WRINT-DFG-Exhibit 2

A RE-EXAMINATION OF FACTORS AFFECTING STRIPED BASS ABUNDANCE IN THE SACRAMENTO-SAN JOAQUIN ESTUARY

Entered by the California Department of Fish and Game for the State Water Resources Control Board 1992 Water Right Phase of the Bay-Delta Estuary Proceedings.

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Executive Summary

Over the past three decades, the striped bass population of the Sacramento-San Joaquin Estuary has experienced a severe decline. The population of about 3 million adult bass in the early 1960's has eroded to less than 600,000 naturally produced fish in 1990. Concurrently, young-of-the-year striped bass abundance suffered an erratic but persistent decline from high index levels sometimes exceeding 100 in the mid-1960's to the all time low of only 4.3 in 1990. Since 1977, average abundance of young striped bass has been less than one-third of previous average levels.

Substantial effort has gone into evaluating factors responsible for the decline in striped bass abundance. This effort has centered on the concept that for the population to decline, there must be a decrease in its birth and/or increase in its death rates. In brief, our explanation of the striped bass decline is that there has been an increase in death rate (decrease in the survival rate) predominately during the first year of life and caused mainly by increased losses of fish entrained in water exports by the State and Federal Water Projects. This has led to a lower adult striped bass population which is producing fewer eggs (lower birth rate) and that, in turn, is producing fewer young fish and subsequently even fewer adults.

More specifically regarding the decline in young bass abundance, during Phase I of these hearings we explained that since 1977, based on the abundance index at the 38-mm stage, young striped bass abundance has consistently fallen below expectations based on the relationship between their abundance, outflows and water diversion rates from 1959-1976. This relationship is the basis for the striped bass outflow standards and water export limitations mandated in Decision 1485. Given this lower production of young bass and its implication that Decision 1485 standards and limitations are inadequate, it is important to determine why young bass are now less abundant. Fundamentally, young bass abundance could have declined for one of three reasons: 1) the mechanism(s) causing the relationship between abundance, outflow and water diversions have changed, resulting in lower survival at any given combination of outflow and diversion rates, 2) mechanisms and striped bass response have not changed (survival of young bass still varies as predicted), but the decline is solely due to the reduced numbers of eggs being spawned, and 3) some combination of 1) and 2).

The only potential reason for the decline in young striped bass abundance consistent with the population data is that egg production has declined substantially (see first paragraph). Survival between the egg and 38-mm stage has not declined relative to outflows and water exports. Since 1977, survival has varied, depending on outflows and water exports, in the same manner as before 1977. The resultant explanation is that the decline of young bass at any given outflow/diversion combination can only be attributable to fewer eggs produced by fewer adults.

Lower recruitment of new 3-year old fish has been the major cause of the declining abundance of adults. This lower recruitment accounts for about three-quarters of the adult bass decline while the estimated annual survival rate of the adults themselves accounts for the remaining quarter. Evidence in WRINT-DFG-Exhibit 3 reveals that recruitment has been reduced by losses of young bass to water diversions both before and after the 38-mm stage.

Significant evidence, critical to the current State Water Resources Control Board deliberations is that substantially increased losses of fish occurred when exports increased due to initiation of the State Water Project and the San Luis Project during the 1970's. After an appropriate lag period, the adult striped bass population declined and it has subsequently failed to rebound. The process described above (lower recruitment, fewer adults, fewer eggs, fewer young, lower recruitment, etc.) has led to the historic low population estimate of only 590,000 naturally produced (total adults minus hatchery stocked fish) adult fish in 1990, and strong incrimination of water project operations as the root cause of the striped bass population decline.

We do not want to imply that other factors such as toxicity or illegal fishing are not potentially significant mortality sources that warrant evaluation, enforcement and correction. Such factors will continue to cause striped bass mortality as in the past and may account for some of the annual variability in the abundance measures unexplained by our model. The evidence, however, is that effects of these other factors have not changed in the persistent manner and magnitude required to account for the major downward trend in striped bass abundance.

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Introduction

The purpose of this Exhibit and WRINT-DFG-Exhibit 3 is to convey new understanding of mechanisms controlling striped bass abundance in the Sacramento-San Joaquin Estuary gained since the 1987 phase of these hearings. These exhibits are designed only to review the importance of the striped bass population, update the status of the population, describe the rationale for our conclusions regarding its decline, and form the basis for our water management recommendations during the water rights phase of these hearings. For a more comprehensive description of the striped bass life history and general requirements, readers should refer to Exhibit 25 presented to the State Water Resources Control Board during Phase I of the Bay-Delta proceedings in 1987, or its counterpart, Technical Report 20 in the Interagency Ecological Study Program technical report series.

Importance of Striped Bass of the Sacramento-San Joaquin Estuary.

Striped bass are a non-native fish introduced from the East Coast more than a century ago. The population exploded shortly after the introduction and major commercial and recreational fisheries developed. Due to public perception about impacts on the valuable recreational fishery, commercial fishing for striped bass was outlawed by the legislature in 1935. Similar public perception about impacts on striped bass also led to legislation that outlawed commercial fishing for salmon and American shad within the Estuary in 1957.

Current angling regulations include 18 inch minimum length and two fish daily bag limits. These restrictions reflect changes imposed in 1982 due to the declining status of the population. Previously, the minimum legal length was 16 inches and the daily bag was three fish.

The annual recreational catch probably exceeded 800,000 fish in at least one year in the early 1960's, but currently the catch is only about 100,000 to 200,000 fish (Figure 1).

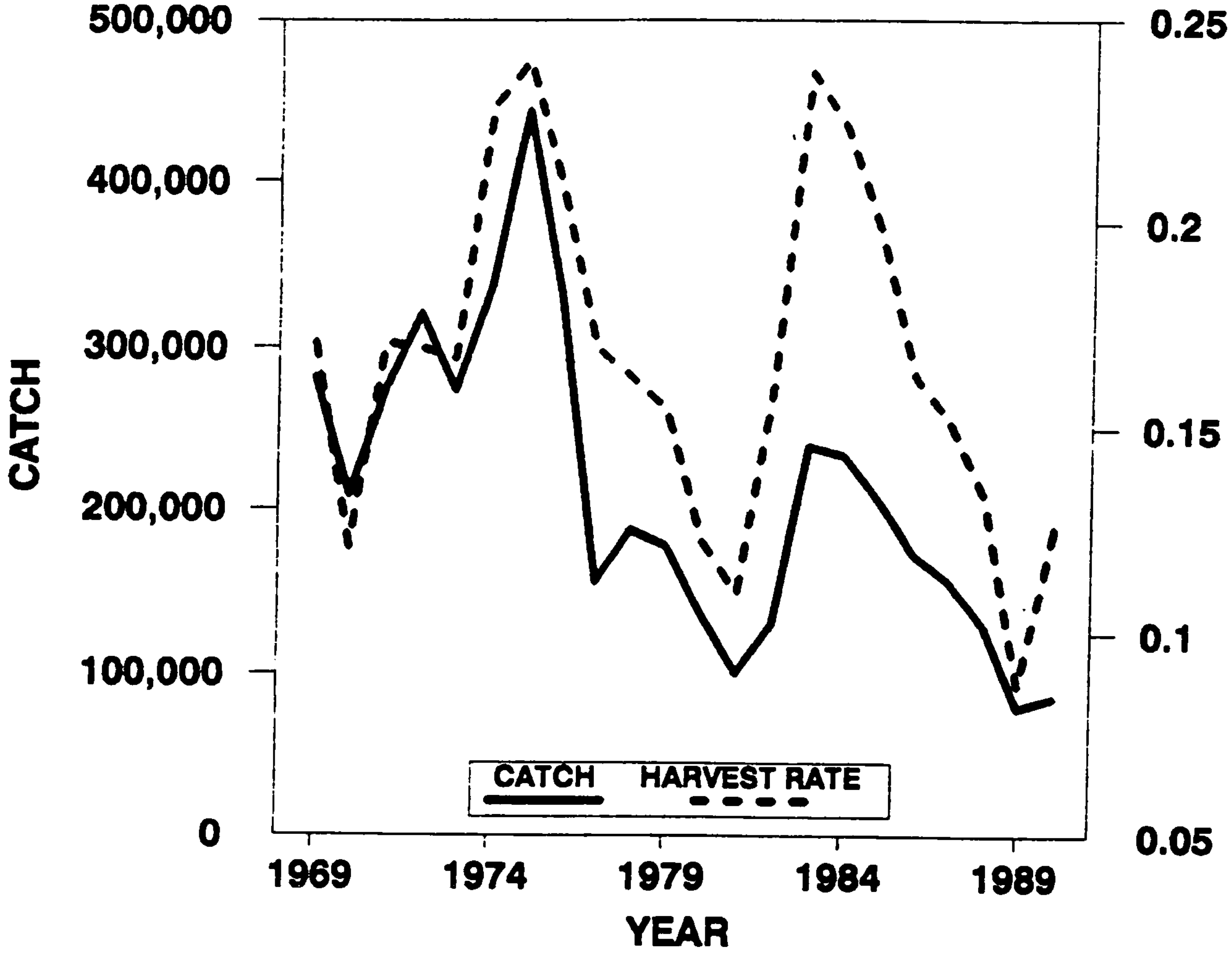

Figure 1. Trend in recreational catch and harvest rate of striped bass in the Sacramento-San Joaquin Estuary, 1969-1990

Angler surveys indicated that about 1.5 million angler days were expended fishing for striped bass in the early 1970's. Such information is not available for more recent years.

The annual recreational value of the striped bass fishery has been estimated to exceed 45 million dollars (Meyer Resources 1985).

Status of the Striped Bass Population and Its Fishery.

Based on mark-recapture population estimates, the number of legal sized (18" or larger) adult striped bass fell to a record low of approximately 680,000 fish in 1990 (Figure 2). This estimate includes approximately 90,000 fish that were raised in hatcheries and stocked into the estuary as yearlings 2 or more years earlier. Thus, the 1990 estimate for naturally produced fish is only about 590,000 fish. The preliminary abundance estimates of 1.2 million total adult striped bass and 960,000 naturally produced adult bass in 1991 are considerably greater than those for 1990, but the 1991 estimates are not as reliable because the estimates for age 3 fish, the most numerous age group, make up about one-half of the total estimates and they are based on an inadequate recapture sample of only two tags during the entire fall creel census. This recapture sample has resulted in a statistical confidence interval of ± 98 percent around the age 3 population estimate for 1991--a much wider interval than on any other estimate (Figure 3). Age 3 fish are the 1988 year class which, when young, provided the second lowest abundance index (4.6) of the record which extends back to 1959. Thus, based on the available information, it is not rational to conclude that a population recovery is in progress. Unless proven otherwise by additional data that will be obtained over the next several years, a more reasonable conclusion is that the 1991 population is at about the same level as the 1990 population.

These current estimates of the adult striped bass population represent a decline from about 1 million bass in the 1980's and 1.7 million bass in the late-1960's and early 1970's when the mark-recapture estimates were initiated. Data from the fishery indicate that the population was probably about 3 million fish in the early-1960's.

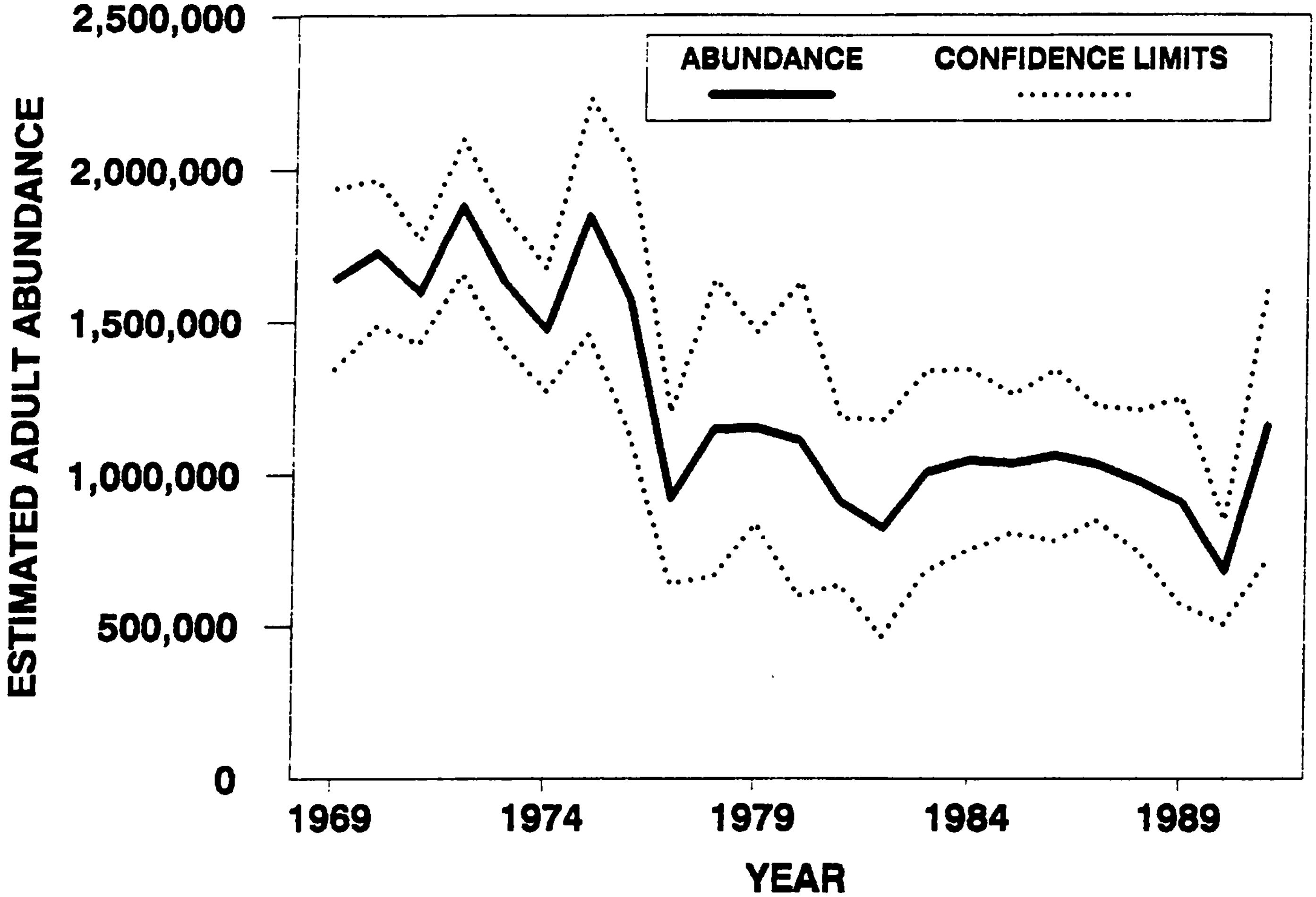

Figure 2. Trend in mark-recapture estimates of adult striped bass abundance in the Sacramento-San Joaquin Estuary, 1969-1991.

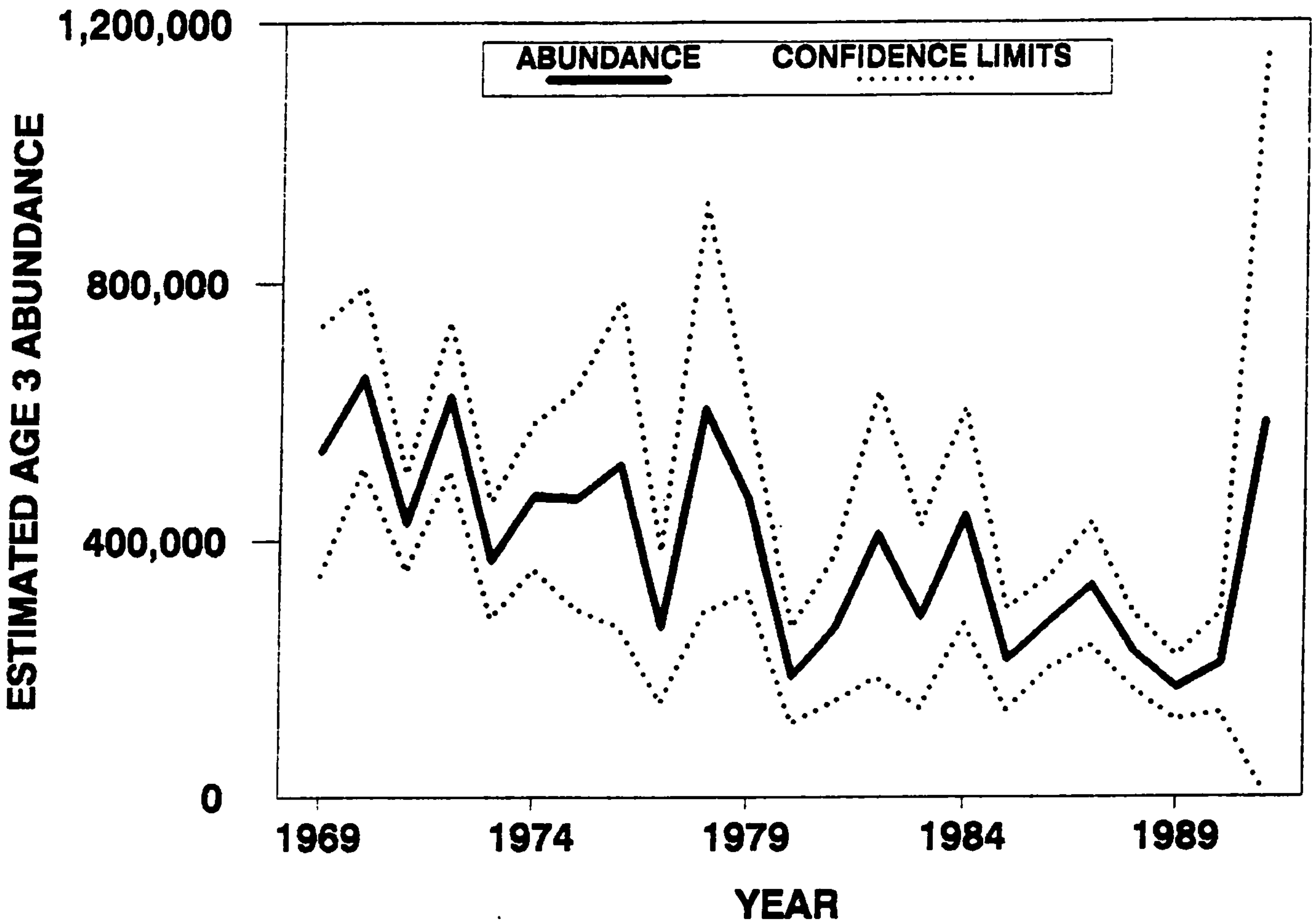

Figure 3. Trend in mark-recapture estimates of age 3 striped bass abundance in the Sacramento-San Joaquin Estuary, 1969-1991.

