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Gut Contents Analysis of Four Fish Species Collected in San Leandro Bay in August 2016

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EXECUTIVE SUMMARY

In support of PCB modeling for San Leandro Bay, a Priority Margin Unit (PMU) for PCB load reduction in the estuary, fish samples of four species (topsmelt, shiner perch, white croaker, and northern anchovy) were obtained in August 2016 for both tissue analysis and examination of gut contents. The bay was sampled at eight locations, with a repeated sampling at one location (Airport Lagoon) for one species (topsmelt). Fish were measured, weighed, and dissected, and their gut contents examined microscopically. Topsmelt (9 samples, 188 specimens) had the greatest variety of food items, with gammarid amphipods and chain diatoms predominating. Some topsmelt, especially larger individuals, consumed macroalgae as a major dietary component. Two samples at two sites for shiner perch (20 fish each) had contents composed of close to 50% gammarids at both sites, but differed in proportions of bivalves and polychaetes among the important food items. The one sample of white croaker had consumed mostly gammarids, with fish and polychaetes ranking next in importance. A single sample of northern anchovy (20 fish analyzed) differed radically from the other species in consuming mainly a diatom that appears to have been filtered from the water column. Trace amounts of plastic fiber were seen in all species except shiner perch. All exposure to sediment appeared to have occurred in the top 2 cm of the sediment column, or as contact with flocculent material on plants or hard substrates, or even in the water column, as some fine sand grains were seen in all fish, even anchovy. There was no conclusive evidence of site-specific foraging (site fidelity). The best spatial coverage was for topsmelt, and these fish appear to have fed opportunistically, with some evidence for having fed outside San Leandro Bay.

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Introduction

The RMP PCB Strategy Team formulated a PCB Strategy in 2009. The goal of RMP PCB Strategy work over the next few years is to inform the review and possible revision of the PCB TMDL (SFBRWQCB 2008) and the reissuance of the Municipal Regional Permit for Stormwater, both of which are tentatively scheduled to occur in 2020. Conceptual model development for a set of four representative priority margin units (PMU) will provide a foundation for establishing an effective and efficient monitoring plan to track responses to load reductions and also help guide planning of management actions. The Emeryville Crescent was the first PMU to be studied in 2015-2016. The San Leandro Bay PMU is second.

The PCB team recommended in 2010 to collect data on PCBs in prey fish and to update the conceptual model of PCB fate based on the information that had been generated since the writing of the TMDL Staff Report. The prey fish monitoring revealed extremely high concentrations of PCBs in the food web in several areas on the Bay margins (Greenfield and Allen 2012) and highlighted a need to develop a more detailed conceptual model than the one-box model used as a basis for the TMDL (Davis et al. 2014). To help inform the model, the PCB team recommended a dietary analysis of the prey fish.

The rationale for characterizing fish diets is that PCB compounds are hydrophobic, which tends to associate them with sediment or other particles, and lipophilic, which makes them tend to accumulate in the fatty tissues of animals. Carnivores thus have greater exposure to PCBs than herbivores, benthic prey are expected to be more contaminated than planktonic prey, carnivores that eat carnivores should show magnification of PCB concentrations, and so on up the food chain. Therefore, the objective of the dietary analysis is to identify the prey organisms and to characterize the diet of each species with respect to size, mode of life, and presumed trophic level of the prey.

Materials and Methods

Primary collections

Sample collection and processing were performed by Coastal Conservation and Research (Moss Landing, CA; Appendix 1 in Davis et al. 2017). The CCR team sampled water, sediment, benthos, and four fish species – topsmelt (*Atherinops affinis*), shiner perch (*Cymatogaster aggregata*, sometimes called shiner surfperch), white croaker (*Genyonemus lineatus*), and northern anchovy (*Engraulis mordax*). Fish were taken by otter trawl, beach seine, and cast net as dictated by logistics. Most of the fish were kept for chemical analysis and generally about 20 or more per station for dietary analysis. The fish samples reported on here were fixed in a 10% formalin solution (3.7% formaldehyde) after being held on ice during the sampling, which occurred during daytime in a two-week period in August 2016.

The stations where fish were taken, and which are referred to in this report, are Alameda Channel (AC), Airport Lagoon (AL), Bayfarm Island (BF), Damon Slough (DS), East Creek (EC), Elmhurst Channel (ELM), San Leandro main bay (SLB), San Leandro Channel mouth (SLC BN1), and San Leandro Channel road (SLC BN2). Table 1 summarizes the stations, gear used, length range (Total Length in mm) of the gut samples and the tissue samples, and dates of capture of the gut samples. There was good overlap of fish sizes between those kept for tissue analysis and those analyzed for gut contents. Of 188 topsmelt analyzed here, only 13 fish were outside the ranges given in Davis et al. (2017). Seven of 40 shiner perch were larger that the range for tissue analysis, but three of them had empty guts anyway. All the white croaker analyzed here were within the range given for the tissue samples. Four northern anchovy were out of range, as discussed in the anchovy section.

Table 1. Collection data for specimens analyzed. TL = total length.

SITE	SPECIES	TL RANGE FOR TISSUES (mm)	TL RANGE FOR GUT ANALYSIS (mm)	Gear	Date
AC	Topsmelt	75-112	71-105	Cast net	8/22/16
	Northern anchovy	60-80	69-98	Cast net	8/12/16
AL 8/9	Topsmelt	34-90	58-77	Cast net	8/9/16
AL 8/23	Topsmelt	54-112	61-106	Beach seine	8/23/16
AL	Shiner perch	100-110	79-116	Trawl	8/11/16
AL	White croaker	100-140	92-115	Trawl	8/10/16
BF	Topsmelt	54-110	65-148	Beach seine	8/23/16
DS	Topsmelt	54-118	62-140	Beach seine	8/24/16
EC	Topsmelt	80-124	78-188	Beach seine	8/24/16
ELM	Topsmelt	45-105	48-161	Beach seine	8/24/16
SLC-BN1	Topsmelt	76-108	76-177	Beach seine	8/23/16
SLC-BN2	Topsmelt	74-110	61-102	Cast net	8/23/16

In September 2017 the samples were delivered to Jahn's laboratory near Ukiah, where they were drained, soaked in tap water for a day, and then preserved in 70% ethanol for laboratory workup. Waste formalin was neutralized by addition of sodium bisulfite.

Fish were measured to the nearest millimeter (mm), weighed to three significant figures (fractional grams , g), and dissected. Guts were removed, cleaned of gonad, liver, fat, and other tissues, and weighed to the nearest milligram (mg). The gut was then placed in a dish with water and teased apart under low magnification (120 x) and the contents removed. The gut was then blotted and weighed again. The difference (in mg) between the two weighings was considered an estimate of the gut volume and is reported here in microliters (µl). A Wild M5 dissecting scope capable of magnification up to 1000 X was used for the rest of the analysis.

Contents were identified to a reasonably fine level of taxonomy, which differed from group to group depending on the degree of digestion, which in turn was related to presence/absence of an exoskeleton. Groups such as polychaetes and unshelled mollusks are particularly difficult, as keys to their identification depend on soft parts that tend to be digested most readily. Also, much of the contents of the gut of a microcarnivore consists of a protein soup which is fixed by formaldehyde into a paste that is difficult to handle or quantify. Therefore, after contents were identified to groups based on taxonomy and size, counts and/or estimates of their abundance among the contents were then used as a guide to assigning a percentage of the gut volume attributable to each group.

Volume estimates, expressed as a percentage of the gut volume, were made in an attempt to approximate the original mass contribution to the diet of each prey item before digestion began. The method used here is thus an approximation of what Ahlbeck et al. (2012) called the Approximate Mass Method using original prey mass (AMM4), which their simulations showed to provide good descriptions of the simulated diet. Items judged to constitute < 1% of the gut volume were recorded as present (p) in trace amounts.

