

1989

STRIPED BASS RESULTS

126

C - 0 2 9 9 0 0

Final Report
Toxicity of Water Samples From Colusa Basin Drain
and the
Sacramento River
to
Larval Striped Bass and Opossum Shrimp

Submitted to:

Chris Foe

Regional Water Quality Control Board
3443 Routier Rd.
Sacramento, California

Victor DeVlaming

State Water Resources Control Board
Division of Water Quality
901 P St.
Sacramento, California 94244-2130

Submitted by:

H. C. Bailey
C. A. Alexander
S. I. Doroshov

Department of Animal Science
Meyer Hall
University of California
Davis, California 95616

Table of Contents

Executive Summary

Abstract

Key Words

Introduction

Methods and Materials

Test Organisms

Test Waters

Dilution Waters

Test Procedures

Water Quality Measurements

Statistics

Results

Striped Bass

96-Hr Static Tests

6-Day Renewal Tests

Ionic Strength Test

Opossum Shrimp

Discussion

Executive Summary

Acute toxicity studies were conducted on grab water samples collected during May and June 1989 from Colusa Basin Drain (CBD) and two sites along the Sacramento river using larval striped bass and opossum shrimp as test organisms. During this time period, discharge from CBD is comprised of return water from rice-growing operations. One of the sampling sites on the Sacramento river was located upstream of all rice field inputs (City of Colusa) and the other was located downstream of rice inputs (City of Walnut Grove). Control water was well water from the Department of Fish and Game's Central Valley Hatchery at Elk Grove. Test procedures generally followed ASTM (1988) and USEPA (1985) guidelines for conducting acute toxicity tests with aquatic organisms and incorporated appropriate modifications developed under contract to the State Water Resources Control Board (Contract No. 5-199-250-0) for conducting bioassays with larval striped bass and opossum shrimp.

A total of 14 samples of CBD were screened with 1- 2 day posthatch striped bass larvae. These were static non-renewal exposures of 96 hr duration. Of these, 10 samples produced significantly higher larval mortality (58 to 100 percent) compared to the controls. Control survival ranged between 68 and 95 percent (mean 85 percent).

A total of 18 samples of CBD were tested with opossum shrimp using 96-hr static non-renewal exposures. Prior to testing, the ionic strength of the test solutions was increased to* 2500 μ mhos/cm by the addition of a small quantity of seawater. Of the 18 samples tested, 14 samples resulted in significantly higher mortality (30 to 100 percent) than the controls. Furthermore, 10 of these produced total mortality within 18 hr. Control survival ranged between 80 and 100 percent (mean 91 percent).

A limited effort was made to test Sacramento River water. Four samples from the River at Colusa were tested with 24-48 hr striped bass larvae. Of these, two exhibited significantly increased mortality (88 percent). Four samples collected from the river downstream of the Drain at Walnut Grove were also tested with 24-48 hr striped bass larvae. Of these, two were found to be toxic (95 to 100 percent mortality). Two samples from Colusa and one from Walnut Grove were tested on neomysids; no evidence of acute toxicity was found.

The data from this study support the hypothesis that agricultural runoff from CBD can

be acutely toxic to larval striped bass and a major fish food organism in the Delta, the opossum shrimp. The data obtained with larval striped bass also suggest that intermittent toxicity occurs in the Sacramento river both downstream and upstream of the discharge point but do not provide an indication of the extent to which CBD contributes to toxicity in the River.

Key Words: striped bass, opossum shrimp, agricultural drain water, toxicity, Sacramento-San Joaquin Delta.

1.0 Introduction

The striped bass population in the Sacramento-San Joaquin drainage of California has declined by approximately 70 percent since the mid-seventies. The cause of this decline has been ascribed to water diversions, reduced river flows, reduced abundance of desirable food organisms, and other factors, including the presence of toxic materials (Cal. Dept. Fish and Game 1987). The last two spawning seasons, 1988 and 1989, have produced the lowest striped bass indices recorded since the inception of the index. This index, a measure of larval survival, provides support for the hypothesis that the decline is related to factors affecting larval dynamics. Since striped bass spawning in the Sacramento river occurs predominately between the cities of Colusa and Knight's Landing, potential impacts on embryos and larvae in the river must be considered.