The adult striped bass population decline primarily reflects a decline in the number of new fish reaching the legal size. Estimates of the abundance of 3-year old fish, which are the youngest and most numerous component of the adult population, have been declining and were at record lows in 1990 (Figure 3). The unreliable preliminary estimate for age 3 fish in 1991 is an aberration in the declining trend, and as already discussed, should not be given credence.

The lower recruitment of 3-year old fish accounts for 76 percent of the adult bass decline (Table 1) when the estimated annual survival rate (Figure 4) is assumed for adults. The remaining 24 percent of the decline is then due to the changes in estimated survival of the adults themselves.

There also has been an irregular but steady decline in production of young striped bass that extends back to the mid-1960's (Figure 5). As measured by the DFG's annual summer tow net survey which was initiated in 1959, the peak abundance of young bass occurred in 1965 when the index was 117.2. The four lowest indices of record have occurred from 1988 to 1991 when the average index was 4.9. The record low was an index of 4.3 in 1990. Since 1977, the average abundance index for young bass has been 19.4. From 1959 to 1976, the average was 66.6.

The declining striped bass population has resulted in a substantial decline in take by anglers which harvest about 10 to 24 percent of the population in most years (Figure 1). Such harvest rates are considered safe for healthy striped bass populations and compare with rates which exceeded 40% on Atlantic Coast populations for many years (National Marine Fisheries Service and U.S. Fish and Wildlife Service 1984).

Based on multiplying abundance estimates by harvest rate, catch ranged from about 200,000 to more than 400,000 fish in the early to mid-1970's. Subsequently annual catch has ranged from about 100,000 to 200,000 fish with the estimates for 1989 and 1990 at the low end of this range. Assuming a population of 3 million bass and the estimated harvest

Table 1. Relative contribution of decreases in recruitment and adult survival to the decline of adult striped bass abundance in the Sacramento-San Joaquin Estuary. Adult bass abundance was simulated from 1969 to 1991 by 1) holding recruitment fixed at 1 million age 3 fish and allowing annual survival rate to vary in the manner observed over this period and 2) holding survival rate constant at 0.55 and allowing recruitment to vary in the manner observed over this period. Predicted rates of decrease are the slopes of regressions of abundance on year from these simulations.

Recruitment	Adult Survival	Predicted Rate of Decrease (number/year)	Percent of Total Rate of Decrease
Fixed @ 1 million[1]	Estimated	-16874	24%
Estimated	Fixed @ 0.55[2]	-53588	76%
	Total	-70462	100%

1 One million is the average estimated number of age 3 recruits from 1969 to 1976 when adult striped bass abundance averaged 1.7 million.

2 Estimated annual survival rate of 0.55 is the average from 1969 to 1976 when adult striped bass abundance averaged 1.7 million.

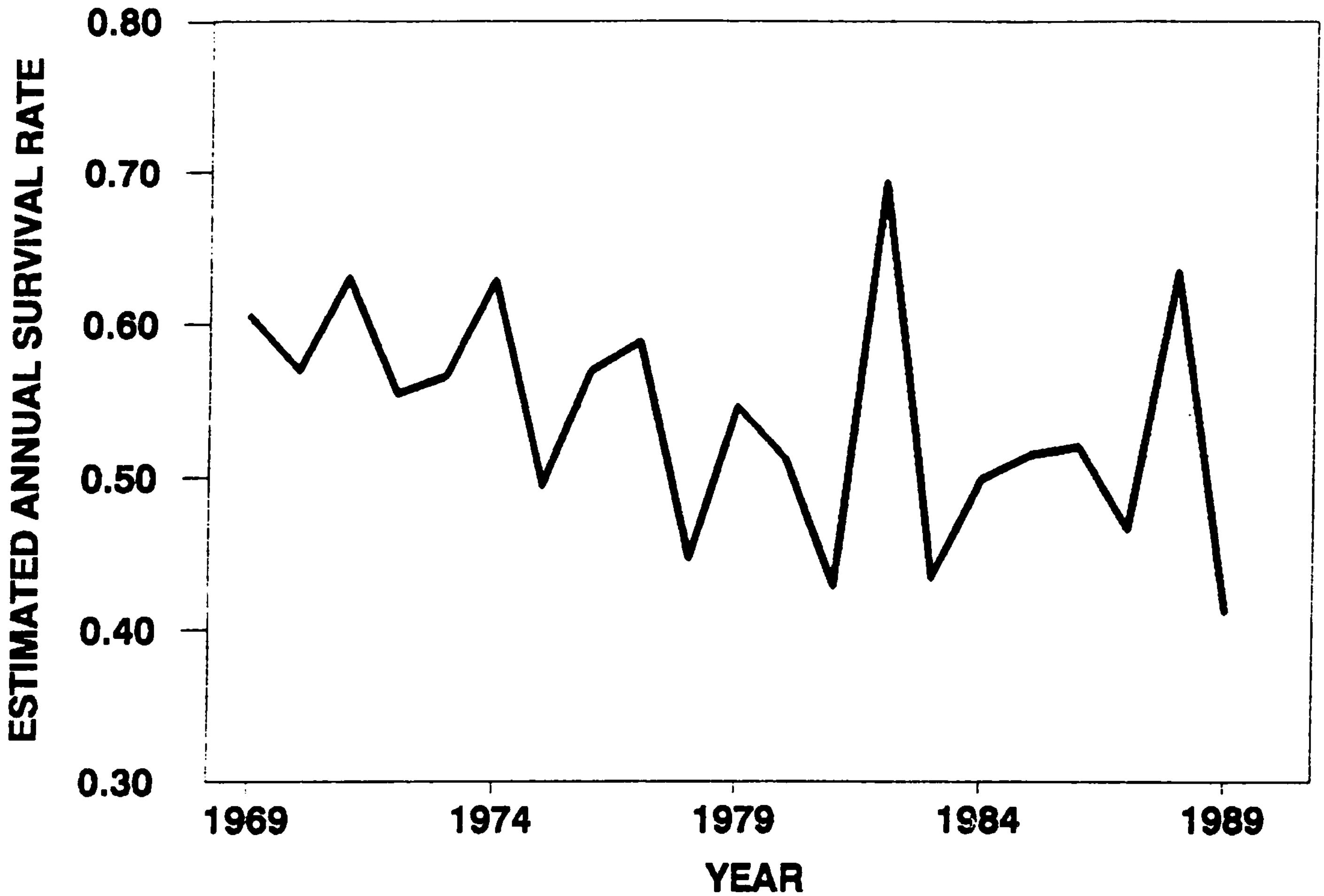

Figure 4. Trend in estimated survival of adult striped bass in the Sacramento-San Joaquin Estuary.

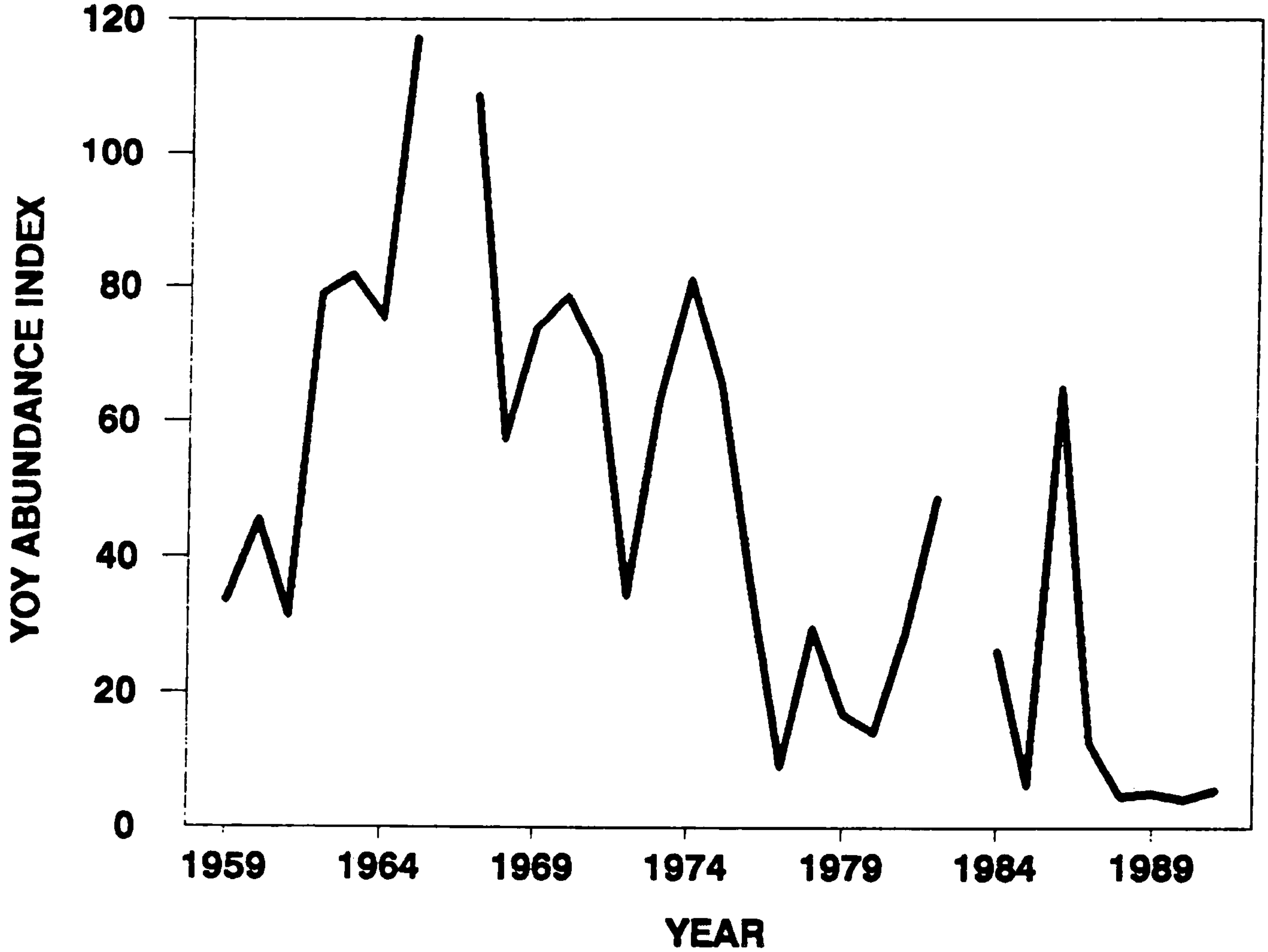

Figure 5. Trend in young striped bass abundance in the Sacramento-San Joaquin Estuary when mean length is 38 mm. Abundance index is based on catches of young bass during an annual tow net survey from 1959-1991.

rate of 28 percent in 1963 (Chadwick 1968), the catch that year would have been about 840,000 fish. Thus, depending on which figures are used, recent catch has been only about one-eighth to one-quarter of levels attained previously during the past 30 years.

Flow Requirements for Striped Bass Spawning.

As indicated during testimony in the Phase I of these hearings (Exhibit 25, page 42-46), in the Sacramento-San Joaquin river system, striped bass have two major spawning areas: the Sacramento River between Sacramento and Colusa and the western Delta in the San Joaquin River between Antioch and Venice Island.

Most spawning in the Delta occurs from April through May. As described in Phase I (Exhibit 25) striped bass spawn in essentially fresh water; therefore, the salinity regime in the western Delta is important. Salinities on the San Joaquin side of the Delta are lowest in the vicinity of the mouth of the Mokelumne River where fresh water from the Mokelumne and Sacramento systems dilutes water flowing from the upper San Joaquin River which has accumulated salts from agriculture drains in the San Joaquin Valley. Farther west, the river becomes more saline due to the intrusion of ocean water.

During Phase I, the Department of Fish and Game (DFG) testified that maintaining the D1485 salinity standard of 1.5 millisiemens at Antioch was appropriate to protect striped bass spawning in the San Joaquin River between Jersey Point upstream from Antioch and Prisoners Point. While the 1.5 millisiemens standard exceeds the 0.3 millisiemens level, below which striped bass usually spawn (Table 2), maintaining 1.5 millisiemens at Antioch would generally maintain adequate salinities between Jersey Point and Prisoners Point.

Upon reconsideration of spawning data (Tables 2 and 3), the substantial decline of the striped bass population and its production of young fish, and our increased understanding of the role of water exports (WRINT-DFG-Exhibit 3), we now believe that a more stringent standard is warranted to encourage spawning in the lowermost 10 km reach of the San

Table 2. Distribution of striped bass eggs between 0 and 8 hours old compared with specific conductance (EC), a function of salinity. Numbers are percentages collected in each EC range. EC is in millisiemens.

EC(MS)	1968	1969	1970	1971	1972	1973	1975	1976	1977	1984	1985	1986	1988	1989	1990
<0.30	8.7	96.6	89.6	100	4.8	100.	100.	51.9	52.7	82.5	71.3	99.8	63.1	62.2	5.6
0.30-0.59	46.7	3.4	7.4		5.6			19.2	14.1	16.1	26.7	0.1	30.3	34.1	53.0
0.60-0.89	40.8		0.4		44.8			11.6	0.1	1.2	1.5		2.4	2.1	2.3
0.90-1.19	0.8		2.5		8.7			11.2	6.8	0.2	0.4		1.0	0.8	3.6
1.20-1.49	3.8		0.1		7.6			5.4					1.0		2.0
1.50-1.79	0.1				25.7			0.2	0.1				0.6		1.4
1.80-2.09					0.2			0.5					0.04	0.5	1.1
2.10-2.49					2.5				1.3				0.7		4.9
2.50-2.99					0.1				1.4				0.5		9.4
3.00-5.99									23.6				0.01	0.2	16.7
6.00-7.99															
8.00-9.99															
10.00-14.99										0.1		0.1			
15.00-35.00															

Table 3. Percentages of striped bass eggs between 0 and 8 hours old in 10 km (6.2 mile) segments of the Delta and Suisun Bay. River km (mile) 0 is at the Golden Gate. * = Not Sampled.

AREA	RIVER kilometer (miles)	1968	1969	1970	1971	1972	1973	1975	1976	1977	1984	1985	1986	1988	1989	1990
Suisun Bay 1/	50 - 59 (31.1 - 36.7)	0	0.7	0	0	0	0	0	*	*	0.1	*	0.1	*	*	*
	60 - 69 (31.1 - 36.7)	0	2.5	0	0	0	0	0	*	*	0	0	0	0	0	0
	70 - 79 (43.5 - 49.1)	0	4.5	0.2	2.3	0	0	0.2	0	0	0.5	0	0.3	0	2.2	0
San Joaquin River 2/ Antioch	80 - 89 (49.7 - 55.3	6.5	27.8	9.0	39.6	55.5	10.0	52.8	1.5	0.1	6.9	0.9	52.2	1.0	28.9	15.8
	90 - 99 (55.9 - 61.5	43.9	13.3	16.6	46.9	37.6	66.2	43.9	32.4	52.8	22.9	20.3	22.8	6.4	12.1	18.9
	100 - 109 (62.1 - 67.7)	39.5	3.3	5.0	10.8	2.4	23.9	1.8	49.3	1.6	53.9	29.3	11.8	25.9	27.5	16.1
	110 - 119 (68.4 - 73.9	8.3	0	59.8	0	2.7	0	0.2	16.2	45.5	15.0	44.2	10.7	63.0	27.1	46.7
Venice Island	120 - 129 (74.6 - 80.2)	0.5	1.9	3.2	0	0.2	0	0.1	0.6	0.1	0.5	3.0	1.1	3.3	.6	2.4
Sacramento River 3/ Collinsville	80 - 89 (49.7 - 55.3)	0	43.5	0.1	0	0	0	0.3	0	0	0.1	0.1	0.2	0	.2	0
	90 - 99 (55.9 - 61.5)	0.3	2.6	5.3	0.4	1.3	0	0.4	*	0	0.1	2.1	0.9	.3	1.4	.1
Rio Vista	100 - 109 (62.1 - 67.7)	0.9	0	0.9	0	0.3	0	0.2	*	0	0	0.1	0	.1	0	.1

1/ Based on sampling of DFG striped bass egg and larva survey stations from Martinez to Collinsville.

2/ Based on sampling of DFG striped bass egg and larva survey stations from Broad Slough to Mandeville Cutoff.

3/ Based on sampling of DFG striped bass egg and larva survey stations from Collinsville to Rio Vista.