The principal reference used in identifying contents was Carlton (2007). Other references included Morris et al. (1980), various photos on the internet, and Moser (1996). Fish nomenclature follows American Fisheries Society (1991) with the modification that Atherinopsidae is recognized as the family name of New World silversides.

<u>Auxiliary observations</u>

At a meeting in Richmond on 3 May 2018, members of the PCB and Dioxin Working Group asked the author for greater precision on feeding locations: specifically, whether there was evidence of site-specific feeding, whether the fish had fed in the water column or from the bottom, and for benthic foragers, whether the feeding occurred in the top 2 cm of the sediment column or deeper. Although there are some clues to answering these questions in the original data, the author made four field trips in an attempt to get further insights.

Concerning site fidelity, the presence in some of the fish guts of a small snail that appears to dwell exclusively on seagrass led to sampling of eelgrass at Pt. Molate on 3 May, and at Bayfarm Island including the mouth of San Leandro Bay on 24 August. Eelgrass was collected by free-diving, held on ice, and examined for epifauna the next day. Other trips seeking eelgrass in San Leandro Bay were made on 12 July and 15 August. The results are given in context with the main findings.

Results

Food categories

A list of food items was assembled as various groups were encountered, beginning with the diet of topsmelt (188 fish), then shiner perch (40 fish), white croaker (20 fish), and northern anchovy (20 fish). These items are arranged in Table 2 in somewhat of a taxonomic order from protists to mullusks, polychaetes, crustaceans, and then vertebrates, with three categories of plastic particles at the end of the list. Data were then entered in full matrix form as the percentage of volume comprised by each item encountered for every fish. For purposes of presentation, the matrix for each fish species was trimmed to include only those items that were encountered in that species (Appendix A).

Table 2. Items and groups found in the gut contents of four species of fish.

Item/Category	# occurrences	# as trace only
Foram	4	3
Pennate diatom	3	1
Chain diatom	61	11
Needle diatom	31	1
Other protist	4	0
Plant material	15	7
macroalgae	23	0
Unidentified stalked egg	16	1
Other invert. Egg	3	0
Green Snail	21	4
Other snail	2	0
Sea Slug	3	0
Bivalve	23	3
Polychaete	30	3
Nechtochaete	3	1
Ostracod	45	22
Sphaeromatid isopod	3	1
Paranthura sp.	13	1
Leptostracan	9	1
Harpacticoids	63	14
Calanoid	9	5
Ampithoe	8	0
other Gammarid	215	4
Caprellid	38	2
unidentified crustacean	2	0
Mysid	9	1
larval mysid	2	0
Crangon	1	0
Crangon zoea	7	5
Crab zoea	3	1
Spider or unidentified insect	6	4
Plant hopper	9	3
Chironomid larva	2	0
Dipteran	2	2
Fish	11	0
Fish egg	2	1
Fish larva	3	0
Fish scales	23	5
Feathers	6	1
Unidentified animal	16	4
Fecal pellets	5	0
Plastic disc	2	2
Plastic fleck	6	6
Plastic fiber	32	32

Foraminifera, which are benthic, shell-forming protozoans, were not very common, nor were they ever especially abundant in the samples. Diatoms were sometimes the only item consumed and were most important to topsmelt and anchovy. Topsmelt consumed very large quantities of a chain-forming species that may be planktonic but may also sink to the bottom or live as a scum on plants or other hard substrates (e.g., *Biddulphia* sp.). Northern anchovy ate a very slender species ("needle diatom") that most resembles, to the eyes of the author, *Cylindrotheca closterium*, a planktonic or epipelic species (UBC Phyto'pedia) which seems to have been planktonic in this case, as discussed in the anchovy results section. Small numbers of this species were also seen in topsmelt. The diatom group called "pennate" is comprised of at least two species that were found in topsmelt; these may not be totally pennate but were found along with enough sediment to indicate strongly that these are benthic forms. "Other protists" are things that were too small to be seen clearly (about 15 microns) but appeared to be organisms.

Plant material was rarely observed, as seeds or small fragments, and may have been ingested incidentally. Macroalgae, mostly filamentous greens but with some tubular greens, possibly *Enteromorpha* sp., were at times consumed in large quantities by topsmelt.

An unidentified stalked egg, roughly 0.5 mm tall, of an invertebrate animal, possibly polychaete, was found in good numbers in some smaller topsmelt. A small (2 to 4 mm), unidentified green snail showed up in several topsmelt, one shiner perch, and one white croaker. This appears to be a species as yet unreported for San Francisco Bay and is difficult to identify owing to its deterioration in the preserving fluids. At least three species of sea slug were observed, all from white croaker, but were too digested for identification (although the genus *Philine* was ruled out). Most of the bivalves were the solitary mussel *Musculista senhausia*, but a few clams were also found, often as very small (2 mm) individuals.

Polychaetes are very difficult to identify in gut contents, as mentioned above. At least three species, and probably more, are lumped here. All are either benthic or part of fouling communities, e.g., on riprap. Leptochaetes are the planktonic larvae of polychaetes. Seen only in anchovy, they were never a large fraction of the prey. However, they are somewhat under-represented as to frequency of occurrence because they were not immediately recognized in the stomachs.

The ostracods seen were typically small (<0.3 mm) and, though frequent, never more than 10% of the diet of any fish. Sphaeromatid isopods are not small, but were rarely found in the guts. *Paranthura* (two species are present in San Leandro Bay; specimens saved from the gut analysis were *P. japonica*, but *P. elegans* were found on eelgrass near the mouth of the bay on 24 August 2018 and may have been part of the gut contents as well) is a relatively large, predatory isopod that can be associated with eelgrass (Carr et al. 2011) or fouling communities (Andrew Cohen, personal communication). *Paranthura* was found in one white croaker and several of the larger topsmelt. Leptostracans, represented by *Nebalia* sp., are benthic crustaceans that the author has captured in beach seine hauls in Seaplane Lagoon on the former Naval Air Station Alameda, where they appeared to be associated with filamentous algae over muddy sand bottom.

Harpacticoid copepods were the second-most frequently seen crustacean group in the study. The genus *Euterpina*, a planktonic form, was recognized in some of the topsmelt guts, but most of the harpacticoids were immature, copepodid stages that are probably also planktonic. A few adults other than *Euterpina* were observed but not identified to species. They did not appear to be benthic infaunal species, but some of them might have been associated with the bottom in some way. Calanoid copepods, considered planktonic, were not frequent or abundant.

Gammarid amphiods are principally bottom-dwelling species, although they occur in fouling communities, and they can and do swarm into the water column at times, mainly at night. *Ampihtoe valida* is a rather large gammarid amphipod that is suspected of being an important grazer of eelgrass (Carr et al. 2011). For this reason, it was tabulated separately from other gammarids, which are considered to be more omnivorous or carnivorous. In the end, *Ampithoe* turned out not be very frequently found in the guts. Other gammarids included, most conspicuously, the aorid *Grandidierella japonica* and *Americorophium stimpsoni*, *Laticorophium baconi*, and other corophiids. Often, gammarids were present as small (< 2 mm) juveniles that are not identifiable, at least by a non-expert. Most gammarids were seen as fragments, and identification usually entailed first using an artist's brush to remove the protein paste coating all objects. Because of these difficulties, and the lack of specific trophic information on the various taxa, all gammarids other than *Ampithoe* were recorded as a single group.

Caprellid amphipods, sometimes called skeleton shrimp, were identified only to family but recorded separately from other amphipods because they do not live on or in sediment, but rather cling to erect vegetation or colonial invertebrates. They are all carnivorous.

