THE STRIPED BASS (MORONE SAXATILIS) DIE-OFF IN THE SACRAMENTO-SAN JOAQUIN ESTUARY IN 1973 AND A COMPARISON OF ITS CHARACTERISTICS WITH THOSE OF THE 1971 AND 1972 DIE-OFFS1/2/

by

David W. Kohlhorst
Bay-Delta Fishery Project

ABSTRACT

This report describes the annual die-off of striped bass and other fish species in the San Pablo-Suisun Bay area in 1973 and compares it with characteristics of the 1971 and 1972 die-offs.

A total of 1,670 striped bass and 329 fish of other species was found dead in a shore survey in 1973. Although some procedures in this survey differed from those in the previous two years, the results indicate that mortality was of the same order of magnitude each year.

There was a positive correlation between daily counts of dead striped bass and American shad (Alosa sapidissima). This correlation may be due to conditions affecting the distribution of dead fish or it may indicate a common cause of death. Carp (Cyprinus carpio) constituted the majority (227) of the other species observed. Their mortality is believed to be unrelated to that of striped bass.

The 1973 kill was centered in about the same locale as the 1971 die-off (Carquinez Strait) and was downstream from the center of the 1972 kill (eastern Suisun Bay). These location shifts corresponded with annual differences in the magnitude of salinity intrusion.

Peak die-offs occurred at about two-week intervals in 1971 and 1973, but there was no consistent relationship between them and the tidal cycle.

1/ Anadromous Fisheries Branch Administrative Report No. 74-13, January 1975.

2/ This work was performed as part of Dingell-Johnson Project, California, F-9-R, "A Study of Sturgeon and Striped Bass" supported by Federal Aid to Fish Restoration funds.

INTRODUCTION

Spring and early summer mortalities of striped bass and several other species occur annually in the Suisun-San Pablo Bay area of the Sacramento-San Joaquin Estuary, California (Figure 1). Attempts to determine the cause of this annual die-off have been unsuccessful (Lollock 1964; Silvey and Irwin 1969; Kohlhorst 1973). This report describes a surveillance of the magnitude, location, species composition, and timing of mortality in 1973 and compares its findings with those of similar studies in 1971 and 1972.

SURVEY METHODS

Basic survey procedures have previously been described in detail (Kohlhorst 1973), so only a brief description will be given here.

Ten beaches from eastern San Pablo to eastern Suisun Bay (Figure 1) were surveyed by two observers three times per week from May 16 to July 27, 1973. Dead fish were identified, enumerated by location, measured in 13 cm (5 inch) increments, and cut completely in half to eliminate recounts.

In 1971 and 1972, the bays were also surveyed by boat and freshly dead striped bass were collected for bacteriological and chemical analysis. These studies were inconclusive and were not repeated in 1973.

RESULTS

Extent of Striped Bass Mortality

In 1973, 1,670 dead striped bass were observed. This total is larger than the total observed in the shore survey in 1971 (921) and 1972 (1,029). The mean number observed per beach each day in 1973 (5.6) was intermediate between 1971 (8.2) and 1972 (3.3).

Distribution of the Striped Bass Die-Off

Dead striped bass were observed on all beaches, from Wilson Point in San Pablo Bay to Pittsburg in eastern Suisun Bay. The die-off was centered in Carquinez Strait in 1973 (Figure 2), with peak numbers occurring at the Port Costa Brickyard (Beach VI-E). The distribution of dead fish in 1973 closely resembled that in 1971 and both of these years differed markedly from 1972, when peak numbers were found in eastern Suisun Bay.

