THE BIOLOGICAL CHARACTERISTICS OF THE MONTEREY BAY SQUID CATCH AND THE EFFECT OF A TWO-DAY-PER-WEEK FISHING CLOSURE

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ABSTRACT

Biological data were obtained by sampling landings of market squid (*Loligo opalescens*) at ports in Monterey Bay, California, from 1989 to 1994. Weight, length, sex, and maturity data were recorded and summarized both annually and daily.

Results were compared with historical data, and squid were found to be significantly smaller now than in the 1950s, 1960s, and 1970s. Daily summaries were used to test the hypothesis that a two-day (weekend) closure produced significant changes in the daily biological characteristics of the catch. Analysis revealed that squid catches were highest on Mondays and that the percentage of spent squid in the catch was also highest on Mondays; there was a declining trend in daily catch and spent squid during the week.

It was concluded that a two-day closure is an effective resource management tool for the squid fishery because this is a terminal fishery on the spawning grounds. The higher proportion of spent squid on Mondays following the weekend closure indicated that squid could concentrate on the spawning grounds during the closure and spawn without being subjected to fishing pressure. These results suggest that the duration of the closure could be adjusted in response to the status of the resource.

INTRODUCTION

The market squid (*Loligo opalescens*) fishery is one of the largest, most important fisheries in the Monterey Bay area. Annual landings since 1943 have averaged approximately 5,863 tons, and after the major El Niño period of 1983–84, landings averaged 6,821 tons (fig. 1). From the late 1980s to the present the market squid fishery has ranked either first or second in annual total landings in the Monterey Bay area.

This important fishery has been studied in the past, but very little since the mid to late 1970s. Fields (1965) was the first to make an extensive study of the biology of market squid. He began sampling squid in the late 1940s and continued into the 1960s. Evans (1976) made morphometric comparisons of squid taken in 1974 from the Monterey Bay area and southern California. In 1973, the Department of Fish and Game and Moss Landing

Marine Laboratories formed the Market Squid Research Program (Recksiek and Frey 1978) and conducted a series of studies on market squid including age and growth (Spratt 1978), morphometrics (Kashiwada and Recksiek 1978), and acoustic target strength and weight-length relationships (Vaughan 1978).

In 1989, the California Department of Fish and Game initiated a program to sample landings of market squid caught in the Monterey Bay area. This program covered the years 1989 to 1992, and 1994. Its purpose was to reestablish a database of biological information on locally caught market squid that would allow comparisons with data collected from other areas. In addition, data would provide answers to the following questions about the local squid resource: (1) What is the current size distribution of squid? (2) Has the size distribution changed over time? and (3) Are there differences in catch or biological characteristics of the catch that could be attributed to current regulations prohibiting squid fishing on weekends?

During the time of the study, the California squid fishery was essentially unregulated, with the exception of the Monterey Bay weekend closure. There were no regulations pertaining to seasons, quotas, boat or equipment size, limited entry, etc.

METHODS

Catchable quantities of market squid usually begin to appear on the traditional spawning grounds in the southern bight of Monterey Bay in April or May (fig. 2). The fishery continues until about the end of October,
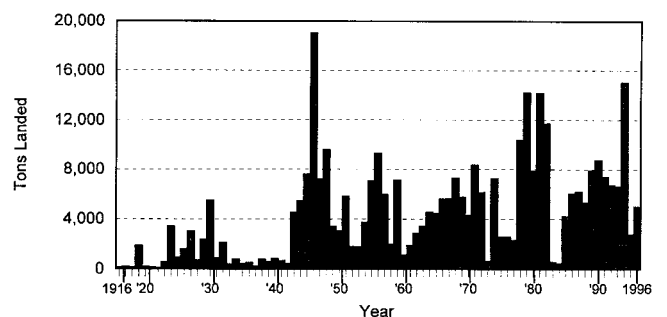