Mysids are epibenthic or "hypoplanktonic" shrimp-like crustaceans that were a minor part of fish diets in this study. Their larvae are more truly planktonic, as are the zoeae of crabs and *Crangon* shrimp.

The most frequently seen insects were plant hoppers, which are probably associated with cord grass. The unidentified insect category were typically disembodied heads of ants or beetles; one small spider (from a shiner perch) was included to avoid another column in the matrix. Among dipterans (flies), only the benthic larvae of chironomids (midges) were present as more than a trace.

Fish were eaten by shiner perch, white croaker, and – surprisingly – by one anchovy (the largest). Without an exoskeleton, fish are digested quickly. A goby, and a few atherinopsids (including larvae and one egg) were recognized, but most fish were not identifiable. To the extent that their lengths could be measured or estimated, prey fish were generally < 25 mm TL. Fish scales, possibly of topsmelt, were important in one topsmelt sample from site AL, though the circumstances are unclear.

The category "fecal pellet" occurred mainly in the BF sample of topsmelt. These were capsule-shaped concretions of very fine mineral grains in an organic matrix, about 0.4 x 0.15 mm, that appeared to be the castings of an invertebrate.

Non-Food Items

Small amounts of sand were nearly ubiquitous, even in fish such as anchovy that appeared to be feeding in the water column. Sand was not recorded as part of the gut contents. Similarly, calcareous skeletal fragments of erect ectoprocts, probably *Bugula* sp., were very commonly present in trace amounts. No zooids were ever seen, and most of these fragments were black, as though they had rotted in the sediment. Accordingly, these fragments were treated as sand grains and ignored.

Finally, at the request of Jay Davis, I noted the frequency of objects that appeared to be plastic. These were mainly rather short fibers of various colors, but also included flecks of more amorphous or sheet-like material, and in a few cases, small (0.1 mm) cookie-shaped, iridescent objects that were recorded as discs.

Fish Diets

TOPSMELT

Topsmelt have no real stomach (Horn et al. 2006), but rather a long intestine, with a large gall bladder that secretes digestive enzymes near the front end. The gut typically has four bends that give rise to five recognizable sections. The last three sections often, but not always, had different food items than the front two sections, possibly indicating the fish had fed in more than one location prior to capture. Topsmelt ingested the widest variety of food items of the four fish species examined (Appendix A), although this is at least partly due to the large number of sites and individuals included, as well as the overall size range of the specimens. In August, age-0 topsmelt should be < 90 mm TL, so some of these samples contain at least some age-1+ fish. For presentation in Table 3, only those items that amounted to an average of 5% or more of the mean estimated gut volume at any site are included.

With two exceptions (sites AC and SLC-BN2), the major portion of the topsmelt diet was gammarid amphipods. Nearly every fish had at least a trace of harpacticoid copepods, but this food item was important only at sites DS and ELM, where harpacticoids formed a very large fraction of the contents in the smaller fish. At site AC all topsmelt diets had a major portion of chain diatoms, and nine also had consumed plastic, the highest incidence of plastic of any site. Chain diatoms were important, but not dominant food items at sites ELM and SBC-BN1 as well. The other exception to gammarid dominance, site SLC-BN2, had at least 10 age-1+ fish in the sample, and these had eaten principally macroalgae.

Most of the topsmelt at site AL on 9 August (but not on 23 August) had consumed a significant mass of fish scales (Table 3). However, the scales appeared to be of topsmelt, and given that this sample was taken by cast net (Table 1), it is possible that the scales were released into the water as part of the sampling effort. Scale eating has not been reported for this species, although topsmelt have been reported to pick parasites and loose skin from gray whales (Swartz 1981).

An interesting item that did not meet the criteria for inclusion in Table 3, but did constitute 1% or more of the topsmelt diet at sites AC, EC, and ELM (Appendix A), was the small green snail mentioned in the food categories section. The unconfirmed identification of the snail is *Smaragdia* sp., a genus of obligate seagrass-eating nerite gastropods. As there is little eelgrass in San Leandro Bay, and none near sites EC and ELM (based on canoe and snorkel surveys during low tide on 12 July and 15 August 2018), this snail indicates at least some off-site feeding, discussed below.

Table 3. Summary of topsmelt samples, their major food items, and incidence of plastic. Units for averages, unless labeled in the heading, are estimated percent volume of contents.

Station		# fish	Total Length (mm)	Mass (g)	Gut volume (ul)	Chain diatom	Macro-algae	Unidentified stalked egg	Paranthura sp.	Harpac-ticoids	"Other" Gammarid	Fish scales	Plastic disc	Plastic fleck	Plastic fiber
AC		20													
	# occurrences					20	1	0	0	20	9	1	0	2	9
	# as trace only					0	0	0	0	0	0	1	0	2	9
	significant occurrences					20	1	0	0	20	9	0			
	Average		85	3.45	306	86.8	0.1	0	0	0.6	7.7	0			
	min		71	1.90	155										
	max		105	5.79	716										
AL 8/9		20													
	# occurrences					11	0	16	0	20	19	16	2	0	2
	# as trace only					9	0	1	0	3	2	1	2	0	2
	significant occurrences					2	0	15	0	17	17	15			
	Average		67	1.38	36	4.6	0	35.1	0	4.0	39.7	14.1			
	min		58	0.93	8										
	max		77	2.15	78										
AL 8/23		20													
	# occurrences					0	0	0	0	20	20	0	0	0	2
	# as trace only					0	0	0	0	0	0	0	0	0	2
	significant occurrences					0	0	0	0	20	20	0			
	Average		76	2.46	128	0	0	0	0	5.5	89.3	0			
	min		61	0.90	29										
	max		106	5.84	326										
BF		20													
	# occurrences					1	0	0	2	20	20	3	0	0	0
	# as trace only					0	0	0	0	1	0	1	0	0	0
	significant occurrences					1	0	0	2	19	20	2			
	Average		77	2.75	83	1.0	0	0	2.5	1.6	71.0	0.6			
	min		65	1.07	18										
	max		148	21.3	638										
DS		22													
	# occurrences					0	0	0	1	22	18	0	0	0	1
	# as trace only					0	0	0	0	1	1	0	0	0	1
	significant occurrences					0	0	0	1	21	17	0			
	Average		86	3.50	86	0	0	0	2.3	29.4	59.3	0			
	min		62	1.28	16										
	max		140	15.1	424										
EC		21													
	# occurrences					3	5	0	6	21	18	1	0	0	1
	# as trace only					0	0	0	0	1	0	1	0	0	1
	significant occurrences					3	5	0	6	20	18	0			
	Average		98	5.81	132	7.4	2.5	0	10.1	0.3	45.2	0			
	min		78	2.23	0										
	max		188	42.6	389										
ELM		22													
	# occurrences					7	0	0	0	22	20	0	0	0	1
	# as trace only					0	0	0	0	1	0	0	0	0	1
	significant occurrences					7	0	0	0	21	20	0			
	Average		73	3.23	88	17.3	0	0	0	21.4	41.8	0			
	min		48	0.54	8										
	max		161	26.3	473										
SLC-BN1		23													
	# occurrences					18	0	0	2	23	23	0	0	0	3
	# as trace only					1	0	0	1	0	0	0	0	0	3
	significant occurrences					17	0	0	1	23	23	0			
	Average		94	5.45	234	32.3	0	0	2.6	0	56.6	0			
	min		76	1.97	53										
	max		177	27.9	473										
SLC-BN2															
	# occurrences			20		0	17	0	1	20	15	2	0	0	2
	# as trace only					0	0	0	0	1	1	1	0	0	2
	significant occurrences					0	17	0	1	19	14	1			
	Average		90	4.21	351	0	56.8	0	0.3	0	28.8	0.3			
	min		61	1.98	117										
	max		102	6.71	626										
GRAND MEAN						16.6	6.6	3.9	2.0	7.0	48.8	1.7			

SHINER PERCH

Shiner perch bear live young in June that grow very rapidly. Judging by fork-length frequencies reported by Orsi (1999), fish <90 mm TL in August are probably age-0, so both samples are a mix of young and older fish. Shiner perch have well developed pharyngeal teeth, where food processing begins, followed by a typical (for teleosts) J-shaped stomach and a fairly long intestine. Most of the guts examined in this study were nearly or completely empty, possibly indicating this species feeds mainly at night in San Leandro Bay. This may have biased the results in favor of prey species with shells or exoskeletons. Gammarids were the main prey, followed by bivalves and, at site SLB, polychaetes (Table 4). All bivalves found in shiner perch guts were the olive mussel, *Musculista senhausia*, a species with a wide range of habitats, discussed below.