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Joaquin River. Table 3 shows that substantial spawning sometimes occurs in this lowermost reach. An appropriate salinity or outflow standard to encourage spawning in this reach would not only assure protection for striped bass spawning, but it would also help reduce the impact of entrainment losses to water exports. Eggs, larvae, and young fish resulting from spawning in the lower reach would be less vulnerable to entrainment in water exports from the south Delta and their transport to the safer environment of Suisun Bay would be enhanced with higher outflows.

In the Sacramento River the spawning grounds are mainly upstream from the city of Sacramento and eggs and larvae are dependent on turbulent river flows rather than tidal currents to keep them in suspension. Spawning in the Sacramento River generally occurs from late-April into June depending upon water temperatures.

A relationship between an index of survival of Sacramento River spawning cohorts and Sacramento River flow at Sacramento indicates that survival between the egg and 6 mm larva stage is low in the Sacramento River when Sacramento River flows are low. At flows less than 13,000 cfs, the survival index was always low (Figure 6). At higher flows, the survival index sometimes was high and sometimes was low. There are four possible mechanisms which would explain this relationship. First, at low flows, eggs and larvae are transported more slowly and may settle out of suspension and die when the river current slows or stops when it is countered by incoming tides. Second, the slower transport may result in lower survival because larvae are delayed in reaching downstream nursery areas where feeding conditions are generally better (Figures 7 and 8). Third, when flows are low more larvae may die due to longer exposures to higher concentrations of toxic substances that may enter the river. The fourth explanation is that more eggs and larvae are diverted from the Sacramento River through the Delta Cross Channel, Georgiana Slough, and Three Mile Slough when flows are low. The percentage of flow, and probably eggs and larvae, diverted is greatest when flows are low and the Cross Channel Gates are open (Figure 9). While such diversion of eggs and larvae may not cause immediate mortality, those eggs and larvae that enter the Cross Channel, Georgiana Slough, and Three Mile Slough are transported more

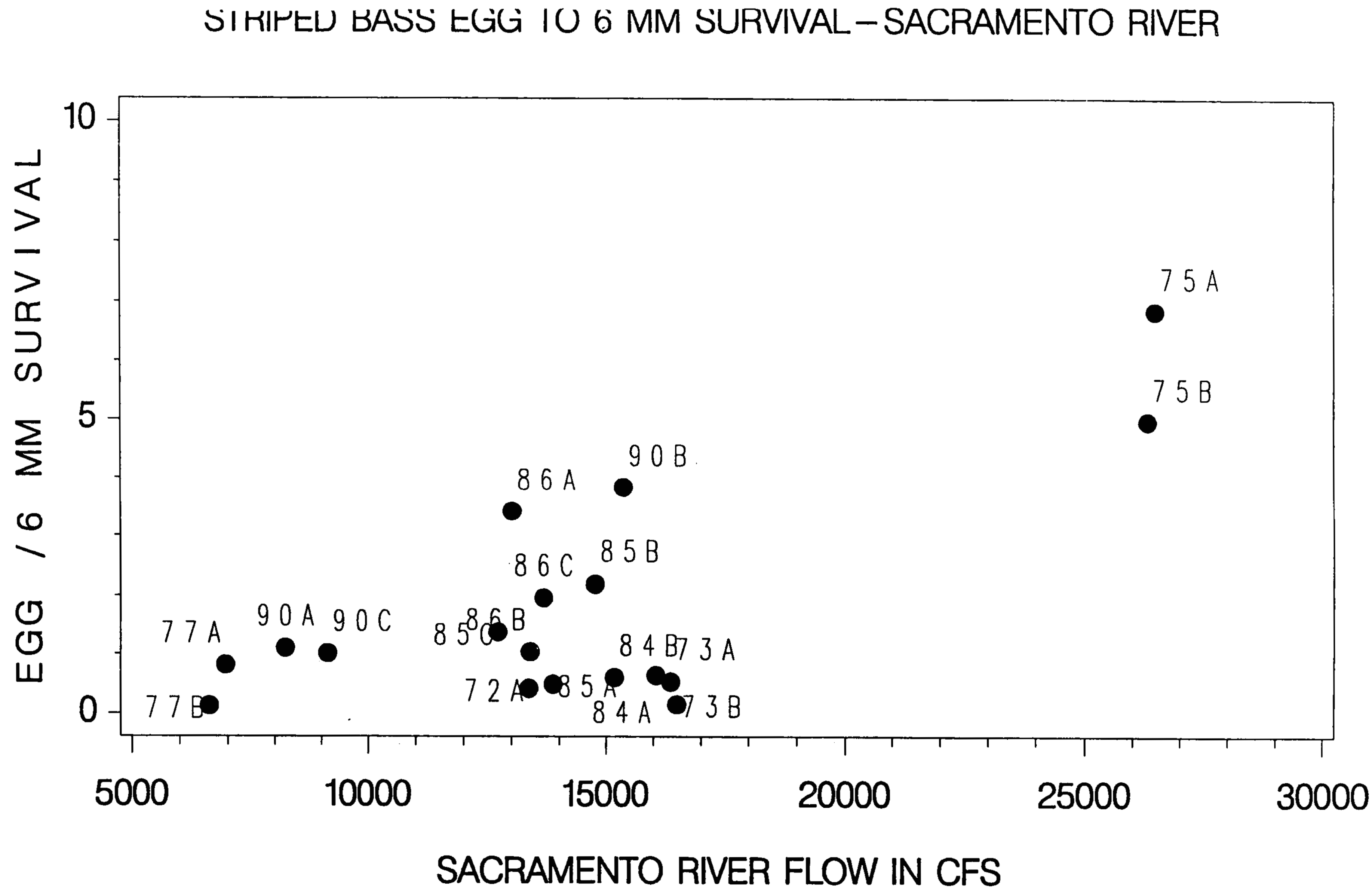

Figure 6. Survival of striped bass from egg to 6 mm larva stage in relation to Sacramento River flow at Sacramento. Survival index is based on egg abundance in the river above Sacramento and the abundance of 6 mm larvae downstream to Collinsville.

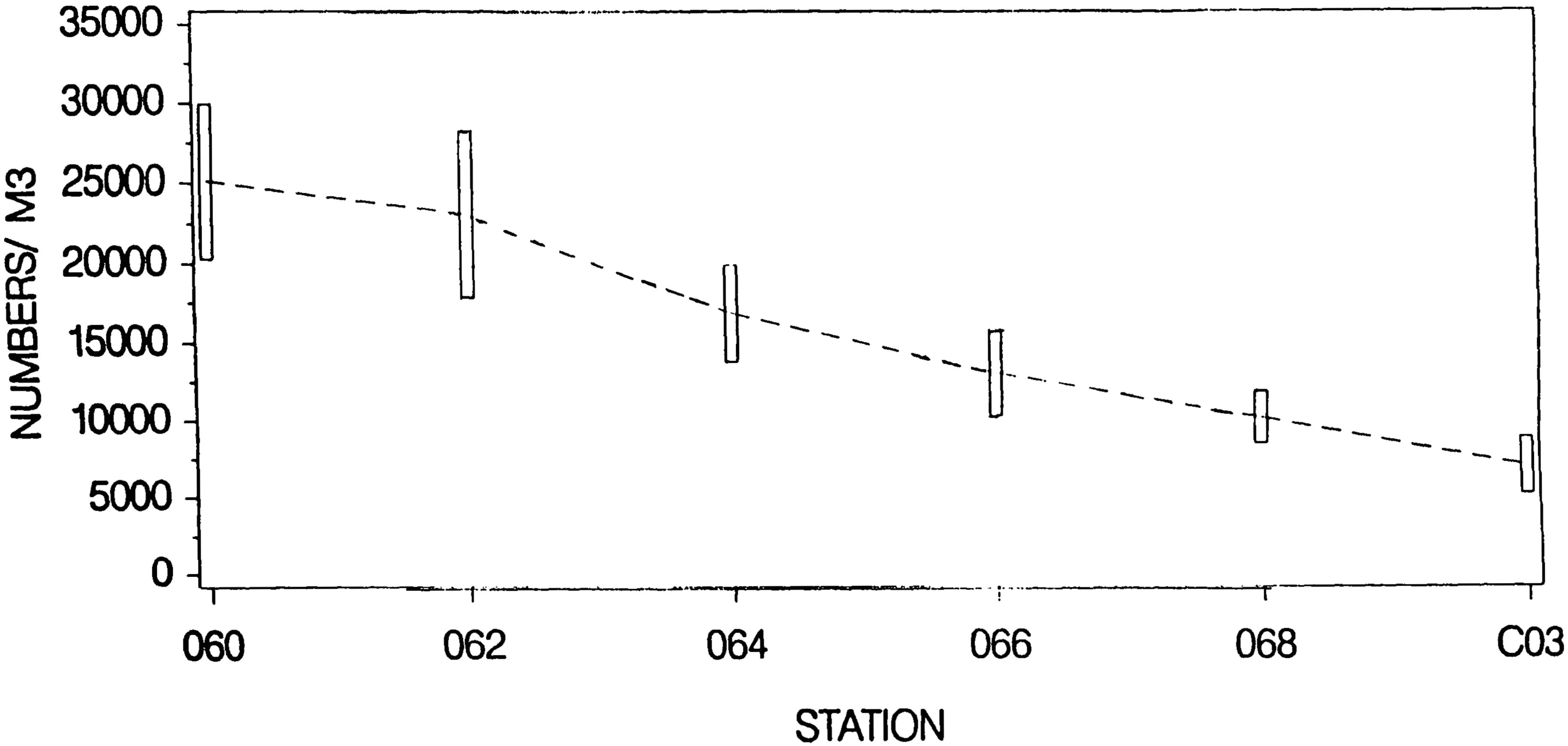

Figure 7. The mean concentration of crustacean zooplankton sampled in the Sacramento River above and below Rio Vista by the Neomysis-zooplankton survey. Only years when station C03 was sampled were included. These years are: 1973, 1974, 1978-1981, 1984, 1988-1990. Station C03 is located near Hood. Stations 60 and 68 are located in the reach from Collinsville to Rio Vista with station 68 at Rio Vista. The bars represent 2 standard errors around the mean concentration.

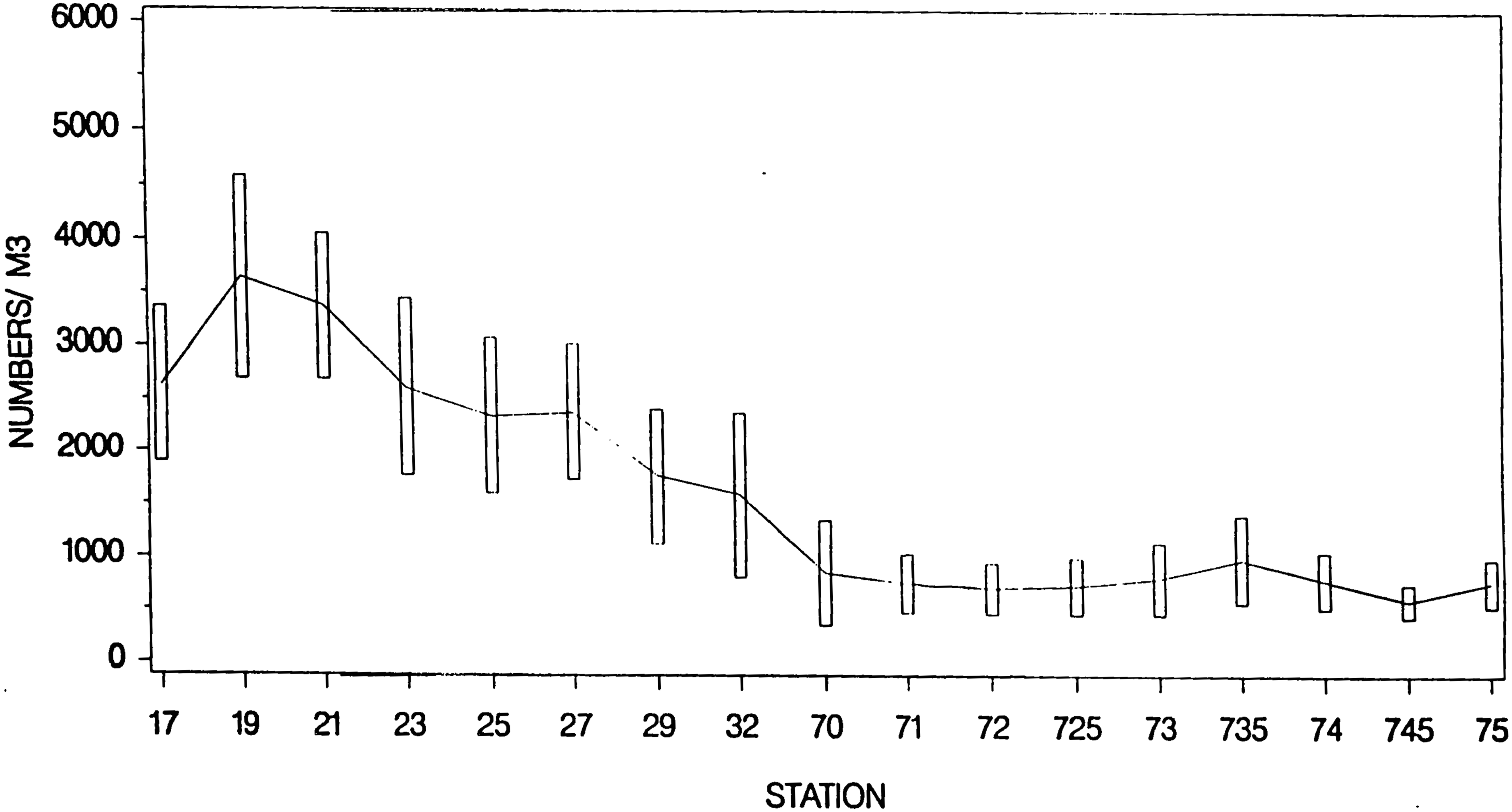

Figure 8. The mean concentration of crustacean zooplankton sampled in the Sacramento River above and below Rio Vista from sampling in 1989, a "low flow" year, by the striped bass egg and larva survey. Stations 70 to 75 and 725 to 745 are located above Rio Vista in the reach between Isleton and Freeport. Stations 17 to 32 are located in the reach from Collinsville to Rio Vista with station 32 located at Rio Vista. The bars represent 2 standard errors around the mean concentration.

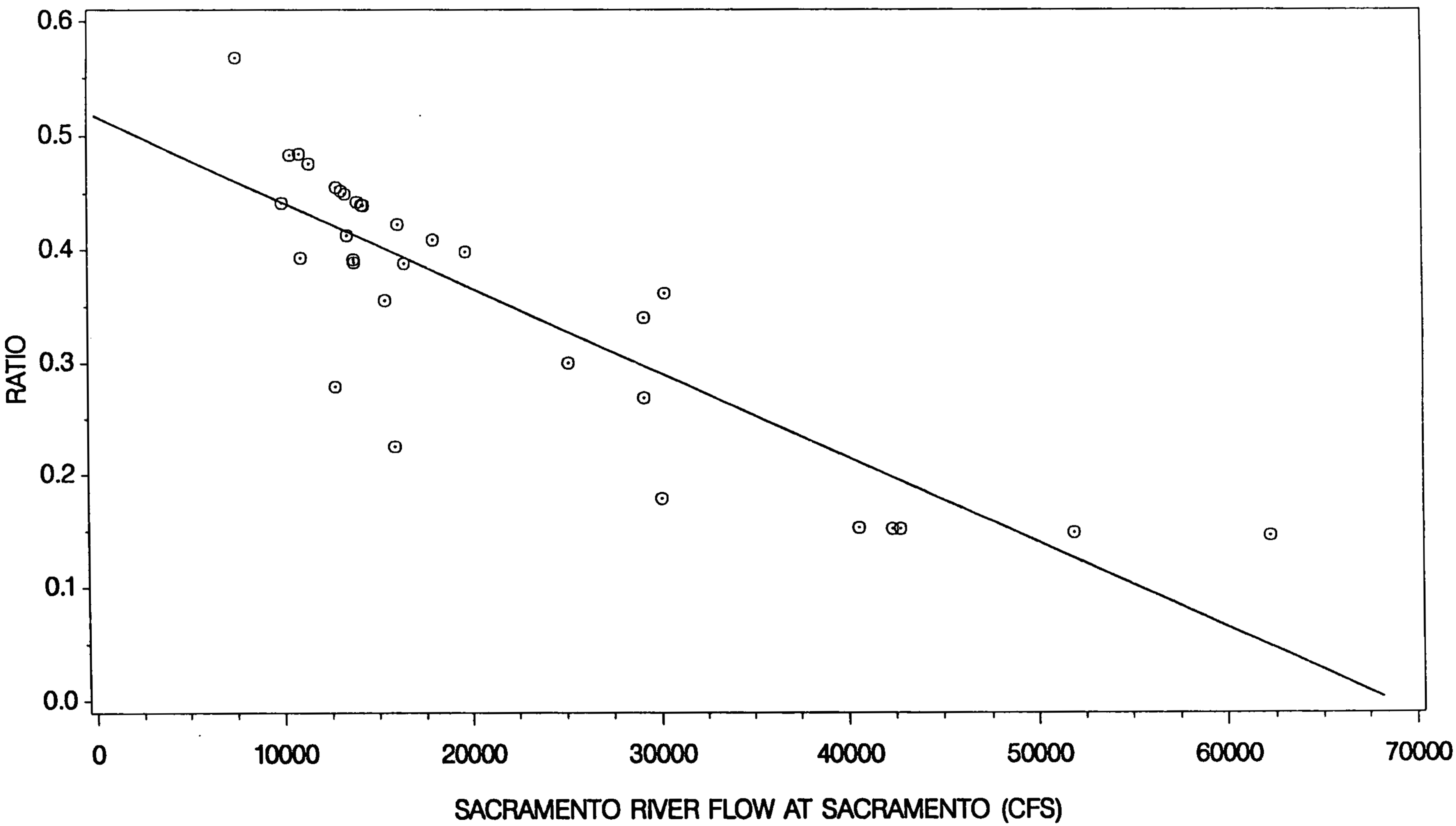

Figure 9. Relationship between the ratio of cross delta flow (Delta cross channel and Georgiana Slough flows) to the Sacramento River flow at Sacramento and Sacramento River flow at Sacramento for the month of May for years 1959-1990.

rapidly to the central and south Delta where they are more vulnerable to becoming entrained in water diverted by the SWP and CVP.

