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The Resources Agency
DEPARTMENT OF FISH AND GAME

INCIDENTAL CATCH AND MORTALITY OF STRIPED BASS,
MORONE SAXATILIS, IN THE COMMERCIAL BAY SHRIMP
TRAWL FISHERY IN THE SAN FRANCISCO ESTUARINE COMPLEX

by

Paul N. Reilly

Marine Resources Division
Administrative Report No. 91-1

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ABSTRACT

The commercial bay shrimp fishery was monitored from April 1989 to September 1990 in south San Francisco Bay, and from September 1989 to September 1990 in San Pablo Bay and Carquinez Strait, to estimate incidental catch and mortality of young-of-the-year (YOY), juvenile and adult striped bass. Of the total estimated by-catch of 44,000 to 52,000 YOY bass, 98.5% were taken in San Pablo Bay. Of the total estimated by-catch of 3160 to 3570 older bass, approximately 75% were taken in San Pablo Bay. Estimated mortality from shrimp tows was 22% for YOY and 2% for older bass. More than 99% of mortalities occurred in San Pablo Bay. July and August 1990, when YOYs were smallest and most vulnerable to trawling, was considered a critical period. A reduction in tow duration as well as effort in San Pablo Bay during this period may be effective in significantly reducing total mortality.

Marine Resources Administrative Report No. 91-1

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INTRODUCTION

The commercial bay shrimp fishery in the San Francisco estuarine complex provides live bait for sport fishers seeking sturgeon, Acipenser sp. and occasionally striped bass, Morone saxatilis. "Bay shrimp" is an aggregate term used to describe four species: 1) the California bay shrimp, Crangon franciscorum; 2) the blacktail bay shrimp, C. nigricauda; 3) the black-spotted bay shrimp, C. nigromaculata; and 4) the oriental shrimp, Palaemon macrodactylus. The California bay shrimp is usually the dominant component of the shrimp catch. The fishery occurred in three regions of the estuarine complex: 1) the northwestern portion of San Pablo Bay, primarily in the approach channel to the Petaluma River; 2) south San Francisco Bay, including Coyote Creek and Redwood Creek; and 3) Carquinez Strait (Figure 1).

Commercial shrimp fishers are required by law to return immediately most trawl-caught fishes to the water. Staghorn sculpin, Leptocottus armatus, yellowfin goby, Acanthogobius flavimanus and longjaw mudsucker, Gillichthys mirabilis, are the only exceptions and may be retained and sold for bait. Young-of-the-year (YOY), juvenile, and occasionally adult striped bass are caught incidentally in shrimp trawls. Sport fishing groups have expressed concerns about mortality of bass from trawling and from handling upon return. Those concerns prompted this study. The primary goals were: 1) to estimate total by-catch and mortality of striped bass in the bay shrimp fishery; and 2) to recommend methods to reduce by-catch and mortality. A similar study in 1974 and 1975 (Smith 1976) focused on bass mortality from bay shrimp trawls from July to January in Suisun Bay (Figure 1) and

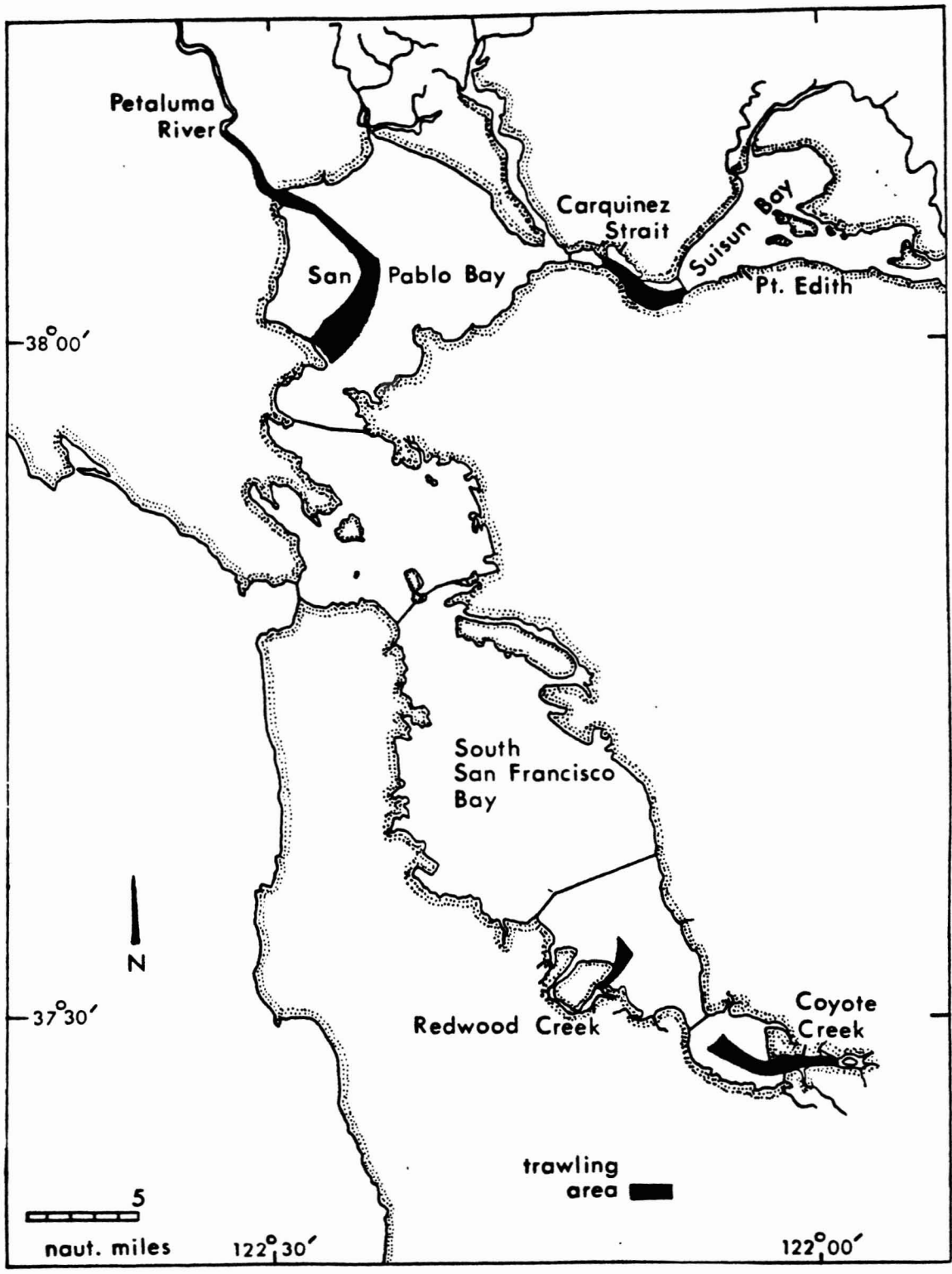


Figure 1. Bay shrimp trawling areas, San Francisco estuarine complex.

to a limited extent in San Pablo Bay.

METHODS

Description of Fishing Operations

The shrimp trawl is a type of beam trawl. All observed nets were of similar design and construction. A 20- to 25-ft long pole of either wood or galvanized steel was used to keep the 3- to 4-ft high net open at the mouth. The 25- to 50-ft net, with a codend mesh size of either 7/8 or 1 in., was set and retrieved with a hydraulic winch. The catch from each tow was placed in a live tank with circulating bay water. Using a small-mesh, hand-held net, part of the catch is then placed on a wooden sorting tray. All species other than shrimp and legal bait fish were then returned to the water. The sorted shrimp were placed into a separate compartment of the live tank. When sorting was completed the weight of shrimp was estimated by volume with 5-gal buckets.

Observation Procedures

I made all observations of trawling and sorting operations. Shrimp trawling was observed 1 day per month in southern San Francisco Bay from April 1989 to September 1990 (no observations October 1989) and 2 to 3 days per month in San Pablo Bay from September 1989 to September 1990. In Carquinez Strait, observations were made on 2 days in September 1989 and 1 day in April 1990. For each observed tow, the following data were recorded: date, time and duration of tow, tidal state, total pounds of shrimp caught, and total number of each species of fish caught. Striped bass and any fish species occurring in small

numbers were counted; fish species occurring in large numbers were either counted or estimated.

