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REGIONAL MONITORING PROGRAM FOR TRACE SUBSTANCES

Cisnet Technical Report: Contaminant Accumulation in Forage Fish

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SUMMARY

The objective of this component of the CISNET San Pablo Bay project was to contribute to the understanding of the ecological impacts of chemical stressors on wildlife species in San Pablo Bay. Ecologically important forage fish species were studied as an indicator of risks to predators in marsh, river, and Bay habitats. Chemical analysis of whole body fish was performed to obtain integrative measures of the degree of food web contamination in San Pablo Bay and to investigate the possible effects of this contamination on wildlife species. Mercury, selenium, PCBs, and DDT were detected in all of the habitats in which the two species were sampled. Concentrations of other contaminants were either well below known thresholds or not detectable. Average DDT (DDE + DDD) concentrations in striped bass (24 ppb wet) and sculpin (16 ppb wet) both exceeded a guideline of 14 ppb wet established by Environment Canada for protection of wildlife consumers of aquatic biota. Average mercury concentrations in striped bass (72 ppb wet) and sculpin (70 ppb wet) also both exceeded the 33 ppb wet guideline for methylmercury also established by Environment Canada for protection of fish predators. Selenium concentrations were all below the 3 ug/g dry threshold for effects on fish predators. No established guideline exists for evaluating PCB risk to wildlife based on concentrations in forage fish. Due to small sample sizes, only suggestive information was obtained on spatial and temporal trends. Some evidence of temporal variation was also observed, with higher selenium concentrations at all sites in 2000 than in 1999. DDT concentrations were apparently elevated at one marsh site (CAN) relative to the other sampling locations. The results did not suggest distinct spatial variation in PCBs, mercury, and selenium. This study demonstrated that monitoring of forage fish is an effective means of evaluating ecological risk due to persistent, bioaccumulative contaminants in diverse habitats of the San Pablo Bay ecosystem.

INTRODUCTION

Toxic contamination is one of the most important anthropogenic stressors in the San Pablo Bay ecosystem. Data collected by the Regional Monitoring Program for Trace Substances in the San Francisco Estuary (RMP) (SFEI 2002) and in other studies suggest that toxic contaminant concentrations in the San Pablo Bay ecosystem are high enough to cause adverse effects on biota. Contaminants of particular concern in this region are mercury, selenium, and polychlorinated biphenyls (PCBs) (Urquhart and Regalado 1991,

Davis 1997, Schwarzbach et al. 1997, Schwarzbach and Adelsbach 2002). Each of these contaminants accumulates to high concentrations at the top of the food web and pose their greatest risks to piscivorous wildlife. Examining contaminant concentrations in forage fish is a good way to characterize the risks to piscivores and characterizing the significance of these persistent toxic contaminants in the San Pablo Bay region.

The objective of the fish monitoring element of the CISNET project was to characterize the ecological hazard posed by toxic chemicals that accumulate in fish in the San Pablo Bay ecosystem. The fish species studied were striped bass (*Morone saxatilis*) and Pacific staghorn sculpin (*Leptocottus armatus*). These species were selected because they are both predators that would accumulate relatively high concentrations of contaminants, and they are both resident in the habitats of San Pablo Bay. Young striped bass were selected because they are more resident than adult striped bass, and are more likely to be consumed by predatory wildlife. Juvenile striped bass are thought to depend heavily on marsh habitat for forage and refuge. No previous studies have looked at contaminants in young striped bass in the Bay. Sculpin are smaller fish that were selected because of their predatory food habits and site fidelity. Their major prey include amphipods (genus *Corophium*), nereid worms, and small anchovy (Jones 1962). Prior to the present study, no sampling of contaminants in sculpin had been performed in the Bay region. This study therefore broke new ground in characterizing accumulation of persistent, bioaccumulative contaminants in forage fish in the Bay.

For this project contaminants measured by the RMP that accumulate in the food web were targeted, including those mentioned above and other trace elements and organochlorine pesticides. Contaminant concentrations were measured in whole body fish to characterize the exposure of piscivores. This study supplemented RMP fish monitoring by covering species, habitats, and tissues not sampled in the RMP. Fish sampling in the marshes was especially valuable as fish contamination in these habitats is not being monitored at present.

METHODS

Fish were sampled in three habitat types: open bay (Davis Point and Point San Pablo), tidal marsh (South Slough and Hudeman Marsh), and freshwater creek (Napa River and Petaluma River). Sampling was performed in late summer of 1999 and 2000. Otter trawls and minnow traps were used to collect the fish. The two species sampled were staghorn sculpin (10-15 cm length) and striped bass (1 year old, 20-27 cm length) (Table 1). Both species are resident in the San Pablo Bay ecosystem and are predators that are exposed to relatively high concentrations of toxicants due to their trophic position. Due to the expense of chemical analysis, compositing strategies were employed. Samples were analyzed as composites of 5 (staghorn sculpin) and 4 (striped bass). One composite sample per year was analyzed from each sampling location. One species was analyzed at each location. Contaminant concentrations were measured in whole body fish, providing data useful for evaluation of hazards to fish predators in the marshes and open waters of San Pablo Bay.

Fish were analyzed for chemical contaminants by RMP subcontractors using methods that have been used in bioaccumulation monitoring in the RMP for the past several years (Davis et al. 2002, Greenfield et al. In press). Trace elements analyzed included mercury (cold-vapor atomic fluorescence), selenium (hydride generation atomic absorption), arsenic (graphite furnace atomic absorption), and silver, cadmium, chromium, copper, lead, nickel, and zinc (inductively coupled plasma atomic emission or mass spectrometry). Trace organics analyzed included PCBs and organochlorine pesticides (dual column gas chromatography with electron capture detection).

Chemical analyses were performed in adherence to the data quality objectives and other guidelines included in the RMP Quality Assurance Project Plan (Lowe et al. 1999). Quality assurance measures included analysis of duplicates, matrix spikes, and standard reference materials. In general, all data quality objectives were met.

