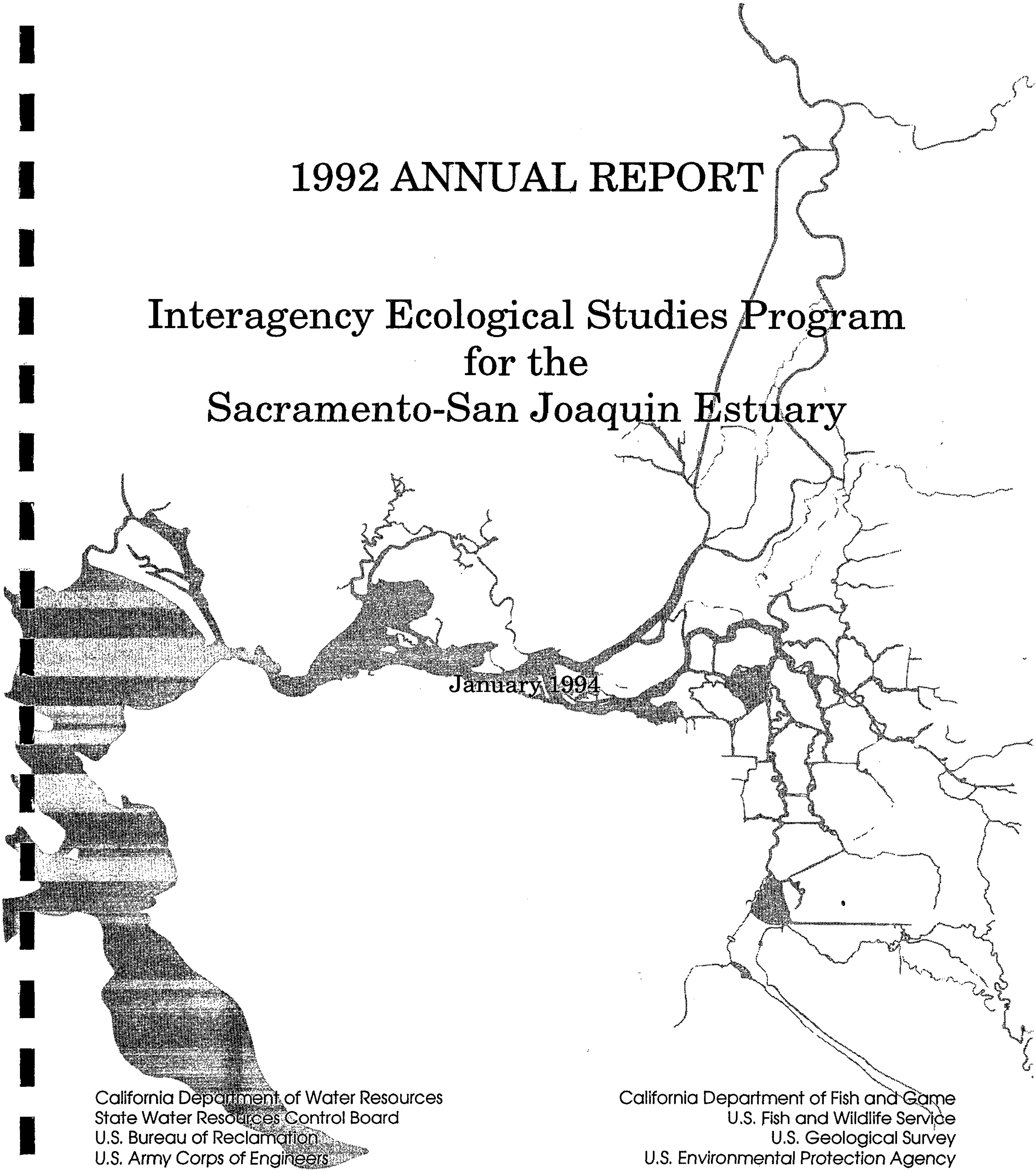
1992 ANNUAL REPORT

Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary

January 1994



California Department of Water Resources
State Water Resources Control Board
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U.S. Environmental Protection Agency

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Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary

Compiled by
Perry L. Herrgesell, Ph.D.,
Study Manager

January 1994

California Department of Water Resources
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CONTENTS

Chapter 1	HIGHLIGHTS	1
	Environmental Factors	1
	Striped Bass	1
	Chinook Salmon	2
	Other Estuarine Fishes	3
	Entrainment of Eggs and Larvae	3
	Delta Outflow/San Francisco Bay	3
Chapter 2	INTRODUCTION	5
	The Interagency Program	5
	Program Elements	5
	Program Organization and Funding	6
	Program Goals	6
	1992 Program Update	6
	Research Enhancement Program	6
	Technical Information Specialist	8
	Expanded Salmon Program	8
	Review and Revision of the Interagency Program	9
	The Sacramento-San Joaquin Estuary	9
Chapter 3	ENVIRONMENTAL FACTORS	13
	Dissolved Oxygen Concentrations in the Stockton Ship Channel	13
	Phytoplankton Chlorophyll and Species Composition	16
	Neomysis/Zooplankton	21
	Delta Vegetation Survey	22
	Methods	23
	Results and Discussion	23
Chapter 4	STRIPED BASS	29
	Adult Striped Bass Tagging and Creel Census	29
	Impacts of Freshwater Outflow and Exports on Striped Bass	29
	Egg Quality	30
	Striped Bass Egg and Larva Survey	31
	Distribution	31
	Abundance	34
	Survival	36
	Potential Competitors	38
	Diet and Feeding Conditions	40
	Summer Tow-Net Survey	42

Midwater Trawl Survey . . . 43
Striped Bass Egg and Larval Management Study . . . 43

Chapter 5 CHINOOK SALMON . . . 47
Sacramento River Beach Seine Survey . . . 48
Tagged Fry Recaptured by Seining . . . 49
Repetitive Beach Seining . . . 50
Sacramento River Fyke-Net Sampling . . . 50
Sacramento River Tow-Net Survey . . . 52
Sacramento River Midwater Trawl . . . 53
Chipps Island Midwater Trawl . . . 55
Montezuma Slough Trawl . . . 57
Coleman Hatchery Smolt Contribution . . . 57
Survival of Coded-Wire-Tagged Smolts in the Northern and Central Delta . . . 58
Effects of an Old River Barrier on Winter-Run Smolts . . . 60
Recoveries at the Fish Facilities . . . 61
Effects of Exports . . . 61
Effects of Flows at Jersey Point . . . 62
San Joaquin River Studies . . . 63
Future Needs . . . 65

Chapter 6 OTHER ESTUARINE FISHES . . . 67
Delta Smelt . . . 67
Monitoring and Field Research . . . 67
Midwater Trawl Surveys During Spawning Season . . . 67
Beach Seine Surveys During Spawning Season . . . 68
Artificial Substrate Egg Collection . . . 69
Timing, Distribution, and Abundance of Larvae and Their Food Supply . . . 69
Estimated Diversion Losses of Delta Smelt Larvae . . . 73
Laboratory Studies . . . 73
Procedures to Differentiate Delta Smelt from Longfin Smelt During Early Larval Stages . . . 73
Diet Analysis and Zooplankton Abundance . . . 73
Cohort Identification from Otoliths . . . 73
Evaluation of Effects of Toxicity and Starvation on Larvae . . . 74
Monitoring Salvage Losses of Older Juveniles and Adults . . . 74
Electrophoretic Analysis . . . 74
Culture and Production Techniques . . . 74
Reproductive Cycle and Gametogenesis . . . 75
Environmental Tolerances . . . 75
Modeling . . . 75
Current Status . . . 75

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Sturgeon . . . 79
Spawning Habitat Preferences . . . 79
Angling Regulation Reevaluation . . . 79

Chapter 7 ENTRAINMENT OF EGGS AND LARVAE . . . 81
Diversion Rates and Environmental Parameters . . . 81
Entrainment of Striped Bass . . . 84
Entrainment of Other Species of Concern . . . 89
Species Composition of Catch . . . 92

Chapter 8 DELTA OUTFLOW / SAN FRANCISCO BAY . . . 95
Species Update . . . 95
Caridean Shrimp . . . 95
Dungeness Crab . . . 97
Fishes . . . 97
Discrete Depth Sampling . . . 102
Central Bay . . . 102
Upriver . . . 103
Shallow Water Sampling of Nursery Habitats . . . 105

Chapter 9 FISH FACILITIES . . . 107
Tracy Fish Collection Facility . . . 107
Predator Removal at Tracy Fish Collection Facility . . . 107
Striped Bass . . . 108
White Catfish . . . 108
Other Species . . . 109
Tracy Pumping Plant Intake Channel . . . 109
Entrainment of Eggs and Larvae . . . 110
Automated Hydraulic Measurements . . . 110
Hydroacoustic Experiments . . . 110
Management Implications . . . 111
Clifton Court Forebay . . . 111
Entrainment and Loss Studies . . . 111
Abundance of Predator-Sized Striped Bass . . . 112
Hydroacoustic Monitoring of Fish Entrainment . . . 113
Predator Monitoring Program . . . 113
Predator Removal . . . 114
South Delta Temporary Barriers . . . 116
North Bay Aqueduct . . . 116

LITERATURE . . . 121

SCIENTIFIC NAMES OF FISH . . . Inside Back Cover

Figures

1	Organization, Interagency Ecological Studies Program	7
2	Sacramento-San Joaquin Estuary	10
3	DAYFLOW Net Delta Outflow	11
4	Dissolved Oxygen Measurement Sites in the San Joaquin River, 1992	14
5	Dissolved Oxygen Concentrations in the Stockton Ship Channel Before and After Installation of the Barrier in Old River, 1992	15
6	1992 Compliance Monitoring Sites	17
7	Mean Monthly Chlorophyll and Phaeophytin and Mean Monthly Percent Chlorophyll Concentrations During 1992	18
8	Mean Monthly Chlorophyll and Phaeophytin Concentrations, 1971-1992	20
9	Aquatic Vegetation Survey Sites	24
10	Variations in Selected Parameters Measured During the Fall Vegetation Surveys	28
11	Sampling Sites, DFG Striped Bass Egg and Larva Survey, 1991	32
12	Striped Bass Egg Distribution, 1991	33
13	April-June Sacramento River Flow at Sacramento, 1956-1991	34
14	Striped Bass Distribution, 1991	35
15	Relationship Between Delta Outflow and the Peterson Survival Index for Eggs to 6-mm Bass	37
16	Relationship Between Log_{10} Mean April-July Delta Outflow and Striped Bass Survival Index Based on the Ratio of 38-mm to 9-mm Abundance	37
17	Predicted Versus Observed Striped Bass Survival Based on the Ratio of 38-mm to 9-mm Bass Abundance	37
18	Spatial and Temporal Distribution of Chameleon Goby and Yellowfin Goby, 1991	39
19	Striped Bass Diet in Relation to Length for All Fish Used in the 1991 Diet Analysis	40
20	Relationship Between Specific Conductance and Density of *Eurytemora*	40
21	Relationship Between Specific Conductance and Density of *Pseudodiaptomus*	40
22	Relative Contribution of *Eurytemora, Pseudodiaptomus,* and Other Calanoid and Cyclopoid Copepods to the Diet of 5- to 14-mm Striped Bass	41
23	Numbers of Striped Bass Eggs and Larvae Moving Down the Sacramento River Past Bryte	44
24	Daily Abundance of Striped Bass Eggs and Larvae in the Sacramento River at Bryte versus Mean Daily Water Temperature	45
25	Average Catch per Seine Haul of Chinook Salmon in the Northern Delta and Mean February Flow in the Sacramento River at Freeport	49
26	Chinook Salmon Captured in the Beach Seine in the Delta and Lower Sacramento River, 1992	49
27	Mean Fork Length of Chinook Salmon Captured in the Beach Seine, All Areas, 1992	49
28	Mean Size and Catch per Minute of Chinook Salmon Caught in the Fyke Nets at Sacramento, 1992	51
29	Mean Size and Catch per 20-Minute Tow Using the Tow-Net at Sacramento	53

30 Mean Size and Catch per 20-Minute Tow in the Midwater Trawl at Sacramento 53
31 Mean Size and Catch per 20-Minute Tow at Chipps Island 55
32 Survival Through the Delta for Fish Released at Miller Park and at Courtland, 1978 to 1989 57
33 Temperature-Corrected Survival for Fish Released at Ryde versus San Joaquin River Flow at Jersey Point, 1984 to 1992 62
34 Temperature-Corrected Survival for CWT Smolts Released at Jersey Point and Recovered at Chipps Island, 1989 to 1991 62
35 DFG Delta Smelt Midwater Trawl Stations, 1992 68
36 Artificial Substrate Stations in Cache Slough and Lindsey Slough, 1992 70
37 Larval Delta Smelt Survey Stations, 1992 71
38 Spatial and Temporal Distribution of Larval Delta Smelt in 1991, Sacramento River, Roe Island to Rio Vista 72
39 Spatial and Temporal Distribution of Larval Delta Smelt in 1991, San Joaquin River, Roe Island to Medford Island 72
40 Fall Midwater Trawl Abundance Index for Delta Smelt 76
41 Mean Catch per Trawl in the Midwater Trawl Survey 76
42 Percent of Monthly Inflow Exported by the SWP and CVP in 1991 versus the Average from 1968 to 1990 77
43 Summer Tow-Net Delta Smelt Abundance Index 77
44 Percent Catch of Delta Smelt in Tow-Net and Midwater Trawl Surveys 77
45 Distribution and Abundance of Delta Smelt in Midwater Trawls in 1992 78
46 Egg and Larval Study Sites 82
47 Daily State Water Project Inflow and Central Valley Project Export, February-July 1992 84
48 Estimated Densities of Striped Bass Eggs and Larvae near the State Water Project and Central Valley Project, April-July 1992 85
49 Total Combined SWP/CVP Diversions, April-June 1985-1992 85
50 Total SWP and CVP Diversions, April-June 1985-1992 89
51 Annual Abundance Indices of All Species of Shrimp, by Embayment, 1980-1992 96
52 Annual Biomass Indices of All Species of Shrimp, by Embayment, 1980-1992 96
53 Bay Goby Annual Abundance Indices 97
54 Plainfin Midshipman Annual Abundance Indices 97
55 White Croaker Annual Abundance Indices 98
56 Speckled Sanddab Annual Abundance Indices 98
57 California Halibut Annual Abundance Indices 98
58 English Sole Annual Abundance Indices 99
59 Northern Anchovy Annual Abundance Indices 99
60 Jacksmelt Annual Abundance Indices 99
61 Shiner Perch Annual Abundance Indices 99
62 Pacific Herring Annual Abundance Indices 100
63 Staghorn Sculpin Annual Abundance Indices 100

64	Longfin Smelt Annual Abundance Indices	101
65	Starry Flounder Annual Abundance Indices	101
66	Yellowfin Goby Annual Abundance Indices	101
67	Recovery Percentages for Salmon Smolts by Length Class, Clifton Court Forebay, December 1992	112
68	Percentages, by Size Class, for Striped Bass Sampled During Predator Abundance Studies at Clifton Court Forebay, February and March 1993	113
69	Catch-Per-Unit-Effort of the Three Most Common Predators in Clifton Court Forebay During 1991 and 1992	114
70	Percentages, by Size Class, for Striped Bass Sampled in the Clifton Court Forebay Catch-Per-Unit-Effort Study, 1992	114
71	Predators Removed from Clifton Court Forebay During 1992	115
72	Percentages, by Size Class, for Striped Bass Removed from Clifton Court Forebay During December 1992	115
73	Relative Fish Composition at Four Temporary Barrier Sites, 1992	116
74	Fish Species Composition at Barker Slough Before and After North Bay Aqueduct Operations	120

Tables

1	Data Summary, November 1992 Littoral Zone Vegetation Survey	25
2	Distribution of Littoral Zone Vegetation	26
3	Egg Quality Measurements in the Sacramento and San Joaquin Rivers, 1990 and 1991	30
4	Correlation Matrices for Egg Weight, Chorion, Yolk, and Oil Globule Diameters from the Sacramento and San Joaquin Rivers	30
5	Abundance of Striped Bass Eggs in 1991, by Area	34
6	Relative Contribution of Live Egg Catch from the Sacramento and San Joaquin Rivers for Years When Both Were Sampled	34
7	Catch of Striped Bass Eggs in the San Joaquin River in 1991, by Specific Conductance Range	34
8	Abundance of Striped Bass Larvae in 1991, by Area	36
9	Striped Bass Abundance Indices, 1968 through 1991	36
10	Correlations Between April-June Flows and the Survival Index Based on the Ratio of Egg Production to 6-mm Striped Bass Abundance	37
11	Comparison of Regressions of 9- to 38-mm Striped Bass Survival on Delta Outflow and Water Exports	37
12	Data Used for the Multiple Regression Relationship of Striped Bass Survival and Mean April-July Delta Outflow and Water Exports for Years of Record, 1968-1991	37
13	Abundance of 6-mm Striped Bass and of Other Fish Larvae in 1991, by Area	38
14	Abundance of Goby Larvae and 6-mm Striped Bass	38
15	Percent of Abundances of Chameleon Goby and 6-, 8-, and 10-mm Striped Bass Where Their Distributions Are Coincident in 1991	39
16	Percent of Abundances of Yellowfin Goby and 6-, 8-, and 10-mm Striped Bass Where Their Distributions Are Coincident in 1991	39

17 Young Striped Bass Abundance Indices 42

18 Young Striped Bass Abundance Indices for Midwater Trawl Surveys, 1967 to 1992 43

19 1992 Beach Seine Catch, by Month and Race 48

20 Average Catch per Seine Haul of Chinook Salmon Juveniles in the Northern and Central Delta and Lower Sacramento River 48

21 Number of Salmon Caught on the Last Seine Haul of the Initial Seining Day and on the First Seine Haul of the Next Day 50

22 Mean Catch of Salmon per Minute in Fyke Nets at Sacramento 50

23 Chinook Salmon Caught in the Fyke Nets at Sacramento, by Race 51

24 Mean Size and Catch per 20-Minute Tow in Fyke Nets and Midwater Trawls near Sacramento, 1992 51

25 Mean Catch per Minute, Standard Deviation, Sample Size, and Z Values for Fyke Net Sets at Sacramento 51

26 Chinook Salmon Caught in the Tow-Net near Sacramento, by Race 53

27 Chinook Salmon Caught in the Midwater Trawl near Sacramento, by Race 54

28 Expanded Number of Chinook Salmon Caught in the Midwater Trawl near Sacramento, by Race 54

29 Mean Catch of Chinook Salmon Smolts per 20-Minute Tow in the Midwater Trawl at Chipps Island, 1978-1992 55

30 Percent Distribution of Midwater Trawl Catch of Chinook Salmon Smolts at Chipps Island, 1978-1992 55

31 Chinook Salmon Caught in the Midwater Trawl at Chipps Island, by Race 56

32 Expanded Number of Chinook Salmon Caught in the Midwater Trawl at Chipps Island, by Race 56

33 Midwater Trawl Catches at Chipps Island and Montezuma Slough, Expanded for Time, Channel Size, and Percent of Fish Diverted into Montezuma Slough for 1987 and 1992 58

34 Chipps Island Tag Summary, Survival Calculations, and Expanded Fish Facility Recoveries for Coded-Wire-Tagged Chinook Salmon Released in 1992 59

35 Survival Indices and Ratios for Coded-Wire-Tagged Salmon Smolts Released in the Sacramento River at Ryde and in Georgiana Slough, April 1992 60

36 Flow and Export Conditions During the Time the Marked Fish Were at Large During Spring 1992 61

37 Temperature, Survival, and Flows During the Time Smolts Released at Ryde in 1983 Were Passing Chipps Island 62

38 Survival Indices for CWT Chinook Salmon Smolts Released at Dos Reis and in Upper Old River, 1985-1991 63

39 Percentage of the Expanded Number of CWT Chinook Smolts Released That Were Recovered at the SWP and CVP Fish Facilities, 1985 through 1992 (Except 1988) 64

40 Bimonthly Mean of Environmental Parameters and Diversion Rates at the State Water Project and Central Valley Project Intakes, 1992 83

41 Mean Density and Estimated Entrainment of Striped Bass Eggs and Larvae at the State Water Project Intake, 1992 86

42 Mean Density and Estimated Entrainment of Striped Bass Eggs and Larvae at the Central Valley Project Intake, 1992 87

43 Estimated Entrainment of Striped Bass Eggs and Larvae, 1985-1992 88

44 Striped Bass Yearling Equivalent Entrainment Losses, 1985-1992 88

45 Striped Bass Yearling Equivalent Losses at the State Water Project and Central Valley Project Export Facilities Based on Densities and Water Exports at the Intakes, February-July 1992 88

46 Mean Density and Estimated Entrainment of Eggs and Larvae of Other Species of Concern at the State Water Project Intake, 1992 90

47 Mean Density and Estimated Entrainment of Eggs and Larvae of Other Species of Concern at the Central Valley Project Intake, 1992 91

48 Larval Fish Species Collected in the Southern Delta, February to July 1992 93

49 Larval Fish Species Collected Near Holland Tract, February to July 1992 93

50 Annual Abundance Indices for the Six Most Common Species of Caridean Shrimp Collected in San Francisco Bay, 1980-1992 95

51 Mean Catch-Per-Unit-Effort of Early Stage Larval *Crangon* from April 1992 Tucker Trawl Sampling in Central San Francisco Bay 103

52 Mean Catch-Per-Unit-Effort of Post-Larval *Crangon* from April 1992 Tucker Trawl Sampling in Central San Francisco Bay 103

53 Mean Catch-Per-Unit-Effort of Larval Longfin Smelt from February and March 1992 Tucker Trawl Sampling in Suisun Bay 104

54 Depth Distribution of Longfin Smelt Larvae, by Length 105

55 Predator Removal Efforts at Tracy Fish Collection Facility, 1992 107

56 Summary of Fish Removed from the Secondary in 1992 Predator Removal Efforts 108

57 Summary of Fishes Collected in Gill-Nets and Fyke-Nets Set in the Delta-Mendota Canal Intake Channel During 1992 109

58 Summary of Clifton Court Forebay Entrainment Loss Studies Using Marked Juvenile Chinook Salmon 112

59 Species Summary for Fish Captured in Clifton Court Forebay Predator Removal Effort, November 1992 to March 1993 115

60 Number of Fish Captured During Resident Fish Sampling at Four Temporary Barrier Sites in 1992 117

61 Species Composition and Sizes of Fish Found in Barker Slough During North Bay Aqueduct Monitoring, 1988-1992 118

62 Average Catch of Fish Less than 100 mm in Barker Slough Otter Trawls, 1988-1992 119

63 Relative Abundance of Predator Fish Greater than 180 mm, Estimated from Barker Slough Gill-Net Samples, 1988-1992 119

HIGHLIGHTS

Environmental Factors

- Flows in the San Joaquin River in 1992 were the lowest since the 1976-1977 drought and contributed to the most significant dissolved oxygen depression measured in the Stockton Ship Channel since the beginning of the 1987-1992 drought. To increase fall flows, a temporary closure was completed at the head of Old River on September 12, 1992, to force more water down the San Joaquin River and through the Stockton Ship Channel. In spite of the closure, exceptionally low dissolved oxygen levels (3.0 mg/L or less) were found in the Rough and Ready Island area from early September through mid-October. Low flows upstream of the closure, warm water, poor water circulation, and channel dredging contributed to the low dissolved oxygen levels. Recovery to levels greater than 5.0 mg/L occurred gradually from late October through November because of improved flows in the San Joaquin River, cooler water, cessation of dredging, and improved water circulation.
- Chlorophyll concentrations remained low throughout most of the delta and Suisun and San Pablo bays during 1992, the sixth year of drought. Chlorophyll maxima were below 7 mg/L for the northern and western delta and Suisun and San Pablo bays. Compared with the long-term record, chlorophyll maxima in the lower San Joaquin River and southern delta were high. Percent chlorophyll values greater than 50 suggest most of the phytoplankton populations in the upper estuary were growing steadily.
- The *Neomysis* population reached record lows during summer and fall of 1992.
- A new species of mysid shrimp invaded the estuary, apparently from the Far East.
- A paper was published describing a new genus and species of mysid shrimp from the estuary.
- An Interagency Technical Report was published describing long-term trends in zooplankton.

Striped Bass

- In 1992, 4,612 adult striped bass were tagged. Based on tags applied in 1991 and recovered during the 1991 summer/fall creel census, the adult striped bass population estimate for 1991 is 1,161,000. However, only two tagged age-3 fish were recovered in the creel census; this small sample size reduces the reliability of the overall estimate. During the early 1970s, adult striped bass population estimates averaged 1.7 million.
- Tag recoveries indicate that anglers harvested 14% of the adult striped bass population in 1991. Harvest rates have typically ranged from 12 to 25%.
- DFG refined the regression model that provides evidence that freshwater outflow and water exports from the delta during the initial year of life are the primary factors controlling adult striped bass abundance in the estuary.
- The midsummer abundance index for young striped bass was 10.6, a low index but nearly twice the 1991 index. A low abundance trend has persisted during the drought years, 1987-1992.
- The 1991 striped bass egg and larva survey samples were processed. Distribution of striped bass larvae in 1991 was almost entirely limited to the delta and lower Sacramento River because of low flows. Abundance of 6- to 14-mm striped bass larvae was low relative to most years of record. Survival was relatively poor compared to other years for two intervals: eggs to 6 mm, and 9 to 38 mm. Poor survival in both cases was related to low flows.
- Chameleon gobies have recently become very abundant in the estuary. In 1991, they were more abundant than 6-mm striped bass. However the relatively low amount of temporal/spatial overlap of striped bass and goby populations suggests the potential for competition is not as great as might be expected based on the total number of gobies.

- The 1992 striped bass fall midwater trawl abundance index was 1988, the highest fall index since 1986.
- The 1992 striped bass spawning in the Sacramento River above Sacramento, as indicated by continuous sampling at Bryte, was an order of magnitude lower than in the three previous years of the study.

Chinook Salmon

- A year-round, multiple-gear sampling program for all juvenile salmonids within the lower Sacramento River and delta area was initiated in September.
- Weekly beach seining at 32 sites in the delta and lower Sacramento River found peak abundances of juvenile fall-run Chinook in March, spring and winter runs in February, and late-fall run in January. This apparent trend should be qualified by the likely bias toward smaller fish when this sampling gear is used.
- Greatest abundances in beach seines were during high flows. Mean length typically dropped off immediately after the flow pulses. This phenomenon could reflect the movement of larger juveniles downstream, out of the range of the seine sites, during flow pulses, with a simultaneous influx of smaller juveniles from upstream.
- The January-through-March catch-per-seine-haul index in the lower Sacramento River was 18 for 1992, versus 30 for 1991. This index has a mean value of 20 for the past 12 years and is highly variable. The catch-per-haul index for the northern delta was 14 in 1992 versus 4 in 1991, with a 16-year mean of 19. In the central delta, the 1992 index was 3 and has been stable since 1986.
- Fyke traps set near both shores at Sacramento proved to be a valuable sampling gear. Fykes caught more Chinook during the day than at night and caught a smaller mean length of salmon than were caught by midwater trawling in the same reach.
- A fifth consecutive year of midwater trawling at Sacramento provided data useful in determining the time salmon arrive in the delta. The data are also used in mark/recapture calculations and for comparison with fyke data to address spatial distribution questions. Due to boat and personnel limitations, there was no sampling in April, a key month.
- Midwater trawling at Chipps Island was conducted in April, May, and June. The mean catch per haul of 21.2 is the highest since 1983, when this index was 44.2. The intervening years ranged from 10.1 to 20.0, with a mean of 14.6. The increase in 1992 may reflect the change to releasing the fall run fish from Coleman National Fish Hatchery in early April rather than late April or May, when delta water temperatures are higher and survival is lower. This hypothesis is supported by the peak of abundance at Chipps Island being in April 1992, as opposed to May in previous years.
- During the April-June sampling at Chipps Island, we captured 17,618 fall run, 2,963 spring run, 69 winter run, and no late-fall run. Most of the Chinook in the spring-run size criteria were likely larger fall run, since true escapement of spring run was quite low.
- Midwater trawling was conducted for 10 days in late April to evaluate the impact of the Montezuma Slough control structure on emigrating smolts and to compare with similar data from 1987, before the control structure was installed. We found no difference in the proportion of smolts diverted through Montezuma Slough in 1992 and in 1987. An average of 0.7% of emigrating smolts travel through Montezuma Slough.
- Coded-wire-tag studies showed a substantially lower survival rate for smolts released in Georgiana Slough compared to those released into the Sacramento River at Ryde. Sacramento River smolts that travel to Chipps Island via the central delta are exposed to a variety of relatively greater mortality factors including: a longer route, with less downstream current; greater predation; higher water temperatures; reverse flows; entrainment into water diversions; and pollution.
- Smolts passing through Georgiana Slough or the Delta Cross Channel must subsequently traverse a portion of the lower San Joaquin River if they are going to make it to sea. Depending on delta inflows and exports, the lower San Joaquin River and all channels south and west of it can have net reverse flows (*ie,* flows with tidal flux factored out). Regression analyses of coded-wire-tag data show a positive correlation between smolt survival and net flow in the western San Joaquin River (Qwest).

- Coded-wire-tagged Chinook were released at Mossdale in a series before and after installation of a barrier at the head of Old River. After being corrected for temperature differences, survival was 0.10 without the barrier and 0.29 with the barrier in place. The barrier keeps more San Joaquin smolts out of upper Old River, which is the most direct path to the export pumps in the southern delta.
- USFWS testimony for the SWRCB Water Right proceedings was published as WRINT-USFWS-7, which summarizes estuary salmon study results from 1978 to 1992.

Other Estuarine Fishes

- The delta smelt project was fully implemented in January.
- All 1992 delta smelt abundance measures are near record-low values.
- The delta smelt population is concentrated in the lower Sacramento River.
- Several additional projects have been added as research needs have been identified:
  - A DWR agricultural diversion study to estimate losses of larval and juvenile delta smelt to diversions in the delta.
  - Culture of a refuge population of delta smelt and research on reproductive cycle and gametogenesis.
  - Laboratory studies to determine environmental tolerances of delta smelt to changes in salinity, temperature, and flow.
- Delta smelt spawned successfully in the laboratory. Larvae survived up to 36 days. Observations indicate that delta smelt are broadcast spawners, spawning is at dusk or in the evening, and eggs hatch between 8 and 14 days at temperatures of 13 to 16°C.
- Larval delta smelt distribution and diets are reported for 1991.
- Sampling for sturgeon eggs with artificial substrates in the Sacramento River in late winter and spring 1992 suggests increases in flow stimulate spawning. Sturgeon seem to spawn where water is at least 6 feet deep and velocity exceeds 4 feet per second so that finer sediments are swept from the substrate.
- Sturgeon angling regulations were re-evaluated in response to substantial reductions in catch and economic hardship for those who depend on the sturgeon fishery for their livelihood. Based on this re-evaluation, DFG recommended to the Fish and Game Commission that the increase in the minimum size limit be halted at the present 46 inches and that the maximum size limit of 72 inches be retained. The Fish and Game Commission adopted this recommendation effective March 1, 1993.

Entrainment of Eggs and Larvae

- Striped bass entrainment losses in 1992 were estimated at 2.9 million eggs and 7.9 million larvae for the SWP and 8.6 million eggs and 11.2 million larvae for the CVP. Striped bass yearling equivalent losses were 13,452 for the SWP and 35,383 for the CVP.
- Entrainment losses for larvae of other species of concern at the SWP in 1992 were estimated at 554,407 for delta smelt, 492,518 for longfin smelt, and zero for splittail. At the CVP, larval losses were estimated at 645,496 for delta smelt, zero for longfin smelt, and 108,773 for splittail.
- Results from the South Delta Egg and Larva Study indicate chameleon goby, threadfin shad, and prickly sculpin accounted for 99% of the total catch at all sites. Chameleon goby comprised 61% of the total catch, a decrease from prior years.

Delta Outflow/San Francisco Bay

- Average annual abundance of several species, including bay goby, plainfin midshipman, white croaker, and California halibut, increased during the drought (1988-1992) compared to previous years (1980-1987). No fish species consistently increased in abundance year after year during the drought.
- Annual abundance of several species remained low in 1992. Included were shiner perch, Pacific herring, and jacksmelt, which utilize high or intermediate (>20 ppt) salinity water as nursery areas, and longfin smelt and starry flounder, which use brackish water as nursery areas. We collected no young-of-the-year starry

flounder in either the monitoring survey or in the recently implemented shallow-water survey.

- Annual abundance of *Crangon franciscorum* was 50% of the previous lowest index; *C. franciscorum* accounted for only 10% of the total shrimp abundance index in 1992. Total shrimp abundance decreased from 1990 and 1991, primarily because of decreased abundance in San Pablo and Suisun bays.

- Major findings of the Tucker trawl survey implemented in 1992 were:
  - Post-larval *Crangon* were collected primarily in the bottom stratum of the water column during night flood tides, which is evidence that behavioral mechanisms are involved in immigration to the nursery area.
  - Distribution of smaller longfin smelt larvae favored the surface waters; larger larvae and juveniles (≥20 mm) were most abundant in the middle and bottom strata.

INTRODUCTION

Perry Herrgesell
Study Manager

This twentieth annual report of the Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary describes results of study efforts during calendar year 1992. In some cases, data discussed were collected during earlier years but were analyzed and interpreted during 1992. This annual report series is a mechanism to informally report recent findings and implications from ongoing Interagency work.

The Interagency Program

The Interagency Program was initiated in July 1970 by a Memorandum of Agreement between the California Department of Fish and Game, California Department of Water Resources, U.S. Bureau of Reclamation, and U.S. Bureau of Sports Fisheries and Wildlife (now Fish and Wildlife Service). The Memorandum of Agreement was an outgrowth of testimony at hearings on Water Right Decision 1379, which indicated construction and operation of the SWP and CVP may have been contributing to fish and wildlife problems in the estuary. Testimony also indicated a need for more information regarding environmental requirements of fish and wildlife and ways to design and operate the water projects to minimize detrimental effects on those resources.

The Memorandum of Agreement contained an appendix that described studies needed to define environmental requirements and agency responsibilities for conducting and funding the studies. Findings were to be documented in annual progress reports to be submitted to the State Water Resources Control Board and other agencies, organizations, and individuals.

Program Elements

The Memorandum of Agreement provided that the program be reviewed annually, with the goal of modifying the studies to reflect changes in engineering and biological needs. Under this provision, the Interagency Program has changed substantially from that envisioned by the originators. For example:

- The Fisheries element was expanded to include resident delta fish as well as striped bass, salmon, sturgeon, and most recently, delta smelt.
- The Water Quality element evolved from an emphasis on adverse effects of too much algae in the estuary (which could cause dissolved oxygen and esthetic problems) to a concern that in certain portions of the delta there may not be enough algae to support desired levels of fish resources.
- The Fish Facilities element was initially concerned with information related to designing fish protective features of the then-proposed Peripheral Canal. With voter defeat of the peripheral canal concept in 1982, emphasis of the program shifted to better understanding effects of existing delta facilities on fish.
- The Suisun Marsh element has gone from a planning program to one in which facilities have been constructed to maintain required water quality in marsh channels and soils. In that regard, the program has moved into a management mode and, in fact, is no longer a part of the Interagency Program. Primarily, this program now has responsibility for implementing the Suisun Marsh Plan of Protection and monitoring effects of the facilities on water quality and on plants and wildlife in the marsh. Activities of the program are not reported in this annual report.

During the 1978 SWRCB hearings to update Water Right Decision 1379, it became clear that it was necessary to expand studies into the lower portions of the estuary. Decision 1485, which resulted from these hearings, mandated that water permit holders for the major projects include a San Francisco Bay element in their studies. The Delta Outflow/San Francisco Bay Study was established in 1979 and began to develop information regarding the need for outflow standards to protect the bay portion of the system. That element of the Interagency Program began with a biological and hydrodynamic component and brought the U.S. Geological Survey and State Water Resources Control Board into the program.

The Data Management element was added in 1984. The vast amount of data collected in the various studies needed to be electronically stored to assure accuracy and to allow access by participating agencies. The Data Management Committee works to achieve standardized station locations, means of data entry, and data verification, among other tasks.

Since 1980, hydrodynamic studies have been carried out through a subcommittee of the Delta Outflow/San Francisco Bay Technical Committee. To be more responsive to overall program needs, a separate Hydrodynamic Study Committee was formed early in 1990.

Program Organization and Funding

The general Interagency Program organization is shown in Figure 1. Technical committees develop specific study proposals and budgets and exercise day-to-day technical supervision over individual studies. A study manager provides administrative and technical oversight to these committees, as well as to the agency coordinators, who resolve issues regarding funding and organization. Agency directors generally meet at least once a year to review progress and to resolve major issues regarding differences in agency policy. An annual workshop is held to bring program participants and others up to date on the various program elements.

Funds contributed to individual program elements by participating agencies in fiscal year 1992 are shown on page 7. The $9.02 million represents almost a $2 million increase over 1991. No funds are identified for the data management activities; funding for that element is derived from within the other program elements.

Program Goals

Goals of the Interagency Program are:

- To provide for the collection and analysis of data needed to understand factors controlling the distribution and abundance of selected fish and wildlife resources in the Sacramento-San Joaquin estuary and make the data readily available to other agencies and the public.
- To comply with permit terms requiring ecological monitoring in the estuary.
- To identify impacts of human activities on fish and wildlife resources.
- To interpret information produced by the program and from other sources and, to the extent possible, recommend measures to avoid and/or offset adverse impacts of water project operation and other human activities on these resources. To seek consensus for such recommendations, but to report differing recommendations when consensus is not achieved.
- To provide an organizational structure and program resources to assist in planning, coordinating, and integrating estuarine studies by other units of member agencies or by agencies that are not members.

1992 Program Update

This section briefly updates selected administrative activities during 1992.

Research Enhancement Program

During 1992, the name of the University Academic Research Involvement Program was changed to the Research Enhancement Program to reflect a broader interest and program support in areas outside the university environment, primarily in areas related to management issues. The budget, which was supported by the Interagency Program and the San Francisco Estuarine Project, totaled about $460,000 for this grant program. Of this, $414,000 was awarded to 6 scientists chosen from 49 who submitted proposals. More than 200 peer scientists participated in the evaluation process, during which the following grantees were selected:

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Figure 1
ORGANIZATION, INTERAGENCY ECOLOGICAL STUDIES PROGRAM

AGENCY DIRECTORS

David Kennedy .... Department of Water Resources
Roger Patterson .... U.S. Bureau of Reclamation
Don Maughn .... State Water Resources Control Board
Leonard Cardoza .... U.S. Army Corps of Engineers
Boyd Gibbons .... Department of Fish and Game
Marvin Plenert .... U.S. Fish and Wildlife Service
John Klein .... U.S. Geological Survey
Daniel McGovern .... U.S. Environmental Protection Agency

AGENCY COORDINATORS

Harold Chadwick, Chair .... Department of Fish and Game
Marty Kjelson .... U.S. Fish and Wildlife Service
Larry Smith .... U.S. Geological Survey
Tom Wakeman .... U.S. Army Corps of Engineers
Randy Brown .... Department of Water Resources
Dave Beringer .... State Water Resources Control Board
Ken Lentz .... U.S. Bureau of Reclamation
Patrick Wright .... U.S. Environmental Protection Agency

STUDY MANAGER

Perry Herrgesell, Department of Fish and Game

TECHNICAL COORDINATING COMMITTEES

Fisheries/Water Quality Program

Marty Kjelson, Chair .... U.S. Fish and Wildlife Service
Jim Arthur .... U.S. Bureau of Reclamation
Donald Stevens .... Department of Fish and Game
Harlan Proctor .... Department of Water Resources
Bellory Fong .... Department of Water Resources
Jim Sutton .... State Water Resources Control Board

Fish Facilities Study

Pat Coulston, Chair .... Department of Fish and Game
Marty Kjelson .... U.S. Fish and Wildlife Service
Marcin Whitman .... National Marine Fisheries Service
Leo Winternitz .... Department of Water Resources
Stein Buer .... Department of Water Resources
Lloyd Hess .... U.S. Bureau of Reclamation
Bruce Herbold .... U.S. Environmental Protection Agency

Hydrodynamics Committee

Larry Smith, Chair .... U.S. Geological Survey
Pete Smith .... U.S. Geological Survey
Chuck Armor .... Department of Fish and Game
Marty Kjelson .... U.S. Fish and Wildlife Service
Tom Wakeman .... U.S. Army Corps of Engineers
Tom Tamblyn .... State Water Resources Control Board
Randy Brown .... Department of Water Resources
Jim Arthur .... U.S. Bureau of Reclamation

Delta Outflow/San Francisco Bay Study

Chuck Armor, Chair .... Department of Fish and Game
Jim Arthur .... U.S. Bureau of Reclamation
Marty Kjelson .... U.S. Fish and Wildlife Service
Steve McAdams .. Bay Conservation/Development Commission
Tom Wakeman .... U.S. Army Corps of Engineers
Randy Brown .... Department of Water Resources
Rick Oltman .... U.S. Geological Survey
Ron Bachman .... State Water Resources Control Board

Data Management Committee

Sheryl Baughman, Chair .... U.S. Bureau of Reclamation
Joel Johnston .... U.S. Geological Survey
Pat Brandes .... U.S. Fish and Wildlife Service
Ann Baker .... Department of Fish and Game
Sheila Greene .... Department of Water Resources
Jim Sutton .... State Water Resources Control Board

PROGRAM FUNDING, FISCAL YEAR 1992
(Thousands of Dollars)

	DWR	USBR	DFG	SWRCB	USGS	USFWS	USCE	USEPA	Total
Fisheries/Water Quality	2333	1832	972	105		134			5376
Fish Facilities	915	431							1346
Delta Outflow/San Francisco Bay	354	556							910
Hydrodynamic Investigations	458	40			438				936
Administration	80	113	245	15					453
Totals	4140	2972	1217	120	438	134	0	0	9021

- Dr. Donald R. Strong, University of California, Davis, "Ecology and Potential for Control of the Invasive Alien Saltmarsh Cordgrass, *Spartina alterniflora*, in San Francisco Bay". The study will focus on the growth pattern and potential control mechanisms for an invasive, eastern species of cordgrass now growing in the South Bay region of the bay area.
- Dr. Nicholas S. Fisher, State University of New York, Stony Brook, and Dr. Samuel N. Luoma, U.S. Geological Survey, Menlo Park, "An Interspecific Comparison of Metal Bioavailability in San Francisco Bay: Comparison of Solute and Particulate Source Terms". The researchers will concentrate on the bioavailability of metals in San Francisco Bay, measuring levels of silver, cadmium, chromium, selenium, and zinc in mussels and clams and determining whether food or water is the primary route of contamination.
- Dr. A. Russell Flegal, University of California, Santa Cruz, "The Biogeochemical Cycles of Trace Elements in the San Francisco Bay Estuarine System". The study will concentrate on the movement of silver, cadmium, cobalt, copper, iron, mercury, lead, and zinc in sediments and in the water column and the physical and chemical availability of these trace elements. This research, together with that of Fisher and Luoma, will provide new data about the flow of metals in the bay and their uptake by aquatic organisms.
- Dr. Joseph Cech and Keith Marine, University of California, Davis, "An Investigation of the Effects of Elevated Water Temperature on Some Aspects of the Physiological and Ecological Performance of Juvenile Chinook Salmon *(Oncorhynchus tsawytschca)*: Implications for Management of California's Central Valley Salmon Stocks". The research will help determine the temperature dose response survival level for juvenile salmon. Presently, increased water temperatures in the delta during certain seasons have contributed to fish mortality. The study will provide a better understanding of the maximum sub-lethal tolerance levels for smolts.
- Dr. Serge I. Doroshov, University of California, Davis, "Reproductive Cycle and Gametogenesis of Delta Smelt, *Hypomesus transpacificus*". The number of delta smelt has declined drastically in recent years, and the species has now been listed as threatened. The study will provide much-needed data about the production of gametes' viability, which could help reverse the present downward trend.
- Dr. David A. Jay, University of Washington, and Dr. Fredrick G. Prahl, Oregon State University, "Channel-Shoal Exchanges of Particles in North San Francisco Bay". The study will address particle exchange in Suisun Bay and the shoal areas in the deep portion of the Sacramento River and the impacts on the food web. The study will provide understanding about the relationship of phytoplankton and fish production to the null zone.

Technical Information Specialist

In December 1992, the Coordinators approved the appointment of a Technical Information Specialist. Olof Hansen was appointed to the position, which was defined as a senior-level technical expert to support the Interagency Program in data management. Hansen was assigned to work toward four immediate objectives:

- Create a comprehensive index of all Interagency Program data.
- Act as librarian of the data system, responsible for keeping all data current and for updating data as required.
- Upload all Interagency Program files to a dedicated work station.
- Re-evaluate the flow of data from sampling to storage and retrieval.

The Technical Information Specialist will report to the chairperson of the Data Management Committee and will serve as the committee's executive secretary and technical advisor.

Expanded Salmon Program

Listing of winter-run Chinook salmon under the Endangered Species Act prompted a major augmentation of the salmon sampling program being carried out by USFWS. This effort is funded by USBR and DWR and is under direction of the National Marine Fisheries Service as a result of its endangered species Biological Opinion. The revised program is designed to answer many questions, some of which are:

- Where are winter-run juveniles rearing between Hamilton City and Isleton?

- When do winter-run salmon enter the delta?
- Do fry use the delta as a nursery area?
- Do present water project operations affect the abundance and distribution of fry and smolts in the delta?

Review and Revision of the Interagency Program

During 1992, in recognition of the rapidly changing biological, regulatory, and political climate, the Coordinators established a small *ad hoc* group to review the Interagency Program and recommend improvements to allow the program to remain effective. Some recent and ongoing developments that affect the Interagency Program include:

- Endangered Species Act
- Water Right Decision 1630 (Draft)
- Central Valley Improvement Act (PL-102-575)
- Bay/Delta Oversight Council

The *ad hoc* group consisted of Perry Herrgesell (Study Manager), Leo Winternitz (DWR), Jim Arthur (USBR), Pat Coulston (DFG), and Marty Kjelson (USFWS). The group developed a 3-phase plan to complete the review, which was guided by a self-generated list of assumptions relevant to the objective of the Interagency Program. The group plans to present its recommendations to the Coordinators by May 1993 and to have a revised program ready for implementation in January 1994.

The Sacramento-San Joaquin Estuary

The Sacramento-San Joaquin estuary, shown in Figure 2, is briefly described here for those not familiar with the area. The estuary has been described in detail by several authors.[1] Geographic features identified in Figure 2 are often referred to in discussions of the program elements.

By definition, an estuary is an area where tidal and river currents meet. As used in this report, the Sacramento-San Joaquin estuary consists of South and Central San Francisco Bay, San Pablo Bay, Suisun Bay, and the Sacramento-San Joaquin Delta. The extent to which tidal currents actually penetrate inland depends on freshwater flow and tidal phase.

The Sacramento and San Joaquin rivers join to form a delta area that contains numerous islands protected by levees. The islands are productive agricultural lands, and the surrounding levees and channels support populations of resident fish, provide nursery areas for both resident and migratory species, serve as passageways for migrating adult and juvenile fish, and are valuable habitat for a wide variety of wildlife.

The Sacramento and San Joaquin rivers are the major source of fresh water to the estuary, with the Sacramento being the largest contributor. In an estuarine system such as this, total freshwater inflow can be important to regulating biological, physical, and chemical processes. The Sacramento-San Joaquin estuary is hydrologically complex, and freshwater inflow cannot be directly measured.

An index of inflow to San Francisco Bay, called "delta outflow", is calculated by summing the known inflows and subtracting in-channel and project diversions. DWR publishes the calculated flows as part of its DAYFLOW program. Figure 3 is a plot of delta outflow for 1992, which was classified a critical year.

Average annual natural runoff to the estuary has been reduced significantly by hundreds of water diversions from upstream channels and in the delta and by the SWP and CVP pumps in the southern delta. At times, the combination of low streamflow and high delta depletions (by agriculture and the water projects) causes flows to move *upstream* in the San Joaquin River to the project pumps. This *reverse flow* occurs because most of the water pumped originates in the Sacramento system, and hydraulic conditions result in this water being drawn around the delta and up the San Joaquin River to the pumps.

During much of the year, streamflows and tidal flows interact most intensively in Suisun Bay. Fresh water, being less dense, flows downstream over the landward-flowing salt water, and the interaction of gravitational and tidal forces on material suspended in the water (algae, sediment, and small fish) can cause these materials to become concentrated. The area of maximum concentration has been termed the "entrapment

1 For example, T.J. Conomos, "Properties and Circulation of San Francisco Bay Waters", in *San Francisco Bay: The Urbanized Estuary*. T.J. Conomos, editor. Pacific Division, AAAS, San Francisco. 1979.

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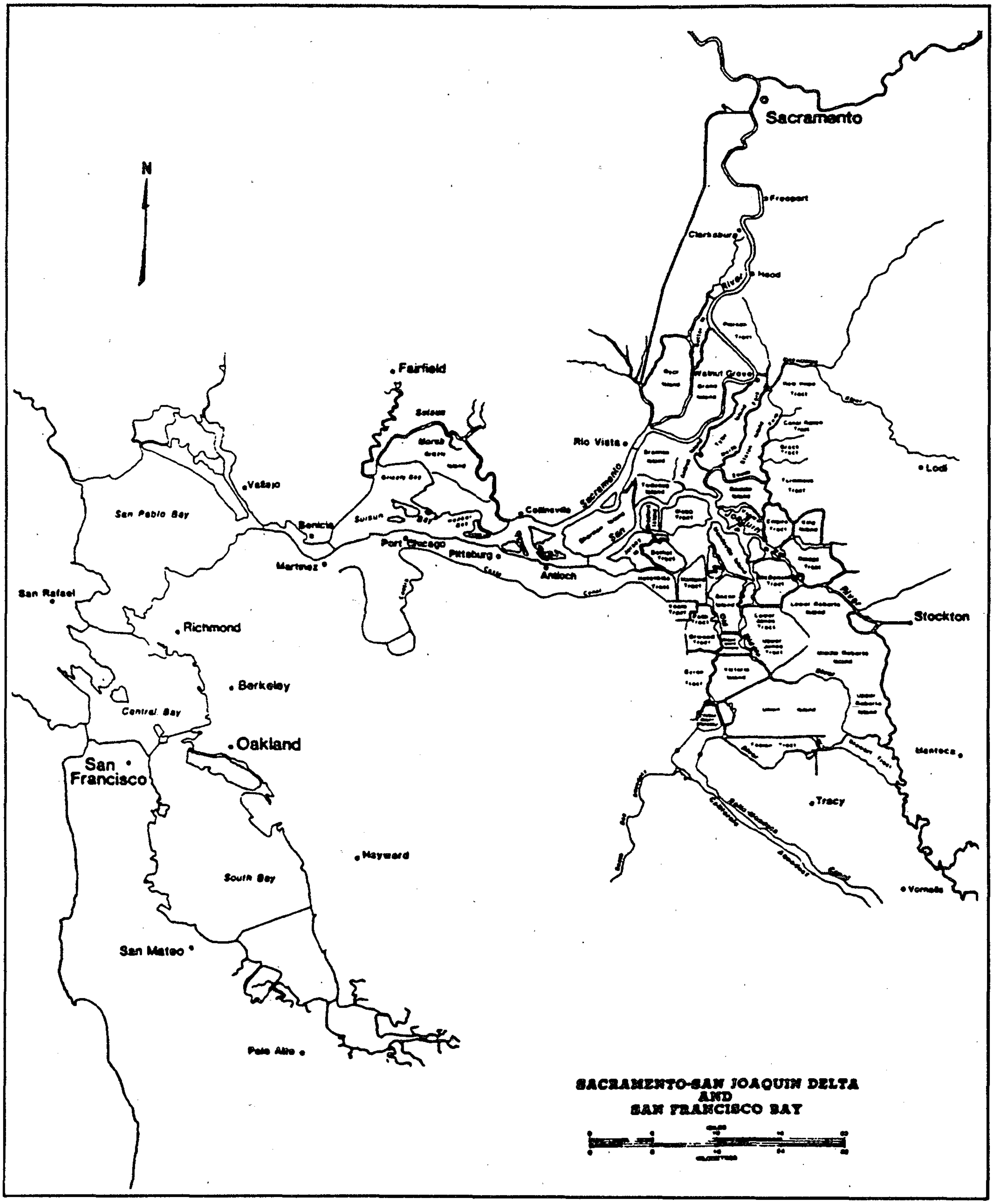

Figure 2
SACRAMENTO-SAN JOAQUIN ESTUARY

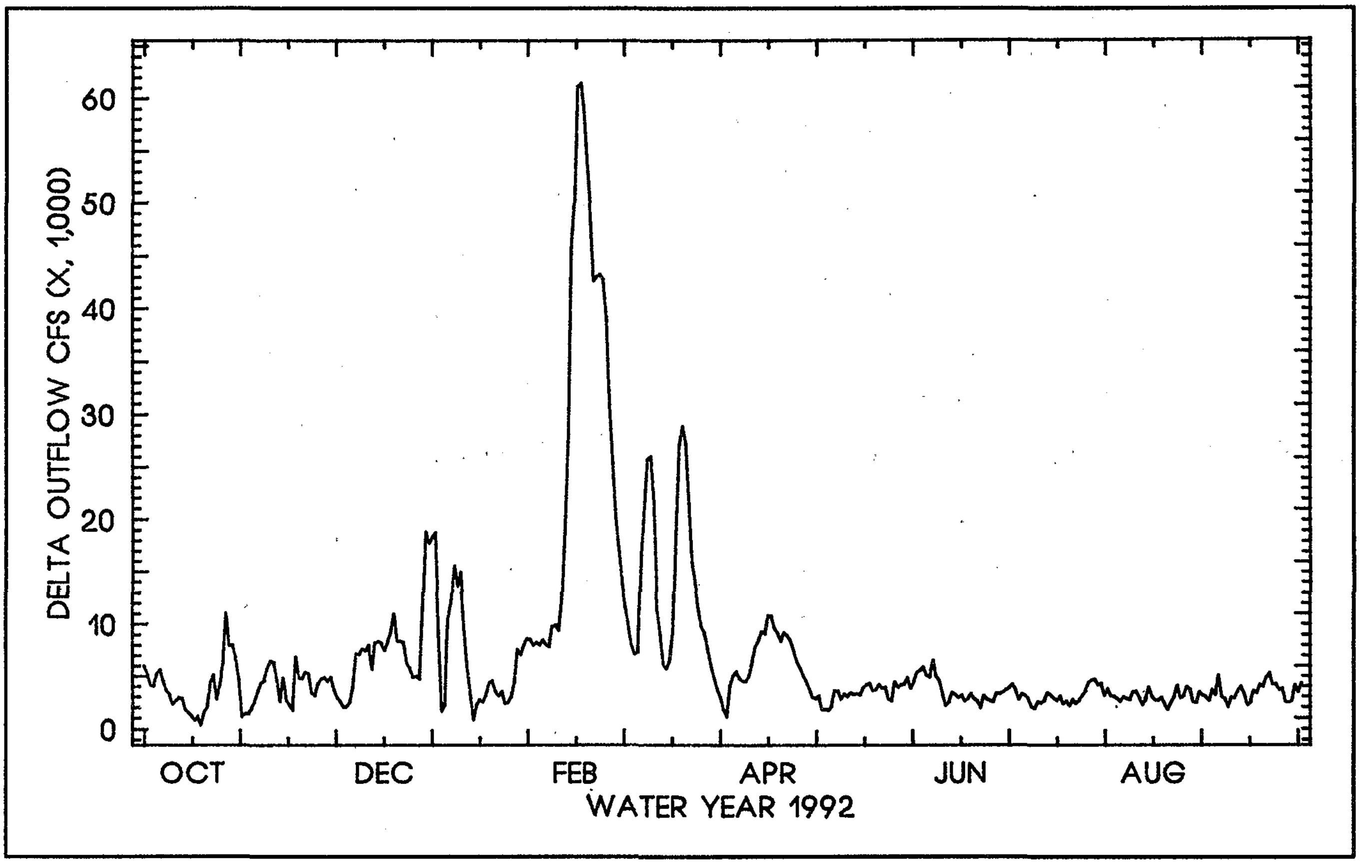

Figure 3
DAYFLOW NET DELTA OUTFLOW

zone" or "null zone". This zone is of ecological significance to many plants and animals living in or migrating through the estuary. Location of the entrapment zone is primarily a function of freshwater flow from the delta; it can be in San Pablo Bay during high flows and in the eastern delta during low flows. Arthur and Ball[1] present more information on the entrapment zone.