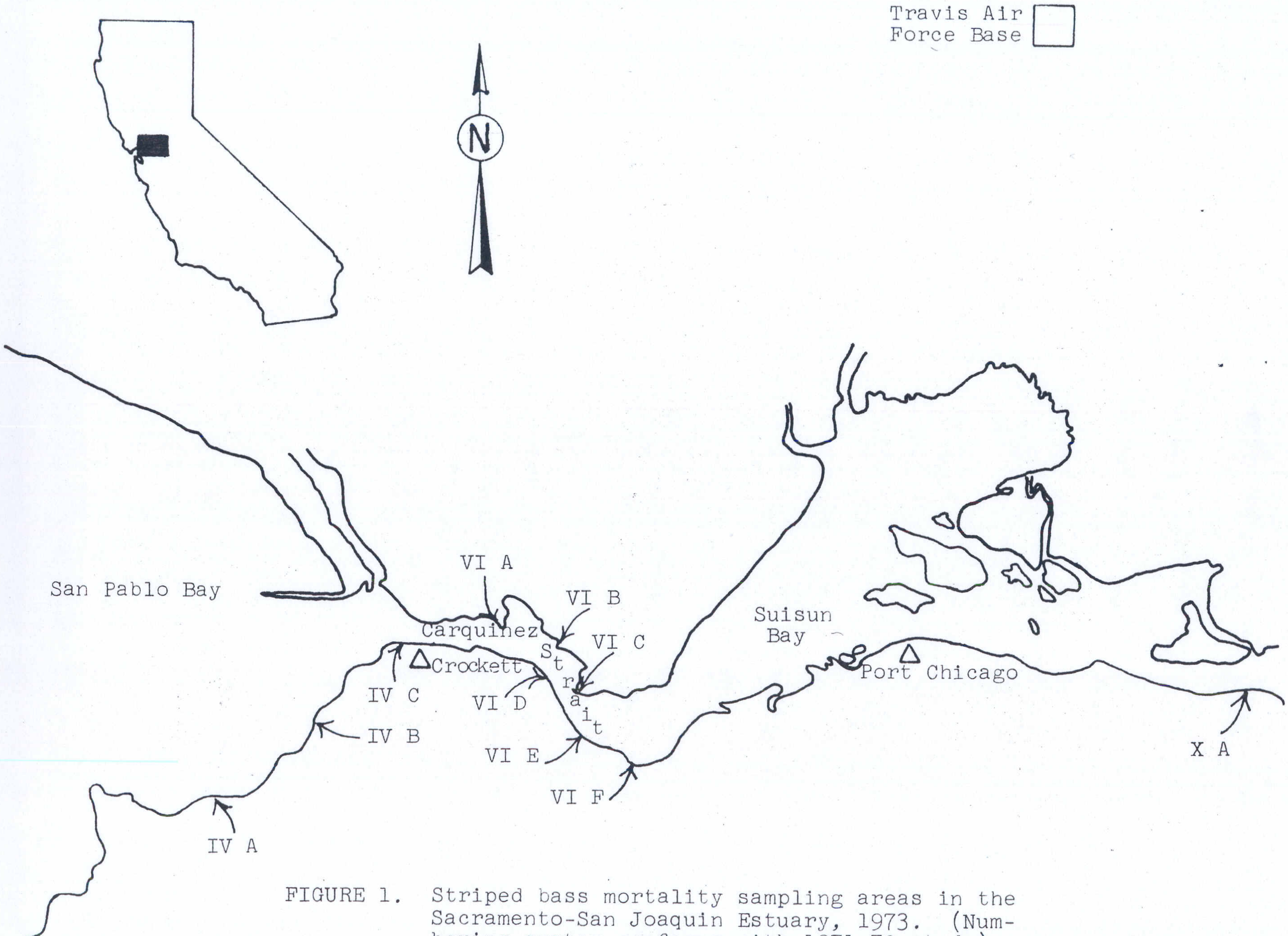

FIGURE 1. Striped bass mortality sampling areas in the Sacramento-San Joaquin Estuary, 1973. (Numbering system conforms with 1971-72 study)

