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6.0 EXPOSURE ASSESSMENT

This risk assessment evaluated three different media associated with potential routes of exposure and measurement endpoints. The concentrations of site-related CoCs in these various media represent a distribution of potential exposure levels to the appropriate ecological receptors. This section provides results of chemical analyses of those three media:

- Surface water,
- Sediment, and
- Biota.

6.1 SURFACE-WATER EXPOSURE CHARACTERIZATION

All of the measurement endpoints in this risk assessment, with the possible exception of the red-winged blackbird food-chain model, are directly affected by surface-water quality to some degree. For herons, water represents a secondary dietary exposure, with additional exposure from wading while feeding. For the other measurement endpoints (e.g., effects to fish and aquatic invertebrates), the concentrations of CoCs in water represent an ambient exposure that may be compared with benchmark values, such as ambient water quality criteria (AWQC) for the protection of aquatic life. Exposure pathways for these species include ingestion, dermal transfer, and uptake via gills.

Table 6-1 presents concentrations of CoCs detected in unfiltered surface-water samples. The highest concentrations of metals were detected in water samples collected from Upper Ferry Creek and the Housatonic Boat Club wetlands. The surface-water sample collected from station SD13 (in Upper Ferry Creek) contained the highest concentrations of chromium, copper, lead, nickel, and zinc detected in Upper Ferry Creek.

Only two organic CoCs were detected in surface-water samples. DDD was detected in samples collected from three locations in Upper Ferry Creek: SD28, SD30, and SD09. PCBs were detected in one sample collected from SD13 at a concentration of 0.072 µg/L. Individual PAH compounds were not detected in surface water at detection limits of 10 µg/L. The results for organic CoCs (i.e., lack of detection) are not surprising, given the hydrophobic nature of these CoCs.

6.2 SEDIMENT-EXPOSURE CHARACTERIZATION

Benthic organisms are generally less mobile than plankton or fish, and they live in or on the sediment. Therefore, these organisms are thought to be generally more subject to the effects of CoCs in sediment. Because of the behavior of most common environmental contaminants, these compounds are typically found in greater concentrations in sediment than in water. Benthic organisms may then take up, concentrate, and/or metabolize these chemicals to either more or less toxic forms. In addition, they may transfer the contaminants to other organisms through the food chain. The importance of the assessment endpoint for benthic invertebrates in this risk assessment lies in (1) their potential to pass contaminants up the food chain, (2) their increased vulnerability to environmental stress, (3) their usefulness as integrators of past and current conditions, and (4) their utility as indicators of localized conditions.

Table 6-1. Concentrations of COCs detected in unfiltered surface water samples.

Contaminant (µg/L)	Upper Ferry Creek (n=10)		Lower Ferry Creek (n=14)		Housatonic Boat Club (n=3)		Reference Area (n=3)		Detection Limits
	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum	Maximum	Minimum
Trace Elements									
Arsenic	4.0	93.4	<3.3	93.4	3.6	16.2	<3.3	4.8	3.3
Cadmium	<1.4	<2.4	<1.4	<3.3	<1.4	2.3	<1.4	<1.4	1.4
Chromium	6.6	20.5	7.7	<1.4	12.1	59.2	3.7	15.9	3.2
Copper	<16	121	<13.6	7.7	<34.8	138	<13.8	<35.8	3.8
Lead	5.5	147	<2.1	<13.6	3.0	37.2	<2.1	5.7	2.1
Mercury	<0.2	1.2	<0.2	<2.1	0.57	3.5	<0.2	6.0	0.2
Nickel	<3.6	11.7	<3.6	<0.2	<3.6	<3.6	<3.6	<3.6	3.6
Zinc	>18.4	127	<8.8	<3.3	<62.0	<62.0	<29.8	<29.8	8.8
Organic Compounds									
DDD	<0.1	<0.1	0.003	0.004	<0.1	<0.1	<0.1	<0.1	0.1
Aroclor 1262	<0.5	0.072	<0.5	<1.0	<0.5	<1.0	<0.5	<1.0	0.5

Infaunal oligochaetes and other annelid worms that live in the sediment dominate the benthic community in the study area. Other infaunal taxa such as arthropods (including amphipods) and molluscs generally composed less than 10% of the total abundance. Epibenthic macroinvertebrates such as fiddler crabs (*Uca* spp.) were also present in intertidal and nearshore subtidal regions. The relatively immobile nature of infaunal and epibenthic species, plus their direct contact with the sediments, result in substantial exposure of these organisms to site-related contaminants in the sediments. This continuous exposure of the organisms would occur through contact with contaminated sediment, pore water, and/or overlying water for all life stages over an organism's entire life span.

For some benthic species, such as the eastern oyster *(Crassostrea virginica)* or the fiddler crab, the life-history characteristics suggest that both the free-living larvae and adults would be exposed to site-related, sediment-bound contaminants. Contaminated upland runoff and sediment resuspension during critical spawning and free-living, early life stages could expose larvae to site-related contamination. Free-living, early life stages would also be exposed to contaminated sediment during spat fall (the *en masse* settlement of larvae). Sessile adults could be exposed to site-related contamination if oyster beds near Ferry Creek receive contaminants through sediment transport (and surface-water discharge) from the creek.

6.2.1 Sediment Characteristics

The physical characteristics of sediment critically affect bioavailability of contaminants within that matrix. Information on the characteristics of sediments also helps predict or identify conditions conducive to the sorption of contaminants (i.e., fine-grained, depositional areas). Understanding the characteristics of the sediment matrix also allows for predictions regarding the potential for colonization by specific benthic infauna or epifauna, given a knowledge of their habitat preferences.