Downstream of Suisun Bay, the estuary is generally dominated by tidal forces, although moderate to high freshwater flows still dramatically affect circulation patterns. In San Pablo and Central bays, landward-flowing bottom currents distribute many bottom-dwelling organisms and free-floating larval and juvenile organisms throughout the estuary. In South Bay, however, often the bottom current is seaward and the surface current is landward (*reverse estuary*). Circulation patterns in the lower estuary are not well understood.

The estuary supports numerous species of fish, many of which are of economic importance. About 40 freshwater fish species (minnows, bass, sunfish, smelts, *etc*) are regularly caught in the delta. Four migratory fish — Chinook salmon, striped bass, American shad, and white sturgeon — are important economically and are particularly vulnerable to project operations.

More than 120 species of fish have been caught and identified in the San Francisco Bay sampling program. Many of the bay fish come from ocean populations that either actively migrate into the bay or are swept in by tidal and density-driven circulation patterns. The bay provides habitat during larval, juvenile, or adult stages of many of these finfish, as well as for shellfish.

1 J.F. Arthur and M.D. Ball. *The Significance of the Entrapment Zone Location to the Phytoplankton Standing Crop in the San Francisco Bay-Delta Estuary*. U.S. Department of the Interior, Bureau of Reclamation, Mid-Pacific Region, Sacramento. 89 pp. 1980.

In addition to such economically important species as Chinook salmon, striped bass, and waterfowl, the estuary provides habitat for numerous other animals and plants, which interact to form a complex and dynamic ecosystem.

The estuary is a focal point for water development in California because water transferred from Northern California moves through the delta. Diversion of water from the delta by DWR and USBR is by authority of water right permits granted by SWRCB. These permits are reviewed periodically to determine conditions to protect fish, wildlife, and other beneficial uses. Data from the Interagency Program and others are used during these reviews to determine if changes are needed in operating criteria or water quality standards.

The Interagency Program is designed to evaluate impacts of the State and Federal water projects on the estuary. Other human activities and natural events also affect the system. Effects of changes in volume and quality of municipal and industrial wastes, irrigation return flows, dredging, bay filling, flooding of delta islands, introduction of exotic organisms, and major climatic events such as El Niño must be considered when trying to assess the impacts of diversions on the health of the estuary.

Chapter 3

ENVIRONMENTAL FACTORS

This chapter reviews some findings of the DWR Decision 1485 compliance monitoring program, provides an update on *Neomysis* and zooplankton studies, presents results of the DWR aquatic vegetation survey, and summarizes activities of the Food Chain Group.

Dissolved Oxygen Concentrations in the Stockton Ship Channel

Stephen P. Hayes and John C. Baker
Department of Water Resources

Dissolved oxygen levels in the Stockton Ship Channel during August and September 1992 were the lowest measured during the 1987-1992 drought. The exceptionally low values (decreasing to 0.5 mg/L) in parts of the ship channel were apparently the result of low flows in the San Joaquin River[1], warm water temperatures, reduced tidal action in the eastern end of the ship channel, and dredging in the channel.

The Old River closure[2] was constructed on September 10 and 11 and was in place through December 2, 1992.

Eight compliance dissolved oxygen monitoring runs were conducted in the San Joaquin River during 1992. For each run, 14 sites were sampled from Prisoners Point to the Stockton turning basin (Figure 4). Discrete samples were taken at each site for dissolved oxygen and water temperature at the top and bottom of the water column at ebb slack tide. Results are summarized in Figure 5.

Pre-closure monitoring, on August 27 and September 9, showed a significant drop in dissolved oxygen levels in the Stockton Ship Channel. In August, surface and bottom dissolved oxygen levels were less than 4.0 mg/L in the Rough and Ready Island area (Lights 41 to 48). Levels dropped to 3.0 mg/L or less in that area and slightly westward (Lights 34 to 48) by September 9. Water temperatures for both runs ranged from 25 to 26°C.

Deterioration of dissolved oxygen levels in mid-September could have been partly the result of dredging. Maintenance dredging[3] west of the Turning Basin from September 7 to 19 caused increased turbidity in the Rough and Ready Island area. Anaerobic sediments brought into suspension by the dredge could have increased biochemical oxygen demand in the area and thereby contributed to the low dissolved oxygen levels measured during the period of operation.

Measurements of dissolved oxygen from the Rough and Ready Island continuous water quality monitoring station[4] support the possibility of adverse impacts of dredging on dissolved oxygen levels. Hourly dissolved oxygen measurements from September 1 through 9 were low, ranging from 2.7 to 5.0 mg/L. From September 12 to 18, dissolved oxygen levels dropped to extraordinarily low levels of 0.5 to 2.1 mg/L, apparently due to the dredging.

Dissolved oxygen conditions did not improve immediately after placement of the Old River closure and completion of the dredging. Post-closure/post-dredge monitoring in the Stockton Ship Channel on September 23, October 9, and October 16 revealed little improvement. Dissolved oxygen levels of less than 5.0 mg/L persisted in the Rough and Ready Island area and westward (Lights 43 to 28), with the lowest levels (3.0 mg/L or less) at Lights 34 to 41. Low flows upstream of the closure, poor water circulation, and warm water temperatures (20-22°C) continued to depress dissolved oxygen in the Stockton Ship Channel.

1 Average daily flows past Stockton ranged from minus 332 to plus 180 cubic feet per second from August through October 19, 1992.
2 A rock barrier across the head of Old River to force more San Joaquin River water downstream into the Stockton Ship Channel.
3 Under contract to the U.S. Army Corps of Engineers.
4 This station is maintained by DWR, Environmental Services Office, Compliance Monitoring and Analysis Branch.

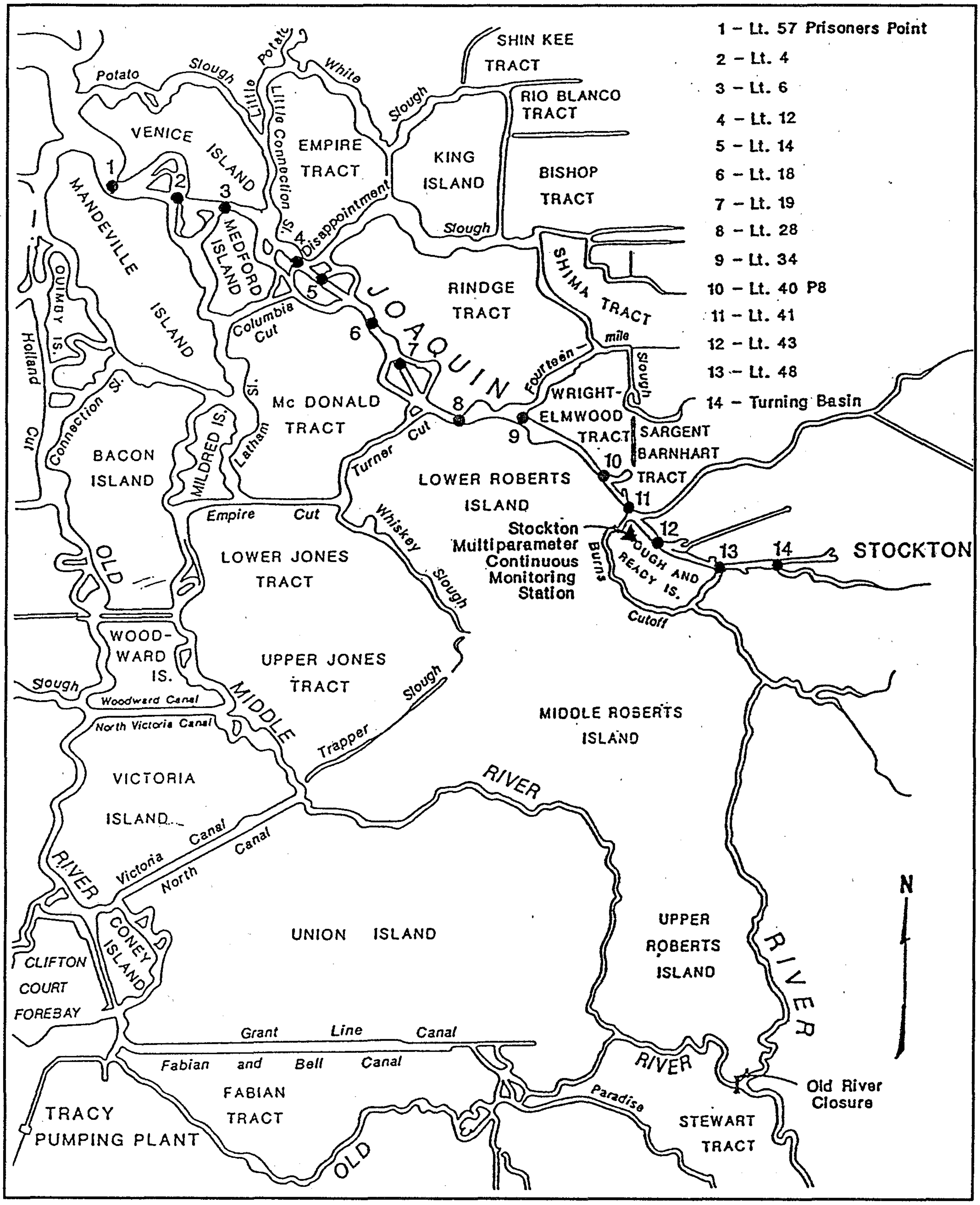

Figure 4
DISSOLVED OXYGEN MEASUREMENT SITES IN THE SAN JOAQUIN RIVER, 1992

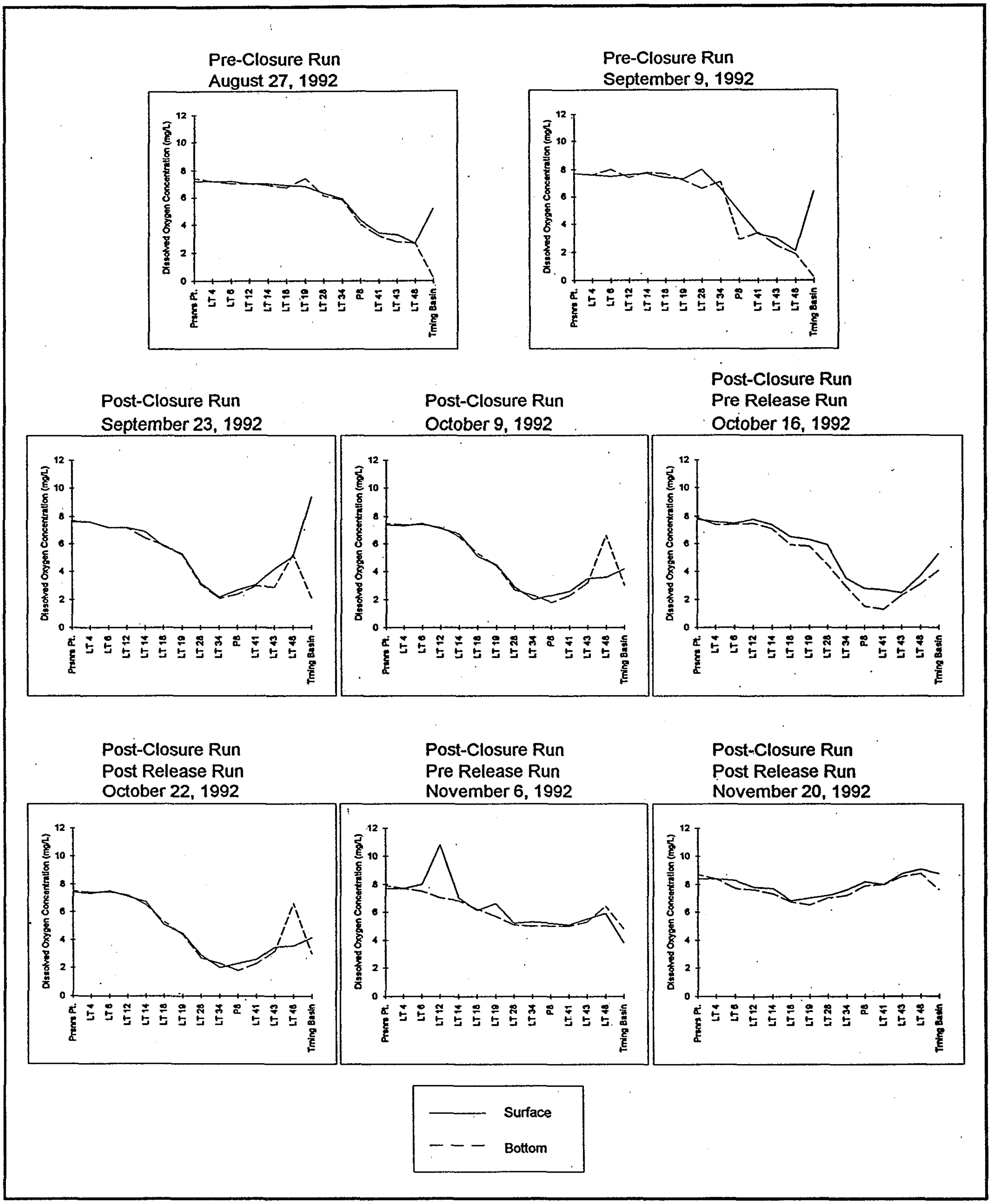

Figure 5
DISSOLVED OXYGEN CONCENTRATIONS IN THE STOCKTON SHIP CHANNEL BEFORE AND AFTER INSTALLATION OF THE BARRIER IN OLD RIVER, 1992

Flows in the San Joaquin River improved in late October through late November, partly because of a water exchange agreement between DFG and irrigation districts on the Stanislaus and Merced rivers. This agreement allowed releases of 2,000 cfs into the San Joaquin River between October 17 and October 21. Objectives of the releases were to upgrade water circulation in the Stockton Ship Channel and to provide downstream flow for fall Chinook salmon. From October 20 through November 20, flow at Vernalis averaged greater than 1,000 cfs. Because of the continued lack of substantial rainfall in the San Joaquin drainage basin during October and November, flows improved only gradually.

Post-closure/post-dredge/post-release monitoring on October 22, November 6, and November 20 revealed a gradual improvement in dissolved oxygen conditions in the Stockton Ship Channel. On October 22, shortly after the releases were increased, all dissolved oxygen values in the area west of Rough and Ready Island (Lights 28 to 41) exceeded 3.0 mg/L, and levels in the Rough and Ready Island area itself exceeded 5.0 mg/L. On November 6, all dissolved oxygen values in the Stockton Ship Channel were 5.0 mg/L or greater, with values from Light 18, between McDonald Tract and Rindge Tract, westward to Prisoners Point ranging from 6.1 to 8.0 mg/L. Dissolved oxygen conditions finally improved significantly in late November. The November 20 monitoring run showed surface and bottom dissolved oxygen levels ranging from 6.2 to 9.1 mg/L, apparently the result of cooler water (13-14°C) and improved flows.

The apparently anomalous dissolved oxygen values measured in the Stockton Turning Basin during August and September were the result of unique biological and water quality conditions. Throughout late summer and early fall, a series of algal blooms, composed primarily of Cryptomonads and other green flagellated algae, produced stratified dissolved oxygen in the water column. Dissolved oxygen levels were high (5.2 to 9.4 mg/L) at the surface and exceptionally low (0.2 to 2.1 mg/L) at the bottom because of poor bottom water circulation, minimum tidal activity, and high biochemical oxygen demand. The high BOD was probably created by inadvertent vessel discharges, other boating activity in the harbor area, and the settling and decomposing of dead or moribund bloom algae.

Phytoplankton Chlorophyll and Species Composition

Peggy Lehman
Department of Water Resources

The DWR Decision 1485 compliance monitoring program was incorporated into the Interagency Program during 1990. This section reviews some of the findings of this program. More comprehensive reports entitled "Water Quality Conditions in the Sacramento-San Joaquin Delta" are published for each year by the DWR Environmental Services Office.

For this summary, sampling stations were grouped into regions. Regions were determined from hierarchical cluster analyses of stations by season and year type, using 15 discrete water quality variables collected at 21 sampling stations (Figure 6) between 1974 and 1990. Water quality variables used in the analysis were average monthly chlorophyll, phaeophytin, nitrate, orthophosphate, total phosphate, silica, dissolved oxygen concentration, pH, Secchi disk depth, air and water temperature, specific conductance, wind velocity, suspended solids, and turbidity.

Regions and their representative sampling stations are:

Region	Stations
Northern Delta	C3
Lower San Joaquin River	D16, D19, D26
Western Delta	D15, D11, D12
Southern Delta	C7, C10, P12
Suisun Bay	D6, D7, D8, D9, D10
San Pablo Bay	D41

Chlorophyll concentrations were low throughout most of the delta in 1992 compared with previous years (Figures 7 and 8). The northern delta maintained its usually low (<5.0 μg/L) chlorophyll concentrations and high chlorophyll ratios. Chlorophyll concentrations were also below 5 μg/L in 1992 for the western delta and in the lower San Joaquin River except in May. Higher chlorophyll concentrations in May were associated with populations of *Melosira granulata* and *Thalassiosira* spp. These populations were healthy but not thriving, since percent chlorophyll values were less than 70. The western delta chlorophyll maximum in May was relatively low compared with previous years, in which chlorophyll maxima often reached 10 to 30 μg/L (Figure 8). In

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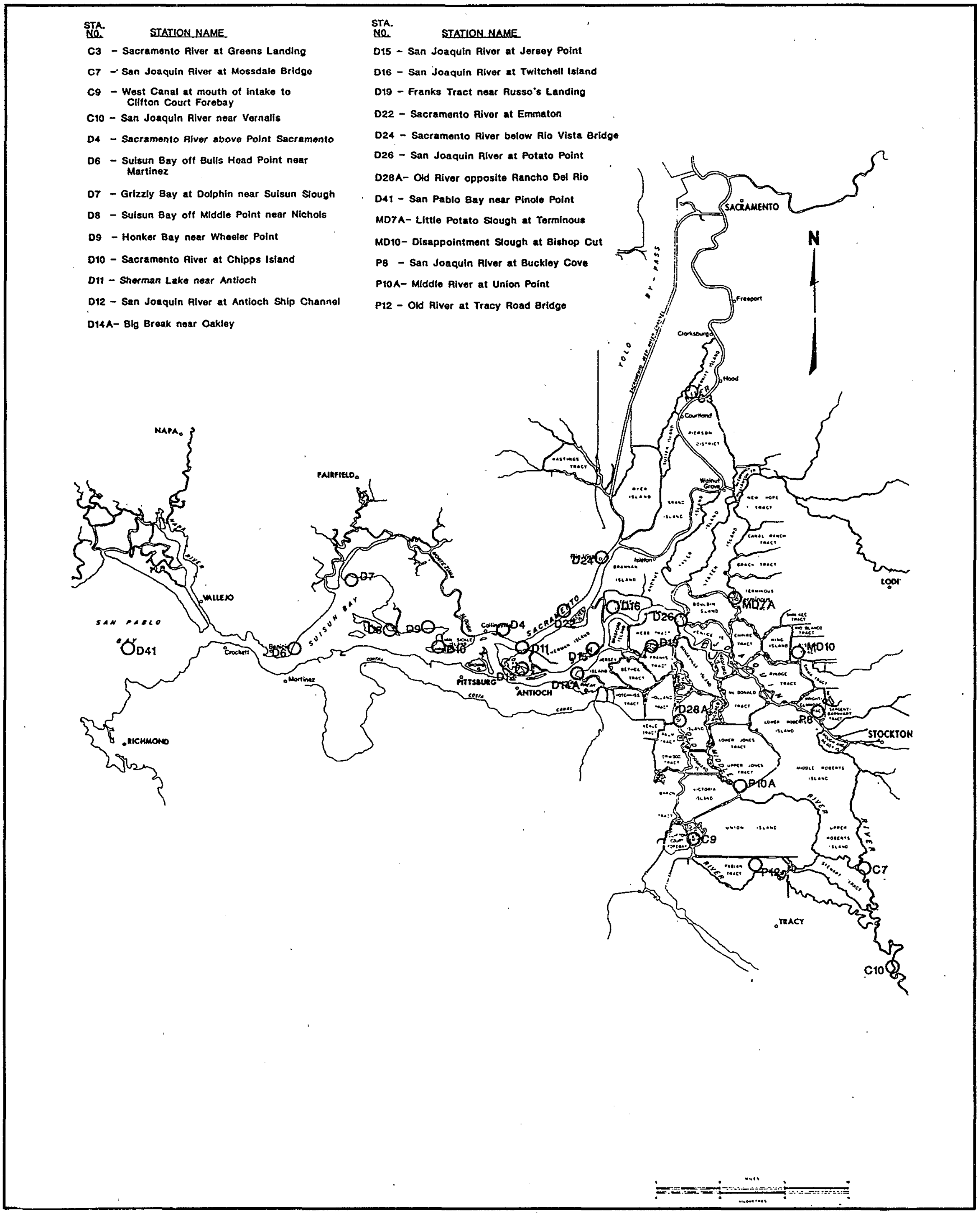

Figure 6
1992 COMPLIANCE MONITORING SITES

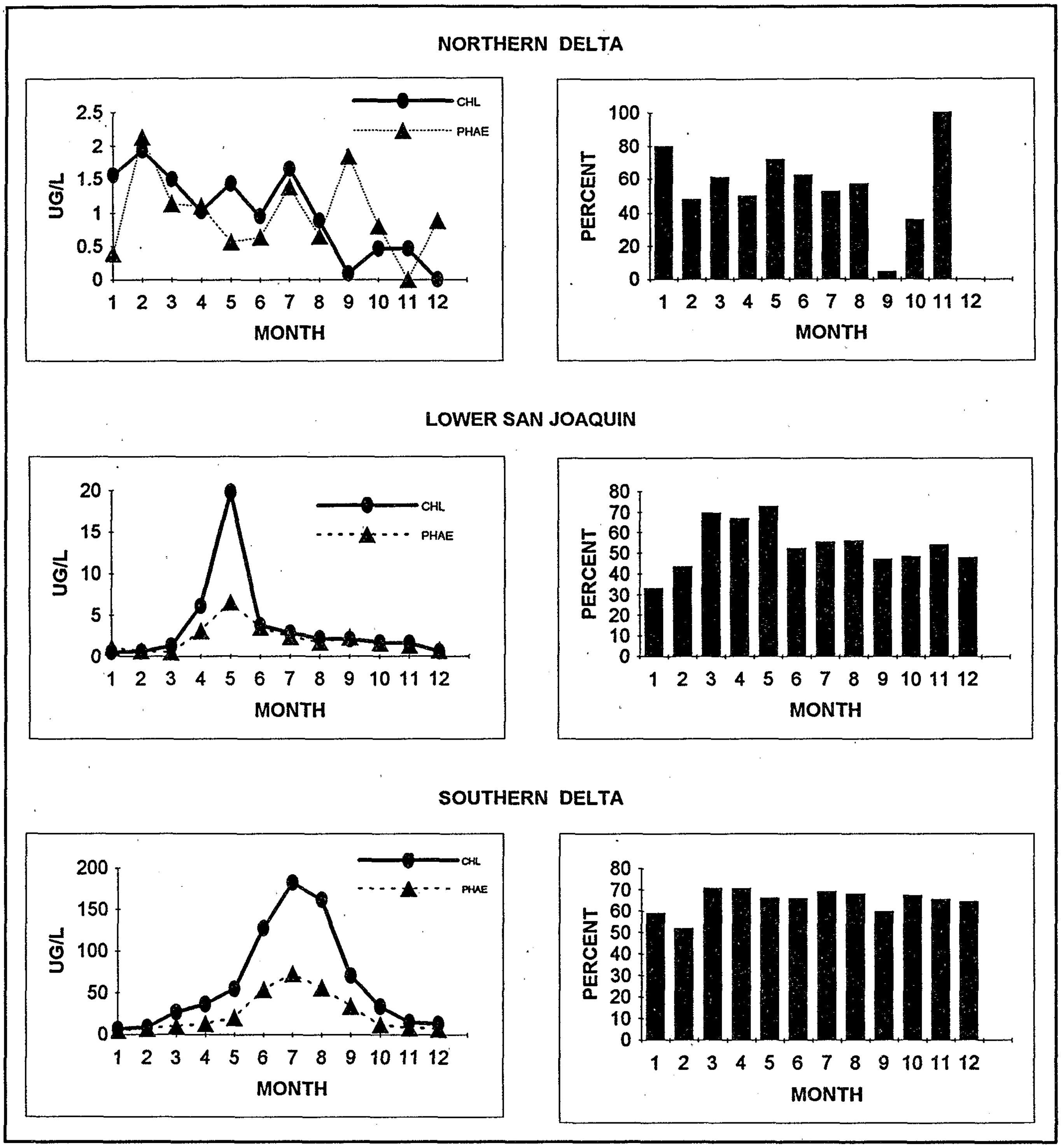

Figure 7
MEAN MONTHLY CHLOROPHYLL AND PHAEOPHYTIN AND
MEAN MONTHLY PERCENT CHLOROPHYLL CONCENTRATIONS DURING 1992

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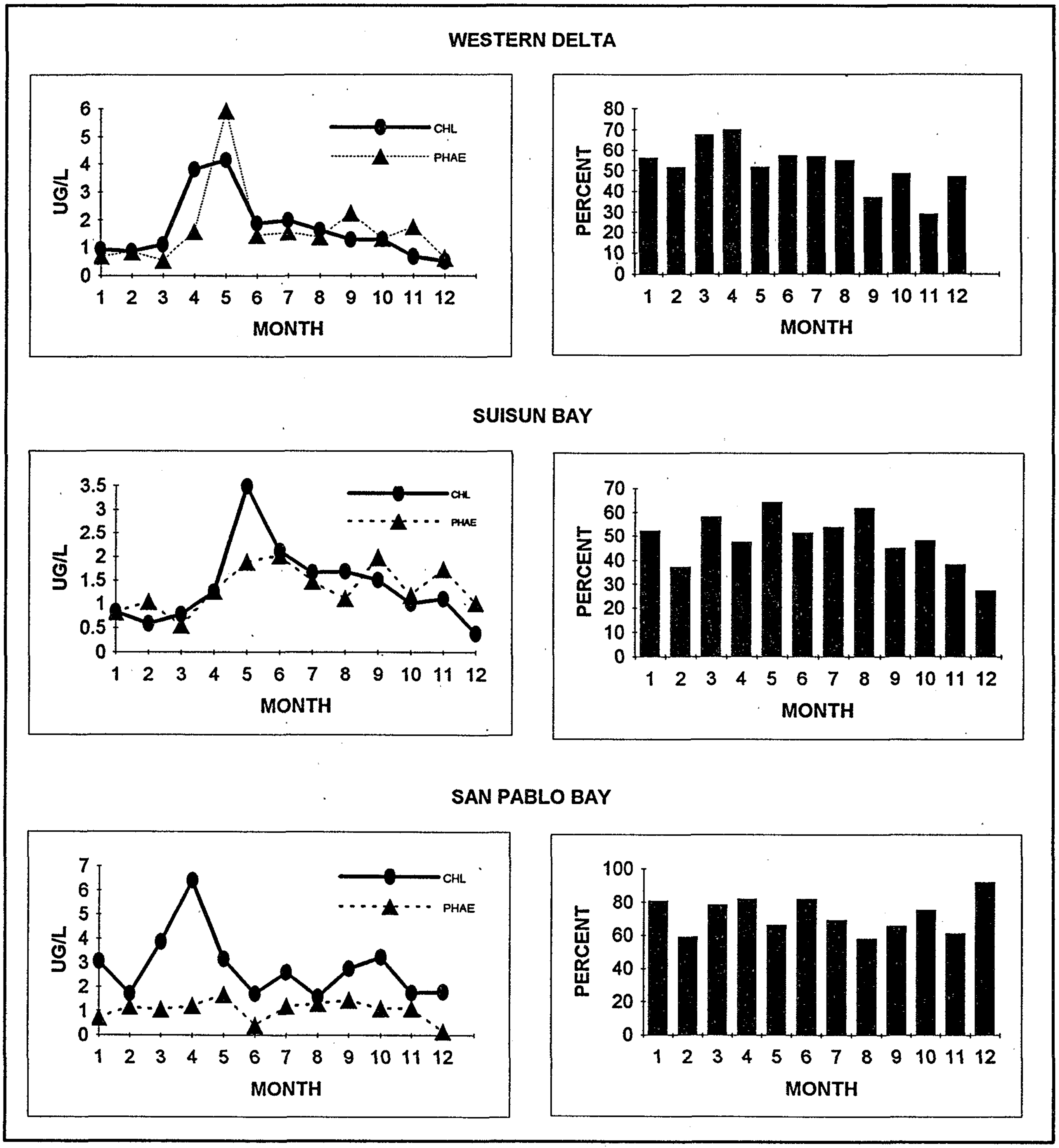

Figure 7 (continued)
MEAN MONTHLY CHLOROPHYLL AND PHAEOPHYTIN AND
MEAN MONTHLY PERCENT CHLOROPHYLL CONCENTRATIONS DURING 1992

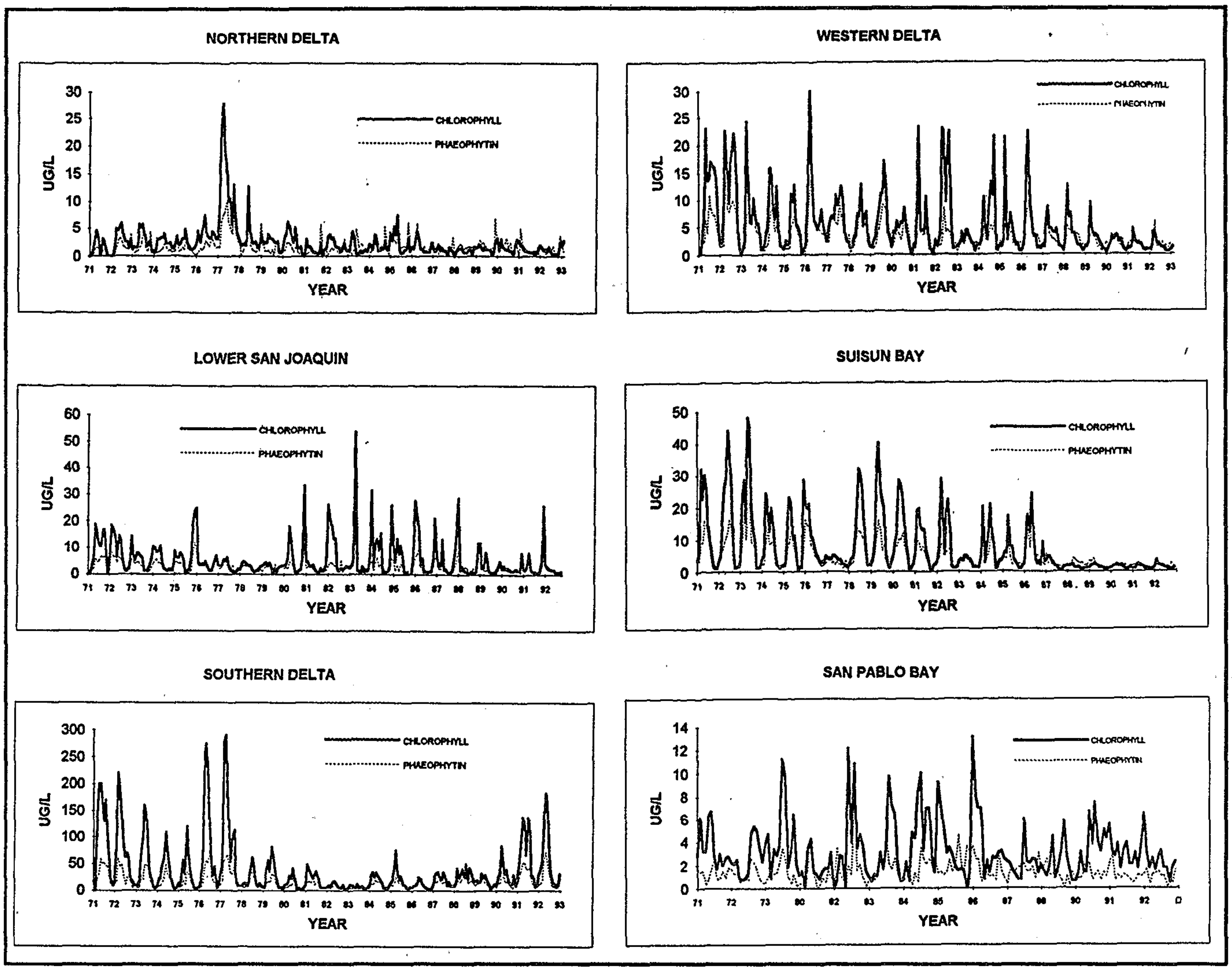

Figure 8
MEAN MONTHLY CHLOROPHYLL AND PHAEOPHYTIN CONCENTRATIONS, 1971-1992

contrast, the chlorophyll maximum for the lower San Joaquin River was one of the highest on record and closely matched those measured between 1981 and 1988 (25-40 µg/L).

Chlorophyll concentrations for the southern delta in 1992 were consistently above 10 µg/L and peaked at 200 µg/L in July (Figure 7). The peak was high compared with those in the 1980s (10-50 µg/L), similar to those in the 1970s (100-300 µg/L), and continued the trend of higher chlorophyll concentrations during the latter years of the 1987-1992 drought (Figure 8). The phytoplankton were actively growing throughout the year, with percent chlorophyll values near 60 or above. Chlorophyll maxima for June through August were associated with populations of *Cyclotella* spp.

Chlorophyll concentrations in Suisun and San Pablo bays were unusually low in 1992 compared with previous years (Figures 7 and 8). Concentrations in 1992 were below 4 µg/L in Suisun Bay and 7 µg/L in San Pablo Bay. These concentrations contrasted with peak chlorophyll concentrations, which reached between 20 and 50 µg/L in Suisun Bay prior to 1987 and between 8 and 14 µg/L in San Pablo Bay during the early 1980s. Low chlorophyll concentrations in Suisun Bay since 1987 were probably due to filter feeding by the introduced clam *Potamocorbula amurensis*, which became abundant during the 1987-1992 drought. Low percent chlorophyll values (30-60%) support the presence of relatively high quantities of chlorophyll breakdown products from grazing.

Neomysis/Zooplankton Study

James Orsi
Department of Fish and Game

The *Neomysis*/Zooplankton study monitors the abundance of the opossum shrimp, *Neomysis mercedis*, and the copepods, cladocerans, and rotifers that comprise the zooplankton fauna of Suisun Bay and the delta. Copepods and cladocerans are the first organisms eaten by larval striped bass, which shift to *Neomysis* as they grow larger. In turn, *Neomysis* and zooplankton feed on phytoplankton and detritus and as a result form important links between the primary production of the estuary and fish. It is necessary to monitor changes in species composition (some of which are caused by introduction of exotic organisms) and abundance of the zooplankton in order to know what is happening at this level of the food chain.

In addition to monitoring the zooplankton, the environmental factors that affect their distribution and abundance must be identified and quantified. Such factors include temperature, salinity, food supply, toxic substances, 2-layered estuarine flow, freshwater outflow, reverse flow in the San Joaquin River, and water exports.

Neomysis abundance reached record lows during late summer and fall of 1992. After the first survey of August, population densities were less than $1/m^3$, compared to maximum concentrations of more than $20/m^3$ in pre-drought years and maxima of 1 to $3/m^3$ in recent drought years. Unusually high temperature is a possible cause of the low population size in 1992. At summer temperatures, *Neomysis* matures earlier and dies at a shorter length and, hence, age than at winter/spring temperatures. Laboratory experiments have also shown that temperatures above 22°C cause mortality.[1] This temperature was frequently exceeded in 1992. However, fecundity[2] was not lower in spring 1992 compared to previous years, indicating that food limitation probably did not occur. Food limitation could not be tested for fall because not enough females were caught, even when extra tows were made.

Eurytemora abundance was fairly high in spring, but dropped sharply in June. No specimens were taken during late July and all of August. *Eurytemora* reappeared in late September. Highest spring abundance was in the Stockton area of the San Joaquin River, where it is found only during dry years. This pattern of spring/fall abundance and summer disappearance has characterized all of the drought years since 1988. These are also the years in which the Asian clam *Potamocorbula* has been abundant in Suisun Bay. Predation rates of the clam on *Eurytemora* nauplii have been calculated from laboratory experiments.[3] The rate of *Eurytemora* population decline is consistent with loss rates calculated from densities of the clam in Suisun Bay and the calculated predation or clearance rates. In other words, *Potamocorbula* is the probable cause of the *Eurytemora* decline. However, it is not clear why *Eurytemora* does not maintain its population in the delta upstream from the range of *Potamocorbula,* where it disappears at the same time as it does in Suisun Bay. This is also the time when the Asian copepod *Pseudodiaptomus forbesi* becomes abundant. Predation by *P. forbesi* on *Eurytemora* seems to be ruled out, as its mouth parts are those of an herbivore. Competition is another possibility and would show up as food limitation of *Eurytemora*, but laboratory experiments have shown that *Eurytemora* was not food limited during the low phytoplankton concentrations that occurred in 1988. The reappearance of *Eurytemora* in fall also occurs at stations where *P. forbesi* has high densities.

Sinocalanus abundance was also low in 1992 and has been low since 1988. It typically peaked during July or August, but since 1988 its peak has shifted to May and is much lower than in pre-drought years. The shift in time of maximum abundance is tantalizing, because it suggests an interaction with *P. forbesi,* which undergoes a sharp increase in May and remains very abundant throughout summer and most of the fall. However, *Sinocalanus* is also vulnerable to *Potamocorbula* predation.

1 J.R. Hair. "Upper Lethal Temperature and Thermal Shock Tolerances of the Opossum Shrimp, *Neomysis awatschensis*, from the Sacramento-San Joaquin Estuary, California". *California Fish and Game* 57:17-27. 1971
2 The number of young/gravid females.
3 W.J. Kimmerer, E. Gartside, and J.J. Orsi. Predation by an Introduced Clam as the Probable Cause of Substantial Declines in Zooplankton of San Francisco Bay. Unpublished Manuscript.

A report on long-term trends in zooplankton was published in 1992 as an Interagency Program technical report.[1] Of 20 zooplankton taxa, 12 declined significantly between 1972 and 1988. Declines were more common in the delta than in Suisun Bay, and more taxa declined during fall than during other seasons.

In collaboration with the Smithsonian Institution, we published a paper[2] on a new species of mysid shrimp, *Deltamysis holmquistae*. This is a rare species in the estuary; only a few specimens are caught each year. It was first taken in 1977 and may have been introduced. On the other hand, its rarity and small size may have caused it to pass undetected during sample processing. Because *Deltamysis* has no close relatives anywhere in the world, it required the creation of a new genus.

During the summer of 1992, a mysid species of the genus *Acanthomysis* appeared in western Suisun Bay. Exploratory tows determined that it was centered in Carquinez Strait. Dr. Bowman of the Smithsonian Institution confirmed that it is not a West Coast North American species and that it is probably a native of Asia. He is searching the literature to see if it has been described. This latest invader underscores the importance of controlling ballast water discharges from ocean-going ships, as ballast has been identified as the vehicle for transmittal of a variety of organisms, including fish, across ocean basins.[3] Starting in January 1994, ships will be requested to exchange their ballast water in mid-ocean before entering a California port.[4] This is a voluntary program, but compliance rate will be recorded.

The preliminary finding that high temperature may drive the *Neomysis* population down could have management implications if delta inflow is found to exert a strong influence on water temperature during summer and fall.

Delta Vegetation Survey

Zachary Hymanson
Department of Water Resources

This section describes the methods and results of the seventh delta vegetation survey, conducted November 16, 1992. Primary objectives of the survey are to:

- Augment the established annual survey conducted by the Department of Food and Agriculture to detect the presence of *Hydrilla verticillata* in the delta;
- Describe the type and extent of existing aquatic vegetation; and,
- Continue compilation of a long-term database that could help in foreseeing impacts to SWP operation.

Between 1989 and 1990, vegetation surveys were conducted twice annually, once in spring and once in fall. Aerial photographs of each site were taken in conjunction with the spring surveys to facilitate documentation of long-term changes in aquatic vegetation. However, a summary analysis of these survey results showed little seasonal variability in vegetative extent or occurrence.[5] Therefore, the number of vegetation surveys was reduced to one per year, and aerial photography was discontinued.

The Department of Food and Agriculture's annual delta survey for *H. verticillata* is part of a statewide program designed to detect the spread of this exotic aquatic weed. This fast-growing aquatic plant propagates by vegetative fragmentation, tuber sprouts, and turion formation and, once established, can quickly clog waterways and pumps, severely curtailing the utility of a water system. The Department of Food and Agriculture did not find any *H. verticillata* in the delta during its 1991 survey; no survey was made in 1992 due to funding cuts.

1 S. Obrebski, J.J. Orsi, and W. Kimmerer. *Long-Term Trends in Zooplankton Distribution and Abundance in the Sacramento-San Joaquin Estuary*. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Technical Report 32. Sacramento. 1992.
2 T.E. Bowman and J.J. Orsi. "*Deltamysis holmquistae*, A New Genus and Species of Mysidacea from the Sacramento-San Joaquin Estuary of California". *Phil. Trans. Wash.* 1992.
3 J.T. Carlton. "Transoceanic and Interoceanic Dispersal of Coastal Marine Organisms: The Biology of Ballast Water." *Oceanogr. Mar. Biol. A. Rev.* 23:313-371. 1985.
4 Senate Bill 3207.
5 Interagency Ecological Studies Program. *1990 Annual Report*. 1991.

Methods

This vegetation survey includes a sampling of 10 representative sites in the central and southern delta (Figure 9). Site selection was based on a surface photograph reconnaissance survey in October 1988. All field sampling was conducted aboard the *Uniflite*, an Interagency monitoring vessel. Site 4 was not sampled during this survey because machinery used to dredge Clifton Court Forebay precluded access.

The following information was collected at each site: water temperature and turbidity at 1 meter, Secchi disc depth, water depth at the waterward edge of the submerged vegetation, the estimated distance any aquatic vegetation extended from shore (vegetative extent), and a general site description, including photographs.

After obtaining the descriptive information, three random grab samples for aquatic vegetation were made using a Hydrilla Hook. Any plant species not previously collected were sorted, washed, and pressed for preservation as herbarium specimens. The initial collection of each species was identified by Dr. Doug Barbe of the Botany Laboratory, Department of Food and Agriculture. Subsequent collections were verified using the voucher herbarium specimens.

Results and Discussion

Aquatic vegetation was collected or observed at all sites sampled during the survey (Tables 1 and 2). In total, seven species of submerged and emergent vascular plants and one species of alga were seen or collected. Plants collected were typical members of the delta flora and included the species *Egeria densa* (anachoris), *Myriophyllum spicatum* (milfoil), *Ceratophyllum demersum* (hornwort), *Potamogeton latifolius* (western pondweed), *P. crispus* (crisp-leaved pondweed), and *Eichhorina crassipes* (water hyacinth).

Scirpus acutis (common tule) was seen at six sites (Table 2). This plant could not be collected with the Hydrilla Hook, so its presence was documented with the site description photographs. The red alga *Compsopogon coeruleus* was found growing epiphytically on submerged plants at Site 9.

Overall, *S. acutis* was the dominant emergent species; *E. densa* and *M. spicatum* were the dominant submerged species. *Hydrilla verticillata* was neither seen nor collected.

This was the first survey in which aquatic plants were collected from Sites 1 and 7. *Egeria densa* was found growing at both sites, which are in flooded islands.

The seven surveys to date show a stable assemblage of aquatic plants (Table 2). The same taxa have been seen or collected in each survey, with the exception of *Potamogeton nodosus*, which was collected only at Site 2 in the May 1988 survey. Some species, such as *Egeria densa* and *Myriophyllum spicatum*, occur at several locations throughout the delta, although their distribution varies seasonally. Other species, such as *Potamogeton latifolius* and *P. crispus*, generally occur only at one site and do not vary seasonally. Epiphytic algae are most often collected in the fall.

Analyses of previous data have revealed no obvious relationships between water quality variables and the occurrence of aquatic vegetation among seasons or years.[1] However, some patterns in surface water quality have emerged when results of all surveys are compared. Secchi disc depths were generally greater in fall than in spring, and water temperature, although more variable, tended to be lower in fall than in spring.[2]

Analysis of data from the fall surveys permits an examination of interannual variability. Secchi disc depth measurements showed limited variation among years (Figure 10), although they were somewhat higher in 1990 and 1992. Since light is probably the factor most limiting to littoral zone vegetation in the delta, this lack of variability suggests growth limitations due to light availability are fairly consistent among years.

Interannual variations in water temperature were more apparent (Figure 10). Temperatures were highest in 1988 and lowest in 1990. The largest temperature range (8°C) was at Site 8 and the smallest range (2°C) was at Site 10. However, changes in water temperature between 1988 and 1992 probably had little effect on the littoral zone vegetation. All the species collected

1 Department of Water Resources. *Water Quality Conditions in the Sacramento-San Joaquin Delta During 1990.* 1992.
2 Z. Hymanson. *November 1990 Survey of Aquatic Vegetation in the Sacramento-San Joaquin Delta.* Office Report. 1991.

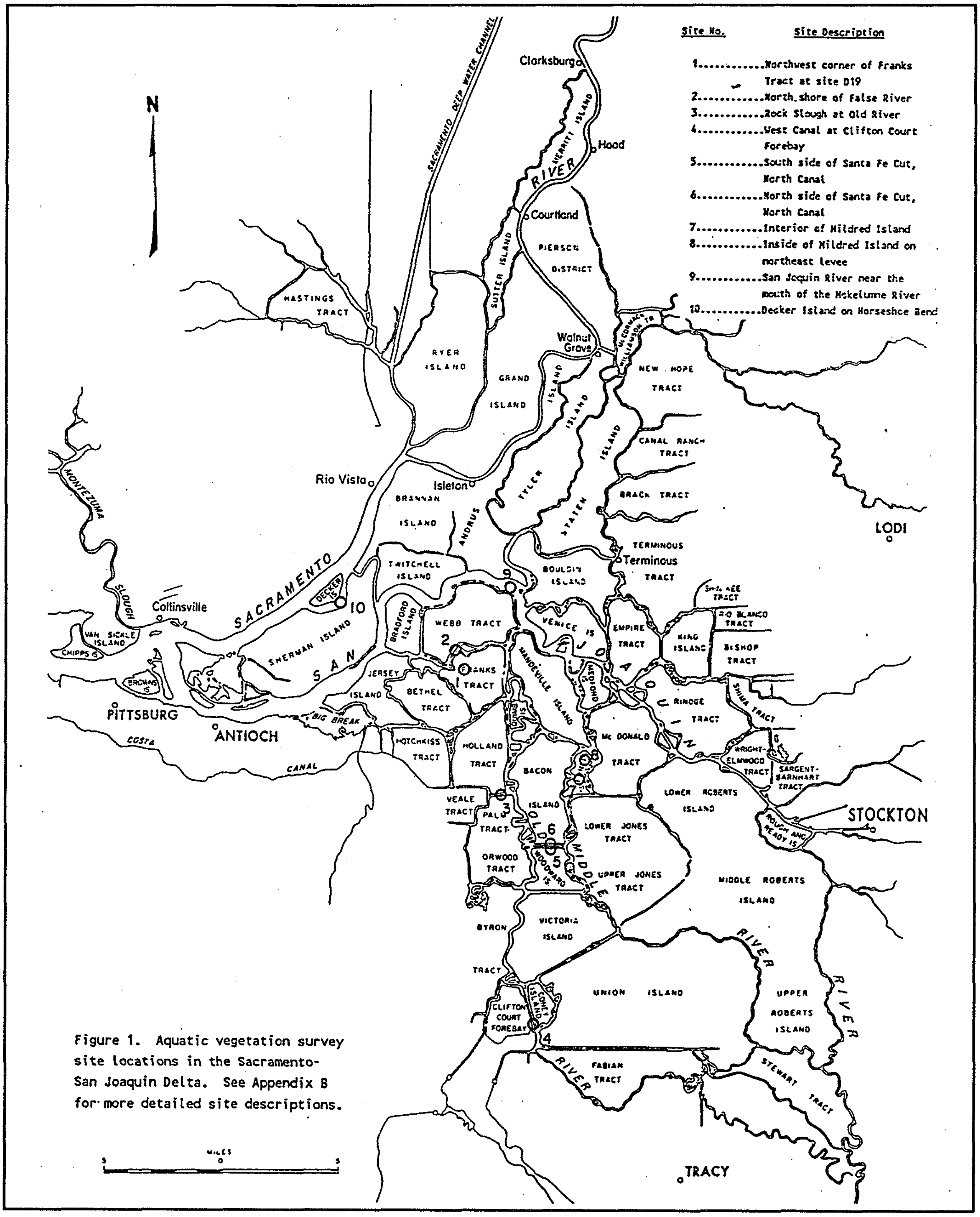

Figure 1. Aquatic vegetation survey site locations in the Sacramento-San Joaquin Delta. See Appendix B for more detailed site descriptions.

Figure 9
AQUATIC VEGETATION SURVEY SITES

Table 1
DATA SUMMARY,
NOVEMBER 1992 LITTORAL ZONE VEGETATION SURVEY

Site[1] Number	Secchi Depth (cm)	Depth[2] (M)	Distance to Shore[3] (M)	Turbidity (NTU)	Temperature (°C)	Plant Species Noted
1	134	2	200	5	15	*E. densa*
2	116	2	20	5	15	*E. densa* *M. spicatum* *S. acrutis*
3	188	1	3	4	14	*S. acrutis* *E. crassipes*
4						Not Sampled
5	116	2	25[4]	5	15	*M. spicatum* *E. densa* *S. acrutis*
6	136	2	3	5	13	*E. densa* *M. spicatum* *S. acrutis*
7	100	3	100	4	14	*E. densa*
8	136	1.5	5	5	14	*E. densa* *M. spicatum* *C. demersum* *S. acrutis* *E. crassipes*
9	100	1.5	70	7	14	*P. latifolius* *P. crispus* *C. coeruleus*
10	70	1.5	11	11	15	*S. acrutis*

1 See Figure 9 for locations.
2 Depth at waterward edge of vegetation.
3 Estimated distance to shore from waterward edge of vegetation.
4 Actually the distance to the railroad tressel, which has water on both sides.

Table 2
DISTRIBUTION OF LITTORAL ZONE VEGETATION

Sampling Date/ Site	Plant Species: *Egeria densa*	*Myriophyllum spicatum*	*Ceratophyllum demersum*	*Potamogeton latifolius*	*Potamogeton crispus*	*Potamogeton nodosus*	*Eichhornia crassipes*	*Scirpus acrutis*
November 1992								
1	X							
2	X	X						X
3							X	X
4**								
5	X	X						X
6	X	X						X
7	X							
8	X	X	X				X	X
9		X		X	X			
10								X
November 1991								
1*								
2	X	X	X					X
3	X	X						X
4	X	X						
5	X	X						X
6	X	X						X
7*								
8	X	X						X
9				X	X			
10	X							X
November 1990								
1*								
2	X	X	X					X
3							X	X
4	X							
5		X					X	X
6	X	X						
7*								
8	X	X	X					X
9				X	X			
10							X	X
May 1990								
1*								
2	X		X					X
3								X
4	X	X						
5	X							X
6		X						X
7*								
8		X						X
9				X	X			
10	X		X					X

* No vegetation.
** Not sampled.

Table 2 (continued)
DISTRIBUTION OF LITTORAL ZONE VEGETATION

Sampling Date/ Site	Plant Species: *Egeria densa*	*Myriophyllum spicatum*	*Ceratophyllum demersum*	*Potamogeton latifolius*	*Potamogeton crispus*	*Potamogeton nodosus*	*Eichhornia crassipes*	*Scirpus acrutis*
November 1989								
1*								
2*								
3							X	X
4*								
5	X	X						X
6	X	X						X
7*								
8		X	X					X
9				X	X			X
10	X	X				X		
May 1989								
1*								
2		X	X			X		X
3								X
4	X	X						
5		X			X			X
6	X							X
7*								
8		X						X
9				X	X			
10	X							X
November 1988								
1*								
2	X	X	X				X	X
3	X							X
4*								
5	X	X						X
6	X	X						X
7*								
8		X	X					X
9				X	X			
10	X							X

* No vegetation.
**Not sampled.