Figure 1. Monterey Bay area commercial market squid landings, 1916 to 1996.
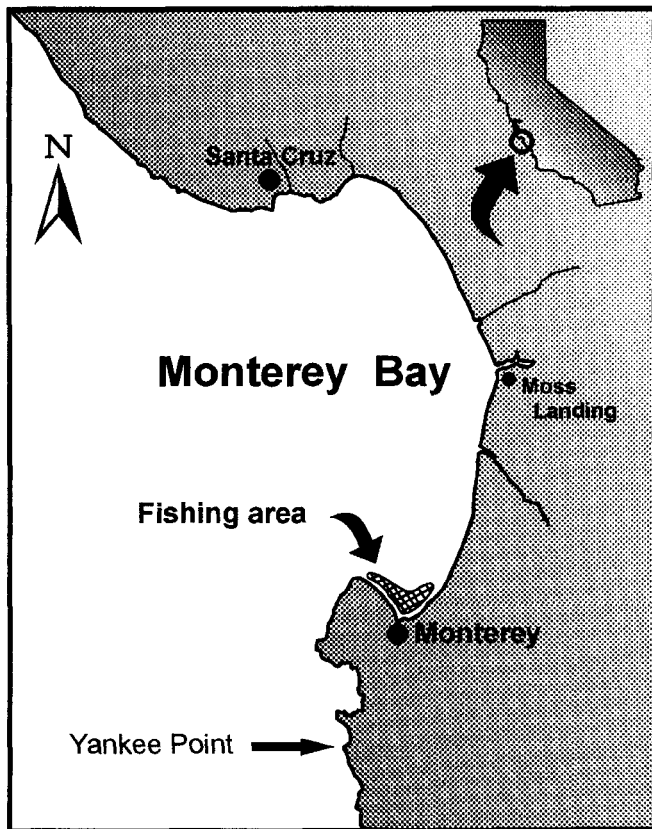
Figure 2. Traditional spawning and fishing area in the southern bight of Monterey Bay, California.

with occasional landings sometimes continuing into December. Occasionally some fishing is done just south of Yankee Point (Monterey County) and as far north as the Point Año Nuevo area (San Mateo County). Because boats frequently fish in several areas during a trip, there is no reliable way to separate or distinguish squid taken from a particular area. As a result, all squid sampled were considered caught in Monterey Bay, regardless of where they actually had been caught.

Sampling Procedures

Generally, one sample per day was taken. To ensure that samples were taken from as many different boats as possible, the three major Monterey Bay area dealers were put on a rotational sequence. The first boat unloading for the dealer at the top of the rotation was sampled on Monday morning. The next morning the next dealer in the sequence was visited, and its first boat was sampled, and so on throughout the week.

Sampling began when a single handful of squid from either the conveyor line or from a forklift bin was placed into a small plastic bucket. Squid were selected by reaching into the mass of squid and blindly grabbing a hand-

ful. This continued throughout the entire unloading procedure. I tried to regulate the timing and number of handfuls so that the first handful was taken at the beginning of the unloading and the last taken near the end, to increase the probability of selecting squid from the entire catch (frequently made up from multiple "sets" made on different schools). When the process was done correctly, the final handful topped off the bucket, resulting in a bucket sample weighing approximately 2,000 grams (g).

Processing the Sample

In the laboratory the bucket of squid was poured into a sink. A subsample of 25 squid was randomly picked, one at a time. Squid were selected by reaching into the mass and picking the first squid touched.

The 25 squid selected were allowed to drain further to allow any excess water in the mantle cavity to drain out as completely as possible—the method used by Fields (1965). Each squid was then weighed to the nearest 0.1 g, and its dorsal mantle length (DML) was measured in millimeters (mm). The DML was measured from the anteriormost point on the dorsal side to the posterior body tip. Sex and sexual maturity were determined visually. Though I did not measure internal structures, I used the general descriptive characteristics described by Kashiwada and Recksiek (1978), except that I combined their "immature" and "intermediate" levels and called them immature because of the difficulty in determining maturity levels in some male squid. Starr and McCrae (1984) also reported difficulty in distinguishing between maturity level 2 (intermediate) and maturity level 4 (spent) in males. Also, I followed Starr and McCrae's (1984) method of assigning females to the "spent" maturity category if more than two-thirds of a female's gonad was spent.

All squid were weighed and measured within one to two hours after removal from the boat. Samples were never frozen.

Data Analysis

The following statistical tests were used, with 0.05 as the level of significance: Student's t test to compare average weights and lengths and weight losses of males and females, and to compare average weights and lengths to historical data; chi-square to compare proportionate weight losses and sex ratio to previous studies, and to test the proportion of spent squid by the day of the week; analysis of variance (ANOVA) to test the significance of average monthly weight and length variations for males and females, and the significance of the number of landings per day, the total tons landed per day, and the catch per unit of effort per day; and Pearson correlation to compare the number of landings and the total tons landed

per day, and to compare the number of landings and the average tons landed per trip.

In order to test for significant differences in the proportion of spent squid found in the daily samples, I stratified samples by day. All samples taken on Monday were grouped, as were Tuesday, Wednesday, Thursday, and Friday samples. I used chi-square to compare the proportion of spent squid from samples taken each day.

RESULTS

Average Weights and Lengths

A total of 248 samples (6,200 squid) was collected during the study period. A total of 3,230 male squid weighed an average of 44.4 g, and 2,970 female squid averaged 35.6 g (table 1; fig. 3).

