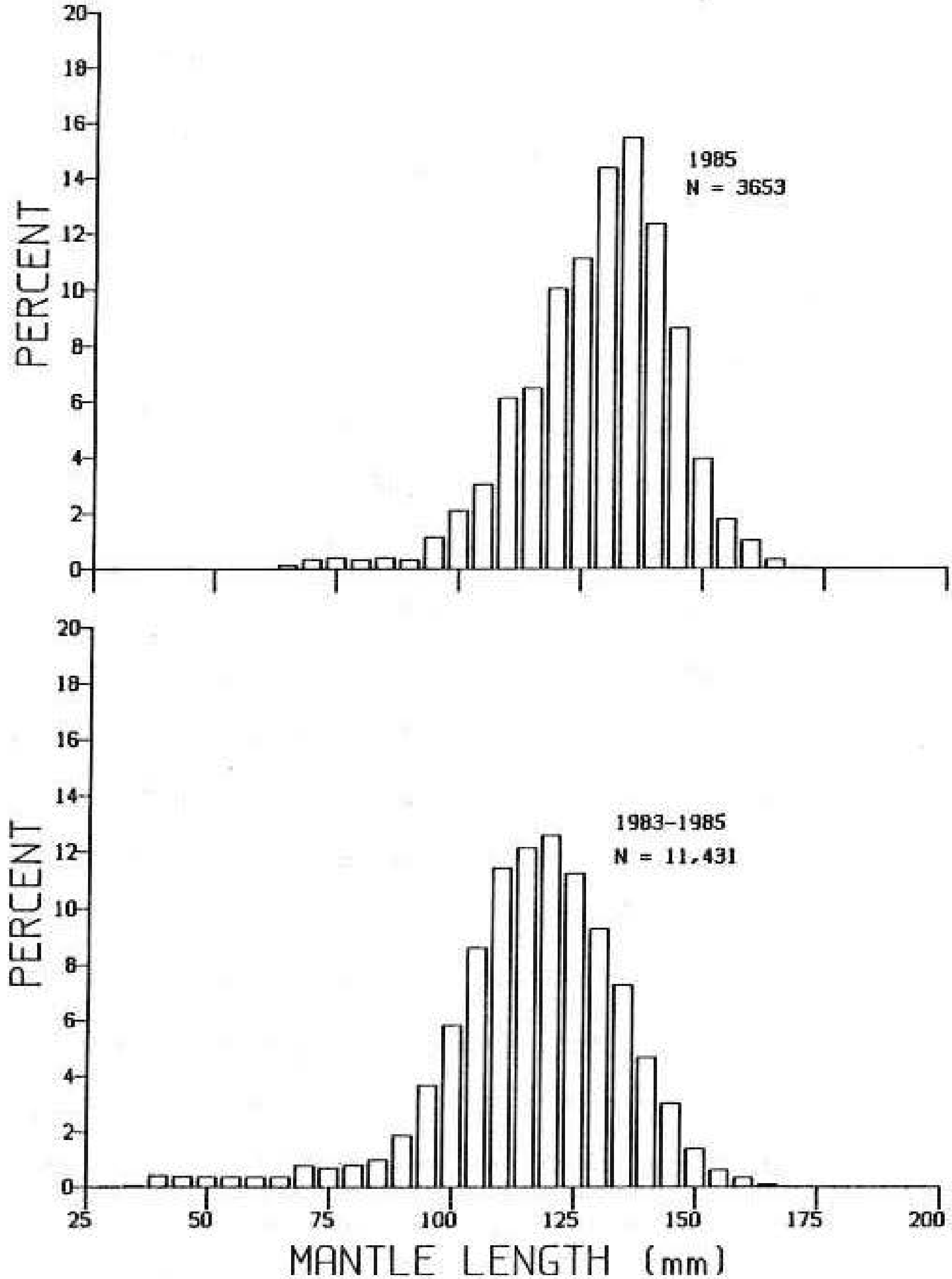

Figure 5. Length frequency (%) of all L. opalescens sampled in 1985 and 1983-1985.

Table 6. Mean dorsal mantle length (mm ± 96% CI), whole weight and mantle weight (gm ± 95% CI) of *L. opalescens*, by area, through time, 1985 (N).