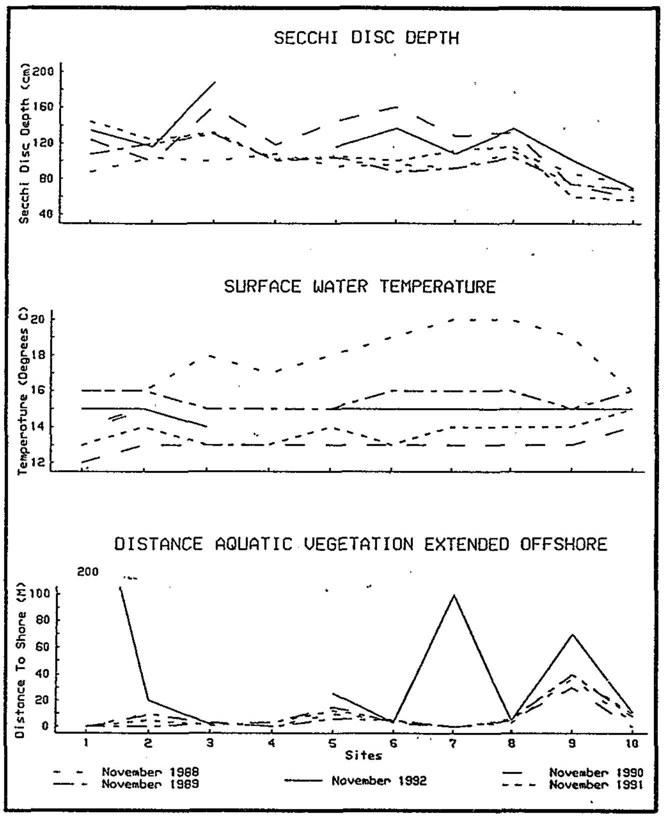

Figure 10
VARIATIONS IN SELECTED PARAMETERS MEASURED DURING THE FALL VEGETATION SURVEYS

have geographic ranges that place them in temperatures well above or below temperatures measured in the survey region.[1]

Measurements of vegetative extent were used to indicate changes in vegetative biomass, since these two variables are related. Increases in vegetative extent can directly affect water project operations by restricting channel flow and accelerating the rate of sediment accumulation.

With the exception of Sites 1, 7, and 9, vegetative extent remained nearly constant over five fall surveys (Figure 10). Variation at Sites 1 and 7 was caused by the presence of vegetation in 1992. Both of these sites are within flooded islands. We think sustained increases in water clarity associated with the drought permitted establishment of aquatic vegetation at these sites. Submerged vegetation was noted at Franks Tract (Site 1) during the 1976-1977 drought.[2] Vegetative extent at Site 9 increased to 70 meters from shore in 1992 compared to an average 32 meters from shore between 1988 and 1991. Site 9 is on a large shoal, which may be expanding under the prevailing low-flow conditions.

Data collected from the five fall surveys show that species occurrence is stable, while vegetative extent is increasing at some locations, even though there are seasonal and annual variations in water quality patterns. This stability probably results in part from the low streamflows and reduced seasonal variability in weather patterns associated with the drought. The variability in vegetative extent or species composition is expected to increase when more seasonally variable streamflows occur.

1 D. Barbe, Department of Food and Agriculture, personal communication.
2 Harlan Proctor, DWR, personal communication.

STRIPED BASS

Adult Striped Bass Tagging and Creel Census

David W. Kohlhorst
Department of Fish and Game

This element of the Striped Bass Program consists of a mark/recapture (tagging) study to determine factors affecting the size and age composition and abundance of adult striped bass. Adult bass abundance indices also are developed directly from catches in nets and traps that are set to catch fish for tagging. The estimates of population strength when the fish reach legal size (recruits) at 3 to 4 years old are compared to abundance indices during their first year to help isolate the life stage where population-limiting mortality may be occurring. Furthermore, total legal-sized bass abundance has been used to explore the relationship between adults and young production and losses to the water project export pumps over a series of years. The adult population estimates and tag returns are also used to estimate age-specific mortality rates (including fishing mortality) and, in combination with fecundity[1], potential total population egg production.

Additionally, temporal trends in age and size composition of females captured for tagging on or near the spawning grounds are being analyzed for evidence that they affect egg quality and subsequent survival of bass larvae. Because larger fish produce larger (and perhaps higher-quality) eggs, changes in the average size of spawning females over the spawning season may result in corresponding changes in egg survival. This hypothesis is being evaluated in conjunction with the Egg and Larva Survey.

Funding for the creel census portion of the adult striped bass element was shifted in 1990 to the Hatchery Evaluation Program funded by the Striped Bass Stamp. The creel census continues to provide information for the mark/recapture abundance estimates as well as data on the contribution of hatchery-raised fish.

In 1992, we tagged 4,612 adult striped bass and observed 2,348 fish during the December-to-June creel census, 52 of which were tagged in 1992 or a previous year.

Based on tags applied in 1991 and recovered during the 1991 summer/fall creel census, the adult striped bass population estimate for 1991 is 1,161,000. However, only two tagged age-3 fish were recovered in the creel census, and this small sample size reduces the precision of the age-3 component and reliability of the overall estimate. A more reliable population estimate for 1991 will be available when tag recaptures are increased through subsequent sampling. Anglers harvested about 14% of the adult striped bass population in 1991, and total mortality in 1990[2] was 43%.

Impacts of Freshwater Outflow and Exports on Striped Bass

David W. Kohlhorst
Department of Fish and Game

Analysis of factors affecting adult striped bass abundance has led DFG to the conclusion that adult bass abundance is primarily determined by hydrologic conditions 3 to 7 years earlier — specifically, April-December delta outflow and year-round water exports. DFG developed a mathematical model[3] composed of regression equations expressing the relationships between:

- Young-of-the-year abundance and outflow/water export,
- Young-of-the-year abundance and egg production,
- Loss rate of young bass entrained in water exports and outflow/water export, and
- Adult abundance and young-of-the-year abundance and entrainment losses 3 to 7 years earlier.

1 Eggs per female.
2 The most recent year for which we can estimate total mortality.
3 The striped bass model is described in detail in DFG's WRINT-DFG-Exhibit 3 submitted to the SWRCB as part of the water rights proceedings.

This model accurately simulates past changes in adult bass abundance and can be used to predict future abundance if future environmental conditions fall within the range used to develop the model. This striped bass model was used to develop DFG's testimony and recommendations for the SWRCB Interim Water Rights Proceeding and was used by SWRCB staff to analyze alternative standards in developing the draft decision.

Egg Quality

Lee W. Miller and Jane Arnold
Department of Fish and Game

The quality of fish eggs produced by different females may affect the size and survival of larvae. Larger females may produce eggs of higher quality, which survive better.[1] DFG examined striped bass eggs from both the Sacramento and San Joaquin rivers to determine if differences in the quality of eggs could be related to size of adult females on the spawning grounds.

Eggs were collected from Egg and Larva Survey stations during the main portion of the spawning period in 1990 and 1991. Laboratory processing and analysis of the 1991 results were completed in 1992. Chorion, yolk, and oil globule diameters were measured using a dissecting microscope with an ocular micrometer. Mean egg weights were calculated by averaging 24- and 48-hour dry egg weights. These parameters were compared to striped bass female length.

Striped bass eggs from the Sacramento River had mean weight of 260 μgrams; eggs from the San Joaquin River had a mean weight of 240 μgrams. The 1991 mean egg weights are similar to those recorded in 1990 (Table 3).

Yolk diameter of Sacramento River eggs correlated reasonably well with chorion/oil globule diameters and with egg weight (Table 4). Yolk diameter of San Joaquin River eggs correlated quite well with oil globule diameter. Yolk/ chorion and chorion/oil globule diameters correlated moderately well. Neither yolk diameter nor oil globule diameter correlated with egg weight.

The effect of female size on egg quality was evaluated by using lengths of spawning female striped bass measured during the DFG adult

Table 3
EGG QUALITY MEASUREMENTS IN THE
SACRAMENTO AND SAN JOAQUIN RIVERS, 1990 AND 1991
Yolk and oil globule diameters are recorded in millimeters.
Egg weights are in micrograms.
N represents the numbers of groups from which the average diameters and weights were derived.
Standard error for each measurement is in parentheses.

SACRAMENTO RIVER

Year	Yolk	Oil Globule	Egg Weight	*N*
1990	1.2 (0.01)	0.9 (0.3)	240 (5.8)	35
1991	1.1 (0.02)	0.8 (0.01)	260 (3.6)	50

SAN JOAQUIN RIVER

Year	Yolk	Oil Globule	Egg Weight	*N*
1990	1.2 (0.02)	0.7 (0.01)	280 (22.5)	25
1991	1.0 (0.02)	0.7 (0.01)	240 (2.9)	30

Table 4
CORRELATION MATRICES FOR
EGG WEIGHT, CHORION, YOLK, AND OIL GLOBULE
DIAMETERS FROM THE
SACRAMENTO AND SAN JOAQUIN RIVERS

SACRAMENTO RIVER

	Chorion	Oil Globule	Egg Weight	Female Length
Yolk	0.58**	0.47**	0.37**	0.28
Chorion		0.36**	0.32*	0.04
Oil Globule			0.22	0.20
Egg Weight				0.02

SAN JOAQUIN RIVER

	Chorion	Oil Globule	Egg Weight	Female Length
Yolk	0.42*	0.91**	-0.11	0.80*
Chorion		0.53**	0.12	0.36
Oil Globule			-0.04	0.73*
Egg Weight				-0.16

* $P \leq 0.05$
** $P \leq 0.01$

1 T.B. Bagenal. "The Inter-Relation of the Size of Fish Eggs, the Date of Spawning, and the Production Cycle". *Journal of Fishery Biology* 3: 207-219. 1971.

striped bass tagging program.[1] Sacramento River female length was not significantly correlated with mean egg weight, chorion, yolk, or oil globule diameter (Table 4). San Joaquin River female length was well correlated with yolk and oil globule diameters but not with chorion diameter or mean egg weight.

Investigation of egg quality has been completed, and a technical report will be prepared summarizing results for 1990 and 1991.

Striped Bass Egg and Larva Survey

Lee W. Miller and Jane Arnold
Department of Fish and Game

An egg and larval survey has been conducted in the major spawning and nursery areas from April to early July in several years since 1968. The purpose of the survey is to measure the distribution, abundance, and survival of striped bass eggs and larvae. Understanding environmental factors that contribute to early survival of striped bass may be useful in managing the estuary and the striped bass population.

Laboratory processing of the 1991 samples was completed in 1992, and the results are presented here.

Ten-minute diagonal tows using 505-µ mesh nets sample at 58 sites (Figure 11) at 2-day sampling intervals in the spawning area during the major spawning period and at 4-day intervals elsewhere and after the major spawning period. This sampling provides measures of spawning periodicity and location and indices of abundance and survival of 6- to 14-mm larvae. Abundance indices of striped bass eggs and larvae are calculated as the density multiplied by the volume of water represented at each station and divided by 10,000 for convenience. Estimates of abundance for areas and times where sampling is done at 4-day intervals are standardized each year to the 2-day sampling schedule in use from 1968 to 1977. This is done by multiplying by two the abundances obtained from sampling every fourth day.

To obtain information on food availability for larval striped bass, zooplankton samples are collected simultaneous with the larval striped bass samples every fourth day, using a Clarke-Bumpus #10 net mounted on top of the larval striped bass net frame. Diet analysis is performed on larval striped bass from a subsample of the stations for comparison with zooplankton abundance. The zooplankton are identified to major species or species group.

Distribution

Striped bass eggs are classified as either 0-8 hours old, 9-36 hours old, or dead when captured. Peak egg densities indicate substantial spawning occurred in the Sacramento River on May 6 and May 22, with a scattering of spawning on other dates (Figure 12). Spawning was almost entirely upstream from Sacramento (station 76). Due to boat breakdowns, the Sacramento River was not sampled as scheduled during portions of May and June, so spawning occurrence is not fully depicted for the Sacramento River. Spawning in the San Joaquin River was mostly upstream of station 43 and occurred on several dates between April 22 and May 26.

In 1991, a year of continued drought, striped bass larvae were located almost exclusively in the delta portion of the estuary above the confluence of the Sacramento and San Joaquin rivers, a distribution typical of low flows. April-June Sacramento River flows during the 1991 spawning period were low compared to most other years since 1956 (Figure 13). Peak density of 6-mm larvae was upstream of Rio Vista (station 32) on the Sacramento River, whereas larger larvae were located primarily downstream of station 32 (Figure 14). A similar distribution of 6-mm larvae occurred in 1977,[2] when Sacramento River flows were the lowest on record.

The 6-mm striped bass in the San Joaquin River were mostly upstream of station 45; 8- to 12-mm larvae were more widely dispersed from station 37 (Antioch) to station 906, the most upstream station (Figure 14).

1 D.W. Kohlhorst. "Age Composition and Population of Striped Bass in California's Sacramento-San Joaquin Estuary". *Job Performance Report, Sport Fish Restoration Act Project California F-51-R, Subproject VIII, Study 1, Job 1*. 1992.
2 Department of Fish and Game. *Striped Bass Egg and Larva Monitoring, and Effects of Flow Regulation on the Larval Striped Bass Food Chain, in the Sacramento-San Joaquin Estuary*. Final Report to the State Water Resources Control Board. 120 pp. 1988.

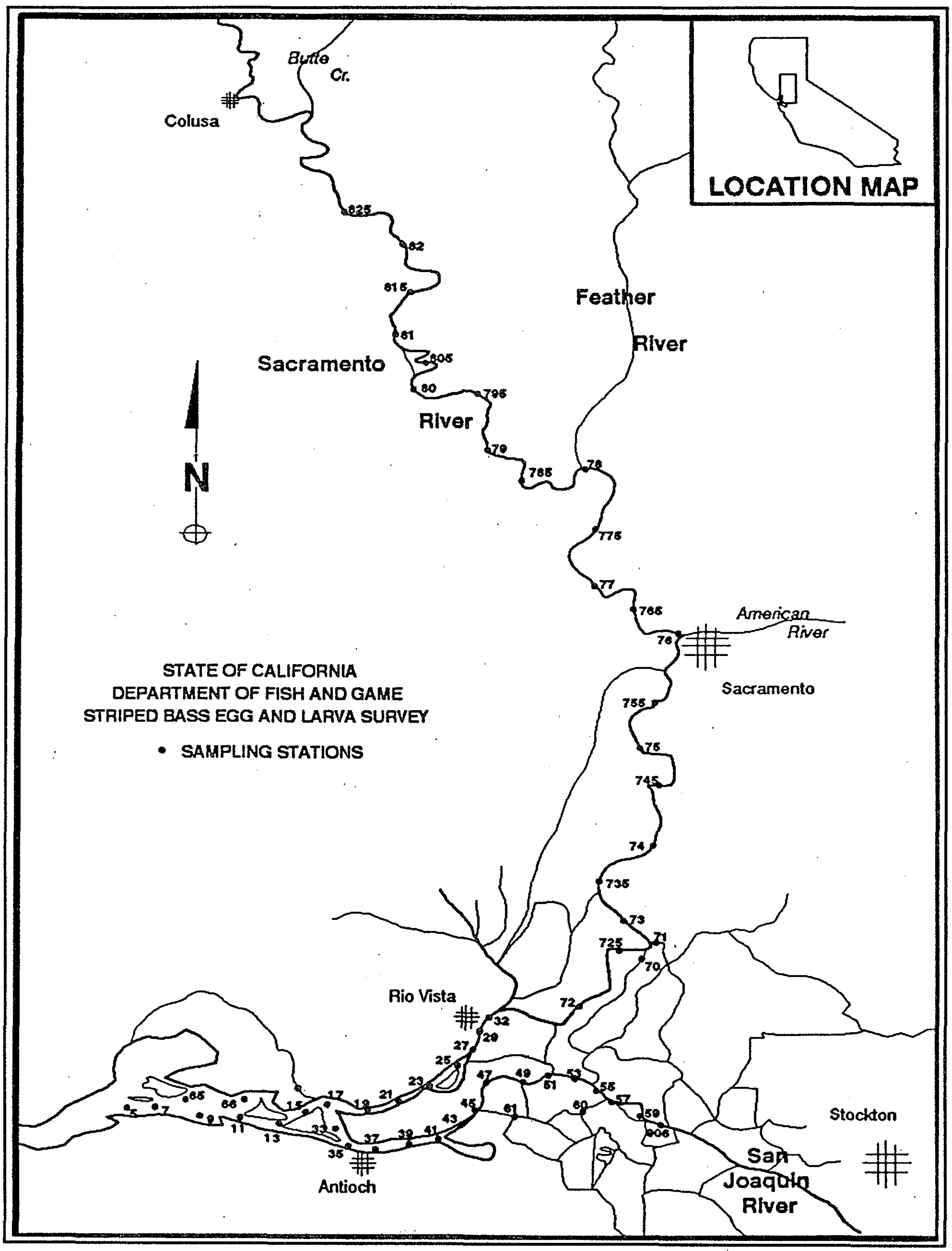

Figure 11
SAMPLING SITES, DFG STRIPED BASS EGG AND LARVA SURVEY, 1991

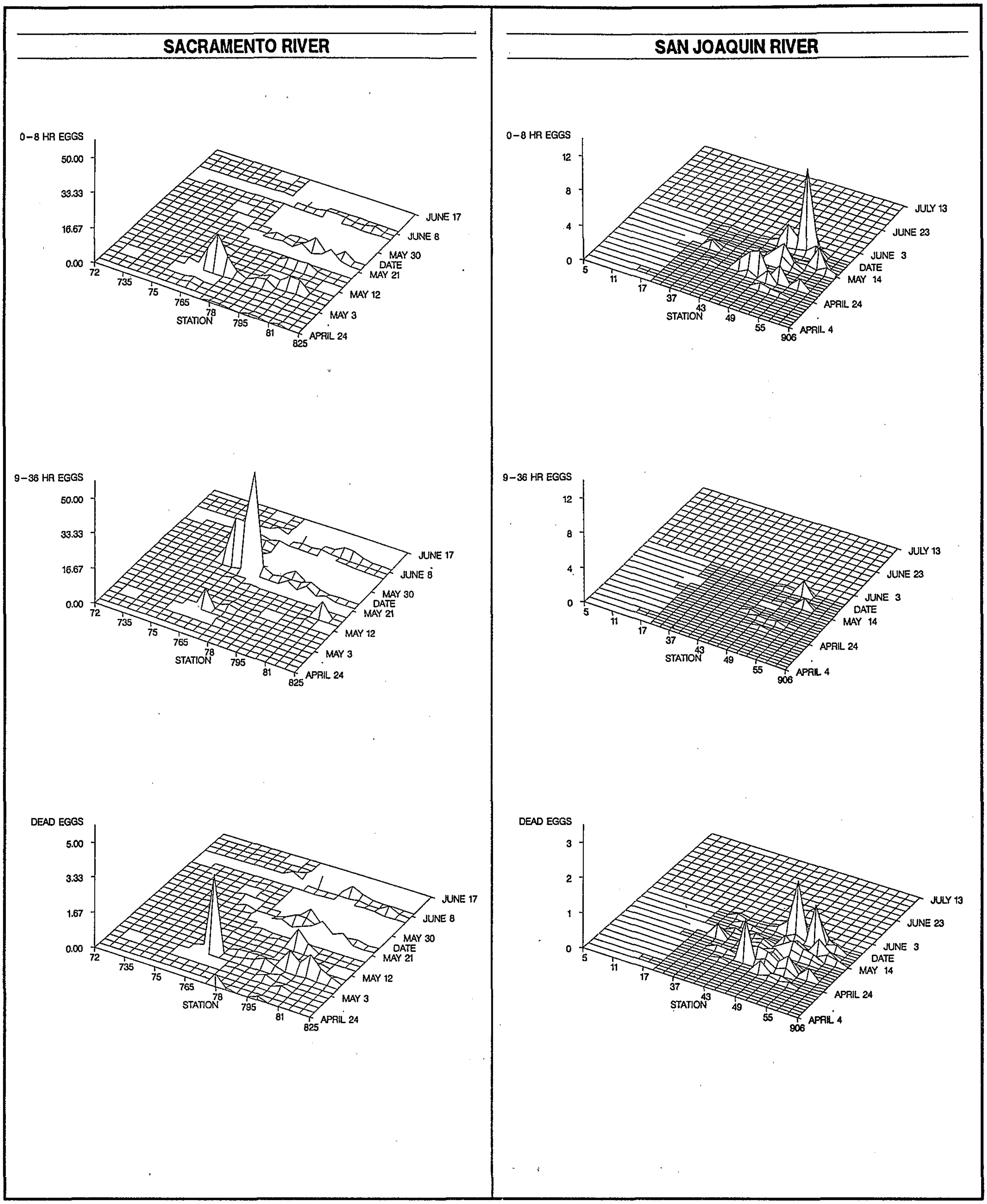

Figure 12
STRIPED BASS EGG DISTRIBUTION, 1991
(In number per cubic meter.)

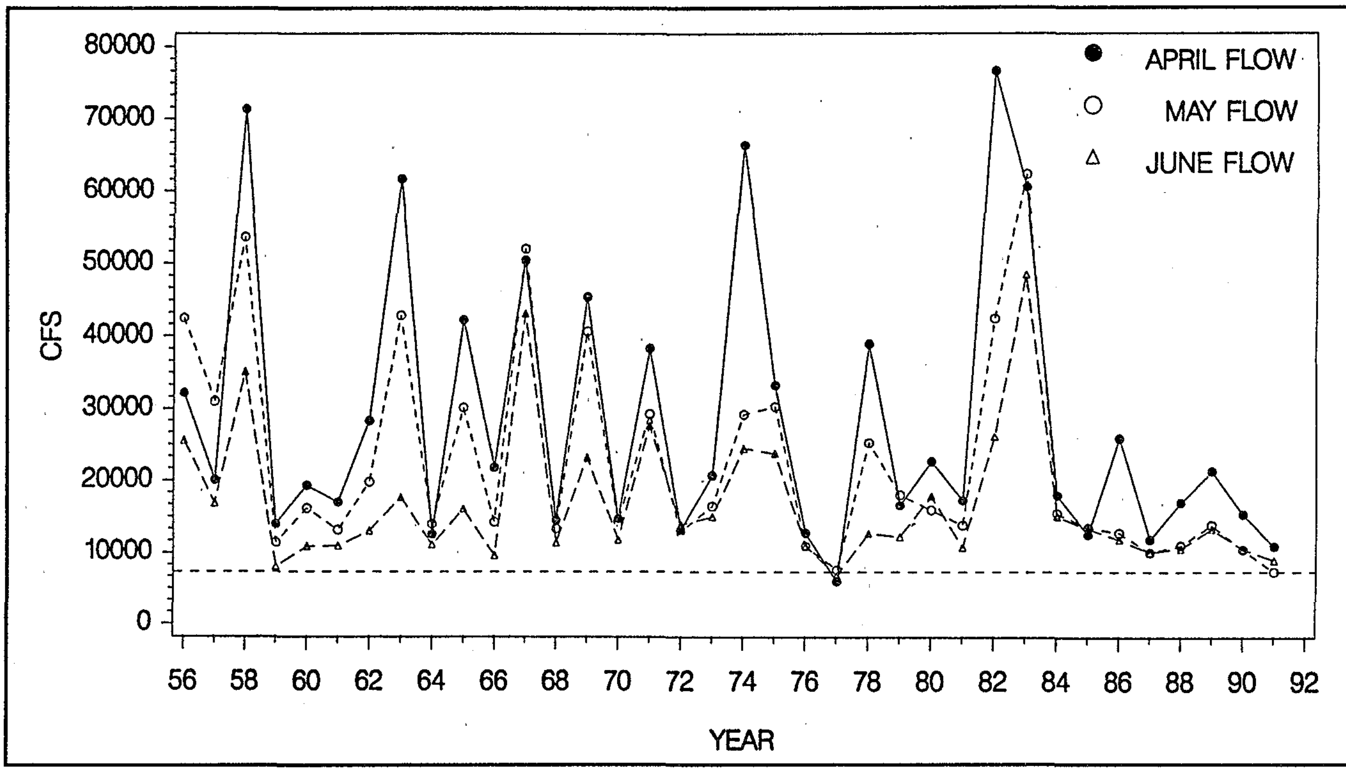

Figure 13
APRIL-JUNE SACRAMENTO RIVER FLOW AT SACRAMENTO, 1956-1991
(The horizontal dashed line is at 7,332 cfs, the low May flow in 1991.)

Abundance

The total number of striped bass eggs was evenly divided between the Sacramento River (137,750; 50.1%) and San Joaquin River (136,812; 49.9%) (Table 5). Sacramento River egg abundance was under-sampled because of boat breakdowns. Although this may have biased the 1991 Sacramento River indices downward, the proportion of egg abundance is within the lower range of historical values (Table 6).

Dead eggs comprised 22% of the total egg abundance sampled on the San Joaquin River but only 4.9% of the Sacramento River total. The proportion of dead eggs in the San Joaquin River increased with specific conductance (Table 7).

Table 5
ABUNDANCE OF STRIPED BASS EGGS IN 1991, BY AREA

Area	0- to 8-Hour Eggs	9- to 36-Hour Eggs	Total Live Eggs	Dead Eggs
Sacramento River	45,637	85,723	131,361	6,825
San Joaquin River	91,492	14,439	105,931	29,937
Suisun Bay	0	97	97	0
Total	137,129	100,259	237,389	36,762

Table 6
RELATIVE CONTRIBUTION OF LIVE EGG CATCH FROM THE SACRAMENTO AND SAN JOAQUIN RIVERS FOR YEARS WHEN BOTH WERE SAMPLED

Year	Percent in Sacramento River	Percent in San Joaquin River
1972	59.5	40.5
1975	66.4	33.6
1977	63.3	36.7
1984	52.7	47.3
1985	46.3	53.6
1986	62.7	37.3
1991	50.1	49.9

Table 7
CATCH OF STRIPED BASS EGGS IN THE SAN JOAQUIN RIVER IN 1991, BY SPECIFIC CONDUCTANCE RANGE

Specific Conductance Range (µS)	Live Eggs	Dead Eggs	Dead Eggs As A Percent of Total
<499	77,328	16,271	17.4
500-999	19,734	9,050	31.4
>1000	8,358	4,404	34.5

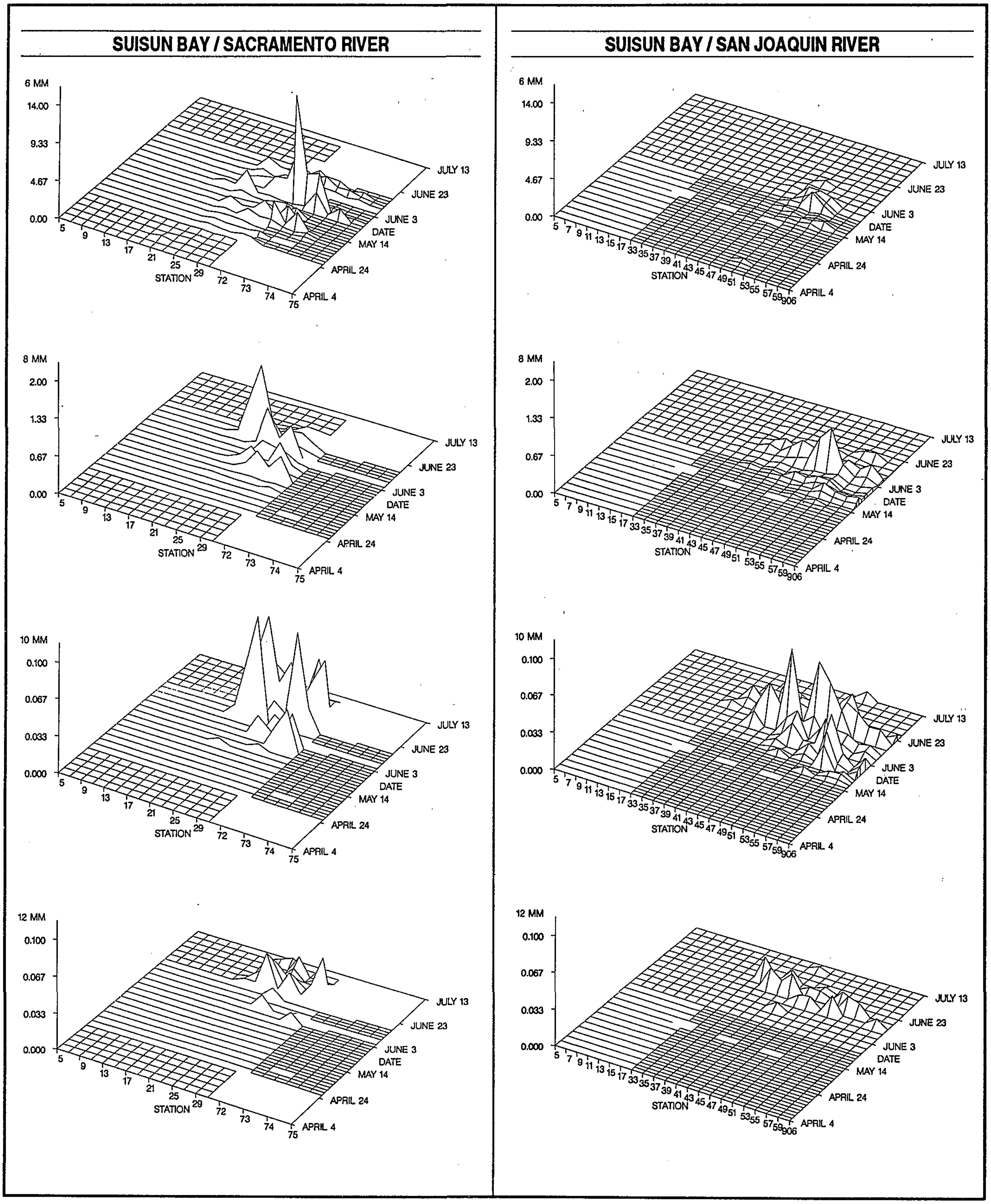

Figure 14
STRIPED BASS DISTRIBUTION, 1991
(In number per cubic meter.)

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Larvae at all sizes were consistently more abundant in the Sacramento River compared to the San Joaquin River (Table 8). The 6-mm bass index in 1991 was only 229,208, second only to the record low in 1977. Hence, the 1991 year class had a poor start. Abundances remained low for all stages including the abundance index when the mean length is 38 mm, as measured by our annual (since 1959) summer tow-net survey. The 38-mm index of 5.5 was the third lowest for years when egg and larval sampling was done (Table 9). Year classes that began with a low 6-mm abundance have never been abundant at 38 mm.

Table 8
ABUNDANCE OF STRIPED BASS LARVAE IN 1991, BY AREA

Size	Sacramento River	San Joaquin River	Suisun Bay	Total
4 mm	33,088	4,408	56	37,552
5 mm	167,320	15,032	264	182,616
6 mm	162,592	66,392	224	229,208
7 mm	50,256	33,048	208	83,512
8 mm	30,960	22,504	24	53,488
9 mm	11,912	9,296	24	21,232
10 mm	3,392	3,016	0	6,408
11 mm	2,024	1,080	0	3,104
12 mm	936	600	0	1,536
13 mm	400	176	0	576
14 mm	240	64	0	304

Survival

A survival index between egg and 6 mm was estimated using the ratio of 6-mm larvae to egg production. This survival index is positively correlated with delta outflow and Sacramento River flow at Sacramento (Table 10), and 1991 results are consistent with this relationship (Figure 15). The mechanisms causing this relationship are not clear. Possible causes are greater exposure to toxicants, predators, and water diversions when flows are low.

A later-stage survival index for 1991, calculated as the ratio between 38-mm and 9-mm abundance indices, is related to delta outflow consistent with years other than 1977 (Figure 16). R-square values were significant for multiple regressions of 9- to 38-mm survival index on the log of delta outflow and delta water exports or the log of water exports by the SWP and CVP (Table 11). The low exports in 1977 account for the high survival in 1977. However, 1991 year class survival was lower than predicted based on the combined effects of delta outflow and water exports (Figure 17). This is the second consecutive year that observed 9- to 38-mm survival was lower than predicted. Mean April-to-July water exports in 1991 were the second lowest on record but were nearly 2.5 times the record low exports in 1977 (Table 12), the year that greatly influences the regression. In 1977 flows were low but survival was high, apparently in response to

Table 9
STRIPED BASS ABUNDANCE INDICES, 1968 THROUGH 1991

Year	Index												
	6-mm	7-mm	8-mm	9-mm	10-mm	11-mm	12-mm	13-mm	14-mm	Delta 38-mm	Suisun 38-mm	Total 38-mm	Midwater Trawl-Fall
1968	691,209	149,859	86,634	79,281	48,204	21,924	13,554	8,847	6,444	39.6	17.7	57.3	4,118
1970	1,728,147	352,024	212,712	102,590	59,302	35,939	24,594	17,568	13,092	36.6	41.9	78.5	8,299
1971	4,408,569	428,530	171,835	75,109	39,329	22,545	13,634	8,447	6,153	24.6	45.0	69.6	9,510
1972	1,766,699	385,019	230,004	116,295	66,271	36,623	23,926	15,224	11,180	13.4	21.1	34.5	6,129
1973	—	—	—	70,756	48,535	29,145	18,898	13,524	8,566	15.6	47.1	62.7	4,285
1975	4,772,381	892,673	159,040	51,952	38,251	23,644	14,693	9,917	5,355	23.4	42.1	65.5	4,548
1977	209,893	88,739	22,026	8,913	—	—	—	—	—	8.3	0.7	9.0	885
1984	453,715	91,640	43,061	25,951	11,410	5,856	3,690	2,546	1,456	6.3	20.0	26.3	6,602
1985	1,254,491	128,009	36790	14,872	6,229	2,207	1,350	943	561	2.2	4.1	6.3	1,760
1986	1,330,763	328,386	119,563	57,268	34,968	15,226	11,489	7,559	5,070	23.8	41.0	64.9	3,944
1988	396,903	113,309	35,777	13,624	5,523	2,960	1,606	961	689	3.9	0.7	4.6	477
1989	1,000,995	147,977	44,336	10,648	4,856	1,136	1,035	420	164	3.1	2.0	5.1	442
1990	324,072	81,475	47,206	15,432	6,686	3,352	1,536	475	157	2.8	1.5	4.3	1,319
1991	229,208	83,512	53,488	21,232	6,408	3,104	1,536	576	304	3.9	1.6	5.5	950

record low exports. The 1991 results, in combination with these previous results, suggest that exports must reach a very low threshold before survival is substantially improved.

Table 10
CORRELATIONS BETWEEN
APRIL-JUNE FLOWS AND THE SURVIVAL INDEX
BASED ON THE RATIO OF
EGG PRODUCTION TO 6-MM STRIPED BASS ABUNDANCE
($P \leq 0.01$)

	Survival Index
Delta Outflow	0.689
San Joaquin River Flow at Jersey Point	0.355
Sacramento River Flow at Sacramento	0.808

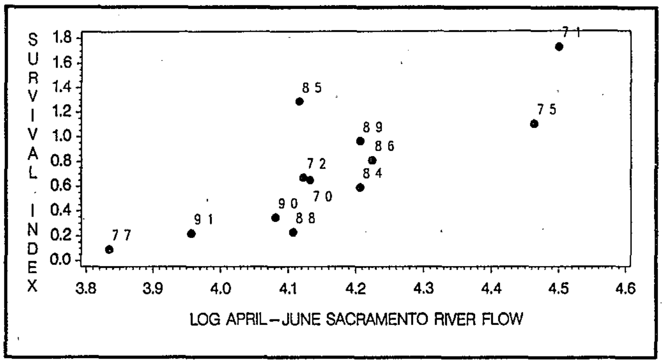

Figure 15
RELATIONSHIP BETWEEN DELTA OUTFLOW AND THE PETERSON SURVIVAL INDEX FOR EGGS TO 6-MM BASS

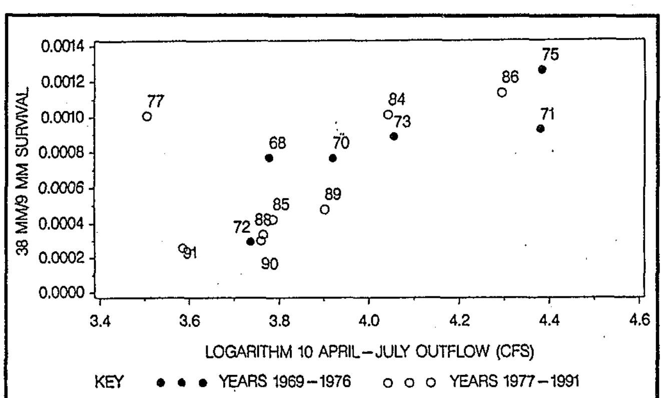

Figure 16
RELATIONSHIP BETWEEN
LOG_{10} MEAN APRIL-JULY DELTA OUTFLOW AND
STRIPED BASS SURVIVAL INDEX BASED ON THE
RATIO OF 38-MM TO 9-MM BASS ABUNDANCE

Table 11
COMPARISON OF REGRESSIONS OF
9- TO 38-MM STRIPED BASS SURVIVAL ON
DELTA OUTFLOW AND WATER EXPORTS

R-Square	Independent Variables	T Value	Probability of Greater T Value
0.67	Delta Exports	4.51	0.0084
	Log_{10} Outflow	–2.76	0.0186
0.75	Log_{10} Exports	5.52	0.0037
	Log_{10} Outflow	–3.67	0.0084

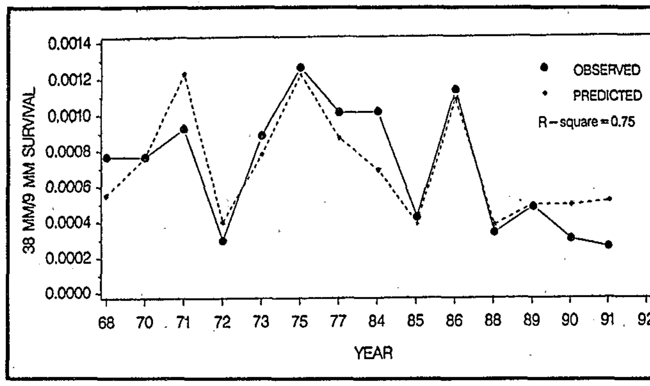

Figure 17
PREDICTED VERSUS OBSERVED
STRIPED BASS SURVIVAL BASED ON THE
RATIO OF 38-MM TO 9-MM BASS ABUNDANCE
Predicted survival index is based on the regression model: Survival index = 0.000503 + 0.001135 (log_{10} of mean April-July delta outflow) – 0.001140 (log_{10} of mean April-July delta exports).

Table 12
DATA USED FOR THE
MULTIPLE REGRESSION RELATIONSHIP OF
STRIPED BASS SURVIVAL AND
MEAN APRIL-JULY DELTA OUTFLOW AND
WATER EXPORTS
FOR YEARS OF RECORD, 1968-1991

Year	April-July Delta Outflow	April-July Water Exports	Survival Index 38-mm/9-mm
1968	5,991	5,219	0.0007688
1970	8,309	4,720	0.0007652
1971	23,982	5,317	0.0009267
1972	5,449	6,478	0.0002967
1973	11,371	6,239	0.0008861
1975	24,167	5,397	0.0012608
1977	3,210	1,473	0.0010098
1984	11,051	7,315	0.0010134
1985	6,110	7,395	0.0004236
1986	19,663	5,848	0.0011333
1988	5,816	7,174	0.0003376
1989	7,985	7,863	0.0004790
1990	5,751	5,684	0.0003028
1991	3,856	3,653	0.0002590

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Potential Competitors

Abundance of other fish larvae was compared to abundance of striped bass larvae to determine the potential for competition. Chameleon goby was the only species more abundant than 6-mm striped bass in 1991 (Table 13). Total goby abundance has been higher than for 6-mm striped bass in both 1990 and 1991 (Table 14). Gobies were not identified to species prior to 1991, but chameleon gobies were abundant in 1990 and likely caused the high total goby abundance.

Despite being accidentally introduced into the estuary sometime in the 1950s, probably in ship ballast water[1], the chameleon goby, a euryhaline native to Asia, was limited to San Francisco Bay until recently. In 1989, however, it had become the third most abundant species identified in DWR's southern delta egg and larval sampling, and in 1990 it was the most abundant fish.[2] In 1991, chameleon and yellowfin gobies were identified and enumerated. The chameleon goby was abundant over a broad area of the estuary, whereas yellowfin goby was more restricted to the area west of the delta (Figure 18).

The recent extension of the chameleon goby into the upper portion of the estuary coincides with the prolonged drought that began in 1987. However, this is not the first drought since its introduction, so it is not clear why the population only recently exploded in this portion of the estuary.

Despite the recent increase in goby abundance, it is relevant that the chameleon goby spawns late in our sampling season, generally after striped bass have spawned, and yellowfin gobies are primarily downstream from early feeding stages of striped bass. Thus, goby larvae would have minimum effect on early survival of striped bass. However, potential for chameleon goby competition would increase for later stages of striped bass. Chameleon gobies co-occur with 36.4% of the 6-mm striped bass, but this increases to 90.7% for 10-mm striped bass (Table 15). Nevertheless, the proportion of the chameleon goby population that co-occurs with striped bass is relatively low for all sizes of striped bass. Therefore, comparisons of total goby abundance with striped bass abundance could be misleading. More information is needed on chameleon goby size, diet, and effect on food density to assess whether significant competition is likely.

There is much less overlap of striped bass and yellowfin goby abundances (Table 16).

Table 13
ABUNDANCE OF 6-MM STRIPED BASS AND OF OTHER FISH LARVAE IN 1991, BY AREA

Species	Sacramento River	San Joaquin River	Suisun Bay	Total
6-mm Striped Bass	162,592	66,392	224	229,208
Northern Anchovy	592	2,008	54,888	57,488
Longfin Smelt	1,288	856	1,656	3,800
Delta Smelt	360	600	216	1,176
Unknown Smelt	480	728	376	1,584
Sculpin	11,384	33,752	3,872	49,008
Chameleon Goby	73,280	379,904	148,416	601,600
Yellowfin Goby	3,224	3,416	44,504	51,144
Other Goby	1,432	2,392	24,152	27,976
Total Gobies	77,936	385,712	217,072	680,720
American Shad	1,728	64	80	1,872
Threadfin Shad	744	3,168	0	3,912
Other Clupeids	0	32	24	56

Table 14
ABUNDANCE OF GOBY LARVAE AND 6-MM STRIPED BASS
Data are not corrected for under-sampling in 1971, 1973, and 1975.
Gobies were not identified to species prior to 1991.

Year	Chameleon Goby	Yellowfin Goby	Other Goby	Total Gobies	6-mm Striped Bass
1968	—	—	—	11,151	691,209
1970	—	—	—	20,430	1,724,166
1971	—	—	—	1,395	3,070,071
1972	—	—	—	31,824	1,776,834
1973	—	—	—	4,914	1,059,300
1975	—	—	—	6,867	3,434,301
1977	—	—	—	150,849	209,893
1984	—	—	—	86,724	419,742
1985	—	—	—	182,133	1,197,792
1986	—	—	—	120,213	1,274796
1988	—	—	—	284,634	396,603
1989	—	—	—	328,779	1,001,700
1990	—	—	—	1,257,624	325,377
1991	601,614	51,147	27,981	680,742	229,208

1 J.C.S. Wang. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories*. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Technical Report 9. 1986.

2 See Interagency Program annual reports for 1989 and 1990.

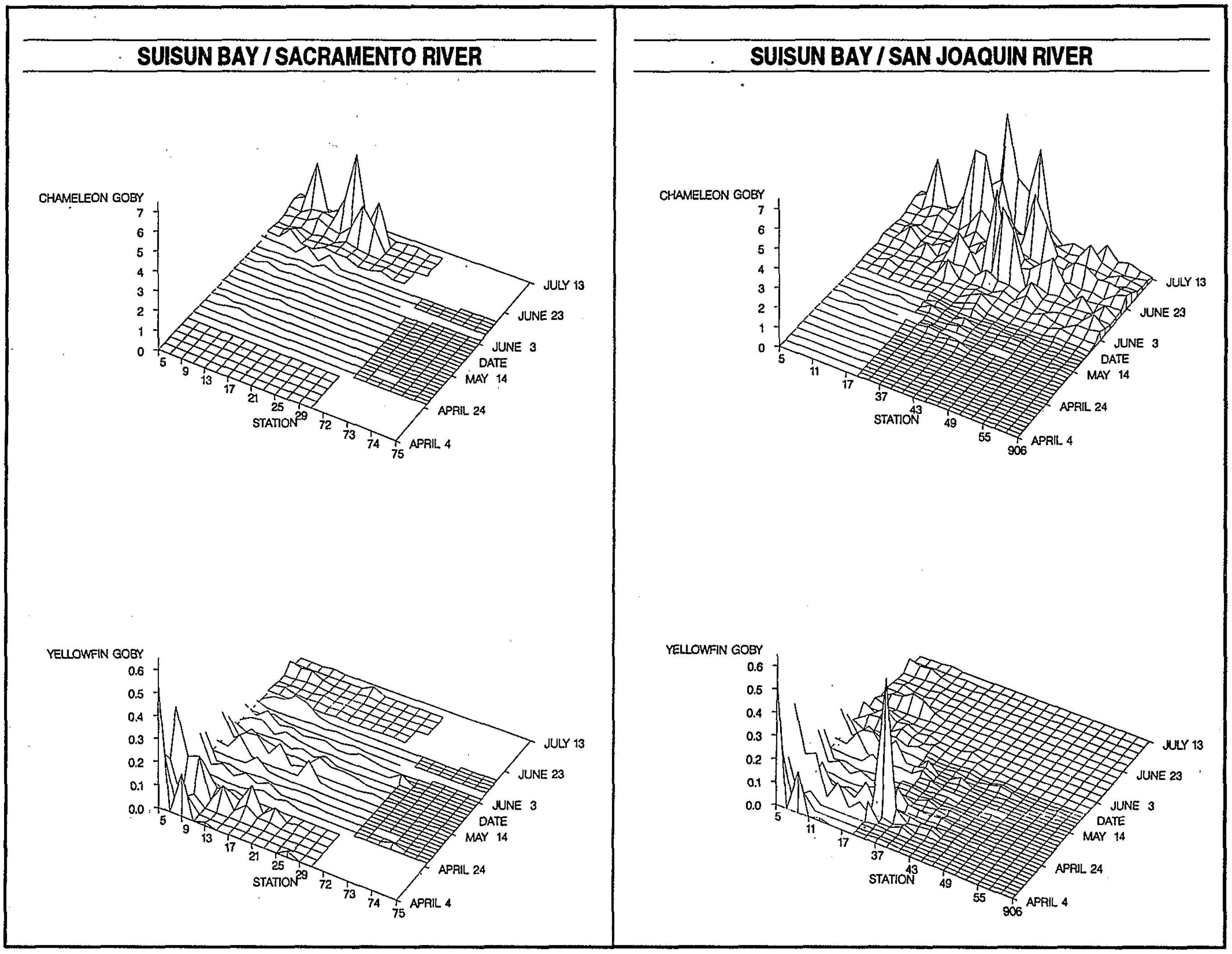

Figure 18
SPATIAL AND TEMPORAL DISTRIBUTION OF CHAMELEON GOBY AND YELLOWFIN GOBY, 1991

Table 15
PERCENT OF ABUNDANCES OF CHAMELEON GOBY AND 6-, 8-, AND 10-MM STRIPED BASS WHERE THEIR DISTRIBUTIONS ARE COINCIDENT IN 1991

Striped Bass Stage	6 mm	8 mm	10 mm
Number of Samples Where Abundance Occurred	300	198	144
% Total Striped Bass Abundance When Goby is Present	36.4	76.5	90.7
% Total Goby Abundance When Striped Bass is Present	20.7	20.3	17.4

Table 16
PERCENT OF ABUNDANCES OF YELLOWFIN GOBY AND 6-, 8-, AND 10-MM STRIPED BASS WHERE THEIR DISTRIBUTIONS ARE COINCIDENT IN 1991

Striped Bass Stage	6 mm	8 mm	10 mm
Number of Samples Where Abundance Occurred	96	37	15
% Total Striped Bass Abundance When Goby is Present	9.6	16.8	14.0
% Total Goby Abundance When Striped Bass is Present	9.2	20.3	0.8

Diet and Feeding Conditions

Diet items for 5- to 14-mm striped bass in 1991 were enumerated and multiplied by their estimated dry weight. Copepods and cladocerans were the major diet items. *Neomysis* and amphipods were minor food items in diets of fish greater than 9 mm (Figure 19).

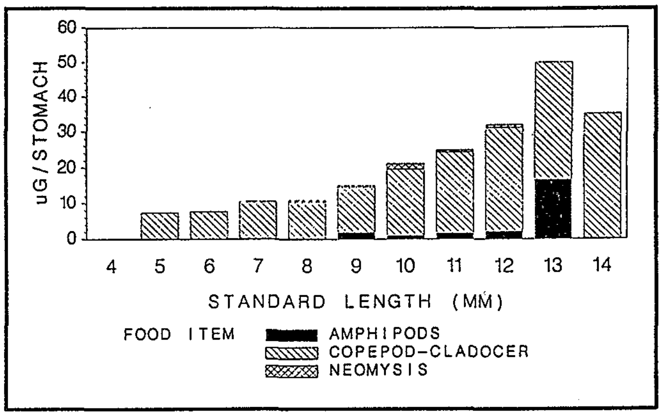

Figure 19
STRIPED BASS DIET IN RELATION TO LENGTH FOR ALL FISH USED IN THE 1991 DIET ANALYSIS

Historically, *Eurytemora affinis* has been one of the most abundant copepods in the diet of striped bass. Its concentration has always been low in fresh water (<1,000 µS/cm specific conductance) and greatest in the entrapment zone (1,000-10,000 µS/cm specific conductance). In 1988 it declined markedly in the entrapment zone and has not rebounded since (Figure 20). The recent accidental introduction of the Asiatic clam *Potamocorbula amurensis* is believed to be responsible for the decline in *Eurytemora*. This clam is now widespread in the estuary[1] and beds of densely concentrated, filter-feeding clams remove *Eurytemora* nauplii and reduce recruitment to the adult population[2].

Pseudodiaptomus forbesi, a new, accidentally introduced copepod, appeared in zooplankton samples late in the 1988 sampling season. Its abundance was first enumerated and quantified in the 1989 sampling season. The concentration of this species in 1991 was nearly equal in fresh water and the entrapment zone. In fresh water, the concentration of *Pseudodiaptomus* is much higher than of *Eurytemora* (compare Figures 20 and 21). Hence, it is an added food source for first feeding stages of striped bass, which are located mostly in the estuary where specific conductance is less than 1,000 µS/cm.[3]

As striped bass grow larger, more inhabit the entrapment zone, where the abundance of *Eurytemora* has declined. This is reflected in the lower dietary contribution of *Eurytemora* to striped bass greater than 8 mm from 1988 through 1991. While *Eurytemora's* contribution to the diet of larger bass has been replaced by *Pseudodiaptomus* (Figure 22), this replacement apparently has not improved survival (Figure 16).

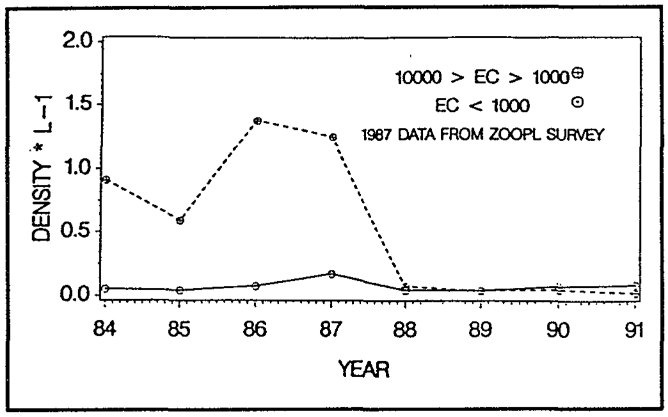

Figure 20
RELATIONSHIP BETWEEN SPECIFIC CONDUCTANCE AND DENSITY OF *EURYTEMORA*

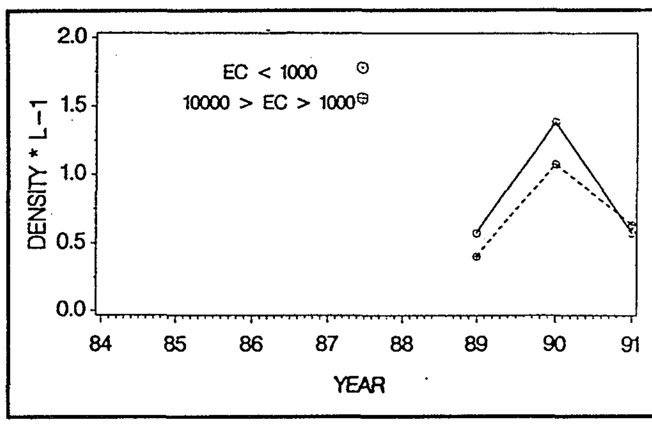

Figure 21
RELATIONSHIP BETWEEN SPECIFIC CONDUCTANCE AND DENSITY OF *PSEUDODIAPTOMUS*

1 Z.P. Hymanson. *Results of a spatially intensive survey for Potamocorbula amurensis in the Upper San Francisco Bay*. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary, Technical Report 30. 21 pp. 1991.
2 W. Kimmerer, E. Gartside, and J. Orsi. "Predation by an introduced clam as the probable cause of substantial decline in zooplankton of San Francisco Bay". Manuscript submitted to *Marine Ecology Progress Series*. 1993.
3 DFG, 1988. Previously cited.