Male squid had an average length of 129 mm DML, and ranged from 62 mm to 185 mm DML. Female squid had an average length of 125 mm DML, and ranged from 58 to 159 mm DML (table 1; fig. 4).

Comparison with Historical Weight and Length Data

In this study, both male and female squid weighed less and were smaller than those weighed and measured by Fields (1965) and Evans (1976; table 2). Student's t tests on the average weights for all males and females indicated that those of this study (males: $t = 85.48$, ∞ df, $P < 0.001$, females: $t = 79.3$, ∞ df, $P < 0.05$) were statistically significantly smaller than those weighed by Fields (1965). Because the means reported by Evans (1976) were nearly equal to the mean weights that Fields (1965)

TABLE 1
Average Weights and Lengths for Market Squid Measured in the Monterey Bay Area, 1989–92 and 1994 Combined

|	Immature		Mature		Spent		Total	
	M	F	M	F	M	F	M	F
Number weighed/measured	264	112	2,304	2,532	662	326	3,230	2,970
Average weight (g)	22.6	20.6	47.4	37.2	43.0	28.5	44.4	35.6
Range	6.7–43.4	5.6–36.4	9.3–124.5	13.6–84.3	16.1–102.7	15.8–55.2	6.7–124.5	5.6–84.3
Standard deviation	5.7	5.5	16.4	9.3	15.5	7.3	17.0	9.9
Average length (mm, DML)	102.7	100.8	131.6	126.6	130.2	123.2	129	125
Range	62–130	58–124	71–185	89–159	93–174	95–147	62–185	58–159
Standard deviation	9.5	11.6	15.4	9.4	15.5	8.6	16.9	10.7
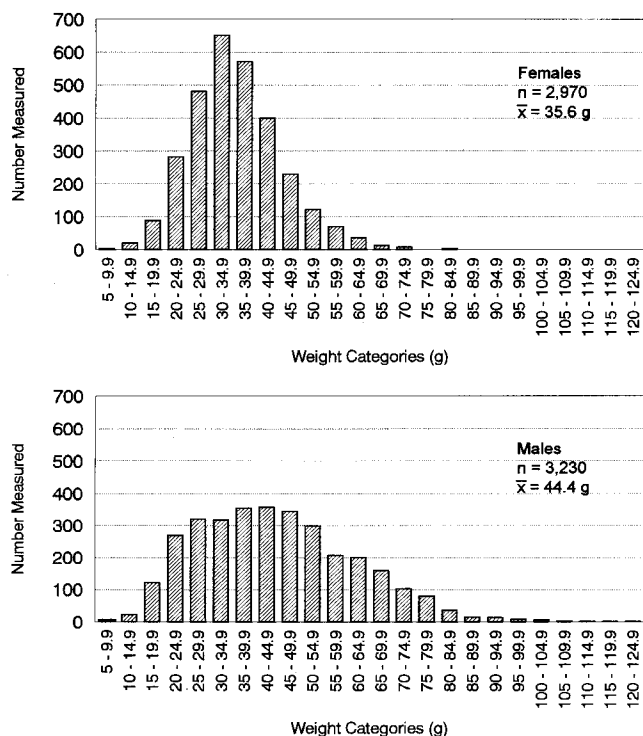
Figure 3. Weights of male and female squid grouped in 5-gram increments taken from the Monterey Bay fishery, 1989–92 and 1994 combined.
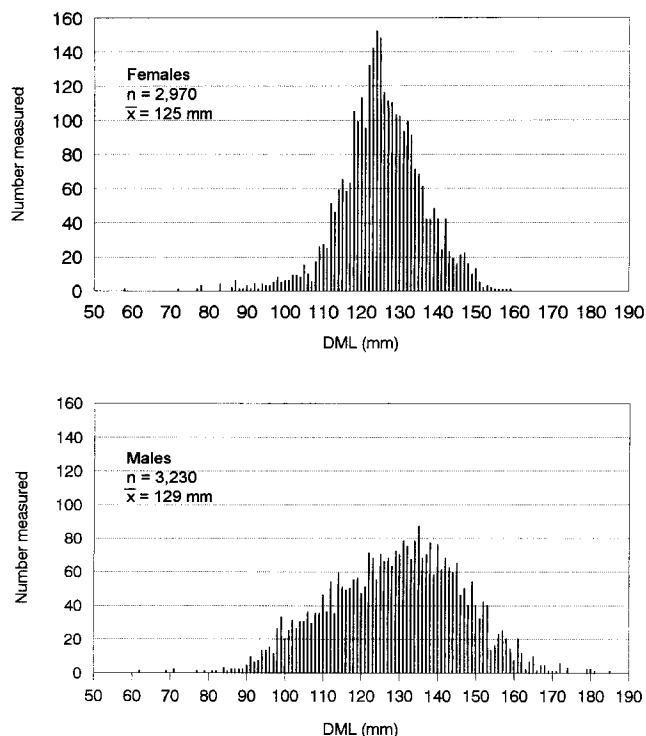

Figure 4. Dorsal mantle lengths (DML) of male and female squid taken from the Monterey Bay squid fishery, 1989–92 and 1994 combined.