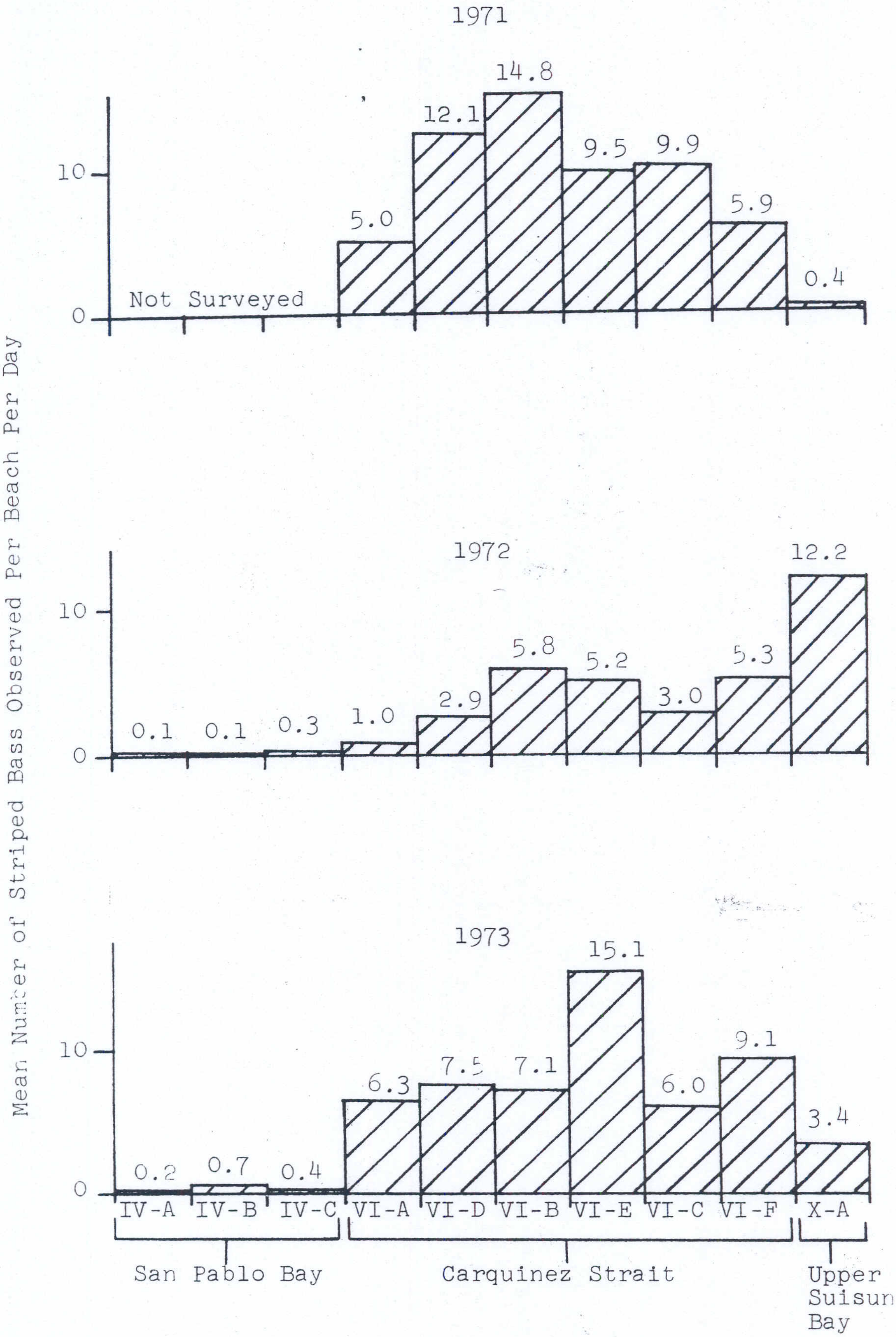

FIGURE 2. Spatial distribution of dead striped bass on shore during the 3 years of the mortality survey in the Sacramento-San Joaquin Estuary.