Chemical concentrations are presented on a wet weight basis. The chemical data are summarized in Table 1. The complete set of concentration data is provided in Appendix 1.

RESULTS AND DISCUSSION

Data Summary

Monitoring chemical contamination of forage fish was demonstrated to be a valuable indicator of general risks to the fish predators in the ecosystem. Consistent with their lower trophic position, the contamination signal was not as strong in the two fish species sampled as it was in cormorant eggs (Davis et al. 2004). However, an easily measurable contamination signal was obtained for PCBs, mercury, and selenium. Average sum of PCB concentrations in juvenile striped bass (38 ng/g wet) and staghorn sculpin (40 ng/g wet) were well above the congener-specific reporting limit of 0.2 ng/g wet. Average selenium concentrations (1.8 ug/g wet in both species) were far above the MDL of 0.02 ug/g wet. The signal was not as strong for mercury; concentrations averaged 72 ng/g wet in striped bass and 70 ng/g wet in sculpin compared to the limit of detection of 3 ng/g wet. DDT residues detected included DDE and DDD, with DDE concentrations about double those of DDD. Average DDE concentrations (24 ng/g wet in striped bass and 16 ng/g wet in sculpin) were closer to the DDE reporting limit of 2 ng/g wet. These chemicals were detected in all of the habitats in which the two species were sampled.

Concentrations of other contaminants were either well below known thresholds or not detectable.

Possible Effects of Contaminants

The two species sampled were shown to accumulate contaminant concentrations across the different habitats that exceed thresholds for predator risk. Average DDT (DDE + DDD) concentrations in striped bass (24 ppb wet) and sculpin (16 ppb wet) both

exceeded a guideline of 14 ppb wet established by Environment Canada for protection of wildlife consumers of aquatic biota (CCME 2002). All of the striped bass samples and four of the seven sculpin samples exceeded this guideline.

Average mercury concentrations in striped bass (72 ppb wet) and sculpin (70 ppb wet) also both exceeded the 33 ppb wet guideline for methylmercury also established by Environment Canada for protection of fish predators (CCME 2002). Although total mercury was measured in this study, based on studies of low trophic level fish from another part of the Estuary (Slotton et al. 2002), it is likely that approximately 95% of the mercury in these fish was methylmercury. All of the samples from both species were above the mercury guideline.

For selenium, 3 ppm dry in forage fish is considered to be a threshold for reproductive failure in piscivorous wildlife (Lemly 1996). Schwarzbach and Adelsbach (2002) found selenium concentrations in great egrets (a piscivorous species found in San Pablo Bay) from the San Pablo Bay that exceed the 6 ug/g dry threshold of concern for avian eggs. However, in this study, selenium concentrations, which averaged 1.9 ug/g dry in striped bass and 1.8 ug/g dry in sculpin, and reached a maximum of 2.3 ug/g dry, were all below the 3 ug/g dry threshold for effects on fish predators.

No established guideline exists for evaluating PCB risk to wildlife based on concentrations in forage fish.

Temporal Trends

Due to small sample sizes, only suggestive information was obtained on spatial and temporal trends. Some evidence of temporal variation was also observed, with higher selenium concentrations at all sites in 2000 than in 1999 (Figure 1). If this was a real shift, it suggests an ecosystem-wide shift in selenium availability between the two years, or a major change in the structure of the San Pablo Bay food web. This is the same period over which an increase was observed in cormorant eggs (Davis et al. 2004). However, it should be noted that the fish data do not suggest an increase in PCBs and DDT as was observed in the cormorant eggs (Davis et al. 2004). In fact, sculpin DDT concentrations were generally higher in 1999 than in 2000 (Figure 3). The data did not suggest any temporal pattern for PCBs (Figure 4) or mercury (Figure 2).

Spatial Patterns

Chemical contamination was observed across the three habitat types sampled. Due to the small sample size and lack of replication, the data are only suggestive of possible spatial patterns. DDT concentrations were apparently elevated at one marsh site (CAN) relative to the other sampling locations. Concentrations in striped bass at CAN averaged 30 ng/g wet, and were consistent in the two years sampled (Figure 3). Striped bass at Davis Point had the second highest average concentration (23 ng/g wet). Concentrations at other locations were generally below 20 ng/g wet. Sculpin at Point San Pedro had the lowest DDT concentrations in both years of sampling.

The results did not suggest distinct spatial variation in PCBs, mercury, and selenium. In other words, contamination due to these chemicals appeared to be consistent across the three habitats sampled.

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Figure 1. Selenium concentrations in one-year old striped bass and staghorn sculpin.