Area B				Other Areas			
Date	Length	Whole Weight	Mantle Weight	Date	Length	Whole Weight	Mantle Weight
4-10	132.4 ± 2.5 (71)	64.4 ± 3.6 (70)	31.1 ± 2.0 (71)	2-19	124.6 ± 4.2 (5)	45.8 + 6.7 (5)	26.8 ± 2.8 (5)
4-13	135.2 ± 3.6 (35)	63.3 ± 4.5 (35)	32.3 ± 2.8 (35)	4-26	133.0 ± 2.1 (117)	67.0 ± 3.1 (112)	31.1 ± 1.6 (117)
4-13	133.5 ± 1.7 (146)	58.1 ± 1.9 (146)	29.7 ± 1.1 (146)	4-15	133.3 ± 4.5 (17)	41.9 ± 5.1 (15)	20.6 ± 2.5 (17)
4-13	133.0 ± 1.6 (193)	57.1 ± 1.8 (192)	28.8 ± 1.1 (193)	5-2	107.7 ± 2.4 (114)	31.8 ± 2.2 (114)	16.2 ± 1.2 (114)
4-14	133.4 ± 1.9 (144)	54.9 ± 2.3 (144)	27.5 ± 1.3 (144)	4-16	115.8 ± 6.8 (20)	32.1 ± 5.3 (20)	18.4 ± 2.8 (20)
4-14	133.2 ± 2.6 (99)	51.9 ± 2.8 (97)	26.0 ± 1.5 (99)	4-18	79.7 ± 2.8 (59)	11.8 ± 1.3 (59)	6.8 ± 0.8 (59)
4-16	133.7 ± 1.9 (122)	53.9 ± 2.1 (122)	25.4 ± 1.1 (122)	7-6	123.1 ± 1.8 (106)	30.3 ± 1.5 (106)	15.2 ± 0.8 (105)
4-16	134.1 ± 2.0 (111)	57.2 ± 2.2 (111)	28.5 ± 1.2 (111)				
4-18	132.0 ± 2.0 (143)	56.0 ± 2.3 (143)	26.9 ± 1.2 (143)				
4-18	132.2 ± 1.9 (141)	55.0 ± 2.5 (141)	27.1 ± 1.3 (141)				
4-21	129.9 ± 2.2 (84)	53.6 ± 2.6 (84)	26.0 ± 1.5 (84)				
4-23	124.7 ± 3.2 (96)	55.9 ± 3.7 (96)	26.7 ± 1.9 (96)				
4-24	133.1 ± 1.7 (163)	56.1 ± 2.0 (163)	26.8 ± 1.1 (163)				
4-25	134.6 ± 1.9 (124)	56.4 ± 2.5 (124)	26.8 ± 1.3 (124)				
4-26	128.0 ± 2.4 (115)	54.7 ± 2.5 (106)	26.5 ± 1.4 (115)				
4-26	124.2 ± 2.2 (124)	52.0 ± 2.4 (124)	24.5 ± 1.2 (124)				
4-29	131.4 ± 2.2 (160)	56.7 ± 2.8 (153)	28.1 ± 1.4 (160)				
4-30	130.6 ± 2.4 (139)	52.2 ± 2.6 (139)	24.2 ± 1.2 (139)				
5-1	131.3 ± 2.4 (138)	51.7 ± 2.6 (138)	23.3 ± 1.2 (138)				
5-2	125.8 ± 2.6 (133)	46.4 ± 2.8 (125)	23.0 ± 1.4 (133)				
5-6	129.4 ± 2.3 (154)	52.7 ± 2.9 (148)	25.8 ± 1.6 (154)				
5-7	132.2 ± 2.8 (117)	52.3 ± 3.2 (118)	25.5 ± 1.7 (118)				
5-9	122.2 ± 2.2 (152)	40.9 ± 2.1 (152)	20.0 ± 1.1 (152)				
5-20	123.9 ± 2.1 (184)	33.8 ± 1.8 (184)	15.9 ± 0.9 (184)				
5-21	124.7 ± 2.6 (127)	37.9 ± 2.5 (127)	18.0 ± 1.2 (127)				
Average	130.2 ± 0.5 (3215)	52.2 ± 0.6 (3182)	25.4 ± 0.3 (3316)		116.0 ± 1.9 (438)	38.4 ± 2.1 (431)	19.1 ± 1.0 (437)

Overall average:		
	Length	128.4 ± 0.5 (3653)
	Whole Weight	50.6 ± 0.6 (3613)
	Mantle Weight	24.6 ± 0.3 (3653)

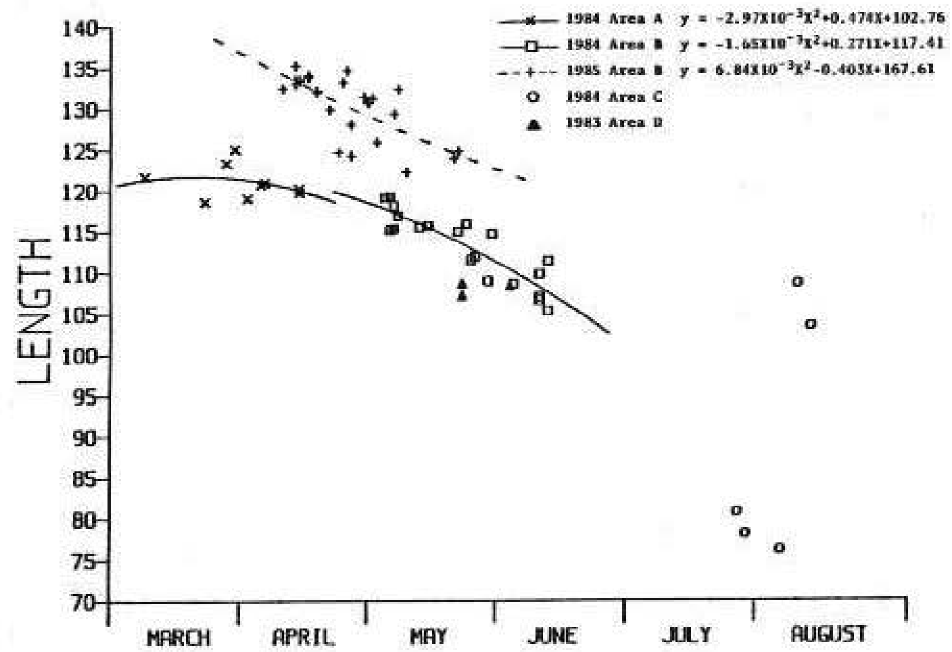

Figure 6. Average dorsal mantle length (mm) of squid sampled from each school, by year, 1983-1985.

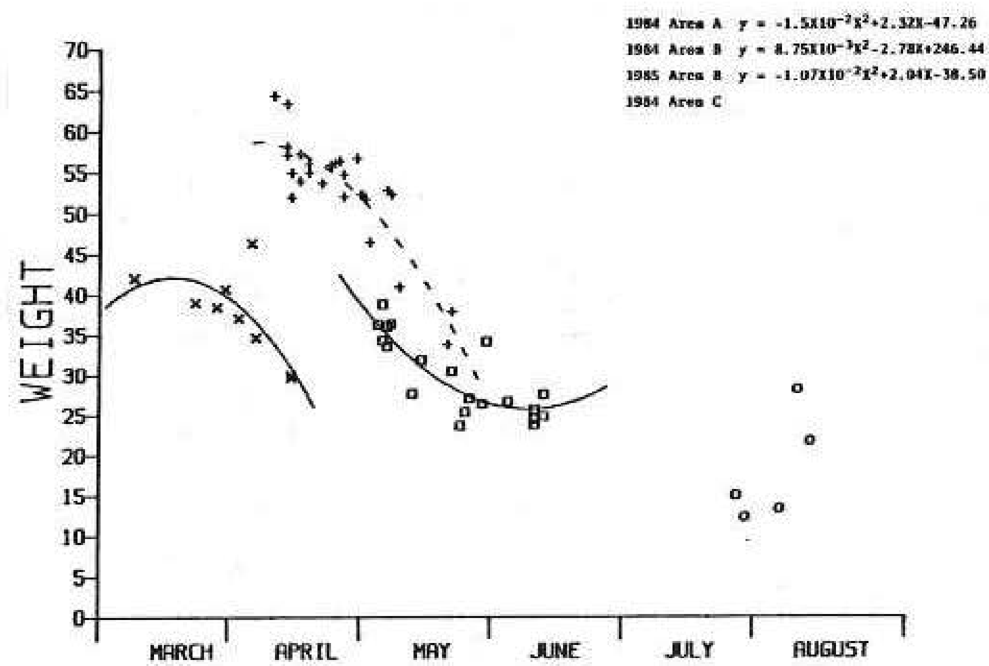

Figure 7. Average whole weight (gm) of squid sampled from each school, by year, 1984-1985.