Dead bass were seen each survey day in all years. Peak kills were at approximately 2 week intervals in both 1971 and 1973. Such periodicity was not evident in 1972 (Figure 3).

Size of Dead Striped Bass

The mean length of dead striped bass increased significantly each succeeding year (Table 1). This increase was accompanied by a decreasing proportion of 25-51 cm (10-20 inch) fish.

For insight into whether or not mortality was size selective, lengths of dead bass were compared with lengths of angler-caught bass observed in a creel census at Crockett. These comparisons were only for bass larger than 51 cm (20 inches) since not all bass in the smaller size groups were recruited to the fishery. The mean lengths of dead bass were greater than mean lengths of sport-caught fish in all 3 years (Table 2), although the difference was statistically significant only in 1973.

Fish Other Than Striped Bass

A total of 20 species other than striped bass was identified during the 3 years. Excluding carp and American shad, the kill of fish other than striped bass was small in all years (Table 3). The high mortality of carp in 1973 was unusual, and it also occurred in inland streams and reservoirs. Therefore, it is probably not related to the annual die-off in the study area.

American shad formed 72% of the non-bass kill (excluding carp) in 1971, 53% in 1972, and 51% in 1973. A significant correlation ($r = 0.78$, $P < 0.001$) existed between the daily counts of shad and striped bass in 1973, and similar correlations existed in 1971 and 1972 (Kohlhorst 1973).

There was no significant correlation in 1973 between daily counts of striped bass and other fish, excluding carp and shad ($r = 0.00$). In 1971 and 1972, significant correlations existed (Kohlhorst 1973).

Striped bass outnumbered other fish, excluding carp, in the 1973 die-off by 16.5:1. Ratios of striped bass to other fish were 17.6:1 in 1972 and 6.0:1 in 1971. It is not known if these ratios represent the relative abundance of live fish.

Tidal Factors

There was a striking relationship between the occurrence of dead striped bass and the tidal cycle in 1973, but the

FIGURE 3. Number of dead striped bass observed on shore during the 3 years of the mortality survey in the San Pablo-Suisun Bay area.

TABLE 1

Length Frequency of Dead Striped Bass Observed in the San Pablo-Suisun Bay Area During the Mortality Survey

Size (cm)	1971 Shore		1972 Shore		1973 Shore	
	No.	(%)	No.	(%)	No.	(%)
0-13	0	(0%)	1	(0.1%)	1	(0.1%)
13-25	63	(7.1%)	30	(3.1%)	116	(6.9%)
25-38	358	(40.5%)	295	(30.1%)	397	(23.8%)
38-51	301	(34.0%)	304	(31.1%)	469	(28.1%)
51-64	108	(12.2%)	215	(22.0%)	377	(22.6%)
64-76	45	(5.1%)	107	(10.9%)	229	(13.7%)
76-89	6	(0.7%)	22	(2.2%)	63	(3.8%)
Over 89	3	(0.3%)	5	(0.5%)	18	(1.1%)
Total	884 1/	(99.9%)	979 1/	(100%)	1,670	(100.1%)

	1971 vs 1972	1971 vs 1973	1972 vs 1973
Mean length	40.9 (16.1 inches)	46.5 (18.3 inches)	48.0 (18.9 inches)
Student's t value for comparison of mean lengths	-8.89	-12.05	-2.40
Probability	<0.001	<0.001	<0.05

1/ These totals include only fish that were measured. Some fish were not measured because they were badly decomposed or through the error of the observer.