Grain Size—Sediment grain-size data are presented in **Figure 6-1**. Results are reported as percent fines, or the percent of material with grain size less than 75µ. The U.S. Bureau of Soils classifies sediment with a grain size less than 62.5µ as silt and clay (Shepard 1948).

Sediment from Lower Ferry Creek and the Housatonic Boat Club generally contained high fractions of fine-grained material. There were notable exceptions, however; the four stations nearest the tide gate generally had lower percentages of fines. The percentage of fines tended to decrease from stations near the mouth of the creek to those out in the river. Values ranged from 34% fines in samples from station SD07 to 100% at SD28. Sediment from Upper Ferry Creek generally contained lower percentages of fine sediment in samples from stations north of, and including, SD12 (10.7% to 41%) than samples from the southern stations (28.7% to 100%). These northern stations tended also to have greater variability. Stations with the highest fines are apparently those in the actual wetland area, out of the main creek channel (e.g., SD04, SD16, SD13). At reference stations, fines ranged from 51% to 100%.

Total Organic Carbon—Results of sediment TOC analyses are presented in **Figure 6-2**. TOC content was moderately uniform in samples from the reference area and Lower Ferry Creek. Nearly all samples had TOC levels between approximately 2% and 5%. TOC in samples from the Housatonic Boat Club wetlands were also moderately uniform, but with notable exceptions. TOC in the HB06 sample was considerably lower than other locations in the wetland. More than half of the samples from the boat club wetlands exceeded 5% TOC, whereas none from the reference area was greater than 5%. Samples from Upper Ferry Creek exhibited the greatest variability. Half of the TOC values were over 5%, and some reached as high as 20%. Conversely, one sample (SD22) fell below 1%. The two highest values, at 20%,

