CONTRIBUTED PAPERS

Exposure of Delta Smelt to Dissolved Pesticides in 2000

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Introduction

Delta smelt abundance in San Francisco Estuary has been declining since 1983. The exposure of delta smelt to toxic pesticides during larval and juvenile life stages may be one possible factor of this decline (Bennett and Moyle 1996; Moyle and others 1996). Although pesticides have been detected in the Delta (MacCoy and others 1995; Kuivila and others 1999), minimal data on pesticide concentrations and the duration of occurrence in delta smelt habitat are documented. A three-year study (1998–2000) was undertaken by the U.S. Geological Survey (USGS) to quantify the exposure of larval and juvenile delta smelt to dissolved pesticides. Moon and others (2000) reported on the exposure of delta smelt to dissolved pesticides in 1998 and 1999, and this article follows up on Moon's work and reports the results from late spring and summer of 2000.

Survey Area and Methods

Delta smelt typically spawn in spring in shallow areas throughout the Sacramento–San Joaquin Delta (Moyle and others 1992, 1996). Specific spawning locations vary from year to year, depending on environmental conditions; however, delta smelt have been consistently found spawning in the northwestern Delta, including Cache and Lindsey sloughs (Figure 1). As juveniles, delta smelt move downstream and congregate near the confluence of the Sacramento and San Joaquin rivers (Figure 1) in waters of salinity near 2 ppt (Moyle and others 1992, 1996).

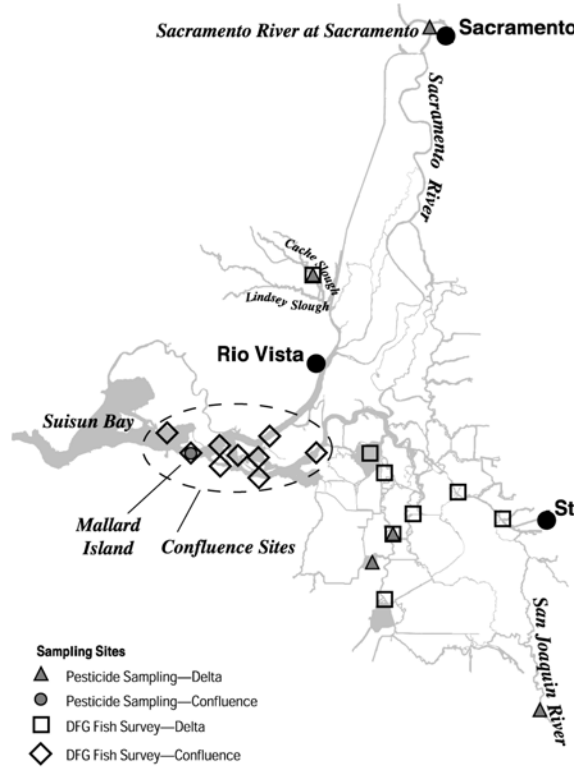

Figure 1 Map of sampling locations for the USGS pesticide analysis and DFG 20-mm Survey in areas of delta smelt habitat in the Sacramento–San Joaquin Delta

The USGS collected water samples for pesticide analysis at six sites from late April to late July, when larval and juvenile delta smelt were expected to occur. Water samples were collected every two weeks at four Delta sites and weekly at two sites (Sacramento River at Sacramento and Suisun Bay at Mallard Island, Figure 1). Samples were analyzed for selected dissolved pesticides using the methods described in Crepeau and others (2000). Total pesticide concentrations were calculated as the sum of all pesticides measured in a single sample.

Concurrent with the USGS pesticide analysis sampling, the California Department of Fish and Game collected delta smelt density data from 17 sites (Figure 1) as part of their 20-mm Survey, which collects both larval and juvenile delta smelt. This concurrent sampling allowed direct comparison of pesticide concentrations and fish abundances.

Exposure of delta smelt to dissolved pesticides was estimated by examining the overlap of measured fish densities and measured dissolved pesticides. To compare pesticide concentrations and fish densities within the Delta, pesticide concentrations from four of five Delta sites (marked with triangles in Figure 1) were averaged and compared with fish densities averaged for eight Delta sites (marked with squares in Figure 1) for each sampling date. The Sacramento River at Sacramento site was sampled as a primary source of pesticides to delta smelt habitat and was considered a Delta site for the purpose of this article. To compare pesticide concentrations and fish densities at the confluence, total pesticide concentrations were sampled at Suisun Bay at Mallard Island and fish densities were averaged over nine sites (marked with diamonds in Figure 1) within the confluence area.

Results

Measured Pesticide Concentrations in Delta Smelt Habitat

Water samples collected in from delta smelt habitat during spring and summer 2000 contained 19 detected pesticides (Table 1). Fifty-four samples were collected, each containing from 3 to 12 pesticides (Figure 2).