Among the inputs to the Sacramento river system that could potentially affect early life stages of striped bass are discharges from irrigated farm lands, primarily in rice production, that border the river in the vicinity of the spawning grounds. One such discharge, the Colusa Basin Drain, collects water from over 150,000 acres of rice and discharges into the Sacramento river at Knight's Landing. This discharge alone can account for over 20 percent of the flow of the Sacramento river downstream at the City of Sacramento with the proportion even higher in the river between Knight's Landing and Sacramento (Cornacchia et al 1984). Because discharge from the rice fields occurs at precisely the same time the striped bass are spawning (April through June), embryonic and early larval developmental stages could be impacted.

The possibility that toxic materials might be implicated in the reduced abundance of striped bass larvae has been difficult to assess because of the difficulty of conducting laboratory studies with the early life stages of this species. However, recent improvements in testing techniques (SWRCB Contract No. 5-199-250-0), have resulted in greater success in conducting studies with early life stages of striped bass.

Preliminary laboratory work with larval striped bass during the 1988 spawning season suggested that discharge from CBD resulted in increased mortality compared to the controls. Consequently, a more intensive sampling and testing program was undertaken during the 1989 spawning season to determine if discharge from the rice fields was toxic to larval striped bass and if the discharge affected water quality in the River. In addition to samples from CBD, samples were also collected from the Sacramento river at a point upstream of all rice discharge (City of Colusa) as well as downstream of such discharges (City of Walnut Grove).

The original study design incorporated acute screening tests using 5-d larvae.

Traditionally, tests with larval striped bass incorporate test solutions that have been "salted up" to between 2000 and 4000 $\mu\text{mhos/cm}$ to enhance survival. However, this study emphasized testing the ambient Drain and river waters to which the larval bass would actually be exposed to under natural conditions. Because the first several weeks of the testing program (mid-April to mid-May) resulted in generally low and variable control survival in the ambient waters which are characterized by low ionic concentrations (100-500 $\mu\text{mhos/cm}$), we initiated additional studies to determine if younger larvae would be more tolerant of the ambient conductivity levels. The results of this work indicated that 1-2 d larvae were more tolerant of low conductivities than were the older larvae. In addition, based on downstream travel times estimated from river flow rates, the younger larvae are more likely to be found in the river in the vicinity of the discharge than are the older larvae. Consequently, beginning in the third week of May, the bioassays incorporated 1-2 d larvae as test organisms, instead of 5-d larvae. These bioassays are the subject of this report.

Switching to younger larvae had the unfortunate consequence of not allowing us to test samples obtained during the early part of the rice season (mid-April to mid-May) on 1-2 day larvae. In addition, only four weekly River samples were collected and tested with the younger fish. This makes it problematic to characterize any relationship between River toxicity and CBD discharge as well as establish temporal trends in toxicity of the discharge. All data obtained in the study are available for inspection.

In addition to striped bass larvae, 1-3 day old opossum shrimp (Neomysis mercedis) were also tested. Opossum shrimp are one of the pivotal food organisms for many fish, including striped bass, in the Delta (Orsi and Knutsen 1979) and previous work has shown them to be sensitive to agricultural drainage (Bailey 1985). These organisms were exposed, in 96-hr static acute tests with the conductivity of the test water adjusted upward to 2500 $\mu\text{mhos/cm}$ by the addition of small quantities of seawater.

2.0 Methods and Materials

2.1.0. Test Organisms

2.1.1. Striped Bass

Striped bass were obtained as either 1-day larvae or 24 hr post fertilization embryos from the California Department of Fish and Game's Central Valley Fish Hatchery in Elk Grove, California. Larvae and embryos were transported in plastic bags in insulated ice chests to the Institute of Ecology at the University of California, Davis. At Davis, they were held in 4-L beakers for 24 hr at the test temperature to monitor handling and transport mortality. During this period, the larvae were randomly divided into different groups and acclimated to the test salinities. At the end of the acclimation period, small groups of larvae were captured in 50-mL beakers and gently introduced into the exposure containers.

2.1.2. Opossum Shrimp

One to three day opossum shrimp were collected from continuous cultures maintained at UCD. As with the striped bass larvae, they were held for 24-hr at the test temperature and salinity to monitor handling mortality. At the end of this period, they were transferred into the exposure containers using wide bore glass pipets.