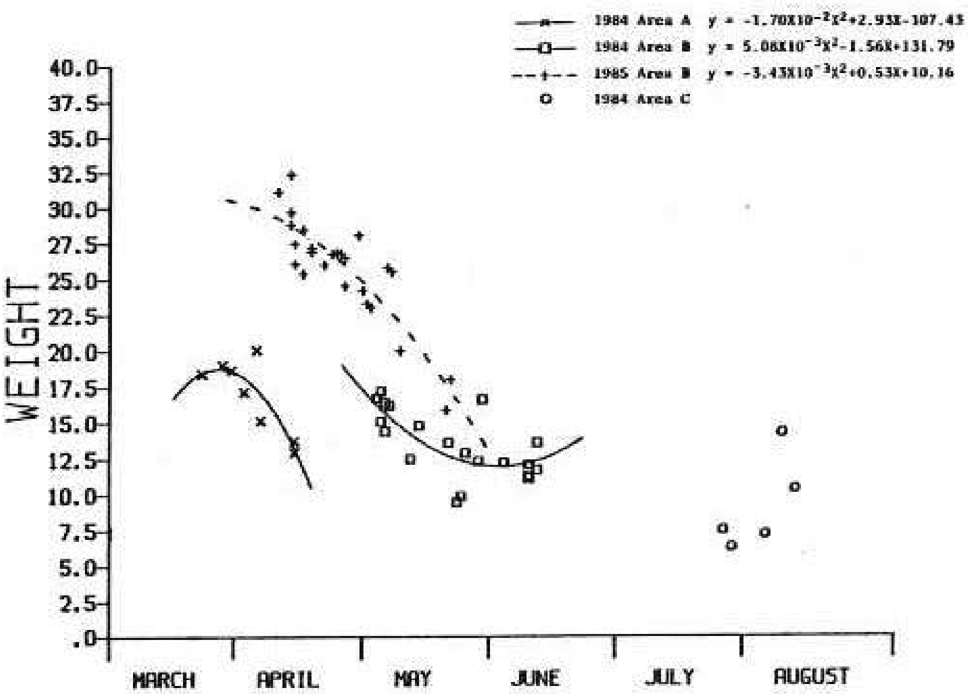

Figure 8. Average mantle weight (gm) of squid sampled from each school, by year, 1984-1985.

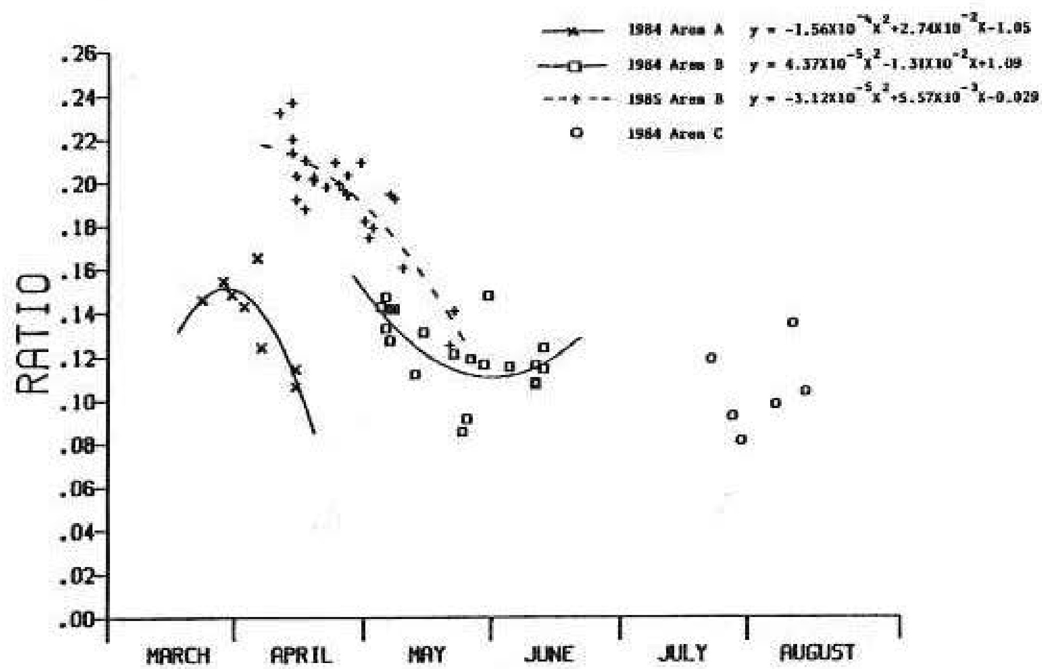

Figure 9. Average ratio of mantle weight to dorsal mantle length of squid sampled from each school, by year, 1984-1985.