Table 4. Summary of shiner perch samples, their major food items, and incidence of plastic.

Station	# Fish	Total Length (mm)	Mass (g)	Gut volume (μl)	Bivalve	Polychaete	Ampithoe	Other Gammarid	Caprellid	Plastic fiber
AL	20									
# occurrences					10	2	0	17	8	2
# as trace only					1	0	0	0	0	2
significant occurrences					9	2	0	17	8	
Average		91	9.29	98	20.3	1.3	0.0	49.0	9.5	
min		79	5.48	13						
max		116	20.3	277						
SLB	20									
# occurrences					5	6	1	17	0	0
# as trace only					0	0	0	0	0	0
significant occurrences					5	6	1	17	0	
Average		108	16.29	173	6.1	15.5	1.3	54.7	0.0	
min		86	7.46	0						
max		142	40.9	1220						

WHITE CROAKER

White croaker have a muscular, blind-sac stomach with a ring of caeca where the food enters the intestine. Unlike the other three species treated here, the white croaker digestive system produces a dense feces with few or no identifiable structures in the posterior third of the intestine. Judging by fork-length frequencies reported by Orsi (1999), fish <135 mm TL in August are probably age-0, which would include all of the fish examined. As with shiner perch and most of the topsmelt samples, the croakers' main food item was gammarids. Of secondary but significant importance were small fish and polychaetes (Table 5).

Table 5. Summary of the white croaker sample, its major food items, and incidence of plastic.

Station	# Fish	Total Length (mm)	Mass (g)	Gut volume (µl)	Sea Slug	Poly-chaete	Leptostracan	"Other" Gammarid	Unidentified crustacean	Mysid	Cran-gon	Fish	Unidentified animal	Plastic fiber
AL	20													
# occurrences					2	7	8	18	1	3	1	7	2	3
# as trace only					0	0	1	0	0	0	0	0	0	3
significant occurrences					2	7	7	18	1	3	1	7	2	
Average		103	11.54	293	1.8	7.8	1.9	62.7	3.5	1.8	2.0	11.8	4.8	
min		92	7.66	128										
max		115	18.2	581										

NORTHERN ANCHOVY

The northern anchovy digestive system resembles that of the white croaker in that there is a muscular, blind-end stomach with a ring of caeca where the food enters the intestine. The anchovy differs from the croaker in that the very long intestine bends forward and makes several loops within a fatty deposit next to the liver before extending back to the anus. Removing this fat was tedious and only partly successful, which made for difficult viewing of the contents. After analysis of three specimens revealed no difference between the contents of stomach and intestine, it was agreed between SFEI and the author that the rest of the anchovy dissections would be stomachs only. This resulted in very clean preparations with good viewing.

The northern anchovy sample had four individuals that were slightly or, in one case, far outside the range of the tissue sample (Table 1 and Appendix A). The largest of these fish out-weighed the average by a factor of two and had gut contents that were completely different from all but one other specimen (Appendix A) and was solely responsible for the presence of fish in Table 6. The main food item of all other anchovies was the "needle diatom" discussed in an earlier section and tentatively identified as *Cylindrotheca closterium*. Whether this species was consumed in the water column (planktonic) or from the floor of the bay (epipelic) is an important question, because exposure to PCBs would be different in the two habitats. Other prey of the anchovies were harpacticoid copepods (ambiguous), nechtochaete larvae of polychaetes (planktonic), larval mysids and zoeae of *Crangon* and crab (planktonic), and calanoid copepods (planktonic). Considering also that northern anchovy is well adapted to filter feeding and not well known for benthic feeding, it is suggested here that the needle diatom was in the plankton.

Table 6. Summary of the northern anchovy sample, its major food items, and incidence of plastic.

Station	# Fish	Total Length (mm)	Mass (g)	Gut volume (μl)	Needle diatom	Harpac-ticoids	Fish	Fish larva	Plastic fleck	Plastic fiber
AC	20									
	# occurrences				19	20	1	2	4	6
	# as trace only				0	5	0	0	4	6
	significant occurrences				19	15	1	2		
	Average	77	2.07	23.25	80.15	13.15	3.75	1.25		
	min	69	1.41	4						
	max	98	4.19	52						

Discussion and Recommendations

Sediment penetration

At the work group meeting on 3 May the author was asked to opine on whether benthic-feeding fish had foraged in the upper 2 cm of the sediment column or deeper. With the caveat that polychaetes were mostly unidentified, there was no indication of feeding deep in the sediment.

It should also be noted that some "benthic" creatures do not live in sediment exclusively or even at all. The most abundant bivalve in the samples, the filter-feeding *Musculista*, can anchor in surface sediment, but also is found on hard substrate and plants (it was the most conspicuous animal on eelgrass at Pt. Molate) and macroalgae (on which it was found in Elmhurst channel; site ELM). Even some of the polychaetes observed (the scale worms) are known to live on plants, hard substrates, or commensally in the tubes of other invertebrates, as well as in the surface sediments.

Site fidelity

Greenfield and Allen (2012) cited Greenfield and Jahn (2010) as stating that Mississippi silverside and young (60-100 mm) topsmelt had "restricted home ranges." However, though Greenfield and Jahn did say this of the Mississippi silverside, they actually called topsmelt a "marine migrant" and noted that this species departs from nearshore habitats during low tides. The degree to which topsmelt stray along-shore during low tide is unknown, and it is a good topic for future work. Evidence for site fidelity based on tissue concentration of PCB was much stronger for Mississippi silverside that for topsmelt (Greenfield and Allen 2012). There is mixed evidence from the gut content data examined here, though some straying is evident.

The fish samples from San Leandro Bay had good spatial coverage for topsmelt, but were limited in time to a single period of approximately two weeks. Repetition in time was limited to a single location (Airport Lagoon) and species (topsmelt). Even so, the information gained is instructive. The two samples, separated in time by 14 days, differed in mean total length by nearly 1 cm (13%) and in mass by just over 1 g (78%). This change is not likely due to growth within a single cohort, but rather indicates visitation to the site by a different school of topsmelt. The invertebrate eggs that formed 35% of the forage of the first group on 9 August may well have hatched and been unavailable to the second group on 23 August. However, it may also be that the larger fish on 23 August simply focused on larger prey. The comparison is further complicated by the different gear used to capture the two samples (Table 1), which may have taken fish from somewhat different habitats.

When the author visited site ELM on 12 July 2018, the bottom sediment was nearly covered with a foliose green alga. A sample of the alga contained 7 *Musculista* ranging from 7.5 to 17 mm in length and 27 amphipods, all identified as *Ampithoe valida* ranging from 1 to 11 mm body length. Though none of the topsmelt from this site had consumed *Musculista*, or macroalgae, two of them had eaten several *A. valida,* a species that was not common throughout the rest of the study. If one assumes the biota of this site was similar in 2016 and 2018, this may be taken as some indication of site-specific foraging. However, if the flora and fauna at site ELM in 2016 were the same as in 2018, then the presence of the little green snail (*Smaragdia* ?) in 8 of the 20 topsmelt examined is an indication that many of the fish had recently visited eelgrass habitats near or beyond the mouth of San Leandro Bay.