TABLE 2

Comparison of Mean Lengths of Dead Striped Bass from the Mortality Survey With Sport-Caught Striped Bass from the San Pablo-Suisun Bay Area[1/]

Year	Shore kill			Angler catch			d[2/]	
	N	Mean length (cm)	SE	N	Mean length (cm)	SE		
1971	162	62.2 (24.5 inches)	0.26	718	61.0 (24.0 inches)	0.10	1.81	NS
1972	349	63.2 (24.9 inches)	0.18	602	62.5 (24.6 inches)	0.12	1.38	NS
1973	687	64.8 (25.5 inches)	0.15	228	61.7 (24.3 inches)	0.20	4.78	**

1/ Including only fish greater than 51 cm TL.

2/ Standard deviate (d), used for large samples, is equivalent to Student's t (Elliott, 1971:p. 96).

TABLE 3

Number of Dead Fish Other Than Striped Bass Observed in the Mortality Survey in the San Pablo-Suisun Bay Area

Species	1971		1972		1973	
	Total	Mean number per day	Total	Mean number per day	Total	Mean number per day
American shad *Alosa sapidissima*	120	5.7	48	1.1	53	1.7
Sturgeon *Acipenser* sp.	6	0.3	8	0.2	12	0.4
Plainfin midshipman *Porichthys notatus*	8	0.4	15	0.4	11	0.4
Carp *Cyprinus carpio*	9	0.4	9	0.2	227 1/	7.6
Catfish *Ictalurus* sp.	2	0.1	5	0.1	1	0.1
Shark and Ray Order Squaliformes and Rajiformes	2	0.1	0	0	6	0.2
Salmon *Oncorhynchus* sp.	3	0.1	0	0	0	0
Other 2/	25	1.2	15	0.4	19	0.6
Total	175	8.3	100	2.3	329 3/	10.9 3/

1/ 185 observed before June 1.

2/ Other includes: Sacramento squawfish, *Ptychocheilus grandis*
Splittail, *Pogonichthys macrolepidotus*
Hitch, *Lavinia exilicauda*
Bluegill, *Lepomis macrochirus*
Rockfish, *Sebastes* sp.
Northern anchovy, *Engraulis mordax*
Pacific staghorn sculpin, *Leptocottus armatus*
Jacksmelt, *Atherinopsis californiensis*
Starry flounder, *Platichthys stellatus*
White croaker, *Genyonemus lineatus*
Perch, Fam. Embiotocidae
Unidentified species

3/ Total and mean, excluding carp, are 101 and 3.4, respectively.

patterns were not synchronized (Figure 4). The tidal cycle followed the die-off cycle by about 4 days ($r = 0.64$, $P < 0.001$ between the maximum daily tidal range and the number of dead bass seen 4 days earlier). There was also a relationship in 1971, but the tidal cycle preceded the die-off by about 6 days. In 1972 there was no obvious relationship between the die-off and the tidal cycle.

Weather

There were no significant linear correlations between daily counts of dead bass in the shore survey and maximum air temperature or average wind velocity at Travis Air Force Base.

DISCUSSION AND SUMMARY

During the surveillance of the annual fish die-off in 1973, 1,670 dead striped bass were observed on 10 beaches in the Suisun-San Pablo Bay area. This total is higher than the totals for 1971 (921) and 1972 (1,029), but it may be inflated since some dead fish were eliminated by boat surveys the first 2 years. Only a small proportion of the shoreline was sampled each year. Therefore, the number of fish observed was an unknown, but certainly small, percentage of total mortality.

While the survey was not precise enough for exact comparisons of annual die-offs, mean counts per beach (8.2 in 1971, 3.3 in 1972, and 5.6 in 1973) indicate losses were of the same order of magnitude each year.

As in past years, striped bass less than 25 cm (10 inches) in length made up only a small part (7%) of the observed mortality. There are three possible explanations for the low numbers of small bass: (1) small fish may actually be scarce in the kill area, (2) small dead fish may be rapidly consumed by the numerous gulls in the area, or (3) the mortality agent is truly selective for large fish.