While the relative contribution of these potential mechanisms cannot be sorted out with present data, it is plausible that all are detrimental. Thus, it would be prudent to establish flow standards and Cross Channel closures for the Sacramento River which will improve survival of striped bass eggs and larvae that result from spawning in the Sacramento River under low flow conditions.

Evidence Supporting the Contention that Water Exports Have Caused the Decline in Striped Bass Abundance.

While water exports are only one of many factors affecting striped bass, it is DFG's opinion that six major pieces of evidence which point toward substantial direct and/or indirect adverse impacts of water project diversions on striped bass, collectively form a conclusive case that water project diversions are responsible for the depleted state of the striped bass population. The evidence is as follows:

1. Losses of young bass entrained in the water project diversions provide a straightforward mechanism to at least partly explain the initial relationships and entirely account for the sequential changes in those close, long-term relationships between young striped bass abundance and Delta outflow and water diversion rates.

   When effects of river flow on striped bass were first evaluated in 1970, there was a close inverse relationship between young striped bass abundance and percentage of inflow diverted during June and July from 1959-1970. This inverse relationship, a similar inverse relationship between Delta outflow and the proportion of Delta inflow diverted ($r = 0.997$, Turner and Chadwick 1972), and large losses of young bass entrained in diverted water (Exhibit 25

Tables 15, 16, 17, 18, 19, 20) are evidence that losses of fish entrained in Delta water exports were greater in low flow years. Thus, we conclude that such entrainment losses were at least partly responsible for the direct relationship between young striped bass abundance and outflow during that period (Figure 10). At that time, most of the exports were by the Central Valley Project (CVP) as the State Water Project (SWP) did not divert more than 600 cfs during June and July until 1971.

Subsequently at all levels of outflow, young striped bass abundance declined in the early 1970's when the SWP began exporting large amounts of water and the CVP increased their diversions (Figures 11 and 12). This decline in young bass abundance was most severe in the Delta portion of the nursery (Figure 13) which is the area most affected by diversions. A regression model using the combination of May-June outflow and water diversion rates accounted for the decline in bass abundance in the Delta nursery (Exhibit 25).

Confirming evidence that use of the Delta as a striped bass nursery has declined more than use of the downstream portion of the Estuary is demonstrated by a decline in the fraction of the population residing in the Delta at any given level of outflow (Figure 14). Over the entire period from 1959-1990, April-July and May-July outflow and water exports account for 65 and 73 percent, respectively, of the variability in the fraction of the young striped bass population residing in the Delta (Table 4).

Furthermore, the regression models that have been developed to account for annual variations in young striped bass abundance and survival have had to be revised to include earlier months as water exports have increased in those earlier months. Specifically, when effects of flow and diversions on young striped bass were first evaluated in 1970, conditions

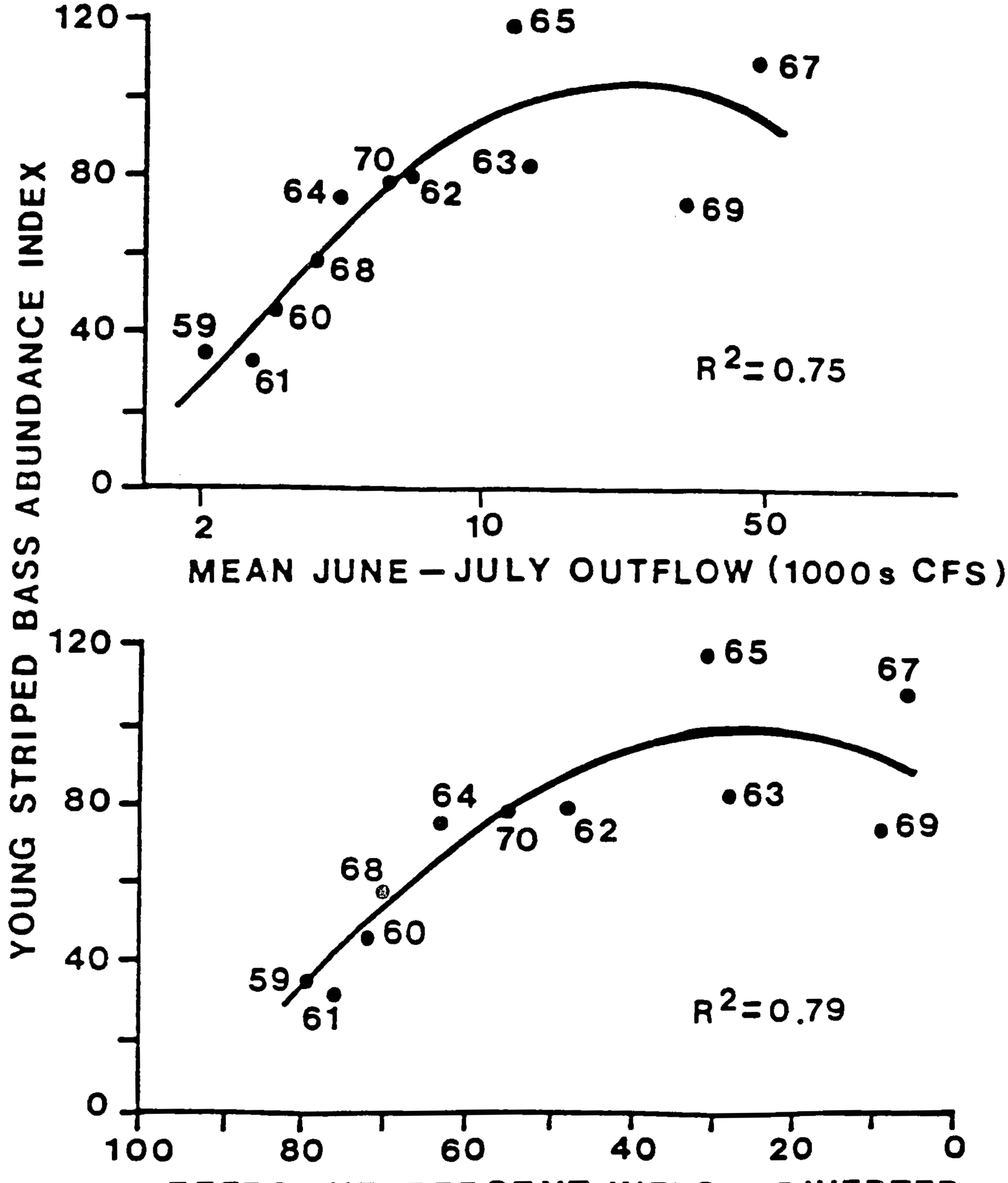

Figure 10. Relationship between total abundance of young striped bass in the Sacramento-San Joaquin Estuary and Delta outflow and diversions from 1959-1979. In years when outflow was high and percent of river inflow diverted was low, the striped bass index was high; conversely, when outflows were low and the percent diverted was high, the young striped bass index was low. Effective percent inflow diverted is the portion of Delta inflow diverted for internal use and exports, except that the portion of the San Joaquin River inflow not reaching the western/central Delta is not included in the calculations.

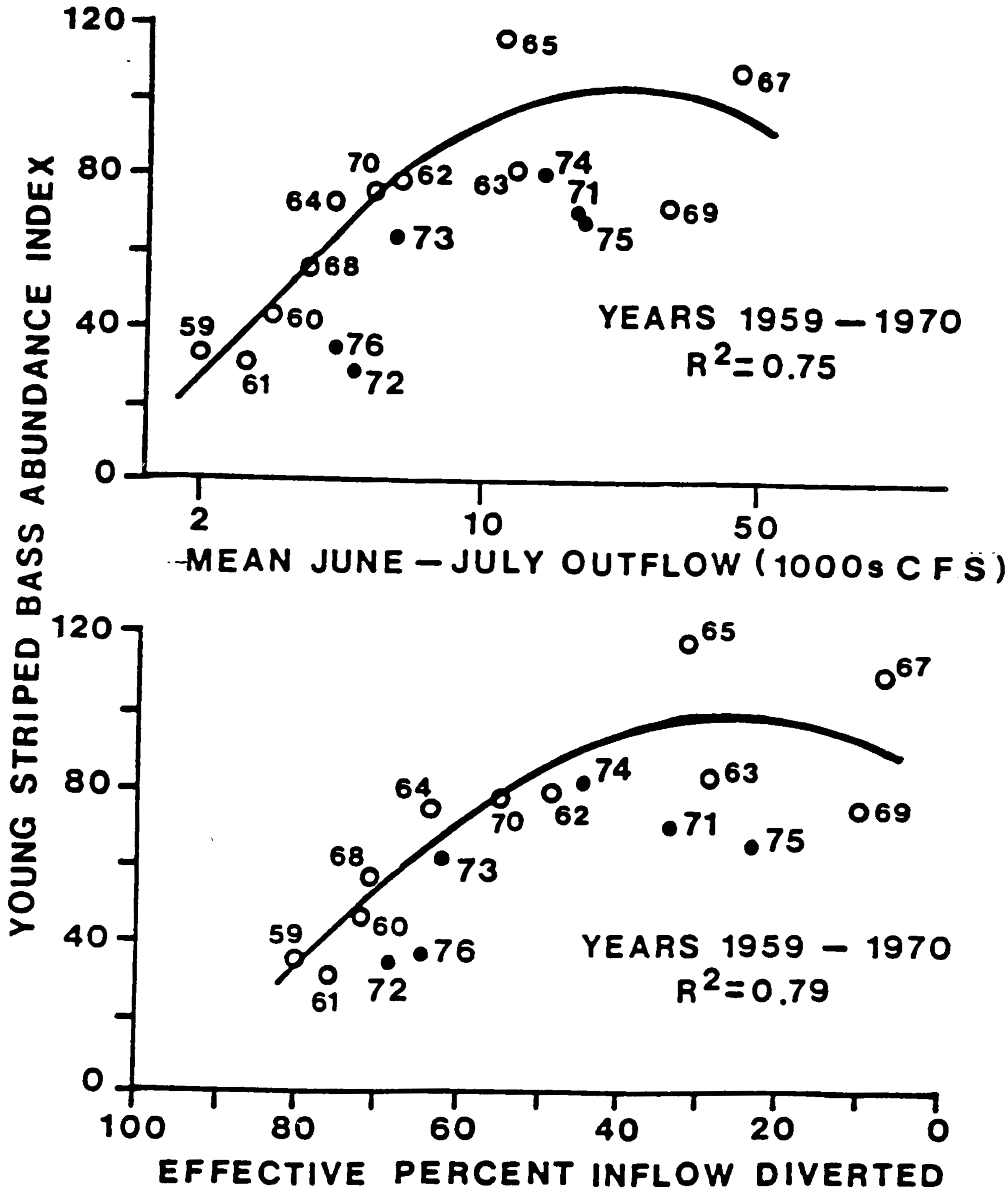

Figure 11. Relationship between total abundance of young striped bass in the Sacramento-San Joaquin Estuary and Delta outflow and diversions, 1959-1976. Curves are fits to 1959-1970 data. In the early to mid-1970s, young bass abundance was consistently lower than expected based on the 1959-1970 relationships of abundance with outflow and abundance with percent diverted. This decline in abundance occurred primarily in the Delta portion of the estuary. Effective percent inflow diverted is the portion of Delta inflow diverted for internal use and exports, except that the portion of the San Joaquin River inflow not reaching the western/central Delta is not included in the calculations.

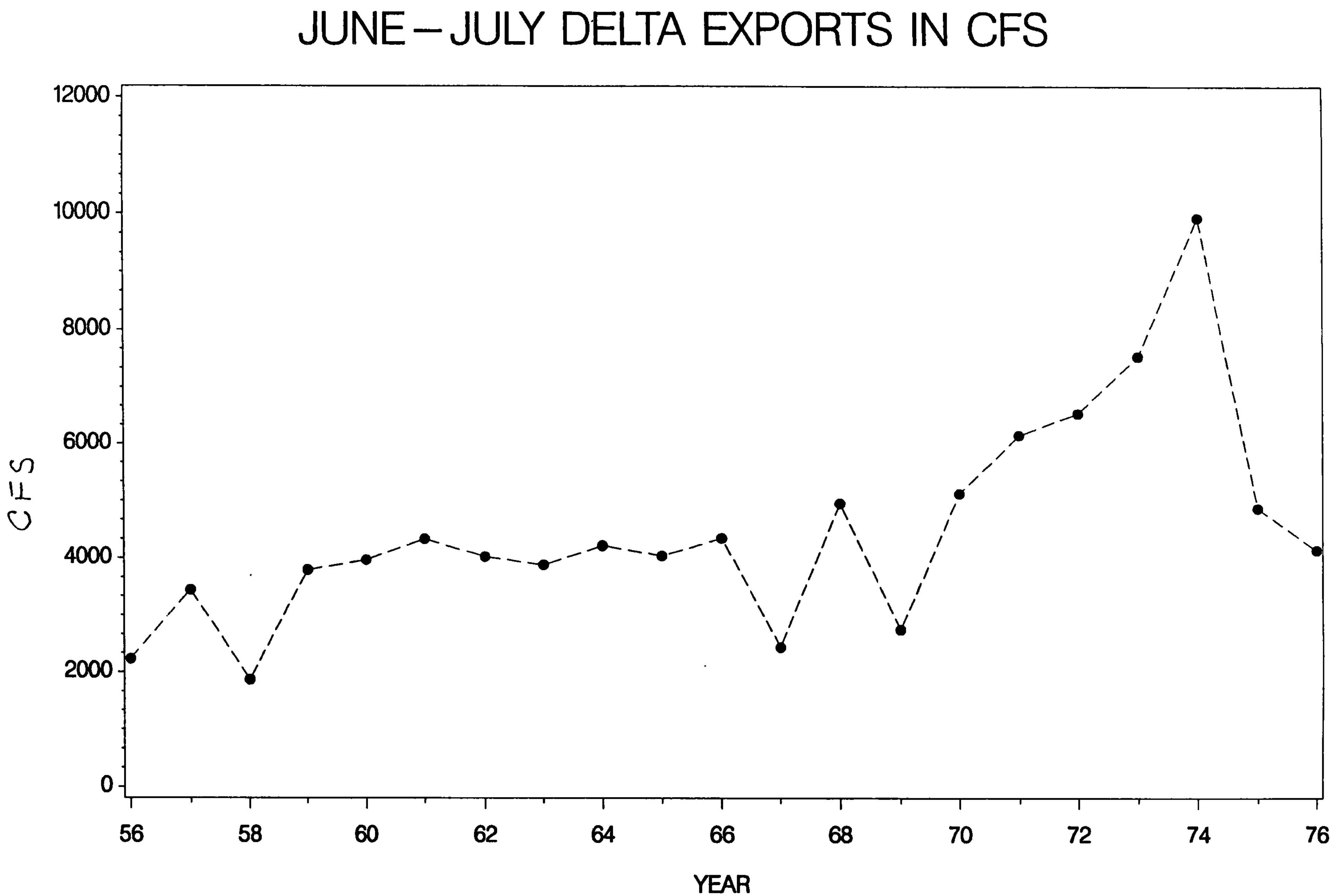

Figure 12. Mean total June-July CVP and SWP Delta water exports in cfs from 1956-1976.