Table 1 Percentage of pesticides detected and maximum concentrations in water samples collected from delta smelt habitat in 2000

Constituent	*Samples detected[a] (%)*	*Maximum concentration (ng/L)*
Alachlor	6	17
Atrazine	54	32
Butylate	11	22
Carbaryl	17	72
Carbofuran	57	50
Chlorpyrifos	11	32
Cycloate	11	38
Dacthal	8	11
Diazinon	24	30
EPTC	52	550
Ethafluralin	4	30
Fonofos	4	5
Metolachlor	91	210
Molinate	83	3,000
Oxyfluorfen	7	80
Pendimethelin	19	31
Simazine	57	49
Thiobencarb	76	1,300
Trifluralin	59	44

[a] Values given are the percentage of samples (n = 54) in which each pesticide was detected.

Metolachlor, the most frequently detected pesticide, was detected in 91% of the samples. Molinate and thiobencarb were detected in 83% and 76% of the samples, respectively. Other frequently detected pesticides (52% to 59%) included atrazine, carbofuran, EPTC, simazine, and trifluralin. Molinate and thiobencarb also had the greatest concentrations, with maximum levels reaching 3,000 and 1,300 ng/L, respectively (Table 1).

In general, nearly the same pesticides were detected with similar frequency in all three years of the study. Only atrazine and trifluralin were detected more frequently (three to five times) in 2000 than in 1998 and 1999, but their concentrations were relatively low with maximum concentrations of 32 and 44 ng/L, respectively (Table 1). In all three years, the pesticides with the greatest concentrations were EPTC, molinate, and thiobencarb.

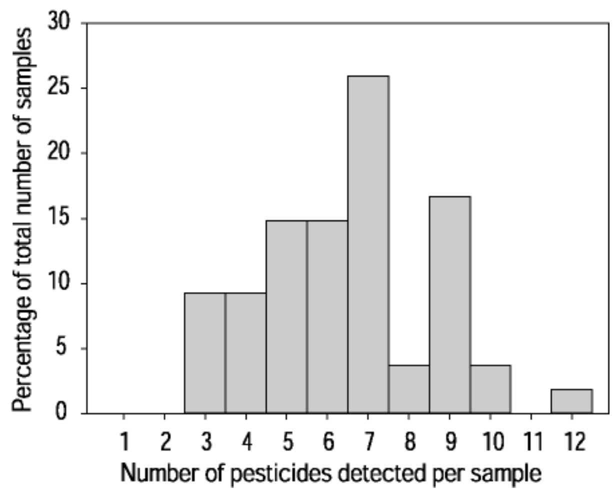

Figure 2 Number of pesticides detected per water sample collected from delta smelt habitat in 2000

Exposure of Delta Smelt to Dissolved Pesticides

Delta smelt were present in the Delta from mid-April through the end of the fish sampling surveys in late June, and their densities remained relatively constant (Figure 3A). Concentrations of pesticides in the Delta were elevated throughout this same period, especially in mid-May; therefore, larval delta smelt were exposed to dissolved pesticides for weeks to months in the Delta (Figure 3A). Total pesticide concentrations at the Sacramento River at Sacramento site were much greater than at other Delta sites (note different scale) and are shown separately in Figure 3A. This difference occurred because of the input of rice field water, which contained elevated concentrations of molinate and thiobencarb, into the Sacramento River (Crepeau and Kuivila 2000).

Delta smelt migrated toward the confluence and continued to be exposed to elevated concentrations of dissolved pesticides through mid-June (Figure 3B). In contrast to Delta sites, fish abundance in the confluence peaked in the first week of June. We observed the greatest number of delta smelt co-occurred with the greatest total concentrations of pesticides at the confluence on June 14 (Figure 3B). The observed peak in pesticide concentration was primarily due to the two rice pesticides, molinate and thiobencarb.