Processing of Striped Bass

With two exceptions, bass were processed in the following manner. Immediately after being transferred from the live tank to the sorting tray, all YOY bass were removed and temporarily placed in 5-gal buckets of bay water. Older bass were measured immediately and returned to the water. Total length measurements (TL in mm) of YOY bass began within 30 min of the onset of sorting. Bass were recorded as either alive or dead, and all live ones were returned to the water. Dead bass were retained in order to avoid recapture in successive trawls. Commercial handling techniques were observed for two tows in San Pablo Bay: bass were not measured and were recorded as either dead or alive from determinations made in the sorting tray. Live bass were returned to the water by crew members.

Age Class Determination

YOY and older bass were not aged; they were placed in broad age groups based on length and time of year criteria developed from previous unpublished ageing studies (Lee Miller, Dept. Fish and Game, Stockton, pers. commun.). Sexual maturity was not determined, and juveniles and adults were treated together as older bass.

Total Fishing Effort Estimation

An estimate of total fishery effort (trawl duration in hours) was necessary to estimate total YOY and juvenile bass

by-catch during the study period from observed tow data. Shrimp fishers are required to submit fishing logs for each day fished. Each log records the start and end time of each tow. Compliance was good during this study and most permittees submitted daily logs each month. Tow durations were summed for each month by study area.

Total Striped Bass Catch Estimation

Separate estimates for total bass catch during the study period were derived for each study area. Mean catch per hour (CPH) of YOY and juvenile bass was calculated for each month. In San Pablo Bay, for March and July 1990, a separate mean CPH estimate was calculated for each half of the month to reflect significant changes in YOY abundance. Mean CPH was multiplied by the appropriate estimate of total fishing effort to calculate the total estimated bass catch.

Scaling Factors

The vessel on which observations were made in San Pablo Bay used a larger net than used by other shrimp fishers in the area. Two sets of scaling factors were developed to account for this difference when estimating bass CPH on unobserved vessels in San Pablo Bay. One set adjusted for differences in net dimensions between the observed and unobserved boats. The observed permittee used a 25-ft by 3-ft mouth opening net from September 1989 to April 1990 and a 25-ft by 4-ft net from May to September 1990. Nets on other vessels were 20- or 21-ft by 3-ft at the mouth. Accordingly, bass CPH scaling factors ranged from 0.60 to 0.84 and averaged 0.70.

Shrimp CPH, based on log book information, varied widely among all permittees in San Pablo Bay. A second set of scaling factors was derived each month based on the ratio of shrimp CPH on each unobserved boat to that of the observed vessel. Although untested, it is assumed that, on a given day in the same area at the same time, a permittee who catches more shrimp per hour would also catch more bass per hour. Shrimpers in San Pablo Bay usually fished at the same time in the same area. Scaling factors based on shrimp catch ranged from 0.39 to 1.00 and averaged 0.48.

Both scaling factors were further adjusted by fishing effort to calculate a monthly mean CPH for bass based on observed data.

Striped Bass Trawling Mortality Estimation

For each month of the study (semi-monthly for March and July 1990 in San Pablo Bay), a mean mortality rate (percent dead of total caught) was calculated for YOY bass. This was multiplied by the estimated total monthly or semi-monthly catch to produce a total estimate of bass deaths due to trawling.

Statistical Analyses

Regression and correlation analyses of observation data were used to describe relationships between YOY bass mortality rate and tow duration, YOY CPH, shrimp CPH, and mean length of bass.

RESULTS

Trawl Observations

In San Pablo Bay, 86 bay shrimp tows were observed on one vessel from September 7, 1989 to September 27, 1990 (APPENDIX A). The vessel was selected because its large size provided ample

working space and because the permittee's net, the largest in the fleet, had the greatest likelihood for incidental bass catch. Observed tows lasted a total of 112.7 hr, ranged in duration from 30 to 145 min, and averaged 78.6 min. In south San Francisco Bay, a total of 52 tows was observed on two vessels from April 26, 1989 to September 4, 1990 (APPENDIX B). Tows totalled 43.8 hr and ranged in duration from 20 to 85 min, with a mean of 50.6 min. A total of eleven tows was observed in Carquinez Strait on two vessels in September 1989 and April 1990 (APPENDIX C); total tow time was 10.4 hr. Tows ranged in duration from 35 to 90 min and averaged 56.8 min.

Total Fishing Effort

In San Pablo Bay, total effort for the 13-month study period was 3157 hr, and monthly effort ranged from 164 hr in September 1989 to 344 hr in May 1990 (Table 1). Average monthly effort was 243 hr. Seven vessels fished during the study period, although not all vessels fished each month. In south San Francisco Bay, a maximum of seven vessels fished for a total of 3707 hr during the 18-month study period (Table 2). Monthly effort ranged from 133 hr (August 1989) to 346 hr (April 1989) and averaged 206 hr. During the September 1989 to September 1990 study period in Carquinez Strait, total effort from three vessels was 548 hr, and averaged 68.5 hr per month (Table 3). No effort occurred from May to September 1990.

Total Striped Bass Catch Estimate

San Pablo Bay-Observed Vessel

A total of 2847 YOY bass was caught in 86 observed tows in

TABLE 1. Number of Bay Shrimp Vessels and Total Effort in San Pablo Bay, September 1989 to September 1990.

Month and year	Number of vessels	Effort (hr)		Total
		Observed vessel	Other vessels	
Sep 89	3	93	71	164
Oct 89	3	69	100	169
Nov 89	3	101	97	198
Dec 89	3	126	96	222
Jan 90	4	114	114	228
Feb 90	4	97	138	235
Mar 90	5	89	243	332
Apr 90	6	110	228	338
May 90	5	129	215	344
Jun 90	5	86	179	265
Jul 90	4	89	155	244
Aug 90	4	76	139	215
Sep 90	5	82	121	203
	Grand Total	1261	1896	3157

TABLE 2. Number of Bay Shrimp Vessels and Total Effort in Southern San Francisco Bay, April 1989 to September 1990.

Month and year	Number of vessels	Total effort (hr)	Month and year	Number of vessels	Total effort (hr)
Apr 89	7	346	Jan 90	6	191
May 89	7	240	Feb 90	6	243
Jun 89	7	180	Mar 90	6	328
Jul 89	4	141	Apr 90	6	252
Aug 89	6	133	May 90	6	193
Sep 89	6	154	Jun 90	6	201
Oct 89	6	204	Jul 90	6	157
Nov 89	6	248	Aug 90	6	138
Dec 89	6	197	Sep 90	7	161
Grand Total					3707

TABLE 3. Number of Bay Shrimp Vessels and Total Effort in Carquinez Strait, September 1989 to September 1990.

Month and year	Number of vessels	Total effort (hr)	Month and year	Number of vessels	Total effort (hr)	
Sep 89	3	133	Apr 90	2	119	
Oct 89	3	95	May 90	1	4	
Nov 89	0	0	Jun 90	0	0	
Dec 89	1	30	Jul 90	0	0	
Jan 90	1	30	Aug 90	0	0	
Feb 90	1	30	Sep 90	0	0	
Mar 90	3	111	Grand Total			552

San Pablo Bay (Table 4). From September 1989 to early March 1990, the 1989 year class of YOY bass was moderately abundant and CPH averaged 20.2. From late March to early July 1990, the 1989 year class was relatively scarce and CPH averaged only 1.5. From late July to the end of September 1990, the 1990 year class of YOY bass made a strong showing, with an average CPH of 56.7. Monthly mean CPH of YOYs ranged from 0.3 in May and early July 1990 to 83.9 in August 1990. Total estimated catch of YOY bass on the observed vessel during the study period was 24,956.

A total of 118 older bass was taken in the 86 tows (Table 5). Monthly CPH ranged from 0.0 in early July 1990 to 2.5 in December 1989. Estimated total catch on the observed vessel during the study period was 1342.

Of 37 fish species observed in trawl catches, striped bass ranked fourth in abundance after yellowfin goby, staghorn sculpin, and northern anchovy, Engraulis mordax.