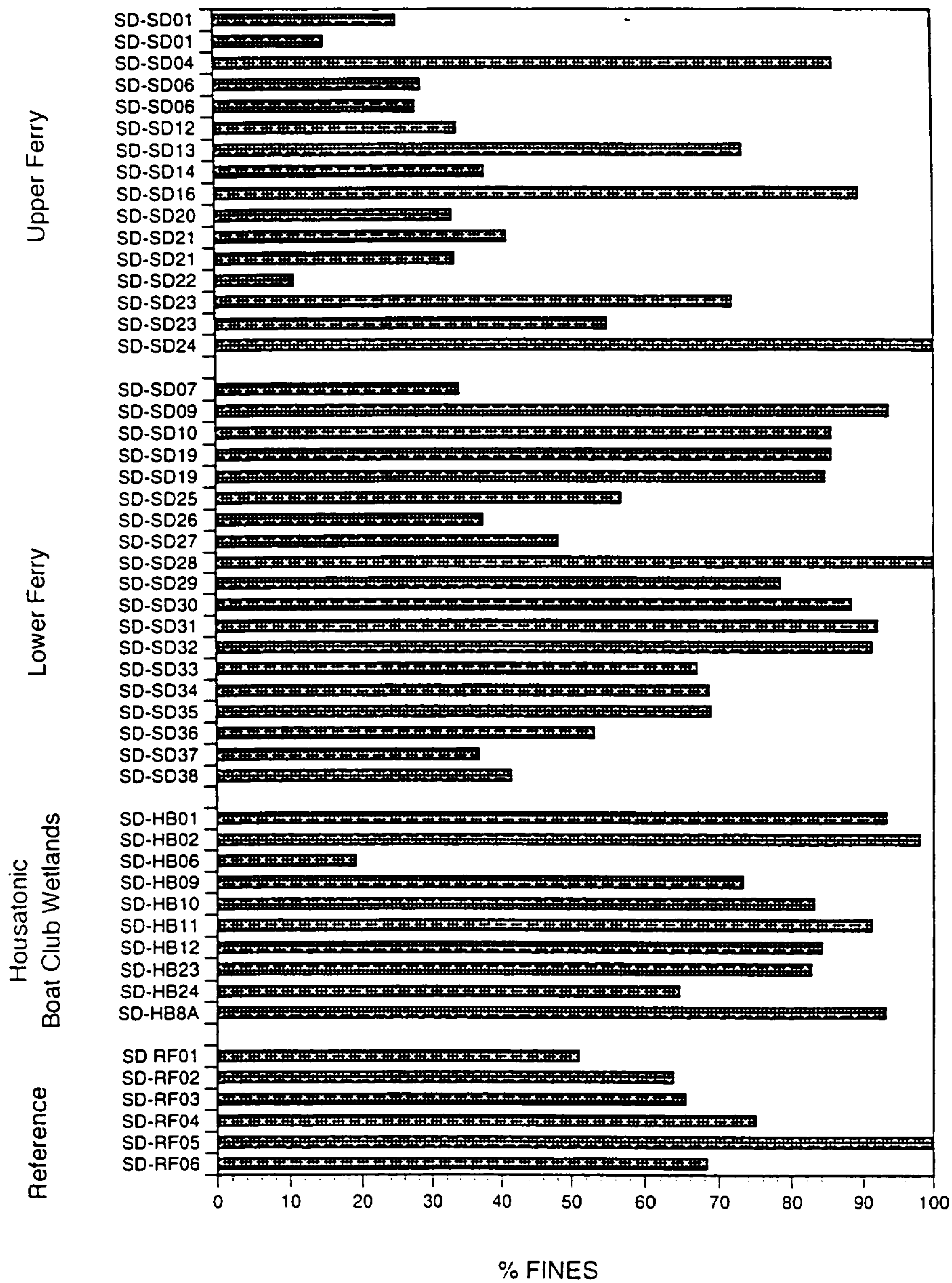

Figure 6-1. Grain size of sediments collected from the Raymark Industries site

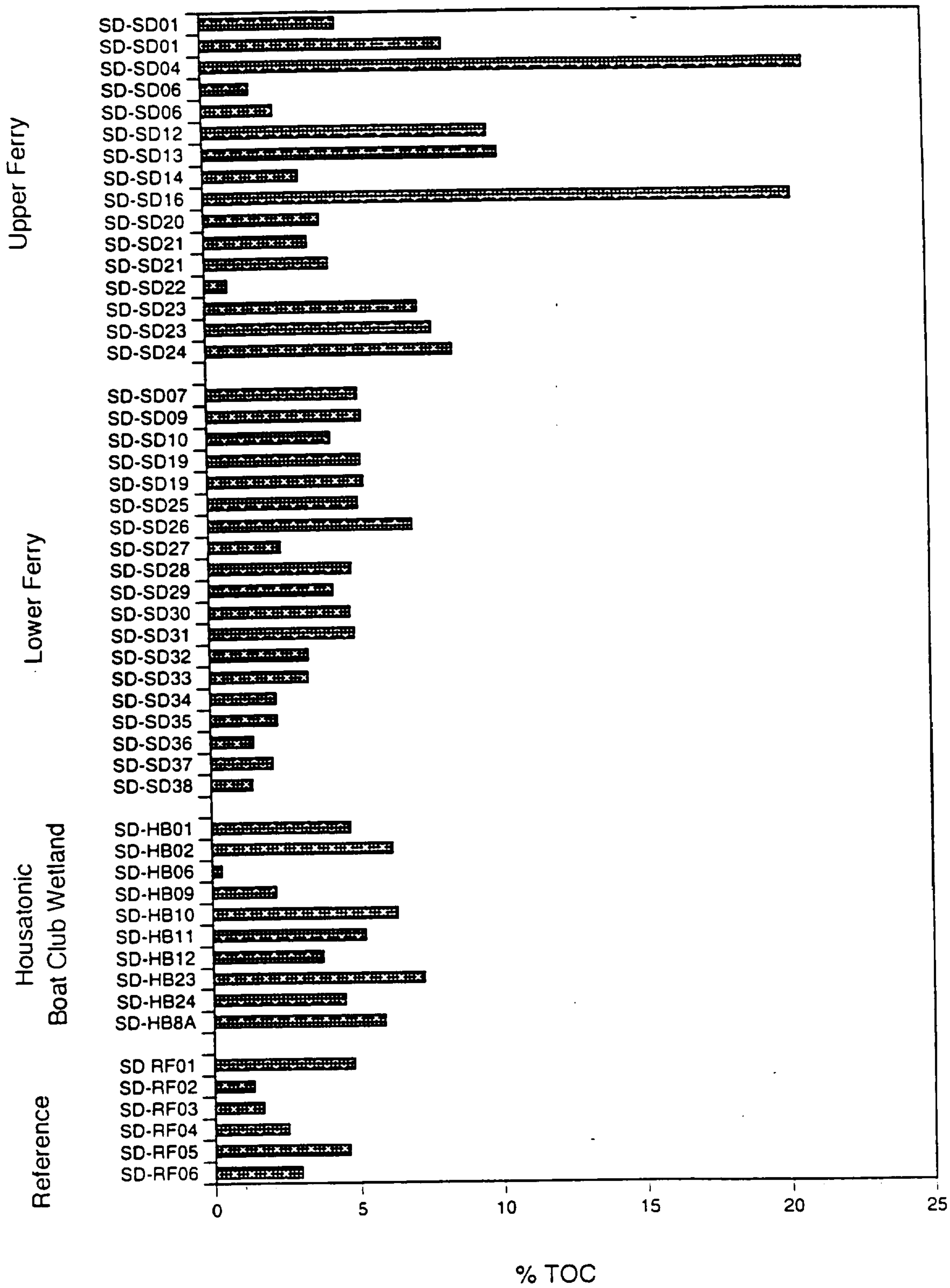

Figure 6-2. Total organic carbon in sediments collected from the Raymark Industries site

were from samples actually located in the vegetated portion of the wetland (SD04 and SD16) and likely represent a large amount of decayed plant debris.

AVS/SEM—As described in Section 3.3.2, comparing the amount of acid-volatile sulfides (AVS) and simultaneously extractable metals (SEM) in the sediment allows a theoretical determination of the potential bioavailability of certain metals. Five divalent metals are predicted not to be potentially bioavailable when the SEM/AVS ratio is less than 1, since there is sufficient sulfide available to bind the metals thus decreasing their bioavailability. These metals are (in increasing order of their binding affinity) nickel, zinc, cadmium, lead, and copper. (Some silver and mercury may also be associated with AVS, although the exact nature of sequestration is still being debated.) Some additional portion of these divalent metals (especially those that can form organometallic compounds) may also be sequestered by organic matter. Therefore, even when the binding capacity of the AVS has been exceeded, not all the metals measured may be readily bioavailable, suggesting that the SEM/AVS ratio is a conservative estimate of bioavailability. Thus the probability of acute lethality may be low when the SEM/AVS ratio is close to 1, and increases as the ratio exceeds 10. When the ratio is less than 1, however, theoretically there is sufficient AVS to bind all the divalent metals present and, therefore, they should not pose an acute lethality risk.