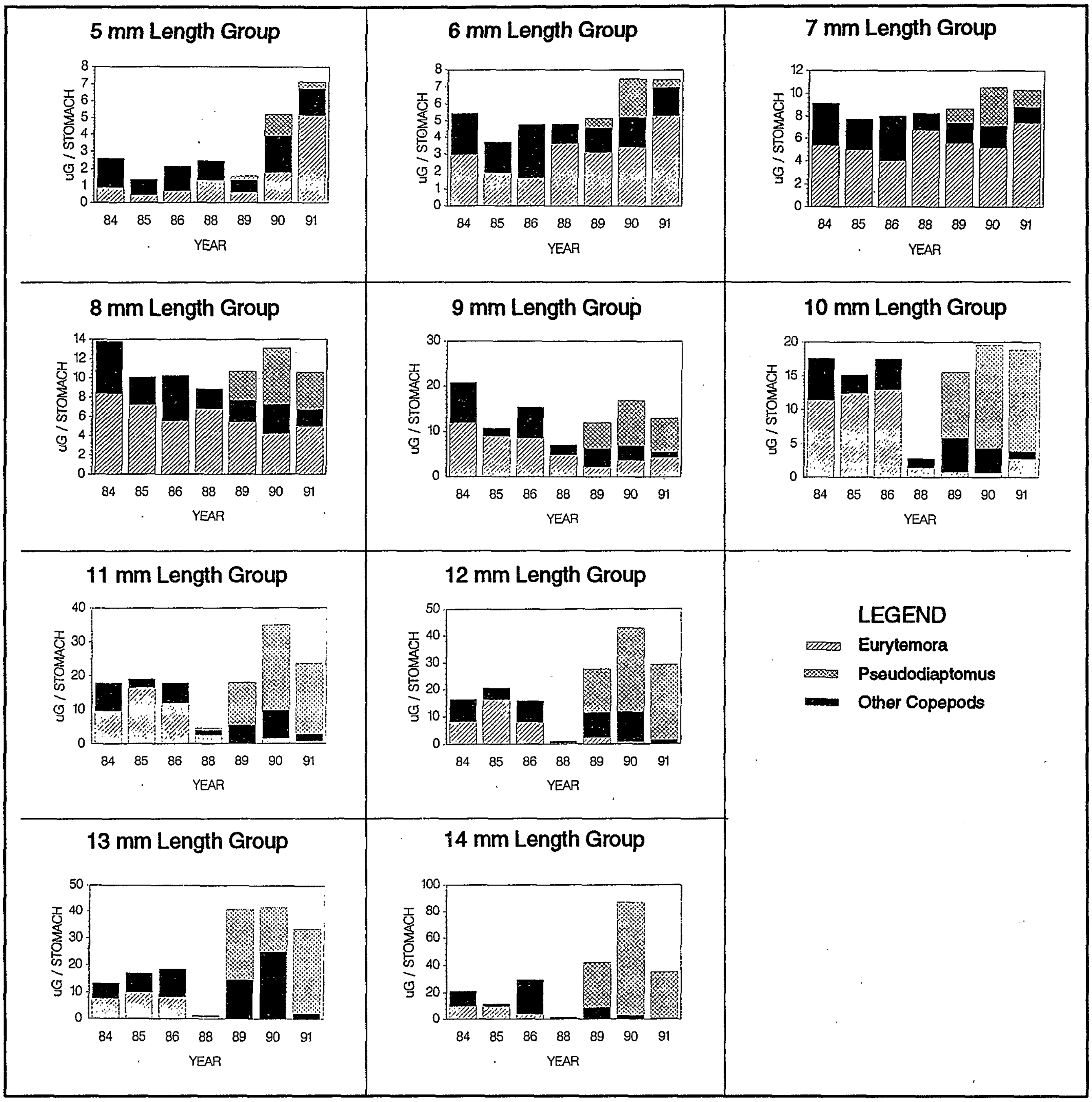

Figure 22
RELATIVE CONTRIBUTION OF *EURYTEMORA, PSEUDODIAPTOMUS,* AND OTHER CALANOID AND CYCLOPOID COPEPODS TO THE DIET OF 5- TO 14-MM STRIPED BASS

Summer Tow-Net Survey

Lee W. Miller and Jane Arnold
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A summer tow-net survey has been conducted annually since 1959 to index the abundance of young striped bass when the mean size reaches 38 mm. The tow-net index is used to evaluate the effects of water management on striped bass year class strength and population trends. This young striped bass abundance index has become a key indicator of the state of the estuary's environment.

In 1992, three surveys lasting 5 days each were conducted at 2-week intervals to determine the young striped bass abundance index. The index for each survey is the sum of the products of the catch from 30 collection sites multiplied by the water volume at each site. The mean length of young striped bass was estimated to be 38 mm on June 26. The total abundance index was 10.6. The index for the delta portion of the estuary was 6.6, and the index for the Suisun Bay portion was 4.0.

The 1992 index is low, but it is nearly double the 1991 index of 5.5 (Table 17). Striped bass abundance indices have been persistently lower since 1977. From 1959 to 1976, the mean index was 66.6; from 1977 to 1992, it was 19.2. This decline in average abundance since 1977 is attributable to a severe decline in abundance of adult striped bass and their egg production in combination with water project operations and the series of drought years. The DFG model indicates entrainment of young fish in water diversions has led to the lower abundance of adults.[1,2] Annual monitoring of young striped bass abundance will continue. The young striped bass abundance index is crucial to evaluating water management impacts.

Table 17
YOUNG STRIPED BASS ABUNDANCE INDICES

Year	Index Date	Delta Index	Suisun Bay Index	Total Area Index
1959	July 12	30.7	3.0	33.7
1960	July 16	32.0	13.6	45.6
1961	July 21	25.2	6.4	31.6
1962	July 26	46.8	32.1	78.9
1963	Aug 3	38.2	43.5	81.7
1964	Aug 1	54.7	20.7	75.4
1965	July 31	49.4	67.8	117.2
1966	No Index Measured; No Boat Available			
1967	Aug 12	35.1	73.6	108.7
1968	July 18	39.6	17.7	57.3
1969	Aug 9	33.6	40.2	73.8
1970	July 18	36.6	41.9	78.5
1971	Aug 11	24.6	45.0	69.6
1972	July 24	13.4	21.1	34.5
1973	July 15	15.6	47.1	62.7
1974	July 22	17.4	63.4	80.8
1975	July 30	23.4	42.1	65.5
1976	July 16	21.1	14.8	35.9
1977	July 24	8.3	0.7	9.0
1978	July 22	16.5	13.1	29.6
1979	July 19	5.4	11.5	16.9
1980	July 27	2.8	11.2	14.0
1981	July 2	15.4	13.7	29.1
1982	July 30	9.5	39.2	48.7
1983	Index Not Valid Due to High Outflows			
1984	July 13	6.3	20.0	26.3
1985	July 16	2.2	4.1	6.3
1986	July 9	23.8	41.1	64.9
1987	June 22	7.3	5.3	12.6
1988	July 24	3.9	0.7	4.6
1989	July 11	3.1	2.0	5.1
1990	July 18	2.8	1.5	4.3
1991	July 25	3.9	1.6	5.5
1992	June 24	6.6	4.0	10.6

1 Department of Fish and Game. *A Re-examination of Factors Affecting Striped Bass Abundance in the Sacramento-San Joaquin Estuary*. WRINT-DFG-Exhibit 2 submitted to the California State Water Resources Control Board. 1992.

2 Kohlhorst, D.W., D.E. Stevens, and L.W. Miller. *A Model for Evaluating the Impacts of Freshwater Outflow on Striped Bass in the Sacramento-San Joaquin Estuary*. WRINT-DFG-Exhibit 3 submitted to the California State Water Resources Control Board. 1992.

Midwater Trawl Survey

Lee W. Miller and Jane Arnold
Department of Fish and Game

The fall midwater trawl survey measures abundance of young striped bass, delta smelt, and other species monthly from September through December. The survey has been conducted annually since 1967, except for 1974 and 1979. The midwater trawl abundance index is the sum of the monthly indices from September through December.

The fall 1992 index of young striped bass abundance is 2,017, the highest index since 1986 (Table 18). However, this index is relatively low compared to those measured before 1977. The mean abundance index before 1977 was 7,460. Since 1977, mean abundance is 3,020, a 60% decline.

Table 18
YOUNG STRIPED BASS ABUNDANCE INDICES FOR MIDWATER TRAWL SURVEYS, 1967 TO 1992

Year	Midwater Trawl Index
1967	21,082
1968	4,118
1969	8,425
1970	8,299
1971	9,510
1972	6,129
1973	4,285
1975	4,548
1976	746
1977	885
1978	2,601
1980	1,463
1981	4,533
1982	4,468
1983	12,496
1984	6,602
1985	1,760
1986	3,944
1987	1,351
1988	477
1989	442
1990	1,319
1991	950
1992	2,017

Striped Bass Egg and Larval Management Study

Melvin D. Ball
U.S. Bureau of Reclamation

A fourth year of continuous monitoring for striped bass eggs and larvae in the Sacramento River at Bryte was completed in 1992. This year's results again indicated temperature rises were the main factor stimulating major spawning periods; however, total annual spawning, as indicated by abundance of eggs and larvae, was unusually low in this section of the river.

Objectives for the 1992 study were to obtain more information on factors influencing bass spawning and to improve the design of the sampling equipment. New equipment designs were incorporated to improve ease of sampling, to reduce mutilation of eggs and larvae retained in the nets during the 12-hour sampling periods, and, most important, to use new, low-velocity meters that would operate adequately under the extremely low flows created by the drought.

Again in 1992, the stationary nets were fished, using normal streamflow, for about 12-hour periods. However, the sampling gear was modified and down-sized from previous years. Sampling was conducted from late March to early June, when the system was vandalized[1]. Based on previous years' data and weather conditions, most of the spawning probably had occurred before the study was terminated.

The use of low-velocity flowmeters with the nets was necessary to adequately measure the extremely low flow in the Sacramento River during 1992. At times, the flow was the lowest since the start of the water projects. The low-velocity flowmeters were factory-mounted in 5-inch-diameter tubular housings. The housings also provided an ideal surface for attaching the smaller-diameter, custom-made plankton nets used in 1992. The 5-inch net opening collected enough eggs and larvae to characterize spawning.

In 1992, the plankton net mesh opening was reduced to 330 microns for the routine samples. Several comparisons were made with the standard 500-μ net used in previous years. Catches were slightly higher with the 330-μ net.

1 Because of the low security at this site, we are looking at other sites in the area for placement of the equipment in 1993.

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Two tests were conducted to compare total catches of bass eggs and larvae when fishing about every half hour for 10 hours and when fishing the nets continuously for 10 hours. Results suggested little egg and larval loss when fishing continuously under river conditions tested. These tests will be repeated in 1993.

A significant drop in striped bass spawning occurred in the Sacramento River above Sacramento this year (Figure 23). Only a few hundred million eggs and larvae were detected for the total season, compared to several billion in the previous 3 years. This is in contrast to DFG's annual striped bass young-of-the-year index for 1992, which was nearly double those measured in the previous years of this drought. The improved index suggests that either bass larvae survived better in the estuary in 1992 or major spawning may have occurred somewhere other than the upper Sacramento River.

As in previous years, increased water temperature within certain ranges was still the single factor most consistently related to large peaks of bass spawning (Figure 24). Spawning started very early in 1992, as in the last few years, due to early warming of the river water.

Questions arise as to why the data indicate such a great reduction in bass spawning in the river above Sacramento this year. Relatively high numbers of bass could have spawned in the river below Sacramento or in the central delta. Results from the 1992 DFG striped bass egg and larval survey, when complete, will help answer where the bass spawned. Rice field pesticides have been a concern in recent years. However, almost all the rice-field water was held on the fields following pesticide application in 1992, and not released back to the river. Therefore, these pesticides should not have caused any problems, as suspected in the past.

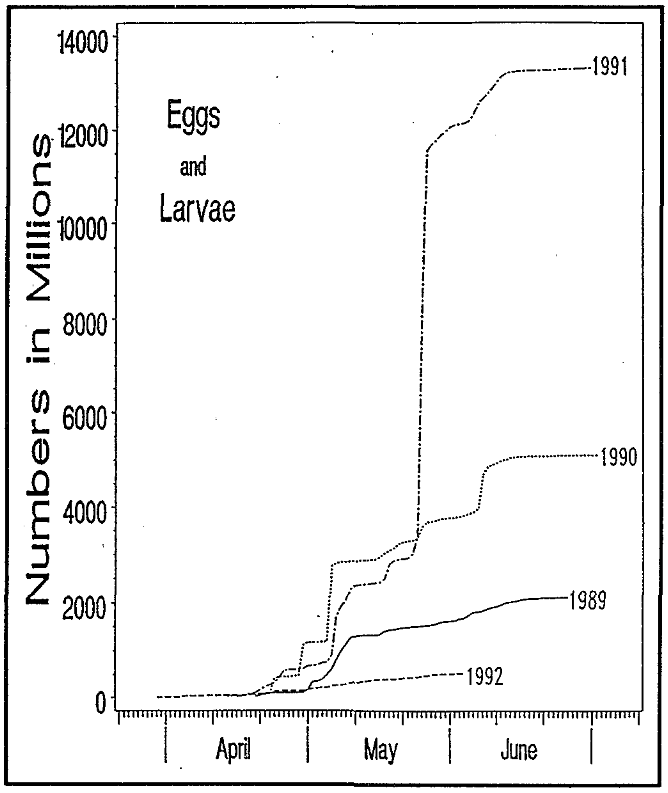

Figure 23
NUMBERS OF STRIPED BASS EGGS AND LARVAE MOVING DOWN THE SACRAMENTO RIVER PAST BRYTE

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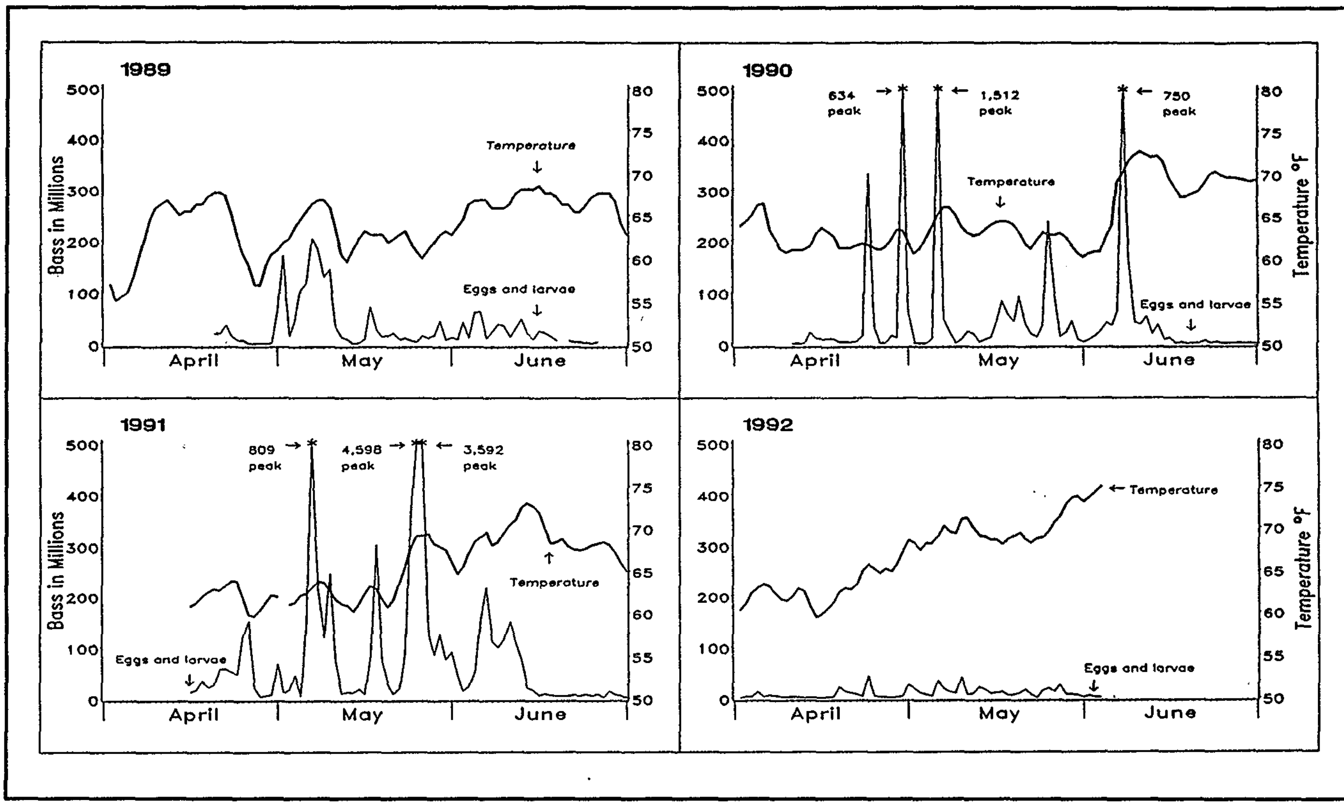

Figure 24
DAILY ABUNDANCE OF STRIPED BASS EGGS AND LARVAE IN THE SACRAMENTO RIVER AT BRYTE VERSUS MEAN DAILY WATER TEMPERATURE

CHINOOK SALMON

Marty Kjelson, Patricia Brandes, and Spencer Hovekamp
U.S. Fish and Wildlife Service

In 1992 we worked to update and refine our knowledge of factors influencing young salmon abundance, distribution, and survival in the Sacramento-San Joaquin estuary. Sampling was expanded to include juveniles of all races.

Overall objectives of the 1992 Salmon Study are to:

- Monitor the abundance of fry and smolt Chinook salmon rearing and migrating through the delta.
- Determine the impacts of water development within the delta on abundance, distribution, and survival of juvenile fall-run salmon.
- Identify management measures that could lessen the impacts of water project operations on salmon using the delta and lower embayments of the estuary.

We employed the usual sampling methods — midwater trawl at Sacramento and Chipps Island and beach seine — and also sampled experimentally with a variety of new gears and techniques, in part to improve the ability to capture all size ranges of juvenile salmonids. Presumably, different sizes and life stages have different spatial and temporal distributions within the delta. These new methods represent a pilot effort, the results of which should be regarded as tentative.

Elements of the study in 1992 were:

- A weekly beach seining survey, December through May, to estimate the abundance of fry. This is an expansion of the past beach seining program.
- A midwater trawl survey at Sacramento, beginning in December 1991, to estimate the abundance of smolts entering the delta.
- Limited tow-net sampling on the trawl vessel at Sacramento to see if fry-sized salmon in the middle of the channel were being effectively sampled with the midwater trawl.
- Fyke sampling to estimate the number of fry entering the delta at Sacramento during the same period that the midwater trawl was sampling at the same location.
- Repetitive beach seining to evaluate how quickly fry immigrate back into the beach seine sites after sampling.
- Trawling at Chipps Island, as in past years, to estimate the number of unmarked fish emigrating from the delta and to recover marked fish released in the mark and recapture experiments.
- Coded-wire-tagged fry released at Verona and Miller Park and recovered at Sacramento in the trawl and fyke sampling to estimate sampling efficiency of the fykes.
- Additional mark/recapture studies to determine survival of fall-run smolts under varied environmental conditions.

Specific questions addressed by tag studies in 1992 were:

- What is the survival of fish migrating down the San Joaquin River with and without a full barrier at the head of Old River?
- What is the impact on the Sacramento Basin salmon (especially the winter run) migrating through the central delta of bringing more water to the export pumps via lower Old River and Middle River with a barrier at the head of Old River?
- What is the impact on salmon smolts of diversion into Georgiana Slough at low- to mid-range temperatures?

CWT recovery data generated by the ocean fishery will be analyzed later to confirm past conclusions based on trawl recovery information.

Sacramento River Beach Seine Survey

A weekly beach seine survey in the lower Sacramento River and northern delta began on December 3, 1991, and continued until May 29, 1992. The central delta stations were added on January 9. Table 19 identifies the number of salmon caught, by race[1], and the number of seine hauls per month.

Table 19
1992 BEACH SEINE CATCH, BY MONTH AND RACE

	Fall	Spring	Winter	Late-Fall	*N*
December	0	0	0	0	78
January	367	0	2	5	131
February	1,201	38	15	3	98
March	1,670	26	3	0	94
April	698	5	0	0	123
May	50	0	0	0	105

N = Number of seine hauls.

Most salmon recovered in the beach seine survey were fall-run, which would reflect the fact that:

- There are larger numbers of fall-run salmon in the Central Valley.
- Fall-run salmon are probably smaller than the late-fall and winter races when they enter the delta, potentially because of the pattern of runoff in late 1991 and 1992, with few storms until February and March.
- Smaller fish would be more vulnerable to the beach seine sampling.

Peak seine catches were in March for fall Chinook, in February for winter Chinook, and in January for late-fall Chinook. Timing of peak catches is expected to vary between races due to spawning difference and their vulnerability to the seine.

Catches were compared with past years based on the catch per seine haul in January through March (the common sampling period for all the data). Abundance of fry in the northern delta in 1992 was somewhat higher than in 1991 and similar to 1987 to 1989. The low numbers in the central delta are similar to past dry years. The numbers recovered in the lower Sacramento River are well within the range of recent years. All three areas reflect catches similar to recent dry years. Mean catch per haul for the three areas since 1977 is shown in Table 20.

Table 20
AVERAGE CATCH PER SEINE HAUL OF CHINOOK SALMON JUVENILES IN THE NORTHERN AND CENTRAL DELTA AND LOWER SACRAMENTO RIVER
January through April, 1977 through 1992

Year	Northern Delta	Central Delta	Lower Sacramento
1992	14	3	18
1991	4	3	30
1990	32	5	11
1989	15	3	22
1988	11	5	9
1987	15	5	19
1986	34	12	34
1985	12	3	2
1984	14	5	14
1983	40	11	35
1982	24	5	15
1981	13	2	36*
1980	16	3	NS
1979	40	8*	NS
1978	24	NS	NS
1977	0.1	NS	NS
N	14	9	7

N Number of seine sites in the area.
* February and March only; no samples in January. This would tend to increase the mean.
NS Not sampled.

The 1992 data continue to support past findings that, in general, fry abundance in the northern delta increases as inflow to the delta increases (Figure 25).

As in previous years, the number of fry entering the lower Sacramento River and delta in 1992 appears to respond to pulses of flow entering the river. The first minor pulse, in mid-January, did not appear to be enough to move the fry all the way into the delta, but catches in the lower Sacramento River did respond within about 7 days of the pulse. The first major flow pulse, in mid-February, did bring additional fry into the lower Sacramento River and northern and central delta (Figure 26).

1 Based on the daily size criteria developed by Frank Fisher, DFG, February 1992.

Mean fork length of fry entering the three areas of the delta in 1992 appeared to increase throughout the season, as would be expected. Just after the three flow pulses in February and March, however, the mean size dropped somewhat (Figure 27), which may reflect an influx of smaller fish into the lower river and delta from the upper river due to the increase in flow. As hypothesized in the past, this may be a behavioral response to the increase in turbidity, or it may reflect involuntary movement downstream due to advection.

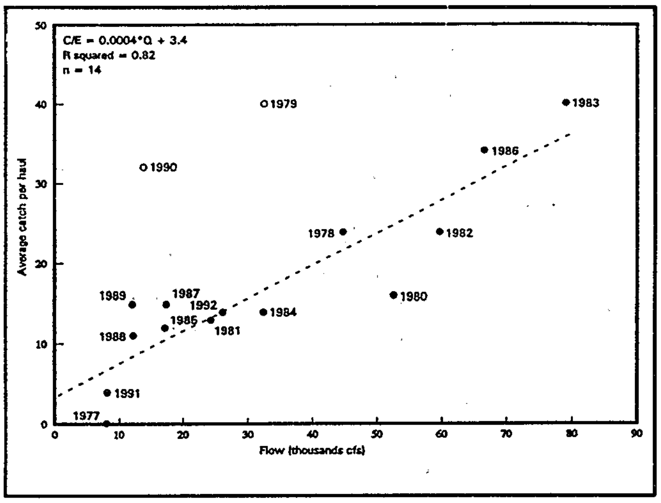

Figure 25
AVERAGE CATCH PER SEINE HAUL OF CHINOOK SALMON IN THE NORTHERN DELTA AND MEAN FEBRUARY FLOW IN THE SACRAMENTO RIVER AT FREEPORT
o Outlying points not used in the regression calculation.

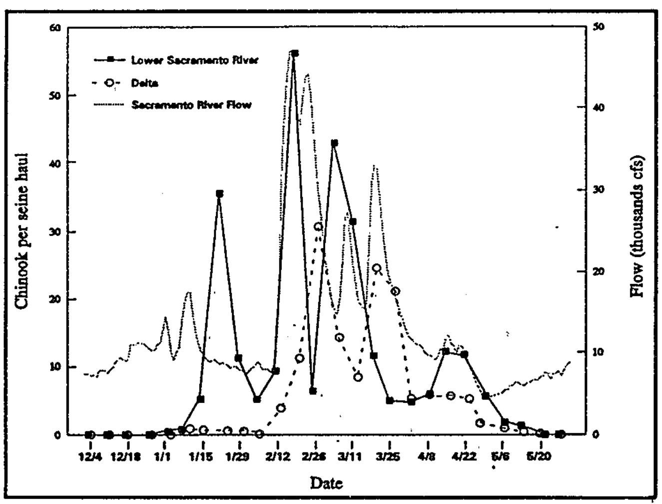

Figure 26
CHINOOK SALMON CAPTURED IN THE BEACH SEINE IN THE DELTA AND LOWER SACRAMENTO RIVER, 1992
Northern and central delta sites are combined for this graph.
Mean daily Sacramento River flow is at Freeport (DAYFLOW).

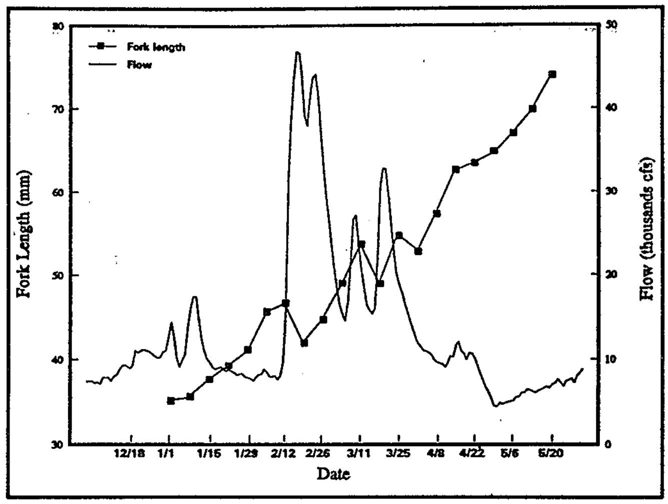

Figure 27
MEAN FORK LENGTH OF CHINOOK SALMON CAPTURED IN THE BEACH SEINE, ALL AREAS, 1992
Winter Chinook were excluded from length calculations.
Mean daily Sacramento River flow is at Freeport (DAYFLOW).

Tagged Fry Recaptured By Seining

A total of 102,862 coded-wire-tagged fry were released in four groups[1], one group per week from February 25 to March 16. Of these, 183 were recovered. During the season, 4,083 unmarked fish were also collected in the seining. Based on the ratio of those recaptured to those released, an estimated 2,295,002 unmarked fry would have been in the delta and lower Sacramento River between December 1991 and May 1992. We believe this is a minimum estimate, because many of the recaptures (120 of 183) were recovered at Verona 7 days after release and probably biased the recovery rate high and, consequently, the absolute abundance low. Omitting the 120 and using 63 as the recapture value yields an estimate of 6,666,437 unmarked fry.

Proportional expansions like these (and others that follow in this chapter) depend on an extensive set of assumptions, few of which are likely to be precisely true. Therefore, reported results should be interpreted as approximations of population variables.

1 Three groups were released at Verona and one at Miller Park.

Repetitive Beach Seining

Multiple seine hauls on a single sampling day were conducted at four stations near Sacramento[1] from February 28 to April 14 to estimate the influx rate of fry moving into these areas. The goal was to seine multiple times until very few fry were caught. After each seine haul, the catches were transported downstream so they would not be resampled. The site was revisited within a day to see how many fry had repopulated the area in the roughly 24 hours since the last sampling. In the following analyses, data were not used if more than one day had elapsed between seining.

Based on the number of fry remaining on the initial day of seining compared with the number of fry captured on the first seine haul of the following day, we estimated that during March and April, fry move into these areas on an average of 0.0023 fish per minute, repopulating the area about threefold in 24 hours (Table 21).

Table 21
NUMBER OF SALMON CAUGHT ON THE LAST SEINE HAUL OF THE INITIAL SEINING DAY AND ON THE FIRST SEINE HAUL OF THE NEXT DAY

Site	Date	Last Catch on Day 0	First Catch on Day 1
Garcia Bend			
	03/02	0	3
	03/09	4	0
	03/23	2	26
	03/30	13	22
	X̄	5	10
Discovery Park			
	03/09	14	2
	03/16	3	10
	04/13	0	14
	X̄	5.6	8.6
Miller Park			
	03/23	0	10
	03/30	0	2
	04/06	1	6
	X̄	0.3	6
Clarksburg			
	04/13	0	13
	X̄	0	13
Mean, All Sites Combined			
	X̄	2.7	9.4

Additional analyses of these data are warranted and may yield additional insight on the influx of fry to the northern delta.

Sacramento River Fyke Net Sampling

Fykes deployed near Sherwood Harbor Marina[2] were used to index and document the influx of near-shore fry moving into the delta. Two fyke traps, one on each side of the river, were fished two or three times per week, both during the day and at night, from January 21 to June 10. Mean catch per minute was 0.0247 during the 6-month sampling period. Catch per minute by month ranged from 0.000 to 0.086, with the least caught in June and the most caught in March (Table 22).

Table 22
MEAN CATCH OF SALMON PER MINUTE IN FYKE NETS AT SACRAMENTO
January 21 through June 10, 1992
The mean catch, by day, was averaged for each month.

	Mean Catch per Minute
January	0.0129
February	0.0274
March	0.0858
April	0.0192
May	0.0030
June	0
X̄	0.0247

Figure 28 shows the catch per minute by day and illustrates the exceptionally high value on March 9 compared to days before and after that peak. Table 23 identifies races of salmon caught in the fykes.

Catches (as number per minute) were less for the fykes than for the midwater trawl at Sacramento. In most months, the mean size caught in the fykes was less than that caught in the midwater trawl (Table 24). This could be caused by a distribution difference (smaller salmon tending to stay closer to shore) or by sampling bias (larger salmon avoiding fykes).

1 Discovery Park, Garcia Bend, Miller Park, and Clarksburg.
2 Within the midwater trawling reach at Sacramento.

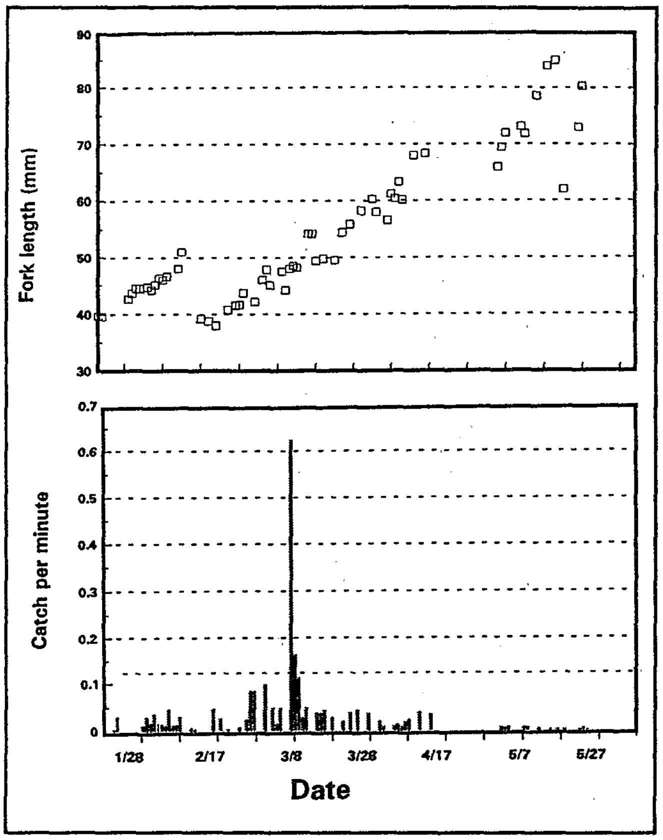

Figure 28
MEAN SIZE AND CATCH PER MINUTE OF
CHINOOK SALMON CAUGHT IN THE FYKE NETS
AT SACRAMENTO, 1992

Since we stratified the fyke sampling both in time and space, we evaluated the differential catches between the east and west side of the channel and between night and day. The night fykes were set in late afternoon and do include some daylight hours.

The fyke on the east side of the river caught significantly ($p<0.01$) more fish per minute than those on the west side (Table 25). The west side drops off rapidly into deep water; the east side offers a broad shoal.

About twice as many more fish were caught per minute during the day than at night. This implies a faster migration rate during daylight, but it could reflect a diurnal distribution shift, with the fry moving inshore during daylight to avoid piscine predators and toward midchannel at night to speed downstream migration. If the latter is true, migration is actually faster at night.

The three groups of coded-wire-tagged fry released at Verona and the one group released at Miller Park were used to estimate efficiency of

Table 23
CHINOOK SALMON CAUGHT IN THE FYKE NETS AT SACRAMENTO, BY RACE*
January 21 through June 10, 1992

	Un-measured	Fall	Marked	Spring	Winter	Late-Fall
January		93	0	1	0	0
February		374	0	3	0	0
March	858	937	91	30	0	0
April	15	244	2	8	0	0
May		93	0	0	0	0
Total	873	1,741	93	42	0	0

* Based on size criteria established by Frank Fisher, DFG, February 1992.

Table 24
MEAN SIZE AND CATCH PER 20-MINUTE TOW IN FYKE NETS AND MIDWATER TRAWLS NEAR SACRAMENTO, 1992

	Mean Size		Catch per 20-Minute Tow	
	Fyke Net	Trawl	Fyke Net	Trawl
December	–	–	–	0.0
January	43.1	112.8	0.258	0.7
February	44.0	41.9	0.548	20.0
March	48.7	54.8	1.716	10.4
April	63.0	–	0.384	–
May	73.6	80.8	0.060	13.2
June	–	83.8	0	0.6

Table 25
MEAN CATCH PER MINUTE, STANDARD DEVIATION, SAMPLE SIZE, AND Z VALUES FOR FYKE NET SETS AT SACRAMENTO
January 21 and June 10, 1992

	East	West
Mean Catch per Minute	0.0358	0.0233
Standard Deviation	0.1321	0.0304
Sample Size	67	65
z Value	439.86	
	Day	**Night**
Mean Catch per Minute	0.0357	0.01824
Standard Deviation	0.1184	0.0332
Sample Size	59	34
z Value	519.41	

the fykes. Although fry released at Verona would have some mortality between Verona and Sacramento, we believed the 25 miles between the two sites would allow the fry to spread out and be more typically distributed than if they were released directly in front of the sampling site. The one release at Miller Park allowed us to evaluate that assumption, since it is only about 4 miles north of the fyke site.

For the three releases at Verona, on February 25, March 3, and March 10, the recoveries began 1 to 9 days after release and continued for up to 30 days. We recovered 5 to 10 fry from each release in the midwater trawl at Sacramento and 4 in the tow-net. This would indicate that fry from these groups moved down into the delta over a long period and that at least some portion were moving downstream via the middle of the channel. Flows during this period were high and may have swept the fry into the middle of the channel, whereas during periods of less flow the fry would perhaps move downstream nearer to the shore. Considering the pattern of recovery for these fish, we did not attempt to estimate efficiency from these groups.

The Miller Park group was released March 16, and most recoveries were on March 16 and 17 in the fykes. No fry were recovered in the midwater trawl. On March 16 and 17, we had fykes on both sides of the river for 47% of the time. Of the 24,350 fish released, 37 were recovered during these two days, which equates to an efficiency rate of 0.0016, or 0.0032 when corrected for sampling time.

If we expand the unmarked catch (n=2,656) based on this efficiency rate, corrected for the fraction of time sampled over the course of the season (0.27), then 6,148,148 fry passed the fykes during the season. Given the extreme fluctuations of flow in February and March and the probable responses of fry immigrating into the delta, the efficiency likely changed dramatically. The efficiency estimate using the Miller Park release group is probably high, given the 24 CWT fry from the Verona releases recovered in the midwater trawl, thus biasing the absolute abundance estimate low.

Future analysis of fyke trap data will be improved with correction for fyke mouth width, which can vary between sets.

Sacramento River Tow-Net Survey

During a 6-week period from December 5, 1991, to January 15, 1992, and a 2-week period from March 11 to March 25, 1992, a fixed-frame tow-net[1] was used to sample concurrently with the midwater trawl at Sacramento. We sampled twice a week, with six 10-minute tows per day. We expected that the tow-net would select for smaller fry in the middle of the channel, which the midwater trawl might miss. We initially partioned the six tows per day into replicates of two tows for each vertical area of the channel (top, middle, bottom) to determine vertical distribution of the fry caught. However, logistical problems did not allow us to continue this protocol for the entire sampling period.

Table 26 identifies salmon caught in the tow-net by race. A total of 76 fry were caught, ranging from 33 to 73 mm long. The mean size of the salmon and the number caught per 20-minute tow increased in March over that in January. This reflects the growth and increased abundance of the fall-run fry over time (Figure 29).

Table 26
CHINOOK SALMON CAUGHT IN THE TOW-NET NEAR SACRAMENTO, BY RACE*
December 5, 1991, to January 15, 1992 and March 11 to March 25, 1992

		Fall		Spring		Winter		Late-Fall	
Dates	Unmeasured	Unmarked	Ad Clip	Unmarked	Ad Clip	Unmarked	Ad Clip	Unmarked	Ad Clip
12/05 - 12/30/91	0	0	0	0	0	0	0	0	0
01/01 - 01/15/92	0	5	0	0	0	0	0	0	0
03/11 - 03/25/92	0	66	4	5	0	0	0	0	0
Total	0	71	4	5	0	0	0	0	0

*Based on size criteria established by Frank Fisher, DFG, February 1992.

1 Mouth 1.5 meters wide, 2.3 square meters.

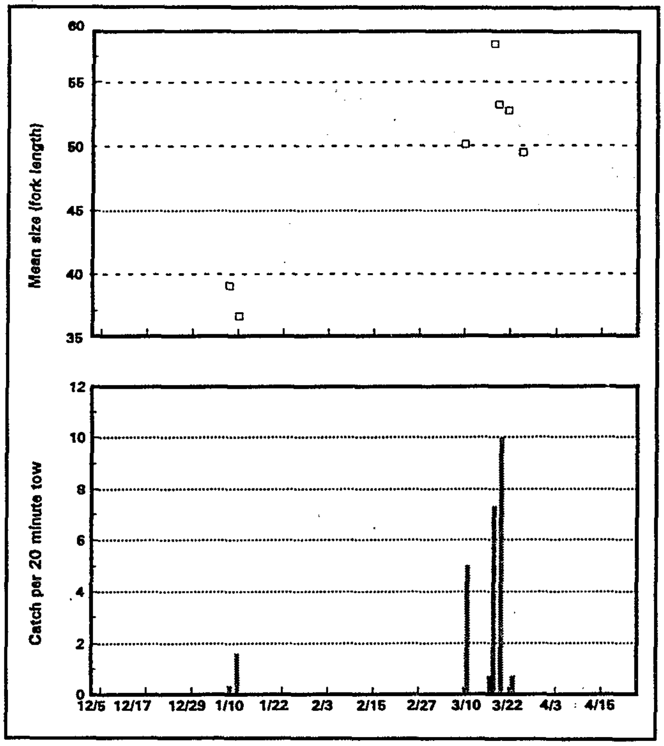

Figure 29
MEAN SIZE AND CATCH PER 20-MINUTE TOW
USING THE TOW-NET AT SACRAMENTO
December 5, 1991, to January 15, 1992 and
March 11 to March 25, 1992

Comparisons were made with the midwater trawl to evaluate whether the tow-net was more efficient for catching smaller fish. During the eight weeks sampled with both nets, the tow-net consistently caught less fish in the smaller size range (<73 mm) than were caught in the midwater trawl (76 versus 262). The concern that the midwater trawl would not effectively catch small fry in mid-channel appears to be unfounded, at least under flow conditions in the spring of 1992.

Sacramento River Midwater Trawl

In 1992, a fifth year of trawling was done on the Sacramento River about 4 miles downstream of Miller Park, the same site used in 1988, 1989, and 1991. The sampling site in 1990 was near Courtland, about 21 miles closer to Chipps Island than the Miller Park site.

Six to ten, 10- to 20-minute tows were made 2 or 3 times per week between December 5, 1991, and June 12, 1992 (excluding April), to index the number of juvenile salmon migrating into the delta. Although targeting smolts, the midwater trawl caught many salmon fry as well.

The monthly catch ranged between 0 and 20 fish per 20-minute tow. Figure 30 shows the mean daily size and catch during the sampling period.

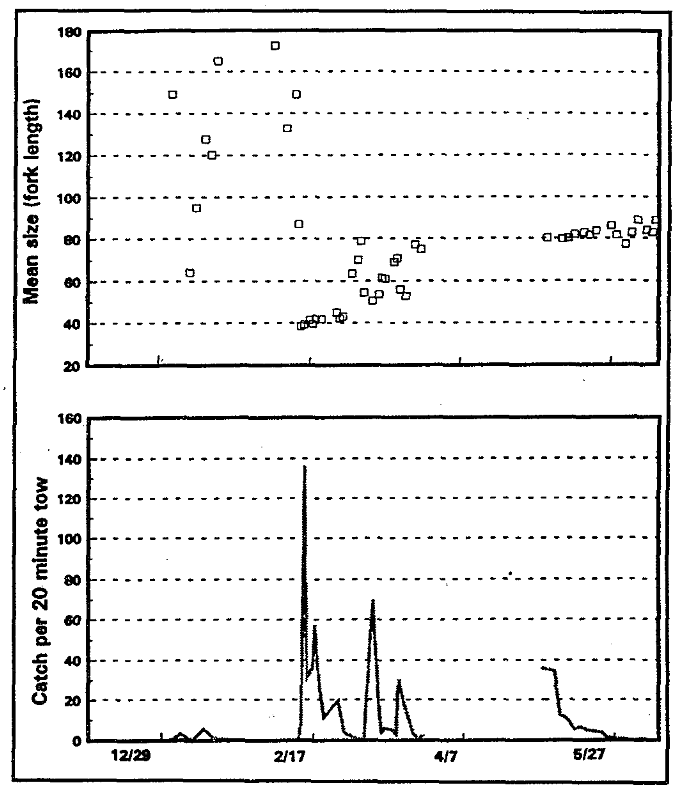

Figure 30
MEAN SIZE AND CATCH PER 20-MINUTE TOW
IN THE MIDWATER TRAWL AT SACRAMENTO
December 5, 1991, to June 12, 1992
No sampling during April.

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The largest catches were during February and May at a mean fork length of 41.9 and 80.8 mm, respectively. This pattern may reflect the peaks of fall-run fry (in February) and smolts (in May) entering the delta. Although very few fish were caught in January (averaging less than 1 fish per tow), those caught had the largest mean size (112.8 mm) and appear to reflect the outmigration of the late-fall race. Table 27 identifies the number of salmon caught by race, based on the most recent size criteria[1].

Many of the salmon caught were not measured, but most likely are fall-run for the same reasons discussed in the beach seining section.

Table 28 shows the absolute abundance estimate for juvenile salmon passing Sacramento, as indexed by the midwater trawl. The lack of sampling during April makes the seasonal estimate much lower than expected, and two to three days sampling per week may not be enough to provide a representative pattern of distribution of salmon moving into the delta over time.

Since we did not sample in April, we did not attempt to calculate survival indices for smolts released at Princeton, Battle Creek, and Red Bluff during April and recovered by trawl at Sacramento.

Table 27
CHINOOK SALMON CAUGHT IN THE MIDWATER TRAWL NEAR SACRAMENTO, BY RACE*
December 5, 1991, to June 12, 1992; No Sampling During April

Month	Unmeasured	Fall Unmarked	Fall Ad Clip	Spring Unmarked	Spring Ad Clip	Winter Unmarked	Winter Ad Clip	Late-Fall Unmarked	Late-Fall Ad Clip
December	0	0	0	0	0	0	0	0	0
January	0	16	0	0	0	0	0	30	5
February	176	1,951	5	12	0	50	9	17	15
March	19	454	16	47	0	25	1	0	0
May	0	641	16	36	3	2	0	0	0
June	0	20	0	0	0	0	0	0	0
Total	195	3,082	37	95	3	77	10	47	20

*Based on size criteria established by Frank Fisher, DFG, February 1992.

Table 28
EXPANDED NUMBER OF CHINOOK SALMON CAUGHT IN THE MIDWATER TRAWL NEAR SACRAMENTO, BY RACE*
December 5, 1991, to June 12, 1992; No Sampling During April
Corrected for the Fraction of Time Sampled by Month and the Fraction of the Cross Sectional Area Sampled (15 Feet / 508 Feet)

Month	Fall Unmarked	Fall Ad Clip	Spring Unmarked	Spring Ad Clip	Winter Unmarked	Winter Ad Clip	Late-Fall Unmarked	Late-Fall Ad Clip
December 1991	0	0	0	0	0	0	0	0
January 1992	15,408						28,890	4,815
February 1992	982,313	2,309	5,542		23,091	4,156	7,851	6,927
March 1992	682,293	23,080	67,796		36,062	1,442		
May 1992	940,541	23,480	52,828	4,402	2,935			
June 1992	16,258							
Total	2,636,912	48,869	126,166	4,402	62,088	5,598	36,741	11,742
Ad Clips Released Upstream of Sacramento		501,434		103,477		11,582		119,145

*Based on size criteria established by Frank Fisher, DFG, February 1992.

1 Frank Fisher, DFG, February 1992.

Chipps Island Midwater Trawl

Juvenile fall-run Chinook abundance in the western delta at Chipps Island was higher than in the last few years. Monthly mean indices were 50.5 for April, 13.1 for May, and 1.3 for June. The mean index for the season was 21.6 salmon per 20-minute tow. The seasonal index has ranged from 10.1 in 1984 to 44.2 in 1983 (Table 29). Indices in Table 29 are slightly different than reported in past annual reports due to a difference in the way the averages are generated. The numbers reflected in Table 29 are the means of the three monthly means.

Table 29
MEAN CATCH OF CHINOOK SALMON SMOLTS PER 20-MINUTE TOW IN THE MIDWATER TRAWL AT CHIPPS ISLAND, 1978-1992

Year	April	May	June	Annual Mean*
1992	50.5	13.1	1.3	21.6
1991**	5.2	26.9	5.5	12.5
1990	17.0	30.6	6.7	18.1
1989	23.2	31.5	5.0	19.9
1988	9.4	24.7	1.1	11.7
1987	15.4	19.3	0.8	11.8
1986	22.5	32.9	4.7	20.0
1985	10.3	24.7	4.1	13.0
1984	3.2	20.0	7.0	10.1
1983	24.8	65.0	42.8	44.2
1982	18.9	51.7	34.6	35.1
1981	17.3	25.3	8.3	17.0
1980	5.6	14.0	21.1	13.6
1979	14.9	41.6	23.2	26.6
1978	23.1	34.0	27.6	28.2

* The mean of April, May, and June, divided by 3.
** These were reported incorrectly in the 1991 USFWS Annual Report.

The 1992 index is the largest since 1983 and likely reflects the change to releasing fall-run salmon from Coleman Fish Hatchery in early April, when temperatures are low and survival through the delta is higher than in late April or May.

Figure 31 shows the mean catch per 20-minute tow and mean size per sampling day between April 3 and June 26. In 1992, most of the fish did migrate out in April, earlier than in past years (Table 30).

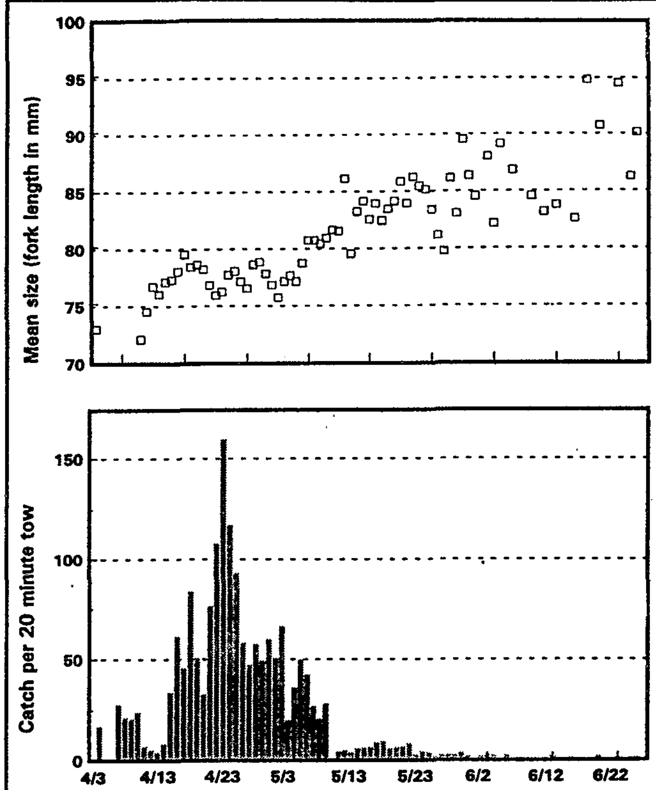

Figure 31
MEAN SIZE AND CATCH PER 20-MINUTE TOW AT CHIPPS ISLAND
April 3 to June 26, 1992

Table 30
PERCENT DISTRIBUTION OF MIDWATER TRAWL CATCH OF CHINOOK SALMON SMOLTS AT CHIPPS ISLAND, 1978-1992

Year	April	May	June
1992	78	20	2
1991	14	72	12
1990	31	56	12
1989	29	62	9
1988	27	70	3
1987	44	54	2
1986	37	55	8
1985	26	63	11
1984	11	66	23
1983	19	49	32
1982	18	49	33
1981	34	50	16
1980	14	34	52
1979	19	52	29
1978	27	40	33
$\bar{X}$ (1978-1992)	29	53	18

Table 31 identifies salmon caught at Chipps Island by race, using the most recent size criteria[1].

As in past years, we estimated absolute production of juvenile Chinook salmon passing Chipps Island between April and June. In the past, we used an efficiency rate of 0.0055, based on the average efficiency from 1980 to 1984.[2] In 1992, we estimated absolute abundance at Chipps Island in two ways.

The first way is by expanding raw catches to correct for the amount of time and area sampled in each month. The fraction of time sampled ranged from 0.065 to 0.132, and the fraction of the channel width sampled is 30/3900 feet = 0.007692. In this expansion process, we assume salmon are equally distributed in time and space and that the net is 100% efficient. Table 32 shows absolute abundance for all Chinook salmon and for each race using this method.

The second way, which is consistent with the past methodology, uses the formula:

$$N_i = n_i / t_i(0.0055)$$

Where:

N_i = Annual number of absolute abundance,

n_i = Number of salmon caught throughout the season with the midwater trawl at Chipps Island,

t_i = Fraction of time sampled, and

0.0055 = Estimated average fraction of smolts passing Chipps Island that are collected by the midwater trawl.

Past estimates of absolute abundance have been generated using method 2, although they should be recalculated based on method 1 to see how different they would be. However, the estimates should still provide a general index of the absolute production passing Chipps Island in these years.

Table 31
CHINOOK SALMON CAUGHT IN THE MIDWATER TRAWL AT CHIPPS ISLAND, BY RACE*
April 3 through June 26, 1992

	Fall		Spring		Winter		Late-Fall	
Month	Unmarked	Ad Clip	Unmarked	Ad Clip	Unmarked	Ad Clip	Unmarked	Ad Clip
April	13,290	362	2,725	13	66	2	0	0
May	3,633	175	224	1	1	0	0	0
June	158	0	0	0	0	0	0	0
Total	17,081	537	2,949	14	67	2	0	0

*Based on size criteria established by Frank Fisher, DFG, February 1992.

Table 32
EXPANDED NUMBER OF CHINOOK SALMON CAUGHT IN THE MIDWATER TRAWL AT CHIPPS ISLAND, BY RACE*
April 3 through June 26, 1992
Corrected for the Fraction of Time Sampled by Month and the Cross Sectional Area Sampled

	Total All Races	Fall		Spring		Winter		Late-Fall	
Month	(Unmarked)	Unmarked	Ad Clip	Unmarked	Ad Clip	Unmarked	Ad Clip	Unmarked	Ad Clip
April		15,411,754	379,837	1,427,014	13,640	34,626	2,098	0	0
May		3,602,719	172,355	195,992	984	984	0	0	0
June		316,012							
Total	20,989,101	19,330,485	552,192	1,623,006	14,624	35,610	2,098	0	0
Ad Clips Released			1,546,432						

*Based on size criteria established by Frank Fisher, DFG, February 1992.

1 Frank Fisher, DFG, February 1992.
2 Methods for determining efficiency and expanding the catches to absolute estimates are provided in USFWS Exhibit 31, Appendix 12, page 125, 1987.

For 1992, estimated absolute abundance was 20,989,101 using method 1 and 28,617,981 using method 2. Considering the number and types of assumptions necessary to make these estimates, the values are remarkably close and serve as a good indicator of the production moving out of the delta between April and June 1992.

Some of the reasons for questioning the efficiency method of expansion (method 2) are:

- Estimates of survival through the delta using the differential ocean recoveries of two groups of marked fish (Sacramento or Courtland and Port Chicago) are not always larger than those obtained with the trawl. If we have a consistent bias associated with net efficiency of the trawl, we would expect the trawl estimates of survival always to be lower.
- Although both the ocean and trawl index of survival through the delta is measuring survival in some years to be over 1, they do track each other very closely (Figure 32), suggesting the correction for net efficiency may not be necessary.

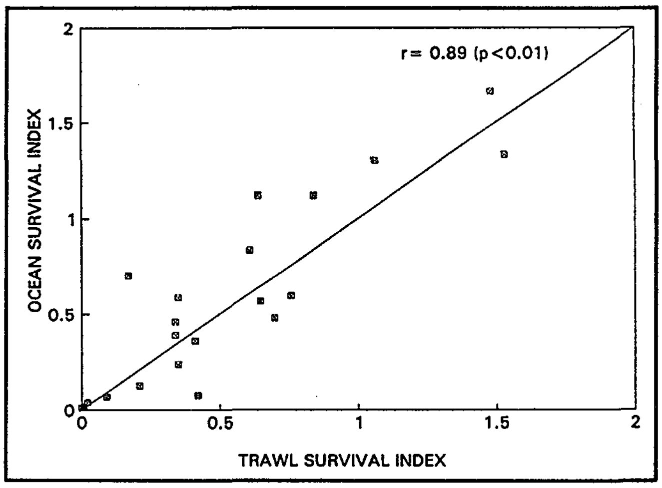

Figure 32
SURVIVAL THROUGH THE DELTA FOR FISH RELEASED AT MILLER PARK AND AT COURTLAND, 1978 TO 1989

Montezuma Slough Trawl

We sampled in Montezuma Slough for a 10-day period in late April, with concurrent trawling at Chipps Island, to evaluate the potential impact of the Suisun Marsh Salinity Control Gates[1] on Sacramento River smolts migrating to the ocean. Similar paired sampling occurred in 1987.

Concurrent sampling in Montezuma Slough and Chipps Island in 1987 and 1992 showed that a small, yet equal percentage ($p<0.01$) of fish leaving the western delta were diverted into Montezuma Slough both with (1992) and without (1987) the Suisun Marsh Salinity Control Gates in place. In both years, 0 to 2.72% (average 0.70%) of fish leaving the western delta were diverted into Montezuma Slough, where presumably their survival would be less because migration would be delayed or the distance to the ocean would be increased (Table 33).

Coleman Hatchery Smolt Contribution

Between April 6 and April 21, 1992, Coleman National Fish Hatchery released 13,839,767 unmarked smolts at Princeton. We measured a survival index between Princeton and Chipps Island of 0.42 for a group of marked fish released on April 17. If we assume a similar survival rate for the unmarked fish, then an estimated 5.8 million survived to Chipps Island. This equals 21 to 28% of the estimated 21 to 28 million smolts passing Chipps Island from April to June.

In 1991, survival from Princeton to Chipps Island was somewhat lower, at 0.36. The release in 1991 was about 2 weeks later (May 2) than in 1992, so higher temperatures may have contributed to the lower survival.