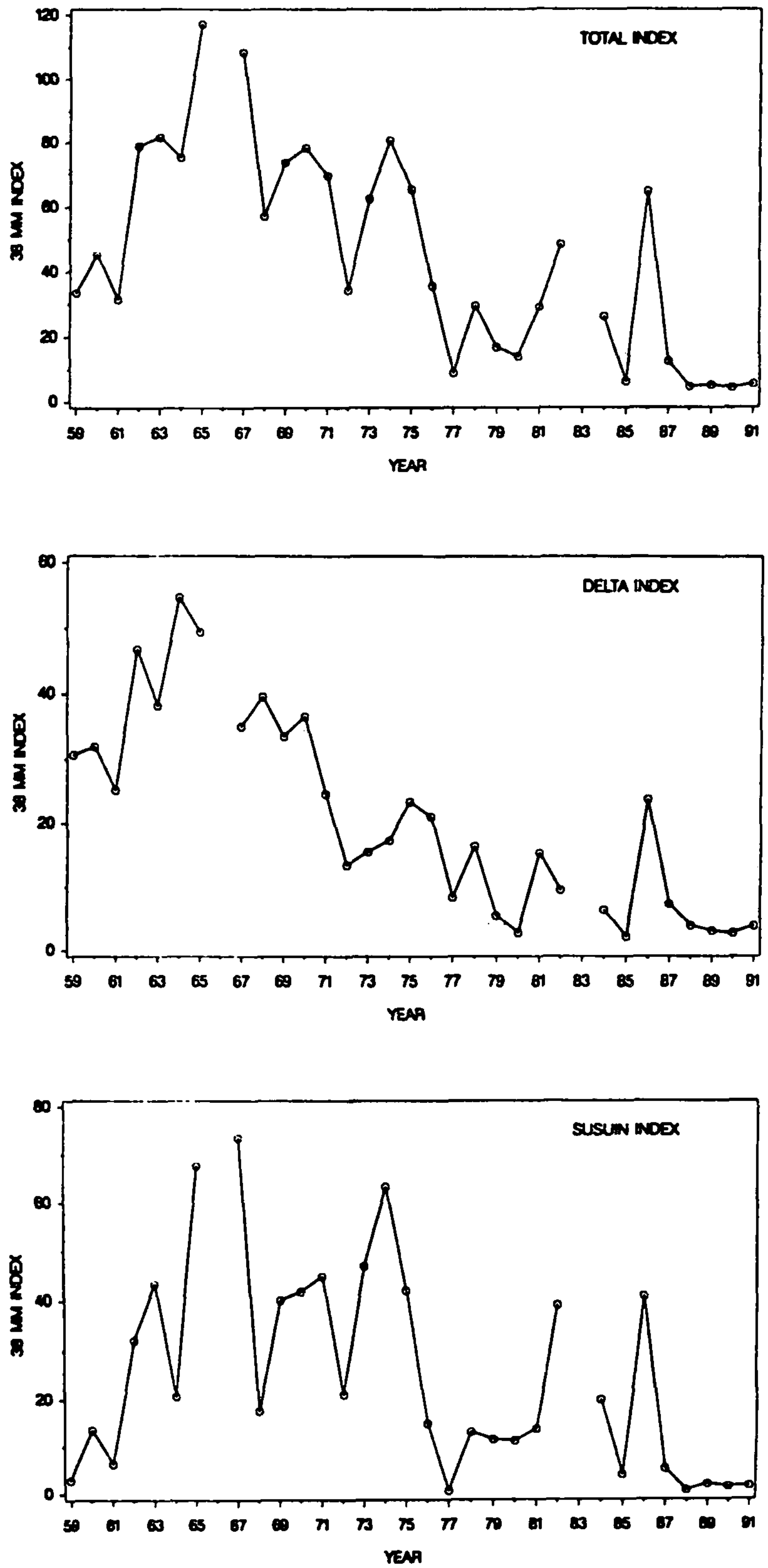

Figure 13. Annual index of young striped bass abundance by area. There has been an unsteady but persistent decline in young bass from the mid 1960s to the present. Lowest abundances have occurred in 5 of the last 7 years. The most pronounced decline is in the Delta, but the it is also clearly visible in Suisun Bay despite greater year to year fluctuations there. No sampling was conducted in 1966, and in 1983 the index was omitted because extremely high flows moved fish downstream of the area efficiently sampled by the townet survey.

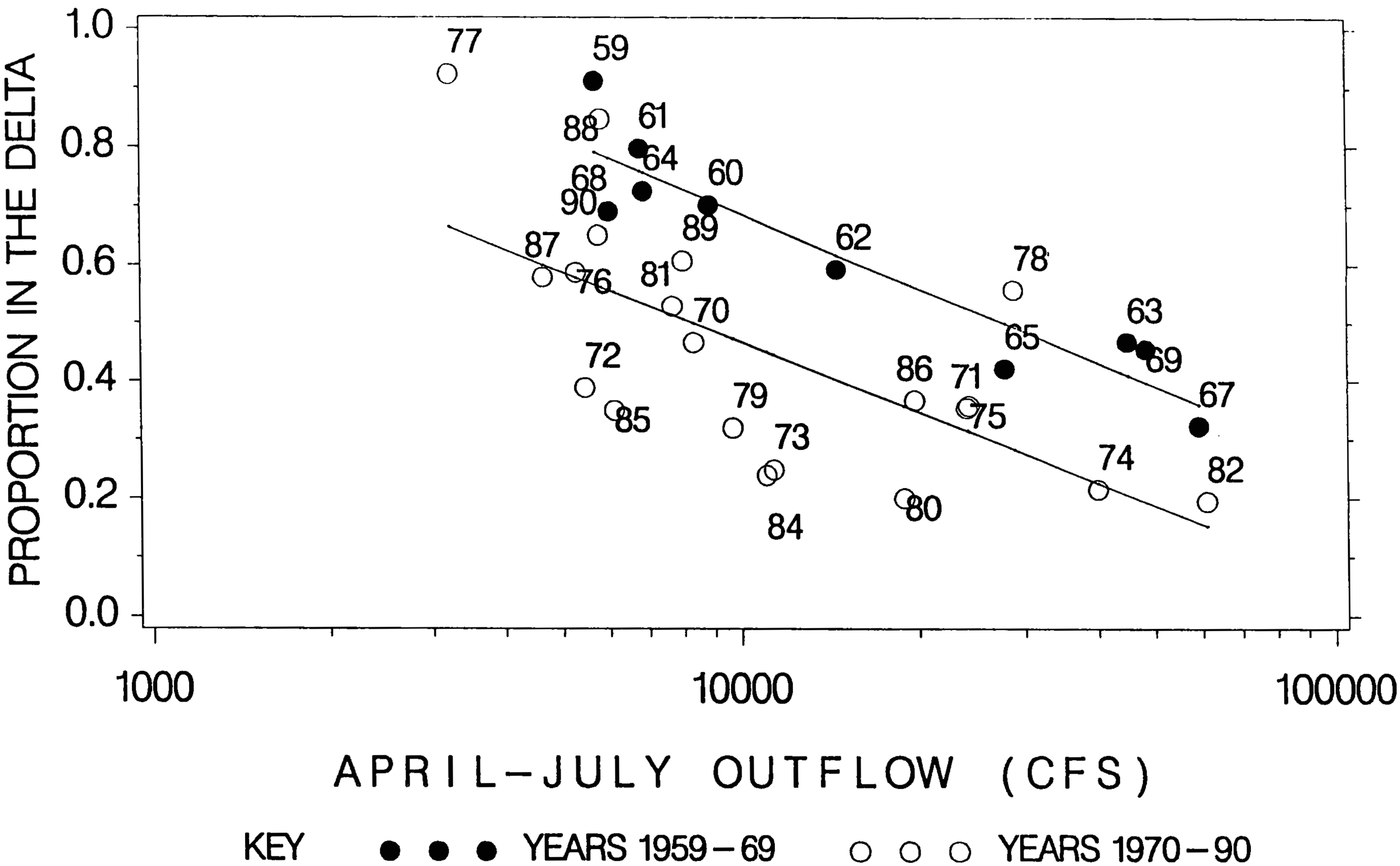

Figure 14. The proportion of striped bass 38-mm index located in the Delta in relation to the mean April to July Delta outflow.

Table 4. Coefficient of Determination (R^2) for multiple regressions of the fraction of the young striped bass population residing in the Delta against water diversion rates and log Delta outflow, 1959-1990.

Months	R^2
April-July	0.65
May-July	0.73

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during June and July accounted for the greatest amount of variation in the young bass index (Table 5). As we obtained data from the 1970's when the bass population began to decline and exports increased in May (Figure 15), inclusion of May in the equations improved coefficients of determination (R^2). In subsequent years (1977-1990) after the spawning stock declined, a new regression model, although with lesser predictive capability, continues to point toward water exports negatively impacting young striped bass abundance and indicates that April is now a critical month (Table 5).

The recent inclusion of April in the critical period has occurred in response to increased water exports in April (Figure 16) while exports in May and June have been limited by State Water Resources Control Board Decision 1485. Spawning surveys indicate that at least 14 to 46 percent of Delta striped bass spawning occurs in April (Table 6). These are minimum estimates of spawning because with the exception of 1968, sampling did not begin until at least April 11.

2. Implicit in the preceding relationships, which are based on young striped bass <u>abundance</u> indices, is that the relationships are created through effects of flows and water export on <u>survival</u> of young bass before the 38 mm stage. Indices which explicitly measure survival of young striped bass between 9 and 38 mm long also are closely and consistently related to water diversion rates and outflow over the years of record since 1968. Combinations of months from April to July provide the best predictive equations (Figure 17, Table 7).

3. The mathematical signs on the coefficients in all of the regression models regarding young striped bass and outflow and diversion rates are consistent with intuitive reasoning about the way in which striped bass abundance would respond to water diversions and outflow (Table 8).

Table 5. R^2 values for regressions between young striped bass abundance or survival and outflow and water diversion rates.

	Jun-July	May-Jul	Apr-Jul
1959-1970 Young striped bass abundance vs. outflow	0.75	0.69	0.58
1959-1976 young striped bass abundance vs. outflow and water diversions	0.59	0.62	0.58
1977-1990 Young striped bass abundance vs. outflow and water diversions	0.37	0.42	0.56
1968-1990 survival of young striped bass from 9 to 38 mm stages vs. outflow and water diversions	0.51	0.52	0.72

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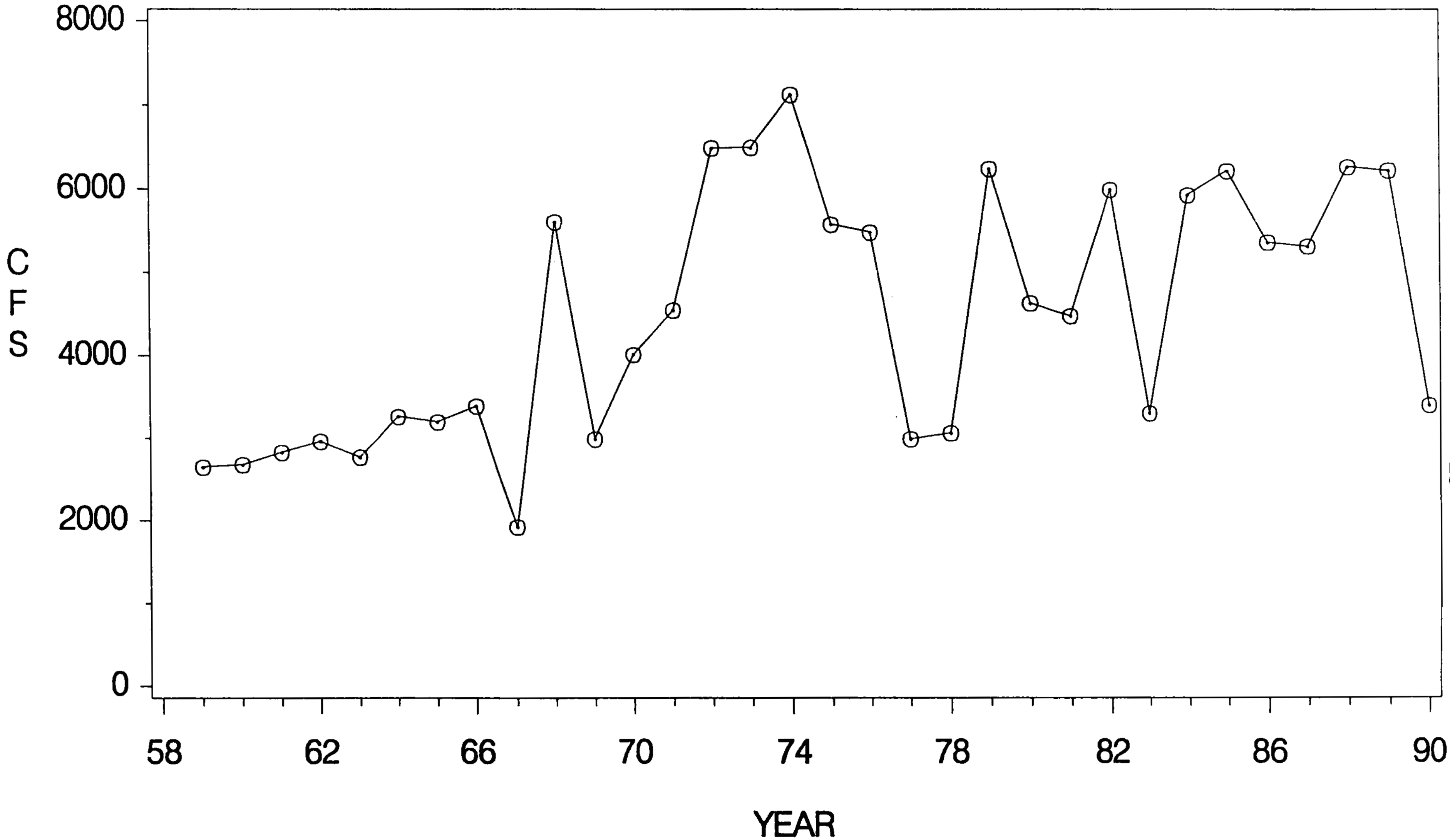

Figure 15. Total Delta water exports for May in cfs from 1959-1990.

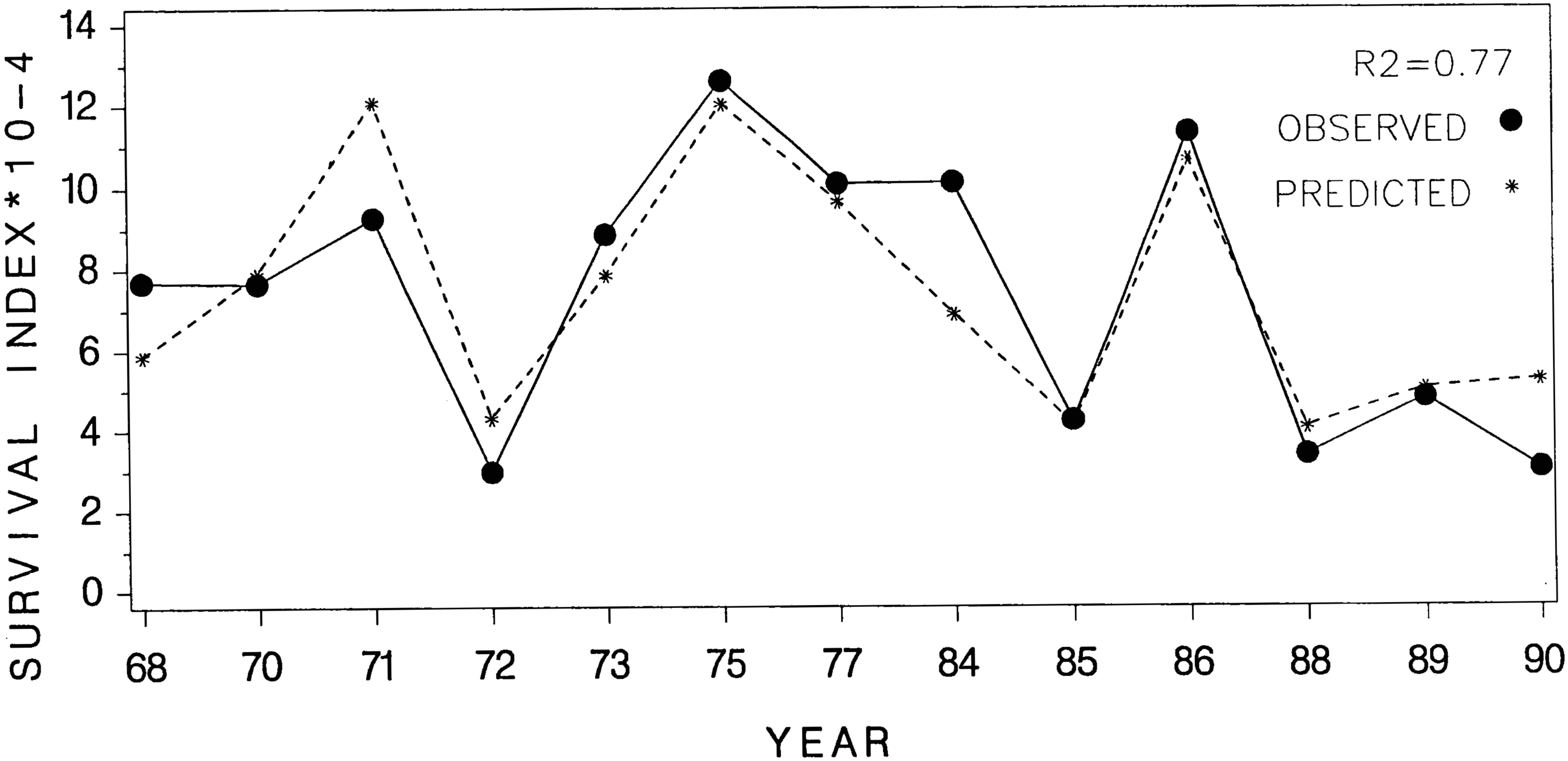

Figure 17. Relationship between observed striped bass survival index and the survival index for the interval 9 mm to 38 mm predicted from outflows and water diversions. The predicted survival index is based on the regression model: survival = 0.001116 + 0.001047 log10 April-July Delta outflow -0.001206 log 10 April-July Delta water exports.

Table 7. R-square values for the 9-38 mm striped bass survival index regressed on combinations of April-July Delta outflow and diversions from 1968 to 1990. The table values include the periods starting with the month at the top through the month on the left.

	April	May	June	July
April	0.629			
May	0.684	0.450		
June	0.735	0.488	0.487	
July	0.716	0.525	0.508	0.369

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Table 8. Regression equations used to predict striped bass abundance at 38mm or the survival index between 9mm and 38mm. Equations are for the time periods producing the highest R^2 value.