SEM/AVS ratios are shown in **Figure 6-3**. As with TOC, less variability was observed in samples from the reference station and Lower Ferry Creek. The sample from one reference station, RF04, had a ratio approaching 10, suggesting metals may be bioavailable in that sample. Otherwise, all of the samples from the reference area and from Lower Ferry Creek had ratios less than 2. However, in Upper Ferry Creek and the Housatonic Boat Club areas, much greater variability and higher ratios were observed. Most sediment samples had SEM/AVS ratios between 1 and 5, although there were three samples from each area with ratios in excess of 10. Two of these samples, from Upper Ferry Creek (SD04 and SD16), were the same samples that had extremely high TOC and fines content and were also located outside the stream channel in the vegetated area. Samples with high ratios could be expected to have some bioavailable, potentially toxic metals present.

In summary, evaluation of grain size, TOC, and SEM/AVS ratios indicate that there is considerable variability in the nature of the sediment, not only within an area but between areas as well. Generally, the sediment characteristics of Lower Ferry Creek and the reference areas appear to be more homogeneous and similar. The other two areas (Upper Ferry Creek and the boat club wetlands) may be characterized as having sediment much more heterogeneous in nature. Clearly, mesoscale conditions within an area dramatically influence the nature of sediment matrix and thus preclude broad generalizations regarding the bioavailability of contaminants within any given locale. This conclusion is corroborated by the lack of simple gradient patterns in CoC concentrations observed in previously-collected sediment data.

6.2.2 Sediment Contamination

This section discusses the concentrations of sediment CoCs collected only in the August 1995 field-sampling effort for this risk assessment. These concentrations are used later in the ERA to evaluate the measurement endpoints.

Table 6-2 compares targeted and actual measured detection limits. **Table 6-3** summarizes concentrations of inorganics detected in sediment samples from Upper Ferry Creek, Lower Ferry Creek, the Housatonic Boat Club, and the reference areas. **Figures 6-4 through 6-12** present the levels of trace elements observed in each sample. **Figures 6-13 through 6-18** show

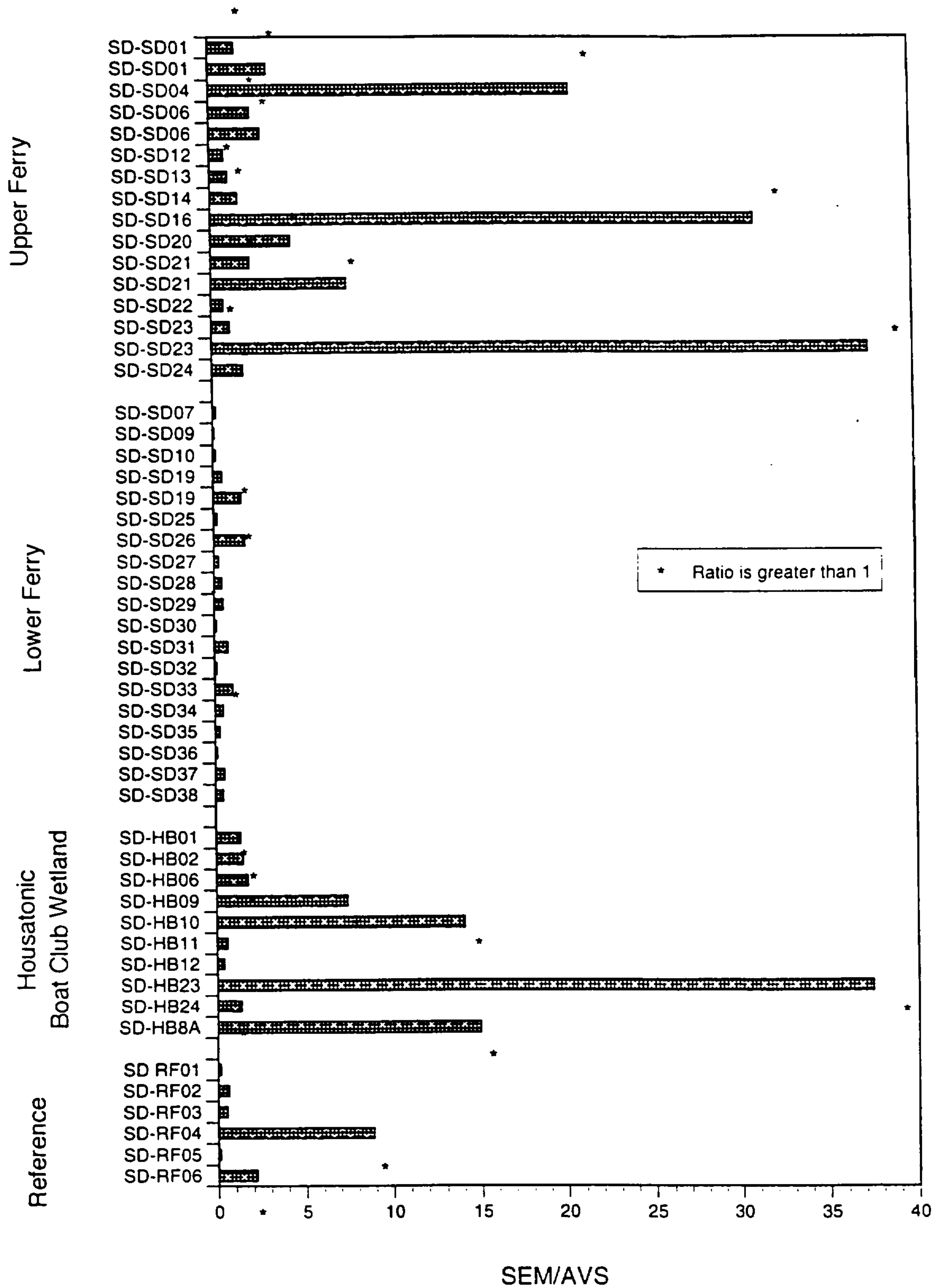

Figure 6-3. Simultaneously extracted metals, acid volatile sulfide ratio of sediments collected from the Raymark Industries site

Table 6-2. Comparison of target detection limits with measured detection limits in sediment.