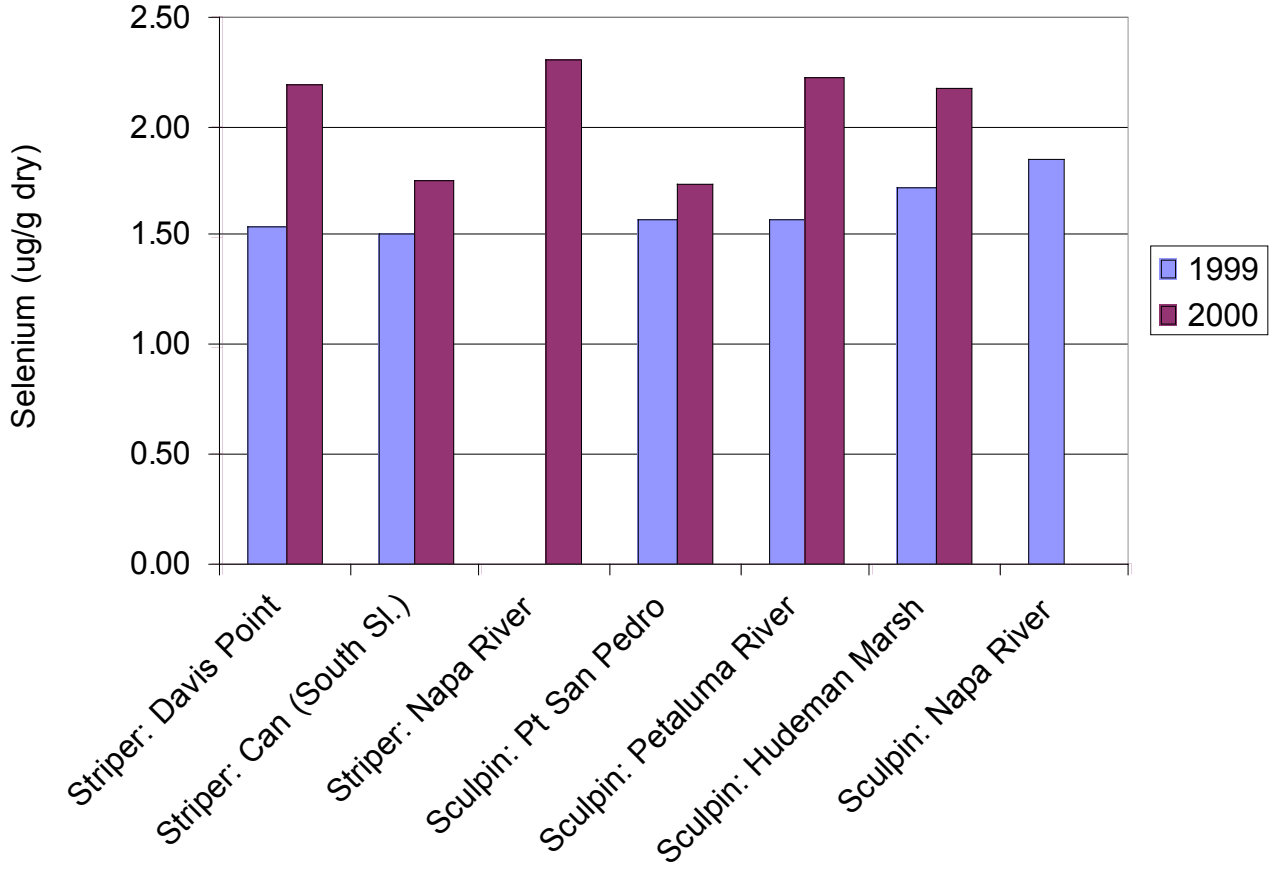

Figure 2. Mercury concentrations in one-year old striped bass and staghorn sculpin.

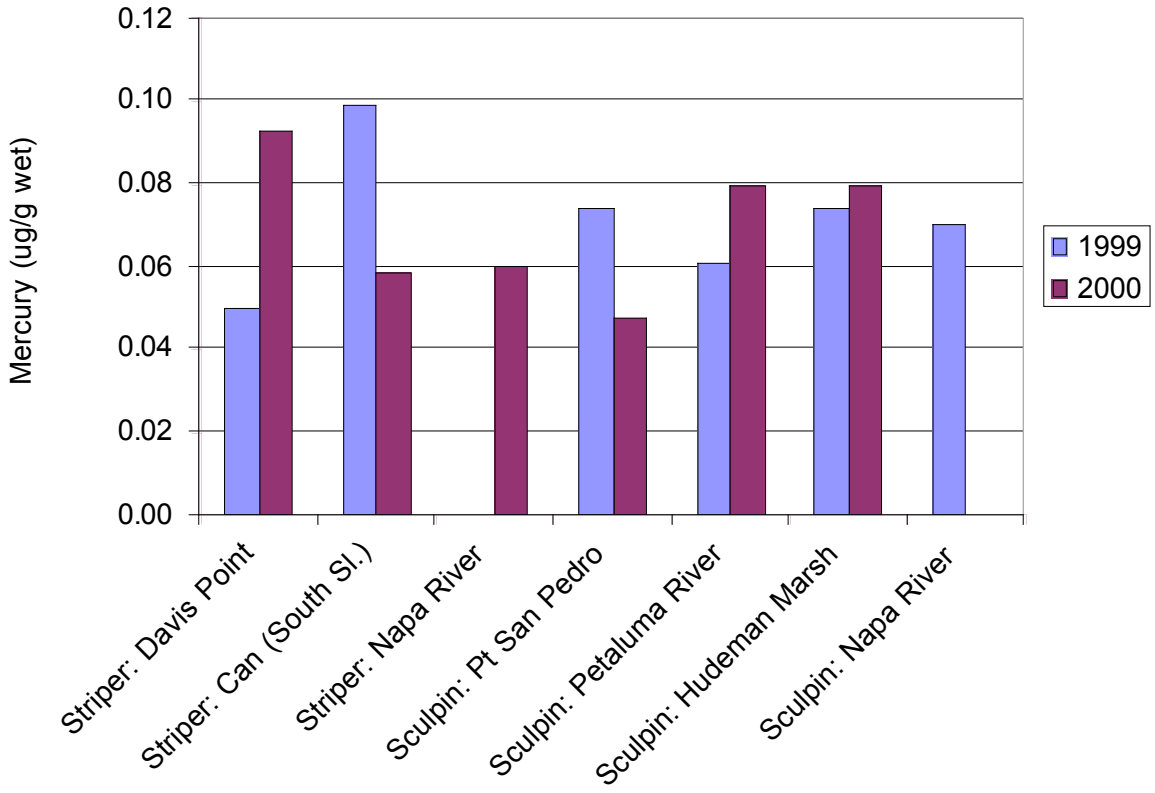

Figure 3. DDT concentrations in one-year old striped bass and staghorn sculpin.