1959-1970		
June-July	Total striped bass abundance index	= 110.99 - 0.816 (percent of effective inflow diverted)
June-July	Total striped bass abundance index	= -1151.7 + 577.5 ($\log_{10}$ outflow)
1959-1976		
May-June	Delta striped bass abundance index	= -507.22 - 0.0553 (diversions) + 282.37 log (outflow) - 34.05 $(\log \text{outflow})^2$
June-July	Suisun striped bass abundance index	= -670.44 + 314.93 (log outflow) - 33.97 $(\log \text{outflow})^2$
1977-1990		
April-July	Delta striped bass abundance index	= -308.7 - 0.00227 (diversions) + 156.09 ($\log_{10}$ outflow) - 17.80 $(\log 10 \text{ outflow})^2$
April-July	Suisun striped bass abundance index	= -107.96 + 30.08 ($\log_{10}$ outflow)
1968-1990		
April-July	Survival index between 38mm and 9mm	= -0.00180 - 0.00000121 (diversions) +0.0092 ($\log_{10}$ outflow)

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Specifically, the diversion terms have negative coefficients and the outflow terms have positive coefficients. The signs on the coefficients are not forced positive or negative by the biologists evaluating the data. The signs and coefficients are determined by the best fit of the dependent variable (young bass abundance or survival) to the independent variables (diversions and outflow).

The negative coefficients on diversions mean that increasing water diversions have a negative effect on young bass abundance. This result is consistent with more fish being removed from the population as diversions increase. The positive coefficients on outflows are consistent with the concept that more flow reduces the impact of diversions by transporting fish away so a smaller portion of the population becomes entrained. Higher flows also may benefit survival of young bass through several other mechanisms including: 1) expanding the nursery area which occurs when more fish are transported downstream, 2) transporting fish to downstream areas with greater food productivity, 3) increasing nutrient input to the estuarine nursery areas, and 4) dilution of toxicity.

To summarize our point regarding the form of the regression models, we reiterate that these models are consistent with intuitive reasoning regarding the way in which striped bass abundance would respond to water diversions in general. Secondly the population decline that has occurred since water exports increased in the early 1970's is consistent with expectations based on these regressions.

4. The magnitude of estimated percentage reductions in abundance due to losses of fish eggs and larvae entrained in water project exports is substantial. Such losses have been estimated (Exhibit 25, pages 70-78) to cause from 31%

to 99% reductions in the population before young bass reach the 20 mm stage (Table 9).

5. Irregardless of assumptions about: 1) pre-screening loss rates at the State and Federal water project intakes and 2) netting efficiencies from 25 to 100% when the young striped bass abundance index (38 mm index) is set, estimates of entrainment losses of young striped bass larger than 20 mm (Tables 10 and 11) are large enough relative to estimates of young bass abundance (Table 12) that significant population reductions would be expected. The only uncertainty is the exact extent of those reductions. If the assumed prescreening losses are based on the experimental data (Table 11), the estimated total loss of young striped bass since 1970 is about twice (2.2 X) the corresponding total for the number of bass remaining in the Estuary based on 100% net efficiency, about equal to the number of bass remaining (1.1 X) based on 50% net efficiency, and about one-half of the number remaining (0.56 X) based on 25% net efficiency. Even conservatively assuming only a 15% prescreening loss, estimated total losses since 1970 are 58, 29, and 14% of the total of the estimated abundances of young bass in the Estuary assuming 100%, 50% and 25% net efficiencies, respectively.

6. Our striped bass model (WRINT-DFG-Exhibit 3) indicates that the adult stock and recruitment of new fish to the adult population have declined in response to the decline in young striped bass abundance and subsequent losses of fish entrained in water exports (Figure 18). In combination, the various relationships in the model indicate that entrainment losses erode the population throughout the year, both before and after the annual index of young bass abundance is set. It is the decline in spawners caused by past entrainment losses, their egg production and current entrainment losses that are now inhibiting the production of new fish. A persistent decline in survival of young striped bass relative to flow and water diversion rates did not occur

Table 9. Estimated percent reduction of young striped bass before the 20 mm stage caused by entrainment losses in CVP and SWP diversions.

Year	Percent Reduction
1985	73.5
1986	31.3
1988	84.3
1989	99.6

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Table 10. Case 1: Striped Bass (21-150 mm) loss estimates for the SWP and CVP * (Table 10 A in Exhibit WRINT-DFG-1)

Year	SWP Loss Estimate	CVP Loss Estimate	Total Estimate
1957	0	1,620,478	1,620,478
1958	0	595,613	535,613
1959	0	7,588,877	7,588,877
1960	0	9,544,050	9,544,050
1961	0	14,914,306	14,914,306
1962	0	14,557,701	14,557,701
1963	0	22,821,857	22,821,857
1964	0	25,964,189	25,964,189
1965	0	12,595,389	12,595,389
1966	0	33,905,326	33,905,326
1967	0	5,001,887	5,001,887
1968	1,518,640	14,009,334	15,527,974
1969	1,509,202	8,329,794	9,838,996
1970	10,996,834	18,717,177	29,714,011
1971	7,635,924	8,459,477	16,095,401
1972	5,721,871	9,133,657	14,855,528
1973	9,906,979	8,547,806	18,454,785
1974	16,884,849	5,935,344	22,820,193
1975	4,405,373	6,192,385	10,597,758
1976	1,651,017	4,403,134	6,054,151
1977	516,665	613,848	1,130,513
1978	3,507,951	3,332,958	6,840,909
1979	2,845,227	2,399,012	5,244,239
1980	2,786,574	1,278,896	4,065,470
1981	857,229	5,746,387	6,603,616
1985	815,078	1,368,322	2,183,400
1983	99,554	160,702	260,256
1984	8,491,434	5,640,468	14,131,902
1985	4,181,702	1,699,641	5,881,343
1986	15,061,909	4,932,410	19,994,319
1987	14,596,798	2,674,519	17,271,317
1988	12,759,277	716,615	13,475,892
1989	9,016,015	1,435,483	10,451,498

* SWP losses are based on a 15% pre-screening loss rate.
CVP losses are based on a 15% pre-screening loss rate.

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Table 11 Case 2: Striped Bass (21-150 mm) loss estimates for the SWP and CVP * (Table 12 A in Exhibit WRINT-DFG-1).

Year	SWP Loss Estimate	CVP Loss Estimate	Total Estimate
1957	0	1,620,478	1,620,478
1958	0	595,613	535,613
1959	0	7,588,877	7,588,877
1960	0	9,544,050	9,544,050
1961	0	14,914,306	14,914,306
1962	0	14,557,701	14,557,701
1963	0	22,821,857	22,821,857
1964	0	25,964,189	25,964,189
1965	0	12,595,389	12,595,389
1966	0	33,905,326	33,905,326
1967	0	5,001,887	5,001,887
1968	1,518,640	14,009,334	15,527,974
1969	1,509,202	8,329,794	9,838,996
1970	10,996,834	18,717,177	29,684,011
1971	42,184,312	8,459,477	56,643,789
1972	39,204,045	9,133,657	48,337,702
1973	64,119,555	8,547,806	72,667,361
1974	107,357,174	5,935,344	113,292,518
1975	30,287,231	6,192,385	36,479,616
1976	11,086,639	4,403,134	15,489,773
1977	3,701,322	613,848	4,315,170
1978	24,358,333	3,332,958	27,691,291
1979	18,640,005	2,399,012	21,039,017
1980	17,890,370	1,278,896	19,169,266
1981	6,337,892	5,746,387	12,084,279
1985	6,001,195	1,368,322	7,369,517
1983	781,438	160,702	942,140
1984	51,916,076	5,640,468	57,556,544
1985	26,371,523	1,699,641	28,071,164
1986	92,705,392	4,932,410	97,637,802
1987	88,480,625	2,674,519	91,155,144
1988	77,770,704	716,615	78,487,319
1989	56,192,155	1,435,483	57,627,638

* SWP losses are based on an 82% pre-screening loss rate (1968 through 1970 are based on a 15% pre-screening loss rate). CVP losses are based on a 15% pre-screening loss rate.

Table 12. Estimated abundance of striped bass (in millions) when the mean size is 38 mm based on assumptions of 100, 50, and 25 percent net efficiency. Estimated abundance is the product of the catch per acre foot of water strained by the net and the water volume in acre feet sampled in the nursery area.

Year	100 percent net efficiency	50 percent net efficiency	25 percent net efficiency
1959	19	38	75
1960	26	51	102
1961	18	35	71
1962	44	88	177
1963	46	91	183
1964	42	84	169
1965	66	131	262
1966	-	-	-
1967	61	122	243
1968	32	64	128
1969	41	83	165
1970	44	88	176
1971	39	78	156
1972	19	39	77
1973	35	70	140
1974	45	90	181
1975	37	73	147
1976	20	40	80
1977	5	10	20
1978	17	33	66
1979	9	19	38
1980	8	16	31
1981	16	33	65
1985	27	54	109
1983	-	-	-
1984	15	29	59
1985	4	7	14
1986	36	73	145
1987	7	14	28
1988	3	5	10
1989	3	6	11
1990	2	5	10

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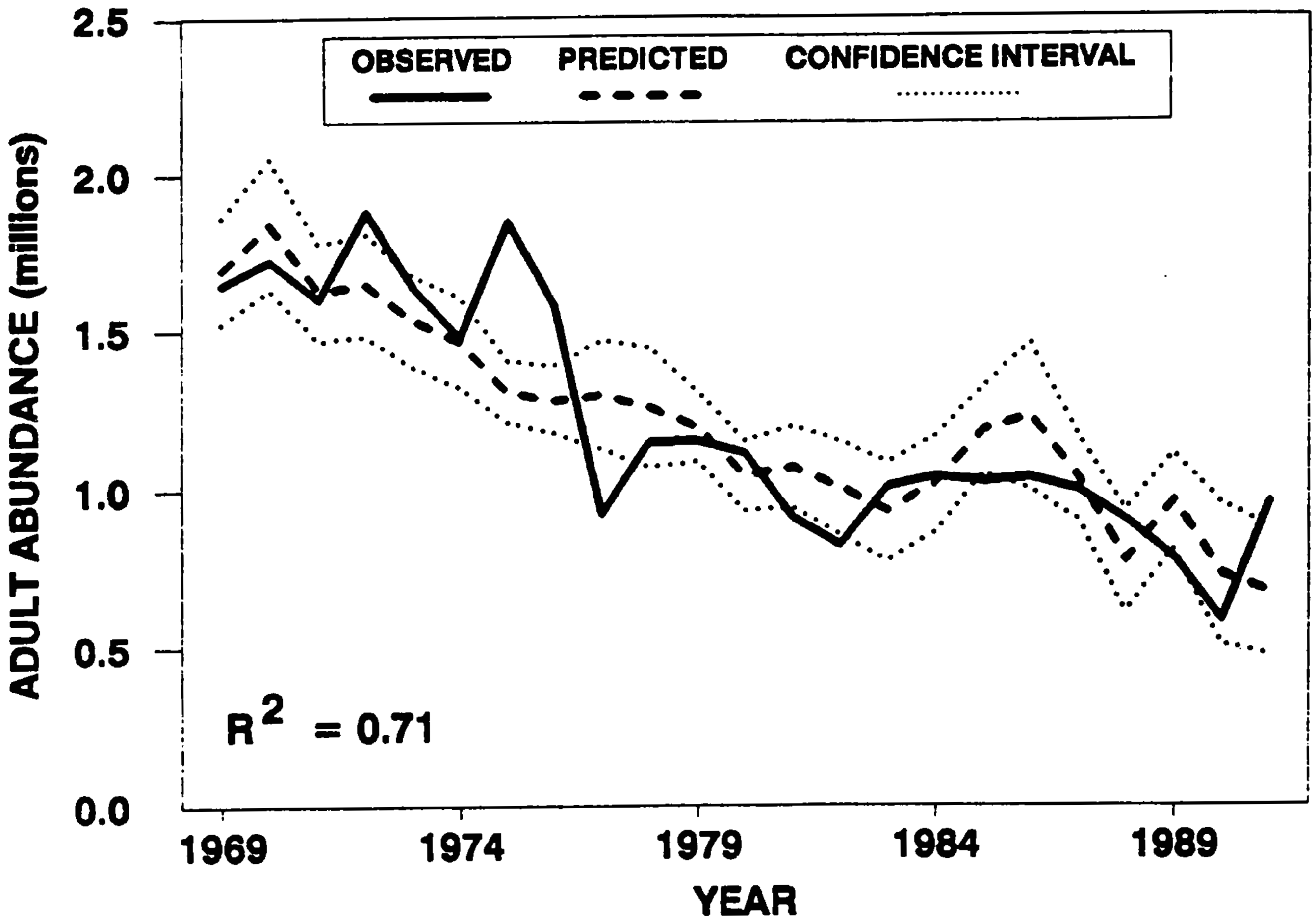

Figure 18. Observed and predicted adult striped bass abundance (exclusive of hatchery raised fish) in the Sacramento-San Joaquin Estuary from 1969-1991. Predicted values are from the relationship between adult abundance and weighted mean young-of-the-year index and export loss rate 3-7 years earlier. The 95% confidence limits for the predicted values are shown.

coincident with the decline in young striped bass abundance (Figure 19) indicating that survival of young bass did not suddenly decline in response to other environmental changes.

Factors Other than the Process Described by the Striped Bass Model Which Have Been Hypothesized as Potential Causes of the Decline in Striped Bass Abundance.

The possible adverse effects of a decline in food availability and increased toxicity are the primary alternative factors that have been considered as potential causes of the decline in striped bass abundance. These and several other factors: competition and predation by other fishes, predation by sea lions, poaching, and temperature, are discussed in Exhibit 25.

The Hypothesis that a Decline in Food Availability Has Caused the Decline in Young Striped Bass Abundance.

This hypothesis is that young striped bass mortality has increased because the zooplankton that they have historically eaten have declined in abundance. There have been substantial changes in the species composition of the zooplankton, at least partly due to accidental introductions of exotic species (Exhibit 28). The historically predominant striped bass food species, Eurytemora affinis, has declined in abundance, possibly partly due to predation or competition from the exotic zooplankton species (Exhibit 28), and also since 1988 probably due to consumption by the clam, Potamocorbula amurensis, which also was accidentally introduced through ship ballast discharge.

The Test of the Food Limitation Hypothesis.

There are two important pieces of information for evaluating the food limitation hypothesis:

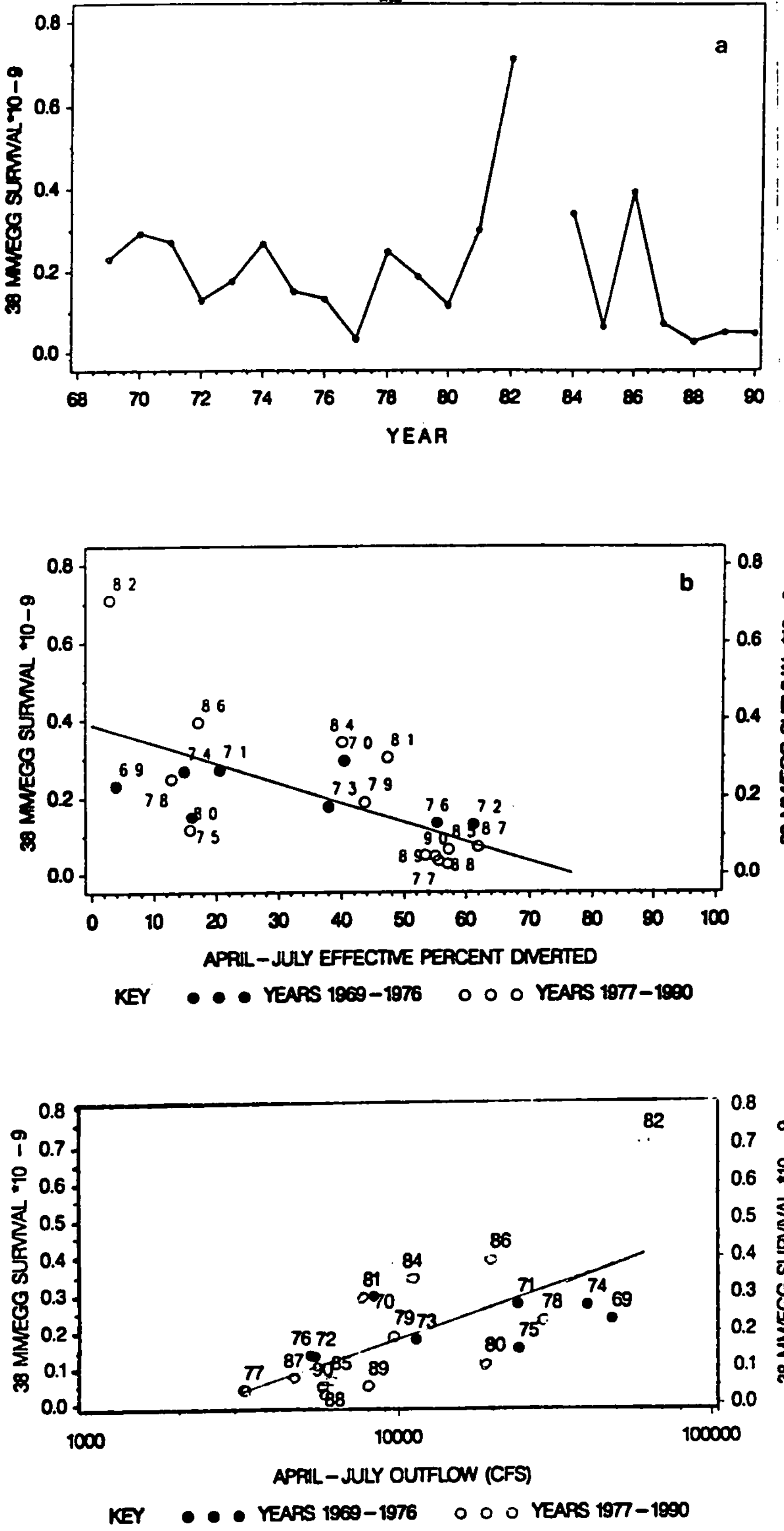

Figure 19. Survival index between striped bass egg production, based on the Petersen population estimates and age-specific fecundity, and the 38-mm abundance index. There is no persistent decline over the years of record (a). There is no trend in recent years of lower survival in relation to either the percent of effective Delta inflow diverted (b) or April-July outflow (c).