The mean length of dead striped bass increased each year. This trend may reflect annual differences in the size composition of the population in this area, although the large difference between the mean length in 1971 and those in the following years could also have resulted from a change in measuring techniques. In 1971 fish were measured to the nearest 2.5 cm (1 inch). They were measured in 13 cm (5 inch) increments in 1972 and 1973.

Average sizes of dead and angler caught bass were compared for fish longer than 51 cm (20 inches). In all 3 years the mean size of dead bass was larger than the mean size of bass taken by anglers. The difference was statistically significant in 1973. However,

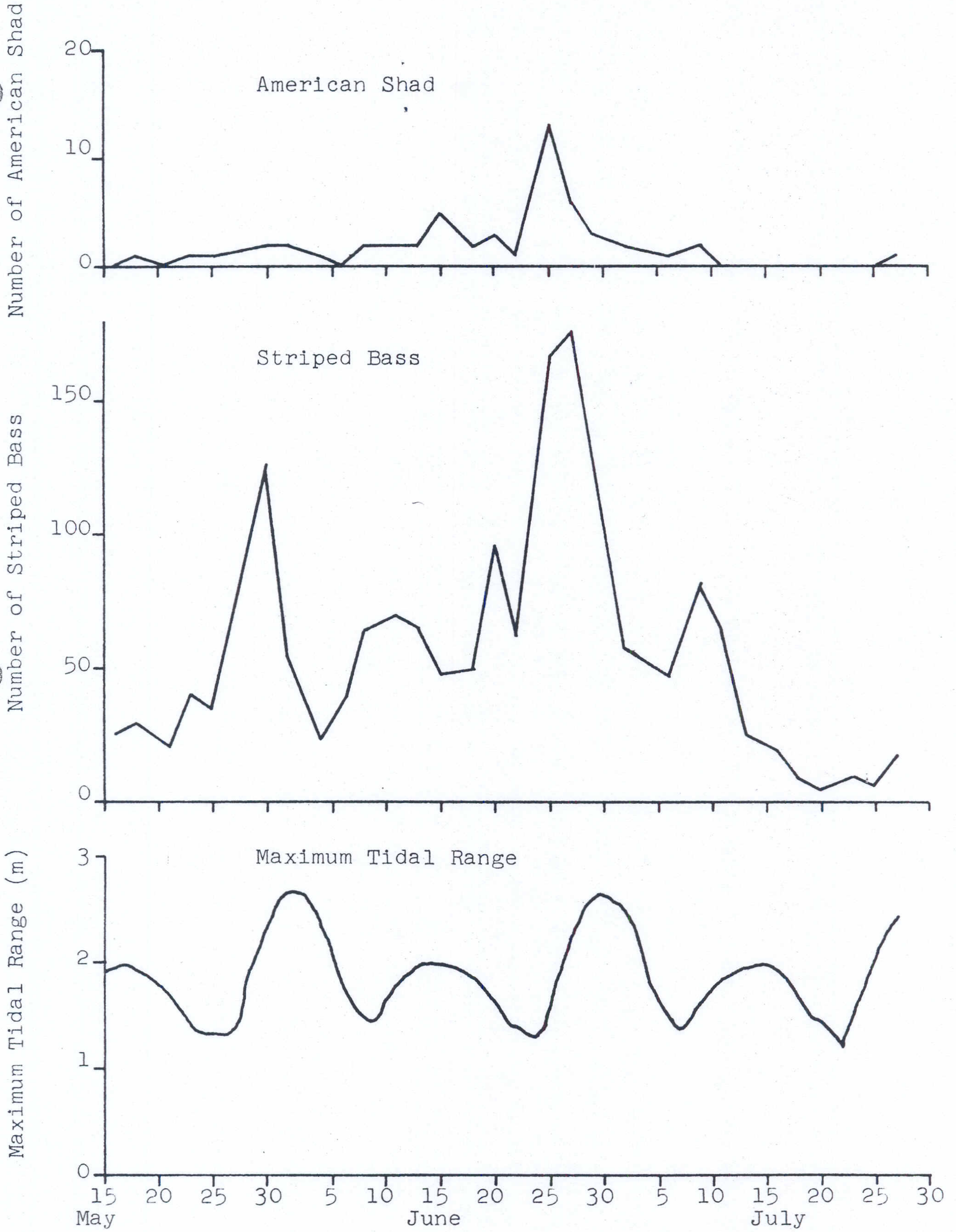

FIGURE 4. Comparison of the number of dead striped bass, American shad, and the tidal cycle for the 1973 mortality survey in the San Pablo-Suisun Bay area.

several factors suggest these differences are not biologically meaningful. (1) The difference was small every year (never more than 3 cm [1.2 inches]). (2) The minimum legal size of angler-caught bass is 41 cm (16 inches); therefore, fish in the 38-51 cm (15-20 inch) size group were not all recruited to the fishery and no fish in smaller size groups were recruited. Hence, there was no way to consider a large segment of the population (<51 cm [20 inches]) when comparing average sizes. (3) Results would be affected if angling methods select for small fish.

A significant positive correlation existed between the daily counts of striped bass and shad in all years. It has not been determined if this relationship is due to conditions affecting the distribution of dead fish or to conditions causing mortality. Many shad die after spawning in the rivers, but it is not known if mortality in the study area resulted from the same cause.

In 1973 dead striped bass were most abundant in nearly the same area as in 1971 and farther downstream than in 1972. Shifts in the distribution of dead fish probably represent shifts in the area where mortality occurred. Mean salinity at Port Chicago in 1972 (10,857 ppm TDS) was much higher than the means for 1971 (2,883 ppm TDS) and 1973 (5,744 ppm TDS). Hence the die-off occurred upstream in 1972 when saltwater intrusion in Suisun Bay was greatest and downstream at low and intermediate salinities.