San Pablo Bay-Other Vessels

The estimated monthly CPH on unobserved vessels, adjusted by net dimension scaling factors, ranged from 0.2 to 50.3 for YOY bass and 0.0 to 2.1 for older bass (Table 6). Total estimated catch on all unobserved vessels was 26,452 YOY and 1398 older bass.

The estimated monthly CPH on unobserved vessels, adjusted by shrimp CPH scaling factors, ranged from 0.2 to 35.6 for YOYs and 0.0 to 2.3 for older bass (Table 7). Total estimated catch on all unobserved vessels with this alternate method was 18,489 YOY and 983 older bass. Thus, the total estimated bass

TABLE 4. Estimated Total Catch of Young-of-the-year (YOY) Striped Bass on Observed Vessel in San Pablo Bay, September 1989 to September 1990.

Month and year	No. of observed tows	Total catch YOY	Total tow hr	Catch per hr	Total effort (hr)	Estimated total catch
Sep 89	5	123	6.2	19.8	93	1841
Oct 89	7	148	6.2	23.9	69	1649
Nov 89	5	43	6.7	6.4	101	646
Dec 89	4	105	6.7	15.7	126	1978
Jan 90	7	270	10.4	26.0	114	2964
Feb 90	5	124	6.9	18.0	97	1746
Mar 90						
(1-15)	2	123	3.2	38.4	45	1728
(16-31)	5	16	5.1	3.1	44	136
Apr 90	5	28	7.3	3.8	110	418
May 90	7	3	11.7	0.3	129	39
Jun 90	5	3	6.6	0.5	86	43
Jul 90						
(1-15)	2	1	2.9	0.3	44	13
(16-31)	6	435	7.7	56.5	45	2542
Aug 90	10	948	11.3	83.9	76	6376
Sep 90	11	477	13.8	34.6	82	2837
Grand Total	86	2847	112.7		1261	24,956

TABLE 5. Estimated Total Catch of Juvenile and Adult Striped Bass on Observed Vessel in San Pablo Bay, September 1989 to September 1990.

Month and year	No. of observed tows	Total catch	Total tow hr	Catch per hr	Total effort (hr)	Estimated total catch
Sep 89	5	5	6.2	0.8	93	74
Oct 89	7	3	6.2	0.5	69	34
Nov 89	5	12	6.7	1.8	101	182
Dec 89	4	17	6.7	2.5	126	315
Jan 90	7	16	10.4	1.5	114	171
Feb 90	5	4	6.9	0.4	97	58
Mar 90						
(1-15)	2	7	3.2	2.2	45	99
(16-31)	5	10	5.1	1.7	44	75
Apr 90	5	2	7.3	0.3	110	33
May 90	7	1	11.7	0.1	129	13
Jun 90	5	6	6.6	0.9	86	77
Jul 90						
(1-15)	2	0	2.9	0.0	44	0
(16-31)	6	11	7.7	1.4	45	63
Aug 90	10	14	11.3	1.2	76	91
Sep 90	11	10	13.8	0.7	82	57
Grand Total	86	118	112.7		1261	1342

TABLE 6. Estimated Total Catch of YOY, Juvenile, and Adult Striped Bass on Unobserved Bay Shrimp Vessels in San Pablo Bay, Adjusted by Net Dimensions, September 1989 to September 1990.

Month and year	Adjusted CPH		Total effort (hr)	Total catch	
	YOY	Other bass		YOY	Other bass
Sep 89	16.6	0.7	71	1179	50
Oct 89	19.8	0.4	100	1980	40
Nov 89	5.6	1.5	97	543	146
Dec 89	13.0	2.1	96	1248	202
Jan 90	21.3	1.2	114	2428	137
Feb 90	14.8	0.5	138	2042	69
Mar 90					
(1-15)	31.1	1.8	122	3794	220
(16-31)	2.2	1.4	121	266	169
Apr 90	3.1	0.2	228	707	46
May 90	0.2	0.1	215	43	22
Jun 90	0.3	0.5	179	54	90
Jul 90					
(1-15)	0.2	0.0	77	15	0
(16-31)	33.9	0.8	78	2644	62
Aug 90	50.3	0.7	139	6992	97
Sep 90	20.8	0.4	121	2517	48
Grand Total				26,452	1398

TABLE 7. Estimated Total Catch of YOY, Juvenile, and Adult Striped Bass on Unobserved Bay Shrimp Vessels in San Pablo Bay, Adjusted by Shrimp Catch, September 1989 to September 1990.

Month and year	Adjusted CPH		Total effort (hr)	Total Catch	
	YOY	Other bass		YOY	Other bass
Sep 89	13.2	0.5	71	937	36
Oct 89	9.5	0.2	100	950	20
Nov 89	3.4	1.0	97	330	97
Dec 89	14.3	2.3	96	1373	221
Jan 90	14.1	0.8	114	1607	91
Feb 90	9.2	0.3	138	1270	41
Mar 90					
(1-15)	16.5	0.9	122	2013	110
(16-31)	1.2	0.7	121	145	85
Apr 90	1.8	0.1	228	410	23
May 90	0.3	0.1	215	64	22
Jun 90	0.2	0.4	179	36	72
Jul 90					
(1-15)	0.2	0.0	77	15	0
(16-31)	22.3	0.6	78	1739	47
Aug 90	35.6	0.5	139	4948	70
Sep 90	22.0	0.4	121	2652	48
Grand Total				18,489	983

catch on all vessels in San Pablo Bay during the study period ranged from 43,445 to 51,408 for YOYs and from 2325 to 2740 for older bass. *The lower number in each range corresponds to the estimated bass catch adjusted by shrimp catch; the higher number corresponds to the estimated bass catch adjusted by net dimensions.

South San Francisco Bay

In 52 observed tows in south San Francisco Bay, mean CPH for YOY and older bass was 0.16 (n = 7) and 0.21 (n = 9), respectively. Of 38 fish species observed in trawl catches, striped bass ranked 20th in abundance. Total estimated catch for the 18-month study period was 593 YOY and 778 older bass, which was relatively low when compared with San Pablo Bay.

Carquinez Strait

In eleven observed tows in Carquinez Strait, only one YOY and one older bass were taken. Mean CPH for each group was 0.10. Striped bass ranked ninth in abundance of 13 fish species occurring in observed tows. The total estimated catch for the 13-month study period of 55 YOY and 55 older bass was insignificant when compared with San Pablo Bay.

Length Frequency Distribution of Striped Bass in San Pablo Bay

The 1989 year class of YOY bass showed a fairly similar length frequency distribution from September 1989 to March 1990. Most YOYs ranged from 70 to 130 mm during this period (Figure 2) and monthly mean length ranged from 91.0 to 104.8 mm until late March (Table 8). As this year class became scarce in trawl