The green snail also occurred in several topsmelt sampled at site EC, as did the predatory isopod Paranthura sp. These taxa co-occurred in three of the fish. If the identification of the snail is correct, then this indicates foraging in eelgrass. The author and his wife both surveyed the area of site EC on 12 July, while the bottom was clearly visible, and saw no eelgrass. A survey by Merkle in 2009 indicated very scant coverage of eelgrass in san Leandro Bay, and none near site EC (Appendix B). Merkle did no ground-truthing within San Leandro Bay, and it is possible that some of the traces were other than eelgrass. For example, on 24 August 2018, the author observed numerous examples of a brown alga (*Gracilaria* sp.) anchored to mussels and extending 50 cm or more up into the water column along the south side of the San Leandro Bay navigation channel.

Caution as to site fidelity is thus also warranted in interpreting contaminant concentration in tissue samples. However, it is notable that the topsmelt sample with the greatest consumption of macroalgae (site SLC-BN2, near Hegenberger Road) did have the lowest concentration of tissue PCB of the eight sites analyzed (Davis et al.. 2017), as might be expected if such a low-fat diet is habitual.

The diets of the fish reported here should not be treated as definitive. With the exception of a few specialists, e.g. parasites, most animals are to some degree opportunists. It would seem profitable in the future to expend some effort in characterizing a PMU more thoroughly as to its distribution of flora, potential prey, and other habitat features. Other work might be done to help answer the question of site fidelity. Tag-and-recapture studies should provide valuable information in this regard. Shiner perch and white croaker are large enough species to support acoustic tags, although age-0 topsmelt are not. It might be possible to develop PMU-specific tracers, such as a “finger print” of PCB congeners or other chemical signature as a measure of site fidelity based on tissue chemistry.

Topsmelt ontogeny

Greenfield and Jahn (2010) reported that estuarine topsmelt <110 mm TL ate >99% animal prey, mainly benthic crustaceans. With specimens ranging from 248 to 349 mm SL (add 10 or 15 mm for TL), Horn et al. (2006) reported estuarine topsmelt diets consisting of >90% macroalgae. In the present study, only six of 133 topsmelt deemed to be age-0 fish (<90 mm TL) contained any amount of macroalgae, and five of the six had algae as ≤10% of the diet. In contrast, 17 of 55 topsmelt >89 mm TL had reportable amounts of macroalgae, and 9 of the 17 had ≥85% algae in the gut contents. Horn et al. (2006) reported that topsmelt in an offshore environment ate mainly an animal diet and differed from their estuarine conspecifics in details of gut anatomy and digestive enzymes. It seems probable that a change from animal to algal diet in estuarine topsmelt tends to begin some time in the second year of life, although the present comparison is confounded by a spatial component, as mentioned in the previous paragraph. This concern should inform future sampling and analysis of this species in the context of PCB contamination.

Stomach vs. intestine

Disadvantages of examining the entire digestive tract include the smearing out of site-specific feeding and differential digestability of items as they pass through the gut. There is some indication that the former occurred in the present study. As mentioned above, the topsmelt gut, though stomachless, is readily seen as five distinct sections. Though details were not all recorded, some notes reveal fore-to-aft changes in food composition. For example, a 61-mm topsmelt from site SLC-BN1 had in section 1 (the most voluminous) about 100 gammarids, 10 ostracods, and some bits of diatom chain. The second section had the same mix, but after the second bend, the gut contained only chain diatoms. It seems more likely that this fish recently encountered the amphipods than that it suddenly acquired a taste for them. Such observations were common, often with the reverse situation, i.e., amphipod fragments dominating in the last section. This last observation may be an indication of the second disadvantage of whole-gut analysis, i.e., that the chitinous exoskeletons of amphipods may bias their recognition as important prey over soft-bodied items such as eggs and larval fish. (In regard to soft-bodied prey, a reference collection of common invertebrates in a PMU would be helpful. Polychaetes and some sea slugs, for example, have identifiable hard parts that can be recognized but that are not the characters that appear in taxonomic keys.)

Advantages of examining the entire gut are that it may be more representational of general habits over the time period preceding capture and that, without this practice, the shiner perch analysis would have produced mostly empty stomachs. The near absence of contents in the shiner perch sample is puzzling. Hobson et al. (1981) described nighttime feeding in this species, but not to the exclusion of daytime feeding. Sampling at night in Oakland Harbor, the author obtained shiner perch with full stomachs (data set previously supplied to SFEI).

Comparison to 2001 Report

Sigala (2001) reported gut contents of shiner perch and white croaker from several sites in San Francisco Bay, including San Leandro Bay. In his study, the stomachs had been removed from the fish prior to preservation; size of fish and season of sampling were not given. Weight of identified prey was estimated from counts and the average weights of species based on sediment core samples. Sigala worked with experts in amphipod and polychaete taxonomy (Peter Slattery and Eugene Ruff, respectively), so that much of the prey was identified to species. Here, the species are lumped into major categories.

Nineteen of 20 shiner perch had non-empty stomachs, contents of which were 60% by weight polychaete, 19% bivalve, and only 9% benthic crustacean (including amphipods). The major part of the polychaete biomass was attributed to the scale worm *Harmothoe imbricata*, which can be found in a wide range of habitats, including sediment. Polychaetes also dominated the gut contents in samples from San Pablo Bay and Oakland Harbor, while bivalves (*Corbula amurensis*), followed by benthic crustaceans, dominated at Redwood Creek.

Five white croaker stomachs from San Leandro Bay had only about 7% benthic crustacean, 18% polychaete, and a very surprising 73% calanoid copepod by weight. As the calanoids would not likely have been in the sediment core samples, it is unclear how the weight contribution of this planktonic organism was estimated. At other locations (Redwood Creek, Oakland Harbor, San

Pablo Bay), benthic crustaceans dominated the (also small) samples by weight, as was the case in the present study.

PCB exposure

PCBs owe their amplification in food chains to their solubility in lipids. For the fishes considered here, small crustaceans, especially gammarid amphipods, and diatoms together comprised the great majority of food consumption. Both of these groups use lipid for energy storage, but there are likely to be differences among species as to their exposure and accumulation rates of contaminants. For the diatoms, even when identified to species (and here they are not), whether or not they dwell in the water column is a key question. For gammarid amphipods, exposure may differ according to food habits and other behavior (see, e.g., Hecht et al. 2004). The literature seems lacking in specifics, and for the present modeling purposes, it would be more productive to measure PCB content directly in the food groups identified than to attempt to divine such information from first principles.

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Appendix A. Raw Data Tables

There are four tables – one each for topsmelt, shiner perch, white croaker, and northern anchovy. Where multiple sites were sampled, the samples are arranged in alphabetical order by the site names given in Table 1 of the main text. Each sample is sorted by fish total length (TL). Columns for food (and non-food, i.e. plastic) items include only the items consumed by the species tabulated. Unless labeled otherwise, numbers in columns are the estimated percentage of gut volume attributable to a food item. m = missing, p = present as trace.