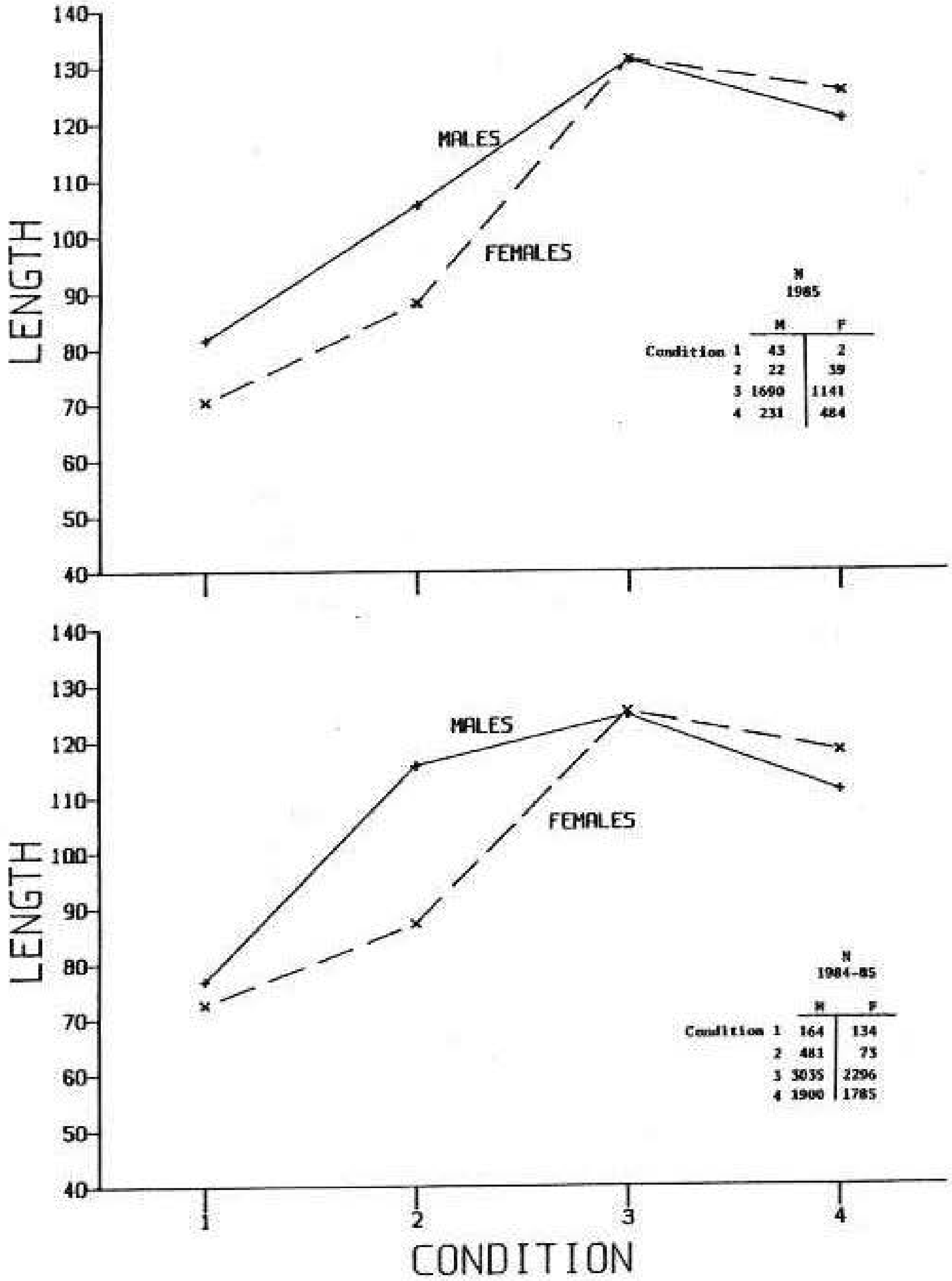

Figure 10. Average dorsal mantle length (mm), by maturity condition and sex, for all squid sampled from the commercial fisheries, 1985 and 1984-1985.

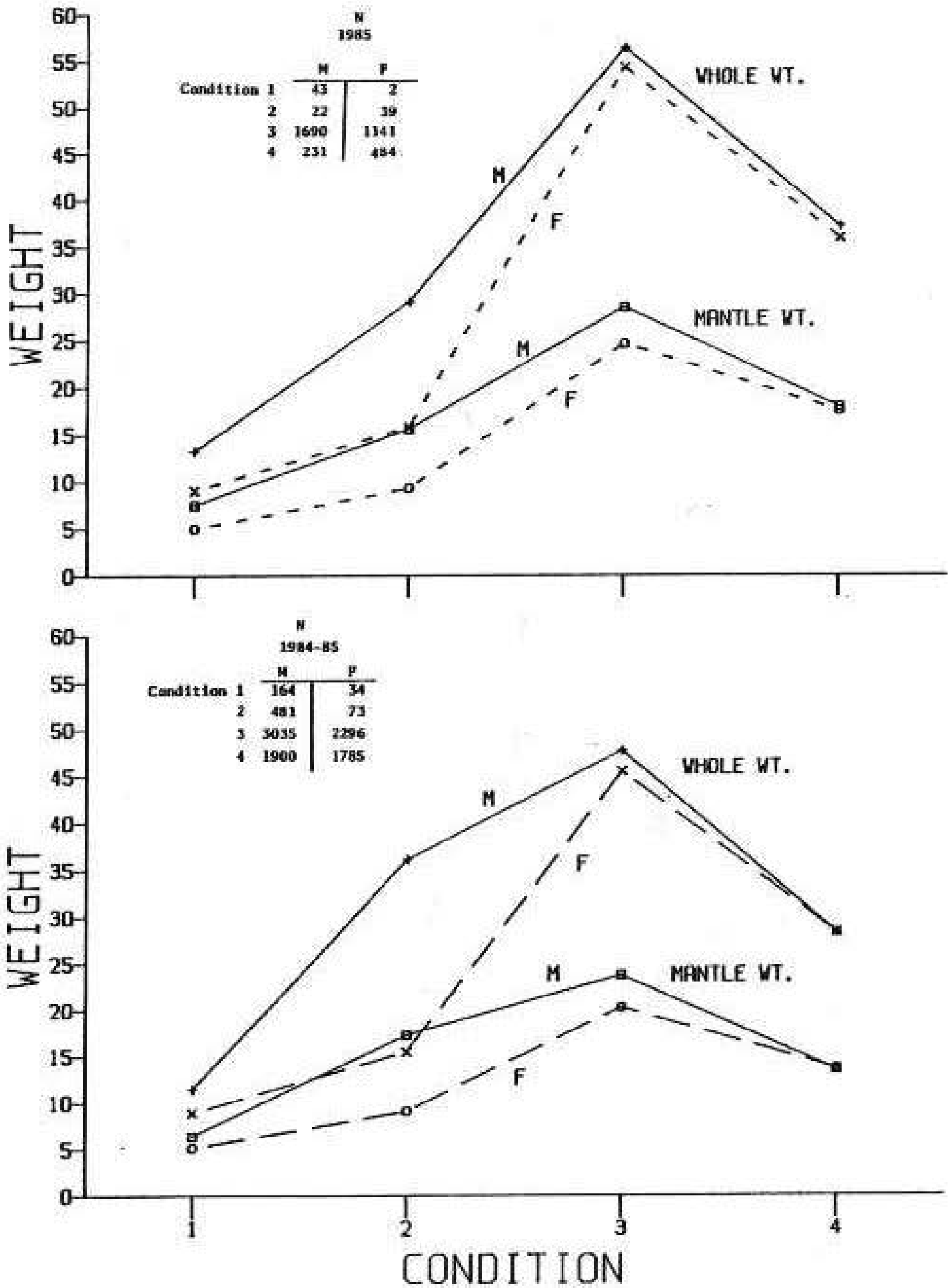

Figure 11. Average whole weight (gm) and mantle weight (gm), by maturity condition and sex, for all squid sampled from the commercial fisheries, 1985 and 1984-1985.