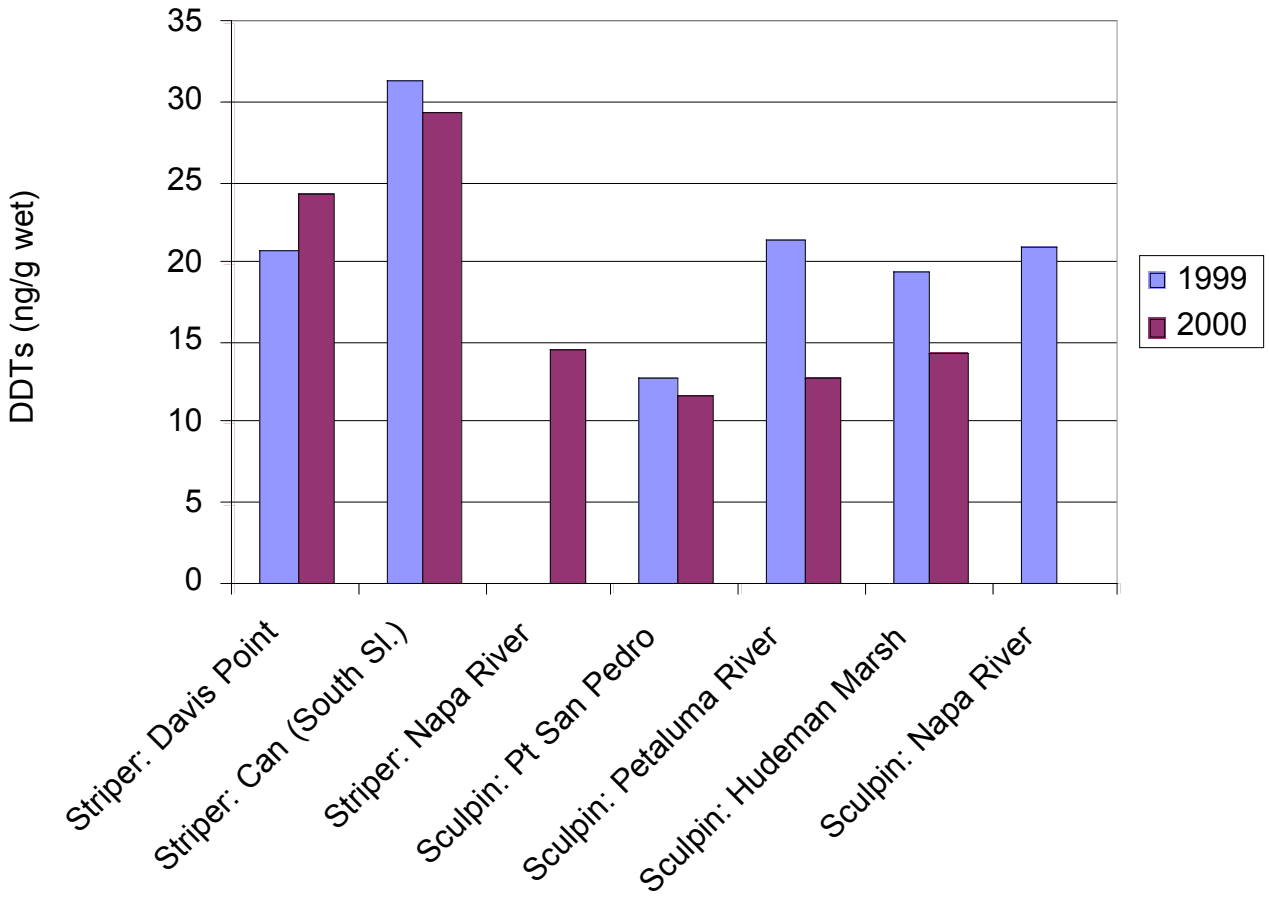

Figure 4. PCB concentrations in one-year old striped bass and staghorn sculpin.