Analytes	Targeted Detection Limits	Measured Detection Limits
Chemical Parameters		
Metals in mg/kg	2.0	2.0
Arsenic	1.0	04–2.9
Cadmium	2.0	nu
Chromium	5.0	nu
Copper	0.6	nu
Lead	0.1	0.11–0.12
Mercury	8.0	nu
Nickel	2.0	0.71–2.7
Silver	40	nu
Zinc		
LPAH in µg/kg	330	440–9,700
Naphthalene	330	440–9,700
2-Methylnaphthalene	330	440–9,700
Acenaphthylene	330	440–9,700
Acenaphthene	330	440–9,700
Fluorene	330	440–9,700
Phenanthrene	330	440–9,700
Anthracene		
HPAHs in mg/kg	330	440–700
Fluoranthene	330	440–700
Benzo(b)fluoranthene	330	440–700
Pyrene	330	440–9,700
Benzo(a)anthracene	330	440–700
Chrysene	330	440–9,700
Benzo(a)pyrene	330	440–9,700
Dibenz(a,h)anthracene		
PCDDs/PCDF in µg/kg		nu
Pesticides/PCBs in µg/kg	33/67	20–680
Total PCBs	3.3	3.1–17
Total DDT		10–51

nu = no undetected values measured.

Table 6-3. Concentrations of trace elements detected in sediment samples. (dry weight basis)

Trace Element (mg/kg dw)	Upper Ferry Creek (n=8)					Lower Ferry Creek [a] (n=17)					Housatonic Boat Club (n=10)					Reference Area (n=6)					Detection Limits [b]		Targeted Detection (n=17)
	Min.	Mean	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Mean	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Mean	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Mean	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Max.	
Arsenic	1.7	7.6	19.1	1.1	0.1	4	7.3	13.7	1	0.1	2.8	11.2	24	1.6	0.2	2.2	6.8	11.2	0.9	0.1	2	2	2.0
Cadmium	2.4	6.4	16.2	9.5	2.4	1.6	6.1	11.9	8.9	1.5	0.49	3.5	6.1	5.1	0.7	1.0	1.2	1.6	1.8	0.4	0.39	2.9	1.0
Chromium	24.4	140.8	501	2.7	1.5	27.2	176	641	3.4	1.8	30.1	365	1,060	7	3.8	39	200	304	3.8	2.2	na	na	2.0
Copper	220	1,800	7,000	100	4.8	30.7	593	2,360	31.7	1.5	75.1	1,364	5,340	72.9	3.5	102	652.5	1,260	34.9	1.7	na	na	5.0
Lead	139	1,700	6,150	56.3	4.0	11.1	333	1,470	11	0.8	22.3	450.4	2,950	14.9	1.0	65.3	97.7	141	3.2	0.3	na	na	0.6
Mercury	0.1	0.39	1	3	1.0	0.21	0.53	2.7	4.1	1.2	0.44	1	1.6	7.5	2.2	0.13	0.6	0.91	4.6	1.5	0.06	0.11	0.1
Nickel	25.3	97.7	272	6.1	0.9	19.5	51.3	132	3.2	0.5	15.5	46	83.1	2.9	0.4	14.7	29	38.1	1.9	0.3	na	na	8.0
Silver	nd		nd			1.1	2.2	3.8	3	3.2	nd		nd			nd		nd			0.71	6.8	2.0
Zinc	154	600	1,420	48	1.5	79.1	431.2	1,110	3.5	1.1	79.7	417.6	1,120	3.4	1.0	158	306.5	551	2.5	0.7	na	na	40

a — Includes river stations SD32-38
na — detection limits not applicable; substance was detected in all samples
nd — not detected

results from sampling of sediment for dioxins and furans (reported as a TCDD toxicity equivalent quotients, or TEQs), PCBs, DDTs, plus total PAHs. **Table 6-4** also presents summaries of these organic compounds detected in samples from each of the four sampling areas.

For risk screening comparisons, the Threshold Effect Levels (TELs) (MacDonald et al. 1996) were used. These guidelines represent the lower thresholds below which adverse biological impacts are not expected to be observed. Thus, the TELs are a conservative measure of the potential impact of bulk sediment contamination on the benthic community. Mean Hazard Quotients (HQs) were calculated as the ratio of observed sediment contamination to the TEL benchmark value (HQ_{TEL}s), and are also presented for each area in Tables 6-2 and 6-3. HQ_{TEL}s for a given CoC below 1 suggest little likelihood that adverse biological responses would result from exposure for that CoC.