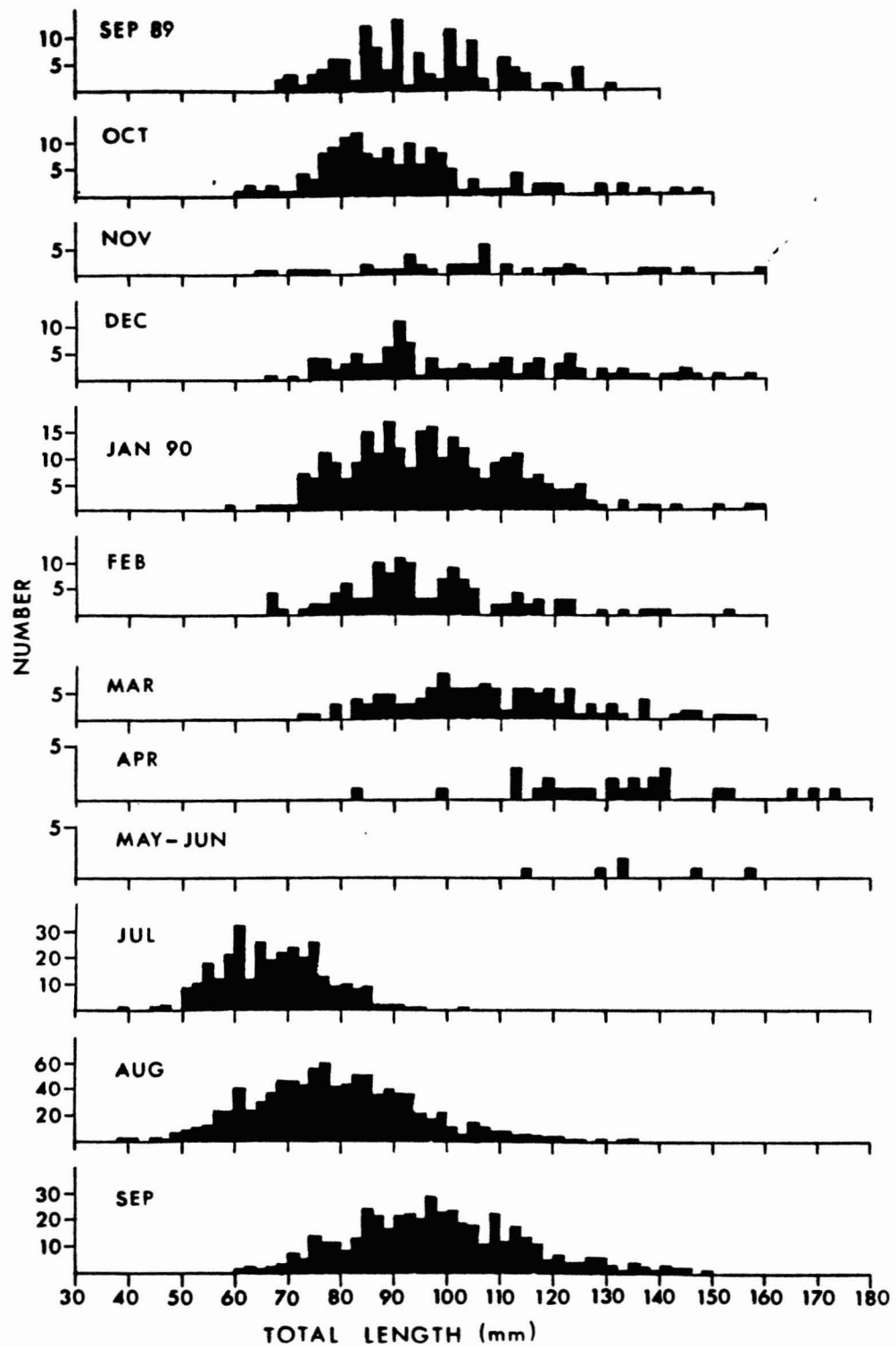


Figure 2. Length frequency distribution (2-mm intervals) of young-of-the-year (YOY) striped bass caught in observed bay shrimp trawls by month, San Pablo Bay, September 1989 to September 1990.

TABLE 8. Mean Total Length of YOY Striped Bass and Percent Mortality by Group and Month of All Striped Bass in Observed Bay Shrimp Tows, San Pablo Bay, September 1989 to September 1990.

Month and year	Mean TL (mm) YOY	Number of YOY	Percent mortality YOY	Number of non-YOY bass	Percent mortality non-YOY
Sep 89	93.8	123	11.4	5	0.0
Oct 89	91.0	148	15.5 ^{1/}	3	0.0
Nov 89	103.1	43	0.0	12	0.0
Dec 89	101.9	105	1.6	17	0.0
Jan 90	97.3	270	4.1	16	0.0
Feb 90	96.2	124	4.0	4	0.0
Mar 90					
(1-15)	104.8	123	4.9	7	0.0
(16-31)	123.6	16	0.0	10	10.0
Apr 90	130.9	28	0.0	2	0.0
May 90	140.7	3	0.0	1	0.0
Jun 90	129.7	3	0.0	6	33.3
Jul 90					
(1-15)	60.0	1	100.0	0	0.0
(16-31)	67.3	435 ^{2/}	44.8	11	0.0
Aug 90	79.2	948	51.3 ^{3/}	14	0.0
Sep 90	98.3	477 ^{4/}	11.9	10	0.0

^{1/}includes anomalous tow with clams

^{2/}only 311 were measured

^{3/}includes two anomalous tows with clams

^{4/}only 452 were measured

catches, only the larger YOYs remained and monthly mean length increased to a range of 124 to 141 mm.

The first 1990 year class striped bass appeared in trawl catches in early July. Growth, as inferred from monthly length histograms, was rapid from July to September (Figure 2). Monthly mean length increased from 67.3 mm in July to 98.3 mm in September (Table 8). By September, the 1990 year class had a length frequency distribution similar to that of the previous year class 1 year ago.

Ninety-one percent of the 118 older bass caught in observed tows were between 170 and 300 mm. The two largest bass measured 405 and 414 mm.

Mortality Rate of Striped Bass on Observed Vessel in San Pablo Bay

Monthly mortality rates of YOY bass on the observed vessel ranged from 0.0% to 51.3% when sample size was greater than three (Table 8). The mortality rate for the 1989 year class was highest in October 1989, at 15.5%. However, this included an atypical tow in which 75 lb. of the Asian clam, Potamocorbula amurensis, were also caught. The clam catch suffocated most small bass in the codend. Excluding this tow, the mortality rate for October was 3.1%. The 1989 year class mortality rate remained low from November 1989 to June 1990. In July the 1990 year class appeared and mortality rate of these smaller bass was 44.8% for the last half of the month. The highest observed monthly mortality rate (August) of 51.3% included two atypical tows in which 300 lbs. and 10 lbs. of Asian clams were caught. Excluding these tows, the August mortality rate was 31.6%. By September, the

mortality rate had decreased to 11.9%, similar to the previous year.

Only three out of 118 older bass were dead in observed tows, for a total mortality rate of 2.5%.

Total Striped Bass Mortality Estimate

San Pablo Bay- Observed vessel

The estimated total mortalities of YOY and older bass on the observed vessel during the study period were 5536 and 33, respectively (Table 9). This represents a total mortality of 22.2% and 2.5%, respectively, of the estimated catch of YOY and older bass on the observed vessel.

San Pablo Bay- Other vessels

Applying the monthly mortality rate from the observed vessel to adjusted fishing effort from other vessels yielded an estimated total mortality of YOY bass that ranged from 4140 to 5916 (Table 10); the total estimated mortality for older bass ranged from 38 to 47. Thus, for all bay shrimp vessels in San Pablo Bay, total mortality estimates ranged from 9676 to 11,452 for YOY and from 71 to 80 for older bass.

South San Francisco Bay

There were no mortalities of YOY or older bass in observed shrimp tows in south San Francisco Bay. This was, in part, due to the relative scarcity of bass in this portion of the San Francisco estuarine complex. Thus the estimated total mortality during the study period was zero.

TABLE 9. Estimated Total Mortality of YOY, Juvenile and Adult Striped Bass on Observed Bay Shrimp Vessel, San Pablo Bay, September 1989 to September 1990.

Month and year	Estimated catch		Total mortality	
	YOY	Other bass	YOY	Other bass
Sep 89	1841	74	210	0
Oct 89	1649	34	256	0
Nov 89	646	182	0	0
Dec 89	1978	315	32	0
Jan 90	2964	171	122	0
Feb 90	1746	58	70	0
Mar 90				
(1-15)	1728	99	85	0
(16-31)	119	75	0	7
Apr 90	418	33	0	0
May 90	39	13	0	0
Jun 90	43	77	0	26
Jul 90				
(1-15)	13	0	13	0
(16-31)	2542	63	1139	0
Aug 90	6376	91	3271	0
Sep 90	2837	57	338	0
Total	24,939	1342	5536	33

TABLE 10. Estimated Total Mortality of YOY, Juvenile, and Adult Striped Bass on Unobserved Bay Shrimp Vessels, San Pablo Bay, September 1989 to September 1990.