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isopod	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
AC	71	2.13	204			90	10																																	p
AC	72	1.90	228			100	p																																	p
AC	72	2.01	211			100			p																									p						p
AC	74	2.15	179			90	10																																	p
AC	75	2.26	226			95	5																																	
AC	75	2.04	181			85				1												10			2	2														
AC	77	2.30	182			90																2			5	3													p	p
AC	81	2.64	330			95	5																																	
AC	84	3.13	317			80							5					p							10	5														
AC	85	2.76	155			50																			50														p	p
AC	88	4.50	480			90	10																																	
AC	88	4.96	m			90			p				1												7	2														p
AC	89	3.47	429			60			p																20	20														p
AC	89	3.87	245			80							10					p							5	5														
AC	93	4.03	204	p		60																			40															
AC	94	5.14	716			100																																		
AC	95	4.42	533			100																																		
AC	97	4.53	331			80							4												15											1				
AC	97	4.92	398			100																																		
AC	105	5.79	562			100			p																															p
# occurrences		20		1	0	20	6	0	4	1	0	0	4	0	0	0	0	2	0	0	0	20	0	0	9	6	0	0	0	0	0	0	0	1	0	1	0	0	2	9
# as trace only				1	0	0	1	0	4	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2	9
significant occurrences				0	0	20	5	0	0	1	0	0	4	0	0	0	0	0	0	0	0	20	0	0	9	6	0	0	0	0	0	0	0	0	0	1	0			
Average	85	3.45	305.6	0	0	86.8	2	0	0	0.05	0	0	1	0	0	0	0	0	0	0	0	0.6	0	0	7.7	1.85	0	0	0	0	0	0	0	0	0	0.05	0			
AL 8/9	58	0.93	34			p					60							5				10			15									10				p		
AL 8/9	60	1.12	36								10							p				40			40									10						
AL 8/9	61	0.93	26			p					20							5				5			10									60						
AL 8/9	61	1.06	35								50							1				4			40									5						p
AL 8/9	62	1.04	40								50							p				p			40									10						
AL 8/9	63	1.11	40			p					45											5			50									p						
AL 8/9	65	1.28	33								90											p			5									5						
AL 8/9	65	1.17	8			p					80											5			5									10						
AL 8/9	66	1.23	63			p					p											1			98									1						
AL 8/9	67	1.35	26			p					2														50									48						
AL 8/9	67	1.34	15		p	1					80							4							p									15						
AL 8/9	68	1.37	28																						90									10						
AL 8/9	69	1.37	65			p					55							5							p									40						p
AL 8/9	70	1.17	36			90												3				2													5					
AL 8/9	70	1.55	23								15							5							40									40						
AL 8/9	72	1.68	22			p					5											7			80									8						
AL 8/9	75	1.84	61																						100															
AL 8/9	75	1.88	25						p		60							10				p			20				p					10				p		
AL 8/9	76	2.10	78			p					80							p							10	10														
AL 8/9	77	2.15	26																						100															
# occurrences		20		0	1	11	0	0	1	0	16	0	0	0	0	0	0	11	0	0	0	20	0	0	19	1	0	0	1	0	0	0	0	16	1	0	0	2	0	2
# as trace only				0	1	9	0	0	1	0	1	0	0	0	0	0	0	3	0	0	0	3	0	0	2	0	0	0	1	0	0	0	0	1	0	0	0	2	0	2
significant occurrences				0	0	2	0	0	0	0	15	0	0	0	0	0	0	8	0	0	0	17	0	0	17	1	0	0	0	0	0	0	0	15	1	0	0			
Average	67	1.38	36	0	0	4.55	0	0	0	0	35.1	0	0	0	0	0	0	1.9	0	0	0	3.95	0	0	39.7	0.5	0	0	0	0	0	0	0	14.1	0.25	0	0			

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isopod	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
AL 8/23	61	0.90	29														p					60			40															
AL 8/23	64	1.22	93																						100															
AL 8/23	64	1.40	108																						100															p
AL 8/23	64	1.36	58																						100															
AL 8/23	67	1.43	m																			50			50															
AL 8/23	69	1.66	108																						100															
AL 8/23	71	2.22	124																						100															
AL 8/23	71	2.13	59																						100															
AL 8/23	71	2.03	168															p	p					5	95															
AL 8/23	72	2.23	119																						100															
AL 8/23	73	1.76	36																						100															
AL 8/23	78	2.45	244	5	80													10							5															p
AL 8/23	79	2.32	118	p														4							96															
AL 8/23	80	2.87	214																						100															
AL 8/23	82	2.81	131																						100															
AL 8/23	82	2.64	94																						100															
AL 8/23	85	3.57	166																						100															
AL 8/23	88	3.77	77																						100															
AL 8/23	94	4.53	288																						100															
AL 8/23	106	5.84	326																						100															
# occurrences		20		2	1	0	0	0	0	0	0	0	0	0	0	0	1	3	1	0	0	20	0	1	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
# as trace only				1	0	0	0	0	0	0	0	0	0	0	0	0	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
significant occurrences				1	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	20	0	1	20	0	0	0	0	0	0	0	0	0	0	0	0			
Average	76	2.46	128	0.25	4	0	0	0	0	0	0	0	0	0	0	0	0	0.7	0	0	0	5.5	0	0.25	89.3	0	0	0	0	0	0	0	0	0	0	0	0			
BF	65	1.07	18					45																	50										5					
BF	65	1.27	33																						90									10						
BF	67	1.36	53																						90												10			
BF	70	1.46	37						40																60															
BF	70	1.49	43					25														20			30												25			
BF	70	1.49	m																						40											60				
BF	70	1.36	32																						100															
BF	71	1.71	73			20	20																		30												30			
BF	71	1.60	75																						95									p	5					
BF	72	1.66	89						50													p	40		10															
BF	73	1.74	52																						70	30														
BF	74	1.81	m																						95					5										
BF	74	1.92	21																						100															
BF	75	1.87	34																						100															
BF	77	1.94	40																						100															
BF	77	2.15	71						2													2			95									1						
BF	82	2.27	117															5				10			80												5			
BF	83	2.61	141																	20					80															
BF	84	2.93	91					30								15									35										10		10			
BF	148	21.30	638																	30					70															
# occurrences		20		0	0	1	1	3	3	0	0	0	0	0	0	1	0	1	0	2	0	20	1	0	20	1	0	0	0	1	0	0	0	3	3	1	5	0	0	0
# as trace only				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0
significant occurrences				0	0	1	1	3	3	0	0	0	0	0	0	1	0	1	0	2	0	19	1	0	20	1	0	0	0	1	0	0	0	2	3	1	5			
Average	77	2.75	82.9	0	0	1	1	5	4.6	0	0	0	0	0	0	0.75	0	0.25	0	2.5	0	1.6	2	0	71	1.5	0	0	0	0.25	0	0	0	0.55	1	3	4			

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isopod	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
DS	62	1.55	77																			100																		
DS	65	1.28	16																			100																		
DS	73	1.85	61																			100			p															
DS	74	1.91	97																			100																		
DS	78	2.10	24																			95														5				
DS	78	2.33	32																			95			1	4														
DS	78	2.35	28																						100															
DS	80	2.79	90														5								95															
DS	82	2.55	50																						100															
DS	82	2.71	m																			30			30	10										30				
DS	82	2.45	21																			1			99															
DS	82	2.68	74																						90								10							
DS	82	2.74	63																			5			95															
DS	85	2.95	33														20								80															
DS	88	3.56	70																			p			100															
DS	90	4.01	79																						100															
DS	91	4.07	143																						100															
DS	94	3.87	49														40								60															
DS	97	4.29	66																			20			80															p
DS	99	4.01	136																						40	60														
DS	103	5.90	170																						90	10														
DS	140	15.13	424														3			50					45			2												
# occurrences		22		0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	22	0	0	18	4	0	1	0	0	0	0	1	0	0	2	0	0	0	1
# as trace only				0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
significant occurrences				0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	1	0	21	0	0	17	4	0	1	0	0	0	0	1	0	0	2	0			
Average	86	3.50	85.86	0	0	0	0	0	0	0	0	0	0	0	0	0	3.09	0	0	2.27	0	29.4	0	0	59.3	3.82	0	0.09	0	0	0	0	0.45	0	0	1.59	0			