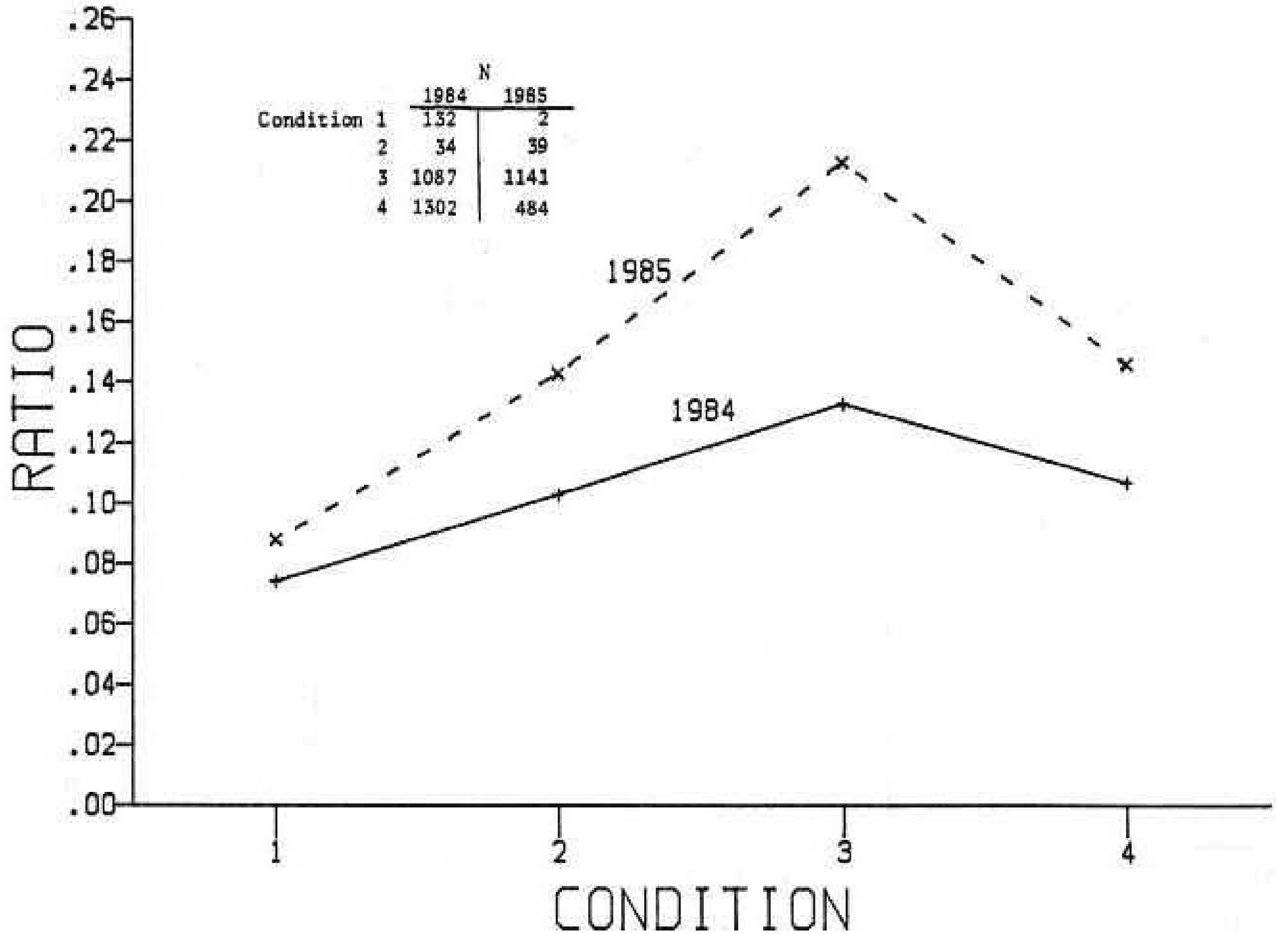

Figure 12. Average ratio of mantle weight to dorsal mantle length by maturity condition and year, for all L. opalescens from commercial fisheries, 1984-1985.

Spawning squid were present along portions of the coast several months after harvest ceased. There was no fishery for squid in the summer, principally because there was no interest in the product at that time. Quite possibly fishermen and processors felt, based on the 1984 experience, that the summer squid were smaller. We have no data to substantiate that presumption, however.

Most of the searching effort occurred near Newport, although one vessel routinely searched near Charleston and one searched near Eureka, CA. Effort was somewhat lower than expected because the 1985 shrimp season was better than 1984. Although effort was lower, participants demonstrated a greater ability to catch squid. Given adequate markets, we expect effort will increase if the catch and catch-per-trip continues to increase.

The total harvest of squid in 1985 was limited more by processor requirements and limitations than by the fleet's fishing capability. Processors primarily wanted to purchase food grade squid, and were particular about the size of the squid purchased. Squid harvested this year were larger than 1984 but processors still did not want to purchase squid that had spawned. A big concern for processors was the size and character of the foreign market this year. The U.S. dollar was strong abroad and foreign distributors would only buy Oregon squid at an adjusted competetive price. Local processors did not know if they would be able to sell a high enough quality product at a profitable price, and they did not want to be stuck with large quantities of squid.