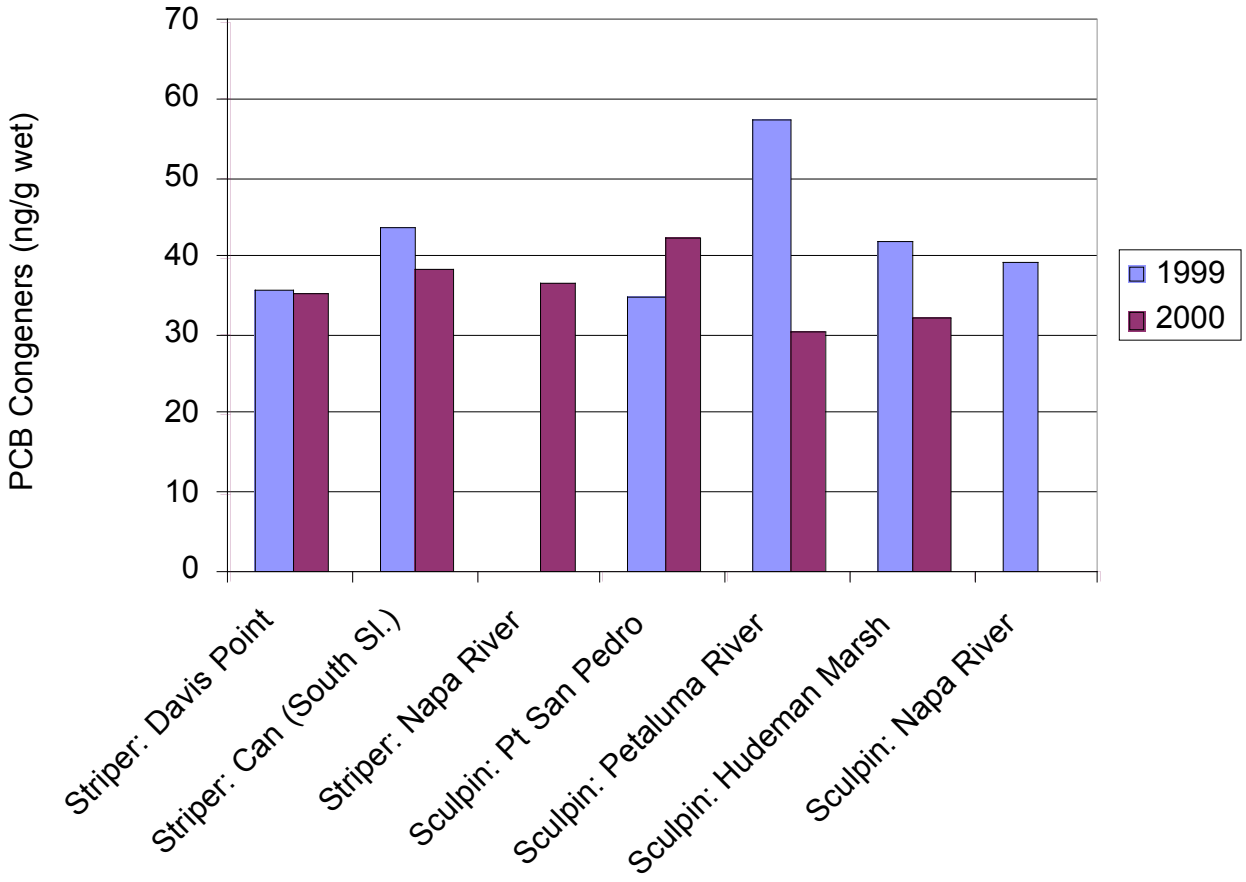

Table 1. Data summary for priority contaminants. Blank cells indicate no data available.

1999	STRIPED BASS		STAGHORN SCULPIN			
Station	Davis Point	Can (South Slough)	Pt San Pedro	Petaluma River	Hudeman Marsh	Napa River
# in Composite	4	4	5	8	8	8
Fish Length	21-25	23-26	9-12	12-14	10-13	8-12
SE_DRY (ug/g)	1.55	1.52	1.58	1.58	1.72	1.86
SE_WET (ug/g)	0.37	0.39	0.35	0.36	0.37	0.38
HG_DRY (ug/g)	0.21	0.38	0.34	0.27	0.35	0.34
HG_WET (ug/g)	0.050	0.099	0.074	0.061	0.074	0.070
DDD, p,p' (ng/g wet)	7	9	3	5	5	4
DDE, p,p' (ng/g wet)	14	23	10	16	15	17
dieldrin (ng/g wet)	2.7	2.1	ND	ND	ND	ND
hexachlorobenzene (ng/g wet)	0.3	<RL	<RL	<RL	<RL	<RL
nonachlor, trans (ng/g wet)	2.3	2.3	<RL	2.1	2.0	2.0
SUM OF CONGENERS (ng/g wet)	36	44	35	57	42	40
Percent Moisture:	72	74	78	78	79	79
Percent Lipid (% of wet)	3.9	2.9	1.5	1.8	1.6	1.5

2000	STRIPED BASS			STAGHORN SCULPIN			
Station	Davis Point	Can (South Slough)	Napa River	Pt San Pedro	Petaluma River	Hudeman Marsh	Napa River
# in Composite	4	4	4	8	8	8	
Fish Length	21-26	23-26	28-30	10-15	10-15	10-15	
SE_DRY (ug/g)	2.20	1.76	2.32	1.74	2.22	2.18	
SE_WET (ug/g)	0.59	0.43	0.45	0.35	0.45	0.46	
HG_DRY (ug/g)	0.34	0.24	0.31	0.24	0.39	0.38	
HG_WET (ug/g)	0.093	0.059	0.060	0.048	0.080	0.080	
DDD, p,p' (ng/g wet)	9	8	4	3	3	4	
DDE, p,p' (ng/g wet)	15	21	11	9	10	11	
dieldrin (ng/g wet)	<RL	<RL	<RL	<RL	<RL	<RL	
hexachlorobenzene (ng/g wet)	<RL	<RL	<RL	<RL	<RL	<RL	
nonachlor, trans (ng/g wet)	1.6	1.5	1.1	<RL	<RL	1.1	
SUM OF CONGENERS (ng/g wet)	36	38	37	43	31	32	
AROCLOR 1254 (ng/g wet)	33	46	34	43	30	31	
AROCLOR 1260 (ng/g wet)	12	11	17	17	14	16	
SUM OF AROCLORS (ng/g wet)	45	57	51	60	44	47	
Percent Moisture:	73	76	80	80	81	80	
Percent Lipid (% of wet)	3.7	1.8	1.5	1.5	1.6	1.6	

APPENDIX 1

Table 1. Ancillary data for CISNET fish samples, 1999-2000.

Station Code	Station	Date	Cruise	Species	# Homogenized	Tissue Analyzed	Range of Lengths	% Lipids - ORG	% Moisture - ORG	% Moisture - TE
							cm	%	%	
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/16/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	1.58	78.6	.
M14	Napa River-Upper	9/14/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	1.53	79.4	.
PEDRO	Point San Pedro	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	1.46	77.7	.
PET	Petaluma River-Upper	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	1.8	77.8	.
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/14/99	1999	Striped bass	4	Whole Body	23 - 26	2.88	74	.
DAVIS PT	Davis Point-San Pablo Bay	9/14/99	1999	Striped bass	4	Whole Body	26.5 - 28.4	3.9	71.8	.
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	8 - 12	1.64	79.5	79.1
M14	Napa River-Upper	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	1.53	79.7	80.4
PEDRO	Point San Pedro	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	1.48	80.2	79.9
PET	Petaluma River-Upper	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	1.62	80.6	79.6
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/27/00	2000	Striped bass	8	Whole Body	8 - 12	1.76	75.9	75.4
DAVIS PT	Davis Point-San Pablo Bay	9/27/00	2000	Striped bass	8	Whole Body	12 - 15	3.66	72.8	73

Table 2. Trace element concentrations in CISNET fish samples, 1999-2000, in ug/g wet.

ND = not detected.