Month and year	Estimated catch				Total mortality			
	(net adjusted)		(shrimp adjusted)		(net adjusted)		(shrimp adjusted)	
	YOY	Other bass	YOY	Other bass	YOY	Other bass	YOY	Other bass
Sep 89	1179	50	937	36	134	0	107	0
Oct 89	1980	40	950	20	307	0	147	0
Nov 89	543	146	330	97	0	0	0	0
Dec 89	1248	202	1373	221	20	0	22	0
Jan 90	2428	137	1607	91	100	0	66	0
Feb 90	2042	69	1270	41	82	0	51	0
Mar 90								
(1-15)	3794	220	2013	110	186	0	99	0
(16-31)	266	169	145	85	0	17	0	14
Apr 90	707	46	410	23	0	0	0	0
May 90	43	22	64	22	0	0	0	0
Jun 90	54	90	36	72	0	30	0	24
Jul 9								
(1-15)	15	0	15	0	15	0	15	0
(16-31)	2644	62	1739	47	1185	0	779	0
Aug 90	6992	97	4948	70	3587	0	2538	0
Sep 90	2517	48	2652	48	300	0	316	0
Total	26,452	1398	18,849	983	5916	47	4140	38

Carquinez Strait

The one YOY and one older bass taken on observed tows were dead. This complete mortality resulted in a total mortality estimate of 55 YOY and 55 older bass in Carquinez Strait during the study period.

Factors Influencing Catch of YOY Striped Bass in San Pablo Bay

Observed tows were partitioned by time of day (day, sunrise, or night) and by tide (ebb and low tides considered as low, flood and high tides considered as high), to evaluate the influence of these factors on bass mortality. Fifty-seven tows were observed during the time period when the 1989 year class of YOY bass was present. Mean CPH of YOYs was highest for tows conducted during sunrise at low tide and lowest for night tows occurring during high tide (Figure 3). However, only nine tows occurred in these two groups. Twenty-nine tows were observed during the period that the 1990 year class was present. The mean CPH for that year class was strongly influenced by both time of day and tide. Highest mean CPH occurred at night during low tide (Figure 4); in general, night tows caught almost 3.5 times as many bass per hour as day tows. Tows during low tide caught more than twice as many YOYs per hour as tows during high tide.

Factors Influencing Mortality Rate of YOY Striped Bass in San Pablo Bay

Factors tested for influence on mortality rate were, in order of absolute Pearson correlation coefficient, mean YOY length, CPH of YOYs, CPH of shrimp, and tow duration (-0.58, 0.32, 0.22, and 0.05). The first two were significant at

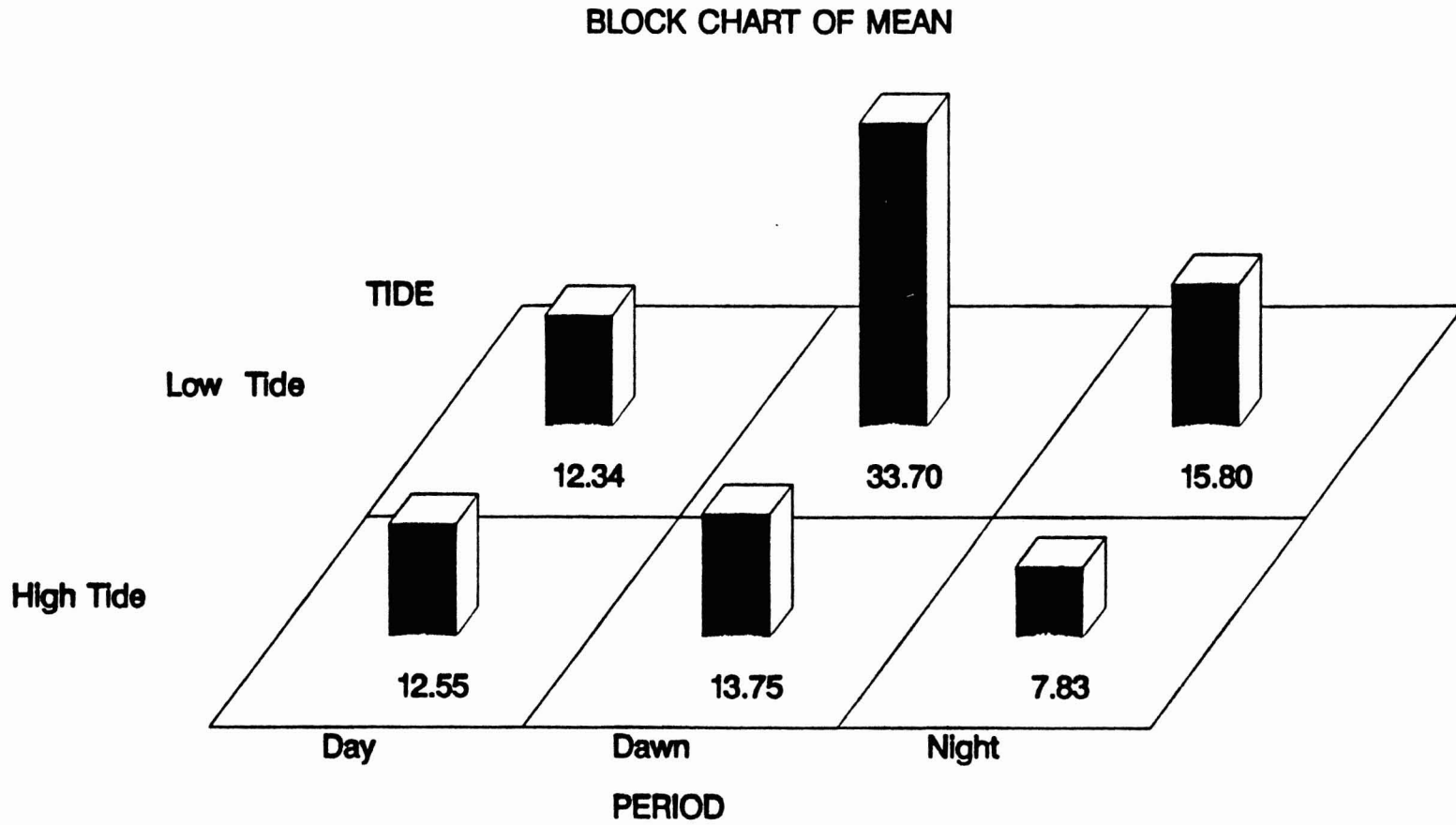
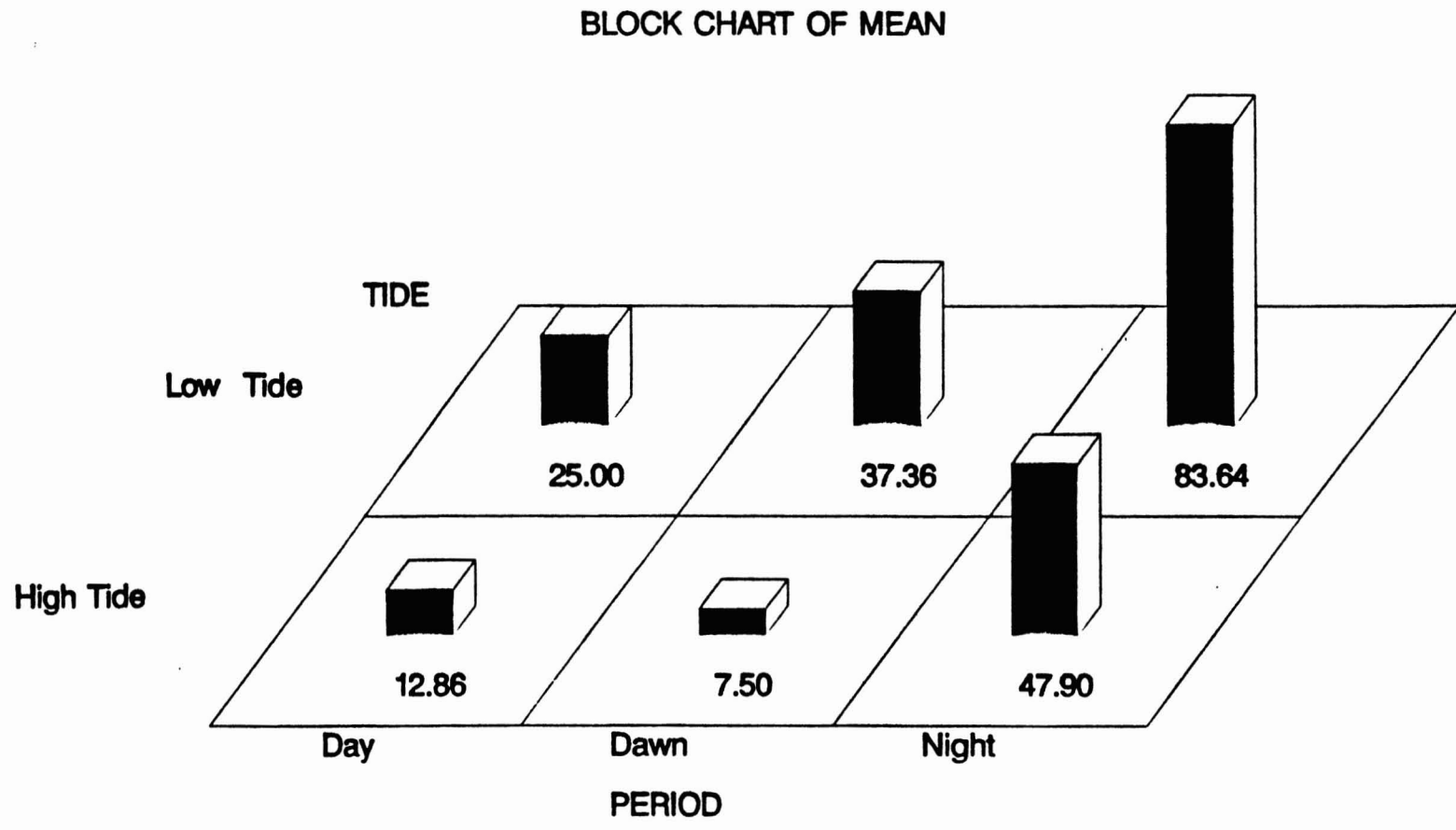