TABLE 2
Historical Weight and Length Data of Monterey Bay
Squid Compared with 1989–92 and 1994 Data Combined

	Fields (1965)	Evans (1976)	This study (1989–92 and 1994)
Males			
Average weight (g)	70	70.1	44.4
Standard deviation	n/a	22.4	17.0
Average length (mm, DML)	150	146.3	129
Standard deviation	n/a	13.9	16.9
Females			
Average weight (g)	50	49.3	35.6
Standard deviation	n/a	13.4	9.9
Average length (mm, DML)	140	133.9	125
Standard deviation	n/a	10.1	10.7

Figure 5. Monthly average weights of male and female squid taken from the Monterey Bay squid fishery, 1989–92 and 1994 combined.

calculated for both sexes, I ran no comparison test using the means in Evans's study.

Evans (1976) reported average weight losses of 37% in male squid and 35% in females. A chi-square test on the proportions of weight loss for male and female squid in this study, using Evans's (1976) weight-loss proportions as the expected, showed significantly less weight loss ($X^2 = 33.5$, 1 df, $P < 0.001$) than for the squid weighed by Evans. No comparison data were available from Fields's 1965 study.

Student's t tests on male and female mean DML in this study compared to squid measured by Fields (1965) and Evans (1976) showed the mean DMLs for both sexes were significantly smaller (males: $t = 70.48$, ∞ df, $P < 0.001$, females: $t = 76.32$, ∞ df, $P < 0.001$) than those found by Fields, and significantly smaller (males: $t = 58.1$, ∞ df, $P < 0.001$, females: $t = 45.3$, ∞ df, $P < 0.001$) than those found by Evans.

Seasonality of Size Differences

The smallest squid were not the first to arrive on the spawning grounds, as had been anecdotally reported by the industry. Instead, squid that appeared in June and July averaged the smallest for both sexes (table 3; figs. 5 and 6).
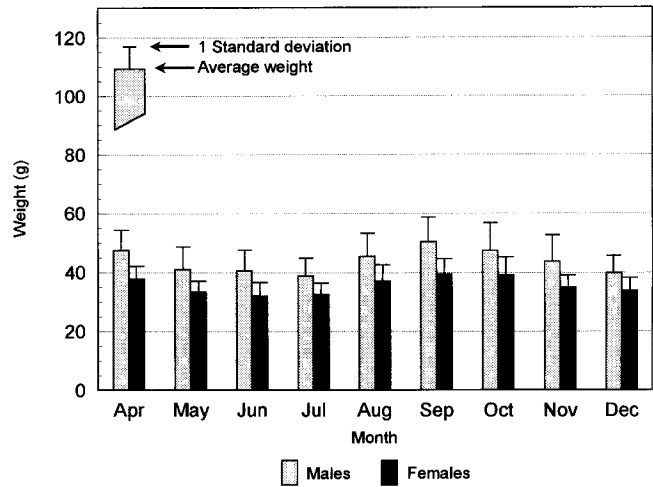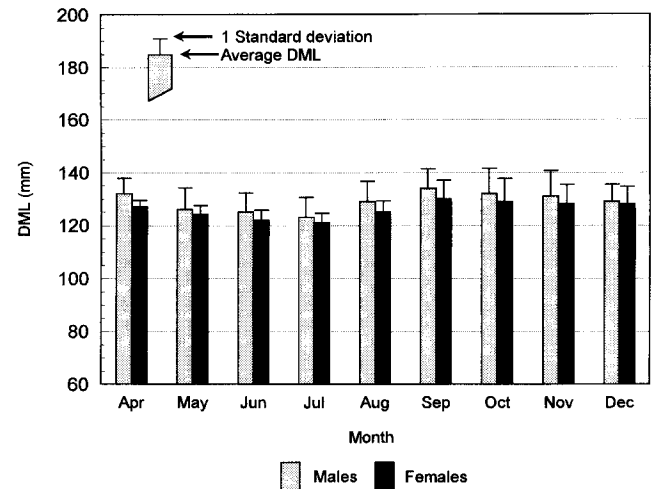

Figure 6. Monthly average lengths of male and female squid taken from the Monterey Bay squid fishery, 1989–92 and 1994 combined.