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isopod	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
EC	78	2.23	101																			1			99															
EC	83	2.66	64										15									5			75											5				
EC	83	2.83	0																																					
EC	87	3.07	152													5									95															
EC	91	3.61	139						3											3					89			5												
EC	91	3.72	138										2				2			20					56	20														
EC	92	3.71	131						3	5							90								2															
EC	92	3.65	149			1	1	10						1		77									5										5					p
EC	92	3.73	128														4								95	1														
EC	92	3.89	103							5			5												40	50														
EC	93	3.77	105			60				35												p			5															
EC	94	3.59	95			95				5																														
EC	95	3.89	38							2															8											90				
EC	96	4.19	136											5			45								50															
EC	99	4.46	234														p								100					p										
EC	99	4.80	33																																					
EC	101	4.80	93										p							75					25															
EC	101	5.25	142														10			5					85															
EC	103	5.66	176						8							2		p							90															
EC	104	5.88	228										15			p				60					20	5														
EC	188	42.60	389														10			50					10			30		p				p						
# occurrences		21		0	0	3	1	1	3	5	0	0	5	2	0	4	7	1	0	6	0	21	0	0	18	4	0	2	0	2	0	0	0	1	1	2	0	0	0	1
# as trace only				0	0	0	0	0	0	0	0	0	1	0	0	1	1	1	0	0	0	1	0	0	0	0	0	0	0	2	0	0	0	1	0	0	0	0	0	1
significant occurrences				0	0	3	1	1	3	5	0	0	4	2	0	3	6	0	0	6	0	20	0	0	18	4	0	2	0	0	0	0	0	0	1	2	0			
Average	98	5.81	132	0	0	7.43	0.05	0.48	0.67	2.48	0	0	1.76	0.29	0	4	7.67	0	0	10.1	0	0.29	0	0	45.2	3.62	0	1.67	0	0	0	0	0	0	0.24	4.52	0			

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isop od	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
ELM	48	0.54	8				5										p					75			15	5														p
ELM	50	0.57	21			45							1					4			40				10															
ELM	53	0.77	27																			90			10															
ELM	54	0.67	22																			80			15	5										p				
ELM	56	0.77	113						5													75			20															
ELM	60	0.98	m															p				60			35	5		p												
ELM	61	1.29	24				95															5																		
ELM	63	1.12	59			90							p												5				5											
ELM	66	1.34	78			10																			80	10														
ELM	67	1.40	31			40							2									15	1		40					2										
ELM	68	1.45	29																						100															
ELM	68	1.34	25																			60			40															
ELM	69	1.53	49																						70				5	20	5									
ELM	70	1.51	44															5				10		50	30					5										
ELM	70	1.52	23			40																			50					10										
ELM	73	1.76	79										40					p				p	p		60															
ELM	75	2.03	m																						100															
ELM	75	2.14	105			60							10												10	20														
ELM	76	2.11	99															p					2		90					8										
ELM	80	2.50	140										p												100															
ELM	150	17.50	473			95							2					3																						
ELM	161	26.30	307										5											55	40															
# occurrences		22		0	0	7	2	0	1	0	0	0	8	0	0	0	1	6	0	0	1	22	3	2	20	5	0	1	2	5	1	0	0	0	0	1	0	0	0	1
# as trace only				0	0	0	0	0	0	0	0	0	2	0	0	0	1	3	0	0	0	1	1	0	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1
significant occurrences				0	0	7	2	0	1	0	0	0	6	0	0	0	0	3	0	0	1	21	2	2	20	5	0	0	2	5	1	0	0	0	0	0	0			
Average	73	3.23	87.8	0	0	17.3	4.55	0	0.23	0	0	0	2.73	0	0	0	0	0.55	0	0	1.82	21.4	0.14	4.77	41.8	2.05	0	0	0.45	2.05	0.23	0	0	0	0	0	0			

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isopod	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
SLC-BN1	76	1.97	64																5						90											5				
SLC-BN1	79	2.37	107										3				1								95						1	p								p
SLC-BN1	80	3.00	229			50												p	5						45											p				
SLC-BN1	81	2.74	53																						100															
SLC-BN1	82	2.77	109			90																			6			4												
SLC-BN1	82	3.89	346			25												5							70															
SLC-BN1	83	2.84	206			3												2							94	1														
SLC-BN1	83	2.95	177			14												1							85															
SLC-BN1	85	2.85	122			5			p									p		p					95	p														
SLC-BN1	85	3.80	281																	60					40															
SLC-BN1	85	3.37	175			p							2					p							98															
SLC-BN1	86	3.22	323			2												p							98				p											p
SLC-BN1	87	3.71	333			40																			60															
SLC-BN1	87	3.52	125			80			p									p							20															
SLC-BN1	88	3.58	229			70												p							30															
SLC-BN1	88	3.39	251	p		50												1							49											p				
SLC-BN1	90	3.34	112															p							98	2														
SLC-BN1	90	4.23	215			5												p							95															
SLC-BN1	92	4.42	303			80												p							10	10														p
SLC-BN1	97	5.19	389			90												1							9															
SLC-BN1	135	15.30	473			4			1															85	5	5														
SLC-BN1	141	15.10	470			80												1						15	4															
SLC-BN1	177	27.90	288			55																		35	5	5														
# occurrences		23		1	0	18	0	0	3	0	0	0	2	0	0	0	1	15	2	2	0	23	0	3	23	6	0	1	1	0	1	1	0	0	0	3	0	0	0	3
# as trace only				1	0	1	0	0	2	0	0	0	0	0	0	0	0	9	0	1	0	0	0	0	0	1	0	0	1	0	0	1	0	0	0	2	0	0	0	3
significant occurrences				0	0	17	0	0	1	0	0	0	2	0	0	0	1	6	2	1	0	23	0	3	23	5	0	1	0	0	1	0	0	0	0	1	0			
Average	94	5.45	234	0	0	32.3	0	0	0.04	0	0	0	0.22	0	0	0	0.04	0.48	0.43	2.61	0	0	0	5.87	56.6	1	0	0.17	0	0	0.04	0	0	0	0	0.22	0			

Station	Total Length (mm)	Mass (g)	Gut volume (ul)	Foram	Pennate diatom	Chain diatom	Needle diatom	Other protist	Plant material	macroalgae	Unidentified stalked egg	Other invert. Egg	Green Snail	Other snail	Sea Slug	Bivalve	Polychaete	Ostracod	Sphaeromatid isopod	Paranthura sp.	Leptostracan	Harpacticoids	Calanoid	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Mysid	Spider or unidentified insect	Plant hopper	Chironomid larva	Dipteran	Fish egg	Fish scales	Feathers	Unidentified animal	Fecal pellets	Plastic disc	Plastic fleck	Plastic fiber
SLC-BN2	61	2.54	164							5		60																								35				
SLC-BN2	76	2.11	144							10												p			90					p										p
SLC-BN2	76	1.98	128																						100															
SLC-BN2	80	2.36	117							70															30															
SLC-BN2	88	4.05	512				45			55						p									p							p								
SLC-BN2	89	3.81	270																						100															
SLC-BN2	89	3.80	331							10															90															
SLC-BN2	90	3.96	372							99															1															
SLC-BN2	90	4.20	388		5					45															50															
SLC-BN2	92	4.21	206							2					80					5				11	2															
SLC-BN2	95	4.34	343				5			70		20													5															
SLC-BN2	95	5.17	550							100																														
SLC-BN2	95	4.33	282							85		14													1															
SLC-BN2	95	4.88	430							90															10															
SLC-BN2	96	4.60	464							100																														
SLC-BN2	96	5.10	599							99								p							1															
SLC-BN2	97	5.35	626							100																														
SLC-BN2	97	5.15	404							95															5									p						
SLC-BN2	99	5.49	452							100																														p
SLC-BN2	102	6.71	232														3								90			2						5						
# occurrences		20		0	1	0	2	0	0	17	0	3	0	0	1	1	1	1	0	1	0	20	0	1	15	0	0	1	0	1	0	1	0	2	0	1	0	0	0	2
# as trace only				0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	1	0	0	1	0	0	0	0	1	0	1	0	1	0	0	0	0	0	2
significant occurrences				0	1	0	2	0	0	17	0	3	0	0	1	0	1	0	0	1	0	19	0	1	14	0	0	1	0	0	0	0	0	1	0	1	0			
Average	90	4.21	350.7	0	0.25	0	2.5	0	0	56.8	0	4.7	0	0	4	0	0.15	0	0	0.25	0	0	0	0.55	28.8	0	0	0.1	0	0	0	0	0	0.25	0	1.75	0			

