

Spatial and temporal patterns in the California market squid (*Loligo opalescens*) fishery

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Squid fishery

The increase in the international demand for squid has made California's market squid (*Loligo opalescens*) fishery one of the state's most valuable fisheries (Fig. 1 and Fig. 2). Seine or brail gear combined with the use of lights as an attractant are used to capture shallow spawning populations in areas over sandy substrate. Spawning may occur year-round; however, the fishery is most active from Apr. to Oct. in Monterey and from Oct. to May in the Channel Islands (Vojkovich 1998).



Fig. 1. *Loligo opalescens* spawning over egg beds. Photo: Mark Conlin Photography.

Sustainable management for this species is critical because market squid live 6-12 months and reproduce at the end of their lifespan (DFG 2004) thereby causing the success of the population to be reliant upon the reproductive output of the previous cohort (Macewicz et al. 2004). Monitoring changes in life history characteristics is needed to maintain effective management (Reckisiek and Frey 1978). This study examines the spatial and temporal trends in biological aspects of market squid to determine if length, weight, and sex ratios have significantly changed through time and if these variables plus mantle condition and gonad weight presently differ among geographic regions.

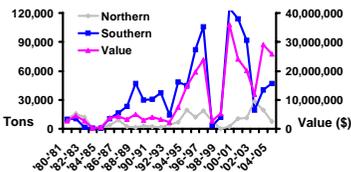


Fig. 2. CA squid fishery landings and value.

Collection and analysis

We compared biological aspects for CA market squid among three historical datasets (Fields '65, Evans '76, and Leos '98) and a current DFG study (Fig. 3). Samples were collected from fishing vessels, dealers, or during research cruises. Geographic comparisons were made for current data ('00-'05). Measurements were carried out the same in all studies:

- Length (mm): a measurement of the dorsal mantle length which, is the anterior-most point on the dorsal side to the posterior body tip
- Weight (g): a measurement of whole body weight; individual squid were drained of excess liquid
- Sex: identified by male or female gonads

Statistical computations were executed with the statistics software JMP 5.1. Specific tests and results are noted with figures.

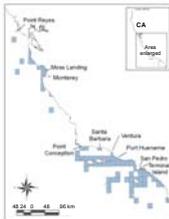


Fig. 3. Sample locations for current ('00-'05) data collection were recorded as DFG block numbers and are depicted in blue.

Historic trends

North of Pt. Conception

A decline in mean length and weight is depicted (Fig. 4 and Fig. 5), however mean length and weight increase from '89-'92, and '94 to '00-'05. Males account for greater percentages in sex ratios through time (Table 1).

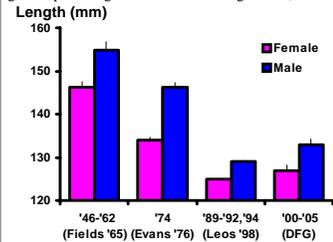


Fig. 4. Mean length (+/-SE). t-Test: Fields '65 vs. DFG, Male df=71, t=7.9, p<0.01; Female df=74, t=9.6, p<0.01.

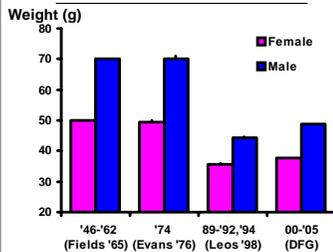


Fig. 5. Mean weight (+/-SE).

Sex Ratios

Table 1. Sex ratios are dominated by males from '50-'04. A 1:1 ratio (Fields '65) was used as the expected value for Chi-square test (significant yrs. are bolded).

	'50-'52	'74	'89	'90	'91	'92	'94	'00	'01	'02	'03	'04
Female	50.4	40.0	48.9	46.9	49.2	46.8	49.3	48.2	45.3	44.4	44.0	41.6
Male	49.6	60.0	51.1	53.1	50.8	53.2	50.7	51.8	54.7	55.6	56.0	58.4
χ^2	0.1	30.3	0.7	6.9	0.2	6.1	0.1	2.7	31.6	57.4	36.9	38.0

South of Pt. Conception

Mean length and weight has declined since '74 (Fig. 6 and Fig. 7). Sex ratios are dominated by males (Table 2).

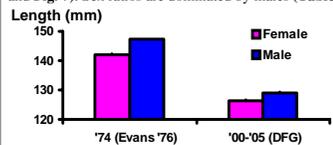


Fig. 6. Mean length (+/-SE). Southern CA squid are shorter than northern CA squid.

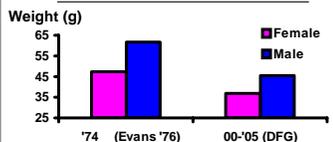


Fig. 7. Mean weight (+/-SE).

Sex Ratios

Table 2. A 1.5:1 (Evans '76) ratio was used as the expected value for a Cochran's test (all yrs. significantly different from '74).