TABLE 3
Seasonality of Weight and Length Differences for Market Squid in the Monterey Bay Area, 1989–92 and 1994 Combined

	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average weights (g)									
Males	47.4	41.0	40.5	38.8	45.4	50.3	47.3	43.6	39.8
(SD*)	14.5	15.4	14.7	13.7	17.2	17.2	19.3	18.1	12.4
Females	37.8	33.3	32.0	32.5	37.0	39.3	39.1	34.8	33.8
(SD)	8.4	7.4	8.0	7.4	8.7	10.7	13.2	9.1	8.8
Average lengths (DML, in mm)									
Males	132	126	125	123	129	134	132	131	129
(SD)	14.1	16.0	15.3	15.0	17.1	14.8	19.2	19.5	13.2
Females	127	124	122	121	125	130	129	128	128
(SD)	6.5	8.4	7.5	8.0	9.0	10.8	15.6	11.8	10.8

*Standard deviation

Single-factor ANOVA runs on the average monthly weights for male and female squid revealed no significant differences between months for males ($F = 1.94$, 8 df, $P = 0.1$), but a significant difference in the average weights between months for females ($F = 3.39$, 8 df, $P < 0.01$). A Student's t test run on the monthly average lengths indicated that there were no significant differences between the two sexes ($t = 1.51$, 16 df, $P = 0.15$). Single-factor ANOVA runs on the monthly average lengths for males and females indicated no significant difference between months for males ($F = 2.06$, 8 df, $P = 0.1$), but indicated a significant difference between months for females ($F = 3.15$, 8 df, $P = 0.01$).

Sex Ratio

A total of 3,230 male squid and 2,970 female squid were examined, yielding a male:female sex ratio of approximately 1.1:1. Wide variations in sex ratios were noted from sample to sample, week to week, and month to month, with males always accounting for slightly greater percentages on an annual basis (table 4). Single samples were frequently dominated by one sex. Monthly variations in sex ratio were also noted, but no discernible pattern was evident. A chi-square test run on the monthly variations, using 0.5 as the expected frequency, indicated no significant differences ($F = 41.4$, 32 df, $P < 0.05$).

Fields (1965) noted variations in sex ratios in his study, with an overall sex ratio of 1:1. Evans (1976) determined a male:female sex ratio of 1.51:1. I ran chi-square tests on the sex ratio of squid in this study using Fields's (1965) and Evans's ratios as the expected. No significant dif-

ferences were found between the ratio of this study and Fields's (1965) ratio ($X^2 = 0.16$, 1 df, $P < 0.01$), or Evans's (1976) ratio ($X^2 = 2.67$, 1 df, $P < 0.001$).

Kato and Hardwick (1975) commented that it was unfortunate that Fields had lumped several years of data and did not give sex ratios by seasons or smaller entities, implying that possibly seasonality in sex ratios may have been evident.

Ally et al. (1975) reported that squid attracted to lights, and caught by jigging, had a sex ratio of 7.68:1 males to females. They hypothesized that males were more attracted to lights than females. My study did not support that hypothesis. It is possible that the high ratio of males reported by Ally et al. (1975) was due to the aggressive behavior of males in their reaction to the jigs rather than their response to the lights. Squid in this study were caught only with purse seine nets and attracting lights.

Proportion of Spent Squid in Daily Landings

It would be expected that the majority of squid from commercial catches at any time of the season would be sexually mature. This study confirmed the assumption, with 78.0% of 4,836 squid identified as mature. There were 988 spent squid (15.9%) and 376 (6.1%) immature squid.

What is of interest, however, is the daily proportion of spent squid that appeared in the sampled landings. The proportion of spent squid in landings may be viewed as an indicator of spawning success. Spent squid were present in greater proportions on Mondays (18.1%), and generally decreased as the week progressed (table 5). A chi-square test run on the proportions of spent squid by day of the week showed that proportions of spent squid were highly significantly different ($X^2 = 14.25$, 4 df, $P < 0.01$).

Analysis of Daily Landings

To determine if there were patterns in daily landings, I totaled the number of landings per day for the years of the study. The total number of landings on Mondays (1,061) was greater than for other days of the week and decreased throughout the week; Friday's total (697) was lowest (table 6). A two-factor ANOVA test (using days

TABLE 4
Monterey Bay Area Male:Female Squid Annual Percentages by Number, 1989–92 and 1994 Combined

Year	Males		Females	
	Percent	Number	Percent	Number
1989	51.1	753	48.9	722
1990	53.1	943	46.9	832
1991	50.8	495	49.2	480
1992	53.2	798	46.8	702
1994	50.7	241	49.3	234
Total		3,230		2,970