To further evaluate Coleman's total contribution to salmon production in the Central Valley, smolts that develop from fry released at Coleman should be included. During February and March 1992, about 11,090,154 unmarked fry from Coleman were released near Red Bluff.

1 Sometimes referred to as Montezuma Slough Control Structure.

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Table 33
MIDWATER TRAWL CATCHES AT CHIPPS ISLAND AND MONTEZUMA SLOUGH, EXPANDED FOR TIME, CHANNEL SIZE, AND PERCENT OF FISH DIVERTED INTO MONTEZUMA SLOUGH FOR 1987 AND 1992

Date	Chipps Island Expanded Catches	Montezuma Sl. Expanded Catches	Total Expanded Catches	Percent of Fish Diverted to Montezuma Sl.
		1987		
04/06	658	—	658	0.00
04/07	—	0		
04/08	1,711	—	1,711	0.00
04/09	—	0		
04/14	—	40	7,014	0.57
04/15	6,974	—		
04/16	—	60	8218	
04/18	8,158	—		
04/21	10,658	100	10,758	0.93
04/23	25,658	60	25,718	0.23
04/28	24,342	100	24,442	0.41
04/29	22,632	260	22,892	1.14
04/30	43,289	560	43,849	1.28
05/01	30,132	400	30,532	1.31
05/02	46,316	460	46,776	0.98
05/03	67,895	260	68,155	0.38
05/04	38,947	300	39,247	0.76
05/05	47,632	260	47,892	0.54
05/06	45,526	660	46,186	1.43
05/07	58,816	340	59,156	0.57
05/08	55,526	140	55,666	0.25
05/09	27,368	440	27,808	1.58
05/10	59,474	100	59,574	0.17
05/11	35,789	0	35,789	0.00
05/12	30,526	240	30,766	0.78
05/13	43,421	360	43,781	0.82
05/14	20,921	260	21,181	1.22
05/15	15,132	140	15,272	0.92
05/19	35,789	0	35,789	0.00
05/21	19,474	340	19,814	1.72
05/26	4,342	60	4,402	1.36
05/28	5,000	140	5,140	2.72
1987 Mean ($\bar{x}$)				0.81
		1992		
04/20	104,737	200	104,937	0.19
04/21	146,974	620	147,594	0.42
04/22	215,789	720	216,509	0.33
04/23	155,263	1,560	156,823	0.99
04/24	123,553	620	124,173	0.50
04/27	77,105	1,220	78,325	1.56
04/29	83,684	1,100	84,784	1.30
04/30	68,816	360	69,176	0.52
05/01	95,395	960	96,355	1.00
1992 Mean ($\bar{x}$)				0.76

For Coleman hatchery fry and smolts released at Red Bluff Diversion Dam in 1987 and 1988, smolt survival is estimated at three times that of fry[1]. If fry survival in 1992 is similar, then the 11 million fish released at Red Bluff Diversion Dam in 1992 would equate to 3.2 million smolts. This would increase Coleman's contribution to the overall juvenile production at Chipps Island to between 32 and 43%.

Survival of Coded-Wire-Tagged Smolts in the Northern and Central Delta

In 1992, we released 300,000 coded-wire-tagged fall smolts at two sites in the northern delta (Ryde and Georgiana Slough) on three days (April 6, 14, 27). The goal was to determine survival of fish diverted into the central delta via Georgiana Slough relative to those remaining in the Sacramento River at low to moderate temperatures and under different flow and export rates.

Results of tests with the fall-run releases would be used in assessing survival of winter-run juveniles through the northern and central delta. Migration to the ocean via the central delta is a longer route and exposes smolts to increased predation, higher temperatures, a greater number of agricultural diversions, and more complex channel configurations. In addition, upon reaching the mouth of the Mokelumne River, on the lower San Joaquin River, the smolts are often exposed to reverse flows, which move the net flow easterly in the San Joaquin River and southerly in Old and Middle rivers.

Results would also be used to determine the impacts to the winter run of a full barrier installed April 23 at the head of Old River for protection of fall-run San Joaquin smolts. Basic information from the 1992 coded-wire-tag experiment is presented in Table 34.

1 Smolt to fry ratio is 1 to 0.29.

Table 34
CHIPPS ISLAND TAG SUMMARY, SURVIVAL CALCULATIONS, AND EXPANDED FISH FACILITY RECOVERIES FOR CODED-WIRE-TAGGED CHINOOK SALMON RELEASED IN 1992

Code	Release Site	Release Date	Temp (°F)	Size (mm)	Number Released	Number Recovered	Fraction of Time Sampled	Estimated Survival	First Day Recovered	Last Day Recovered	Expanded Recoveries CVP	Expanded Recoveries SWP
Upper Sacramento River Releases												
5-28-12	Coleman	04/14		79	58,593	9	0.1366	0.138	04/27	05/21	0	0
5-28-13	Coleman	04/14		76	54,047	9	0.1372	0.158	04/25	05/20	0	0
5-28-14	Coleman	04/14		69	54,707	3	0.1369	0.052	04/29	05/20	0	0
Total					167,347	21	0.1368	0.117	04/25	05/21	0	0
5-28-18	Red Bluff DD	04/15		75	54,556	18	0.1370	0.313	04/27	05/19	0	0
5-28-19	Princeton	04/17		74	54,144	24	0.1389	0.415	04/24	05/03	2	0
Sacramento River Releases												
6-1-14-2-11	Ryde	04/06	64	77	53,630	78	0.1389	1.361	04/11	04/24	0	34
6-1-14-2-10	Georgiana Slough	04/06	64	74	51,846	23	0.1389	0.415	04/14	04/25	10	4
6-1-14-3-1	Ryde	04/14	63	82	42,534	97	0.1389	2.135	04/17	05/07	0	0
6-1-14-3-2	Georgiana Slough	04/14	64	81	52,374	41	0.1389	0.733	04/17	05/06	12	8
6-31-29	Ryde	04/27*	67	81	53,099	93	0.1364	1.669	04/29	05/28	0	0
6-31-30	Georgiana Slough	04/27*	67	83	51,914	11	0.1347	0.204	05/01	05/10	1	4
San Joaquin River Releases												
6-1-14-2-12	Mossdale	04/07	64	78	54,073	9	0.1389	0.156	04/13	05/05	25	2,603
6-1-14-2-13	Mossdale	04/07	64	79	53,030	11	0.1389	0.194	04/13	05/01	46	2,777
Total					107,103	20	0.1389	0.175	04/13	05/05	71	5,380
6-1-14-2-14	Mossdale	04/13	63	81	53,754	10	0.1389	0.174	04/16	04/27	37	1,734
6-1-14-2-15	Mossdale	04/13	63	82	51,830	3	0.1389	0.054	04/21	05/01	69	1,651
Total					105,584	13	0.1389	0.115	04/16	05/01	106	3,385
6-1-14-3-3	Mossdale	04/24*	69	85	53,294	6	0.1389	0.105	05/03	05/06	15	24
6-1-14-3-4	Mossdale	04/24*	69	83	51,445	2	0.1362	0.037	05/04	05/19	13	4
Total					104,739	8	0.1364	0.073	05/03	05/19	28	28
6-31-31	Mossdale	05/04*	71	85	51,262	1	0.1389	0.018	05/16	05/16	0	12
6-31-32	Mossdale	05/04*	71	83	48,455	0		0.000			8	16
Total					99,717	1	0.1389	0.009	05/16	05/16	8	28
6-31-33	Mossdale	05/12*	72	85	52,454	0		0.000			0	0
6-31-34	Mossdale	05/12*	72	87	54,163	2	0.1331	0.036	05/21	05/23	6	0
Total					106,617	2	0.1331	0.018	05/21	05/23	6	0
Mokelumne River Releases												
6-63-38	New Hope Marina	04/21	66.2	80.4	104,500	15	0.1362	0.137	04/29	05/14	8	4
6-63-39	New Hope Marina	05/06	71.6	90.3	100,700	6	0.1389	0.056	05/12	05/19	0	0

*Upper Old River Barrier was in place.

On average, survival was about 5 times greater for the Ryde groups than for the Georgiana Slough groups (Table 35). The first two releases at Ryde, on April 6 (64°F) and April 14 (63°F), had 3.3 and 3.0 times greater survival than the corresponding Georgiana Slough groups. For the April 27 release (67°F), there was an 8.3 times difference. Winter-run smolts may not experience the same magnitude of loss in Georgiana Slough as fall-run have shown, because winter Chinook are migrating during lower temperatures.

Effects of an Old River Barrier on Winter-Run Smolts

Putting a barrier into upper Old River increases reverse flows in lower Middle River and Old River, which could affect survival of winter smolts diverted into the central delta through Georgiana Slough or the Delta Cross Channel. The percent diverted with the barrier in Old River is expected to change from about 44% to 55% at lower Middle River and from about 32% to 42% at Old River near Bacon Island.[1]

Since releases were made at different temperatures, survival indices for the six groups of fish were standardized to 63°F so impacts of the barrier could be evaluated. The temperature correction was based on a multiple regression equation for survival in reach 2 (interior delta) and reach 3 (Ryde to Chipps Island via the mainstem river) using data obtained in 1983 through 1992. When results are compared among and between groups, trends are different for each site.

For the Ryde groups, temperature-corrected survival indices ranged from 2.15 on April 14 at the lowest export level to 1.43 on April 6 at the highest export level. The medium export level yielded a mid-range survival index of 1.93 on April 27 (Table 36). This was as expected, based on past modeling, which has shown that exports are important to survival.

The Georgiana Slough groups did not display that trend. Highest temperature-corrected survival (0.71) was on April 14 with the lowest exports, as with the Ryde group. However, the April 27 group had a lower survival rate (0.32) than the April 6 group (0.41). Although water temperature was higher on April 27, survival was lower than expected, even after the temperature correction. The barrier placed in upper Old River on April 23 could account for the difference.

The difference in survival due to the barrier is unknown, but it may be as great as 45%. This is based on the assumption that the survival difference between the April 6 and April 14 releases in Georgiana Slough (0.30) was due only to the increase in exports (2,425 – 1,093 = 1,332 cfs) (Table 36). Based on the mid-range export level of 1,883 cfs for the April 27 group, the estimated survival index would have been 0.59. The difference between expected survival (0.59) and the actual temperature-corrected survival index (0.32) is 45%, which may be attributable to the barrier. However, this difference is greater than the increase in percent of flow diverted at lower Old River and Middle River, estimated at 25 to 30%.

Table 35
SURVIVAL INDICES AND RATIOS FOR CODED-WIRE-TAGGED SALMON SMOLTS RELEASED IN THE SACRAMENTO RIVER AT RYDE AND IN GEORGIANA SLOUGH, APRIL 1992

	Ryde		Georgiana Slough		Ratio:			
Date of Release	Survival Index	Temperature at Release (°F)	Survival Index	Temperature at Release (°F)	Ryde / Georgiana	Flow at Antioch*	CVP + SWP Exports**	Flow at Freeport
04/06	1.36	64	0.42	64	3.2	972	4,999	9,904
04/14	2.14	63	0.74	64	2.9	1,321	1,085	11,212
04/27	1.67	67	0.20	67	8.3	736	1,345	4,615
$\bar{X}$					4.8			

* Average flow (cfs) at Antioch during the time the Ryde fish were recovered at Chipps Island.
**Five-day mean flow or export (cfs) starting on the release date.

1 Rick Oltman, USGS, personal communication.

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Table 36
FLOW AND EXPORT CONDITIONS DURING THE TIME THE MARKED FISH WERE AT LARGE DURING SPRING 1992

Date	Flow at Vernalis (cfs)	Flow at Freeport (cfs)	CVP+SWP Exports (cfs)	Flow at Antioch (cfs)	Survival	Temperature (°F)	Temperature Corrected Survival	Fish Facilities Expanded Recoveries SWP	Fish Facilities Expanded Recoveries CVP
Mossdale — Release Date to 5 Days Later (Temperature Corrected to 63°F)									
04/07	1,606	9,462	3,573	-353	0.17	64	0.13	71	5,380
04/13	1,445	11,027	2,211	1,518	0.12	63	0.07	106	3,385
04/24	1,393	5,985	2,365	836	0.08	69	0.25	28	28
05/04	1,281	5,240	3,758	1,388	0.01	71	0.28	8	28
05/12	936	6,069	2,357	929	0.02	72	0.32	6	0
Ryde — Release Date to Peak Recovery at Chipps Island (Temperature Corrected to 63°F)									
04/06	1,594	9,981	3,073	53	1.36	64	1.43	0	34
04/14	1,325	10,984	1,097	1,410	2.15	63	2.15	0	0
04/27	1,486	4,637	1,578 2,148* 1,433* 1,601*	729	1.67	67	1.93	0	0
Georgiana Slough — Release Date to Peak Recovery at Chipps Island (Temperature Corrected to 64°F)									
04/06	1,497	10,341	2,425	499	0.41	64	0.41	10	4
04/14	1,361	11,012	1,093	1,449	0.71	64	0.71	12	8
04/27	1,485	4,718	1,883	749	0.2	67	0.32	1	4

*Release Date to Complete Recovery at Chipps Island.

Recoveries at the Fish Facilities

The number of expanded recoveries at the CVP and SWP fish facilities for the Georgiana Slough groups shows the group with the highest survival had the most recovered and the group with the lowest survival had the least recovered. This would tend to support the hypothesis that the number recovered at the fish facilities reflects survival.

For Ryde, the group released April 6 was the only one to have any recoveries at the fish facilities; 34 were recovered at Tracy Fish Facility. Although survival for this group was high, it was not the highest for the Ryde groups and may, instead, reflect the higher exports and lower flows at Antioch in early April.

Effects of Exports

For the Georgiana Slough groups, results also suggest higher delta exports may have caused the lower survival rate for fish released April 6 relative to those released April 14, when exports were lower.

Effects of exports on Sacramento Basin smolts would be greatest when both the Delta Cross Channel and Georgiana Slough are open. These effects would decrease when the Cross Channel is closed, since fewer smolts would likely be diverted into the central delta, where they are exposed to greater reverse flows. As noted earlier, CWT smolts released at Ryde have higher survival than those representing fish diverted into the central delta (Table 35).

Effects of Flows at Jersey Point

Analyses of coded-wire-tagged fish released at Ryde, after correcting for temperature[1], indicated increased flow at Jersey Point, on the San Joaquin River, was beneficial to survival ($r=0.49$, $p<0.10$; Figure 33). Data from 1983 were not included in the analyses because flow of about 35,000 cfs at Jersey Point made it difficult to detect a relationship at the lower flows. In addition, data from 1986 were not used in the regression calculations.

We also evaluated the impact of Antioch flow on the Ryde raw survival indices by comparing releases made at the same temperatures. We found an average 39% increase in the raw survival index when Jersey Point (Qwest) flows were greater (Table 37).

Also, for fish released at Jersey Point from 1989 to 1991, temperature-corrected survival increased with increased flow at Jersey Point (QWEST in DAYFLOW) ($r=0.76$, $p<0.10$; Figure 34).

Table 37
TEMPERATURE, SURVIVAL, AND FLOWS DURING THE TIME SMOLTS RELEASED AT RYDE IN 1983 WERE PASSING CHIPPS ISLAND

Year	Temperature (°F)	Raw Survival Index	Jersey Point Flow (cfs)	% Increase in Raw Survival
1983	61	1.33	35,026	
1988	61	1.28	-271	4
1988	63	0.94	285	
1992	63	2.15	1,321	56
1987	64	0.88	511	
1992	64	1.36	972	35
1984	66	1.05	1,108	
1985	66	0.77	-147	27
1987	67	0.85	1,046	
1992	67	1.67	736	
1989	67	0.48	-1,563	62
1986	74	0.68	6,984	
1988	74	0.34	-1,736	50
			Mean Difference =	39

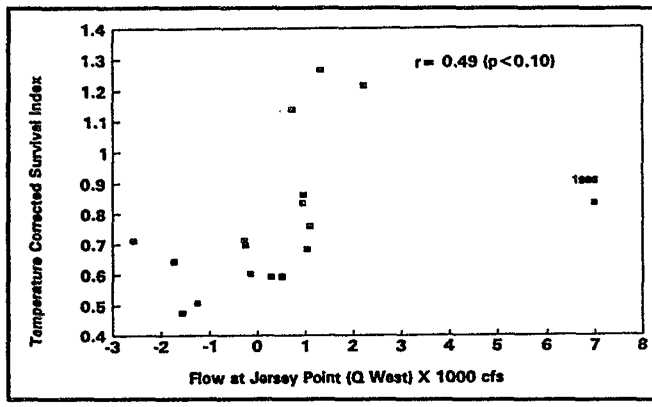

Figure 33
TEMPERATURE-CORRECTED SURVIVAL FOR FISH RELEASED AT RYDE VERSUS SAN JOAQUIN RIVER FLOW AT JERSEY POINT, 1984 TO 1992
Data from 1986 were not used in the regression calculation.

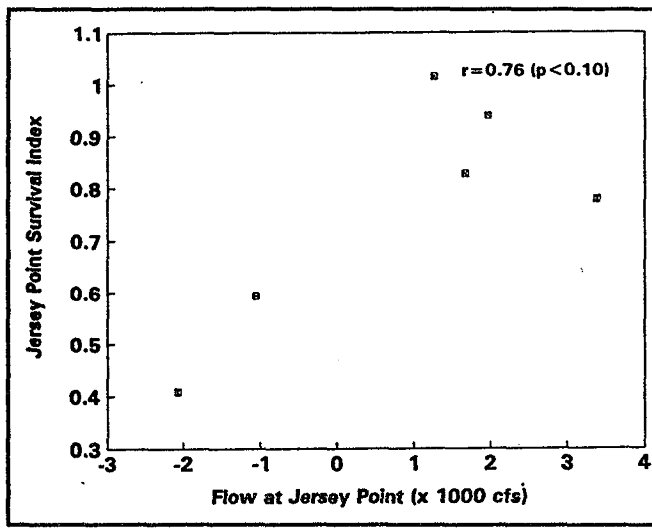

Figure 34
TEMPERATURE CORRECTED SURVIVAL FOR CWT SMOLTS RELEASED AT JERSEY POINT AND RECOVERED AT CHIPPS ISLAND, 1989 TO 1991
Temperature corrected to 61°F
Flow estimates were the 5-day mean starting on the release date.

These findings support the premise that positive net flow in the western San Joaquin River, at Antioch or Jersey Point, increases survival for fish migrating down both the Sacramento River past Ryde and the San Joaquin River past Jersey Point.

1 All indices were standardized to 61°F.

San Joaquin River Studies

Coded-wire-tag data generated since 1985 have shown, in general, that fish released in the San Joaquin River downstream of the head of Old River survive about 50% better than those released into upper Old River (Table 38). This has been demonstrated by both ocean and trawl data. This implies that natural smolts diverted into upper Old River would have greater mortality than those migrating down the mainstem San Joaquin.

A barrier at the head of Old River would force all of the migrating salmon down the mainstem San Joaquin and prevent them from being diverted into upper Old River and directly toward the SWP and CVP pumping plants.

To evaluate the effects of a full barrier at the head of Old River as a management alternative to improve survival of San Joaquin fall-run smolts, 500,000 fall-run coded-wire-tagged smolts were released at Mossdale in 1992 in lots of 100,000, one group per week for five weeks (April 7 to May 12). The full barrier was installed April 23, so three groups were released before and two groups after barrier installation. Average exports (1,979 and 1,665 cfs) were similar before and after the barrier was installed.

Table 38
SURVIVAL INDICES FOR CWT CHINOOK SALMON SMOLTS RELEASED AT DOS REIS AND IN UPPER OLD RIVER, 1985-1991

Release Date	Survival to Chipps Island	Ocean Recovery Rate	CVP/SWP Exports (cfs)	Ocean Trawl Index Dos Reis/ Upper Old River	Index, Dos Reis/ Upper Old River
Upper Old River Releases					
04/29/85	0.62				0.95
05/30/86	0.20	0.011		1.9	1.7
04/27/87	0.16	0.005		2.4	2.4
04/21/89	0.09	0.00073	High	0.8	1.5
05/03/89	0.05	0.00044	Low	2.2	2.8
04/17/90	0.02		High		2.0
05/13/90	0.01		Low		4.0
Mean	0.16			1.8	2.2
Dos Reis Releases*					
04/22,23/82	0.70**		5,598	7,861	65
04/30/85	0.59		6,311	513	70
05/29/86	0.34	0.021	5,386	2,514	70
04/27/87	0.38***	0.012	6,093	471	70
04/20/89	0.14	0.00062	10,297 (High)	112	69
05/02/89	0.14	0.00096	2,470 (Low)	790	71
04/16/90	0.04		9,549 (High)	0	68
05/02/90	0.04		2,461 (Low)	490	68
04/15/91	0.16		5,153 (High)	60	60
Mean (85-87, 89-91)	0.24				

* 5-day averages after release date.
** Original survival estimate (0.60) modified based on the ratio of recovery rates between the Dos Reis and Merced River releases.
*** Original survival estimate (0.82) modified based on the ratio of recovery rates between the Dos Reis and upper Old River releases.

Survival indices to Chipps Island ranged from 0.01 to 0.17, with the greatest survival for groups released in early April, when temperatures were lower (64 and 63°F) and the barrier was not in place (Table 36). This was not consistent with past Dos Reis and upper Old River data, which implied a barrier would be beneficial.

Since the five releases were made over a range of temperatures, we attempted to factor out the influence of temperature on survival by standardizing survival to a constant temperature (63°F), as done in previous analyses. Resulting temperature-corrected survival indices were compared.

After being corrected for temperature, survival ranged from 0.07 to 0.32, with the greatest survival for smolts released while the barrier was in place. Average survival was 0.10 without and 0.29 with the barrier. This would reflect a threefold benefit with the barrier in place, which is somewhat greater than, although of similar magnitude to, the almost double improvement in the upper Old River and Dos Reis survival data comparisons.

Expanded recoveries at the CVP and SWP fish facilities (Table 36) indicated the greatest numbers of marked fish salvaged (5,451 for April 7, 3,491 for April 13) were from the groups released when no barrier was present and uncorrected survival was greatest. The later groups also had higher temperatures at release and lower uncorrected survival indices. It is unclear whether the higher number salvaged for the earlier groups reflects higher survival, lack of a barrier at the head of Old River, or both.

While the 1992 releases without a barrier had the highest number of marked fish recovered at the facilities, the actual combined CVP and SWP expanded numbers indicate only 3 to 5% of the smolts released were recovered at the fish facilities. Even at low temperatures (63 and 64°F), we accounted for less than 25%[1] of any of the groups of fish released at Mossdale in 1992. As in recent dry years, most of the fish released at Mossdale in 1992 apparently did not survive to be salvaged at the fish facilities and indirect (in-channel) losses comprise a large fraction of the mortality.

In 1986, although temperatures were higher than in 1992, a large percentage (74%) of the fish released in upper Old River were salvaged at the facilities when flows were high in all southern delta channels (Table 39).

Table 39
PERCENTAGE OF THE EXPANDED NUMBER OF CWT CHINOOK SMOLTS RELEASED THAT WERE RECOVERED AT THE SWP AND CVP FISH FACILITIES, 1985 THROUGH 1992 (EXCEPT 1988)

Year	Upper Old River	Dos Reis	Jersey Point	Mossdale	Notes
1985	20	3	NR	NR	
1986	74	3	NR	NR	
1987	27	8	NR	NR	
1989	6.9	5	0.2	NR	High Exports
1989	2	0.6	1.6	NR	Low Exports
1990	2.5	1.7	0.2	NR	High Exports
1990	1.3	0.1	0.1	NR	Low Exports
1991	NR	8	0.5	NR	April
1991	NR	NR	0.01	NR	May
1992				0.0-5.0*	

* Estimate based on the range of recoveries for the five groups released at Mossdale between April 7 and May 12, 1992.

Installing a barrier to prevent salmon from entering upper Old River appears to increase survival of smolts migrating down the San Joaquin River. Additional data need to be collected with and without the barrier at low temperatures. We should continue to evaluate the benefit of the barrier to smolt survival at similar temperatures under a range of exports and delta inflows.

While the Old River at Head barrier alone will increase survival of San Joaquin Basin smolts, the more comprehensive approach to increasing salmon smolt survival would be to reduce exports and increase San Joaquin River flows simultaneously. Using all three actions in combination is expected to yield the greatest survival.

Similar experiments need to be repeated to confirm the 1992 results.

1 The expanded number recovered at Chipps Island plus the expanded number recovered at the fish facilities.

Future Needs

Results of these and previous studies in the delta have been used to evaluate the benefit of both operational and structural salmon protective measures for the Scoping and Water Rights phases of the Bay/Delta Water Quality Hearings and in planning for future Interagency Program salmon studies. The focus of the 1993 coded-wire tagging effort will be to further evaluate the effect of the barrier at the head of Old River on the winter-run from the Sacramento Basin and on San Joaquin Basin smolts.

Additional work is needed in the southern and central delta, where great uncertainty remains regarding smolt survival. Evaluation is also needed with regard to impacts of the pumping plants on fry entering the delta and the correlation between adult runs and the amount of water being exported.

In the San Joaquin delta, we should:

- Evaluate smolt survival under a wide range of inflow and export conditions.
- Test the benefit of a full barrier at the head of Old River to CWT smolt survival under high and low export conditions between April 15 and May 15. (This is scheduled for 1993.)
- Define the pattern of migration through the southern delta under various flows, export rates, and tidal conditions using hydraulic modeling.
- Continue to evaluate the effect of high cross-delta flow[1] on smolt survival through the San Joaquin delta. A full barrier in upper Old River with high exports would cause more reverse flows in Turner Cut, lower Old River, and Middle River and would more closely represent conditions proposed in the SWP delta alternatives projects.
- Evaluate smolt survival in the San Joaquin delta at various temperatures (60 to 70°F).

Information we have implies indirect mortality associated with the pumps is significant. Perhaps under certain conditions, those fish that live to be salvaged are a large proportion of those that survive to Chipps Island. During 1993, the Fish Facilities Committee will be releasing marked fish into Clifton Court Forebay. These releases may provide a way to measure the number of survivors at Chipps Island that are a result of the salvage process.

Modeling and recent field studies have helped us better understand the factors that may influence smolt survival in the Sacramento side of the delta. This work has identified areas needing further research. There is a need to:

- Expand the knowledge to races other than fall-run Chinook and impacts of the pumping plants on their survival and distribution.
- Evaluate smolt survival in the central delta under various temperature and flow conditions, particularly reverse flows.
- Further evaluate reasons for high levels of unexplained mortality in the central delta.

In early 1992, the Delta Cross Channel gates were closed to protect winter-run salmon from being diverted into the central delta and being impacted by the pumps. Additional work is being proposed to release late-fall marked fish in November and December 1993 to evaluate the differential mortality of being diverted into the central delta for the endangered winter run.

The emphasis in central valley Chinook research and management has shifted from maximizing production to maintaining (or restoring) the viability of all races and runs of wild salmon. This new emphasis requires a year-round monitoring program in the estuary and development of new techniques to effectively sample the less abundant races. Some of the experimental methods used in the 1992 pilot program should be incorporated into the regular monitoring program. More new techniques need to be explored to effectively sample the diverse habitats in the estuary and describe the spatial and temporal distribution of all developmental stages of salmon.

1 Such as would occur if the SWP were to use its full pumping capacity of 10,300 cfs.

Chapter 6

OTHER ESTUARINE FISHES

Delta Smelt

Dale Sweetnam
Department of Fish and Game

The delta smelt study was fully implemented in January 1992. Its purpose is to monitor and investigate factors potentially affecting delta smelt population levels to ensure their long-term survival and to address management and recovery objectives set forth by the California Fish and Game Commission. It is also intended to provide the U.S. Fish and Wildlife Service with information relevant to the Federal listing of the delta smelt as a threatened species. Federal listing took place in March 1993 and will go into effect on April 5, 1993. The California Fish and Game Commission is also reviewing the status of delta smelt and is expected to make a listing decision in 1993.

The study plan was originally divided into ten projects, but several projects have been added as research needs have been identified. The projects can be classified as monitoring and field research, laboratory studies, and modeling studies.

Monitoring and Field Research

Monitoring is structured around improving knowledge and understanding of delta smelt life history requirements and losses of delta smelt in State, Federal, and agricultural diversions. Such monitoring is essential to reducing water management impacts on delta smelt.

Midwater Trawl Surveys During Spawning Season

The fall midwater trawl survey was extended to document the distribution of delta smelt during the spring spawning season. Delta smelt may spawn from mid-February to June or July.[1] In 1992, peak spawning occurred in April and May.[2] Complete surveys were conducted in January, February, March, and June, with a limited one-day survey in April due to boat scheduling constraints. Delta smelt spawn in the rivers and adjoining sloughs in the western delta and Suisun Marsh[3], areas under tidal influence with moderate to fast flows[4], and dead-end sloughs[5]. Ripe and near-ripe spawning delta smelt have been captured recently in the Cache Slough area.

Single 12-minute stepped-oblique midwater trawl tows were made monthly at about 119 sites throughout the estuary, including existing fall midwater trawl stations, plus additional stations near spawning areas (Figure 35). These additional stations included one in the Napa River, three in the central delta, one in Cache Slough, four on the north and south forks of the Mokelumne River, and six on the Sacramento River as far upstream as Hood. Drought conditions did not warrant extra sampling in San Pablo Bay.

During the spring survey, to reduce delta smelt escapement yet retain consistency in the sampling method, 1/8-inch bobbinnet covered the rear end of the net and cod-end to measure losses of delta smelt and to produce a correction factor for the larger mesh net.

1 J.C.S. Wang, *Early Life Stages and Early Life History of the Delta Smelt, Hypomesus Transpacificus, in the Sacramento-San Joaquin Estuary, with Comparison of Early Life Stages of the Longfin Smelt, Spirinchus Thaleichthys.* Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. Technical Report 28. 1991.
2 Larval sampling survey data.
3 P.B. Moyle, B. Herbold, D.E. Stevens, and L.W. Miller. "Life History and Status of Delta Smelt in the Sacramento-San Joaquin Estuary, California". *Transactions of the American Fisheries Society.* 121(1). 1992.
4 Wang 1991.
5 L.D. Radtke. "Distribution of Smelt, Juvenile Sturgeon, and Starry Flounder in the Sacramento-San Joaquin Delta with Observations on Food of Sturgeon". pp. 115-129 in *Ecological Studies of the Sacramento-San Joaquin Delta.* J.L. Turner and D.W. Kelley, editors. California Department of Fish and Game, Fish Bulletin 136. 1966.

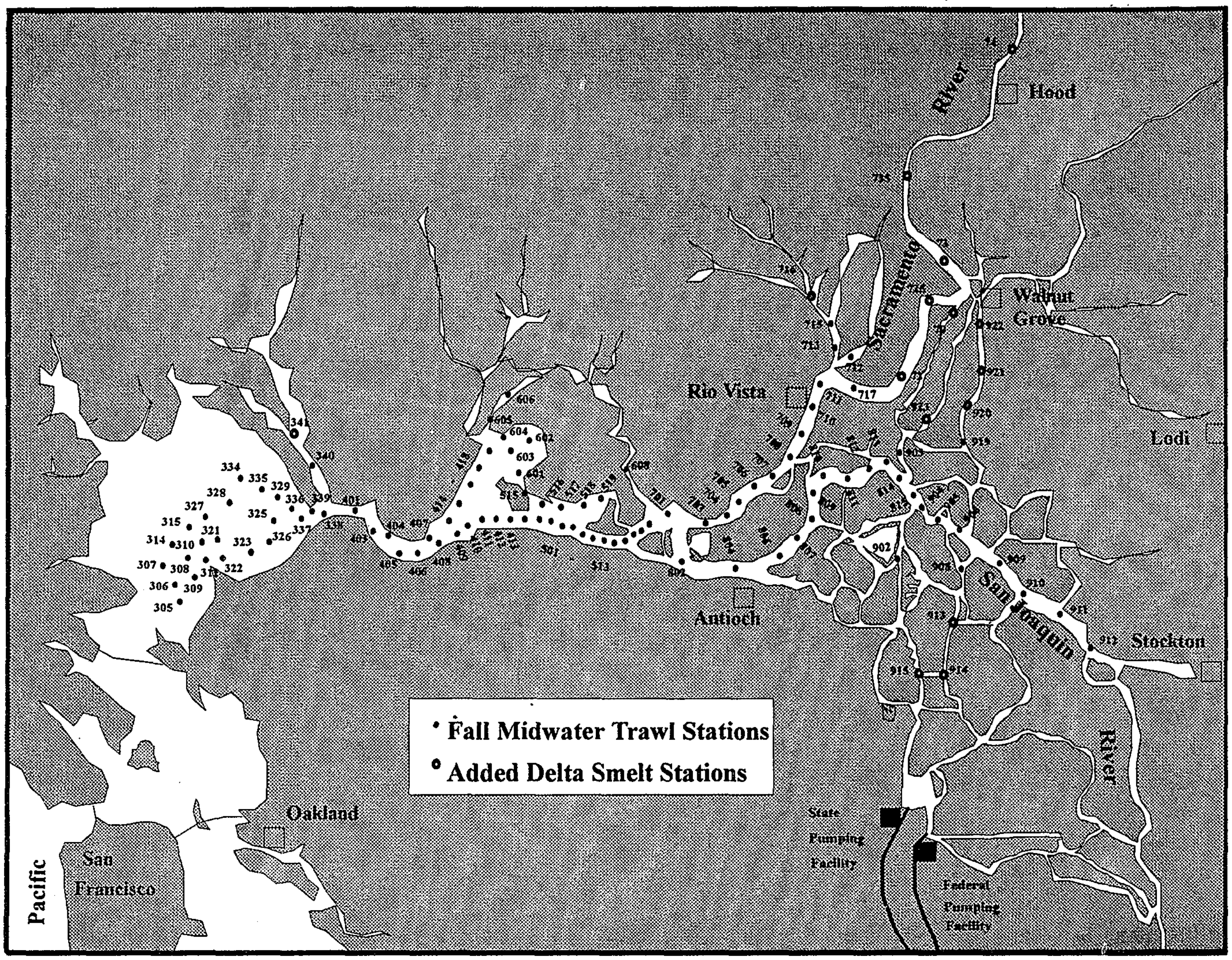

Figure 35
DFG DELTA SMELT MIDWATER TRAWL STATIONS, 1992

Beach Seine Surveys *During Spawning Season*

Beach seine surveys were conducted in association with the Interagency salmon fry program to identify adult delta smelt abundance and distribution during spawning season in low-velocity areas such as side channels, backwater locations, and dead-end sloughs. Previous reports are vague as to habitat where delta smelt actually spawn. For example, Wang reports that delta smelt may deposit eggs over submerged branches and stems or in open water above sandy or rocky substrates.[1] Beach seining should aid in identifying whether delta smelt use these low-velocity areas to spawn.

The beach seine survey was conducted weekly from December through June at about 35 sites, including Suisun Marsh, Cache Slough, Sacramento River, the delta, and other suitable habitat that would allow proper fishing of the seine. A total of 19 delta smelt were captured at stations ranging from Discovery Park in Sacramento on the Sacramento River to the lower San Joaquin River near Antioch.

1 J.C.S. Wang. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories.* Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report 9. 1986.

Artificial Substrate Egg Collection

Delta smelt eggs are demersal and attach to aquatic vegetation.[1] Hence, artificial egg-collecting substrates could be used to specifically identify spawning locations. Eggs of other smelt species have been similarly collected.[2,3]

Sampling required placing frames (1 m^2) fitted with burlap sheets[4] to which eggs adhere in areas of adult fish concentrations[5]. Frames were raised and inspected every 2 or 3 days. Sampling was conducted from April through May. Artificial substrates were placed in response to high abundances of adult delta smelt identified by the trawl or seine surveys, suitable habitat, and accessibility of locations. Five sites in the Cache Slough area, in areas of high to moderate flow, were selected (Figure 36).

No delta smelt eggs were collected in 1992 from the artificial substrate frames or natural substrate inspection despite the simultaneous presence of ripe delta smelt in the study area. The failure of the artificial substrate frames to collect eggs may have been due to a 2- to 3-mm layer of silt that accumulated on the frames, which could have covered attached eggs or prevented broadcasted eggs from attaching. Other possibilities are that the flat design of the frames, combined with the silting, may not have allowed the frames to stand out as suitable spawning structure, or the small collection surface of the frames may have been inadequate to collect descending broadcasted eggs. Temperatures ranged from 17 to 23°C during April and May. This is consistent with the normal temperature range of 15 to 23°C and largely within the delta smelt spawning range of 10 to 19°C. The greatest concentration of ripe delta smelt was found at Station 3, where an apparent attraction current was caused by tidal exchange between the slough and a flooded tract.

The artificial substrate frames are being modified for the 1993 spawning season. A curved surface will be used to minimize silting. Potentially suitable spawning substrates are being tested for egg attachment at the University of California delta smelt culturing project.

Timing, Distribution, and Abundance of Larvae and Their Food Supply

This project monitors larval delta smelt occurrence, distribution, and abundance along with associated environmental conditions. Larval fish surveys are critical to identifying factors controlling survival and abundance of young smelt and their food supply.

A 505-m nitex egg and larva net attached to a sled was towed in a stepped-oblique fashion. A Clarke-Bumpus net of 154-m mesh was attached to the upper frame of the net to collect zooplankton samples. Single 10-minute tows were made at stations throughout the estuary (Figure 37). Sampling began on February 12, 1992, and was conducted every fourth day until late March, when effort was increased to every second day. All historical systematic egg and larval stations were sampled except for upper Sacramento River stations (81-85). To identify optimal delta smelt spawning areas, additional areas sampled included Cache Slough, North Fork and South Fork Mokelumne River, and several dead-end sloughs. All samples were sorted, and larval smelt were identified to species in the laboratory. Gut analysis was used to identify prey items and allow comparison with abundance of prey species in the Clarke-Bumpus net and in routine zooplankton monitoring.

Processing of 1991 samples was completed in 1992. Catches of larvae indicated spawning was limited during February, March, and April in the Sacramento River between Isleton and Sacramento and in the Cache Slough area. The most prominent spawning peak was in mid-April, based on back-calculating 9 to 14 days for egg incubation, from peak abundance of larvae during the first part of May.

Greatest concentrations of delta smelt larvae were between Isleton and Walnut Grove (Stations 72-735), and in the northern part of Georgiana Slough (Station 70) during April

1 Moyle *et al.* 1992; Wang 1986.
2 D.A. Misitano. "Technique for Incubating and Hatching Eggs of Surf Smelt for Bioassay". *Progressive Fish Culturist.* 39(4):187. 1977.
3 J.R. Moring. "Smelt Culture ... A New Business for Maine". *Maine Fish and Wildlife.* Summer 1985 pp. 13-15. 1985.
4 Moring 1985.
5 For methods, see G.T. McCabe. "Use of An Artificial Substrate to Collect White Sturgeon Eggs". *California Fish and Game.* 76(4):248-250. 1990.

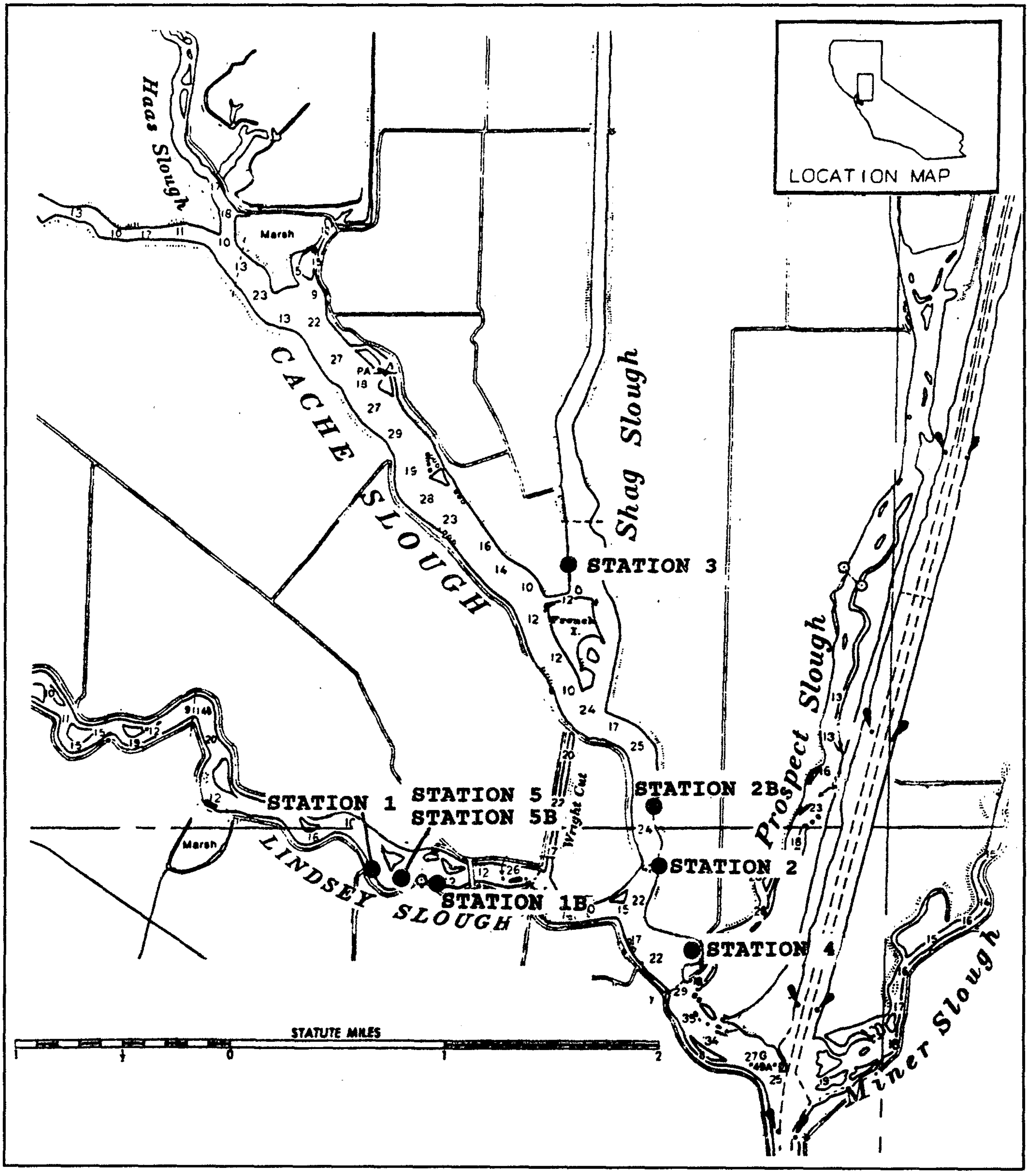

Figure 36
ARTIFICIAL SUBSTRATE STATIONS IN CACHE SLOUGH AND LINDSEY SLOUGH, 1992

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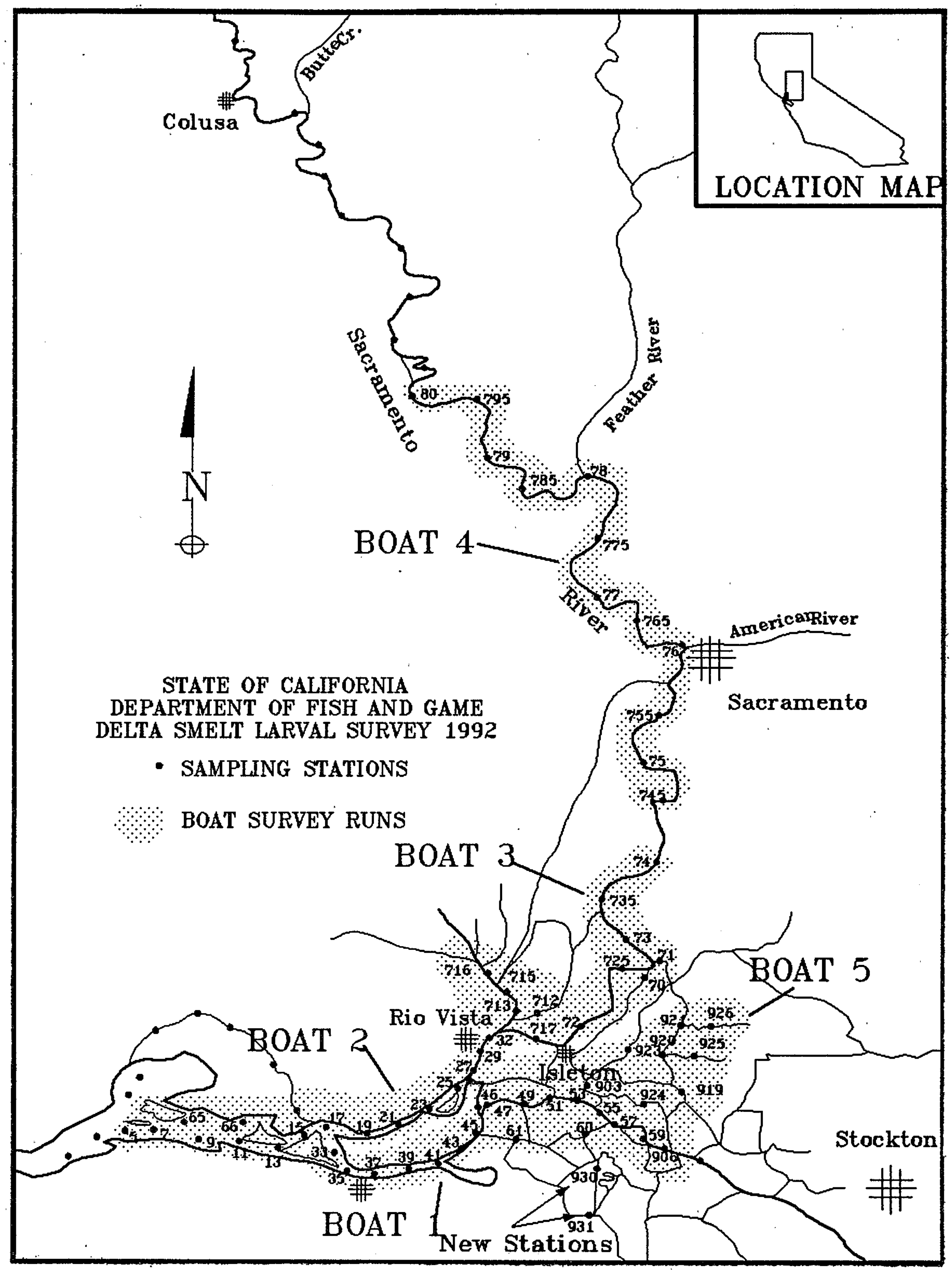

Figure 37
LARVAL DELTA SMELT SURVEY STATIONS, 1992

C-042935

through June. Abundance of delta smelt larvae was consistently low throughout the study period. Peak concentration in the Sacramento River was only 0.049 larvae per cubic meter at station 72 on May 14 (Figure 38); peak concentration in the San Joaquin River was even lower at 0.035 larvae per cubic meter at Station 59 on May 6 (Figure 39). Delta smelt larvae were still present in the Isleton/Walnut Grove area during June, although abundance decreased. A downstream shift in distribution occurred in July, when larvae were in the Sacramento River near Chipps and Decker islands. In the San Joaquin River, the center of larval distribution was from West Island to Venice Island (Stations 43-51) during May and June. The greatest concentrations were near Andrus, Bouldin, and Venice islands (Stations 51-61) during May. Larval delta smelt were also found in the Mokelumne River and adjacent sloughs.

Preliminary results of the 1992 delta smelt samples suggest spawning was sporadic in February and March. Spawning occurred between Isleton and Verona on the Sacramento River and again in Cache Slough. Newly hatched prolarvae (4-6 mm) were in those areas in April, while postlarvae (6-18 mm) were mostly found in Cache Slough in May and June. Prejuveniles (18-25 mm) were primarily downstream between Sherman and Decker islands during June, near the upper limit of the entrapment zone. Spatial and temporal distribution in the San Joaquin River was similar to 1991. Stations 31 to 61 mostly contained postlarvae. Considering the size of the postlarvae[1] (6-8 mm) collected at the beginning of April, spawning likely occurred at the beginning of March, which was about 2 weeks earlier than in the Sacramento River. Postlarvae were also found in the Mokelumne River and adjacent sloughs in April and May.

These results indicate that in 1991 and 1992, delta smelt spawned at water temperatures of 10-19°C. Optimal spawning temperatures were 14-19°C based on back-calculating approximate larval ages and the 9- to 14-day egg incubation period from the first and latter part of prolarvae peak abundance in the Sacramento River. No prolarvae were found after water temperatures reached 19°C.

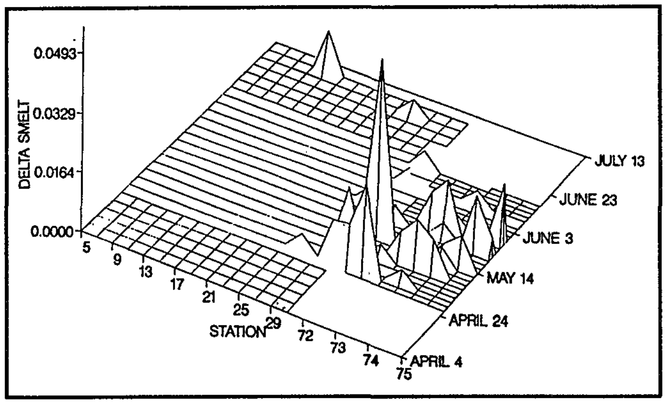

Figure 38
SPATIAL AND TEMPORAL DISTRIBUTION OF LARVAL DELTA SMELT IN 1991, SACRAMENTO RIVER, ROE ISLAND TO RIO VISTA

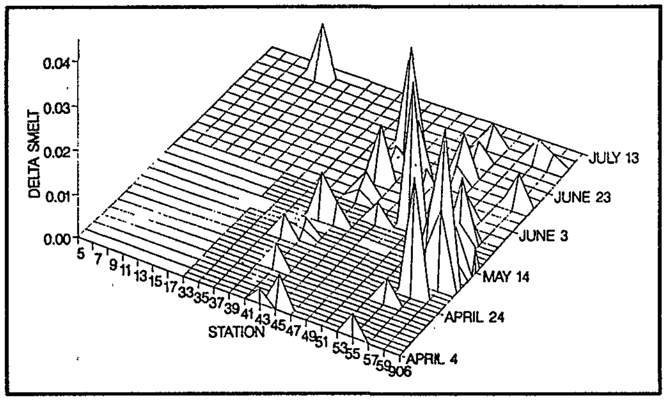

Figure 39
SPATIAL AND TEMPORAL DISTRIBUTION OF LARVAL DELTA SMELT IN 1991, SAN JOAQUIN RIVER, ROE ISLAND TO MEDFORD ISLAND

Spatial and temporal distributions of larvae in 1991-1992 were similar to 1989-1990.[2] Prolarvae and small postlarvae were generally found where specific conductance was 200-500 µS/cm. Late postlarvae and early juveniles moved downstream to the upper end of the entrapment zone with conductivities of 1,000-2,000 µS/cm. The lack of prolarvae in the San Joaquin River and presence of prolarvae in the Sacramento River and Georgiana Slough, which connects the two river systems, suggest that the San Joaquin River may draw larvae that were spawned in the Sacramento River. However, DWR collected prolarvae in samples from the San Joaquin River, Old River, and Rock Slough,[3] suggesting that spawning also occurred in the central and southern delta.

1 Aging of postlarvae was based on culturing study from the University of California.
2 Wang 1991.
3 See Chapter 7, this report.

Estimated Diversion Losses of Delta Smelt Larvae

The significance of losses of smelt larvae to State and Federal water project diversions will be assessed through a combination of the estuary-wide larval fish survey and DWR sampling in the southern delta using the same sampling methods.[1] Also, USBR has been sampling eggs and larvae at the CVP diversion and at several other sites in the estuary, using several different types of sampling devices.[2] Sampling in 1992 began on February 12. Estimated losses of delta smelt larvae in 1992 are 554,407 at the SWP diversion and 645,496 at the CVP diversion.

An agricultural diversion study was initiated by DWR in May 1992 to determine the magnitude of larval fish losses to agricultural diversions in the delta. Sampling has been conducted at five sites. Results are presented in Chapter 7 of this report. There are plans to increase the number of sampling sites in 1993.

Laboratory Studies

Laboratory studies will assist in evaluating possible environmental threats to the delta smelt population. Studies will include an attempt to create a "refuge" population.

Procedures to Differentiate Delta Smelt from Longfin Smelt During Early Larval Stages

The purpose of this project, which has been completed, was to produce a reliable key to separate larval delta smelt from longfin smelt starting at hatching size of 5.5 to 6 mm[3]. Larval delta smelt are easily confused with the similar longfin smelt, and these species coexist over a large portion of their range. Proper identification is necessary if many of the projects included in this study are to be successful.

Dr. Johnson Wang has developed a key based on taxonomic characteristics such as morphological differences of gas bladder formation and relationship of the gut to the gas bladder. This key was published in Interagency Technical Report 28[4] and is being used in the laboratory for smelt identification.

Diet Analysis and Zooplankton Abundance

Delta smelt diet analysis and zooplankton abundance for 1992 has not been completed. Diet analysis for 1991 has been completed, but the data are awaiting keypunching. Preliminary results indicate 34% (34/100) of the delta smelt analyzed had food present in the gut. For larvae less than 18 mm[5], the diet consisted mainly of calanoid copepodids (present in 46% of the stomachs with food), harpacticoid copepods (36%), copepod nauplii (25%), and cyclopoid copepodids (21%). Other food items included the cladocerans, *Bosmina longirostris* and *Diaphanosoma* sp., *Eurytemora affinis, Sinocalanus doerri,* and adult calanoida. For larvae greater than 18 mm[6], the diet consisted mainly of calanoid copepodids. Other food items included *S. doerri* the amphipod *Gammarus* sp., and cyclopoid copepodids.

Cohort Identification from Otoliths

Otolith (ear bone) extraction from larval and juvenile delta smelt has begun and analysis began in September, when the new image analysis system became fully operational. The purpose of this project is to estimate delta smelt ages to help determine when and where most of the population was produced. Otoliths are currently being extracted from larval delta smelt of known age that were hatched in the laboratory to age-verify deposition of circuli (daily growth rings). This verification will aid in aging field-caught larvae to identify cohorts. This information, combined with environmental information such as food supply, water temperature, salinity, diversions, and other water quality and quantity factors, will improve understanding of how environmental conditions affect delta smelt growth and survival.

1 Study design and additional results are presented in Chapter 7, this report.
2 For methods, see J.F. Arthur. *Continuous Monitoring of Striped Bass Eggs and Larvae in the San Francisco Bay-Delta Estuary: A Potential Management Tool.* U.S. Bureau of Reclamation, Mid-Pacific Region. 1990.
3 Wang 1986.
4 Wang 1991.
5 Total 93, range 3.8-16 mm SL, mean length 6.8 mm SL, 28 with food present.
6 Range 19-30 mm SL, mean length 22.2 mm, 6 with food present.