The potential overharvest of a specific school of squid concerned us this year, and the OFWC imposed a 1 million lb harvest guideline for each school to prevent overharvest. As landings from the first school approached the 1 million lb level, we addressed the question of whether to impose a temporary fishing closure on the school. A combination of visual and hydroacoustic observations, and analysis of biological paramaters lead to the determination that the school was of sufficient quantity to allow further harvest. Results of our acoustic biomass assessment project indicate that the area off Heceta Head contained between 4.6 and 8.2 million lb (Starr 1985). Thus, the 1.75 million pounds harvested in 1985 represented a removal of 20-40% of the school.

Biological analyses are conducted primarily for stock delineation purposes. We hope at some later date to be able to differentiate schools or stocks of squid from different areas at different times based on macro-morphometric parameters. The data already suggest some interesting patterns, however, and it is becoming apparent that Oregon squid do not exhibit the same biological characteristics as California squid.

The sex ratio of the Oregon catch in the last three years has been significantly different than the 1:1 ratio reported by Fields (1965) and Kato and Hardwick (1975). However, Fields (1965) apparently lumped several years of data and did find large imbalances in the sex ratio of particular schools, with either males or females predominating. Also Evans (1976) reports finding a sex ratio of approximately 1.3:1 males per female in Monterey in 1974. Sexual dimorphism is apparent, but the sexes do not have the same morphometry as in California. In fact, although lighter than males, females in each of the past three years have exhibited longer average dorsal mantle lengths than males.

Temporal differences exist between California and Oregon. The range in time of spawning is similar to the season in Monterey, but so far the date of peak spawning activity has been earlier in Oregon. In our samples, average whole weight, mantle weight, and dorsal mantle length decreased with time (Figures 6-7), just the opposite of the trend reported for California squid (Fields 1965). The gradual decline is due to slightly smaller squid spawning at later times, and not due to changes in spawning condition or an influx of immature squid.

The apparent difference between fecundity of Oregon and California squid was totally unexpected. Few fecundity estimates have been reported for L. opalescens, but several reports have suggested that Fields' (1965) estimates are appropriate (Evans 1976, Hixon 1983, Recksiek and Frey 1978). Assuming that the sampling techniques of the California researchers were unbiased and equivalent to our techniques, there are three possible explanations for the discrepancy between our fecundity estimates and those presented by Fields (1965). First, it is possible that the egg capsules we collected were prematurely spawned on the webbing of the purse seine and thus may be biased estimates. There is some reason to suspect that this was the case in at least the early samples as they contained the lowest egg counts. The later samples were definitely from eggs that had been dredged off the bottom, however, and they still had significantly fewer eggs than reported for Monterey squid.

A second possibility is that fecundity of L. opalescens has changed over the years since Fields conducted his work, or that fecundity was lower in 1985 due to a remnant effect of the recent El Nino conditons. Most other species seem to have recovered from the effects of El Nino, and we find it difficult to believe that squid fecundity has changed that dramatically.

The third possiblity is that Oregon L. opalescens indeed do have a fecundity that is 25-50% less than California squid. If our data are reliable and L. opalescens in Oregon do have a lower fecundity, the results hold tremendous implications with respect to the harvest strategy of L. opalescens that spawn off Oregon. The lower reproductive capability implies that Oregon stocks do not have the same capacity to sustain high harvest rates that Monterey stocks have.

One aspect of squid biology that is similar to California is the low incidence of feeding by L. opalescens on the spawning grounds. In most samples few squid contained full stomachs. The percentage of squid with full stomachs was a little higher than in 1984, but still less than 10%. An interesting anomaly occurred both in 1984 and 1985. In both years we obtained one sample of partially spawned squid from depths of 100 m. In each sample almost 100% of the individuals had full stomachs.

In 1984 we noticed a pattern in the progression of spawning in a school. The sex composition of the samples changed from predominately females in the early stages to predominately males as females spawned then died. The percentage of spawned females in the samples smoothly progressed from 0-100% in about 12-15 days. With the increase in percentage of spawned females came a corresponding decrease in the weight to length ratio of females (Starr and McCrae 1984). Using the percentage of spawned females and the average weight to length ratios we were able to demonstrate the influx of three separate groups of spawning squid into an area.

In 1985 we again observed evidence of several groups of squid entering the harvest area at different times. The sex composition changed with time; the samples contained primarily males towards the end of the season. This may be what McGowan (1954) was seeing when he sampled dead and dying squid during a period of spawning activity (which suggests he sampled toward the end of the spawning period) and found 63% males. The percentage of spawned females fluctuated early then gradually increased with time. Just before the samples contained 100% spawned females, the spawning curve quickly declined and began another increase (Figure 13b). The shape of the curve can be explained by an initial small group of squid moving into the area to spawn followed shortly by a much larger influx of a new group of squid. Just prior to the completion of spawning of the first two groups a third group moved into the area to spawn. This scenario is graphically presented in Figure 13a.

To strengthen the hypothesis that three groups moved into the area to spawn, we graphed the frequency histogram of the weight to length ratios (Figure 14), and plotted the average weight to length ratios of female squid in each sample (Figure 15). Only samples collected with purse seines were plotted to avoid bias introduced by the use of different gear types.

In 1984 we determined that spawned squid have significantly smaller weight to length ratios than unspawned squid (Starr and McCrae 1984). This relationship is true for all squid larger than 95 mm. As the percentage of spawned squid in the population increases, the weight to length ratio decreases. Thus, an increase in the mean weight to length ratio of a sample indicates that squid in an earlier spawning stage have moved into the area.

The weight to length relationships of females only are used because Fields (1965) reported that, for larger squid, males have a greater weight to length ratio than females. Using the average weight to length ratios of all animals to explain differences in the percentage of spawned females in a sample would thus bias the data. It would be possible to attribute an increase in the mean weight to length ratio to a change in spawning condition when it was really due to a change in the sample sex ratio.