All inorganic CoCs were detected in at least one sediment sample at a concentration above their respective screening concentrations. Copper and lead concentrations were the most elevated with respect to TELs (Table 6-2). Mean HQ_{TEL}s for these elements (calculated from only the above detection samples) were generally above 10, and reached 100 for copper in Upper Ferry Creek samples. These elevated concentrations for both element are apparently co-located with each other, with the maximum concentrations found in samples from Upper Ferry Creek stations (SD21, SD24, SD13, and SD01) and the Housatonic Boat Club wetland stations (HB01 and HB23). Cadmium, chromium, and zinc were also elevated in comparison with TELs, but to a much lower degree. Mean HQ_{TEL}s for these elements were usually less than 5, but never exceeded 10. Maxima in zinc levels were apparently co-located with those for copper and lead, but at less elevated concentrations. Mean zinc HQ_{TEL}s never exceeded 5.

Chemical analyses indicate that sediment samples collected from Upper Ferry Creek also contained the highest concentrations of organics (Table 6-3). Samples from stations in Upper Ferry Creek (especially, SD01, SD13, SD21, SD23, and SD24) had consistently high levels of TCDD TEQs and/or PCBs[†]. The mean HQ_{TEL} in Upper Ferry Creek samples for total PCBs was 117.3 and 53.4 for TEQs. The sample from SD24 had the highest total PCB concentration observed. One sample in the Housatonic Boat Club, from station HB23, had elevated sediment concentrations of TCDD TEQs and total PCBs (HQ_{TEL}s of 150 and 180, respectively). These samples are the same ones that generally contained the highest concentrations of metals as well. Three samples from Lower Ferry Creek (from stations SD26, SD28, and SD33) contained elevated total PCB levels, comparable with those seen in samples from the upper creek area (HQ_{TEL}s of 85, 164, and 123, respectively). The samples taken from stations SD26 and SD33 also had the highest TCDD TEQ level observed in Lower Ferry Creek (HQs of 20 and 30, respectively). The trend of very heterogeneous deposition of organic contaminants within each area is quite evident from these data and reinforces the constraints on inferences made from these data.

Generally, the highest concentrations of total PAHs (Figure 6-17) in site-related samples were from Upper Ferry Creek (mean HQ_{TEL} of 20), followed by those from Lower Ferry Creek (mean HQ_{TEL} of 11), and from the Milford Point reference area (mean HQ_{TEL} of 8.6). However, the highest PAH sediment concentration was found in a sample from the Beaver Brook reference station (RF01; HQ_{TEL} of 43), just downstream of a light industrial area. Roadway runoff probably contributes substantial PAH contamination to sediment at this location.

† Aroclor 1262 and Aroclor 1268 were the only PCBs reported above detection limits from the laboratory. The summation of these two Aroclors is used to represent total PCBs throughout this assessment, except where noted.

Table 6-4. Concentrations of organic compounds detected in sediment samples (dry weight basis).

	Upper Ferry Creek					Lower Ferry Creek					Housatonic Boat Club					Reference Area					Detection Limits[a]	
	Min.	Mean (no.)[b]	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Mean (no.)[b]	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Mean (no.)[b]	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Mean (no.)[b]	Max.	Mean HQ_{TEL}	Mean HQ_{AET}	Min.	Max.
Total PAHs (μg/kg)	10,310	34,343	64,800	20.4	3.8	4,110	19,592	50,290	11	2.1	1,710	8,879	21,000	4.2	0.8	1,500	14,467	72,700	8.6	1.6	440	9,700
Total PCBs (μg/kg)	69	4,000 (0)	18,200	117.3	30.8	65	1124 (3)	5,600	32.9	7.5	18	882 (2)	6,100	25.9	5.4	7	28 (1)	99	0.8	0.2	33	350
DDD (μg/kg)	5.4	31 (9)	80	17.1	n/a	1.5	7.47 (4)	32	2.3	n/a	0.34	8.92 (2)	20	2.52	n/a	0.46	3.78 (1)	9.0	1.07	n/a	3.2	17
DDE (μg/kg)	0.33	8.9 (7)	37	6	n/a	0.18	2.97 (3)	7.9	2.1	n/a	1.1	3.21 (2)	6.6	2.26	n/a	0.09	0.72 (2)	1.8	0.51	n/a	2	17
DDT (μg/kg)	0.41	5.68 (12)	16	n/a	n/a	0.31	3.9 (11)	14	n/a	n/a	0.12	4.2 (2)	16	n/a	n/a	0.13	1.1 (1)	4.4	n/a	n/a	2	17
TEQs[c] (ng/kg)	9.03	267	1,099.7	53.4	10.7	0.48	27.2	149	5.4	1.1	0.17	90.2	745.03	18	3.6	0.39	6.6	16.33	1.3	0.3	n/a	n/a

n/a - not applicable; screening guideline not available

[a] — Detection limits for total PAHs and total PCBs are for individual compounds or congeners.
[b] — Number in parantheses is the number of samples with levels below the detection limit.
[c] — TCDD TEQs were calculated using dioxin and furan data; a benchmark of 5 μg/kg was used for HQ_{TEL} and 25 for HQ_{AET}