Evaluation of Effects of Toxicity and Starvation on Larvae

The purpose of this project is to use histological and morphometric methods to compare condition of larval delta smelt collected in the field with that of larvae held under various conditions in the laboratory. These analyses will allow evaluation of the extent to which delta smelt condition is affected by variations in their food supply, toxicity, and parasites. This knowledge is important to overall evaluation of factors responsible for the population decline and for development of a recovery plan.

Histological analyses involve microscopic examination of retina attachment and digestive tract tissue development to indicate whether or not starvation is occurring. Liver histology measures the extent to which larval fish have been exposed to toxicity. Morphometric analyses consist of measuring various ratios involving fish length and body depth at various locations along the length of the fish. Body shape is then used as a measure of condition. Comparison of the condition of delta smelt larvae collected at different times and locations during the spawning season will allow evaluation of how often larvae are subjected to starvation or toxicity and whether starvation is associated with the lack of any specific food item or particular times or areas.

Monitoring Salvage Losses of Older Juveniles and Adults

Fish screens at the State and Federal water project diversions prevent many older juvenile and adult delta smelt from entering the aqueducts and canals south of the delta. However, some portion of the smelt that approach the screens pass through them. Many other smelt that enter the diversion facilities probably die due to handling associated with screening and trucking. Survival of 2,590 delta smelt retained at the Byron growout facility was reported to be 0% in 1989.[1] Use of salt to reduce stress during handling and trucking appears to reduce mortality in striped bass, American shad, threadfin shad, and white catfish.[2,3,4] Studies aimed at reducing mortality could be done on delta smelt salvaged at the facility or maintained in the laboratory.

Improved sampling procedures planned for 1992 at the SWP and CVP diversions should increase accuracy of estimates of delta smelt lost to these diversions. Studies of the effects on delta smelt of handling and trucking, using methods similar to Raquel (1989) or Cech *et al* (1988), are being considered. However, recent results from attempts to transport live delta smelt for culture work at the University of California at Davis have proven that delta smelt are very fragile and do not transport well.

Electrophoretic Analysis

The purpose of this project is to document genetic differences between delta smelt *(Hypomesus transpacificus)*, wakasagi *(Hypomesus nipponensis)*, and longfin smelt *(Spirinchus thaleichthys)*. Studies of these related species are needed because hybridization is possible, and wakasagi adults and larvae have been collected from the American River[5]. Loss of genetic integrity is a threat to the delta smelt population.

Delta smelt, longfin smelt, and wakasagi will be collected from throughout the estuary and possibly from other locations. Electrophoretic analysis of proteins will be used to document genetic differences between species and populations.

Culture and Production Techniques

The purpose of this project is to develop culture and production techniques for delta smelt. DWR contracted with Dr. Serge Doroshov at UC-Davis to develop culture techniques and with BioSystems Analysis, Inc., to work on hatchery production techniques. Success would yield fish for

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1 D. Odenweller. "Delta Fish Facilities Study". Chapter 8 in *1989 Annual Report*. P.L. Herrgesell, Compiler. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. Sacramento. 1990.

2 P.F. Raquel. *Effects of Handling and Trucking on Chinook Salmon, Striped Bass, American Shad, Steelhead Trout, Threadfin Shad, and White Catfish Salvaged at the John E. Skinner Fish Protective Facility.* Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report 19. 1989.

3 J.J. Cech, P. Young, M. Brick, T. Hopkins, and S. Bartholow. *Striped Bass Exercise Stress in Freshwater: Physiological Responses to Recovery Environment. Final Report to California Department of Fish and Game.* Department of Wildlife and Fisheries Biology. University of California, Davis. 1988.

4 Odenweller 1990.

5 Unpublished data.

the condition investigations and perhaps release of cultured fish into the wild. DFG supplied these contractors with live adults from the estuary. Initial attempts at maintaining them in good condition were unsuccessful. Of 257 delta smelt collected in beach seines and trawls in 1991, only 2 survived more than 48 hours. The smelt apparently died due to stress incurred not only during capture but during handling and transport.

Alternative capture methods were evaluated, and in 1992 a larval purse seine capture technique proved more successful. Handling is kept at a minimum by transferring the smelt in water directly to a specially designed transport tank. Transport procedures now include transporting delta smelt in a shock-dampened ice chest fitted with a water movement dampener and aerated with pure oxygen. A total of 488 smelt were captured and transported in this manner. Their 48-hour survival rate was greater than 64%. Most of these smelt were captured in Cache Slough shallows, where tidal flows were moderate. An additional 107 delta smelt collected from Skinner Fish Facility had a survival rate of 53%.

Two culture sites were prepared specifically to culture delta smelt, one at UC-Davis and one at the now closed Central Valley Hatchery. Both culture sites provided successful delta smelt spawning and hatching. Over 7,000 eggs were produced, with a wide range of viability (0-84%). Hatching success ranged from 0 to 90%, but larvae only survived up to 36 days. Laboratory observations indicate that delta smelt are broadcast spawners, spawning occurs either at dusk or in the evening, hatching occurs between 8 and 14 days post spawn, feeding begins at 4 to 5 days post hatch when two-thirds of the yolk is absorbed, and larvae will accept a wide range of both natural and artificial diets.

In fall 1992, we started collecting adults for the second year of culture work and for research on the reproductive cycle and gametogenesis of delta smelt. Only one contractor, Dr. Serge Doroshov at UC-Davis, will be culturing smelt this year. Full-scale production is not yet feasible because of limited delta smelt fecundity and low survival of larvae.

Reproductive Cycle and Gametogenesis

The purpose of the study on reproductive cycle and gametogenesis will be to investigate the annual reproductive cycle of delta smelt and examine population sexuality, gonadal growth, normal and abnormal gametogenesis, and fecundity. This information will provide crucial information on reproduction of a threatened population.

Environmental Tolerances

The purpose of this study is to investigate the effect of three environmental factors — temperature, salinity, and water velocity — on the physiology of delta smelt. Research will be conducted by Dr. Joseph Cech's laboratory at UC-Davis. Results should provide a range of tolerances of delta smelt to these factors.

Modeling

Modeling of delta smelt population dynamics and persistence will attempt to develop extinction probabilities and will evaluate how changes in water management may affect delta smelt. Data from the DFG summer tow-net and fall midwater trawl surveys will be used, as well as environmental data (flow, diversions, reverse flow, *etc*), to look for spatial relationships that will aid in predicting extinction probabilities. A population dynamics model will also be produced.

Dr. Louis Botsford from UC-Davis will head this project.

Current Status

Information from seven independent datasets has demonstrated a dramatic decline of the delta smelt population and consistently low population levels since 1983.[1,2] A rough estimate placed the delta smelt population at several hundred thousand fish in 1985.[3] Based on September-December midwater trawl survey data, this represents an 80% drop in the population since 1983 compared to the average from 1967 to 1982

1 D.E. Stevens, L.W. Miller, and B.C. Bolster. *A Status Review of the Delta Smelt (Hypomesus transpacificus) in California*. Department of Fish and Game, Candidate Status Report 90-2. 1990.
2 Moyle *et al* 1992.
3 Stevens *et al* 1990.

and a 90% decline from the peak level observed in 1980.[1]

The 1991 index value was 689, demonstrating a slight upward trend. However, the 1992 index plummeted to 157 (Figure 40). The abundance index for September 1992, was 71.5 and represented 61 delta smelt captured, with 89% of these fish caught in the lower Sacramento River. The October index was 3.5 and represented only 2 delta smelt captured. This is the lowest index ever for October and the second lowest index for any month. The November index was 57.5 and was based on 48 delta smelt captured, with 98% from the lower Sacramento River. In December, 22 delta smelt were captured — 17 (77%) from the lower Sacramento River — for an index of 24.3.

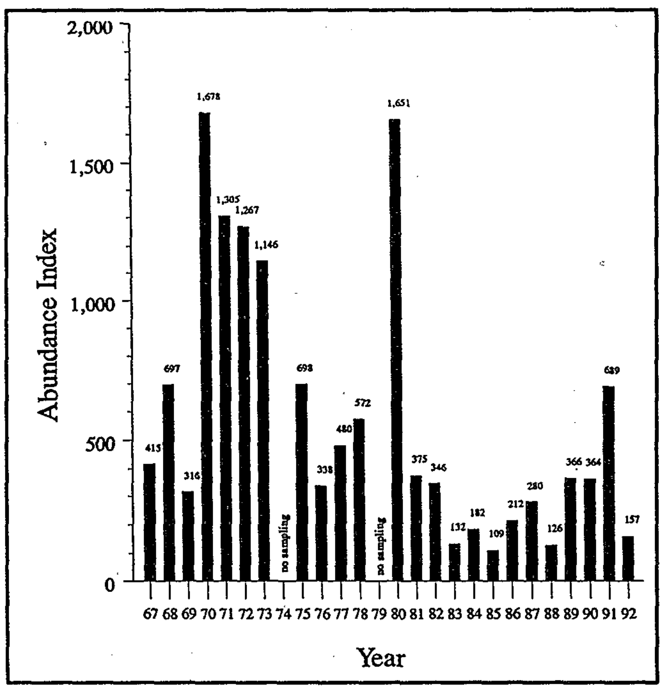

Figure 40
FALL MIDWATER TRAWL ABUNDANCE INDEX FOR DELTA SMELT

Although in recent years except 1992, the midwater trawl index has suggested a slight increase in abundance, the index currently shows both a decline in abundance of delta smelt and a constriction in their distribution. Delta smelt have been concentrated in the lower Sacramento River, whereas historically they were widely distributed throughout the delta (Figure 41).

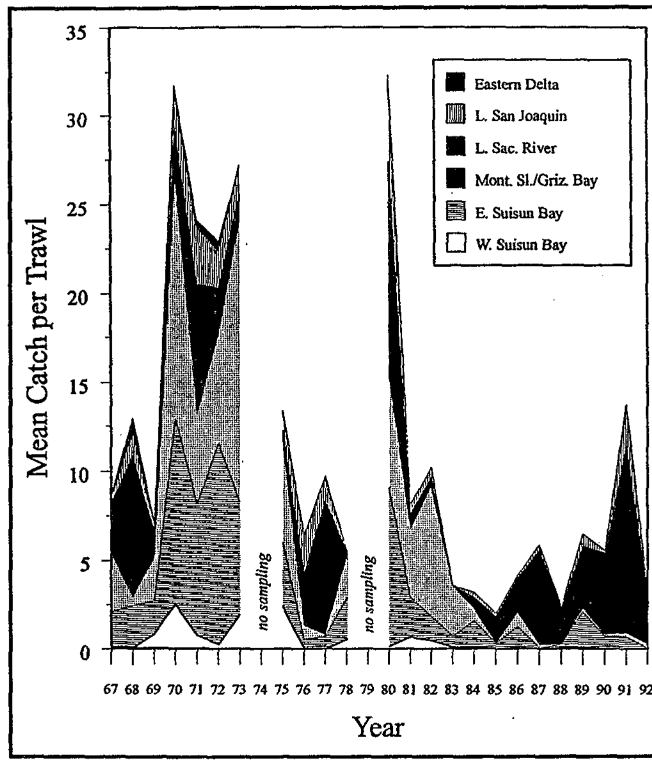

Figure 41
MEAN CATCH PER TRAWL IN THE MIDWATER TRAWL SURVEY
Annual mean catch per trawl for specific areas.

The modest increase in the abundance index in fall 1991 may reflect better-than-average survival of the year class. A possible explanation is that entrainment losses were reduced because both SWP and CVP exports in summer 1991 were at the lowest level since 1976, and agricultural diversions in the delta were reduced due to the drought and the DWR water banking program (Figure 42).

The mean catch-per-trawl during the midwater trawl survey has increased steadily in the lower Sacramento River stations, climbing to about 9.3 in 1992. In the lower San Joaquin River, the mean catch per trawl also exhibited a slightly increasing trend, though it dropped in 1992 to 0.3. The average catch per trawl in all other areas of the midwater trawl have consistently shown decreasing trends for the past 10 years.

1 Stevens *et al* 1990.

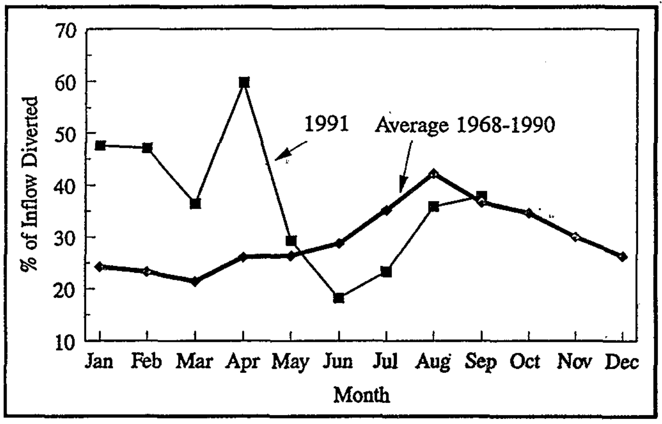

Figure 42
PERCENT OF MONTHLY INFLOW EXPORTED BY THE SWP AND CVP IN 1991 VERSUS THE AVERAGE FROM 1968 TO 1990

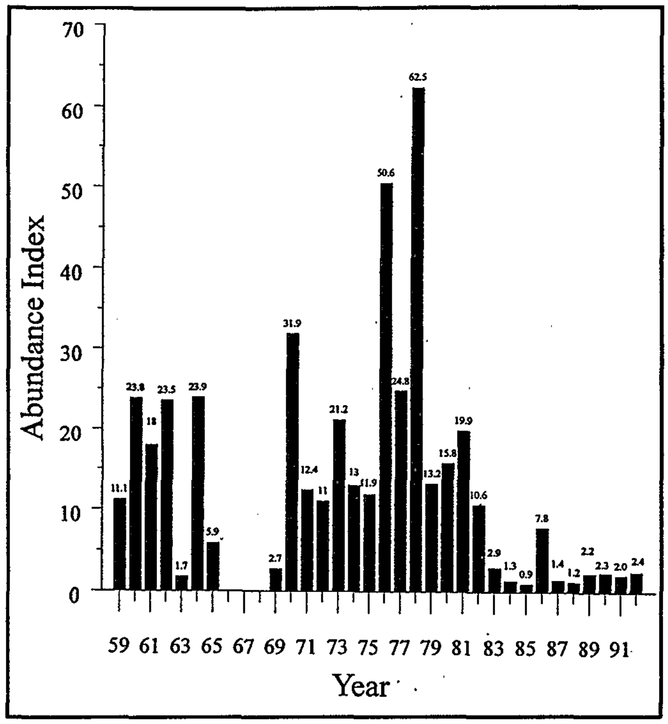

Figure 43
SUMMER TOW-NET DELTA SMELT ABUNDANCE INDEX
Only surveys 1 and 2 were used.

The 1992 tow-net abundance index, at 2.4, was consistent with the declining trend exhibited by previous indices, though it exhibited a slight increase from the 1991 index of 2.0 (Figure 43). The average tow-net index for 1983 to 1992 is 2.4. Years prior to 1983 averaged 19.5, with the highest index, in 1978, at 62.5 — 26 times the 1992 index.

Frequency of occurrence of delta smelt in tow-net and trawl tows has remained low since 1983 (Figure 44). From 1959 to 1982, delta smelt were caught in 43% of the summer tow-net tows; from 1983 to 1991, delta smelt were caught in only 16% of the tows. In 1992, only 13% of the tows caught delta smelt. For the midwater trawl survey, 25% of the tows caught delta smelt from 1967 to 1982, and only 11% from 1982 to 1991. In 1992, delta smelt were caught at 7.6% of the stations.

Seasonal movement of delta smelt can be observed from monthly geographical plots of distribution (Figure 45). Radtke (1966) described a similar seasonal movement in 1963-1964 as a spawning migration.

This information on distribution and abundance of delta smelt will help focus future surveys to further assess population status and will aid in recommending water project management options with regard to delta smelt.

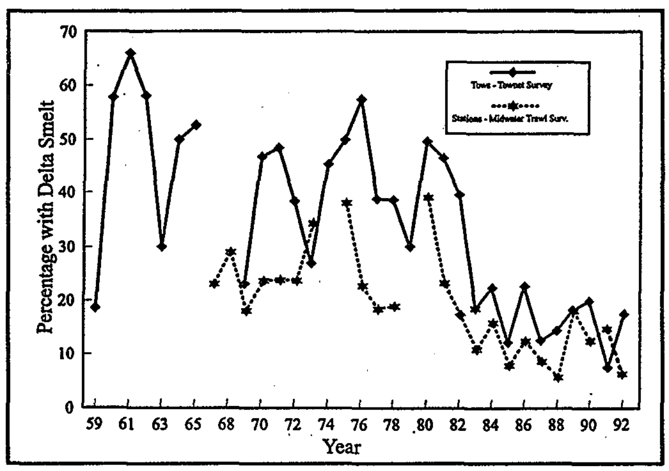

Figure 44
PERCENT CATCH OF DELTA SMELT IN TOW-NET AND MIDWATER TRAWL SURVEYS
Tow-net values represent percent occurrence in all tows in the first and second surveys.
Midwater trawl values represent percent occurrence at stations.

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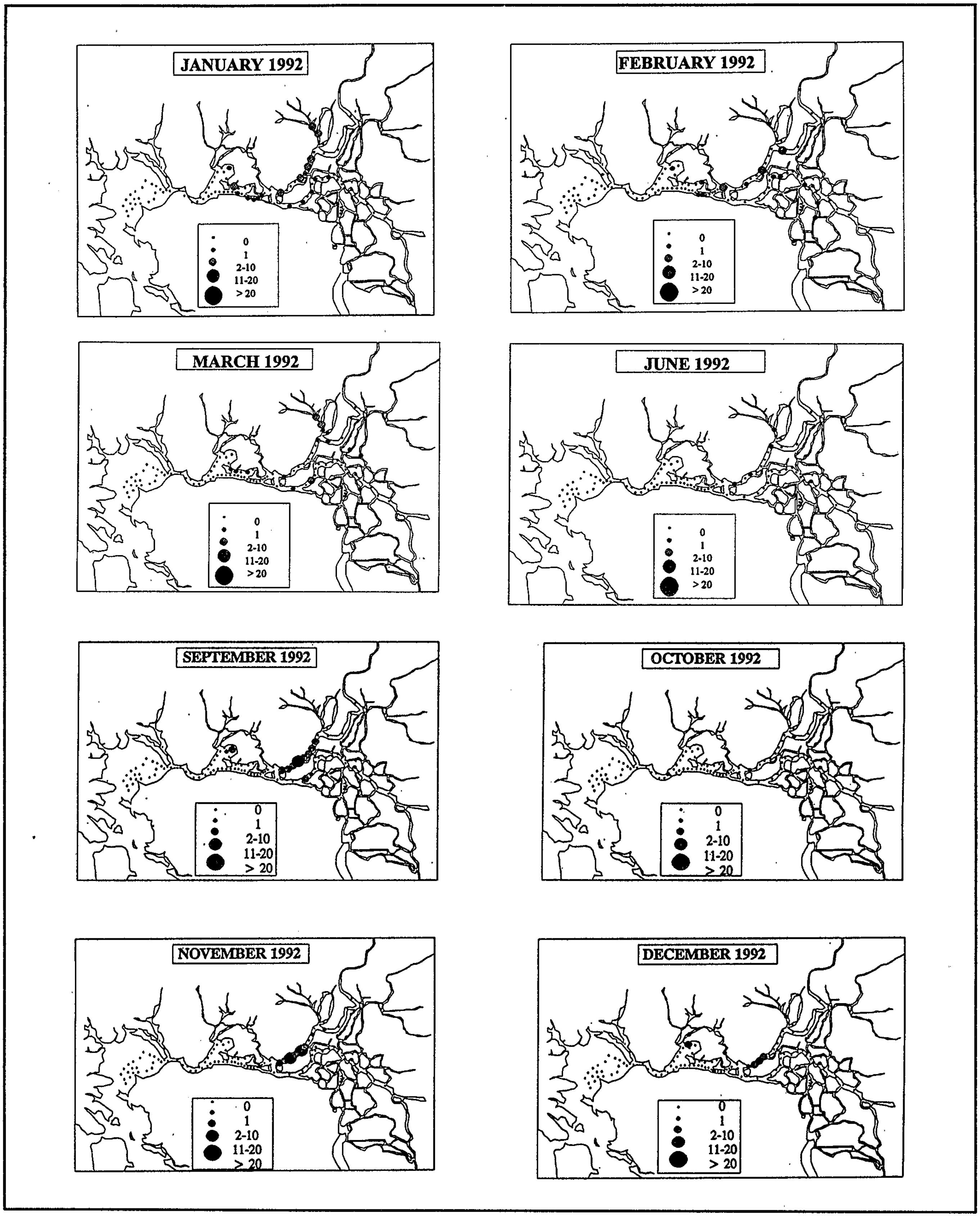

Figure 45
DISTRIBUTION AND ABUNDANCE OF DELTA SMELT IN MIDWATER TRAWLS IN 1992

Sturgeon

David W. Kohlhorst
Department of Fish and Game

The 1992 sturgeon program consisted of two elements:

- Sampling with artificial substrates to collect sturgeon eggs and determine spawning habitat preferences.
- Reevaluation of the angling regulation changes first proposed in 1989.

Spawning Habitat Preferences

To determine spawning locations and sites of egg deposition, we deployed artificial substrate egg samplers of latex-coated animal hair at six locations on the Sacramento River between Colusa and Princeton. Transects were established to sample a variety of water velocities, depths, and substrates and included areas of reported sturgeon spawning or congregation. Usually, three artificial substrates were fished across each transect. The artificial substrates were examined twice weekly for attached eggs, cleaned of debris and sediment, and reset.

Water temperature, depth, transparency, and surface and bottom[1] velocity were recorded each time the substrates were examined. We also recorded the composition of the natural substrate, which was collected with a clamshell dredge at each sampling site. Eggs were aged according to known temperature-related development times.

River stage and flow data were obtained from the California Data Exchange Center maintained by DWR.

We started sampling for sturgeon eggs with artificial substrates at three locations on February 4. A flow increase from 4,800 to 34,000 cfs, with its accompanying debris load, washed out the artificial substrates on February 10. Two transects were re-established by March 20, a third by March 27, and all six by April 14. Some spawning undoubtedly occurred while sampling was precluded.

We collected sturgeon eggs on March 24 (1 egg), March 31 (1 egg), April 17 (25 eggs), and April 21 (2 eggs). Aging these 29 eggs suggested they represented six spawning events. Flows during this time ranged from 6,400 to 12,400 cfs, and temperatures ranged from 54 to 61°F. Again, as last year, spawning seemed to be stimulated on April 15 and 17 by a small increase in flow starting on April 13 following a period of declining flows. Spawning documented on March 22 may have been the end of a spawning peak associated with high flows from March 15 to March 22, when we were unable to sample.

Sturgeon eggs were taken by artificial substrates placed at depths from 6 to 15 feet where bottom flows exceeded 4 feet per second. All eggs were collected over substrates that were primarily gravel and small rubble, suggesting sturgeon spawn where water is at least 6 feet deep and velocities are sufficient to sweep finer sediments from the substrate.

Angling Regulation Reevaluation

When stricter angling regulations were implemented in 1990, the imposition of a maximum size limit was readily accepted by sturgeon anglers, as were the initial increases in the minimum size limit from 40 inches to 42 inches in 1990 and 44 inches in 1991. However, a second phase of angling regulation changes, in which the minimum size was to be raised to 46 inches in 1992 and 48 inches in 1993, precipitated considerable protest from charter boat operators and the sporting press.

In the meantime, continuation of the DFG tagging program in 1990 and 1991 had suggested a substantial decline in abundance of sturgeon (from 128,000 fish larger than 40 inches in 1984 to 27,000 in 1990) and a decrease in exploitation rate to 3.3% in the year following tagging in fall 1990. Thus, the perception by many anglers that sturgeon fishing had become poor was substantiated by estimated abundance and harvest rate.

DFG personnel met with angler representatives and charter boat operators in spring 1992 to re-evaluate the need for the planned regulation change. Charter boat operators and bait shop owners had suffered economic hardship as the result of the declining sturgeon fishery and the perception by anglers that catching a legal-sized sturgeon was improbable. Additional angling regulation alternatives were proposed for evaluation using the sturgeon population model, either as

1 12 inches above the substrate.

ways to lessen the impact of the changes on those whose livelihood depends on the sturgeon fishery or as scenarios providing maximum protection to the resource (catch and release or complete closure of sturgeon fishing). In spite of the lower exploitation rate estimated in 1990, we continued to use a conservative value of 10% in the model evaluation. All alternatives evaluated had a positive effect on abundance; those that allowed continued harvest reduced catch from 27 to 42%.

DFG personnel believed it was inappropriate to reverse course and make major changes in the original recommendations to the Fish and Game Commission. Therefore, a compromise was reached to halt increases in the minimum size limit at 46 inches and retain the maximum size limit of 72 inches. This was recommended to the Fish and Game Commission in fall 1992 and was adopted effective March 1, 1993.

ENTRAINMENT OF EGGS AND LARVAE

Stephani Spaar
Department of Water Resources

The objective of this survey is to determine yearling equivalent losses of striped bass less than 21 mm long at the SWP and CVP facilities. These losses are calculated from the estimates of eggs and larvae entrained, which are based on estimated density of eggs and larvae near the project intakes and the amount of water diverted.

A second objective is to determine the timing, abundance, and distribution of delta smelt larvae in the southern delta and impacts of SWP operations on the early life history of this species. The delta smelt portion of this study is conducted in accordance with an informal agreement with the California Fish and Game Commission to better determine the status of delta smelt and impacts of SWP operations.

DWR and DFG conducted the 1992 survey from February 12 to July 15 at seven locations in the southern delta and two new locations in the central delta (Figure 46). The central delta sites were added as part of the Delta Smelt Study to monitor larval smelt abundance near the Delta Wetlands Inc. proposed intake structure off Holland Cut and at the Contra Costa water diversion in Rock Slough. To estimate entrainment, Station 92 was used for the SWP and Station 96 was used for the CVP. Other channels near the diversion sites were also sampled to determine the source of eggs and larvae transported toward the pumps. Station 93 was relocated downstream on April 28 due to installation of a temporary barrier in Old River near Tracy.

The 1992 survey was conducted as in previous years.[1,2,3,4] Initial sampling began in mid-February on every fourth day, as part of the Delta Smelt Study. Routine sampling on every second day resumed on April 4 for striped bass. Stations 91-98 were not accessible on April 14, April 20-26, May 8, and May 12-24 due to closure of the Highway 4 bridge on Old River to boat traffic. (The bridge must be open for passage of the survey boat.)

Diversion Rates and Environmental Parameters

SWP and CVP diversion rates, volume of water sampled per tow, and several environmental parameters were averaged bimonthly (Table 40). Intake rates at the SWP were greatest in mid-February through March, with an average daily diversion of about 12,400 acre-feet (Table 40 and Figure 47). SWP diversions were reduced for an extended period from early April through July. During this period, daily diversion into Clifton Court Forebay was generally less than 4,000 acre-feet. On some days no water was diverted. Intake rates at the CVP were greatest from mid-February into early April, with a daily average of about 8,300 acre-feet diverted. CVP diversions were reduced to about 2,000 acre-feet for an extended period from early April through July.

Water temperatures in the spring of 1992 warmed early (Table 40). Temperatures were low in February and rose in March and April, about

1 P.F. Raquel. *Estimated Entrainment of Striped Bass Eggs and Larvae at State Water Project and Central Valley Project Facilities in the Sacramento-San Joaquin Delta, 1985 and 1986*. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report 13. 1987.

2 P.F. Raquel. *Estimated Entrainment of Striped Bass Eggs and Larvae at State Water Project and Central Valley Project Facilities in the Sacramento-San Joaquin Delta, 1987*. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary. Technical Report 15. 1988.

3 Stephani A. Spaar. *Results of 1988 Striped Bass Egg and Larva Study Near the State Water Project and Central Valley Project Facilities in the Sacramento-San Joaquin Delta*. Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. Technical Report 25. 1990.

4 Stephani A. Spaar. "1991 Entrainment of Striped Bass Eggs and Larvae to the State Water Project and Central Valley Project Intakes in the Sacramento-San Joaquin Delta". Department of Water Resources Memorandum. May 28, 1992. 17 pp.

a month earlier than in 1991.[1] Water temperatures in early to mid-March averaged 15 degrees Celsius, which is at the low end of the spawning range for striped bass.[2] Average water temperatures in May to July were slightly warmer near the CVP than near the SWP.

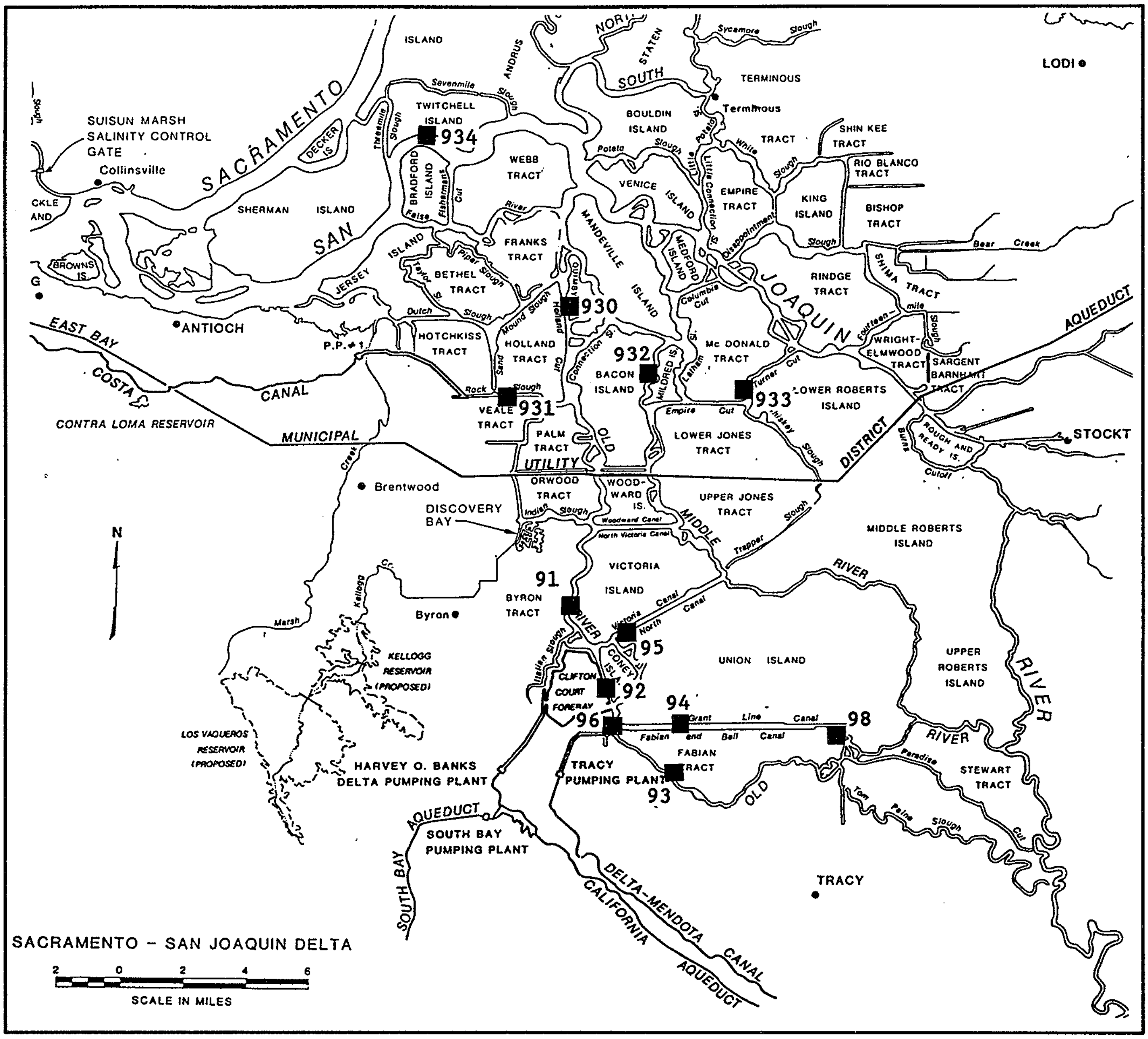

Figure 46
EGG AND LARVAL STUDY SITES

1 Spaar 1991.
2 Wang, J.C.S. *Fishes of the Sacramento-San Joaquin Estuary and Adjacent Waters, California: A Guide to the Early Life Histories*. Interagency Ecological Study Program for the Sacramento-San Joaquin Estuary, Technical Report 9. 1986.

Table 40
BIMONTHLY MEAN OF ENVIRONMENTAL PARAMETERS AND DIVERSION RATES AT THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT INTAKES, 1992

STATE WATER PROJECT

	Specific Conductance (µmhos)	Secchi (cm)	Water Temperature (degrees C)	Diversion (acre-feet)	Water Volume Sampled (cubic meters)
FEB 1-15	NS	NS	NS	1999	NS
FEB 16-28	525	44	13.4	12361	255
MAR 1-15	352	57	15.0	12419	231
MAR 16-31	339	69	15.6	12448	145
APR 1-15	384	83	17.9	4203	182
APR 16-30	555	46	19.9	738	118
MAY 1-15	411	55	21.8	2036	150
MAY 16-31	531	49	23.1	1224	148
JUN 1-15	695	49	23.7	2520	182
JUN 16-30	801	48	23.8	1870	202
JUL 1-11	764	46	24.9	1601	215

CENTRAL VALLEY PROJECT

	Specific Conductance (µmhos)	Secchi (cm)	Water Temperature (degrees C)	Diversion (acre-feet)	Water Volume Sampled (cubic meters)
FEB 1-15	NS	NS	NS	2047	NS
FEB 16-28	514	32	13.0	8303	261
MAR 1-15	760	43	15.1	8280	223
MAR 16-31	528	53	15.4	8254	222
APR 1-15	524	58	17.5	5471	162
APR 16-30	547	37	19.7	1917	163
MAY 1-15	412	50	22.0	2047	154
MAY 16-31	538	50	23.0	2042	120
JUN 1-15	706	54	24.0	1935	213
JUN 16-30	838	46	24.3	1953	191
JUL 1-11	765	55	25.5	2218	182

NS = No sampling February 1-15, 1992.

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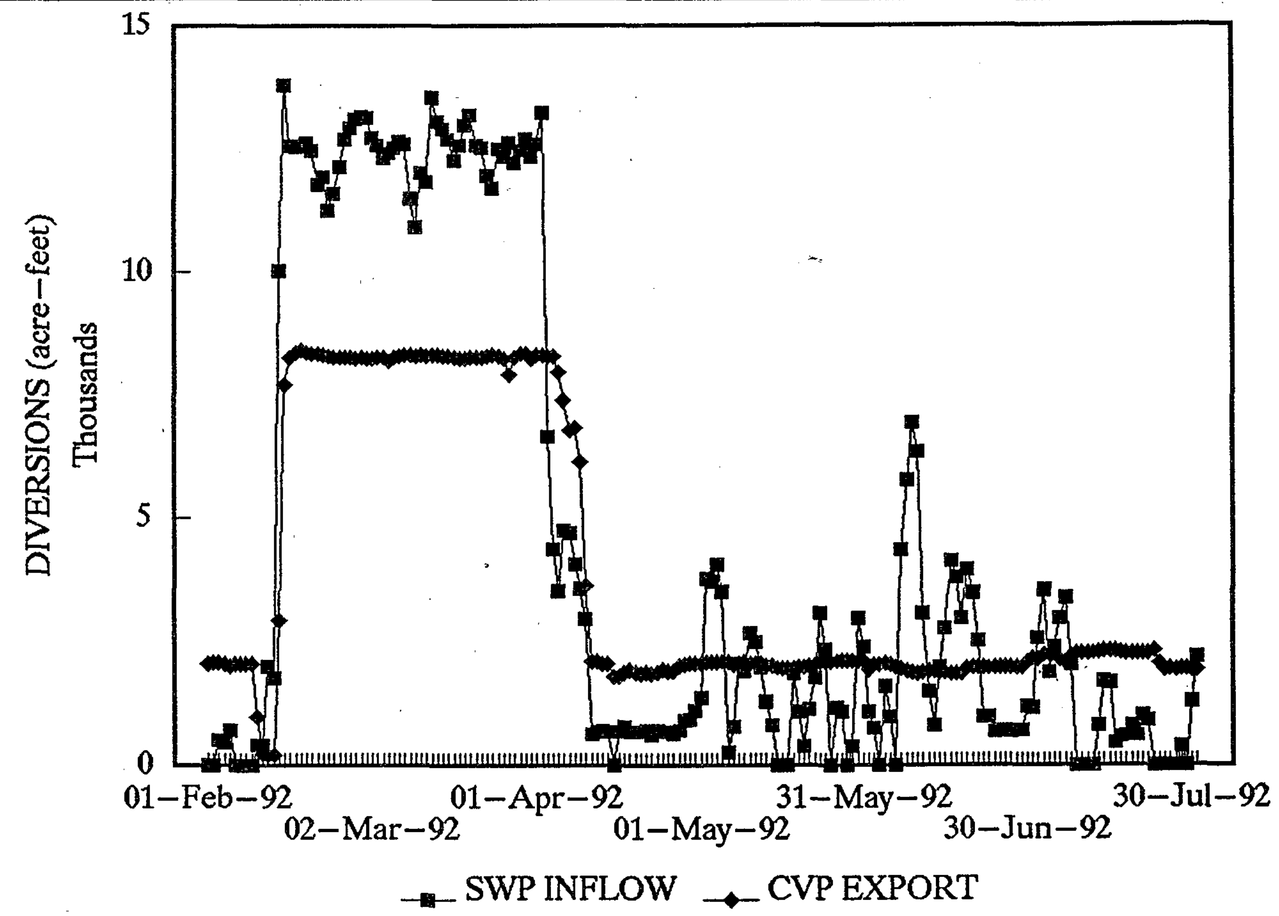

Figure 47
DAILY STATE WATER PROJECT INFLOW AND CENTRAL VALLEY PROJECT EXPORT, FEBRUARY-JULY 1992.
Source: California Department of Water Resources

Entrainment of Striped Bass

Striped bass eggs were collected near the SWP intake (Station 92) on April 16, April 28, and May 6 and near the CVP intake (Station 96) on April 28 (Figure 48). April 16 and May 6 bracket the period eggs were collected at any of the southern survey stations in 1992. In comparison, eggs were collected from April 14 (initial sample) through May 16 at a site off Twitchell Island, on the San Joaquin River. Egg occurrence at the SWP and CVP sites appears to reflect the general period of spawning in the delta for 1992.

Based on 1987-1991 survey results, striped bass eggs are usually most abundant during the May 1-15 period, except in 1987 when an early spawn occurred.[1] In 1992, eggs were most abundant near the SWP and CVP intakes during the April 16-30 period (Tables 41 and 42), slightly earlier than average due to warm water temperatures early in spring. In addition, eggs are generally abundant through May near the CVP intake and upstream at Station 93 due to local spawning.[2] This was not the case in 1992. No eggs were collected at Station 93 prior to the closure of the Old River near Tracy barrier or downstream of the barrier after closure.

Striped bass larvae were collected April 6 through June 29 near the SWP and April 4 through June 15 near the CVP (Figure 48). In comparison, larvae were collected April 6 through June 17 at central delta sites. Occurrence of larval striped bass in the southern delta appears to reflect the

1 Spaar 1992.
2 Spaar 1992.

general period of occurrence in the delta for 1992. Based on mean 1987-1991 daily larval densities, striped bass larvae are most abundant during the May 16-31 period.[1] In 1992, larvae were most abundant near the SWP and CVP intakes during the May 1-15 period, slightly earlier than average (Tables 41 and 42). This was most likely due to the early spawn in 1992.

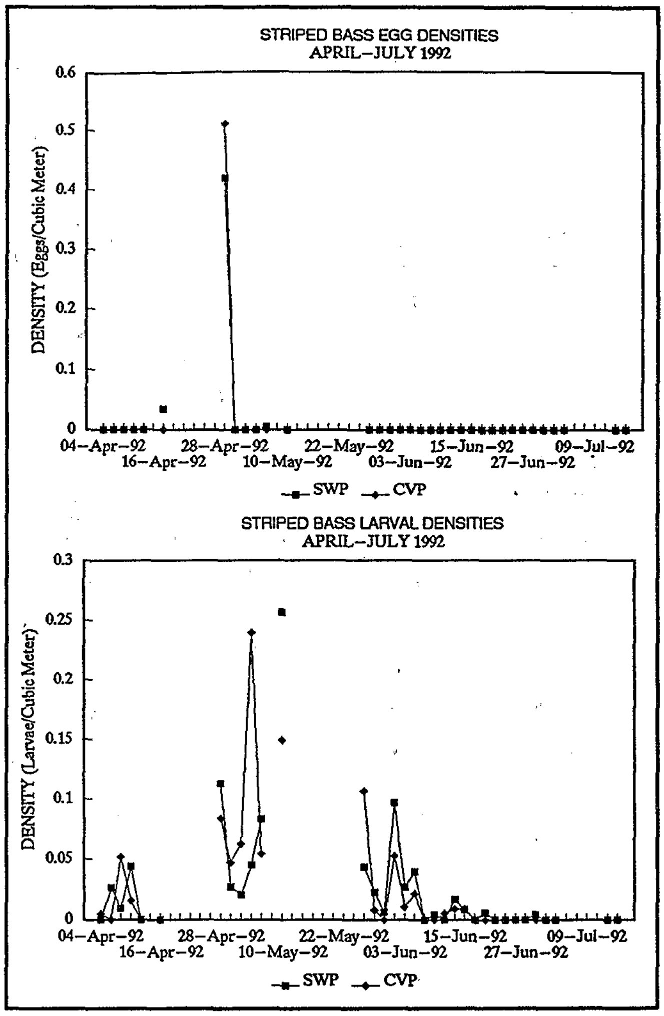

Figure 48
ESTIMATED DENSITIES OF STRIPED BASS EGGS AND LARVAE NEAR THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT, APRIL-JULY 1992

Total estimated SWP entrainment in 1992 was 10.8 million: 2.9 million eggs and 7.9 million larvae (Table 41). Entrainment of eggs was greatest April 16-30, and entrainment of larvae was greatest May 1-15. In comparison to past years, estimated entrainment was low for both eggs and larvae (Table 43). Yearling equivalent loss for the SWP was 13,452 fish, also low in comparison to past years (Tables 44 and 45). The 11-14 mm size class of striped bass experienced the highest yearling equivalent losses (Table 45).

Total estimated CVP entrainment in 1992 was 19.8 million: 8.6 million eggs and 11.2 million larvae (Table 42). Entrainment of eggs was greatest April 16-30, and entrainment of larvae was greatest May 1-15. In comparison to past years, estimated entrainment was moderate for eggs and low for larvae (Table 43). Yearling equivalent loss for the CVP was 35,383 fish, moderate in comparison to past years (Tables 44 and 45). The 15-18 mm size class had the highest yearling equivalent losses (Table 45).

The low larval entrainment in 1992 appears to reflect the low SWP/CVP combined diversions for April through June. From 1985 to 1992, diversions during this period were lowest in 1991 and 1992 and highest in 1985, 1988, and 1989 (Figure 49). The higher entrainment reflects higher diversion rates (Table 43). The large entrainment in 1985 in comparison to 1986, which had only a slightly lower April-June diversion, was most likely due to high flows in Old River during early spring 1986, forcing eggs and larvae farther downstream, out of the influence of the project diversions.[2] In 1987, entrainment at the CVP was somewhat higher than at the SWP probably due to higher CVP diversions

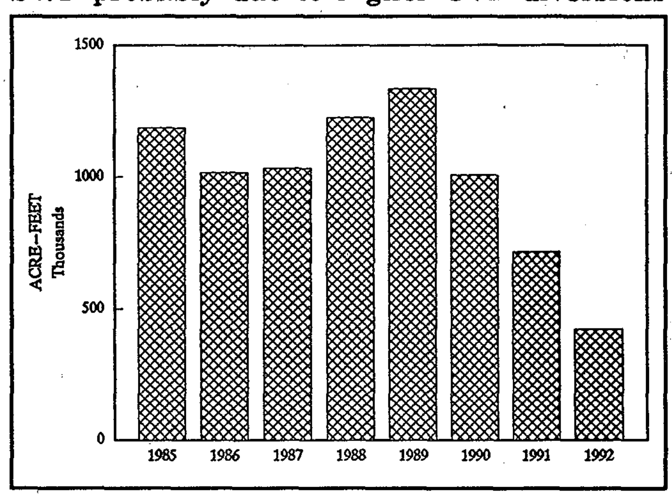

Figure 49
TOTAL COMBINED SWP/CVP DIVERSIONS, APRIL-JUNE 1985-1992

1 Spaar 1992.
2 Raquel 1987.

Table 41
MEAN DENSITY AND ESTIMATED ENTRAINMENT OF STRIPED BASS EGGS AND LARVAE AT THE STATE WATER PROJECT INTAKE, 1992

MEAN DENSITY *(Number per 10,000 Cubic Meters)*

		Size Groups					
	EGGS	3-6 mm	7-10 mm	11-14 mm	15-18 mm	19-20 mm	3-20 mm
FEB 1-15	NS	NS	NS	NS	NS	NS	NS
FEB 16-28	0	0	0	0	0	0	0
MAR 1-15	0	0	0	0	0	0	0
MAR 16-31	0	0	0	0	0	0	0
APR 1-15	24	113	0	0	0	0	113
APR 16-30	2,126	0	343	200	0	0	543
MAY 1-15	9	169	718	394	78	0	1,359
MAY 16-31	0	40	337	358	123	0	858
JUN 1-15	0	0	39	116	62	33	250
JUN 16-30	0	0	0	7	6	5	18
JUL 1-11	0	0	0	0	0	0	0

ENTRAINMENT *(Thousands of Fish)*

		Size Groups					
	EGGS	3-6 mm	7-10 mm	11-14 mm	15-18 mm	19-20 mm	3-20 mm
FEB 1-15	NS	NS	NS	NS	NS	NS	NS
FEB 16-28	0	0	0	0	0	0	0
MAR 1-15	0	0	0	0	0	0	0
MAR 16-31	0	0	0	0	0	0	0
APR 1-15	14	588	0	0	0	0	588
APR 16-30	2,889	0	478	275	0	0	753
MAY 1-15	17	524	2326	1244	234	0	4,328
MAY 16-31	0	74	636	741	261	0	1,712
JUN 1-15	0	0	62	180	178	47	467
JUN 16-30	0	0	0	49	42	9	100
JUL 1-11	0	0	0	0	0	0	0
TOTAL	2,920	1,186	3,502	2,489	715	56	7,948

TOTAL EGGS AND LARVAE ENTRAINED = 10,868

NS = No sampling February 1-15, 1992.

Table 42
MEAN DENSITY AND ESTIMATED ENTRAINMENT OF STRIPED BASS EGGS AND LARVAE AT THE CENTRAL VALLEY PROJECT INTAKE, 1992

MEAN DENSITY *(Number per 10,000 Cubic Meters)*

		SIZE GROUPS					
	EGGS	3-6 mm	7-10 mm	11-14 mm	15-18 mm	19-20 mm	3-20 mm
FEB 1-15	NS	NS	NS	NS	NS	NS	NS
FEB 16-28	0	0	0	0	0	0	0
MAR 1-15	0	0	0	0	0	0	0
MAR 16-31	0	0	0	0	0	0	0
APR 1-15	0	102	0	0	0	0	102
APR 16-30	2,388	3	240	177	0	0	420
MAY 1-15	0	184	476	410	135	11	1,216
MAY 16-31	0	19	145	245	386	109	904
JUN 1-15	0	8	16	52	48	14	138
JUN 16-30	0	0	0	0	6	0	6
JUL 1-11	0	0	0	0	0	0	0

ENTRAINMENT *(Thousands of Fish)*

		SIZE GROUPS					
	EGGS	3-6 mm	7-10 mm	11-14 mm	15-18 mm	19-20 mm	3-20 mm
FEB 1-15	NS	NS	NS	NS	NS	NS	NS
FEB 16-28	0	0	0	0	0	0	0
MAR 1-15	0	0	0	0	0	0	0
MAR 16-31	0	0	0	0	0	0	0
APR 1-15	0	1,025	0	0	0	0	1,025
APR 16-30	8,578	10	867	638	0	0	1,515
MAY 1-15	0	699	1,806	1,554	505	39	4,603
MAY 16-31	0	76	573	972	1,547	440	3,608
JUN 1-15	0	28	57	191	172	52	500
JUN 16-30	0	0	0	0	20	0	20
JUL 1-11	0	0	0	0	0	0	0
TOTAL	8,578	1,838	3,303	3,355	2,244	531	11,271

TOTAL EGGS AND LARVAE ENTRAINED = 19,849

NS = No sampling February 1-15, 1992.

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Table 43
ESTIMATED ENTRAINMENT OF STRIPED BASS EGGS AND LARVAE, 1985-1992
(Thousands of Fish)

	STATE WATER PROJECT		CENTRAL VALLEY PROJECT	
	Eggs	Larvae	Eggs	Larvae
1985	90,241	373,312	89,174	281,191
1986	3,964	50,583	9,743	40,499
1987	2,191	96,915	7,183	138,340
1988	9,156	125,580	25,761	108,965
1989	390	141,177	9,398	62,954
1990	6,374	28,671	3,003	46,728
1991*	6,279	44,540	5,549	22,647
1992	2,920	7,948	8,578	11,271

* 1991 includes estimated April 16-May 26 period based on mean 1987-1990 densities for that period.

Table 44
STRIPED BASS
YEARLING EQUIVALENT ENTRAINMENT LOSSES,
1985-1992
(Number of Fish)

	State Water Project	Central Valley Project	Total
1985	68,488	46,360	114,848
1986	37,109	52,976	90,985
1987	43,846	71,958	115,804
1988	59,625	51,085	110,710
1989	56,306	30,997	87,303
1990	7,717	16,936	24,653
1991 *	15,117	8,861	23,978
1992	13,452	35,383	48,835

* 1991 includes estimated April 16-May 26 period based on mean 1987-1990 densities for that period.

Table 45
STRIPED BASS YEARLING EQUIVALENT LOSSES AT THE STATE WATER PROJECT AND CENTRAL VALLEY PROJECT EXPORT FACILITIES
BASED ON DENSITIES AND WATER EXPORTS AT THE INTAKES,
FEBRUARY-JULY 1992

Size Group	Survival Rate To Age 1*	Number of Yearling Equivalents SWP	CVP
EGGS	0.000047	137	403
3-6 mm	0.000124	147	228
7-10 mm	0.000338	1184	1116
11-14 mm	0.002509	6242	8414
15-18 mm	0.006415	4584	14393
19-20 mm	0.020414	1158	10829
TOTAL		13,452	35,383

* Survival rates to age 1 for different size groups were calculated by Ecological Analysts and presented in "Contra Costa Power Plant Cooling Water Intake Structures — 316(b) Demonstration", prepared for Pacific Gas and Electric Company, 60-G-1, 1981. Egg survival rate was estimated by calculating the potential number of eggs spawned compared to the estimated number of age-1 fish in the estuary.

(Table 43, Figure 50). Similarly in 1989, SWP entrainment was higher than CVP probably due to higher SWP diversions and an abundant source of larvae north of the site (Spaar 1992).

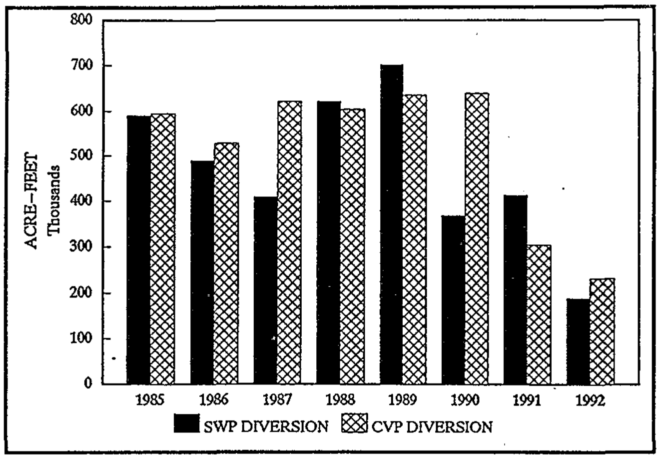

Figure 50
TOTAL SWP AND CVP DIVERSIONS, APRIL-JUNE 1985-1992

Entrainment of Other Species of Concern

As part of the 1992 permit requirements for the Temporary Barriers Project, direct losses of eggs and larvae of several species of concern were evaluated. SWP and CVP entrainment was estimated for miscellaneous eggs, delta smelt, longfin smelt, Sacramento splittail, and cyprinids (family Cyprinidae). Miscellaneous eggs and cyprinids could include Sacramento blackfish and hardhead), which were identified only to family.

Miscellaneous eggs collected near the SWP intake in March (Table 46) were identified as bigscale logperch and prickly sculpin and will not be discussed further in this analysis. Eggs were collected near the CVP during April 1-15 and May 16-31 (Table 47). The May eggs were identified as carp eggs and the April eggs only as cyprinid eggs. Estimated entrainment based on the April cyprinid eggs was 775,426 eggs.

No delta smelt eggs were collected. Their eggs are adhesive and demersal and not likely to be collected with an egg and larval sled towed in mid-channel. Delta smelt larvae were collected near the SWP intake on March 23 and April 4, 6, and 8 and near the CVP intake on April 4, 6, and 12. No delta smelt were collected at Stations 93, 94, and 98. Prior surveys have collected delta smelt at all sites except Station 98.[1] Delta smelt were collected at other southern delta sites (Stations 91, 95) between February 25 and April 10, 1992. They appear to be transported into the southern delta past these stations via Old River and North/Victoria Canal. February 25 is the earliest known time of occurrence for delta smelt larvae in this area. No delta smelt were collected in the southern delta after April 12, 1992. In comparison, delta smelt were collected at central delta sites (Sites 930-934) February 25 through June 7, 1992.

Entrainment of delta smelt larvae at the SWP occurred during the March 16-31 and April 1-15 periods (Table 46). Total entrainment was estimated to be 554,407 fish. Delta smelt larvae were entrained at the CVP during the April 1-15 period, and was estimated to be 645,496 fish (Table 47).

Longfin smelt larvae were collected near the SWP intake on February 20 and March 23, 1992. None were collected near the CVP intake in 1992. Longfin smelt were collected at only one other southern delta site, Station 91 on Old River on February 20, 1992. These smelt also appear to be transported into the southern delta past Station 91 via Old River. In comparison, longfin smelt were collected in February only at central delta sites on Old River (Site 930, Holland Cut on February 12 and Site 931, Rock Slough on February 25, 1992). Entrainment of longfin smelt larvae at the SWP occurred during the March 16-31 period and was estimated to be 492,518 fish.