Figure 3. Mean catch per hour of YOY striped bass, 1989 year class, in bay shrimp tows in San Pablo Bay, September 1989 to June 1990, by tide and period.



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Figure 4. Mean catch per hour of YOY striped bass, 1990 year class, in bay shrimp tows in San Pablo Bay, July to September 1990.

$p = 0.05$. Another factor which could affect bass mortality is the total weight or volume of other incidentally caught fish and invertebrates in the shrimp trawl. This was highly variable and was not analyzed in this study.

When all YOY bass caught in San Pablo Bay were pooled by 10-mm TL intervals, an inverse relationship was evident between length and percent mortality (Figure 5). Mortality rate for 50-59 mm bass was 64.8%, while that of 90-99 mm bass was 7.9%. Although sample size was small, mortality rates were below 3.0% for all size groups larger than 100 mm. Eighty-five percent of all dead YOY bass in observed tows were less than 90 mm.

The low correlation of mortality rate and tow duration, when all tows are considered, may be due to the relatively low mortality of the 1989 year class in the first 57 observed tows. When tows with more than 10 YOYs from July and August 1990 (the time of year when the 1990 year class was most vulnerable to trawling) were selected, the Pearson correlation coefficient increased to 0.39, with $p = 0.21$. When a further subset ($n = 8$) was examined in which number of YOYs per tow exceeded 25, the coefficient increased to 0.72 and was significant at $p = 0.05$. Thus, mortality rate varied directly with tow duration for relatively large catches ($n > 25$) in July and August, when YOY bass averaged 80 mm or less in length.

Observations of Avian Predators and Fish Return Procedures

Gulls of the genus Larus were usually present during daylight trawling and sorting operations. During the sorting process, they were usually successful at consuming any dead or

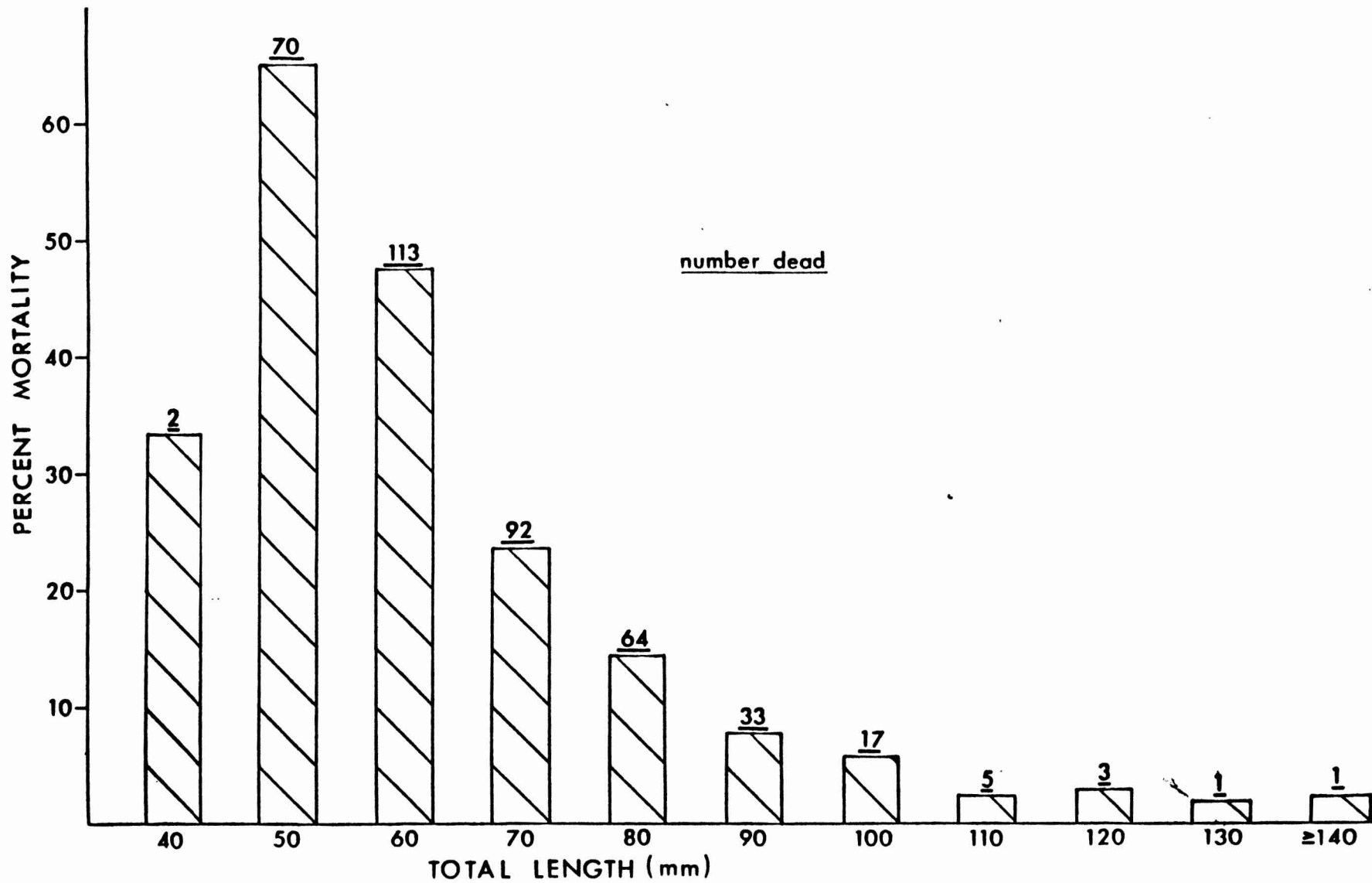


Figure 5. Mortality (10-mm total length intervals) of YOY striped bass caught in observed bay shrimp trawls, San Pablo Bay, September 1989 to September 1990.

stunned fish that were discarded by the crew. However, when care was used in returning live bass to the water, gull predation was minimal. This could be accomplished simply by dropping the bass adjacent to the vessel rather than tossing them farther away. A healthy bass would immediately swim away from the surface. Alternatively, if all YOY bass were temporarily retained in buckets of bay water during sorting, as in this study, and returned as a group promptly, avian predation was avoided. Gulls left the immediate area when sorting was completed.

DISCUSSION

Smith (1976) observed 61 bay shrimp tows in Suisun Bay and 30 tows in San Pablo Bay from July 1974 to January 1975. Monthly CPH of all bass ranged from 27.2 in July to 278.8 in January in Suisun Bay and from 0.0 in July and August to 86.0 in December in San Pablo Bay. Ninety-five percent of all sampled bass were taken in Suisun Bay. Monthly mortality rates in Suisun Bay were highest in July and August (similar to this study in San Pablo Bay) at 70.6% and 52.8%, respectively. Bass were also smallest during this period, with mean lengths ranging from 43 to 85 mm. Percent mortality in Suisun Bay declined to 24.3% in September and reached a low of 2.1% in January.