2.2.0 Test Waters

All Drain and river water samples were surface grabs, collected by Regional Board personnel. In general, samples were taken at weekly intervals except in those cases when we wanted to evaluate daily variations in toxicity. The collected samples were held in polyethylene Cubi-tainers in the dark at 4°C until testing. Samples were usually tested within 24 hr of receipt except in those cases where it was desired to test a series of samples with one batch of larvae. Samples tested with neomysids were held for a longer period to enable Board staff to first screen them for invertebrate toxicity with Ceriodaphnia. This delay may have decreased the toxicity of some of the samples to Neomysis. Conductivities of the River and Drain waters were approximately 120 and 500 µmhos/cm, respectively. Except for one case in which the conductivities were adjusted to 1000 µmhos, samples were tested without adjustment for the larval striped bass. However, samples used for testing neomysids were adjusted upwards to 2500 µmhos with the addition of a small quantity of natural seawater.

2.3.0 Reference Waters

2.3.1 Striped Bass

Well water used at the Central Valley Hatchery (Elk Grove) for striped bass culture was used to provide a basis (control) for comparing the response of the striped bass larvae to the test samples. This water has a hardness of approximately 200-250 mg/L as CaCO₃. Because this water has a conductivity of approximately 200-250 µmhos/cm, it was

necessary to adjust it upwards to match the conductivity of the Drain samples (approximately 500 μmhos) so the control and treatment waters would be equivalent in this regard. This was accomplished by measuring the conductivity of the Drain sample and adjusting the conductivity of the control water upwards with the addition of a small quantity of natural seawater.

2.3.2 Opossum Shrimp

The reference water for the neomysids was well water from the Central Valley Hatchery with sufficient natural seawater added to maintain the conductivity at approximately 2500 $\mu\text{mhos/cm}$.

2.4.0 Test Procedures

All tests were conducted in a temperature controlled room maintained at 17-19°C with a photoperiod of 16 hr L:8 hr D. Light intensity was 80-100 lumens at the surface of the exposure containers. Exposure containers for the striped bass larvae included 2-L glass beakers and 1.5-L glass crystallizing dishes containing 1 L of test solution. Container types were not mixed within a particular test. Neomysids were only tested in the crystallizing dishes. Aeration was not supplied to the test containers. Striped bass larvae were not fed but the neomysids received a maintenance ration of <24 hr *Artemia* nauplii daily. At the start of the test, test and reference waters were distributed among the exposure containers (one replicate per test sample) and allowed to come up to the test temperature before adding test organisms. At this time, any necessary salinity adjustments to the test and reference waters were made by adding small quantities of seawater to the appropriate solutions. Striped bass larvae were stocked at a rate of 30-70 larvae/L, depending on availability. Neomysids were stocked at 10 per L. Organisms were added using stratified random assortment. Mortality was monitored on a daily basis using opaque coloration and lack of response to prodding as the criteria for death.

2.5.0 Water Quality Measurements

Temperature, dissolved oxygen, pH and conductivity were checked in each solution prior to adding the test organisms. Dissolved oxygen was also determined in test solutions at conclusion of each testing event. Dissolved oxygen was monitored with a YSI D.O. meter, pH with a Nestor pH pen, and conductivity with a YSI conductivity meter. Temperature was also monitored daily with either the sensors on the meters or with a glass mercury thermometer.

Water quality for tests with striped bass larvae remained satisfactory throughout the test period. Dissolved oxygen remained in excess of 87 percent of saturation, pH ranged between 7.4 and 7.5, and conductivity ranged between 110 and 1000 μmhos . Test

temperatures were between 16.5 and 18.9 °C. The actual water quality measurements are appended.

Water quality in the tests with opossum shrimp was also satisfactory. Dissolved oxygen remained above 89 percent saturation, pH between 7.6 and 7.9, and conductivity (previously adjusted upwards by the addition of seawater) between 2500 and 2650 μmhos . Temperatures ranged between 17.0 and 19.6°C throughout the test period. Water quality data are appended.

2.6.0 Evaluation of the effect of ionic strength

During the study period, it became apparent that striped bass larvae, particularly 4- and 5-day old fish, incurred high mortalities at conductivities associated with the ambient test samples (100-500 $\mu\text{mhos/cm}$). To further investigate this phenomenon, a test was designed to assess the effect of low ionic strength on larval survival. Two-day old larvae were placed directly into solutions of different conductivities (three replicates per treatment level) up to 4000 μmhos for 144 hours and mortality monitored. Since the larvae were hatched and reared in water of 250 μmhos conductivity, the exposure regimen was analogous to 84 hr (including embryonic stage) at 250 μmhos followed by introduction to the test solution for an additional 144 hr. In addition, two groups of larvae were held at 250 μmhos for an additional 24 hr (total 108 hr) before being transferred to water of 500 or 1000 μmhos (two replicates per treatment) to assess the effect of an additional day in comparatively soft water.