No Sacramento splittail larvae were collected near the SWP intake in 1992 (Table 46). Splittail were collected near the CVP intake on April 16. Splittail were also collected on Grant Line Canal (Stations 94, 98) on March 27, April 1, and April 6 and on Old River upstream of the Old River at Tracy barrier site (Station 93) on April 4 and 8. No splittail were collected at Station 91 on Old River or Station 95 on North Victoria Canal. Splittail appear to be more of a resident species in the southern delta and do not appear to be present primarily due to transport from the central delta, as appears to be the case for delta smelt and longfin smelt. In comparison, splittail were collected only at central delta sites 930 and

1 Spaar 1992.

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Table 46
MEAN DENSITY AND ESTIMATED ENTRAINMENT OF EGGS AND LARVAE OF OTHER SPECIES OF CONCERN AT THE STATE WATER PROJECT INTAKE, 1992

MEAN DENSITY *(Number per 10,000 Cubic Meters)*					
	Miscellaneous Eggs	Delta Smelt Larvae	Longfin Smelt Larvae	Sacramento Splittail Larvae	Cyprinidae Larvae
FEB 1-15	NS	NS	NS	NS	NS
FEB 16-28	0	0	20	0	0
MAR 1-15	5	0	0	0	0
MAR 16-31	24	17	17	0	0
APR 1-15	0	44	0	0	12
APR 16-30	0	0	0	0	66
MAY 1-15	0	0	0	0	6
MAY 16-31	0	0	0	0	0
JUN 1-15	0	0	0	0	19
JUN 16-30	0	0	0	0	6
JUL 1-11	0	0	0	0	0

ENTRAINMENT *(Thousands of Fish)*					
	Miscellaneous Eggs	Delta Smelt Larvae	Longfin Smelt Larvae	Sacramento Splittail Larvae	Cyprinidae Larvae
FEB 1-15	NS	NS	NS	NS	NS
FEB 16-28	0	0	268	0	0
MAR 1-15	60	0	0	0	0
MAR 16-31	335	224	224	0	0
APR 1-15	0	330	0	0	102
APR 16-30	0	0	0	0	90
MAY 1-15	0	0	0	0	41
MAY 16-31	0	0	0	0	0
JUN 1-15	0	0	0	0	126
JUN 16-30	0	0	0	0	9
JUL 1-11	0	0	0	0	0
TOTAL	395	554	492	0	368

NS = No sampling February 1-15, 1992.

Table 47
MEAN DENSITY AND ESTIMATED ENTRAINMENT OF EGGS AND LARVAE OF OTHER SPECIES OF CONCERN AT THE CENTRAL VALLEY PROJECT INTAKE, 1992

MEAN DENSITY *(Number per 10,000 Cubic Meters)*

	Miscellaneous Eggs	Delta Smelt Larvae	Longfin Smelt Larvae	Sacramento Splittail Larvae	Cyprinidae Larvae
FEB 1-15	NS	NS	NS	NS	NS
FEB 16-28	0	0	0	0	0
MAR 1-15	0	0	0	0	0
MAR 16-31	0	0	0	0	21
APR 1-15	157	58	0	0	23
APR 16-30	0	0	0	31	0
MAY 1-15	0	0	0	0	36
MAY 16-31	36	0	0	0	18
JUN 1-15	0	0	0	0	0
JUN 16-30	0	0	0	0	0
JUL 1-11	0	0	0	0	0

ENTRAINMENT *(Thousands of Fish)*

	Miscellaneous Eggs	Delta Smelt Larvae	Longfin Smelt Larvae	Sacramento Splittail Larvae	Cyprinidae Larvae
FEB 1-15	NS	NS	NS	NS	NS
FEB 16-28	0	0	0	0	0
MAR 1-15	0	0	0	0	0
MAR 16-31	0	0	0	0	191
APR 1-15	775	645	0	0	148
APR 16-30	0	0	0	109	0
MAY 1-15	0	0	0	0	137
MAY 16-31	151	0	0	0	76
JUN 1-15	0	0	0	0	0
JUN 16-30	0	0	0	0	0
JUL 1-11	0	0	0	0	0
TOTAL	926	645	0	109	552

NS = No sampling February 1-15, 1992.

934 on April 14 and 16, 1992. Entrainment of splittail larvae at the CVP occurred during the April 16-30 period and was estimated to be 108,773 fish (Table 47).

The collection of cyprinid larvae could be an indicator of the occurrence of blackfish and hardhead; however, most cyprinid larvae are thought to be carp. Cyprinid larvae were collected about twice a month near the SWP intake from April 6 to June 23 and near the CVP intake from March 23 to May 30, 1992. Larvae collected near the CVP intake on March 23 and April 4 were identified as carp larvae. Cyprinid larvae were collected at all other sites in the southern delta between April 6 and May 26. They appear to be resident fish in the southern delta. No cyprinids were collected after May 6 in Old River directly downstream of the temporary barrier. In comparison, cyprinids were collected at central delta sites (Sites 930-934) April 4 through June 17.

Entrainment of cyprinid larvae at the SWP occurred during the April 1-June 30 periods (Table 46). Total entrainment was estimated to be 368,568 fish. Cyprinid larvae were entrained at the CVP during the March 16-May 31 periods, and entrainment was estimated to be 551,418 fish (Table 47).

Species Composition of Catch

The 1992 survey collected 15 varieties of larval fish in the southern delta (Table 48). The most abundant fishes over all sites and at the SWP and CVP sites were:

Chameleon goby	83,293
Threadfin shad	35,504
Prickly sculpin	16,602

These species accounted for 99% of the total catch at all sites. Chameleon goby comprised 61% of the total catch, a decrease from prior years.

Moderately low in abundance and comprising less than 1% of the total catch were:

Striped bass (3-38 mm)	666
Bigscale logperch	208
Lepomis spp.	198

Captured in very low numbers were:

Delta smelt	29
Sacramento splittail	7
Longfin smelt	5

The two new sites sampled near Holland Tract in 1992 had 11 varieties of larval fish (Table 49). Species collected at these sites were the same varieties as found at the southern delta sites. Chameleon goby, prickly sculpin, threadfin shad, and striped bass were the most abundant species collected. The total number of striped bass caught near Holland Tract was greater than at Stations 91-98 combined. Delta smelt and longfin smelt numbers were proportionately higher than in the southern delta.

Table 48
LARVAL FISH SPECIES COLLECTED IN THE SOUTHERN DELTA, FEBRUARY TO JULY 1992

Species	Type**	Total Catch* All Sites	Total Catch* SWP	Total Catch* CVP	% Total Catch All Sites	% Total Catch of Species SWP	% Total Catch of Species CVP
Chameleon goby *Tridentiger trigonocephalus*	E	83,293	14,988	11,702	61	18	14
Threadfin Shad *Dorosoma petenense*	E	35,504	2,090	3,956	26	6	11
Prickly sculpin *Cottus asper*	FE	16,602	2,724	4,965	12	16	30
Striped bass *Morone saxatilis*	E	662	124	123	<0.5	19	19
Bigscale logperch *Percina macrolepida*	F	208	16	54	<0.5	8	26
Lepomis spp.	F	198	22	49	<0.5	11	25
Inland silverside *Menidia beryllina*	FE	62	2	6	<0.1	3	10
Cyprinidae	F	52	6	8	<0.1	12	15
Delta smelt *Hypomesus transpacificus*	E	29	6	4	<0.1	21	14
Ictalurus spp.	F	26	0	0	<0.1	0	0
Yellowfin goby *Acanthogobius flavimanus*	EM	13	13	0	<0.1	0	0
Sacramento splittail *Pogonichthys macrolepidotus*	E	7	0	1	<0.1	0	14
Sacramento sucker *Catostomus occidentalis*	F	6	0	0	<0.1	0	0
Longfin smelt *Spirinchus thaleichthys*	E	5	2	0	<0.1	40	0
Mosquitofish *Gambusia affinis*	F	2	0	0	<0.1	0	0
TOTAL		136,669	19,993	20,868			

* Actual number of fish caught. Stations 930 and 931 not included.
** E = Estuarine, F = Freshwater, M = Marine, A = Anadromous

Table 49
LARVAL FISH SPECIES COLLECTED NEAR HOLLAND TRACT, FEBRUARY TO JULY 1992

Species	Type**	Total Catch* Both Sites	Total Catch* #930	Total Catch* #931	% Total Catch All Sites
Chameleon goby, *Tridentiger trigonocephalus*	E	7,757	4,785	2,972	62
Threadfin shad, *Dorosoma petenense*	E	578	401	177	5
Prickly sculpin, *Cottus asper*	FE	2,878	1,097	1,781	23
Striped bass, *Morone saxatilis*	E	917	725	192	7
Bigscale logperch, *Percina macrolepida*	F	167	8	159	1
Lepomis spp.	F	59	39	20	<0.5
Inland silverside, *Menidia beryllina*	FE	12	2	10	<0.1
Cyprinidae	F	37	27	10	<0.5
Delta smelt, *Hypomesus transpacificus*	E	15	11	4	<0.5
Sacramento splittail, *Pogonichthys macrolepidotus*	E	2	2	0	<0.1
Longfin smelt, *Spirinchus thaleichthys*	E	5	4	1	<0.1
TOTAL		12,427	7,101	5,326	

* Actual number of fish caught.
** E = Estuarine, F = Freshwater, M = Marine, A = Anadromous

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Chapter 8

DELTA OUTFLOW / SAN FRANCISCO BAY

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Department of Fish and Game

Objectives of the Delta Outflow/San Francisco Bay Study are to:

- Determine how the abundance and distribution of fishes, shrimp, and crabs are affected by changes in the amount and timing of freshwater outflow to the bay.
- Develop life history models for those species that have a strong relationship between annual abundance and outflow, with emphasis on identifying the outflow-related mechanisms.
- Quantify the impacts of water development projects on species sensitive to changes in outflow and the outflow-related mechanisms.

Species Update

This section updates abundance trends through 1992 for the most common species of shrimp, crabs, and fish from San Francisco Bay. In 1992 we changed the method of calculating abundance indices such that we can now compare abundance between embayments or areas.

Caridean Shrimp

In 1992, the abundance index of *C. franciscorum* was the lowest since the study began in 1980 and was about 50% of the previous lowest indices (Table 50). *C. franciscorum* accounted for only 10% of the total shrimp index in 1992. Distribution was centered in South Bay below the Dumbarton Bridge,

Table 50
ANNUAL ABUNDANCE INDICES FOR THE SIX MOST COMMON SPECIES OF CARIDEAN SHRIMP COLLECTED IN SAN FRANCISCO BAY, 1980-1992
Data are for all months sampled and are from the otter trawl.

Year	*Crangon franciscorum*	*Crangon nigricauda*	*Crangon nigromaculata*	*Palaemon macrodactylus*	*Heptacarpus stimpsoni*	*Lissocrangon stylirostris*	Total
1980	202,855	47,076	2,276	4,107	2,653	0	258,967
1981	104,775	25,566	754	4,277	1,444	0	136,816
1982	310,556	18,401	1,368	2,683	1,875	3	334,886
1983	343,619	38,877	16,131	1,535	2,359	5	402,526
1984	268,664	14,179	6,491	5,895	2,464	2,805	300,498
1985	49,989	17,702	2,814	3,450	3,265	750	77,970
1986	225,593	55,405	8,062	4,680	3,344	4,895	301,979
1987	125,985	97,291	14,131	2,166	10,489	1,955	252,017
1988	81,490	105,786	12,849	1,527	9,832	231	211,715
1989	100,633	120,929	16,417	4,589	24,877	111	267,556
1990	67,303	168,554	44,827	3,470	19,905	643	304,702
1991	51,417	190,318	62,983	4,685	41,125	261	350,788
1992	24,845	134,643	66,453	4,554	18,485	129	249,109
Average	150,594	79,594	19,658	3,663	10,932	907	265,348

NOTE: Numbers are different than in previous Annual Reports because a different method is now being used to calculate abundance indices.

upper Suisun Bay, Honker Bay, and the lower Sacramento River. Only 8% of the total *C. franciscorum* catch was collected at the lower Sacramento and San Joaquin River stations above our original study area. This indicates that our index, which includes only the original study area, did not account for a small portion of the *C. franciscorum* population in 1992.

Abundance of *C. nigricauda* decreased in 1992, ending the trend of increasing abundance indices since 1986 (Table 50). *C. nigromaculata* abundance increased in 1992 relative to 1991 and comprised a record high 27% of the total shrimp index. In 1992 the *Heptacarpus* index declined from 1991, although abundance from 1989 to 1992 was high relative to previous years. Abundance of *Palaemon* was similar to recent years, and the *Lissocrangon* index was again low.

The 1992 total shrimp abundance index decreased from 1990 and 1991, primarily because of decreased abundance in San Pablo and Suisun bays (Figure 51). Although the index in each embayment decreased from 1991 to 1992, the percentage of the total index attributed to Central Bay increased to 54%. This shift in abundance from San Pablo and Suisun bays to Central Bay was due to a decrease in abundance of *C. franciscorum* and *C. nigricauda* and an increase in abundance of *C. nigromaculata*.

In comparing the drought years (1988-1992) to previous years, there was a distinct change in contribution of the embayments to the total index (Figure 50). Central Bay accounted for an increasing portion of the total index, while San Pablo and Suisun bays comprised an ever decreasing portion. In the early 1980s, San Pablo Bay accounted for up to 57% (1980 and 1982) of the total index. The contribution of Suisun Bay declined from 26% in 1987 to 4% in 1992. The contribution of South Bay was as little as 13% (1982) but has been relatively constant since 1984, ranging from 24% to 30% of the total index. The western delta area index varied from zero or a very low number in years with high freshwater outflow to 8% in years with low outflow (1981 and 1988). With the decrease in *C. franciscorum* abundance in 1991 and 1992, the western delta area accounted for only 2% of the total index.

A shrimp biomass index was calculated for 1980 to 1992 using length-weight equations developed by this study. General trends in annual biomass indices (Figure 52) are similar to trends in abundance indices, but there are some important differences. The highest abundance index was in 1983, but because the mean size of *C. franciscorum* was slightly smaller than in other years, the highest biomass index was in 1982. The average abundance index from 1988 to 1992

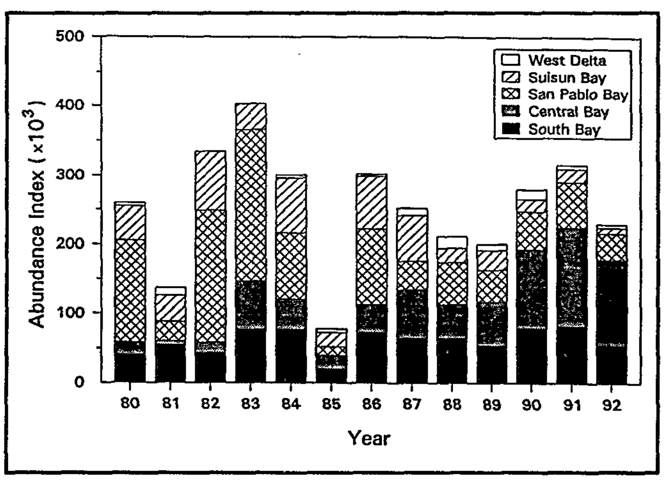

Figure 51
ANNUAL ABUNDANCE INDICES OF ALL SPECIES OF SHRIMP, BY EMBAYMENT, 1980-1992

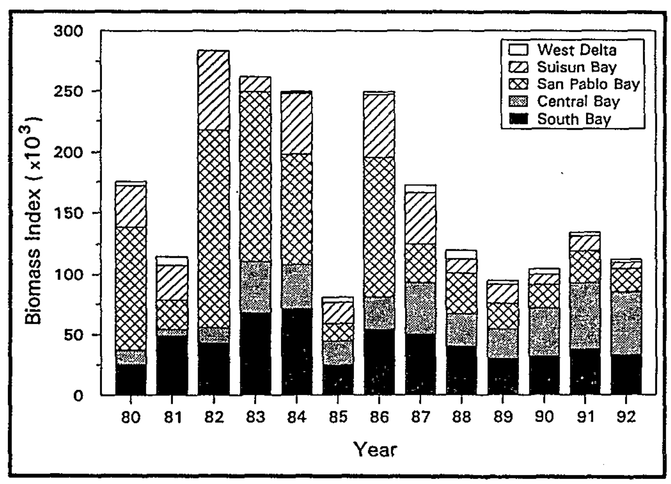

Figure 52
ANNUAL BIOMASS INDICES OF ALL SPECIES OF SHRIMP, BY EMBAYMENT, 1980-1992

was 85% of the average for the high outflow years (1980, 1982, 1983, 1986), but the average biomass index for 1988 to 1992 was only 47% of the average for the high outflow years. From 1988 to 1992, the bay shrimp population was composed of a large number of juveniles and species that do not grow as large as *C. franciscorum*.

Dungeness Crab

In 1992 we collected no juvenile Dungeness crab *(Cancer magister)* in our boat or ring-net surveys. This poor year class was probably due to above-average ocean water temperatures in the winter of 1991-92 when Dungeness crab larvae were hatching. Higher water temperatures have been shown to reduce egg survival and hatching success.[1] There has not been a strong year class of Dungeness crabs in the bay since 1988.

Fishes

The annual abundance indices of 14 commonly collected species of fish are discussed in this section. Locations of spawning and nursery areas of these species were summarized in the 1991 Annual Report.[2] Species are again grouped by the salinity of their nursery area, with species that use the higher salinity areas presented first.

Species that use the higher salinity areas (>20 ppt) as a nursery have had both relatively high and low abundance indices since 1987. With the addition of the 1992 data, no species exhibited consistent increases in annual abundance throughout the entire drought.

Bay goby abundance decreased in 1992 after being relatively high from 1988 to 1991 (Figure 53). One hypothesis for this decrease is that the increased outflow in February and March of 1992 resulted in a movement of fish from the bay to the nearshore ocean area. Even with the decreased abundance in 1992, the average index from 1988 to 1992 was about three times the average index from 1980 to 1987.

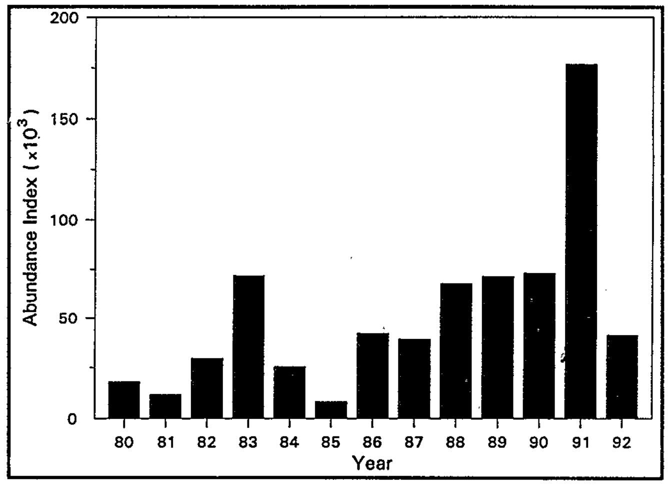

Figure 53
BAY GOBY ANNUAL ABUNDANCE INDICES
All Sizes; February-October; Otter Trawl.

In 1992 the abundance of young-of-the-year plainfin midshipman increased slightly from 1991 (Figure 54). Abundance has been high since 1986, and this increase is believed to be attributed in part to the stable salinities and a larger area of the bay with salinities >20 ppt associated with the drought.

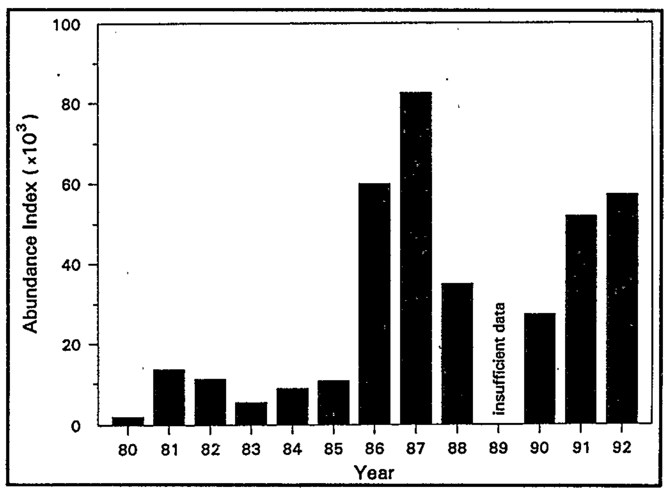

Figure 54
PLAINFIN MIDSHIPMAN ANNUAL ABUNDANCE INDICES
Young-of-the-Year; July-October; Otter Trawl.

1 P.W. Wild. The influence of sea water temperature on the spawning, egg development, and hatching success of the Dungeness crab, *Cancer magister*. In: *Life History, Environment, and Mariculture Studies of the Dungeness Crab,* Cancer magister, *with Emphasis on the Central California Fishery Resource.* P.W. Wild and R.N. Tasto, editors. Calif. Dept. Fish and Game Fish Bull. 172:197-214. 1983.

2 Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. *1991 Annual Report.* 1993.

The abundance index of white croaker was a record high in 1992; it was composed of the strongest year class of young-of-the-year since 1986 and a relatively high abundance of older fish (Figure 55). The high abundance of YOY in 1986 resulted in a large year class that contributed to our catch at least through 1990. White croaker may have also benefited from the drought, although their abundance increase was partially due to the strong 1986 year class.

Speckled sanddab abundance increased slightly from 1991 to 1992, but there was no trend in abundance in recent years or since the study began (Figure 56). The annual indices from 1988 to 1992, except 1990, were above average.

The 1992 abundance index of California halibut increased from 1991 and was the highest since the study began (Figure 57). Our catch was dominated by young-of-the-year, 1-year-old, and 2-year-old fish in 1992. In 1990 and 1992, warmer ocean waters resulted in strong year classes. California halibut abundance indices are still very low relative to several other common species of flatfish; the highest halibut annual index was 1,500, whereas the lowest English sole index was 9,000, and the lowest speckled sanddab index was 3,000.

In 1992 abundance of young-of-the-year English sole was the third lowest for the study (Figure 58). The fluctuations in annual abundance have not been large, with the highest index only four times the lowest index. Several of the lowest indices (1987, 1990, and 1992) had higher-than-average ocean temperatures in winter, when English sole spawn. As for several other species, warm-water events or the currents associated with them may result in lower egg or larval survival and subsequently poor recruitment of juveniles to the bay.

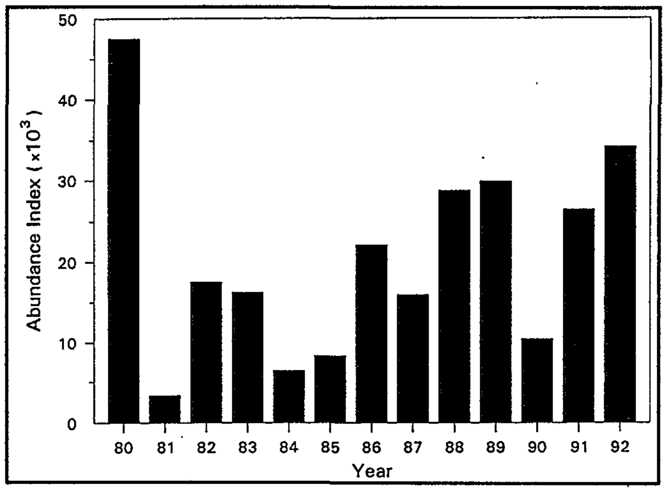

Figure 56
SPECKLED SANDDAB ANNUAL ABUNDANCE INDICES
All Sizes; February-October; Otter Trawl.

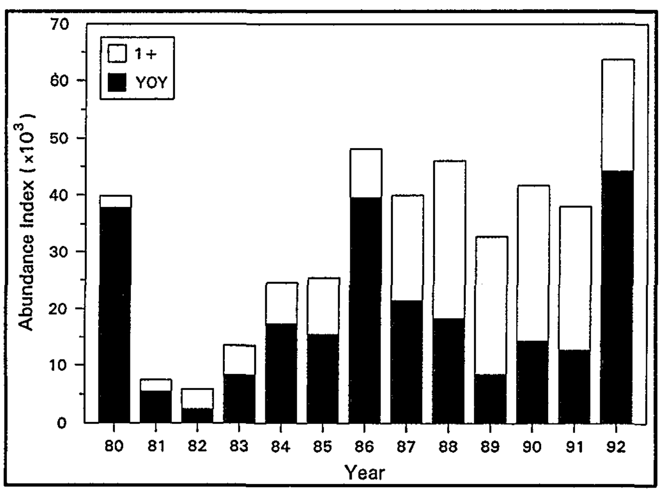

Figure 55
WHITE CROAKER ANNUAL ABUNDANCE INDICES
Young-of-the-Year and 1+; February-October; Otter Trawl.

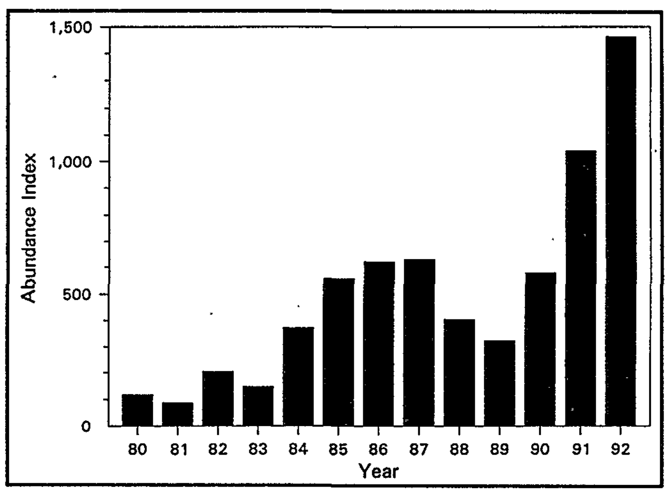

Figure 57
CALIFORNIA HALIBUT ANNUAL ABUNDANCE INDICES
All Sizes; February-October; Otter Trawl.

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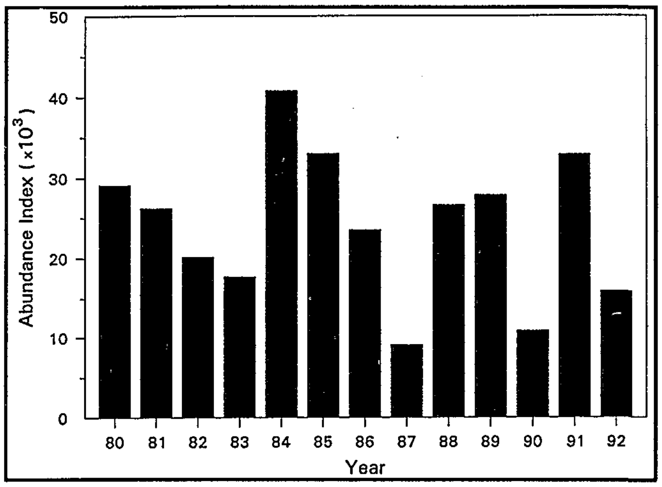

Figure 58
ENGLISH SOLE ANNUAL ABUNDANCE INDICES
Young-of-the-Year; February-October; Otter Trawl.

Northern anchovy abundance increased in 1992 from previous years and was the highest since 1986 and 1987 (Figure 59). We have yet to determine what the controlling factors are for anchovies, as there is no apparent relationship between annual abundance and ocean conditions (temperature, upwelling) or bay conditions (salinity, temperature, outflow).

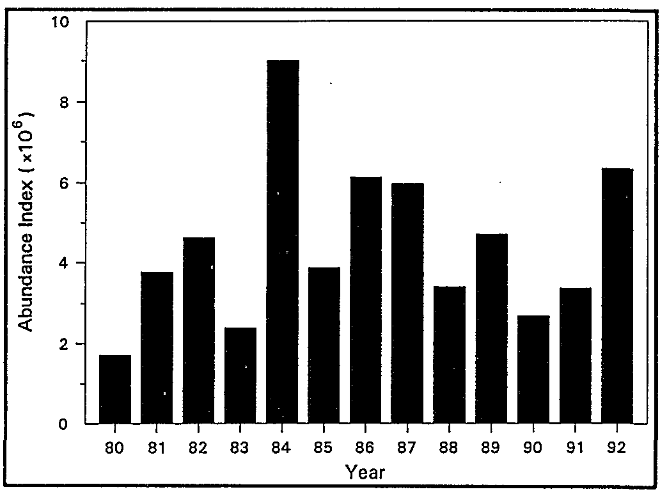

Figure 59
NORTHERN ANCHOVY ANNUAL ABUNDANCE INDICES
All Sizes; February-October; Midwater Trawl.

Jacksmelt young-of-the-year abundance has been very low for 4 of the last 5 years, with insufficient data in 1989 because we only sampled through August (Figure 60). Shiner perch YOY abundance has been very low since 1987, with the five lowest indices the last five years (Figure 61). These two species use higher salinity habitats as nursery areas, and one could hypothesize that their abundance would increase in the bay during the drought because a larger area had suitable salinities. We have not determined what factors are affecting their abundance in the bay.

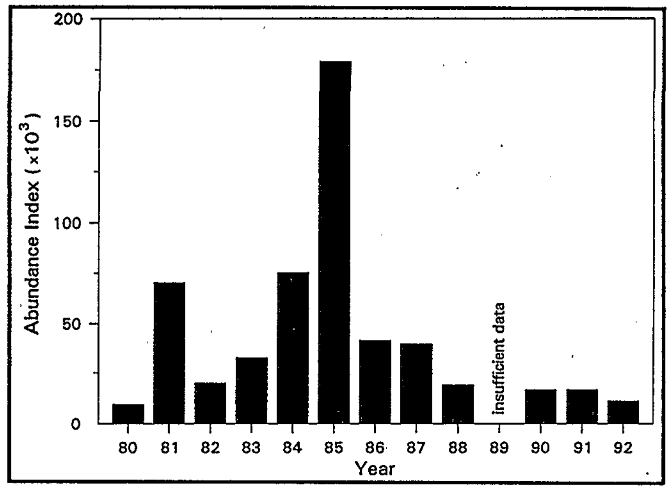

Figure 60
JACKSMELT ANNUAL ABUNDANCE INDICES
Young-of-the-Year; July-October; Midwater Trawl.

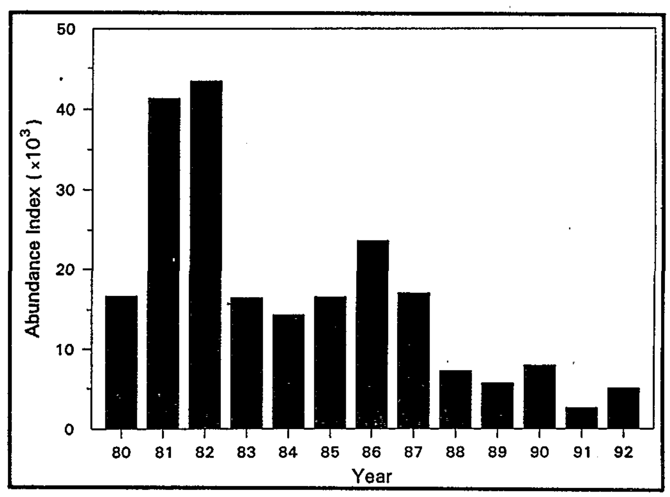

Figure 61
SHINER PERCH ANNUAL ABUNDANCE INDICES
Young-of-the-Year; May-October; Otter Trawl.

Pacific herring abundance has been low since 1990, with the 1992 index only slightly higher than the 1991 index (Figure 62). Based on the return of 2-year-old fish to the bay, the 1990 year class was the weakest since 1981.[1] In anticipation of low numbers of spawners (primarily 2- and 3-year-old fish) returning to the bay in the winter of 1992-93, fishing quotas were the lowest ever. With the exception of 1983, when larvae were transported out of the bay by extremely high flows, the years with the highest YOY indices were years with high outflow (1980, 1982, 1986). It is well documented that Pacific herring spawn in areas with low temperatures and salinities between 8 and 28 ppt.[2,3] Hatching success and survival and growth of larvae may also be positively affected by reduced salinities.[4] We are continuing to develop our life history model for Pacific herring and have planned a special study for 1993 to determine if the vertical distribution of larvae would result in transport from the spawning areas (primarily South and Central bays) to San Pablo Bay, which is an important nursery area.

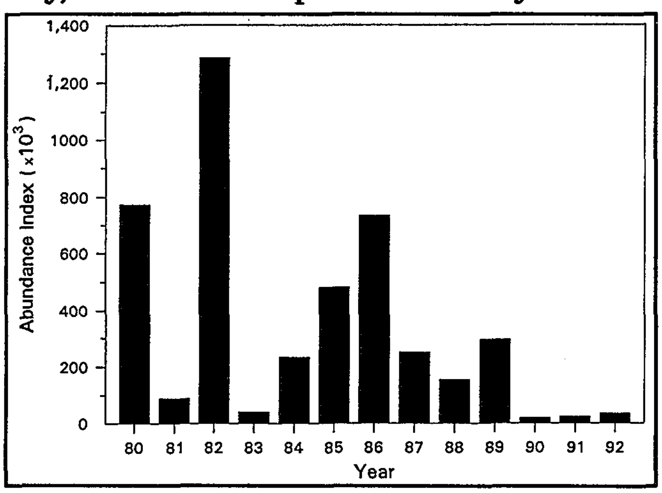

Figure 62
PACIFIC HERRING ANNUAL ABUNDANCE INDICES
Young-of-the-Year; April-September; Midwater Trawl.

Abundance of young-of-the-year staghorn sculpin decreased in 1992 from 1991 (Figure 63). There was no trend in abundance over recent years, as there have been low and high indices since 1987. Unlike species discussed above, staghorn sculpin rear over a wide range of salinities.

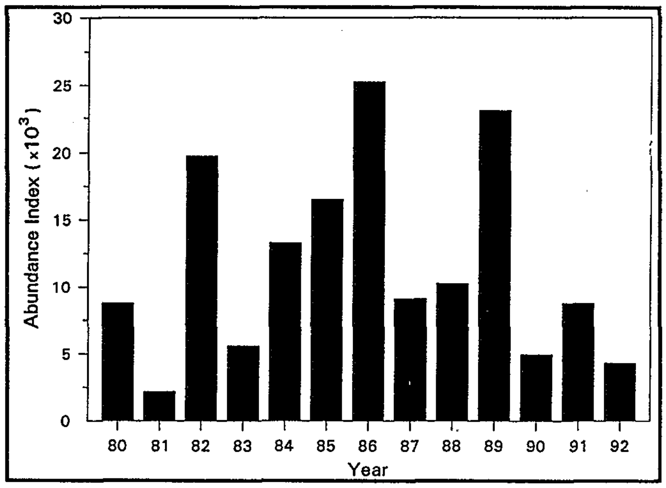

Figure 63
STAGHORN SCULPIN ANNUAL ABUNDANCE INDICES
Young-of-the-Year; February-October; Otter Trawl.

Longfin smelt and starry flounder, two native species that use low salinity habitats as a nursery area, had very low abundance in 1992. Longfin smelt young-of-the-year abundance has been very low since 1987 (Figure 64a); 1-year-old abundance has been low since 1989 (Figure 64b). We collected no YOY starry flounder in 1992 in either the monitoring survey (Figure 65a) or our shallow water survey. Because an unknown portion of the population of YOY fish are distributed upstream of the study area, abundance of 1-year-old fish may be a better indicator of year class strength. Abundance trends for 1-year-old starry flounder closely follow those for YOY fish, with a 1-year time lag (Figure 65b). Factors affecting abundance

1 K. Oda, Department of Fish and Game, personal communication.

2 D.F. Alderdice and F.P.J. Velsen. Some effects of salinity and temperature on early development of Pacific herring (*Clupea pallasi*). *J. Fish. Res. Bd. Canada* 28:1545-1562. 1971.

3 D.E. Hay. Reproductive biology of Pacific herring (*Clupea harengus pallasi*). *Can. J. Fish. Aquat. Sci.* 42 (Suppl. 1):111-126. 1985.

4 Alderdice and Velsen 1971.

of these two species and outflow-related mechanisms were recently discussed in an exhibit prepared for the SWRCB[1] and in the 1991 Annual Report.

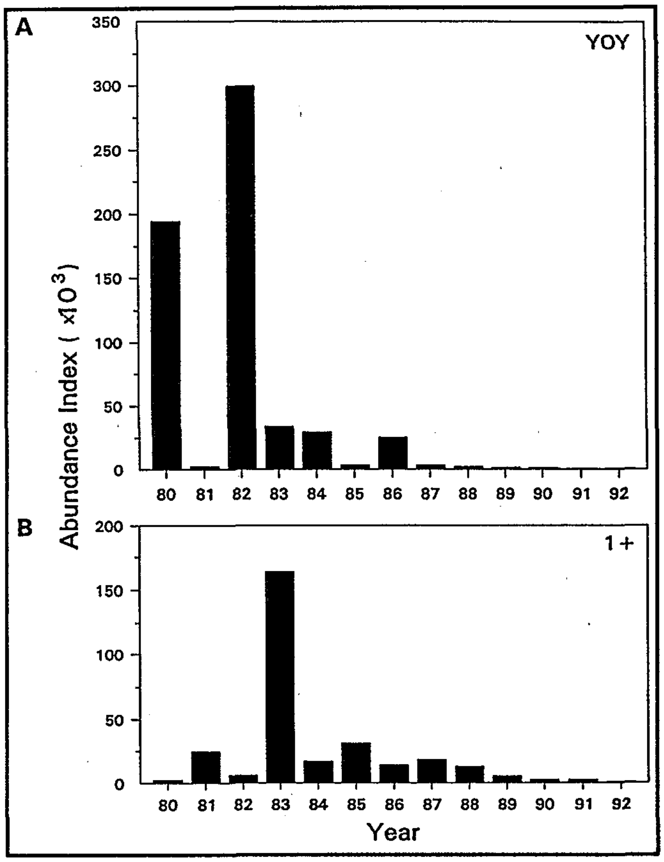

Figure 64
LONGFIN SMELT ANNUAL ABUNDANCE INDICES
A: Young-of-the-Year; May-October; Midwater Trawl.
B: 1+; February-October; Midwater Trawl.

Yellowfin goby is an introduced species that also uses low-salinity or freshwater habitats as nursery areas. They spawn in higher salinity waters, primarily San Pablo Bay, in the winter and early spring, and juveniles rapidly migrate upstream. In low-outflow years, a large portion of the young-of-the-year population is located upstream of the study area. Abundance of YOY yellowfin gobies was high in 1992 relative to 1990 and 1991 (Figure 66).

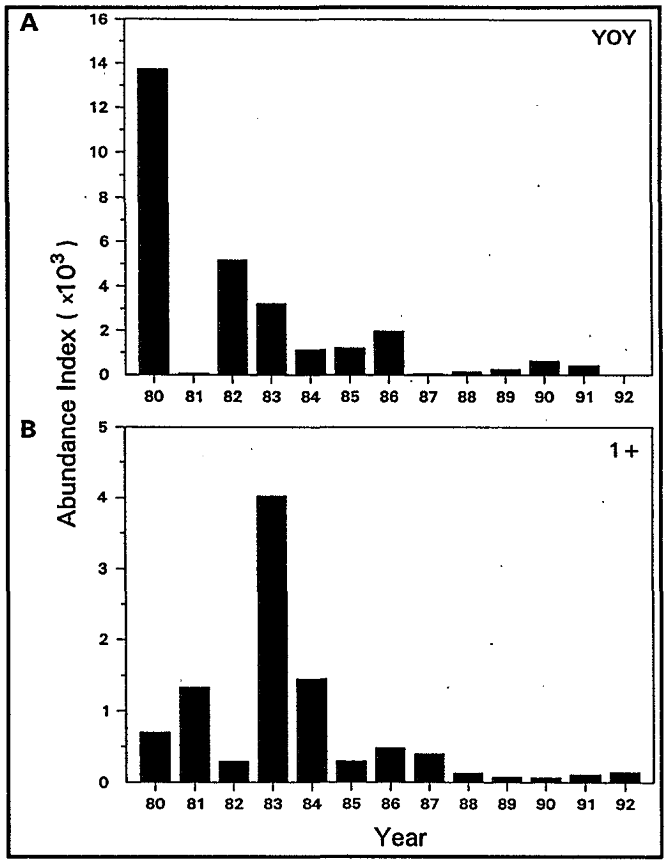

Figure 65
STARRY FLOUNDER ANNUAL ABUNDANCE INDICES
A: Young-of-the-Year; May-October; Otter Trawl.
B: 1+; February-October; Otter Trawl.

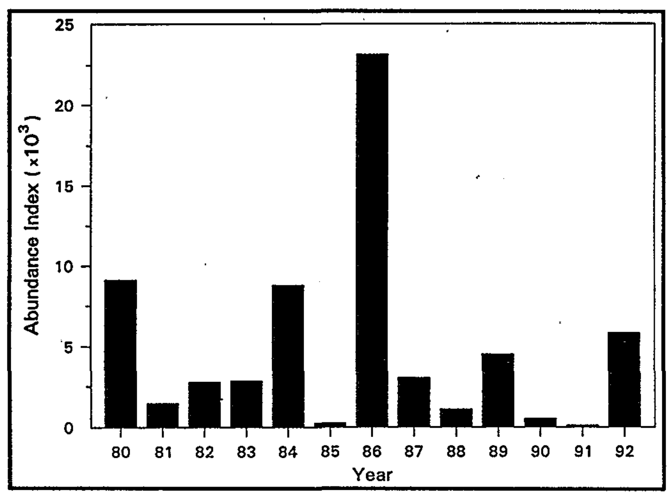

Figure 66
YELLOWFIN GOBY ANNUAL ABUNDANCE INDICES
Young-of-the-Year; May-October; Otter Trawl.

1 California Department of Fish and Game. *Estuary Dependent Species.* Exhibit entered for the State Water Resources Control Board 1992 Water Quality/Water Rights proceedings on the San Francisco Bay/Sacramento-San Joaquin Delta. WRINT-DFG #6, 97 pp. 1992.

C-042964

Discrete Depth Sampling

The discrete depth sampling study was designed to determine if larvae and small juveniles of selected species of shrimp and fish exhibit non-random depth distributions and if these distributions change in response to tidal stage, light level, or organism age. We hypothesize that certain estuarine-dependent species change depth distributions to take advantage of tidal or outflow-related currents in migrating from their spawning areas to nursery areas and to maintain their position in the nursery area during the early part of their lives. By determining the means by which these organisms immigrate to nursery areas, we can identify factors that are critical in determining year class strength. In 1992, we targeted starry flounder and *Crangon* shrimp, which spawn in marine water, and longfin smelt, which spawn in fresh water.

Central Bay

In 1992, three Tucker trawl surveys targeting larval and juvenile starry flounder and *Crangon* shrimp were completed in Central Bay. Each tow discretely sampled the top, middle, and bottom portions of the water column with a 1-meter-square 505-micron mesh net. Sampling was conducted at a single location for each survey, except in late April, when tows alternated from the east side to the west side of the channel. Dates and sampling locations were:

March 17 and 18: Day/night sampling off Tiburon, full moon, 20 tows completed (5 day flood, 5 day ebb, 5 night flood, 5 night ebb).

April 1: Night sampling off Point San Pedro, new moon, 7 tows (5 night flood, 2 night ebb).

April 29 and 30: Day/night sampling at two locations off Tiburon, new moon, 24 tows, alternated between the east and west side of the channel (6 day flood, 6 day ebb, 6 night flood and 6 night ebb).

Due to the large numbers of larval northern anchovies present in the March and early April samples, only bottom samples from night flood tides were sorted for larval fish since these had the highest likelihood of containing starry flounder. No starry flounder were found in these samples, so no other samples were sorted from these surveys.

By the late April survey, anchovy numbers decreased and all samples were sorted. Once again, no starry flounder were found. These samples also were processed for *Crangon* larvae and post-larvae (juveniles <11 mm). We cannot reliably speciate *Crangon* larvae and post-larvae, but based on the abundance of ovigerous females in April and larger juvenile *Crangon* in May, it was assumed most of the larvae and post-larvae were *C. franciscorum* and *C. nigricauda*.

Numbers of *Crangon* early-stage larvae (stages 1 and 2) and post-larvae from the late April survey were sufficient to statistically test the data. There was a sample size of six for each factor level combination of depth, tide, and day/night factors. A balanced 3-factor factorial design fixed-effect model ANOVA was used to test effects of each factor on the catch-per-unit-effort (number/10^3 m^3) of early stage larvae and post-larvae.

For early stage larvae, the ANOVA indicated no significant depth effect ($p > 0.5$). Although more larvae on average were collected at the surface for day ebb samples and the bottom for night flood samples (Table 51), extreme variability between samples at all depths obscured any trends. Both tidal ($p < 0.05$) and day/night ($p < 0.05$) effects were significant, with higher densities on the ebb tide and at night. No interactions were significant ($p > 0.10$). A comparison of means for each factor level and the grand mean shows all daytime samples were below the grand mean except the surface samples on the ebb tide. With the exception of surface and mid-depth flood samples, the opposite was true for night collections.

Table 51
MEAN CATCH-PER-UNIT-EFFORT OF EARLY STAGE LARVAL *CRANGON* FROM APRIL 1992 TUCKER TRAWL SAMPLING IN CENTRAL SAN FRANCISCO BAY
Data are for larval stages 1 and 2.

	Flood	Ebb
Day		
Surface	379	3,020
Midwater	464	703
Bottom	679	686
Night		
Surface	468	4,304
Midwater	1,837	2,758
Bottom	2,190	5,158

n = 6
Grand Mean = 1,887

For *Crangon* post-larvae, the ANOVA indicated all main and 2-way interaction effects were significant ($p < 0.05$). Average catch-per-unit-effort for each factor indicates post-larval depth distribution favored the bottom and more were collected on flood tides and during the night (Table 52).

Table 52
MEAN CATCH-PER-UNIT-EFFORT OF POST-LARVAL *CRANGON* FROM APRIL 1992 TUCKER TRAWL SAMPLING IN CENTRAL SAN FRANCISCO BAY

	Flood	Ebb
Day		
Surface	6	0
Midwater	4	0
Bottom	249	7
Night		
Surface	194	4
Midwater	613	36
Bottom	3,045	238

n = 6
Grand Mean = 366

Based on previous sampling, an early stage larval depth distribution favoring the surface was expected.[1] Early stage *Crangon* larvae are believed to be transported from estuaries by surface currents created by freshwater discharge.[2,3,4] Observed larval depth distributions favoring the bottom at night for some tows are hypothesized to have resulted from recent hatching and slow movement of larvae to the surface. Post-larval depth distribution favoring the bottom based on limited sampling has been previously reported.[5] Post-larvae are hypothesized to use bottom currents, gravitational and tidal, to immigrate into estuaries.[6] Collection of post-larvae primarily during flood tides but not ebb tides indicates a behavioral mechanism is involved in tidally-assisted immigration. The increase in numbers at night could be because post-larvae immigrate primarily at night to avoid visual predators. *Crangon* post-larvae may also have been more vulnerable to the nets at night because they ascend in the water column to follow vertically migrating prey.

Upriver

During upriver sampling an attempt was made to follow the same water mass through two tides with the use of floating, radar reflective drogues. By sampling the same water mass, we attempted to reduced the variability associated with sampling different "patches" of larvae when sampling is spread through a large volume of water. Sampling was conducted during neap tide to reduce the effect of tidal-induced turbulent mixing, which might have obscured patterns in depth distribution. Sampling dates and locations were:

1 Interagency Ecological Studies Program for the Sacramento-San Joaquin Estuary. 1990 Annual Report. 123 pp. 1991.
2 P.A. Sandifer. The role of pelagic larvae in recruitment to populations of adult decapod crustaceans in the York River estuary and adjacent lower Chesapeake Bay, Virginia. *Estuarine Coastal Mar. Sci.* 3:269-79. 1975.
3 S.E. Hatfield. Seasonal and interannual variation in distribution and population abundance of the shrimp *Crangon franciscorum* in San Francisco Bay. *Hydrobiologia* 129:199-210. 1985.
4 Department of Fish and Game 1992.
5 Interagency Program 1991.
6 Hatfield 1985; Department of Fish and Game 1992.

February 27: Carquinez Strait, day, 9 tows (4 flood, 1 high slack, 4 ebb).

March 27: Port Chicago to lower Sacramento River, day, 10 Tows (5 flood, 5 ebb).

April 27: Chipps Island to lower Sacramento River, day, 10 tows (5 flood, 5 ebb).

May 26: Broad Slough to Decker Island on the Sacramento River, day, 10 tows (5 flood, 5 ebb).

A total of 39 tows were completed, and all 117 samples were sorted. All species were separated by life stage (yolk-sac, post-yolk-sac, and juvenile) and enumerated. All longfin smelt were measured.

Only the longfin smelt data have been analyzed to date. There was a sample size of 4 or 5 for each factor-level combination of depth and tide factors for each of the four surveys. A balanced 2-factor factorial design fixed-effect model ANOVA was used to test effects of each factor on the catch-per-unit-effort of larvae (combined yolk-sac and post-yolk-sac). Nonparametric ANOVA techniques were used for juveniles (>20 mm total length). Data for each survey were analyzed separately.

For longfin smelt larvae, ANOVA indicated significant depth effects for February ($p < 0.05$) and March ($p < 0.05$); in April and May, catches were insufficient to allow testing. There were no significant tidal effects ($p > 0.10$) or interactions ($p > 0.10$) for either month, although about twice as many larvae were collected from the flood samples as from the ebb samples (Table 53). Comparisons of mean catch-per-unit-effort by depth and tide indicate larvae favored the surface in comparison to mid- and bottom depths for both tides and surveys.

Low juvenile numbers and frequent zero catches at the surface necessitated use of nonparametric techniques. An extension of the Kruskal-Wallis test was used. Few juvenile longfin smelt were collected before April, so only April and May data were analyzed. For juveniles, Kruskal-Wallis tests detected significant depth effects for both April and May ($p<0.05$ for both) but no effect of tide ($p>0.05$) or interaction between depth and tide ($p>0.05$ for either month. In April, juveniles were in significantly higher concentrations at mid-depths than at either surface ($p<0.002$) or bottom ($p<0.05$) depths; in May, juveniles were in higher concentrations at mid-depths than at the surface ($p<0.005$), but no other comparisons were significant. Average juvenile densities per thousand cubic meters of water filtered in April tows were 0.2 at the surface, 6.5 at mid-depth, and 1.1 at the bottom. In May, average densities were 0.3 at the surface, 23.2 at mid-depth, and 9.3 at the bottom. These depth distributions show a transition from a surface-oriented larvae to a mid-depth and bottom-oriented juvenile with growth (Table 54).

Surface-oriented larval longfin smelt would be vulnerable to downstream dispersal by freshwater outflow until they reach 15 to 25 mm and move deeper in the water column. A mid-depth or bottom orientation would help them maintain their position longitudinally in the estuary. Knowledge of growth rates during different months should allow predictions of how long longfin smelt larvae would be vulnerable to dispersal and when managed pulse flows would be of benefit to them. The size (or size range) at which larvae move toward the bottom is still in some question because of the low number of

Table 53
MEAN CATCH-PER-UNIT-EFFORT OF LARVAL LONGFIN SMELT FROM FEBRUARY AND MARCH 1992 TUCKER TRAWL SAMPLING IN SUISUN BAY

	Flood	Ebb
February		
Surface	201	81
Midwater	20	30
Bottom	22	20
n = 4		
Grand Mean = 64		
March		
Surface	175	81
Midwater	24	9
Bottom	18	7
n = 5		
Grand Mean = 52		

Table 54
DEPTH DISTRIBUTION OF LONGFIN SMELT LARVAE, BY LENGTH
Catch by length interval and depth were combined from all 1992 Tucker Trawl surveys.

	Surface		Mid-Depth		Bottom	
Length *(mm)*	Number	% of Total Catch	Number	% of Total Catch	Number	% of Total Catch
5-9.9	605	79	84	11	75	10
10-14.9	281	76	42	11	49	13
15-19.9	27	51	12	23	14	26
20-24.9	5	19	14	54	7	27
25-29.9	2	5	25	64	12	31
30-34.9	0	0	44	71	18	29
35-39.9	0	0	11	55	9	45

larger larvae and small juveniles collected in 1992. This life stage will be targeted with additional sampling in 1994.

Shallow Water Sampling of Nursery Habitats

Bay Study beach seine and otter trawl data suggest numerous estuarine species spend much of their first few months in the bay in shallow water (<1.5 meters). This may be a critical period in the life of certain species. The timing, amount, and location of brackish, shallow-water habitat has been shown to be positively related to the subsequent abundance of *C. franciscorum* and starry flounder.[1] In attempting to refine habitat/abundance relationships, there is a need to quantify use by depth and substrate type. Previous sampling efforts, mostly beach seining, concentrated on easily accessible areas such as beaches and boat ramps. These data cannot be used to assess the relative importance of shallow water areas, because sampling was not representative of all types of shallow water habitats.

In this study, our first objective was to test different gear types for their ability to quantitatively sample organisms from different substrates in shallow water. In 1992, a 1-meter beam trawl, a 15.2-meter beach seine, and fyke traps with 15.2-meter wings (all gear 3-mm mesh) were used. Sampling in soft substrates and in areas with a large number of clams proved to be a problem when beach seining or beam trawling. Setting fyke traps on soft substrates was also a problem because of difficulty in walking in the mud. Minor modifications to the weight and manner of towing the beam trawl met with limited success. Possible modifications include the addition of mud lines and raising the lead line, in conjunction with addition of a tickler line. We also plan to try some drop boxes or other similar gear. Lack of ready access to a suitable shallow-draft sampling boat limits progress on this study.

Sampling was conducted from March through June 1992 and concentrated in the area from San Pablo Bay upstream to the Sacramento River below Rio Vista and the San Joaquin River to Big Break. No young-of-the-year starry flounder were collected in 93 beam trawl or 53 beach seine samples; however, six 1-year-old starry flounder were collected. The most commonly collected inshore fish species in Suisun Bay and the western delta were juvenile striped bass (YOY and 1-year-old), tule perch (all year classes), splittail (YOY and 1-year-old), Sacramento squawfish, yellowfin goby, chameleon goby, and inland silverside. Some delta smelt were collected in the Sacramento River. In San Pablo Bay, northern anchovy,

1 Department of Fish and Game 1992.

jacksmelt, staghorn sculpin, and 2- and 3-year-old striped bass were most common in collections. *C. franciscorum* was common in beam trawl samples from Suisun and Honker bays, but less so in shallow water farther upstream.