	'74	'00	'01	'02	'03	'04
Female	40.9	43.3	49.0	48.2	48.4	43.5
Male	59.1	56.7	51.0	51.8	51.6	56.5

Recent trends: temporal and geographic

Our most recent data ('00-'05) show a significant decline in mean length for the entire state (Fig. 8). Mean weight also follows a similar trend. The mean length and weight for market squid is greatest in northern California near the Monterey Peninsula than in fishing areas around the northern and southern Channel Islands (Fig. 9, weight not shown).

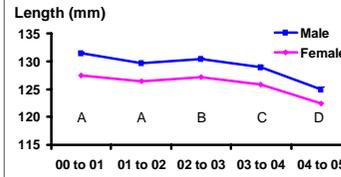


Fig. 8. There is a decreasing trend in mean length (+/-SE) through time with most seasons being significantly less than the previous (ANOVA, $F_{4,31416} = 78.6$, $p < 0.0001$).

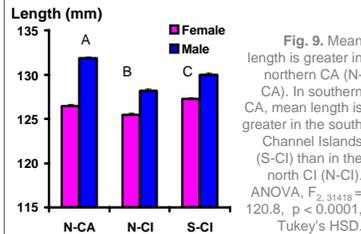


Fig. 9. Mean length is greater in northern CA (N-CA). In southern CA, mean length is greater in the south Channel Islands (S-CI) than in the north CI (N-CI). ANOVA, $F_{2,31416} = 120.8$, $p < 0.0001$, Tukey's HSD.

Mean length and weight differ significantly among geographic regions (Fig. 10a-b, weight not shown) and across seasons. Lengths are generally greatest in the Monterey area in northern CA. In southern CA, lengths are greater in the southern Channel Islands (CI) area when compared to the northern CI area.

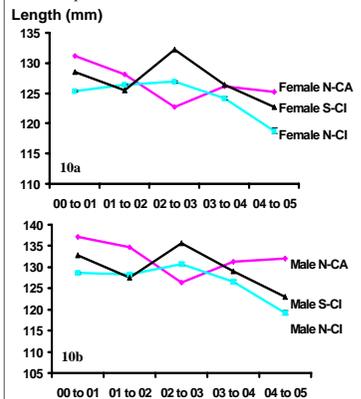


Fig. 10a-b. Mean length of females and males significantly decrease from '00 to '05 and differ among regions. Two-way ANOVA results:

Factor	DF	Female		Male		
		F	P	F	P	
Region	2	146.2	<0.0001	2	225.9	<0.0001
Season	4	145.2	<0.0001	4	120.9	<0.0001
Region*Season	8	142.6	<0.0001	8	112.2	<0.0001
Error	27466			31406		

Mantle condition can be used as a proxy for the amount of eggs that females released during spawning (Macewicz et al. 2004). As females release eggs, the condition of the mantle decreases. Squid caught in northern CA have the lowest mantle condition among the three regions (Fig. 11a) and also have gonads that weigh more than in the other areas (Fig. 11b).

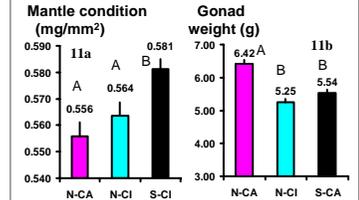


Fig. 11a-b. Female mantle condition (MC, mg/mm²) and gonad weight (GW, g) are significantly different between different geographic regions. Mean values are shown. MC ANOVA, $F_{2,2662} = 8.8$, $p < 0.0001$, Tukey's HSD. GW ANOVA, $F_{2,2662} = 28.3$, $p < 0.0001$, Tukey's HSD.

Conclusions

- There has been an overall decline in mean length and weight from the 1940s to the present statewide. This may be correlated with long-term climatic patterns such as regime shifts that influence nutrients or food sources.
- Males have remained as the more abundant sex since the 1940s. This may be due to spawning behavior.
- Squid in northern CA are larger (in length and weight), release more eggs, and have bigger gonads.
- This may also be a function of nutrient supply – the northern fishery is located near the Monterey Submarine Canyon, a source a nutrient-rich, upwelled water.
- The number of eggs that are spawned should therefore be greater in northern CA than in southern CA.
- Lengths, weights and sex ratios are significantly different geographically and through time, but the question is whether this is biologically significant.

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Acknowledgments

Data collection and sample processing were carried out by the National Marine Fisheries Service and the California Department of Fish and Game (CDFG). We thank Greg Cailliet (Moss Landing Marine Labs - MLML), Rick Starr (Sea Grant Advisor at MLML), Marcie Yaremko (CDFG), and Sarah Lester and Scott Hamilton (UC Santa Barbara) for valuable input and advice; Gina Wade (CDFG) for map creation; and Kevin Aceituno (CDFG) for data extractions.

For further information

Please contact
bbrady@dfg.ca.gov. More information on the market squid fishery can be obtained at www.dfg.ca.gov/mr/.