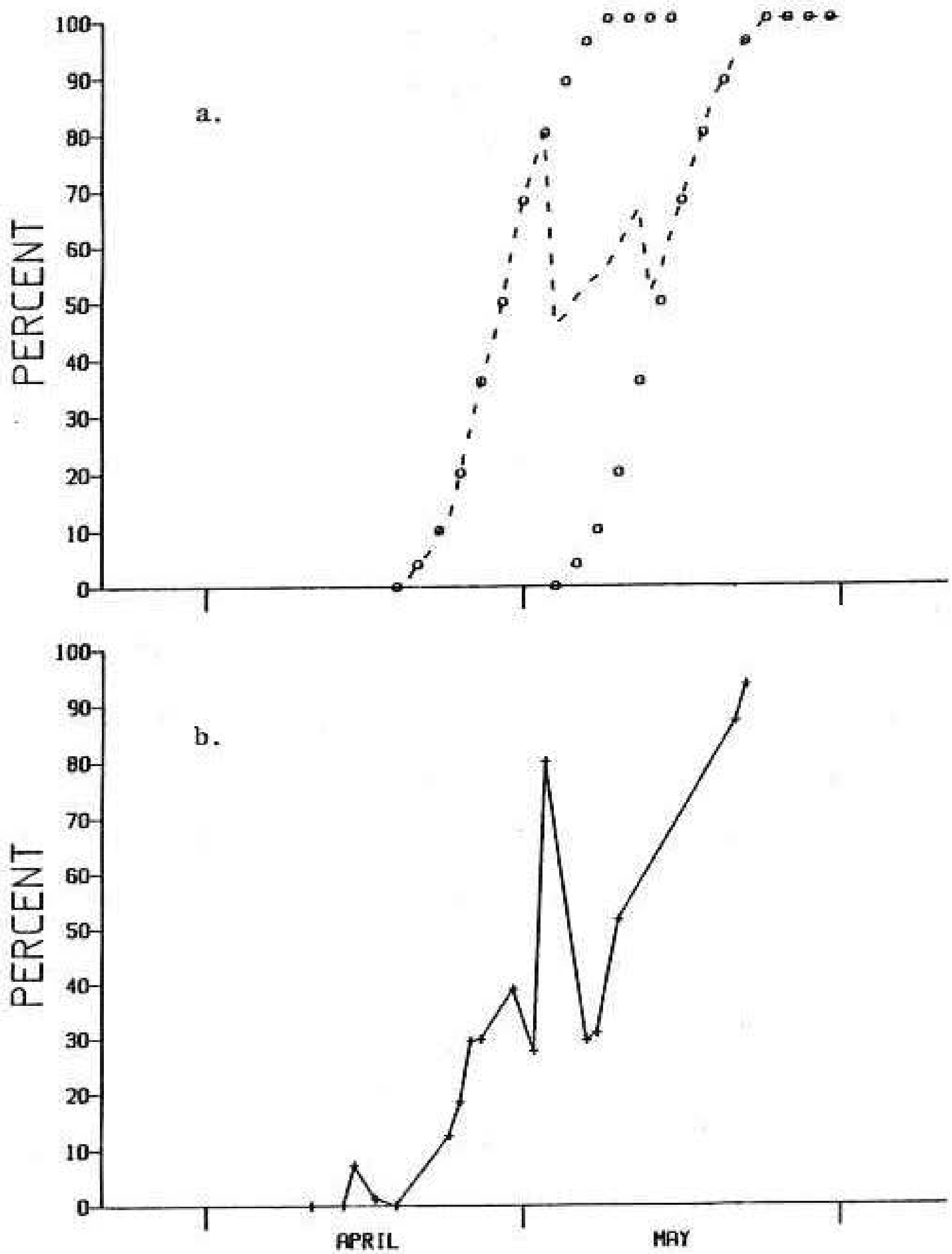

Figure 13. a. Hypothetical curve of percent spawned female squid over time, showing an influx of two groups of animals. b. Observed percent of spawned females from samples collected in 1985 (standardized to purse seine gear only).