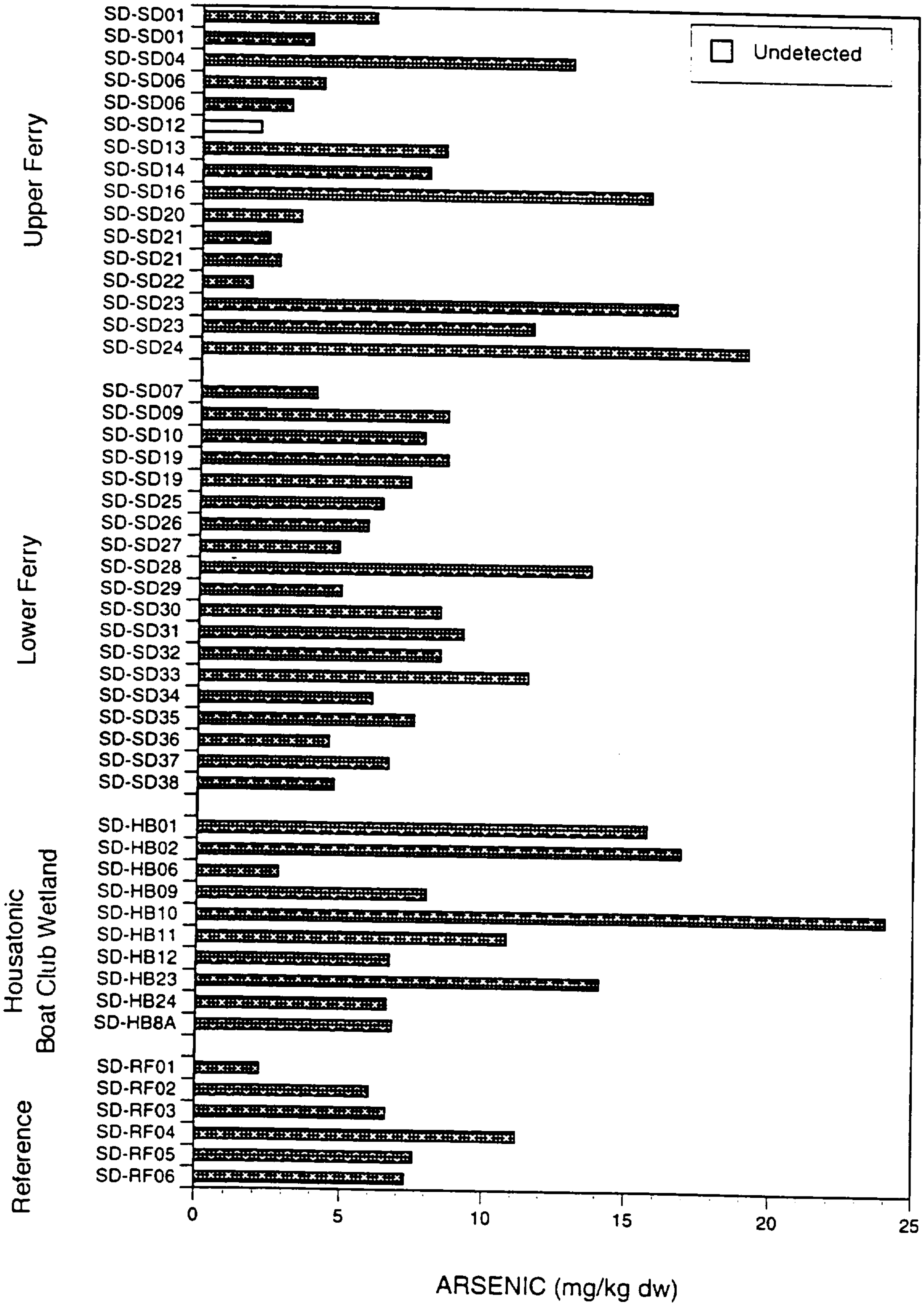

Figure 6-4. Arsenic concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

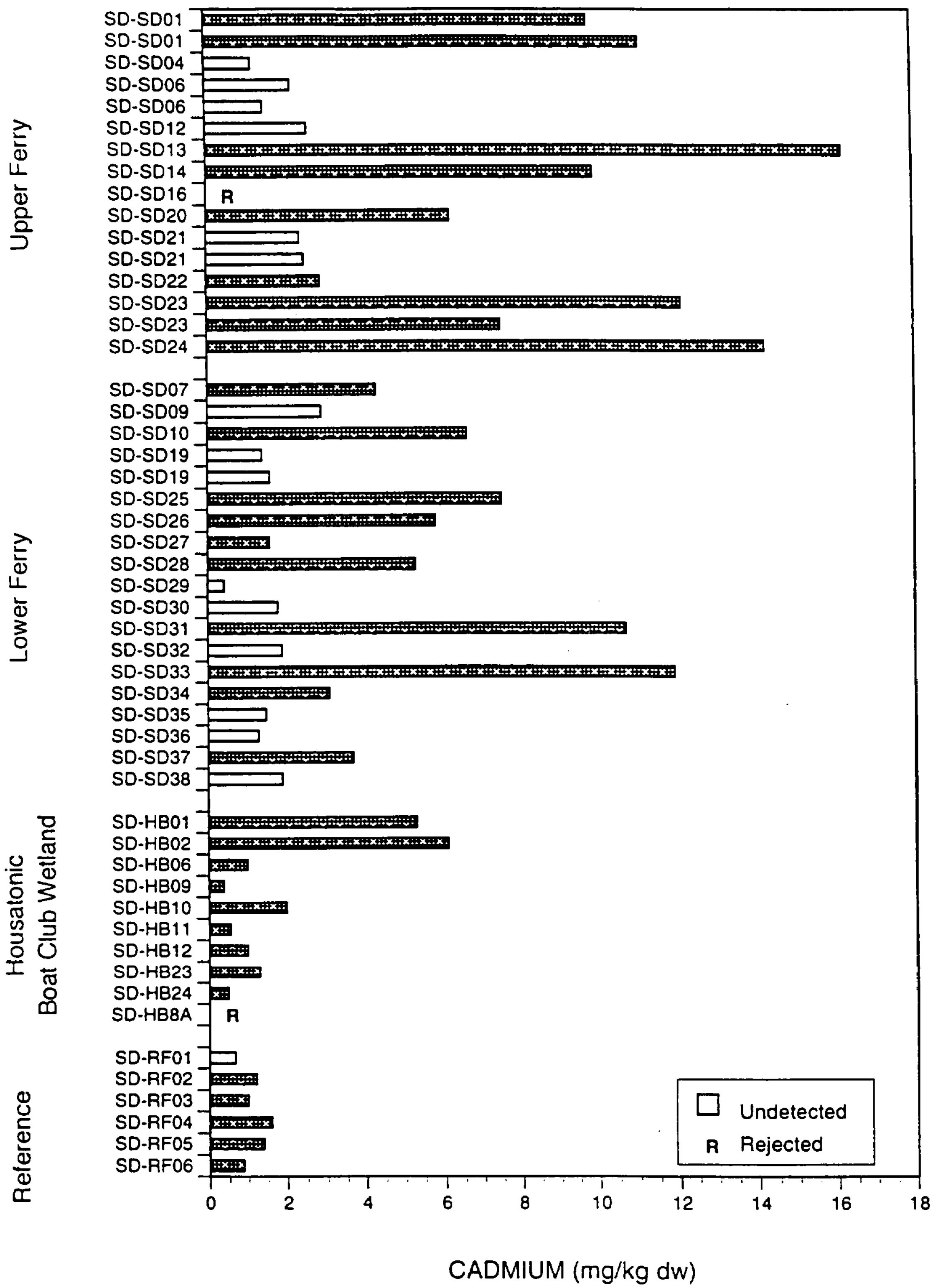