Station	Total Length (mm)	Mass (g)	Gut volume (μl)	Green Snail	Bivalve	Poly-chaete	Ostracod	Harpac-ticoids	Ampithoe	Other Gammarid	Caprellid	Unidentified crustacean	Larval mysid	Spider or unidentified insect	Fish	Fish larva	Uniden-tified animal	Plastic fiber
AL	79	5.48	29							75					25			
AL	81	5.95	13							40			10			50		
AL	82	6.62	77							80	20							
AL	82	6.04	29															
AL	84	7.09	41	5	10					80	5							p
AL	84	7.48	28							30	70							
AL	85	7.38	132		50	15	5			15	15							
AL	87	7.2	57		60		5			30	5							
AL	87	7.78	37		80					20								
AL	88	7.6	16		p					100								
AL	89	8.17	168							90	10							
AL	89	8.31	91		90					10								
AL	90	8.79	168			10				90								
AL	90	9.44	227		25					15	60							p
AL	91	8.48	46		30					70								
AL	93	9.16	105		50			p		45	5							
AL	105	14.2	115							100								
AL	108	16	241		10					90								
AL	108	14.3	58															
AL	116	20.3	277												40		60	
# occurrences		20		1	10	2	2	20	0	17	8	0	1	0	2	1	1	2
# as trace only				0	1	0	0	1	0	0	0	0	0	0	0	0	0	2
significant occurrences				1	9	2	2	19	0	17	8	0	1	0	2	1	1	
Average	91	9.29	98	0.3	20.3	1.3	0.5	0.0	0.0	49.0	9.5	0.0	0.5	0.0	3.3	2.5	3.0	
min	79	5.48	13															
max	116	20.3	277															
SLB	86	7.46	96							100								
SLB	93	9.93	35							100								
SLB	95	9.75	120			95				5								
SLB	100	11.66	60							50							50	
SLB	100	13	250		5	5				85		5		p				
SLB	101	11.8	144							100								
SLB	102	12.9	326		5	5				90								
SLB	102	13.4	158		60					40								
SLB	102	14.05	86							100								
SLB	104	15.2	228			20				80								
SLB	106	15.9	126			90				10								
SLB	107	14.3	99		50					50				P				
SLB	108	14.1	236		2					3					95			
SLB	113	22.9	33							100								
SLB	115	20.5	0															
SLB	116	13	10							100								
SLB	119	21.9	66															
SLB	120	20.3	118			95				5								
SLB	123	22.9	48														p	
SLB	142	40.9	1220						25	75								
# occurrences		20		0	5	6	0	20	1	17	0	1	0	2	1	0	2	0
# as trace only				0	0	0	0	0	0	0	0	0	0	2	0	0	1	0
significant occurrences				0	5	6	0	20	1	17	0	1	0	0	1	0	1	
Average	108	16.29	173	0.0	6.1	15.5	0.0	0.0	1.3	54.7	0.0	0.3	0.0	0.0	4.8	0.0	2.5	
min	86	7.46	0															
max	142	40.9	1220															

Station	Total Length (mm)	Mass (g)	Gut volume (μl)	Green Snail	Sea Slug	Bivalve	Polychaete	Ostracod	Paranthura sp.	Leptostracan	"Other" Gammarid	Caprel-lid	Unidentified crustacean	Mysid	Cran-gon	Cran-gon zoea	Fish	Unidentified animal	Plastic fiber
AL	92	7.66	230							5	95								
AL	93	8.6	164							4	95			1					
AL	93	8.07	235							5	95								
AL	94	8.95	152				25						70	5					
AL	95	8.94	282								60					p	40		
AL	100	10.6	262								100								
AL	100	10.3	581			5					80							15	p
AL	100	10.7	282							10	90								
AL	101	11.7	425				25				4			30	40		1		
AL	102	11.2	128							5	15							80	
AL	104	11.1	469	p			20				50	5					25		p
AL	105	12.6	394				30			5	65	p				p			
AL	105	11.7	347				10	p			80	10							
AL	105	12.2	360							3	45					2	50		
AL	106	12.4	144		15		35				35						15		
AL	107	13.3	268								95						5		
AL	110	13.9	320														100		
AL	111	13.9	m								100					p			
AL	112	14.7	313							p	100					p			
AL	115	18.2	500		20	5	10		15		50								p
# occurrences		20		1	2	2	7	1	1	8	18	3	1	3	1	5	7	2	3
# as trace only				1	0	0	0	1	0	1	0	1	0	0	0	4	0	0	3
significant occurrences				0	2	2	7	0	1	7	18	2	1	3	1	1	7	2	
Average	103	11.54	293	0.0	1.8	0.5	7.8	0.0	0.8	1.9	62.7	0.8	3.5	1.8	2.0	0.1	11.8	4.8	
min	92	7.66	128																
max	115	18.2	581																

Northern Anchovy

Station	Total Length (mm)	Mass (g)	Gut volume (µl)	Chain diatom	Needle diatom	Nechto-chaete	Ostracod	Harpac-ticoids	Calanoid	"Other" Gam-marid	larval mysid	Crangon zoea	Crab zoea	Fish	Fish egg	Fish larva	Feathers	Plastic fleck	Plastic fiber
AC	69	1.41	4		90	5		2					3						
AC	70	1.56	12		95			5											
AC	71	1.66	10		88	5		2	p						p	5			
AC	72	1.56	8		98			2	p										
AC	73	1.96	37		100														
AC	73	1.92	45		100			p											
AC	73	2.08	43	p	99		p	p	p		1	p	p				p	p	p
AC	73	1.84	31		95			5										p	p
AC	74	1.97	22		80			20	P									p	p
AC	74	1.64	7		5		5	90											
AC	74	1.95	33		100														
AC	75	1.79	27		70			30											p
AC	75	1.89	52		95			1				4							p
AC	76	1.91	21		100			p											
AC	79	2.2	34		100			p											
AC	79	2.17	13		98			1	1										
AC	82	2.44	14		100	p		p											
AC	83	2.68	15		80			20											
AC	89	2.67	8		10			85					5					p	p
AC	98	4.19	29							5				75		20			
# occurrences		20		1	19	3	2	20	5	1	1	2	3	1	1	2	1	4	6
# as trace only				1	0	1	1	5	4	0	0	1	1	0	1	0	1	4	6
significant occurrences				0	19	2	1	15	1	1	1	1	2	1	0	2	0		
Average	77	2.07	23.25		80.15	0.5	0.25	13.15	0.05	0.25	0.05	0.2	0.4	3.75		1.25			

Appendix B. 2009 Eelgrass Survey