TABLE 5
Number and Percentage by Maturity of Squid Sampled per Day in Monterey Bay Area, 1989–92 and 1994 Combined

Condition	Monday		Tuesday		Wednesday		Thursday		Friday	
Immature	90	(5.9%)	80	(6.3%)	64	(5.4%)	46	(4.3%)	96	(8.3%)
Mature	1,159	(76.0%)	976	(76.5%)	941	(80.1%)	860	(80.0%)	900	(78.3%)
Spent	276	(18.1%)	219	(17.2%)	170	(14.5%)	169	(15.7%)	154	(13.4%)
Total	1,525		1,275		1,175		1,075		1,150	

as the randomized blocks) revealed a statistically significant difference among the days ($F = 13.19$, 4 df, $P < 0.001$). The total number of tons landed on Mondays was also greatest and decreased as the week progressed (table 6). Here too, a two-factor ANOVA test revealed a significant difference among the days ($F = 8.78$, 4 df, $P < 0.001$).

Daily Catch per Unit of Effort

I calculated the daily catch per unit of effort (CPUE) of squid boats, using the rationale that the unit of effort is a boat trip rather than actual effort on the fishing grounds (the number of sets or the hours fished). I used this method because there were no other effort data available from the squid fishery. Current Department of Fish and Game regulations do not require squid boat captains to document their effort or activity in any manner (e.g., logs). Therefore, a landing is equivalent to one boat trip. This follows the method described by Hardwick and Spratt (1979), except that I refined the CPUE estimate by dividing the combined total tons landed for each day of the week (for all years combined) by the number of trips per day of the week (all years combined) to arrive at a CPUE defined as the average catch (in tons) per trip per day of the week (table 6).

The CPUE was highest on Monday (11.58 tons/trip) and lowest on Thursday (10.23 tons/trip), with an overall average of 10.7 tons/trip. An ANOVA test run on CPUE with days and years as factors showed no statistically significant differences ($F = 0.7$, 4 df, $P = 0.06$).

Daily Changes in CPUE

A correlation coefficient analysis between the number of trips for each day of the week and the total tonnage of these landings indicated a positive relationship between the two variables ($r = 0.98$, 3 df, $P < 0.001$). This is to be expected, because more effort tends to result in greater landings (assuming that sufficient squid are on the fishing grounds).

A correlation coefficient analysis between the number of trips per day of the week and the average tons landed per trip resulted in no statistically significant relation between the two variables ($r = 0.65$, 3 df, $P = 0.80$). In other words, CPUE did not change from day to day.

DISCUSSION

Comparisons of Size Difference

The first of the two key questions that arise from the examination of these data is, Why were squid smaller in the 1989–94 catches than in the catches from the 1940s to 1970s? One reason may be that the ocean's primary productivity was greater during the times of the

TABLE 6
Catch per Unit of Effort, on a Daily Basis, for the
Monterey Squid Fishery, 1989–92 and 1994 Combined

Day	Number of landings	Total tons landed	Total tons/ landing (CPUE)
Monday	1,061	12,283	11.58
Tuesday	928	9,625	10.37
Wednesday	824	8,590	10.42
Thursday	758	7,755	10.23
Friday	697	7,496	10.75
Total	4,268	45,749	
Average CPUE			10.72

previous studies; water temperatures in the eastern Pacific were cooler (Reid 1988). From the early 1950s through the mid-1970s, zooplankton volumes were generally above average (Reid 1988), except during the 1957–58 El Niño period. Squid measured from catches during that time may have had more euphausiids (their main food) to feed on.

Squid measured during this study were taken during a period of relatively warmer water temperatures, linked to one of the strongest El Niño events (1982–83) recorded in this century. The period after the 1982–83 El Niño event was generally characterized by water temperatures at or just above normal in the Monterey Bay area. Another, less intense, El Niño event in 1992 continued the warm-water regime into the mid-1990s. The 1992 event certainly appears to have reduced primary productivity and zooplankton abundance in the central coast area (Lenarz et al. 1995). In fact, a warm-water period from 1990 to 1995, associated with an El Niño/Southern Oscillation event, is the longest event of its type in 130 recorded years (Trenberth and Hoar 1997). This entire warm-water period resulted in lower primary productivity (McGowan et al. 1996). The growth rate of squid may have been affected, reducing the overall size of squid caught from the late 1980s through the mid-1990s, compared to the sizes measured from catches in the late 1940s to the mid-1970s.

Seasonality of Size Differences

The fact that larger squid appeared on the spawning grounds during the first part of the season and then again later in the year suggests the possibility that spawning arises from two broods. This supposition has been addressed in the South African chokka squid (*Loligo vulgaris reynaudii*) fishery (Augustyn et al. 1992) and may be the case in the Monterey Bay area squid fishery.