1) A study at U.C. Davis recently compared the condition and tissue structure of field caught striped bass larvae with condition and tissues of fed and starved larvae maintained in a laboratory. Despite recent changes in the kinds and abundances of food organisms in the Estuary, over 94 percent of field-caught larvae classified by morphometric analysis (N= 793 for 1988-1990) appeared in as good or better condition than laboratory-fed larvae (Table 13, Figure 20). Furthermore, all 363 field-caught specimens evaluated for tissue structure were scored as fed and had food in their guts (Figure 21). The tissue method is considered to be the most accurate so the U.C. Davis researchers have concluded that <u>none</u> of the field-caught larvae should have been classified as starved. Thus, these results are inconsistent with the hypothesis that reduced food availability has limited striped bass survival.

2) If an environmental factor such as reduced food was the cause of the reduced abundance of young striped bass, recent survival rates would be lower for young bass at any given outflow or diversion rate. In contrast, the process described by our striped bass model is consistent with our observation (described below) that survival is unchanged except for effects of water exports and outflows. The reduced spawning of the depleted adult stock alone accounts for the decline in abundances of young fish.

We have used several approaches to evaluate whether or not the survival rate has declined. All approaches indicate that the survival rate varies among years, but there has not been a persistent unexplained decline in this rate. An example is in Figure 19. The top portion of this figure shows the trend in an annual index of survival between the egg and 38 mm stages. Note that survival is quite variable over the period of record and also that survival has been low during the low flow drought years since 1987. However, also note that there have been several years since 1977 with higher than average survivals, for example 1981, 1982, 1984, and 1986. Yet, these years all

Table 13. Classification results (Percent classified as fed) from discriminate analyses of the condition of striped bass larvae from the Sacramento-San Joaquin Estuary, 1988-1990. Table from William Bennett, U.C. Davis.

	1988			1989			1990		
	Classification Method			Classification Method			Classification Method		
Group	N	Ratio[1/]	PCA[2/]	N	Ratio	PCA	N	Ratio	PCA
With Food				89	74.4	83.2			
Starved				79	19.0	13.9			
Sacramento River	117	92.3	95.7	76	68.4	88.2	75	84.0	94.7
San Joaquin River	221	93.7	95.5	63	90.5	100.0	82	75.6	89.0
Antioch	-	-	-	59	64.4	97.0	20	100.0	94.7
Collinsville	-	-	-	61	95.1	93.4	19	89.5	95.0
Total Field	338	93.2	95.6	259	79.2	94.2	196	82.6	92.4

1/ Classified based on eye diameter: length ratio

2/ Classified by Principle Components Analysis

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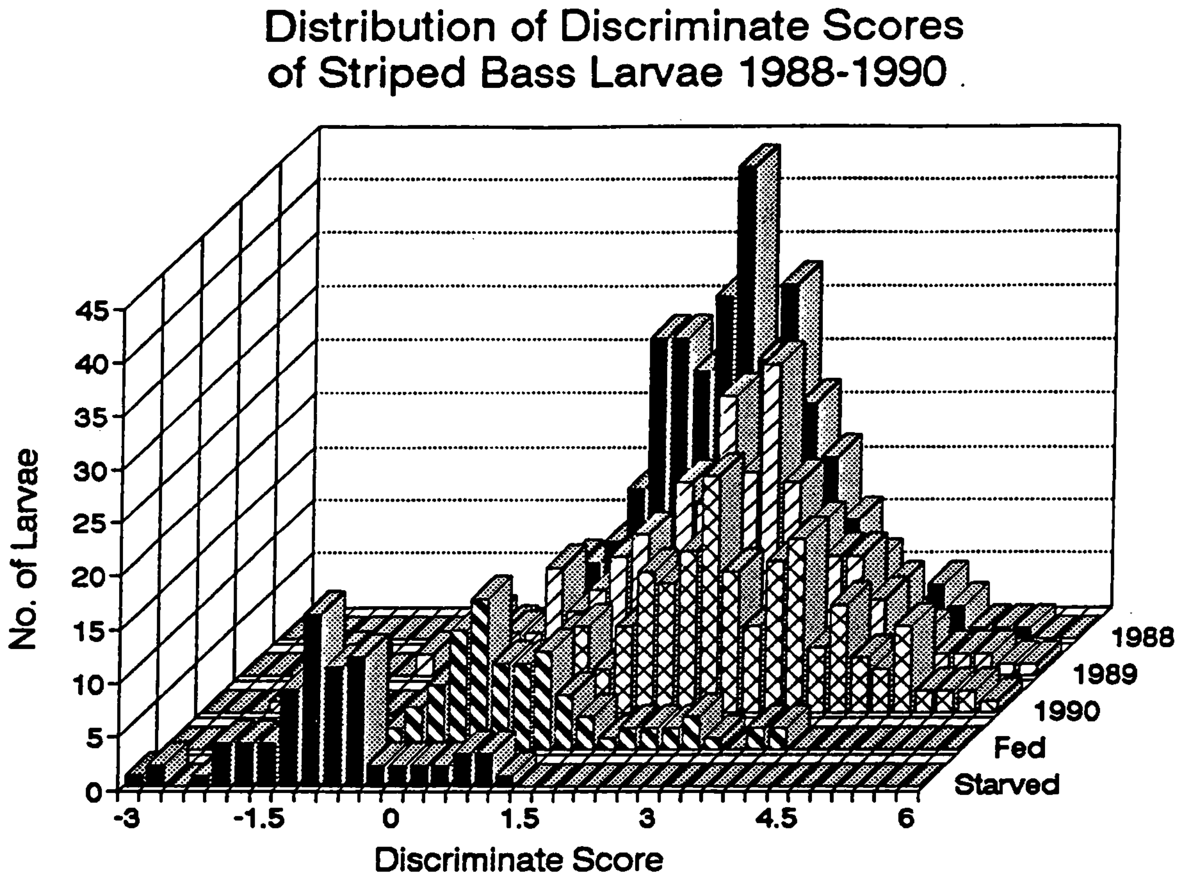

Figure 20. Discriminate scores of striped bass larvae show differences between fish from the Estuary (1988-1990) and fish starved or fed in the laboratory. (Figure from William Bennett, U.C. Davis.)

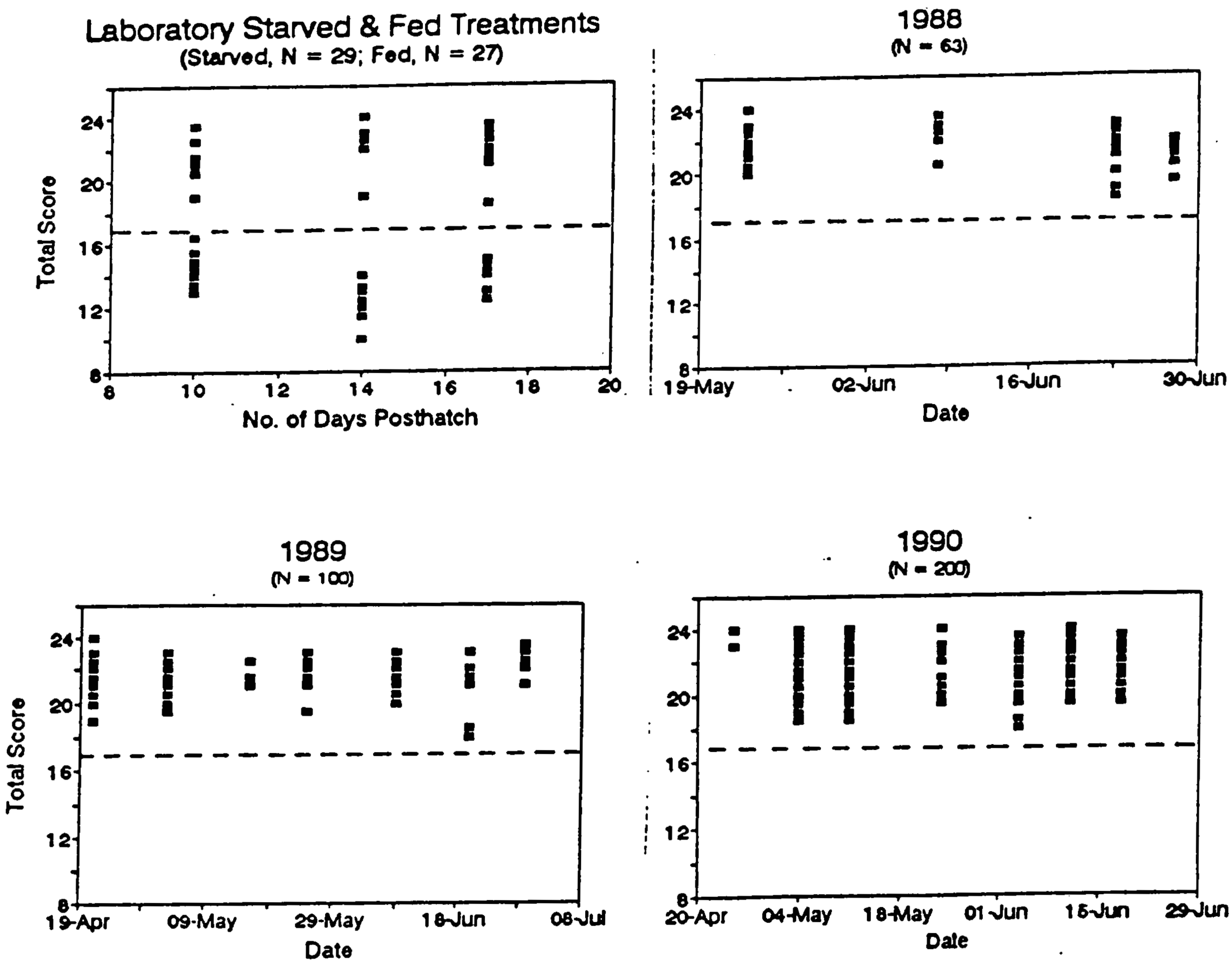

Figure 21. Results from histological analyses of striped bass larvae: Comparison of laboratory "starved and fed" treatments with specimens from the Sacramento-San Joaquin Estuary. (Figure from William Bennett, U.C. Davis).

produced year classes that were less abundant than predicted by the relationship between young bass abundance, outflow, and diversions from 1959-1976. The middle and lower portions of this figure reveal that, since 1977, the survival rate has not been persistently lower than expected from the outflow and diversion conditions that have occurred. The years since 1977, depicted by the open data points, are spread about equally above and below the regression lines representing the best straight line fit to the data over the entire period of record back to 1969.

These results are inconsistent with any explanation for the decline in young striped bass abundance except the one regarding the reduced egg supply associated with the depleted spawning stock which we have shown is strongly associated with past losses of young fish to water exports (WRINT-DFG-Exhibit 3).

The Hypothesis that Increased Toxicity Has Caused the Decline in Young Striped Bass Abundance.

Much concern has been expressed regarding the possibility that young striped bass survival has been reduced due to toxic effects of insecticides, herbicides, and trace elements in agricultural drains which discharge to the Sacramento and San Joaquin rivers. A particularly appealing hypothesis to some, is that there may have been increased toxicity related mortality starting in the late 1970's associated with the increase in rice cultivation and changes in kinds and amounts of pesticides used on rice. These changes roughly coincided with the major decline in young striped bass abundance and led to analyses (Central Valley Regional Water Quality Control Board Division of Standards and Assessment) which have shown strong statistical associations between the use of some of the pesticides and young striped bass abundance over part of the 1959-1991 striped bass record (pesticide analysis is from 1970-1988 or subset of those years depending on chemical).

In the early 1980's there were highly visible fish kills in the agricultural drains that discharge rice field water to the Sacramento River. These kills consisted largely of carp which are particularly susceptible to the rice herbicide: molinate (Finlayson and Faggella 1986). However, two hazard assessments completed by the Department of Fish and Game have concluded that rice herbicides: molinate and thiobencarb, have had minimal, if any, adverse effects on striped bass inhabiting the Sacramento-San Joaquin Estuary (Faggella and Finlayson, 1987; Harrington 1990).

Additionally, according to a Central Valley Region Water Quality Control Board staff report (Consideration of Approving Department of Pesticide Regulation's 1992 Management Procedures for Rice Pesticides), in addition to the herbicides: molinate and thiobencarb, three insecticides used on rice: carbofuran, malathion, and methyl parathion, were present in drains at concentrations that posed a threat to aquatic resources. Laboratory studies by the U.S. Fish and Wildlife Service (Saiki et al. 1992), and scientists at U.C. Davis (Bailey et al 1991) have shown that drain waters from both the Sacramento and San Joaquin valley's may sometimes be toxic to striped bass larvae, although testing by the Department of Fish and Game's Aquatic Toxicology Laboratory has not shown such evidence of toxicity to striped bass larvae either in the major Sacramento Valley drain (Colusa Basin Drain) or in the Sacramento River (Finlayson et al. 1991; Figures 22, 23, and 24).

Why the Department of Fish and Game Model Provides a Better Explanation for the Decline in Striped Bass Abundance than the Statistical Associations between the Use of Some of the Pesticides and Young Striped Bass Abundance.

The statistical associations are based on insecticide and herbicide <u>use</u>, not on drain discharge, environmental exposure levels, or measurements of toxicity. Thus, they do not reflect the chemical degradation that occurs before the insecticides and herbicides are discharged to the river and the actual exposure of striped bass. This point is important because major changes in rice field water management have been

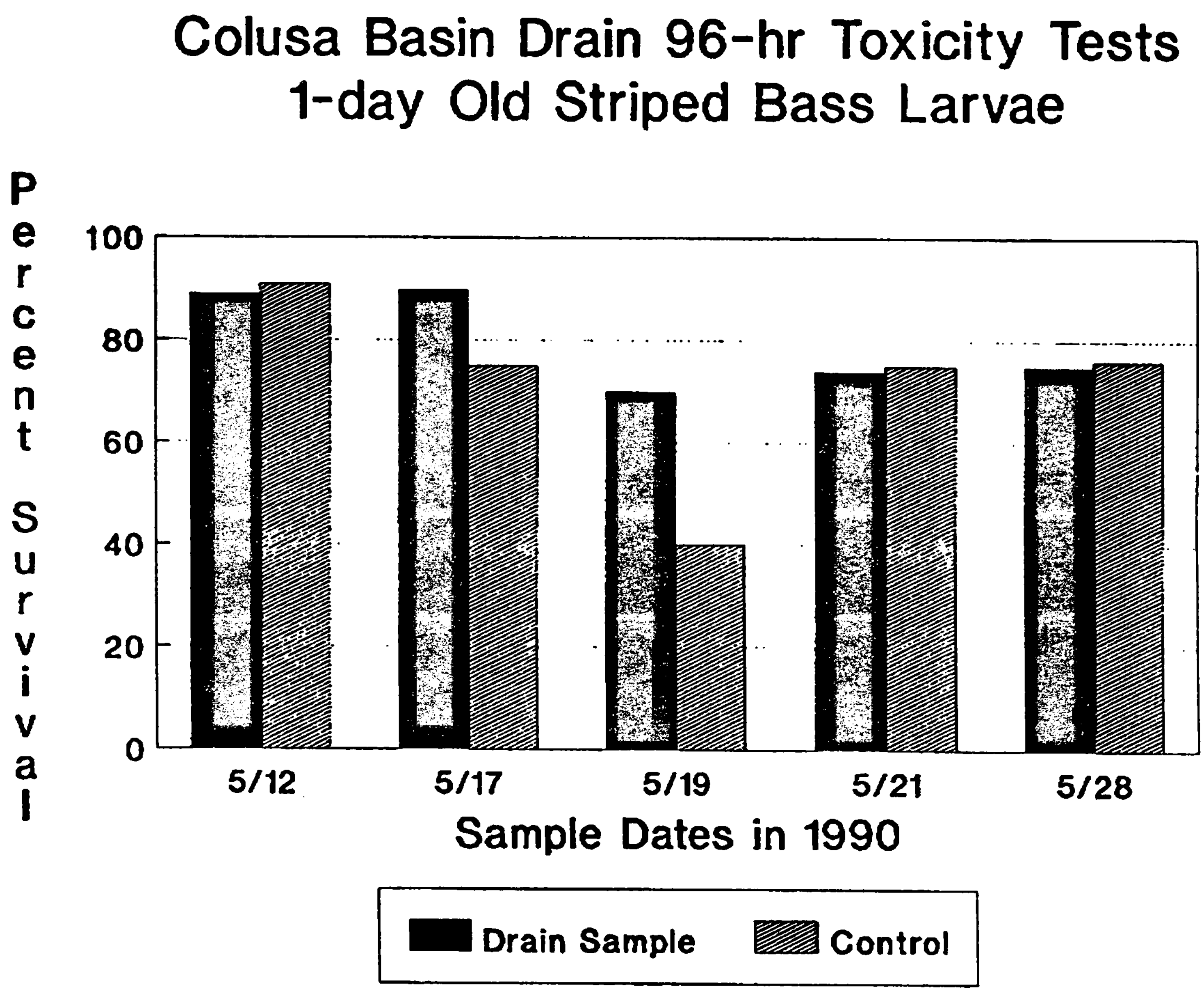

Figure 22. Colusa Basin Drain 96-hour toxicity tests in 1990: 1-day old striped bass larvae.