Only 615 bass were taken in San Pablo Bay during Smith's study, and none were taken in July and August. In 1974-75 fishing effort in San Pablo Bay occurred primarily in the southern and eastern portions. Striped bass may be more abundant in the northwest portion of the bay where the present fishery exists. The highest monthly mortality rate in Smith's study was

10.9%, in December. Mean total length of bass in each San Pablo Bay tow was at least 100 mm and mortality was relatively low for these larger fish (mean length of all fish was 120 mm). Smith stated that bass length was the most important factor affecting by-catch mortality.

In this study, the most critical time period for YOY bass relative to bay shrimp trawling operations was the 6-wk period from mid-July to the end of August. Eighty-five percent of all YOY mortalities during the study occurred then. Mean length of all observed bass was also smallest during July and August.

Smith (1976) recorded an average duration of 41 min for observed tows in San Pablo Bay from October to January, with a corresponding total mortality of 7.4%. For the same period in this study, observed tows averaged 78 min and total mortality was 6.4%. Neither this study nor Smith's found a significant correlation between tow duration and bass mortality when all tows were considered. However, this study suggests that longer tows with relatively large bycatches in July and August yielded higher mortalities for small YOY bass. The regression for the eight-tow subset ($n > 25$):

$$\text{Percent dead} = -12.173 + 0.67 \text{ tow duration (min)}$$

predicts that a 90-min tow would cause 48% mortality, while a 45-min tow would cause only 18% mortality.

The presence of the Asian clam has created a new hazard for bay shrimp trawling. This accidentally introduced bivalve has experienced a tremendous population explosion since 1986 and is now extremely abundant in many shallow areas of the bay complex

(Carlton et al. 1990). Three atypical tows in San Pablo Bay, in which clams were unintentionally caught, resulted in bass mortality rates of 95, 88, and 75% - the three highest rates per tow during this study. Fortunately, care during trawling operations can prevent the net from digging into the substrate and avoid capture of any clams.

Smith (1976) estimated that bay shrimp fishers caught approximately 1.8% of the total young bass population in the bay complex and killed approximately 0.2% during his 6-month study period. Striped bass abundance indices showed an estimated population of 5.1 million YOYs in 1989 and 4.3 million YOYs in 1990 (Katie Perry, Dept. Fish and Game, Stockton, pers. commun.). Using an average of 4.7 million YOYs, approximately 0.2% of the population was estimated to have been killed by shrimp fishers during this 13-month study.

RECOMMENDATIONS

The incidental catch and associated mortality of striped bass in the bay shrimp fishery was low or insignificant in south San Francisco Bay and Carquinez Strait during this study. Regulation changes in 1985 eliminated shrimp trawling in Suisun Bay east of Point Edith (Figure 1), thus significantly reducing the potential impact to YOY bass. For the three to six vessels that fished in northwestern San Pablo Bay, the by-catch of bass, occasionally in numbers exceeding 100 per tow, appeared to be unavoidable if live bay shrimp are to be provided year-round to sport fishers.

Although tide and period were shown to have an effect on YOY

bass catch, prohibiting fishing during low tides at night would have a significant impact on the fishery. Market conditions require shrimp to be transported to bait shops in the morning, and shrimp are generally caught between 0300 and 1000 hr. Every second week, low tides occur during this period.

The potential for YOY mortality due to gull predation exists during any daytime sorting operation, since incidentally caught fish are usually thrown into the water by hand. Care in returning bass to the water will minimize this potential. A sluice or pipe return system has been suggested for bass by United Anglers of California, a sportfishing organization. However beneficial or practical this may seem, it would be difficult to enforce.

The presence of the Asian clam on trawling grounds requires particular attention by shrimpers to insure that the trawl does not dig into the bottom and take clams in quantity. This will avoid unusually high mortality rates for bass.

In the statistical analysis, mean length of bass and tow duration were two important factors relating to mortality of YOY bass in shrimp tows. Since the critical time period when bass are smallest and most vulnerable on the shrimping grounds was less than 2 months in this study, it would be beneficial to voluntarily reduce trawling effort then. It is important to realize that this study occurred during the fourth year of a drought in central California. YOY bass will be more abundant in San Pablo Bay during normal and wet years (D. Stevens, CDFG, Stockton, pers. comm.). With occasional monitoring by CDFG observers during the critical summer period, the appearance of small YOYs on the shrimping grounds each year could be

documented. Recommendations or regulations could then be made to reduce effort accordingly.

The strongest and most obvious recommendation would be to reduce tow duration during the critical summer period. During July and August observed tows averaged 73 min in San Pablo Bay. Although difficult to enforce, it would be beneficial to reduce tows to a maximum of 60 min and preferably to 45 min to lower the mortality rate. It is in the best interests of all bay shrimp fishers to minimize mortality to bass for the obvious reason that the bait they provide is used occasionally by bass sport fishers.

A recommendation with significant fishery impacts would be to implement a 2-month closure in San Pablo Bay during July and August to protect YOY bass. This would have a financial impact on several of the permittees whose primary source of annual income is the bay shrimp fishery.

LITERATURE CITED

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- Smith, Gary E. 1976. Impact of a commercial shrimp fishery on young striped bass (Morone saxatilis) in the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game. Anadramous Fisheries Branch. Admin. Rep. No. 76-11: 1-20.

APPENDIX A. Summary of Observed Bay Shrimp Tows in San Pablo Bay, September 1989 to September 1990.

Date	Tow no.	Tow length (min)	Period ¹	Tide ²	Number of striped bass		Mean TL(mm)	Pounds shrimp
					YOY	Other	YOY	
7 Sep 89	1	70	3	1	13	1	88.8	50
7 Sep 89	2	30	2	1	17	0	88.9	15
7 Sep 89	3	60	1	2	33	4	105.5	80
30 Sep 89	4	120	2	2	38	0	88.8	50
30 Sep 89	5	90	1	1	22	1	91.7	40
25 Oct 89	6 ³	100	3	2	20	1	88.6	5
25 Oct 89	7	30	2	1	27	0	90.0	10
25 Oct 89	8	45	1	1	24	1	94.1	10
25 Oct 89	9	45	1	1	5	1	108.8	10
27 Oct 89	10	60	3	2	37	0	89.8	5
27 Oct 89	11	45	3	1	19	0	84.5	5
27 Oct 89	12	45	2	1	16	0	90.9	5
6 Nov 89	13	75	2	1	7	0	106.0	25
6 Nov 89	14	75	1	1	11	1	93.4	30
6 Nov 89	15	60	1	2	9	3	92.7	15
20 Nov 89	16	90	2	1	5	1	117.0	30
20 Nov 89	17	105	1	2	11	7	113.3	20
6 Dec 89	18	100	3	1	21	3	97.8	25
6 Dec 89	19	105	1	2	21	6	110.4	40
19 Dec 89	20	115	2	1	26	2	102.0	45
19 Dec 89	21	85	1	2	37	6	99.5	40
2 Jan 90	22	110	3	2	7	1	93.3	30
2 Jan 90	23	80	1	2	25	1	96.4	30
17 Jan 90	24	105	2	2	82	3	96.5	60
17 Jan 90	25	60	1	2	58	6	99.1	70
26 Jan 90	26	110	3	2	47	2	94.2	50
26 Jan 90	27	85	2	1	32	2	95.3	60
26 Jan 90	28	75	1	1	19	1	109.0	35
9 Feb 90	29	85	3	2	32	0	92.3	20
9 Feb 90	30	80	2	2	47	1	97.1	20
9 Feb 90	31	75	1	1	30	1	95.3	25
22 Feb 90	32	95	3	1	8	0	103.4	45
22 Feb 90	33	80	2	1	7	2	103.6	45
8 Mar 90	34	120	2	1	81	5	105.3	20
8 Mar 90	35	75	1	1	42	2	103.9	15
21 Mar 90	36	65	2	1	5	5	127.2	25
21 Mar 90	37	115	1	1	6	2	132.3	15
28 Mar 90	38	35	1	2	3	2	107.0	8
28 Mar 90	39	30	1	2	0	0	-	4
28 Mar 90	40	60	1	2	2	1	113.0	8
11 Apr 90	41	70	3	2	5	0	127.4	20
11 Apr 90	42	70	1	2	10	0	131.6	23
11 Apr 90	43	135	1	2	13	2	131.8	30
30 Apr 90	44	90	2	1	0	0	-	12
30 Apr 90	45	75	1	2	0	0	-	15
3 May 90	46	110	2	1	1	1	156.0	8
3 May 90	47	65	1	1	0	0	-	5
3 May 90	48	85	1	1	0	0	-	7
17 May 90	49	120	2	1	0	0	-	40

APPENDIX A. Summary- San Pablo Bay Shrimp Tows (continued).