2.7.0 Statistics

Mortality in non-replicated test samples was compared directly against mortality in the reference water using the Chi^2 test for independent samples (Sokal and Rohlf 1969). Mortality in the replicated test (Section 2.6.0 only) was analyzed with one-way ANOVA using the arcsin transformation of the square root of the proportion dead. Control/treatment comparisons were made with Dunnett's multiple comparison test. Both tests were judged significant at $p < 0.05$.

3.0 Results

3.1.0 Striped Bass

The results of the 96-hr static tests with 1-2 day old striped bass larvae are summarized in Table 1. Compared with the controls, 10 of the 14 different CBD samples tested showed significantly increased mortality that ranged between 57.5 and 100 percent. Control survival averaged 85.1 percent over the five testing events (five separate progenies), with a range of 67.5 to 94.9 percent.

Two samples of CBD (5/24 and 6/1) were tested on 3 June and again on 24 June to assess the effects of storage and the response of a different progeny on toxicity. Both samples exhibited toxicity to a new progeny, even after the additional 3-week storage period. The 5/24 sample retained almost as much of its toxicity when tested again (100 vs 97% mortality) while the 6/1 sample appeared to lose approximately 40 percent of its toxicity (90 vs 57.5% mortality-- $p < 0.05$). These results suggest that the observed toxic responses were not artifacts; the same samples produced significant mortalities in two separate testing events using two different progenies of larvae.

Four samples from the River collected upstream of all rice inputs (Colusa) and four River samples collected downstream of all rice inputs (Walnut Grove) were also tested (see Table 1). Of these, two samples obtained from each of the two sites were toxic. Within the context of this particular study, the limited number of samples tested suggests that there may be a toxicity problem but precludes establishing cause and effect relationships between inputs and toxicity within the river. The response to the River samples was most likely not due to low ionic strength and subsequent ionic stress in the larvae; in two of the three sampling events in which toxicity was noted, the corresponding upstream or downstream sample did not show toxicity. Since the conductivities of both samples were virtually identical, this suggests that conductivity was not the primary cause of the increased mortality.

3.2.0 Opossum Shrimp

Data from the tests with Neomysis are summarized in Table 2. Of 18 different CBD samples tested, 14 produced significantly higher mortality than in the controls. Mortality in these tests ranged between 30 and 100 percent and, in ten of the samples, total mortality occurred within 18 hr. Control survival averaged 91.2 percent, with a range of 80 to 100 percent. Two samples from Colusa and one from Walnut Grove were also tested with no apparent effect. One sample from CBD--5/23--was tested on 9 June and again on 3 July. In both cases, the sample produced 100 percent mortality.

3.3.0 Effect of Conductivity on Survival of Larval Striped Bass

The mortality of 48-hr larvae exposed to Elk Grove well water at five different conductivities for 96 and 144 hr is summarized in Table 3. The data are presented as "dead" and "moribund". The latter includes those larvae lying on their sides on the bottom of the exposure containers. These incapacitated larvae were prevalent at conductivities of 250 to 1000 μ mhos and absent in 2000 to 4000 μ mhos solutions. The results demonstrate that a negative relationship exists between mortality (and moribundity) and conductivity within the range of 250 to 4000 μ mhos. Not only is the effect influenced by the ionic strength of the solution, but also by the duration of exposure. For example, conductivities of 250 and 500 μ mhos resulted in approximately 60 and 15 percent mortality, respectively over the 144-hr exposure period, while conductivities of 1000 - 4000 μ mhos resulted in less than 5 percent mortality. Larvae held an additional day at 250 μ mhos before transfer to 500 or 1000 μ mhos had significantly higher mortalities (40 and 18 percent, respectively), than those transferred directly into 500 and 1000 μ mhos (15 and 2.5 percent, respectively) at the beginning of the exposure. These data suggest that toxicity tests conducted with larval striped bass at conductivities below 4000 μ mhos will be subject to background mortality. However, it is apparent, given the variation in control survival (8.5 to 32.5 %) of the different progenies exposed to 500 μ mhos during the bioassays, that considerable variation exists between progenies in their ability to tolerate low conductivity.