Comparison of Weight Loss

One reason for a lesser weight loss when compared to Evans's (1976) study may be linked to the greater

efficiency of today's purse seiners and the use of attract-ing lights mounted on the purse seiners and their asso-ciated light boats (Spratt and Ferry 1993). Rarely did we observe a completely spent male or female squid. Nearly all squid categorized as spent still had some spermatophores or eggs within the body cavity. Because squid show a strong positive phototaxis response, it was not necessary for the purse seine net to reach the bottom to capture the squid. Consequently, completely spent squid, near the bottom, apparently weakened by the spawning process and possibly not as reactive to the lights, may not have been as likely to be caught as the stronger squid. Thus, one result of the use of attracting lights may be that most, or at least a large percentage, of squid are caught before they complete their spawn-ing (as some fishermen contend). The use of lights selects for stronger, more mobile squid that have yet to suffer the degenerative changes associated with spawning noted by Fields (1965).

Effect of a Weekend Closure

The second key question arising from this study is, Why were more spent squid in the Monday samples of the catch, with a decreasing trend as the week pro-gressed? I speculate that this is directly associated with the weekend closure in the Monterey Bay area. If squid do regroup so that spawning increases during the 60-hour weekend closure (no squid fishing was allowed from noon Friday to midnight Sunday in CDFG districts 16 and 17), a greater number of spent squid would be pres-ent on the spawning grounds by the time fishing re-sumed at Sunday midnight. A greater percentage by number of spent squid was found on Monday (table 5). A chi-square test among proportions of spent squid by day of the week was significant ($P < 0.01$) among the days of the week.

Evidently, early in the week a greater proportion of the catch was made up of spent squid. This suggests and supports the possibility that the weekend closure allows squid to reschool and engage in increased, undisturbed spawning. The increased spawning is reflected in the re-sulting higher proportion of spent squid appearing in the samples taken from Monday. As fishing continued throughout the week, fewer spent squid were present on the spawning grounds, making a smaller proportion of the total catch.

Catch per Unit of Effort

The fairly consistent CPUE (table 6) may be a result of the processors' knowledge of the fishery and how to adjust the number of boats sent out in relation to the numbers of squid they feel are present on the fishing grounds. As the week progressed and squid became more difficult to catch because of lack of availability or scat-

tering as a result of fishing pressure, processors sent out fewer boats; those that did fish had a better chance of reaching their trip limit or catching as much as possi-ble. In effect, this affected the landings per day, CPUE, and the number of boats in the Monterey squid fishery and how much they ultimately caught. As a result, while the total daily tonnage that was landed decreased dur-ing the week and the number of landings decreased, CPUE remained relatively steady, especially from Tuesday to Friday (table 6).

Daily first-hand observations of the fishery confirmed this practice. I found that quite often toward the end of the week processors sent out only company boats or more successful boats. Smaller boats or those that had not been as successful during the beginning of the week were often ordered to stay in port. Frequently this order stayed in effect until reports came in that a new school of squid had arrived on the spawning grounds or until the uncaught, scattered squid were allowed to regroup. The scattered squid appeared to regroup during the week-end closure.

Hardwick and Spratt (1979) calculated CPUE by using the total annual landings divided by the number of "boat delivery days." They did not calculate CPUE on a daily basis. In both cases (Hardwick and Spratt 1979 and this study), CPUE so defined should be approached with a degree of caution. Boats that were unsuccessful for a given night's efforts are not factored in this definition of CPUE. This introduces a bias in CPUE as an indi-cator of relative availability in the squid fishery. Hardwick and Spratt (1979) point this out, stating that the aver-age catch per delivery day is higher than it should be be-cause these unsuccessful boats are not included. Also, CPUE as I calculated it did not and could not take into consideration boats placed on trip limits with possible smaller loads, yet another source of bias.

SUMMARY AND CONCLUSION

Squid measured during the 1989–92 and 1994 Monterey Bay area seasons were significantly ($P < 0.001$) smaller (mean weight and mean DML) than squid mea-sured by Fields (1965) and Evans (1976). El Niño events during the 1980s and 1990s may have contributed to decreased productivity, resulting in less food for squid, with the end result that they were smaller.

Squid caught at the time of this study were attracted by powerful lights, and the amount of spawning may have been affected. Further studies should be conducted to test this hypothesis. Spent squid in this study did not lose as much weight as spent squid measured in previ-ous studies. Again, this may have been an effect of the attracting lights. Further studies comparing squid caught by boats not using lights and those using lights may pro-vide an answer.