Station Code	Station	Date	Cruise	Species	# Homogenized	Tissue Analyzed	Range of Lengths	Ag	Al	As	Cd	Cr	Cu	Hg	Mn	Ni	Pb	Se	Zn
							cm												
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/16/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	ND	101	0.49	0.008	0.31	1.55	0.074	5.2	0.156	0.062	0.37	9.3
M14	Napa River-Upper	9/14/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	ND	39.4	0.56	0.024	0.18	1.97	0.07	7.5	0.045	0.027	0.38	8.9
PEDRO	Point San Pedro	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	23 - 26	0.013	104	0.64	0.018	0.37	2.13	0.074	2.9	0.172	0.053	0.35	10.0
PET	Petaluma River-Upper	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	0.013	40.5	0.48	0.026	0.26	1.96	0.061	3.3	0.089	0.041	0.36	8.6
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/14/99	1999	Striped bass	4	Whole Body	23 - 26	ND	22.9	0.54	0.017	0.18	0.85	0.099	14.6	0.057	0.024	0.39	11.2
DAVIS PT	Davis Point-San Pablo Bay	9/14/99	1999	Striped bass	4	Whole Body	26.5 - 28.4	ND	9.82	0.61	0.043	0.09	0.63	0.05	3.7	ND	0.012	0.37	11.6
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/29/00	2000	Pacific staghorn sculpin	8	Whole Body	8 - 12	0.006	31.2	0.46	0.011	0.17	1.18	0.08	3.5	ND	0.036	0.456	9.1
M14	Napa River-Upper	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	0.006	36.5	0.55	0.021	0.20	1.58	0.06	4.9	0.023	0.016	0.454	8.9
PEDRO	Point San Pedro	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	0.007	30.2	0.50	0.012	0.19	1.61	0.048	1.3	ND	0.025	0.35	9.8
PET	Petaluma River-Upper	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	0.015	60.4	0.51	0.066	0.27	1.81	0.08	2.5	0.072	0.043	0.453	9.3
CAN	Canvas Back Duck Club--Napa/Sonoma Marsh	9/27/00	2000	Striped bass	8	Whole Body	8 - 12	ND	16.5	0.64	ND	0.16	0.73	0.059	9.8	ND	0.01	0.432	13.8
DAVIS PT	Davis Point-San Pablo Bay	9/27/00	2000	Striped bass	8	Whole Body	12 - 15	0.006	7.4	0.65	0.067	0.14	1.34	0.093	3.2	ND	0.017	0.593	12.8

Table 3. Pesticide concentrations in CISNET fish samples, 1999-2000, in ng/g wet.
E = estimated value, NA = not available/not analyzed, ND = not detected.

Station Code	Station	Date	Cruise	Species	# Homogenized	Tissue Analyzed	Range of Lengths	Sum of DDTs (SFEI)	o,p'-DDD	o,p'-DDE	o,p'-DDT	p,p'-DDD	p,p'-DDE	p,p'-DDT	Sum of Chlordanes	alpha-Chlordane	gamma-Chlordane	cis-Nonachlor	trans-Nonachlor	Heptachlor	Heptachlor Epoxide	Oxychlordane	Sum of HCHs (SFEI)	alpha-HCH	beta-HCH	delta-HCH	gamma-HCH	Aldrin	Dieldrin	Endrin	Hexachlorobenzene	Mirex	alpha-Chlordene	Chlorpyrifos
							cm																									ng/g wet	ng/g wet
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/16/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	19	E	E	E	4.86	14.6	E	2	E	E	E	1.97	ND	E	E	ND	ND	ND	ND	ND	ND	ND	ND	E	E	ND	ND
M14	Napa River-Upper	9/14/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	21	E	E	E	4.45	16.6	E	2	E	E	E	2.03	ND	E	E	ND	E	ND	ND	E	ND	ND	ND	E	E	ND	ND
PEDRO	Point San Pedro	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	13	E	E	E	3.1	9.71	E	ND	E	E	E	E	ND	ND	ND	ND	E	ND	ND	ND	ND	ND	ND	E	ND	ND	ND
PET	Petaluma River-Upper	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	23.5 - 27.5	21	E	E	E	5.22	16.2	E	2	E	ND	E	2.05	ND	E	E	ND	E	ND	ND	E	ND	ND	ND	E	E	ND	ND
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/14/99	1999	Striped bass	4	Whole Body	23 - 26	31	E	E	E	8.77	22.7	E	2	E	E	E	2.27	ND	E	E	ND	E	ND	ND	ND	ND	2.05	E	E	ND	ND	ND
DAVIS PT	Davis Point-San Pablo Bay	9/14/99	1999	Striped bass	4	Whole Body	26.5 - 28.4	21	E	E	E	7.27	13.6	E	2	E	E	E	2.33	ND	E	E	ND	E	E	ND	E	ND	2.68	ND	0.31	E	ND	ND
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	8 - 12	14	E	E	E	3.74	10.7	E	1	E	E	E	1.14	ND	E	E	ND	E	ND	NA	ND	ND	E	ND	E	E	E	ND
M14	Napa River-Upper	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	15	E	ND	ND	3.73	11	E	1	E	E	E	1.07	ND	E	E	ND	E	ND	NA	ND	ND	E	ND	E	ND	ND	ND
PEDRO	Point San Pedro	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	12	E	E	E	2.97	8.9	E	ND	E	E	E	E	ND	E	E	ND	E	E	NA	ND	ND	E	ND	E	ND	ND	ND
PET	Petaluma River-Upper	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	13	E	E	E	3.11	9.8	E	ND	E	E	E	E	ND	E	E	ND	E	ND	NA	ND	ND	E	ND	E	ND	ND	ND
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/27/00	2000	Striped bass	8	Whole Body	8 - 12	29	E	E	E	8.45	21	E	1	E	E	E	1.45	ND	E	E	ND	ND	ND	NA	ND	ND	E	ND	E	ND	ND	ND
DAVIS PT	Davis Point-San Pablo Bay	9/27/00	2000	Striped bass	8	Whole Body	12 - 15	24	E	E	E	9.41	15	E	2	E	E	E	1.6	ND	E	E	ND	E	E	NA	E	ND	E	ND	E	E	E	E

Table 3. Pesticide concentrations in CISNET fish samples, 1999-2000, in ng/g wet.
E = estimated value, NA = not available/not analyzed, ND = not detected.