4.0 Discussion

It is important to keep in mind that this testing program was designed as a screening tool to determine if rice field return water posed a potential toxicity problem. Thus, relatively simple static tests were used in the interest of processing a large number of samples. It is likely that such tests provide conservative estimates of toxicity compared with renewal or continuous-flow test methodologies in which fresh solutions replace potentially toxic constituents lost through sorption, metabolism, volatilization, and so on. Nonetheless, the data obtained indicate that samples of rice discharge water from the Colusa Basin Drain are acutely toxic to larval striped bass and opossum shrimp. Of the 14 samples tested with larval striped bass, 10 produced significantly higher mortality than the controls. Similarly, of the 18 samples tested with opossum shrimp, 14 produced significantly higher mortality than the controls. The observed toxicity is of particular concern for the striped bass whose spawning period coincides with the timing of the discharge. Consequently, because the bass spawn in the vicinity of the discharge, their embryos and larvae are exposed to the discharge throughout the spawning period. Toxicity data obtained in the study for the ambient river water samples from Colusa and Walnut Grove are comparatively sparse but indicate that toxicity was associated with two of the four samples obtained from each site.

An alternative hypothesis explaining the toxicity of the Drain to striped bass larvae might be that the Drain, which maintains a conductivity of approximately 500 $\mu\text{mhos/cm}$ compared to river values of approximately 120 $\mu\text{mhos/cm}$, contains an unusual ionic salt composition which is lethal. This hypothesis is not supported by the fact that 4 of the 10 samples tested did not produce significant mortality while conductivity in all ten remained constant. Thus, mortality appears to be the result of periodic inputs into the Drain which have no measurable effect on conductivity.

For striped bass, samples obtained in June appeared to be as toxic as those obtained in May (see Table 1). Seven of the 9 samples obtained from 15 to 31 May produced significant mortality (average mortality of 80.9 percent) in larval striped bass. Five samples from the period of 1 to 12 June were also tested. Of these, three produced toxicity with an average mortality of 80.1 percent. Unfortunately, because the test methodology was not finalized until mid-May, we do not have any comparative data from April and early May.

In contrast to the data obtained with striped bass larvae, samples obtained from May and June differed appreciably in their toxicity to the neomysids (Table 2). Of the 10 samples obtained between 15 and 31 May, 9 resulted in total mortality, generally within the

first 24 hr of exposure. Eight samples were obtained from the period of 3 to 14 June. Of these, 5 resulted in significant mortality but only averaged 56 percent mortality over the 96 hr exposure period.

In addition to temporal differences in toxicity, there are other indications that the larval striped bass and the neomysids were not always responding to the same components within the Drain waters. Of the six samples from May for which we have comparative data, five produced significant mortality to both test organisms. However, the remaining sample--31 May--showed no toxicity to the neomysids but caused 75 percent mortality in the larval bass. There are three samples from June for which we have comparative data. Of these, one was not toxic to either species, one was toxic to the larval striped bass but not to the neomysids, and the other was toxic to the neomysids but not to bass.

Data obtained for both organisms suggests that the composition of the drain water changes markedly over short time periods with regard to toxicity. For example, samples taken on 24, 26 and 31 May and 1, 8 and 9 June were toxic to larval bass but samples obtained on 25 and 29 May and 6 June were not. Similarly, samples from 15 to 28 May were toxic to neomysids but the sample from 31 May was not. For June, samples from 3, 5, 10, 12 and 14 June were toxic while the samples from 4, 6 and 9 June were not. Such changes in toxicity may reflect agricultural management practices in the drainage basin. Because the toxicity results appear so pronounced, it may be possible to use the bioassays in conjunction with TRE methods to determine the precise chemicals causing toxicity to larval bass.

The results of the experiment evaluating the response of larval striped bass to water of* different ionic strengths has important implications for bioassays. The data suggest that there may be appreciable background mortality in bioassays conducted at ambient river and Drain water conductivities. This may limit the usefulness of the tests to determining only the largest instream impacts unless the experimental design is able to compensate through the use of more test organisms or replicates. An alternative approach to intensive experimental designs would be to use the test as a screen for concentrated inputs, such as CBD, to help identify those discharges that are likely to pose a problem. Next, by passing the water through columns with different sorption characteristics and retesting, inferences could be made as to the nature of the toxic constituent(s). Salting up the water is probably not appropriate because of potential interactions with toxic components, such as metals. In addition, since larval survival is positively correlated with conductivity, and larval exposure would occur in river water of low conductivities, larval exposures conducted in salinity-adjusted solutions would likely underestimate the actual level of toxicity.