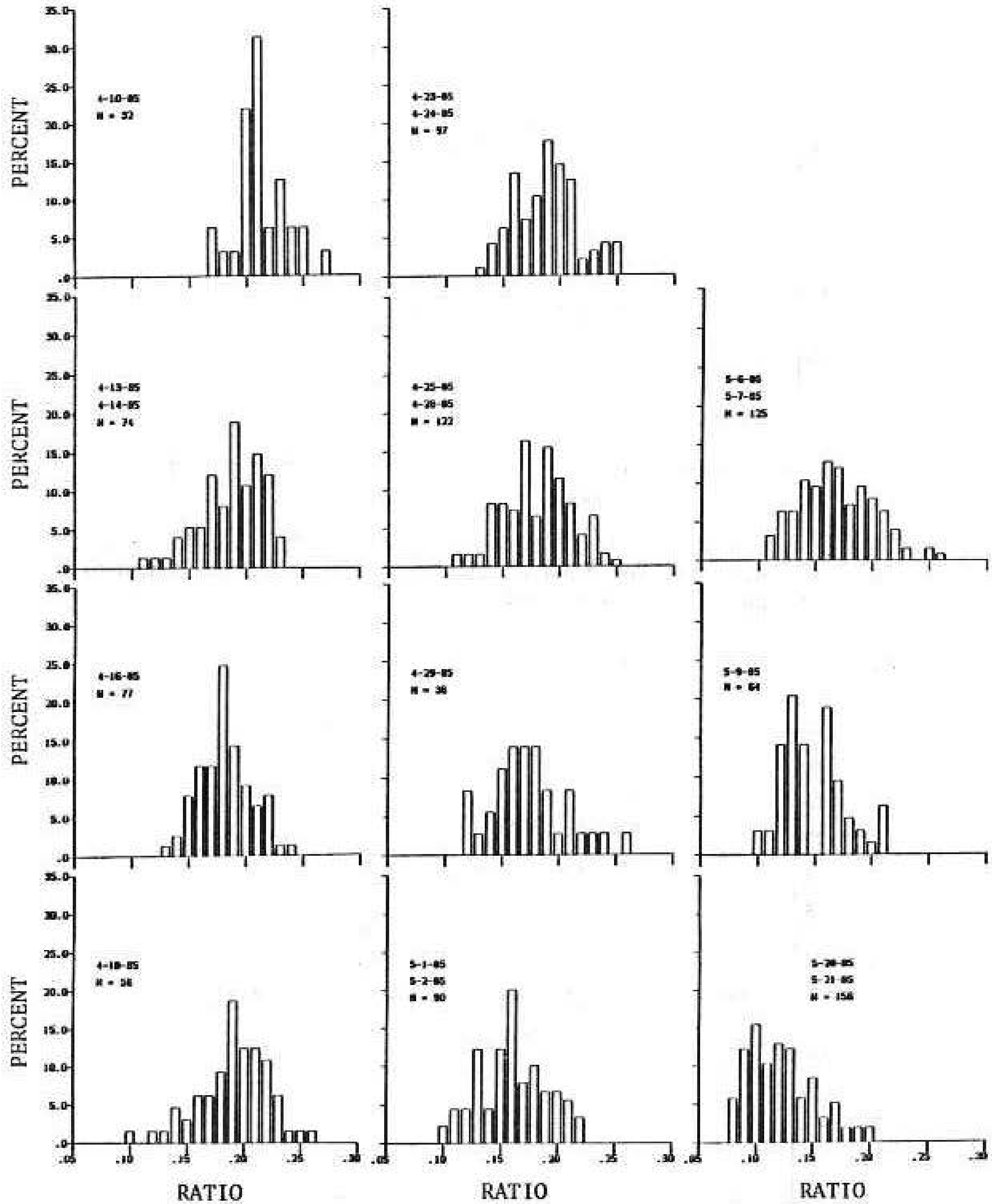

Figure 14. Frequency (%) of mantle length to mantle weight ratio of female squid sampled in 1985 (standardized to purse seine gear only).

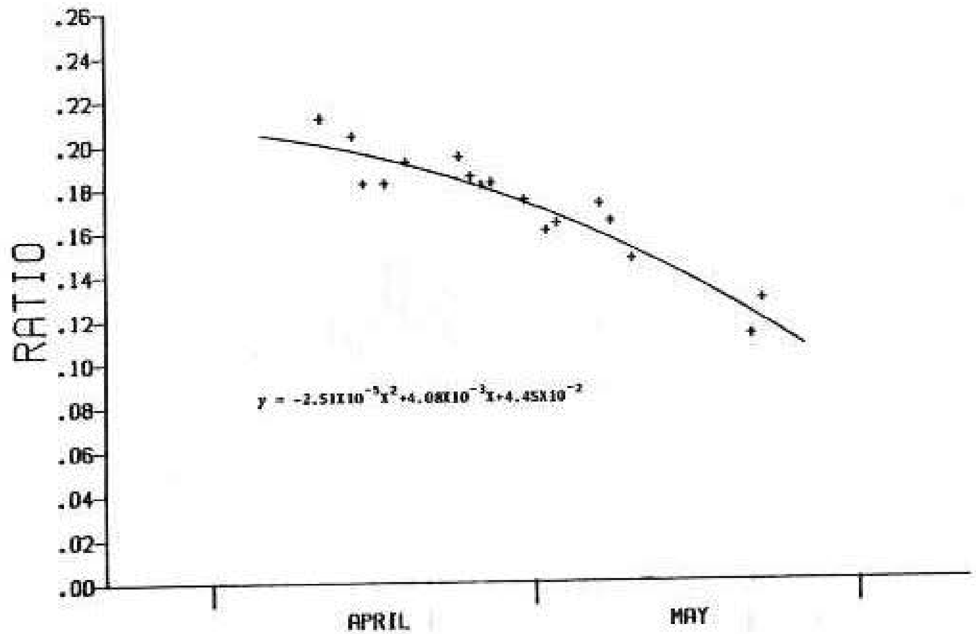

Figure 15. Average ratio of mantle weight (gm) to mantle length (mm) for female squid collected in 1985 (standardized to purse seine gear only).

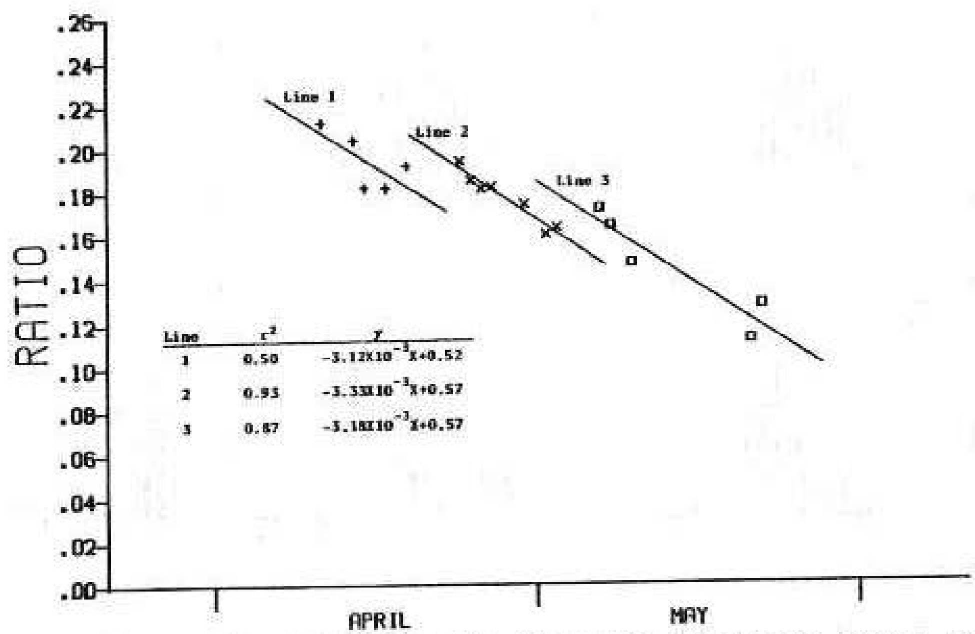

Figure 16. Average ratio of mantle weight to dorsal mantle length for samples collected in 1985, showing three groups of squid in the sample area (standardized to purse seine gear only).

If no new squid move into the area one would expect the mode of the frequency histograms and the mean weight to length ratios to display a gradual decrease with time. If a new group of squid enters an area, however, higher intervals would appear in the frequency histograms, and one would expect the mean sample ratios to gradually decline then quickly increase as squid in an earlier spawning stage appear in the samples. The mean sample ratios should subsequently decline at approximately the same rate as the initial group. If a third group of squid enters the area the mean ratio would again increase, then begin to decrease as the new squid spawned.

The result should be three relatively parallel lines or curves that would be offset by a factor influenced by the amount of new squid moving into an area, and the relative spawning states of the existing and entering groups of squid. Figure 14 suggests that new squid entered the area around April 18, and May 16, and Figure 16 indicates that there indeed were three groups of squid in different spawning conditions that entered Area B to spawn at different times.

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