Station Code	Station	Date	Cruise	Species	# Homogenized	Tissue Analyzed	Range of Lengths	Dacthal	Diazinon	Endosulfan I	Endosulfan II	Endosulfan Sulfate	Ethion	Ethyl Parathion	gamma-Chlordene	Methoxychlor	Methyl Parathion	Oxadiazon	p,p^-DDMU	p,p^-Dichlorobenzophenone	Tetradifon	Toxaphene
							cm	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet	ng/g wet
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/16/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	E	E	ND	NA	NA	ND	E	E	ND	ND	E	E	.	ND	ND
M14	Napa River-Upper	9/14/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	E	E	ND	NA	NA	ND	ND	E	ND	ND	E	E	.	ND	ND
PEDRO	Point San Pedro	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	E	E	ND	NA	NA	ND	ND	E	ND	ND	ND	E	.	ND	ND
PET	Petaluma River-Upper	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	23.5 - 27.5	ND	ND	ND	NA	NA	ND	ND	E	ND	ND	E	E	.	ND	ND
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/14/99	1999	Striped bass	4	Whole Body	23 - 26	E	ND	ND	NA	NA	ND	ND	E	ND	ND	E	E	.	ND	ND
DAVIS PT	Davis Point-San Pablo Bay	9/14/99	1999	Striped bass	4	Whole Body	26.5 - 28.4	E	ND	ND	NA	NA	ND	ND	E	ND	ND	E	E	.	ND	E
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	8 - 12	ND	ND	ND	NA	NA	ND	ND	E	ND	ND	E	E	ND	ND	ND
M14	Napa River-Upper	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	ND	ND	ND	NA	NA	E	ND	E	ND	ND	E	E	ND	ND	ND
PEDRO	Point San Pedro	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	ND	ND	ND	NA	NA	ND	ND	E	ND	ND	ND	E	ND	ND	ND
PET	Petaluma River-Upper	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	ND	ND	ND	NA	NA	ND	ND	E	ND	ND	E	E	ND	ND	ND
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/27/00	2000	Striped bass	8	Whole Body	8 - 12	ND	ND	ND	NA	NA	ND	ND	E	ND	ND	E	E	ND	ND	E
DAVIS PT	Davis Point-San Pablo Bay	9/27/00	2000	Striped bass	8	Whole Body	12 - 15	ND	ND	ND	NA	NA	ND	ND	E	ND	ND	ND	E	ND	ND	E

Table 4. PCB concentrations in CISNET fish samples, 1999-2000, in ng/g wet.
E = estimated value, NA = not available/not analyzed, ND = not detected.

Station Code	Station	Date	Cruise	Species	# Homogenized	Tissue Analyzed	Range of Lengths	Aroclor 1248	Aroclor 1254	Aroclor 1260	Sum of PCBs (SFEI)	PCB 008	PCB 018	PCB 028	PCB 031	PCB 033	PCB 044	PCB 049	PCB 052	PCB 056	PCB 060	PCB 066	PCB 070	PCB 074	PCB 087	PCB 095	PCB 097	PCB 099	PCB 101	PCB 105	PCB 110	PCB 118	PCB 128	PCB 132	PCB 138	PCB 141	PCB 149	PCB 151	PCB 153
							cm																																
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/16/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	.	.	.	42	E	E	0.3	E	E	0.3	0.4	0.6	E	E	0.5	0.4	0.2	0.5	1.1	0.4	1.7	2.2	0.6	1.8	2.0	0.8	0.6	5.3	0.4	2.4	1.1	7.0
M14	Napa River-Upper	9/14/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	.	.	.	39	E	E	0.3	E	E	0.3	0.3	0.6	E	E	0.5	0.3	0.3	0.4	0.8	0.3	1.6	1.7	0.6	1.6	2.2	0.6	0.4	5.1	0.4	2.0	0.9	6.7
PEDRO	Point San Pedro	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	23 - 26	.	.	.	35	E	E	0.3	E	E	0.3	0.4	0.7	E	E	0.5	0.4	0.2	0.5	1.0	0.4	1.4	2.1	0.5	1.5	1.7	0.5	0.5	4.1	0.4	2.1	0.9	5.2
PET	Petaluma River-Upper	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	.	.	.	57	E	E	0.3	E	E	0.5	0.6	1.0	E	E	0.8	0.5	0.4	0.8	1.5	0.6	2.2	3.3	0.8	2.5	2.9	0.9	0.8	6.9	0.6	3.2	1.5	9.0
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/14/99	1999	Striped bass	4	Whole Body	23 - 26	.	.	.	43	E	E	0.4	E	E	0.4	0.6	0.8	E	E	0.7	0.6	0.3	0.6	1.2	0.6	2.1	2.8	0.5	2.4	2.1	0.7	0.6	5.2	0.4	2.9	1.0	7.1
DAVIS PT	Davis Point-San Pablo Bay	9/14/99	1999	Striped bass	4	Whole Body	26.5 - 28.4	.	.	.	35	E	E	0.5	0.3	0.2	0.6	0.7	1.1	E	E	0.8	0.7	0.3	0.7	1.4	0.5	1.5	2.3	0.4	1.9	1.7	0.4	0.5	3.5	0.3	2.2	0.9	4.4
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	8 - 12	ND	31	16	32	ND	ND	E	ND	E	0.2	0.3	0.6	ND	E	0.4	0.2	E	0.3	0.7	ND	1.3	1.5	E	1.0	1.8	0.3	.	4.2	0.3	1.6	1.1	5.1
M14	Napa River-Upper	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	ND	34	17	37	ND	ND	E	ND	ND	E	0.3	0.6	ND	E	0.4	0.3	0.2	0.3	0.8	0.2	1.4	1.8	0.2	1.2	1.9	0.4	.	4.8	0.4	2.1	1.2	5.8
PEDRO	Point San Pedro	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	ND	43	17	43	ND	ND	E	ND	ND	0.3	0.4	0.7	ND	E	0.6	0.4	0.3	0.5	0.9	0.3	1.6	2.3	0.5	1.7	2.1	0.6	.	5.6	0.5	2.4	1.3	6.6
PET	Petaluma River-Upper	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	ND	30	14	31	ND	ND	E	ND	ND	E	0.3	0.5	ND	E	0.4	0.2	E	0.3	0.7	0.2	1.2	1.4	E	1.1	1.6	0.3	.	4.1	0.3	1.6	1.1	4.7
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/27/00	2000	Striped bass	8	Whole Body	8 - 12	ND	46	11	38	ND	ND	0.2	ND	E	0.4	0.7	0.8	ND	E	0.8	0.5	0.3	0.5	0.9	0.5	2.1	2.3	0.4	2.4	2.1	0.6	.	5.1	0.3	2.4	0.9	6.7
DAVIS PT	Davis Point-San Pablo Bay	9/27/00	2000	Striped bass	8	Whole Body	12 - 15	E	33	12	35	ND	E	0.3	0.2	E	0.5	0.6	1.0	0.2	E	0.8	0.5	0.3	0.5	1.2	0.4	1.5	2.0	0.3	1.8	1.9	0.4	.	4.0	0.3	2.0	1.2	4.5