From an ecological and water management perspective, the interaction between larval striped bass and ionic strength also has important implications. It implies that there is a critical point at which the larval survival is markedly reduced in water of low conductivity, such as in the Sacramento river and western Delta. If correct, then the upstream limit of spawning in the Sacramento river at Colusa may be determined by river conductivity and transport time necessary to carry the larvae downstream to higher salinities. Considering the difference in survival that even an additional 24 hr in 250 μmho water makes, the relationship between downstream transport time (flow) and survival appears to be critical. It should be noted that survival is only part of the picture; in the treatments between 250 and 1000 μmhos there were nearly as many moribund larvae as there were dead larvae. These larvae would not be capable of performing basic biological functions necessary for survival, such as feeding and inflation of the swimbladder.

5.0 Recommendations

- Repeat this study next rice season with CBD and River samples to obtain a better picture of temporal variation in toxicity in the Drain and the relationship between toxicity in the Drain and downstream and upstream sites in the river.
- Conduct Toxicity Identification Studies on toxic River and Drain samples with striped bass larvae to determine the extent to which metals and/or organics contribute to toxicity; i.e, pass the water through different columns and chelation treatments and see which ones are effective at removing toxicity.
- Conduct TRE on Drain samples with neomysids to determine the constituents responsible for toxicity. Once these are identified, compare literature values for acute and chronic toxicity with dilution factors to assess the potential for effects in the Delta.
- Because spawning occurs in the area of the discharge and the presence of dead embryos has been noted in samples taken from the river, initiate preliminary studies to evaluate the success of fertilization and embryo development in River and Drain samples.

6.0 References

1. ASTM. 1985. Standard Practice for Conducting Acute Toxicity Tests with Fishes, Macroinvertebrates, and Amphibians. E 729-80. American Society for Testing and Materials. Philadelphia, PA.
2. Bailey, H. C. 1985. Acute and Chronic Toxicity of San Luis Drain Effluent to Neomysis mercedis. SRI International Project LSU-7665. Final Report Submitted to Bureau of Reclamation. SRI International, Menlo Park, CA.

3. Cal. Dept. Fish and Game. 1987. Factors Affecting Striped Bass Abundance in the Sacramento-San Joaquin River System. Technical Report 20. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Calif. Dept. Fish and Game. Sacramento, CA.

4. Cornacchia, J. W., D. B. Cohen, G. W. Bowes, R. J. Schnagl and B. L. Montoya. 1984. Rice Herbicides: Molinate (Ordram®) and Thiobencarb (Bolero®). California State Water Resources Control Board, Special Projects Report No. 84-4SP.

5. Orsi, J. J. and A. C. Knutsen, Jr. 1979. The Role of Mysid Shrimp in the Sacramento-San Joaquin Estuary and Factors Affecting Their Abundance and Distribution. In: San Francisco Bay: The Urbanized Estuary., Conomos T. J., ed., Pacific Division of the American Association for the Advancement of Science, San Francisco, CA.

6. Sokal, R. R. and F. J. Rohlf. 1969. Biometry. W. H. Freeman and Co. San Francisco, CA.

7. USEPA. 1985. Methods for Measuring the Acute Toxicity of Effluents to Freshwater and Marine Organisms. Third Edition. EPA/600/4-85/013. USEPA, Cincinnati, OH.

Acknowledgements

L. Meng, graduate student in Wildlife and Fisheries, assisted with the bioassays. J. P. Swenson, graduate student in Economics, performed the data entry and statistical analyses. Special thanks go to Mike Cochran and the staff of the Central Valley Hatchery who provided the striped bass larvae and the State and Regional Water Quality Control Boards who provided the funding for this research.

Table 1. 96 Hr mortality of 1-2 day striped bass larvae exposed to Colusa Basin Drain and Sacramento River water samples.