The smallest squid did not appear on the spawning grounds at the beginning of the season, as had been previously reported. Instead larger squid appeared first, and then again later in the year. This gives rise to the possibility that the spawning population of Monterey Bay is composed of two broods.

Spent squid were present in significantly greater proportions early in the week, and the proportions declined until the last day of the fishing week. Increased spawning probably took place during the 60-hour weekend closure, resulting in the higher proportions early in the week.

Industry representatives reported that generally more squid were caught on Mondays and that the numbers decreased with each successive day of fishing. They feel the greater landings on Mondays are attributable to the weekend closure. Total landings were highest on Monday and decreased as the week progressed, although CPUE did not significantly change.

A weekend closure appears to be a cost-effective management tool that benefits the squid resource. I speculate that the weekend closure provides a respite period for squid, since this period of no fishing allows them to "regroup" after being subjected to five nights of fishing pressure. As a result, spawning increases and a higher proportion of spent squid appear in catches immediately after the closure. I recommend continuing a weekend closure of at least this duration. Further research may indicate that additional closure time may be necessary to allow increased spawning. Future research may also indicate that, as a management tool, a statewide weekend closure would be appropriate or necessary for the squid fishery.

ACKNOWLEDGMENTS

LITERATURE CITED

Ally, J. R. R., R. G. Evans, and T. W. Thompson. 1975. The results of an exploratory fishing cruise for *Loligo opalescens* in southern and central California June 5–25, 1974. Moss Landing Mar. Lab. Tech. Publ. 75-2, 22 pp.

Augustyn, C. J., M. R. Lipinski, and W. H. H. Sauer. 1992. Can the *Loligo* squid fishery be managed effectively? A synthesis of research of *Loligo vulgaris reynaudii*. S. Afr. J. Mar. Sci. 12:903–918.

Evans, R. G. 1976. Aspects of the population biology of the California market squid (*Loligo opalescens*, Berry). Master's thesis, Calif. State Univ., Hayward, 88 pp.

Fields, W. G. 1965. The structure, development, food relations, reproduction, and life history of the squid *Loligo opalescens* Berry. Calif. Dep. Fish Game, Fish Bull. 131, 108 pp.

Hardwick, J. E., and J. D. Spratt. 1979. Indices of the availability of market squid, *Loligo opalescens*, to the Monterey Bay fishery. Calif. Coop. Oceanic Fish. Invest. Rep. 20:35–39.

Kashiwada, J., and C. W. Recksieck. 1978. Possible morphological indicators of population structure in the market squid, *Loligo opalescens*. Calif. Dep. Fish Game, Fish Bull. 169, 185 pp.

Kato, S., and J. Hardwick. 1975. The California squid fishery. *In* Contributed papers submitted to the expert consultation on fishing for squid and other cephalopods. Tokyo and Hakodate (Japan) 9–13 September 1975. FAO Fish. Rep. (170) Suppl. 1, 150 pp.

Lenarz, W. H., D. A. VenTresca, W. M. Graham, F. B. Schwing, and F. Chavez. 1995. Explorations of El Niño events and associated biological population dynamics off central California. Calif. Coop. Oceanic Fish. Invest. Rep. 36:106–119.

McGowan, J. A., D. B. Chelton, and A. Conversi. 1996. Plankton patterns, climate, and change in the California Current. Calif. Coop. Oceanic Fish. Invest. Rep. 37:45–68.

Recksiek, C. W., and H. W. Frey, eds. 1978. Biological, oceanographic, and acoustic aspects of the market squid, *Loligo opalescens* Berry. Calif. Dep. Fish Game, Fish Bull. 169, 185 pp.

Reid, J. L. 1988. Physical oceanography, 1947–1987. Calif. Coop. Oceanic Fish. Invest. Rep. 29:42–65.

Spratt, J. D. 1978. Age and growth of the market squid, *Loligo opalescens* Berry, from statoliths. Calif. Coop. Oceanic Fish. Invest. Rep. 20:58–64.

Spratt, J. D., and L. A. Ferry. 1993. A profile of the Monterey squid fleet in 1992. Calif. Dep. Fish Game, Mar. Res. Div. Admin. Rep. No. 93-2, 18 pp.

Starr, R. M., and J. E. McCrea. 1984. Market squid (*Loligo opalescens*) investigations in Oregon, 1983–85. Oregon Dep. Fish and Wildlife, Mar. Region, 41 pp.

Trenberth, K., and T. Hoar. 1997. The 1990–1995 El Niño–Southern Oscillation event: longest on record. Geophys. Res. Lett., Jan. 1997.

Vaughan, D. L. 1978. The target strength of individual market squid, *Loligo opalescens*. Calif. Dep. Fish Game, Fish Bull. 169, 185 pp.