Table 4. PCB concentrations in CISNET fish samples, 1999-2000, in ng/g wet.
E = estimated value, NA = not available/not analyzed, ND = not detected.

Station Code	Station	Date	Cruise	Species	# Homogenized	Tissue Analyzed	Range of Lengths	Aroclor 1248	Aroclor 1254	Aroclor 1260	Sum of PCBs (SFEI)	PCB 156	PCB 158	PCB 170	PCB 174	PCB 177	PCB 180	PCB 183	PCB 187	PCB 194	PCB 195	PCB 201	PCB 203	PCB 027	PCB 029	PCB 114	PCB 137	PCB 157	PCB 189	PCB 200	PCB 206	PCB 209
							cm																									
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/16/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	.	.	.	42	0.3	0.5	1.0	0.6	1.0	2.8	1.1	2.9	0.5	E	0.6	0.4	ND	ND	.	E	E	E	E	0.2	E
M14	Napa River-Upper	9/14/99	1999	Pacific staghorn sculpin	4	Whole Body	26.5 - 28.4	.	.	.	39	0.4	0.4	0.9	0.5	1.0	2.9	1.0	3.0	0.5	E	0.6	0.3	ND	ND	.	E	E	E	E	0.2	E
PEDRO	Point San Pedro	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	23 - 26	.	.	.	35	0.2	0.3	0.8	0.6	0.9	2.4	0.8	2.3	0.4	E	0.5	0.3	ND	ND	.	E	E	ND	E	E	E
PET	Petaluma River-Upper	9/15/99	1999	Pacific staghorn sculpin	4	Whole Body	21 - 25	.	.	.	57	0.4	0.6	1.3	0.7	1.4	3.6	1.4	3.8	0.6	0.2	0.8	0.5	ND	ND	.	ND	E	E	E	0.3	0.2
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/14/99	1999	Striped bass	4	Whole Body	23 - 26	.	.	.	43	0.2	0.4	0.8	0.5	0.8	2.2	0.9	2.7	0.4	E	0.5	0.3	ND	ND	.	ND	E	ND	E	0.3	0.2
DAVIS PT	Davis Point-San Pablo Bay	9/14/99	1999	Striped bass	4	Whole Body	26.5 - 28.4	.	.	.	35	E	E	0.5	0.4	0.6	1.7	0.5	1.9	0.3	E	0.6	0.3	ND	ND	.	ND	E	ND	E	0.5	0.4
HUDE	Hudeman Slough-Napa/Sonoma Marsh	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	8 - 12	ND	31	16	32	0.3	0.3	1.1	0.3	1.0	2.9	0.9	3.2	0.4	E	0.6	0.3	ND	ND	E	E	E	ND	E	E	E
M14	Napa River-Upper	9/27/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	ND	34	17	37	0.3	0.3	1.2	0.4	1.1	3.2	1.0	3.5	0.4	E	0.7	0.4	ND	ND	E	E	E	ND	E	E	E
PEDRO	Point San Pedro	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 15	ND	43	17	43	0.3	0.4	1.2	0.6	1.2	3.4	1.1	3.3	0.4	E	0.7	0.3	ND	ND	E	E	E	ND	E	E	E
PET	Petaluma River-Upper	9/28/00	2000	Pacific staghorn sculpin	8	Whole Body	12 - 14	ND	30	14	31	0.3	0.3	0.9	0.3	1.0	2.8	0.9	3.0	0.4	E	0.6	0.3	ND	ND	E	E	E	ND	E	E	E
CAN	Canvas Back Duck Club-Napa/Sonoma Marsh	9/27/00	2000	Striped bass	8	Whole Body	8 - 12	ND	46	11	38	E	0.3	0.6	0.3	0.6	1.7	0.7	2.3	0.2	E	0.4	0.3	ND	ND	E	E	E	ND	E	E	E
DAVIS PT	Davis Point-San Pablo Bay	9/27/00	2000	Striped bass	8	Whole Body	12 - 15	E	33	12	35	0.2	E	0.7	0.3	0.8	2.2	0.7	2.8	0.3	E	0.6	0.3	ND	ND	E	E	E	ND	E	0.2	E