Date	Tow no.	Tow length (min)	Period ^{1/}	Tide ^{2/}	Number of striped bass		Mean TL(mm)	Pounds shrimp
					YOY	Other	YOY	
17 May 90	50	110	1	2	0	0	-	40
30 May 90	51	85	3	1	1	0	133.0	25
30 May 90	52	130	1	2	1	0	133.0	30
18 Jun 90	53	80	3	2	2	5	121.0	25
18 Jun 90	54	65	2	1	1	1	147.0	20
18 Jun 90	55	60	1	1	0	0	-	17
28 Jun 90	56	80	3	1	0	0	-	65
28 Jun 90	57	110	2	1	0	0	-	80
11 Jul 90	58	115	3	1	0	0	-	80
11 Jul 90	59	60	3	2	1	0	60.0	50
17 Jul 90	60	75	3	2	209	7	64.9	25
17 Jul 90	61	100	3	2	124	2	- ^{4/}	21
17 Jul 90	62	60	1	1	13	0	62.5	16
26 Jul 90	63	80	3	1	16	1	73.4	25
26 Jul 90	64	70	3	1	47	0	72.2	35
26 Jul 90	65	80	2	2	26	1	74.7	75
1 Aug 90	66	60	3	2	155	3	73.9	25
1 Aug 90	67	70	2	2	161	3	72.8	30
1 Aug 90	68	60	1	1	8	2	76.2	20
1 Aug 90	69	55	1	1	7	1	74.9	15
14 Aug 90	70 ^{5/}	90	3	2	223	4	78.0	45
14 Aug 90	71	70	3	1	91	1	81.7	30
14 Aug 90	72	55	3	1	115	2	79.7	25
28 Aug 90	73 ^{6/}	80	3	1	161	3	86.4	30
28 Aug 90	74	60	3	1	17	0	91.7	30
28 Aug 90	75	80	2	1	10	2	94.7	30
6 Sep 90	76	60	3	2	32	0	90.8	12
6 Sep 90	77	55	3	2	42	0	94.6	18
6 Sep 90	78	55	2	2	26	0	97.7	25
21 Sep 90	79	50	3	2	148	2	98.8	25
21 Sep 90	80	70	2	2	80	1	103.5	41
21 Sep 90	81	60	1	2	25	3	104.6	35
26 Sep 90	82	80	3	1	9	0	104.2	15
26 Sep 90	83	100	1	1	38	1	95.6	6
27 Sep 90	84	145	3	2	39	1	94.0	40
27 Sep 90	85	55	3	1	13	1	98.5	20
27 Sep 90	86 ^{7/}	90	3	1	25	1	-	20

^{1/}Period: 1-day, entire tow occurred during daylight hours.
 2-sunrise, sunrise occurred during tow.
 3-night, entire tow occurred between sunset and sunrise.

^{2/}Tide: 1-midpoint of tow occurred during flood or high tide.
 2-midpoint of tow occurred during ebb or low tide.

^{3/}Anomalous tow, contained 75 pounds of clams.

^{4/}Striped bass not measured

^{5/}Anomalous tow, contained 300 pounds of clams.

^{6/}Anomalous tow, contained 10 pounds of clams.

^{7/}Striped bass not measured

APPENDIX B. Summary of Observed Bay Shrimp Tows in South San Francisco Bay, April 1989 to September 1990.

Date	Tow length (min)	Period ^{1'}	Tide ^{2'}	Number of striped bass		Pounds shrimp
				YOY	Other	
26 Apr 89	75	3	1	0	0	75
26 Apr 89	60	3	2	2	0	80
18 May 89	70	1	2	0	0	10
18 May 89	50	1	1	0	0	35
18 May 89	60	1	1	0	0	35
15 Jun 89	70	2	2	0	0	105
15 Jun 89	70	1	2	0	0	85
15 Jun 89	75	1	1	0	0	75
27 Jul 89	60	1	1	0	0	25
27 Jul 89	65	1	1	0	0	15
27 Jul 89	55	1	1	0	0	10
24 Aug 89	60	1	1	0	0	35
24 Aug 89	55	1	1	0	0	25
22 Sep 89	60	2	1	0	0	75
22 Sep 89	60	1	1	0	0	75
22 Sep 89	65	1	1	0	0	105
16 Nov 89	60	1	2	0	0	70
16 Nov 89	40	1	2	0	0	50
14 Dec 89	75	3	2	0	0	50
14 Dec 89	85	1	2	1	0	60
14 Dec 89	85	1	2	1	2	45
14 Dec 89	45	1	1	0	0	20
24 Jan 90	50	1	1	0	0	65
24 Jan 90	40	1	1	0	0	60
24 Jan 90	30	1	1	0	0	45
24 Jan 90	30	1	1	0	0	25
15 Feb 90	30	3	1	0	0	15
15 Feb 90	70	3	1	0	0	35
15 Feb 90	60	2	2	0	0	45
15 Feb 90	20	1	2	0	0	10
13 Mar 90	25	1	2	0	0	3
13 Mar 90	20	1	2	0	0	2
13 Mar 90	50	1	2	1	0	4
13 Mar 90	40	1	2	1	0	5
13 Mar 90	40	1	1	1	0	12
13 Mar 90	35	1	1	0	0	10
6 Apr 90	40	1	1	0	0	25
6 Apr 90	75	1	1	0	0	45
6 Apr 90	30	1	1	0	0	25
6 Apr 90	90	1	1	0	1	65
6 Apr 90	45	1	2	0	0	30
11 May 90	25	1	2	0	2	40
11 May 90	40	1	2	0	0	50
27 Jun 90	45	3	1	0	0	30
27 Jun 90	50	2	1	0	0	70
27 Jun 90	30	1	2	0	0	35
25 Jul 90	40	1	2	0	0	90
16 Aug 90	40	1	1	0	0	70
16 Aug 90	50	1	1	0	0	90

APPENDIX B. Summary- South San Francisco Bay Shrimp Tows
(continued).

Date	Tow length (min)	Period	Tide	Number of striped bass		Pounds shrimp
				YOY	Other	
4 Sep 90	25	1	2	0	0	20
4 Sep 90	20	1	2	0	0	35
4 Sep 90	45	1	2	0	1	75

¹Period: 1-day, entire tow occurred in daylight hours;
2-sunrise, sunrise occurred during tow.
3-night, entire tow occurred between sunset and sunrise.

²Tide: 1-midpoint of tow occurred during flood or high tide.
2-midpoint of tow occurred during ebb or low tide.

APPENDIX C. Summary of Observed Bay Shrimp Tows in Carquinez Strait, September 1989 and April 1990.

Date	Tow length (min)	Period ^{1/}	Tide ^{2/}	Number of		Pounds shrimp
				striped bass YOY	Other	
14 Sep 89	35	1	1	1	1	10
14 Sep 89	60	1	1	0	0	25
14 Sep 89	75	1	1	0	0	15
29 Sep 89	50	1	1	0	0	15
29 Sep 89	55	1	1	0	0	18
29 Sep 89	50	1	1	0	0	10
29 Sep 89	60	1	1	0	0	12
19 Apr 90	55	3	1	0	0	3
19 Apr 90	45	1	1	0	0	10
19 Apr 90	50	1	1	0	0	8
19 Apr 90	90	1	1	0	0	6

^{1/}Period: 1-day, entire tow occurred during daylight hours.
 3-night, entire tow occurred between sunset and sunrise.

^{2/}Tide: 1-midpoint of tow occurred during flood or high tide.