Date <u>Sampled</u>	Date <u>Tested</u> ^{1/}	<u>Mortality (%)</u>			
		<u>Colusa</u>	<u>CBD</u>	<u>Walnut Grove</u>	<u>Control</u>
15 May	20 May*	8.2	62.2 ^a	8.8	5.1
21 May	24 Jun	--	81.3 ^a	--	32.5
22 May	24 Jun	--	87.1 ^a	--	32.5
23 May	24 Jun	--	69.2 ^a	--	32.5
24 May	3 Jun	--	100.0 ^a	--	14.3
24 May	24 Jun ^{2/}	--	97.0 ^a	--	32.5
25 May	26 May	17.8	8.5	100.0 ^a	8.5
26 May	24 Jun	--	91.3 ^a	--	32.5
29 May	3 Jun	--	43.6 ^a	--	14.3
31 May	24 Jun	--	75.0 ^a	--	32.5
1 Jun	3 Jun	88.2 ^a	90.2 ^a	95.3 ^a	14.3
1 Jun	24 Jun ^{2/}	--	57.5 ^a	--	32.5
6 Jun	24 Jun	--	43.9	--	32.5
8 Jun	10 Jun	88.2 ^a	75.0 ^a	33.9	14.3
9 Jun	24 Jun	--	75.0 ^a	--	32.5
12 Jun	24 Jun	--	25.2	--	32.5

^a Significantly greater than the controls, $p < 0.05$; χ^2 test for independence.

* 15 May reference and test solutions "salted up" to 1000 μmhos with addition of seawater.

1/ Same test date indicates use of same group of progeny.

2/ Retest of same water sample.

Table 2. 96 Hr mortality of 1-3 day old opossum shrimp exposed to Colusa Basin Drain and Sacramento River water samples.

Date Sampled	Date Tested	Mortality (%)			
		Colusa	CBD	Walnut Grove	Control
15 May	23 May	--	100.0 ^a	-	0.0
16 May	31 May	--	100.0 ^a	-	15.0
19 May	9 Jun	--	100.0 ^a	-	20.0
20 May	9 Jun	-	100.0 ^a	-	20.0
21 May	9 Jun	--	100.0 ^a	-	20.0
22 May	31 May	-	--	10.0	15.0
22 May	9 Jun	--	100.0 ^a	-	20.0
23 May	9 Jun	--	100.0 ^a	-	20.0
23 May	3 Jul ^{1/}		100.0 ^a	-	0.0
24 May	31 May	--	100.0 ^a	-	15.0
28 May	2 Jul	--	100.0 ^a	-	0.0
31 May	7 Jul	--	20.0	-	0.0
1 Jun	7 Jul	20.0	--	-	0.0
3 Jun	7 Jul	--	30.0 ^a	-	0.0
4 Jun	9 Jun	-	0.0	-	20.0
5 Jun	2 Jul	--	100.0 ^a	-	0.0
5 Jun	9 Jun	5.0	--	-	20.0
6 Jun	7 Jul	--	10.0	-	0.0
9 Jun	7 Jul	--	20.0	-	0.0
10 Jun	7 Jul	--	40.0 ^a	-	0.0
12 Jun	7 Jul	--	40.0 ^a	-	0.0
14 Jun	7 Jul	--	70.0 ^a	-	0.0

^a Significantly greater than the controls, $p < 0.05$; χ^2 test for independent samples.

1/ Retest of same water sample.

Table 3. Mortality of 48-hr Striped Bass Larvae Reared in Elk Grove Well Water Amended to Different Conductivities.

Conductivity (μ mhos)	Percent Mortality		Moribund (%) ¹
	Mean \pm std. dev.		Mean \pm std. dev.
	96 hr	144 hr	144 hr
250	41.8 \pm 8.2 ^a	62.8 \pm 17.8 ^a	79.5 \pm 17.7 ^a
500	9.3 \pm 8.5 ^{b,c}	13.4 \pm 9.2 ^{c,d}	31.0 \pm 12.7 ^b
1000	2.7 \pm 0.4 ^{c,d}	2.7 \pm 0.4 ^{d,e}	6.3 \pm 0.9 ^c
2000	4.6 \pm 3.1 ^{c,d}	5.2 \pm 3.0 ^{c,d,e}	5.2 \pm 3.0 ^c
4000	0.0 ^d	0.0 \pm 0.0 ^e	0.0 ^c
250-500 ²	15.7 \pm 6.1 ^b	41.5 \pm 2.1 ^b	48.6 \pm 8.1 ^b
250-1000 ²	9.7 \pm 4.3 ^{b,c}	18.1 \pm 7.4 ^c	30.3 \pm 6.6 ^b

Treatments with the same superscript within the same column are not significantly different from each other ($p < 0.05$).

^{1/} Dead or lying on their sides on bottom of exposure container.

^{2/} Held an additional 24 hr at 250 μ mhos before salinity adjustment to 500 and 1000 μ mhos.