A 14-day cycle in the striped bass die-off was very apparent in both 1971 and 1973 when the kill was centered in Carquinez Strait. This cycle closely resembled the tidal cycle, although the die-off preceded the peak tidal ranges in 1973 and followed them in 1971. No cycle was apparent in 1972 when the kill was centered in upper Suisun Bay. The differences in timing suggest that losses are not a direct function of the tidal cycle.

Weather does not appear to affect the magnitude of striped bass mortality. Wind velocity was important in determining the number of striped bass observed in the boat survey in 1972, but it did not directly influence mortality (Kohlhorst 1973).

The 1973 survey did not produce any pertinent information not already known from previous studies. Surveillance studies have provided a description of the die-off, but they are not capable of determining its cause. Therefore, the surveillance was not repeated in 1974.

ACKNOWLEDGEMENTS

This survey could not have been conducted without the assistance of the personnel of the two Department of Fish and Game Regions involved, particularly Sterling Davis of Region 2 and James Lemieux of Region 3. Donald Stevens and Harold Chadwick helped plan the survey and critically reviewed this report. I express my sincere appreciation to all those involved.

LITERATURE CITED

Elliott, J. M. 1971. Some methods for the statistical analysis of samples of benthic invertebrates. Freshwater Biol. Assoc., Sci. Publ. No. 25, 144 p.

Kohlhorst, D. W. 1973. An analysis of the annual striped bass die-off in the Sacramento-San Joaquin Estuary, 1971-72. Calif. Dept. Fish Game, Anad. Fish. Admin. Rept. 73-7, 22 p. (mimeo.)

Lollock, D. L. 1964. Investigation of San Francisco Bay fish kills during 1964. Unpubl. Rept., Calif. Dept. Fish Game, Region 3, Inland Fish., 17 p. (typewritten)

Silvey, W. D. and G. S. Irwin. 1969. Relation of water quality to striped bass mortalities in the Carquinez Strait in California. Open-file Rept., U. S. Dept. Int., Geol. Surv., Water Res. Div., 12 p.