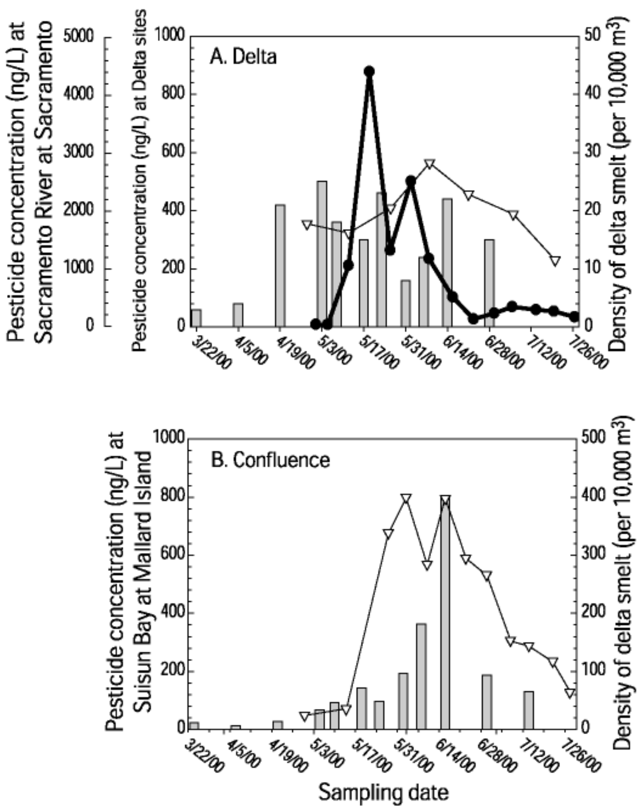

Figure 3 Co-occurrence of pesticides and delta smelt in the Sacramento-San Joaquin Delta (A) and at the confluence of the Sacramento and San Joaquin rivers (B). (A) Circles represent total pesticide concentration at Sacramento River at Sacramento; triangles represent average of total pesticide concentrations at the other four Delta sites; and bars represent average fish abundance at eight Delta sites. (B) Triangles represent total pesticide concentrations at Suisun Bay at Mallard Island and bars represent average fish abundance at nine Confluence sites.

Conclusions

Overall, the detection of multiple pesticides in all samples collected in delta smelt habitat in spring and summer of 2000 was similar to the findings in 1998 and 1999 (Moon and others 2000). Elevated pesticide concentrations in the Delta and at the confluence co-occurred with the presence of larval and juvenile delta smelt for weeks to several months. Although these concentrations are well below LC50 values (Tomlin 1997), the concentrations could potentially cause sublethal effects on delta smelt, especially during early larval development. The combination of multiple pesticides and chronic exposure could hinder growth rate, reproduction, and swimming performance, or indirectly, cause such effects as alteration of diet (Rand 1995). More information on chronic exposure to pesticide mixtures is needed to evaluate the potential effects of environmental pesticide exposures on the delta smelt population.

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Adult Chinook Salmon Migration Monitoring at the Suisun Marsh Salinity Control Gates, Sept.–Nov. 2001

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Introduction

In October 1988, the Suisun Marsh Salinity Control Gates (SMSCG) were installed in Montezuma Slough to meet water quality criteria in Suisun Marsh. The structure consists of three radial gates, a section of removable flashboards, and a boat lock. As part of the permit to build the gates, a monitoring program was developed to study the effects of the gates on migratory fish. Of special concern were winter-run chinook salmon, one of four races of adult salmon, which may use Montezuma Slough during upstream migration.

Since its first application in 1960, biotelemetry has been commonly used for studies of fish migration, orientation, mechanisms, and movement patterns at obstructions (Stasko and Pincock 1977). Studies conducted in 1998 and 1999 focused on modifying the flashboard structure with openings to allow passage of migrating salmon during full-bore operations. This modification was one of several mitigation options proposed for adult and juvenile salmon passage at the SMSCG (DWR 1997). From September 24 through November 1, 2001, as a continuation of telemetry studies started in 1993 (Tillman and others 1996; Edwards and others 1996), adult fall-run chinook salmon, *Oncorhynchus tshawytscha*, were used as a proxy for winter-run chinook salmon and were monitored for passage time and passage rate through the SMSCG. The 2001 study focused on the possible use of the existing boat lock as a means of fish passage for migrating adult chinook salmon.

Methods

Adult fall-run chinook salmon were captured using a large mesh gill net, tagged internally with ultrasonic transmitters, and released downstream of the SMSCG. Each tag was coded with a unique pulse interval and frequency to allow identification of individual fish. Ultrasonic signals were detected by stationary monitoring equipment consisting of a hydrophone, receiver, and palmtop computer to determine the locations of tagged fish. Monitoring sites were located upstream, downstream, and on the SMSCG (Figure 1).

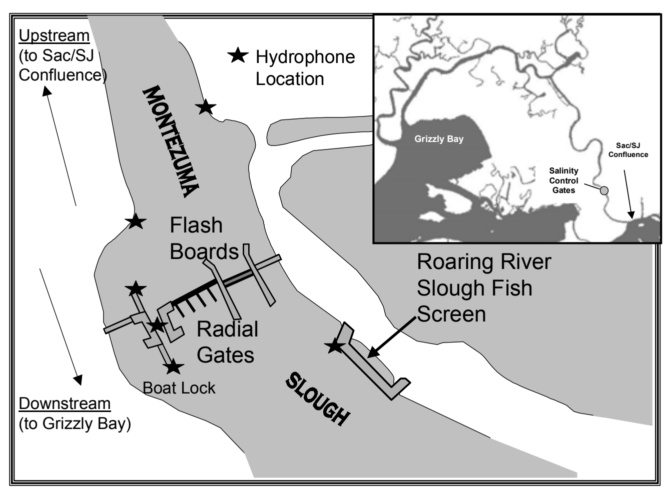

Figure 1 Hydrophone locations at the Suisun Marsh Salinity Control Gates, September through November 2001

Sixty-six tagged salmon were released at the beginning of each two-week operational phase and monitored for passage rate and passage time through the SMSCG. Tagged fish ranged in size from 600 to 1070 mm fork length and, overall, fish were evenly distributed between