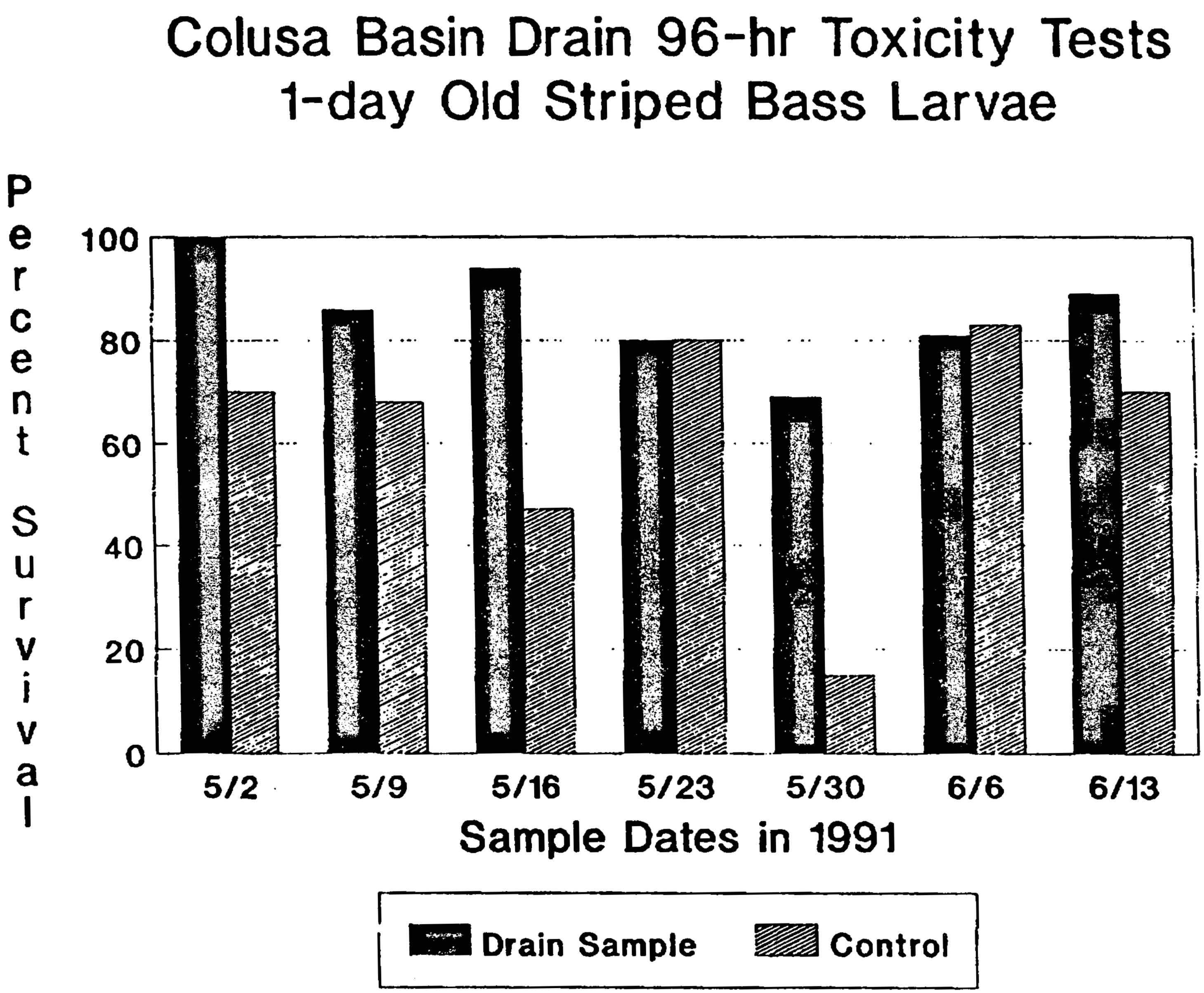

Figure 23. Colusa Basin Drain 96-hour toxicity tests in 1991: 1-day old striped bass larvae.

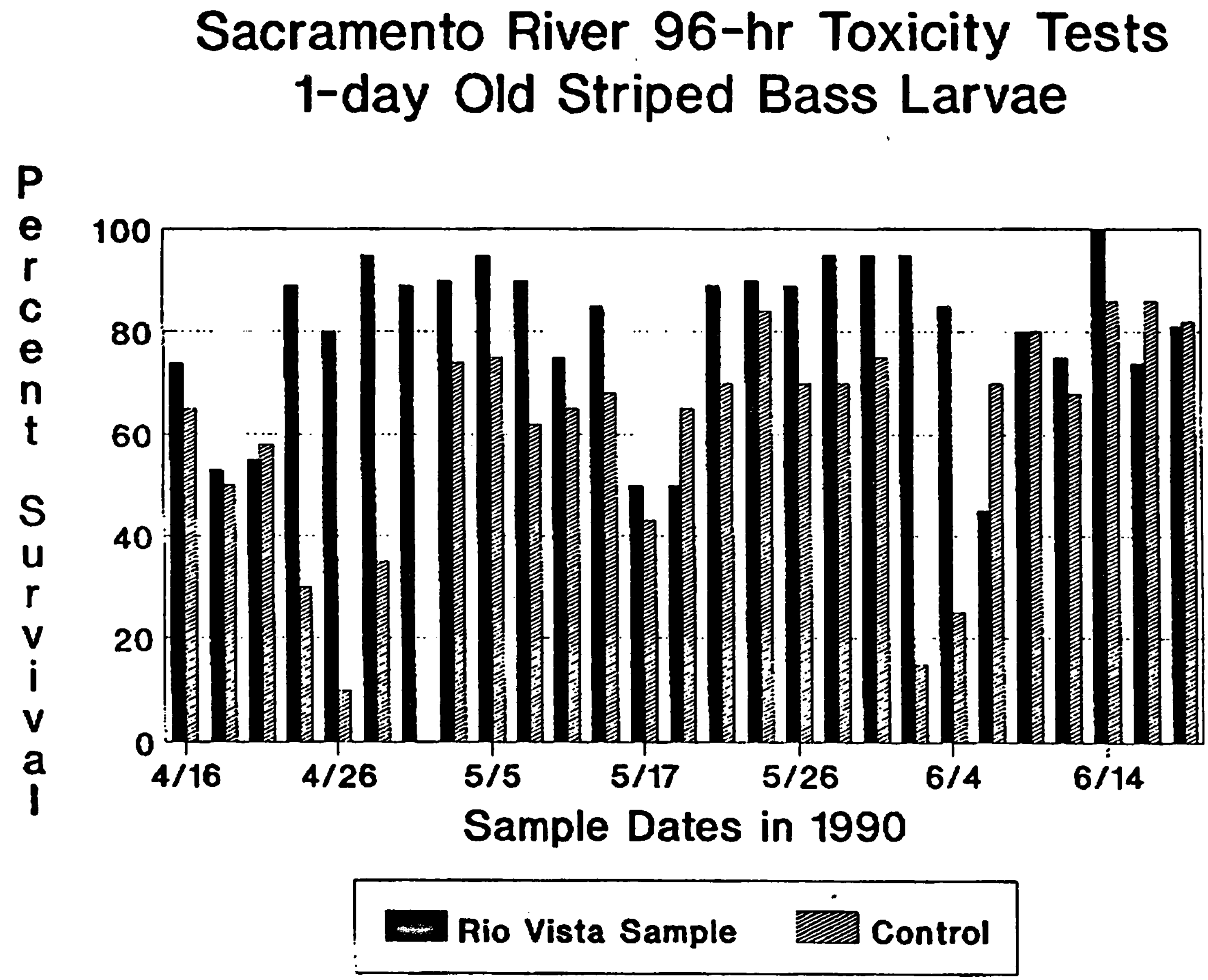

Figure 24. Sacramento River 96-hour toxicity tests in 1990: 1-day old striped bass larvae.

implemented to increase chemical degradation and reduce potential toxic effects of these chemicals. It is the amount discharged, not amounts applied, that potentially affect fish in the Sacramento River. For any given amount applied, the amount discharged is now less than it used to be. This change has come about because the Department of Pesticide Regulation (formerly Department of Food and Agriculture) established a program in 1984 to reduce and control the discharge of pesticides from rice fields. This program has resulted in the prohibition of discharge of carbofuran, malathion, methyl parathion, molinate, and thiobencarb unless the discharger is following a management practice approved by the Regional Water Quality Control Board. The program requires that rice field water be held for varying periods of time, depending on herbicide or insecticide, before it can be discharged.

As indicated by Tables 14 and 15, the quantity of the major insecticides and herbicides transported by the river past Sacramento has been <u>substantially</u> reduced in recent years. In 1991, the total mass transport of the herbicide, molinate was reduced 96.9 percent from 1990 and 99.5 percent since 1982. Concurrently, concentrations of the herbicides in the Colusa Basin Drain have been reduced from 340 to 18 ug/L for molinate and from 57 to less than 1 ug/L for thiobencarb during the last 10 years. Similarly, concentrations of these herbicides in the Sacramento River have been reduced from 16 to 0.6 ug/L for molinate and from 3.7 to < 0.1 ug/L for thiobencarb during the same period (Harrington and Lew 1992.)

Data on insecticides also show order of magnitude reductions in the Colusa Basin Drain (R. Schnagel, Central Valley Regional Water Quality Control Board). In 1991, the <u>maximum</u> concentration of malathion was 0.11 ug/L in the Colusa Basin drain at Knights Landing. (CVRWQCB staff report on Consideration of Approving Department of Pesticide Regulation's 1992 Management Practices for Rice Pesticides). For comparison, in 1990 (data from R. Schnagel) the maximum for malathion was 0.59 ug/L, and in 1989 the maximum malathion concentration was 14.0 ug/L in the Colusa Basin Drain. Similarly, the maximum concentration for

Table 14. Estimated mass transport of molinate and thiobencarb in the Sacramento River past Sacramento in the years 1982-1991. This table is Table 10 in Central Valley Regional Water Quality Control Board Staff Report: *Consideration of Approving Department of Pesticide Regulation 1992 Management Practices for Rice Pesticides.*

Year	Kg (pounds) Transported			
	molinate		thiobencarb	
1982	18,464.9	(40,666.9)	[1]	
1983[2]	2,752.9	(6,056.5)	623.7	(1,372.2)
1984	7,352.0	(16,174.4)	715.2	(1,573.5)
1985	6,014.8	(13,232.5)	2,317.5	(5,098.6)
1986	4,622.1	(10,168.7)	845.7	(1,860.6)
1987	2,342.3	(5,153.2)	22.8	(50.2)
1988	3,194.2	(7,027.2)	68.1	(149.8)
1989	1,984.1	(4,365.2)	11.4	(25.1)
1990	3,204.1	(7,049.1)	51.4	(113.1)
1991	99.2	(217.9)	0	(0)[3]

1. Mass transport was not calculated due to incomplete monitoring data.

2. The Colusa Basin Drain, a major agricultural drain, did not contribute to the mass transport at Sacramento because the drain was routed into the Yolo Bypass during unusually high Sacramento River flows.

3. Thiobencarb was not detected in the Sacramento River in 1991 (limit of detection = 0.1 ppb).

Table 15. Maximum concentrations (MC) and frequency of detection (FD) of major rice pesticides in the Coulsa Basin Drain near Knights Landing during April, May and June. Data from Central Valley Regional Water Quality Control Board and Harrington and Lew (1989). N.D. means not detected.

	Year				
Pesticide	1987	1988	1989	1990	1991
Malathion					
MC(ug/L.)			14.0	0.59	0.11
FD			7 of 10 days	3 of 31 days	1 of 13 days
Methyl Parathion					
MC			6.04	0.66	0.20
FD			9 of 10 days	13 of 31 days	4 of 13 days
Carbofuran					
MC	13.0	4.4	1.5	0.8	N.D.
FD	9 of 12 days	8 of 13 days	16 of 16 days	8 of 23 days	0 of 9 days

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methyl parathion in the Colusa Basin Drain in 1991 was 0.2 ug/L, in 1990 the maximum concentration detected was 0.66 ug/L, and in 1989 the maximum detected concentration was 6.04 ug/L. Concentrations of carbofuran have also declined dramatically in the Colusa Basin Drain. Maximum concentrations of carbofuran in the Colusa Basin Drain at Knights Landing have declined from 13 to < 0.1 ug/L between 1987 and 1991. Thus, due to restrictions on rice field water management, the amounts of herbicides and insecticides discharged to the Sacramento River have decreased substantially as a result of the Department of Pesticide Regulation Program.

Based on this information, if discharges of herbicides or insecticides had been responsible for the decline in young striped bass abundance, one would expect to see a substantial recent rebound in the young striped bass abundance index, particularly in 1991. Yet, the 1991 index of 5.5 was the fourth lowest of record and consistent with expectations based on the Department of Fish and Game's model. Furthermore, if rice field drain toxicity accounted for the post-1976 decline in young striped bass abundance to about 30% of its previous average level, toxic exposure would have to be sufficient to kill more than the entire production of the roughly 55% of the population that spawns in the Sacramento River. This is inconsistent with sampling by ourselves, the U.S. Bureau of Reclamation and State Water Contractors which shows that numerous live striped bass eggs and larvae still occur in the Sacramento River.

Toxicity as a Potential Source of "Background Mortality".

The conclusion that toxicity is not responsible for the striped bass decline does not mean that toxicity does not affect striped bass. Our findings do not discount toxicity as a potential source of "background" striped bass mortality.

The studies of larval bass tissue structure from 1988-1990 at U.C. Davis, while showing no evidence of starvation in field-caught fish, do show evidence of toxicity in 26-30 percent of the larvae (Table 16). We do not dispute the results of these U.C. Davis studies which suggest that toxicity is adversely affecting some bass larvae. A reasonable conclusion that is consistent with all of the available information is that toxicity is the source of an unknown level of "background mortality" which has not changed appreciably over the past 30 years. As discussed previously, toxicity dilution may be included in the correlations which show that young striped bass survival improves with increasing outflow.

Table 16. Number and percent of striped bass larvae with "poor" liver scores (1 or 1.5) from histological analyses of specimens from the Sacramento-San Joaquin Estuary. Table from William Bennett U.C. Davis.

	1988			1989			1990		
Group	**N**	**No**	**Percent**	**N**	**No.**	**Percent**	**N**	**No.**	**Percent**
Sacramento River	32	15	46.8	46	13	28.2	78	28	35.9
San Joaquin River	31	2	6.5	19	4	21.0	87	21	24.1
Antioch	-	-	-	7	3	42.8	21	5	23.8
Collinsville	-	-	-	28	6	21.4	14	6	42.8
Total	63	17	27.0	100	26	26.0	200	60	30.0

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REFERENCES

Bailey, H.C., D.J. Ostrach and D.E. Hinton. 1991. Effect of Rice Irrigation Water in Colusa Basin Drain on Fertilization Success and Embryonic Development in Striped Bass. Draft Report submitted March 11, 1991 to State Water Resources Control Board (Contract # 9-169-250-0) 6 p. and tables, figures and appendices.

Chadwick, H.K. 1968. Mortality rates in the California Striped Bass Population. California Fish and Game 54:228-246.

Faggella, G.A. and B.J. Finlayson. 1987. Hazard assessment of rice herbicides molinate and thiobencarb to larval and juvenile striped bass. California Department of Fish and Game, Environmental Services Branch Administrative Report No. 87-2.

Finlayson, B.J. and G.A. Faggella. 1986. Comparison of laboratory and field observations of fish exposed to herbicides molinate and thiobencarb. Transactions of the American Fisheries Society. 115:882-890.

Finlayson, B.J., J.M. Harrington, R. Fujimura, and G. Isaac. 1991. Toxicity of Colusa Basin Drain Water to Young Mysids and Striped Bass. California Department of Fish and Game Environmental Services Division Administrative Report 91-2. 65 p.

Harrington, J.M. 1990. Hazard assessment of the rice herbicides molinate and thiobencarb to aquatic organisms in the Sacramento River system. California Department of Fish and Game, Environmental Services Division Administrative Report No. 90-1.

Harrington, J.M. and T.S. Lew. 1989. Rice Pesticide Concentrations in the Sacramento River and Associated Agricultural Drains, 1987-1988. California Department of Fish and Game Environmental Services Division Administrative Report. 89-1. 32 p.

Harrington, J.M. and T.S. Lew. 1992. Rice Pesticide Concentrations in the Sacramento River and Associated Agricultural Drains, 1989-1990. California Department of Fish and Game Environmental Services Division Administrative Report 92-2. 27 p. and appendices. (In press)

Meyer Resources. 1985. The economic value of striped bass, Morone saxatilus, chinook salmon, Oncorhynchus tshawytscha, and steelhead trout, Salmo gairdneri, of the Sacramento and San Joaquin River systems. California Department of Fish and Game Anadromous Fisheries Branch Administrative Report 85-03. 44 p.

National Marine Fisheries Service and U.S. Fish and Wildlife Service. 1984. Emergency Striped Bass Research Study. Report for 1982-1983. 37 p.

Saiki, M.K., M.R. Jennings, R.H. Wiedmeyer. 1992. Toxicity of Agricultural Subsurface Drainwater from the San Joaquin Valley, California, to Juvenile Chinook Salmon and Striped Bass. Transactions of the American Fisheries Society 121: 78-93.

Turner, J.L., and H.K. Chadwick. 1972. Distribution and Abundance of Young -of-the-Year Striped Bass, Morone saxatilis, in Relation to River Flow in the Sacramento-San Joaquin Estuary. Transactions of the American Fisheries Society 101: 442-452.