C-042969

Tracy Fish Collection Facility

Charles Liston, Lloyd Hess, Catherine Karp,
Steve Hiebert, Gordon Mueller, Perry Johnson,
Ron Brockman, and Joseph Kubitschek
U.S. Bureau of Reclamation

Fisheries and engineering studies and evaluations completed in 1991 at Tracy Fish Collection Facility[1] were expanded in 1992 as part of a long-term program to improve fish salvage efficiencies through greater biological assessment and monitoring, altered operations, and potential structural modifications. Biological studies focused on frequent predator removal and assessment, fisheries resources in the Tracy Pumping Plant intake channel near Tracy Fish Collection Facility, and entrainment of fish eggs and larvae. Engineering programs involved an assessment with recommendations for upgrading and automating hydraulic measurements at key sites in the Tracy Fish Collection Facility. Also, preliminary experiments were conducted with a new single-beam hydroacoustic system to determine if sizes and numbers of fish near Tracy Fish Collection Facility structures could be estimated. Emphasis was on large fish that may represent predators residing in front of the trash racks.

Predator Removal at Tracy Fish Collection Facility

Predators and associated fish species were systematically removed from Tracy Fish Collection Facility by draining the secondary louver sump area and closing escape routes with a hinged fish screen. There were eight monthly predator removal efforts in 1992, with 32 secondary louver chamber drawdowns (Table 55). All fish removed from most drawdowns were identified and measured, but large numbers occasionally required subsampling. Fish were combined with other salvaged fish in the transport trucks and stocked into delta waters.

Table 55
PREDATOR REMOVAL EFFORTS AT TRACY FISH COLLECTION FACILITY, 1992
(For overnight samples, the facility was flushing for 15 to 20 hours; flushing time for day samples ranged from 1 to 3.5 hours.)

February 19	Wednesday	0915
		1145
		1430
March 19 & 20	Thursday	0900
		1105
		1430
	Friday	0830
April 16	Thursday	0900
		1100
		1300
May 19 & 20	Tuesday	0915
		1330
		1515
	Wednesday	0915
		1105
June 2 - 4	Tuesday	1030
		1345
	Wednesday	0915
		1330
	Thursday	0920
September 29 - October 1	Tuesday	1000
		1425
	Wednesday	1000
	Thursday	0815
October 27 & 28	Tuesday	0925
		1408
	Wednesday	0915
December 8 - 10	Tuesday	0945
		1330
	Wednesday	1015
		1400
	Thursday	0830

1 C. Liston, S. Hiebert, and G. Mueller. *Preliminary Results of Initial Studies for Increasing Fish Salvage Efficiencies at the Tracy Fish Collection Facility, and Assessing Fishery Resources in the Upper Delta-Mendota Canal System, California.* Bureau of Reclamation, Applied Sciences Branch, Environmental Sciences Section, Denver Office. Progress Report to Mid-Pacific Region. 1992.

A total of 11,519 fish comprising 23 species were taken with 32 sump drawdown samples (Table 56). Fish predators, including striped bass (40.6%) and white catfish (37.2%) clearly dominated samples.

Striped Bass

Average length for striped bass ranged from 2.6 inches in June to 8.0 inches in May, although larger bass were sampled occasionally. Maximum length ranged from 11.5 inches in June to 27.0 inches in December. Average size of bass has remained well below 10 inches in all predator removal samples since May 1991. Initial efforts in early 1991 revealed many large bass that had undoubtedly been residing within Tracy Fish Collection Facility for several years. Systematic removal efforts, now a regular part of operations, prevent many bass from taking up residence at the facility.

Striped bass were most abundant in September, when 48% (2,238 fish) of all bass were sampled. The fewest bass were sampled in May (92 fish). Stomach contents were analyzed from 18 striped bass (6.5-10.9 inches) in May and from 97 bass (3.4-15.2 inches) in September. Fish were found in 43 stomachs and included striped bass larvae and juveniles, smelt larvae, gobies, and threadfin shad. Invertebrates were found in 24 stomachs and included *Neomysis*, amphipods, and *Corbicula*.

White Catfish

Average total length for white catfish ranged from 3.3 inches in October to 8.0 inches in February. Minimum length was 0.4 inch; maximum was 15.6 inches. The most catfish were removed in September (1,527 fish). Mean length was 3.7 inches, with a range of 2.2 to 15.6 inches. The least were removed in March (161 fish). Mean

Table 56
SUMMARY OF FISH REMOVED FROM THE SECONDARY IN 1992 PREDATOR REMOVAL EFFORTS

Species	Total Number	% of Total Number	Total Weight	% of Total Weight	Length Range (inches)
American shad	48	0.4	4.1	0.4	3.5 - 15.5
Threadfin shad	1,490	12.9	50.3	5.5	2.0 - 5.9
Chinook salmon	428	3.7	94.3	10.3	3.6 - 11.4
Steelhead trout	63	0.6	32.3	3.5	7.4 - 20.9
White catfish	4,286	37.2	244.5	26.6	0.4 - 15.6
Channel catfish	306	2.7	16.6	1.8	2.7 - 16.1
Bullhead[1]	9	0.1	1.0	0.1	3.2 - 9.8
Common carp	1	<0.1	4.1	0.4	26.3
Goldfish	5	<0.1	4.2	0.4	6.3 - 12.9
Golden shiner	4	<0.1	0.3	<0.1	4.3 - 7.9
Sacramento blackfish	2	<0.1	1.4	0.2	5.7 - 15.8
Sacramento splittail	4	<0.1	2.7	0.3	5.7 - 14.6
Striped bass	4,683	40.7	449.0	48.8	1.2 - 27.0
Black crappie	2	<0.1	1.0	0.1	5.2 - 11.1
Bluegill	40	0.4	5.3	0.6	2.2 - 7.6
Largemouth bass	12	0.1	1.5	0.2	1.9 - 11.4
Smallmouth bass	2	<0.1	0.1	<0.1	3.1 - 3.2
Inland silverside	7	<0.1	0.2	<0.1	2.0 - 3.9
Tule perch	33	0.3	2.8	0.3	1.8 - 7.0
Bigscale logperch	6	<0.1	0.1	<0.1	3.4 - 4.7
Yellowfin goby	57	0.5	3.2	0.3	2.2 - 7.1
Chameleon goby	22	0.2	0.4	<0.1	1.9 - 3.8
Sculpin[2]	9	<0.1	0.3	<0.1	2.9 - 4.5
Total	11,519		919.7		

1 May include black or brown bullhead.
2 May include prickly and/or riffle sculpin.

length was 5.3 inches, with a range of 1.7 to 12.3 inches. Of 11 white catfish stomachs examined, 1 contained unidentified fish remains and 4 contained invertebrates (*Neomysis* and amphipods).

Other Species

Threadfin shad were third in abundance (1,490 fish), and 95% were removed in September (1,409 fish). Immature Chinook salmon (428 fish) were removed, and 84% of those (361 fish) were taken in March. Channel catfish, another potential predator at Tracy Fish Collection Facility, were common in May, June, September, and October samples and ranged from 2.7 to 16.1 inches. Steelhead trout, observed only in February, March, and April, ranged from 7.4 to 20.9 inches. The other 263 fish sampled represented 17 species and only 2.3% of all fish collected.

Tracy Pumping Plant Intake Channel

Fish escaping downstream through the Tracy Fish Collection Facility louver systems colonize the 2.5-mile-long Tracy Pumping Plant intake channel and, eventually, areas within the Delta-Mendota Canal and reservoir systems below the pumping plant. These resources are poorly known, and part of the 1992 Tracy studies were designed to survey the fishes in the intake channel immediately below the fish facility. Experimental bottom gill-nets were fished at night (n=24) and day (n=20) during June, September, and December predator removals. Four sites were sampled within a quarter-mile below the fish facility. Similarly, Fyke-nets, fished during night (n=13) and day (n=10), were tethered off two points of the fish facility.

A total of 495 fish composed of 12 species were sampled with gill-nets (Table 57). Night netting produced most of the fish. Striped bass comprised 54.3% of all numbers; total length ranged from 4.0 to 20.4 inches. Catches were similar among the months, although slightly greater populations of bass were indicated in December data. Native tule perch were second in abundance (16.6%) and occurred primarily in September samples. All other species except Sacramento splittail were introduced species. Sacramento splittail was represented by both juveniles and adults (length range was 8.4 to 17.1 inches), indicating that this species may be sustaining populations in this habitat. Further work is being planned to help us better understand splittail use of the channel. Splittail were also observed during 1991 in the Delta-Mendota Canal near the Tracy Pumping Plant outlet.

Fyke-net catches were less diverse (7 species) and were composed mainly of white catfish (76%; Table 57). Over 90% of fish were caught at night. Catches were greatest in September (53.2%), intermediate in June (42.9%), and least in December (only 10 fish were caught with 8 samples, composed exclusively of tule perch).

Table 57
SUMMARY OF FISHES COLLECTED IN GILL-NETS AND FYKE-NETS SET IN THE DELTA-MENDOTA CANAL INTAKE CHANNEL DURING 1992

	Gill-Net[1]		Fyke-Net[2]	
Species	Total Number	Length Range (*inches*)	Total Number	Length Range (*inches*)
American shad	2	6.1 - 6.3	—	—
Threadfin shad	49	4.4 - 7.0	1	5.1
White catfish	41	4.5 - 9.8	192	6.2 - 15.9
Channel catfish	8	5.0 - 9.4	41	6.9 - 10.9
Common carp	2	12.4 - 30.7	—	—
Sacramento splittail	17	8.4 - 17.1	—	—
Striped bass	269	4.0 - 20.4	—	—
Black crappie	2	5.2 - 7.5	3	7.5 - 9.1
White crappie	5	4.8 - 6.1	1	7.0
Bluegill	—	—	1	7.8
Largemouth bass	15	4.0 - 12.9	—	—
Tule perch	82	3.8 - 7.8	13	4.5 - 5.4
Yellowfin goby	2	6.9 - 7.9	—	—
Total	494		252	

1 Includes 44 gill-net sets (24 night, 20 day).
2 Includes 23 fyke-net sets (13 night, 10 day).

Entrainment of Eggs and Larvae

A continuous-pump egg and larval sampling system was operated at Tracy Fish Collection Facility during February 3 through June 3, 1992. The system was on a small pontoon barge immediately downstream of the trash racks. A centrifugal pump lifts water into a headbox/energy dissipater. From the headbox, water and material move through an inclined 250-micron wedge-wire screen and down through an automated diverter arm to screened sample collection buckets. A small peristaltic pump injects formalin into the filled sample bucket to preserve samples and reduce predation by amphipods. A total of 1,512 samples were collected, each of 60-minute duration with an average sample volume of 42 cubic meters. Sample analysis and quantification are not yet complete.

In decreasing order of abundance, the following nine species of fish larvae were collected: prickly sculpin, gobies, striped bass, threadfin shad, sunfish sp., bigscale logperch, Sacramento sucker, cyprinid sp., and delta smelt. Striped bass larvae appeared sporadically and in low numbers on April 8, 20, 22, 29, and 30 and more consistently and in higher numbers throughout May. Peaks in striped bass larvae were on May 11 (the highest), 16, 19, and 23.

Eggs of only three fish species were identified: striped bass, prickly sculpin, and gobies.

For comparative purposes, plankton nets were fished simultaneously with selected pump samples. Nets were 0.5-meter-diameter, 250-micron mesh, fitted with flowmeters to determine water volume sampled. A total of 227 plankton net samples were taken during February 17 through June 1. Sample analysis and quantification are not yet complete.

The following 12 species were collected, in decreasing order of abundance: prickly sculpin, chameleon goby, bigscale logperch, inland silverside, striped bass, threadfin shad, Sacramento sucker, delta smelt, white catfish, splittail, cyprinid sp., and sunfish sp. Prickly sculpin dominated the catch (75.1%) followed by chameleon goby (24.3%). Striped bass were relatively sparse in samples, with only 16 larvae and 49 eggs collected, mainly from May 3 to 20. Only 4 delta smelt larvae were collected, on March 23 and 26.

Automated Hydraulic Measurements

Numerous hydraulic parameters must be monitored for ongoing and future efficiency evaluations of Tracy Fish Collection Facility. Present instrumentation is not extensive enough and is in need of modernization. In 1992 the Denver Office Hydraulics Branch prepared a report outlining the types of parameters to be measured, locations, and appropriate instrumentation.[1] Plans are to select the instrument package in spring 1993, with installation to proceed shortly thereafter.

Water depths at Tracy Fish Collection Facility are influenced by tides and pumping plant operations. Changes in water surface elevation would be monitored at the following locations: upstream of the trash-rack structure, upstream of the primary louver in the primary forebay, downstream of the primary louvers, upstream of the first louver line in the secondary louver structure, between the first and second louver lines in the secondary louver structure, downstream of the second louver line in the secondary louver structure, and in each of the four fish holding tanks.

Approach velocities and louver line velocities are critical parameters that should be managed for effective louver operation. Velocities are strongly influenced by tides and pumping plant operations. Critical sites for monitoring are: across the face of the trash-rack structure, approach to the primary louver line in the primary louver forebay, across the face of the primary louver line, in each of the four primary bypass intakes, upstream of the first louver line in the secondary louver structure, along each of the louver faces in the secondary louver structures, in the secondary bypass intake, and in each of the four holding tanks.

Automated monitoring at key sites for water temperatures and dissolved oxygen are also being considered with the instrumentation package.

Hydroacoustic Experiments

Hydroacoustic systems can help determine fish densities, locations, and relative sizes. The experimental system used at Tracy Fish Collection Facility consisted of a single-beam Simrad EY-200P ecosounder equipped with a

1 J. Kubitschek. *Tracy Fish Collection Facilities (TCFC) Instrumentation Selection Recommendations - Final Report.* Bureau of Reclamation, Hydraulics Branch, Denver Office. Report to Mid-Pacific Region. 1993.

7-degree transducer operating at 200 kHz.[1] Data files were digitized and analyzed using the Hydro-Acoustical Data Analysis System (HADAS) developed at the University of Oslo, Norway. Acoustic surveys were made at three sites during June 2 and 3: day and night surveys were conducted in the primary louver bay, the area between the trash rack and debris boom, and off the boat dock in Old River.

Survey conditions were ideal in that water diversions were low and turbulence was minimal. Using a side-mounted transducer, fish could be detected at up to 15 meters. Daytime density of large fish in front of the trash rack was about twice as high as in Old River (0.187 to 0.103 fish/1000 m^3). In front of the trash rack, large fish were about 10 times more numerous at night than during the day (1,913 to 0.187 fish/1000 m^3). Densities of large fish in the primary forebay were quite low and ranged from 0.0 (night) to 0.085/1000 m^3 (day).

Hydroacoustics worked well under these experimental conditions, and there were relatively higher densities of fish in front of the trash rack than behind it or in Old River. Further quantification of densities will require more intensive sampling. The hydroacoustic system is well enough developed and refined to allow for its application at the delta fish stocking sites to help determine the extent of predation on stocked fish. Further hydroacoustic studies will be concentrated at those sites in 1993 to determine if alternative sites or altered fish stocking patterns should be considered.

Management Implications

Successful development of efficient predator removal methods at Tracy Fish Collection Facility suggests such activities can be easily incorporated into regular operations and maintenance programs. Since it is well documented that various sizes of small striped bass and catfish (usually 12 inches or less) continue to move into Tracy Fish Collection Facility through the 2-inch trash racks and that these fish easily take up residence within the facility, systematic predator removal programs are recommended.

The unlined intake channel below Tracy Fish Collection Facility provides habitat for a number of species, including native species. Further work on native species in the intake channel is planned to provide knowledge of reproductive times, feeding habits, habitat preferences, population sizes, and seasonal movements in anticipation of further threatened species listings.

Continuous sampling of eggs and larvae in flows to Tracy Fish Collection Facility is providing a record of abundance patterns and relative entrainment rates that is clearer than with past sampling. Future mitigation activities may be adjusted based on the continuous sampling, and operational changes may be considered to minimize entrainment during high-density periods. The continuous sampling methods under development are being considered for other intakes around the delta.

Improved and automated hydraulic measurements at Tracy Fish Collection Facility will provide modern tools for operating the louver systems more efficiently for fish collection and salvage. The instrumentation will also allow for accurate documentation of facility performance.

New hydroacoustic tools under development at Tracy Fish Collection Facility will provide timely assessments of fish numbers and sizes at locations important to the overall salvage activity. The initial management value from application of these methods will be related to the delta stocking sites.

Clifton Court Forebay

Terry Tillman
Department of Fish and Game

Entrainment and Loss Studies

During 1992, two additional entrainment loss studies were completed using hatchery-reared Chinook salmon released in Clifton Court Forebay. This effort was part of a series of studies to estimate juvenile fish losses in the forebay, define the causes, and develop guidelines to reduce these losses (Table 58).

Loss rates for spray-dyed salmon are calculated by monitoring salvage recoveries at Skinner Fish Protective Facility. Factors being evaluated as contributors to loss of entrained fish are water temperature, salmon size at entrainment, export

1 G. Mueller and S. Hiebert. *Preliminary Evaluation in the Use of Single-Beam Hydroacoustics at Tracy Fish Collection Facility, California*. U.S. Bureau of Reclamation, Applied Sciences Branch, Environmental Sciences Section, Denver Office. Progress Report to Mid-Pacific Region. 1992.

Table 58
SUMMARY OF CLIFTON COURT FOREBAY ENTRAINMENT LOSS STUDIES USING MARKED JUVENILE CHINOOK SALMON

Month/ Year	Loss Rate (%)	Mean Fork Length at Release (mm)	Water Temperature (°F)	Pump Exports at Release (cfs)	Striped Bass Abundance
10/76	97.0	114	68.7	252	—
10/78	87.7	87	60.0	4,476	—
04/84	63.3	79	61.0	6,000	35,390
04/85	74.6	44	61.5	6,852	—
06/92	98.7	77	74.5	2,260	162,281
12/92	77.2	121	47.4	3,390	156,667
04/93	94.0	66	63.0	3,390	223,000

pumping rates, and resident fish predator abundance. With each consecutive study, we obtain additional information on the individual roles of these factors in influencing salmon losses at the forebay.

Table 58 presents results from previous and recent studies, conducted under diverse forebay conditions. In the experiments, salmon survival rates vary widely with fish size, water conditions, and predator abundance. For the December 1992 study, marked salmon in the larger size classes (FL >120 mm) had higher survival rates. This size/survival relationship, depicted in Figure 67, supports earlier observations of larger fish being recovered over longer periods following release.[1]

Additional studies of this kind are planned for April and December 1993 and April 1994. These additional studies should provide information to help us better understand how various factors affect survival. The goal is to develop reliable survival projections related to size at entrainment, export rates, temperature, and predator abundance.

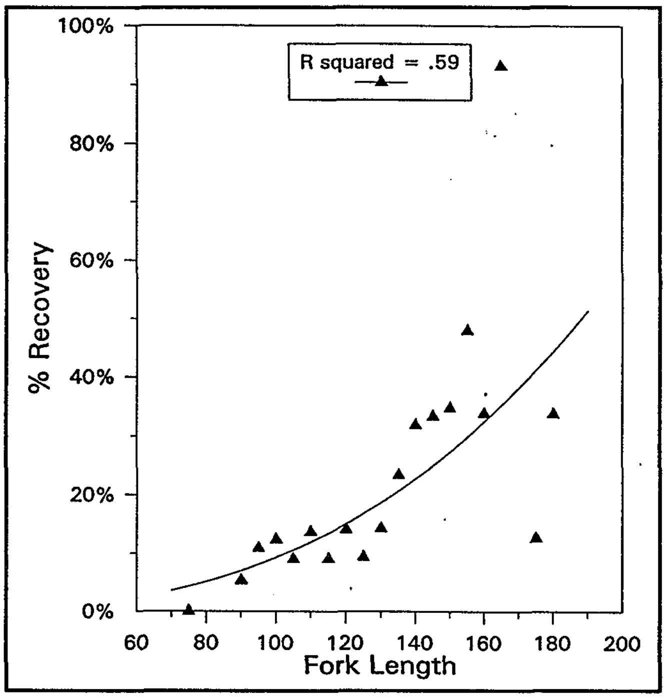

Figure 67
RECOVERY PERCENTAGES FOR SALMON SMOLTS BY LENGTH CLASS, CLIFTON COURT FOREBAY, DECEMBER 1992

Abundance of Predator-Sized Striped Bass

During 1992, DFG completed two predator population studies at Clifton Court Forebay. The objective was to estimate the number of chief predator fish species inhabiting the forebay. Such abundance estimates can then be compared to other environmental factors at the forebay to identify mechanisms influencing predator fish numbers.

Predatory fish are assumed to be a major component of total fish losses at the SWP delta export facilities. Recent data strongly suggest that age 1-plus and 2-plus striped bass (over 180-mm fork length) are the principal species preying on juvenile fish in the forebay. Accordingly, striped bass were marked and released as part of a modified Petersen mark/recapture procedure referred to below.

1 R.G. Schaffter. *An Evaluation of Juvenile King Salmon* (Oncorhynchus tshawytscha) *Loss in Clifton Court Forebay.* Dept. of Fish and Game, Anadromous Fisheries Branch, Admin. Report 78-21. 1978.

Striped bass were captured, marked with a ventral fin clip, and released in the spring, summer, and fall of 1992. Fish in poor condition were not clipped. Capture and marking lasted for 6 days, and marking mortalities were carefully monitored at a large holding pen set up in the forebay. Abundance estimates were 162,281 for August and 156,667 for November. A length/percent frequency distribution of stripers measured during a winter abundance study (February and March 1993) is given in Figure 68. This graph shows most striped bass sampled were in the 260- to 320-mm size range.

In addition to the work described above, we plan to do quarterly striped bass abundance studies for 1993, in February, May, August, and November.

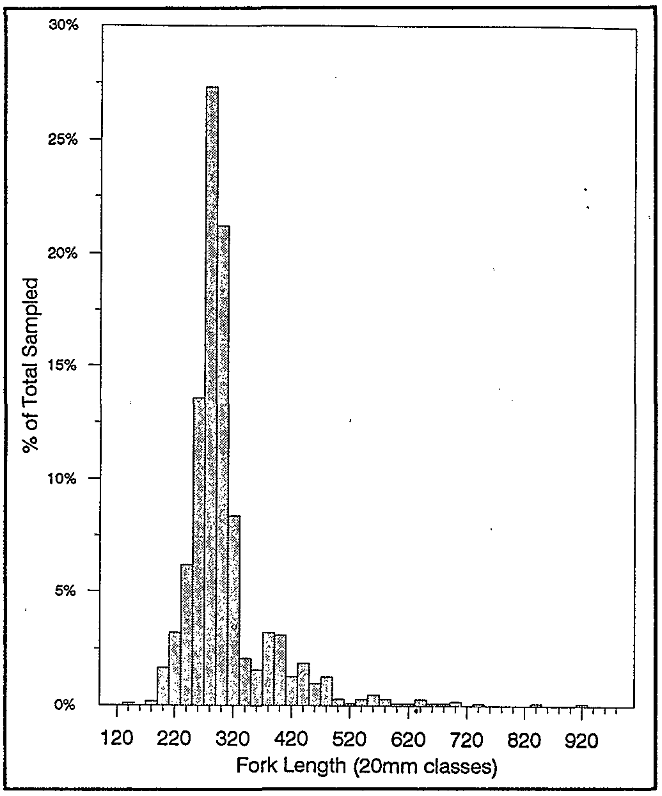

Figure 68
PERCENTAGES, BY SIZE CLASS, FOR STRIPED BASS SAMPLED DURING PREDATOR ABUNDANCE STUDIES AT CLIFTON COURT FOREBAY, FEBRUARY AND MARCH 1993

Hydroacoustic Monitoring of Fish Entrainment

Hydroacoustic sampling was suspended for 1992, but may resume in 1993 at the forebay radial gates and at the outlet channel. Objectives are to detect fish movement into the forebay and to monitor the net passage through to the fish screens. This will provide added information regarding survival across Clifton Court Forebay of fish entrained at the forebay radial gates.

The sonar equipment configuration consists of an echo-sounder, a multiplexer, a digital-tape recorder and chart recorder, two dual-beam and six single-beam transducers, an oscilloscope, and a portable personal computer. Transects are located just outside the radial gates in the forebay inlet channel and upstream of the trash boom in the outlet channel leading to the California Aqueduct. During each sampling series, a sonar impulse will cycle between transducers along the transect, according to a preprogrammed timing sequence. Recorded signal information from digital tape is then analyzed at the laboratory to determine numbers and sizes of sonar targets detected during each 2-hour interval. This information can be expanded into total numbers of fish and passage rates when multiplied by a cross-sectional channel width for each transect.

A rotary-trap and/or push-net will be used periodically in conjunction with the hydroacoustic equipment to calibrate acoustic target strengths for fish sizes and possibly individual species.

Predator Monitoring Program

Since spring 1991, the Department of Fish and Game has conducted weekly catch-per-unit-effort sampling to provide an index of predator abundance in Clifton Court Forebay. The objective is to maintain a low-effort method of tracking the abundance of predators.

In 1992, 1,744 predators were captured, composed mostly of striped bass (80.6%), white catfish (15.5%), and channel catfish (3.6%). Catch-per-unit-effort for all gear types combined did not decrease during summer, as it did in 1991 (Figure 69). Furthermore, the CPUE for striped bass was consistently greater than in 1991 for all months sampled except April and December. The CPUE for white catfish generally increased in 1992, but most of the increase was in late spring and summer.

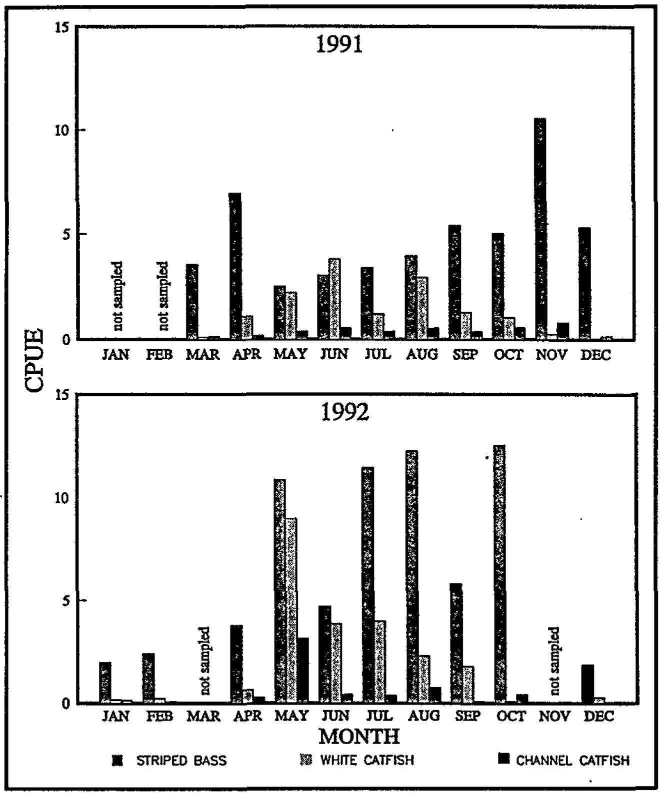

Figure 69
CATCH-PER-UNIT-EFFORT OF THE THREE MOST COMMON PREDATORS IN CLIFTON COURT FOREBAY DURING 1991 AND 1992

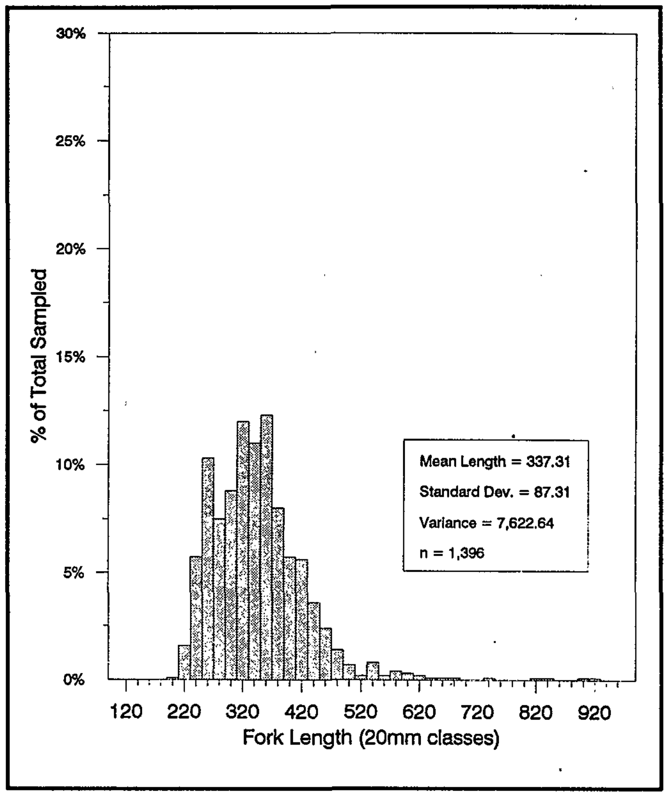

Figure 70
PERCENTAGES, BY SIZE CLASS, FOR STRIPED BASS SAMPLED IN THE CLIFTON COURT FOREBAY CATCH-PER-UNIT-EFFORT STUDY, 1992

Length/frequency distributions for striped bass sampled in the catch-per-unit-effort study differ from those in samples from the abundance and predator removal studies discussed below. As shown in Figure 70, most striped bass sampled in the CPUE study do not fall in the 260- to 320-mm classes as seen in the abundance and removal sampling. This difference in size frequency is cause for investigating possible inherent bias with the sampling methods in the CPUE and abundance work.

Predator Removal

Initial efforts to evaluate the feasibility of capturing and removing predatory fish from Clifton Court Forebay began in fall 1991. During this initial effort, fish were captured and returned to the forebay. Several sampling methods, including 1,000- and 2,000-foot-long seines, hook-and-line angling, and gill-nets proved effective in capturing predators.

Attempts at removing predatory fish from Clifton Court Forebay began in March 1992. Over the course of 3 weeks, about 2,000 predatory fish, including about 1,500 striped bass, were captured and transported by tank truck to the western delta. This effort indicated fish could be successfully captured, transported, and released alive.

From November 1992 through March 1993, predators were removed weekly at the forebay. This program targets age one-plus and two-plus striped bass, but all fish of a size that might prey on juvenile salmon were removed. Predators removed included striped bass, channel catfish, and smallmouth and largemouth bass.

A 600- by 12-foot Kodiak trawl with 2-inch stretched mesh as well as hook-and-line angling were used to take predator-sized fish. Fish were identified to species, enumerated, and measured. Often, large trawl collections had to be subsampled according to a random process. After completing all measurements, predator fish were placed in trucks and relocated to various sites in the delta.

A total of 80 days were spent capturing and removing predators using trawl gear, besides 40 angling days and 2 days of gill-netting. Of the

30,611 predators removed, 96% were striped bass (Figure 71). Mean fork lengths of fish removed were: striped bass (313 mm), smallmouth bass (368 mm), largemouth bass (361 mm), and channel catfish (490 mm) (Table 59). Length/frequency distributions for striped bass removed (Figure 72) were similar to those in the routine striped bass abundance studies for the same period.

Results indicate predatory fish can be removed from Clifton Court Forebay most efficiently during the cool-water periods (October through March).

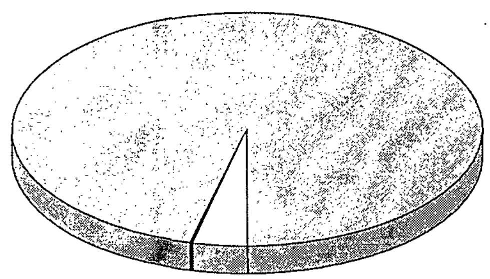

Figure 71
PREDATORS REMOVED FROM CLIFTON COURT FOREBAY DURING 1992

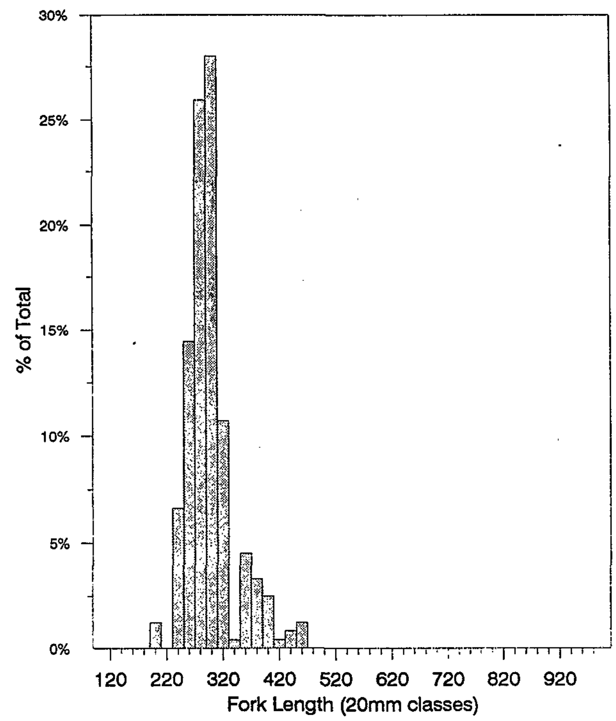

Figure 72
PERCENTAGES, BY SIZE CLASS, FOR STRIPED BASS REMOVED FROM CLIFTON COURT FOREBAY DURING DECEMBER 1992

Table 59
SPECIES SUMMARY FOR FISH CAPTURED IN
CLIFTON COURT FOREBAY PREDATOR REMOVAL EFFORT, NOVEMBER 1992 TO MARCH 1993

	Number Captured	Fork Length (mm)			Number Relocated
		Mean	Minimum	Maximum	
Hardhead	1				
Pacific brook lamprey	1	69	69	69	
Threadfin shad	1				
Tule perch	1				
Sacramento sucker	2	472	472	472	
Smallmouth bass	2	368	298	438	2
Black crappie	15				
Chinook salmon	15	653	235	887	
Golden shiner	35				
Sacramento blackfish	41	433	295	471	
Green sturgeon	45	751	416	1,736	
Bluegill	51	171	151	203	
Red-ear sunfish	53	248	247	248	
Largemouth bass	54	361	235	497	54
Steelhead trout	55	307	205	745	
Brown bullhead	63				
White sturgeon	138	1,060	562	1,646	
Goldfish	152	405	372	425	
Splittail	234	327	282	376	
Carp	588	587	420	758	
American shad	614	282	178	405	
Channel catfish	1,037	490	236	628	1,037
White catfish	1,281	359	215	520	
Striped bass	26,670	317	67	1,105	26,670
Total	31,149				27,763

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South Delta Temporary Barriers

Terry Tillman
Department of Fish and Game

Sampling near the temporary barriers at Middle River near Victoria Canal, Old River at head, Old River near Tracy, and Grant Line Canal continued through 1992 except in December, when bad weather prevented sampling. A DFG report on fish communities, predation, and adult salmon migration near the temporary barriers was submitted to DWR in December 1992.

We compared species abundance between reference sites, barrier sites, and sites influenced by barrier operation to detect changes in fish communities. Hoop-nets and electrofishing were used to document changes in abundance and distribution of resident or migratory fish.

Sunfish, minnows, and catfish, the most common fish at all sites, were indicator species used to register changes in the fish community. Species composition and relative abundance at the barriers are shown in Figure 73 and in Table 59. Fluctuations in fish communities were greatest at the barriers and at sites influenced by barriers. Overall, white catfish abundance increased due to the barriers, whereas bluegill, largemouth bass, golden shiner, and silverside abundance decreased when the barriers were in place. This shows the barriers do influence fish community composition and relative abundance near the barriers.

Length measurements and stomach contents were taken from predators collected while electrofishing. Striped bass, largemouth bass, and channel catfish were the most abundant piscivorous species caught while the barriers were in place. Largemouth were most abundant near the barriers, whereas striped bass were seen more at reference sites and channel catfish were about equal in abundance at all sites. Identifiable prey species found in predator stomachs included yellowfin goby, chameleon goby, and juvenile Chinook salmon. Additional stomach information is being evaluated and will be reported later.

No adult salmon were taken in large-mesh driftnets during September sampling below the barriers on Old River at head (four samples) and Middle River (one sample). We conclude that the barriers did not impede adult salmon migration in 1992.

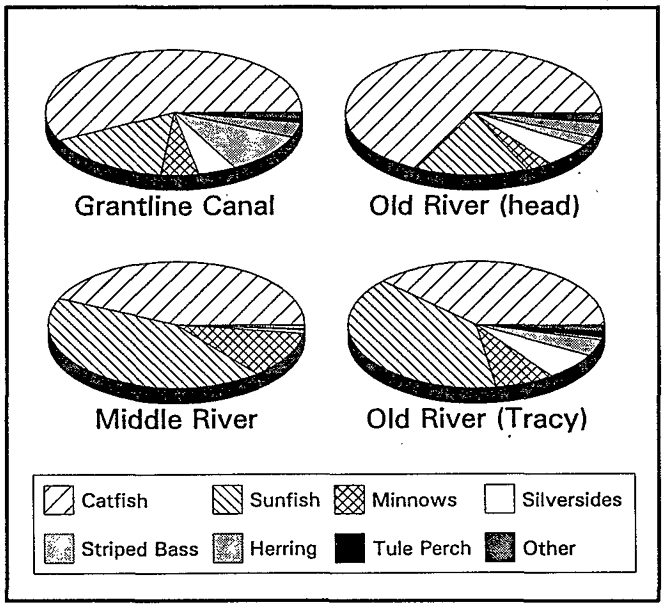

Figure 73
RELATIVE FISH COMPOSITION AT FOUR TEMPORARY BARRIER SITES, 1992

North Bay Aqueduct

Terry Tillman
Department of Fish and Game

The North Bay Aqueduct study measures the impact of NBA diversions on the composition and relative abundance of fish populations in Barker Slough. Primary objectives are to:

- Determine if a significant number of juvenile fish (Chinook salmon, striped bass, American shad, and delta smelt) are entrained by the NBA diversion, and
- Determine if predator populations near the intake increased after NBA operations began.

Sampling is biweekly during February, June, and October. Each sampling venture consists of two days of otter trawling and overnight gill-netting. Five-minute Otter trawls are made at two locations in Barker Slough using a 16-foot trawl with 1-inch stretch-mesh body and 0.5-inch stretch-mesh cod-end. Gill-nets are set about 0.25 mile downstream from the intake site, using a 200-foot variable-mesh (2.5- to 4-inch stretch) monofilament net and a 100-foot-long 1-inch stretch-mesh monofilament net.

During 29 samplings from June 1988 to October 1992, a total of 4,478 fish were caught, representing 37 species (Table 61). Most numerous were striped bass, tule perch, threadfin shad,

Table 60
NUMBER OF FISH CAPTURED DURING RESIDENT FISH SAMPLING AT FOUR TEMPORARY BARRIER SITES IN 1992

	Grant Line Canal		Head of Old River		Middle River		Old River	
	Number Caught	% of Total	Number Caught	% of Total	Number Caught	% of Total	Number Caught	% of Total
Catfish	2,580		2,724		748		1,666	
White catfish	2,395	53.2	2,540	62.9	694	40.2	1,639	37.3
Channel catfish	171	3.8	177	4.4	14	0.8	21	0.5
Brown bullhead	14	0.3	4	<0.1	34	2.0	3	<0.1
Black bullhead	0	0	3	<0.1	6	0.3	3	<0.1
Sunfish	719		581		734		1,738	
Bluegill	486	10.8	310	7.7	364	21.1	1136	25.9
Largemouth bass	154	3.4	116	2.9	169	9.8	345	7.9
Red-ear sunfish	66	1.5	59	1.5	187	10.8	238	5.4
Smallmouth bass	0	0	37	0.9	0	0	0	0
Green sunfish	5	0.1	24	0.6	2	0.1	6	0.1
Black crappie	7	0.2	5	0.1	2	0.1	11	0.3
Warmouth	1	<0.1	30	0.7	10	0.6	1	<0.1
White crappie	0	0	0	0	0	0	1	<0.1
Minnows	216		130		205		329	
Golden shiner	139	3.1	9	0.2	195	11.3	223	5.1
Carp	72	1.6	110	2.7	9	0.5	77	1.8
Goldfish	0	0	8	0.2	0	0	25	0.6
Sacramento blackfish	1	<0.1	3	<0.1	1	<0.1	1	<0.1
Sacramento squawfish	4	<0.1	0	0	0	0	1	<0.1
Splittail	0	0	0	0	0	0	2	<0.1
Silversides	216		253		15		304	
Inland silverside	216	4.8	253	6.3	15	0.9	304	6.9
Temperate Basses	483		100		6		183	
Striped bass	483	10.7	100	2.5	6	0.3	183	4.2
Herring	169		142		14		32	
Threadfin shad	92	2.0	141	3.5	14	0.8	32	0.7
American shad	77	1.7	1	<0.1	0	0	0	0
Surfperch	43		26		4		69	
Tule perch	43	1.0	26	0.6	4	0.2	69	1.6
Gobies	65		40		0		29	
Yellowfin goby	59	1.3	2	<0.1	0	0	15	0.3
Chameleon goby	6	0.1	38	0.9	0	0	14	0.3
Suckers	5		25		0		4	
Sacramento sucker	5	0.1	25	0.6	0	0	4	<0.1
Salmon	1		14		0		4	
Chinook salmon	1	<0.1	14	0.3	0	0	4	<0.1
Livebearers	0		0		0		14	
Mosquitofish	0	0	0	0	0	0	14	0.3
Sculpin	2		0		1		10	
Prickly sculpin	2	<0.1	0	0	1	<0.1	10	0.2
Perch	3		0		0		8	
Bigscale logperch	3	<0.1	0	0	0	0	8	0.2
Unidentified	0	0	0	0	0	0	2	<0.1
Total Captured	4,502		4,035		1,727		4,392	

and white catfish. Young-of-the-year striped bass were the most abundant, with an overall average density of 0.0131 fish per cubic meter (Table 62).

Table 61
SPECIES COMPOSITION AND SIZES OF FISH FOUND IN BARKER SLOUGH DURING NORTH BAY AQUEDUCT MONITORING, 1988-1992

Family Species	% of Total Catch	Length Range (mm)
Ictaluridae		
White catfish	9.8	13 - 326
Black bullhead	2.4	73 - 256
Brown bullhead	1.9	48 - 311
Channel catfish	0.8	45 - 570
Percichthyidae		
Striped bass	23.6	11 - 963
Clupeidae		
Threadfin shad	15.5	25 - 125
American shad	2.4	22 - 414
Centrarchidae		
Black crappie	5.1	65 - 308
Bluegill	0.3	135 - 191
Largemouth bass	0.3	247 - 438
White crappie	0.1	108 - 230
Green sunfish	0	64 - 215
Warmouth	0	91 - 174
Redear sunfish	0	201
Cyprinidae		
Hitch	2.0	50 - 354
Sacramento blackfish	1.3	38 - 448
Carp	0.8	51 - 514
Sacramento squawfish	0.3	107 - 504
Golden shiner	1.7	53 - 133
Goldfish	0.2	72 - 259
Splittail	0.1	101 - 292
Fathead minnow	0	51 - 57
Hardhead	0	54
Gobiidae		
Yellowfin goby	1.7	44 - 220
Chameleon goby	0.5	48 - 101
Embiotocidae		
Tule perch	18.8	41 - 304
Cottidae		
Prickly sculpin	2.1	60 - 193
Riffle sculpin	0.1	84 - 120
Staghorn sculpin	0	95
Percidae		
Bigscale logperch	4.4	62 - 119
Salmonidae		
Steelhead trout	1.3	139 - 819
Chinook salmon	0.2	43 - 868
Catostomidae		
Sacramento sucker	0.4	247 - 582
Osmeridae		
Delta smelt	0.6	58 - 116
Longfin smelt	0.6	36 - 111
Atherinidae		
Inland silverside	0.5	11 - 120
Gasterostiedae		
Threespine stickleback	0	58
Unidentified Larvae	0	10

Six species of predator fish were caught in Barker Slough during post-project sampling: striped bass, white catfish, channel catfish, black crappie, largemouth bass, and Sacramento squawfish. Relative predator abundance for these species was estimated from gill-net catch-per-unit-effort data and limited to fish longer than 180 mm (Table 63). The most abundant predators were striped bass (0.108 fish/hour) and white catfish (0.109 fish/hour).

Species composition in Barker Slough has been similar before and after the North Bay Aqueduct began operating. Brown bullhead, striped bass, and threadfin shad constituted the majority of fish caught during pre-project sampling. As shown in Figure 74, brown bullhead have decreased in relative abundance, while striped bass have increased throughout the post-project sampling.

Post-project monitoring provides some evidence that the fish population has been affected by operation of the North Bay Aqueduct pumping plant. Modification of slough habitat, rather than diversion-related entrainment, probably accounts for most of the difference in fish composition and abundance. Extensive channel alterations and construction (dredging, bank reinforcement, vegetation removal) may have disrupted populations and affected species composition.

Table 62
AVERAGE CATCH OF FISH LESS THAN 100 MM IN BARKER SLOUGH OTTER TRAWLS, 1988-1992

Species	Mean Length (mm)	Average Catch (Fish/m^3 x 10^{-3}) Winter	Summer	Fall	Overall
Striped bass	52.4	0.76	14.86	21.95	13.11
Tule perch	87.1	11.65	0.58	7.39	6.37
Threadfin shad	72.9	2.15	0	7.24	3.24
Bigscale logperch	83.0	6.39	0.06	1.05	2.34
White catfish	58.8	1.45	2.65	1.36	1.82
Hitch	66.5	2.65	0	0.10	0.84
American shad	75.5	0.76	0	1.70	0.84
Prickly sculpin	84.8	0.54	0.42	1.25	0.75
Golden shiner	72.6	1.93	0	0	0.59
Yellowfin goby	72.8	0	1.58	0	0.54
Delta smelt	73.0	1.23	0.04	0	0.38
Chameleon goby	70.8	0.26	0.05	0.78	0.37
Longfin smelt	53.9	0	1.09	0	0.37
Inland silverside	57.9	0.72	0.05	0.05	0.25
Black crappie	87.7	0.26	0.12	0	0.12
Channel catfish	67.7	0.12	0.21	0	0.11
Sacramento blackfish	72.7	0.33	0	0	0.10
Brown bullhead	71.4	0	0.03	0.19	0.08
Carp	75.3	0.05	0.04	0.04	0.04
Black bullhead	83.3	0	0.07	0.05	0.04
Goldfish	82.0	0	0	0.10	0.04
Fathead minnow	54.0	0.09	0	0	0.03
Warmouth	91.0	0.08	0	0	0.02
Hardhead	54.0	0.06	0	0	0.02
Chinook salmon	43.0	0.06	0	0	0.02
Staghorn sculpin	95.0	0.05	0	0	0.02
Unidentified Larvae	10.0	0	0.04	0	0.01
Riffle sculpin	84.0	0	0.03	0	0.01
Number of Tows		32	39	40	
Average Cubic Meters Sampled per Tow		542.2	652.2	561.9	

Table 63
RELATIVE ABUNDANCE OF PREDATOR FISH GREATER THAN 180 MM, ESTIMATED FROM BARKER SLOUGH GILL-NET SAMPLES, 1988-1992

Species	Mean Fork Length (mm)	Mean Catch Rate (Fish/Hour) Winter	Summer	Fall	Overall
Striped bass	388.5	0.04	0.14	0.12	0.108
White catfish	249.4	0.07	0.19	0.06	0.109
Channel catfish	360.2	0.02	0.06	0.02	0.033
Black crappie	217.6	0.03	0.06	0.03	0.038
Largemouth bass	355.6	0.01	0.03	0.02	0.022
Sacramento squawfish	391.0	0.01	0.01	0.01	0.011
Number of Samples		8	10	10	
Mean Hours per Sample		24	23	23	

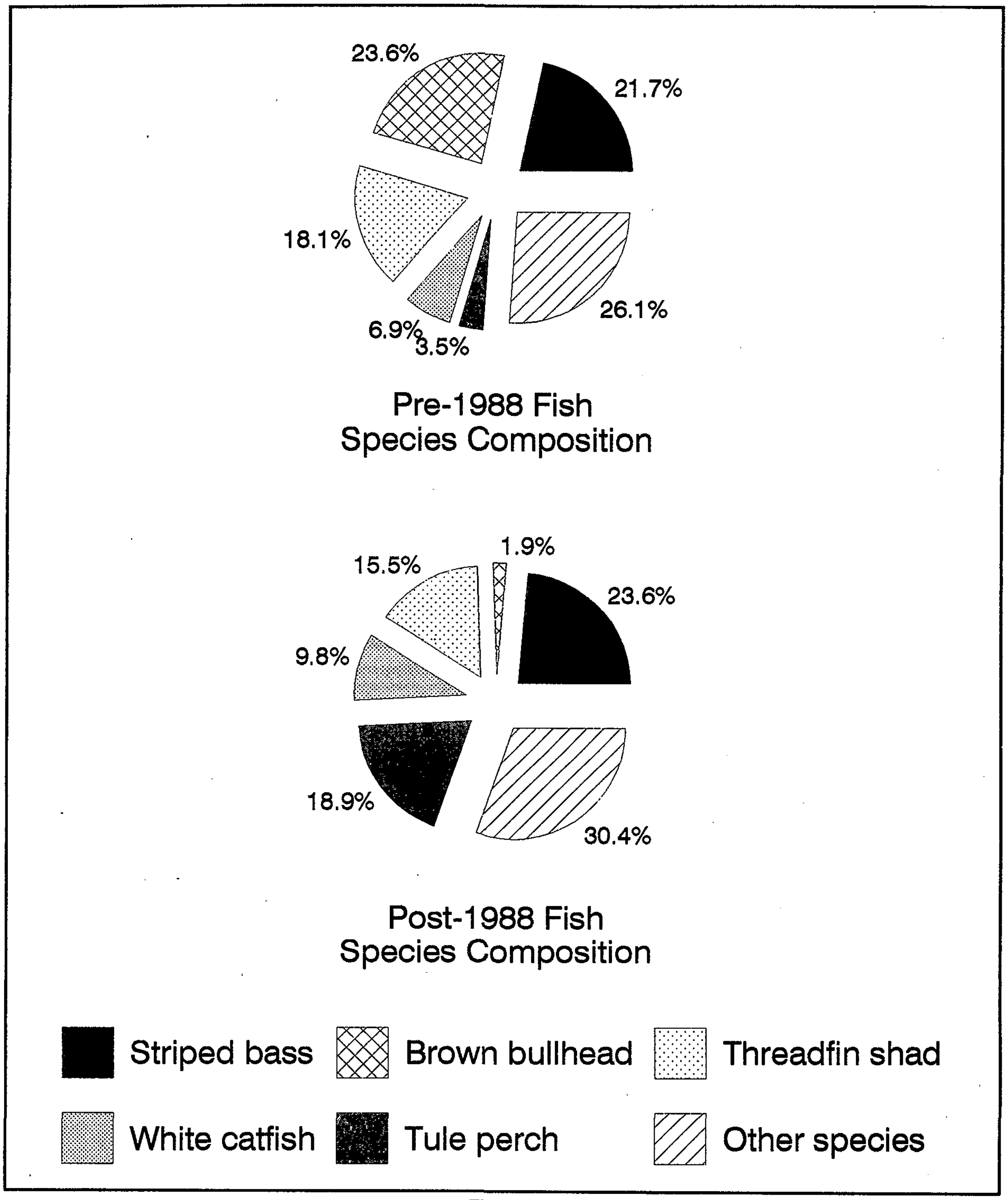

Figure 74
FISH SPECIES COMPOSITION AT BARKER SLOUGH BEFORE AND AFTER NORTH BAY AQUEDUCT OPERATIONS

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SCIENTIFIC NAMES OF FISH

American eel	*Anguilla rostrata*
American shad	*Alosa sapidissima*
bay goby	*Lepidogobius lepidus*
bigscale logperch	*Percina macrolepida*
black bullhead	*Ameiurus melas*
black crappie	*Pomoxis nigromaculatus*
blue catfish	*Ictalurus furcatus*
bluegill	*Lepomis macrochirus*
brown bullhead	*Ameiurus nebulosus*
brown trout	*Salmo trutta*
California halibut	*Paralichthys californicus*
California roach	*Hesperoleucus symmertricus*
chameleon goby	*Tridentiger trigonocephalus*
channel catfish	*Ictalurus punctatus*
Chinook salmon	*Oncorhynchus tshawytscha*
common carp	*Cyprinus carpio*
delta smelt	*Hypomesus transpacificus*
English sole	*Pleuronectes vetulus*
fathead minnow	*Pimephales promelas*
golden shiner	*Notemigonus crysoleucas*
goldfish	*Carassius auratus*
green sturgeon	*Acipenser medirostris*
green sunfish	*Lepomis cyanellus*
hardhead	*Mylopharodon conocephalus*
hitch	*Lavinia exilicauda*
inland silverside	*Menidia beryllina*
jacksmelt	*Atherinopsis californiensis*
largemouth bass	*Micropterus salmoides*
longfin smelt	*Spirinchus thaleichthys*
mosquitofish	*Gambusia affinis*
northern anchovy	*Engraulis mordax*
Pacific herring	*Clupea pallasii*
Pacific lamprey	*Lampetra tridentata*
pink salmon	*Oncorhynchus gorbuscha*
plainfin midshipman	*Porichthys notatus*
prickly sculpin	*Cottus asper*
pumpkin seed	*Lepomis gibbosus*
rainwater killifish	*Lucania parva*
redear sunfish	*Lepomis microlophus*
red shiner	*Cyprinella lutrensis*
riffle sculpin	*Cottus gulosus*
river lamprey	*Lampetra ayresii*
Sacramento blackfish	*Orthodon microlepidotus*
Sacramento perch	*Archoplites interruptus*
Sacramento splittail	*Pogonichthys macrolepidotus*
Sacramento squawfish	*Ptychocheilus grandis*
Sacramento sucker	*Catostomus occidentalis*
shiner surfperch	*Cymatogaster aggregata*
silver salmon	*Oncorhynchus kisutch*
smallmouth bass	*Micropterus dolomieu*
speckled dace	*Rhinichthys osculus*
speckled sanddab	*Citharichthys stigmaeus*
splittail	*Pogonichthys macrolepidotus*
staghorn sculpin	*Leptocottus armatus*
starry flounder	*Platichthys stellatus*
steelhead trout	*Oncorhynchus mykiss*
striped bass	*Morone saxatilis*
striped mullet	*Mugil cephalus*
surf smelt	*Hypomesus pretiosus*
threadfin shad	*Dorosoma petenense*
threespine stickleback	*Gasterosteus aculaetus*
tui chub	*Gila bicolor*
tule perch	*Hysterocarpus traski*
wakasagi	*Hypomesus nipponensis*
warmouth	*Lepomis gulosus*
white catfish	*Ameiurus catus*
white crappie	*Pomoxis annularis*
white croaker	*Genyonemus lineatus*
white sturgeon	*Acipenser transmontanus*
yellow bullhead	*Ameiurus natalis*
yellow perch	*Perca flavescens*
yellowfin goby	*Acanthogobius flavimanus*