Figure 6-5. Cadmium concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

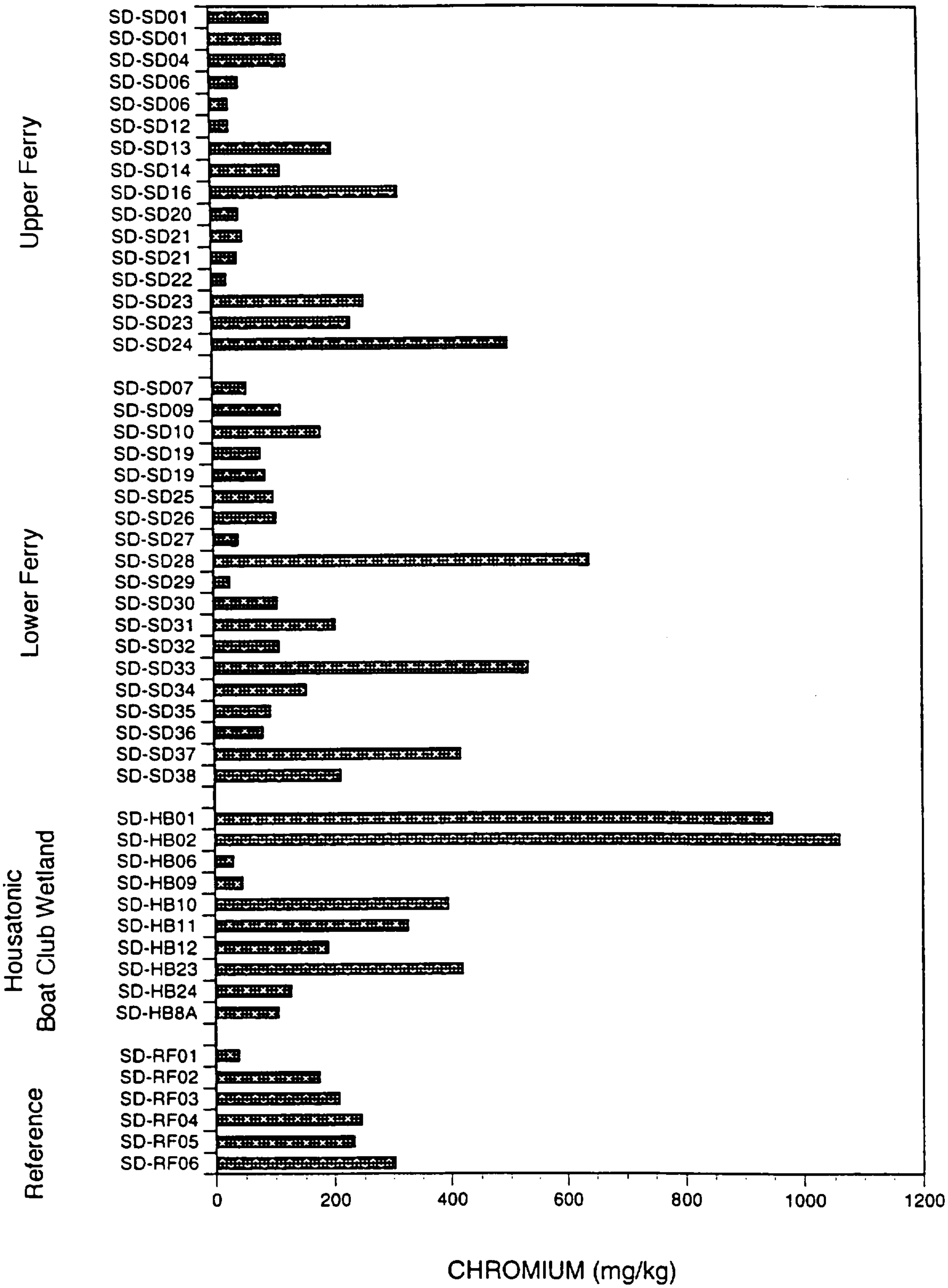

Figure 6-6. Chromium concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

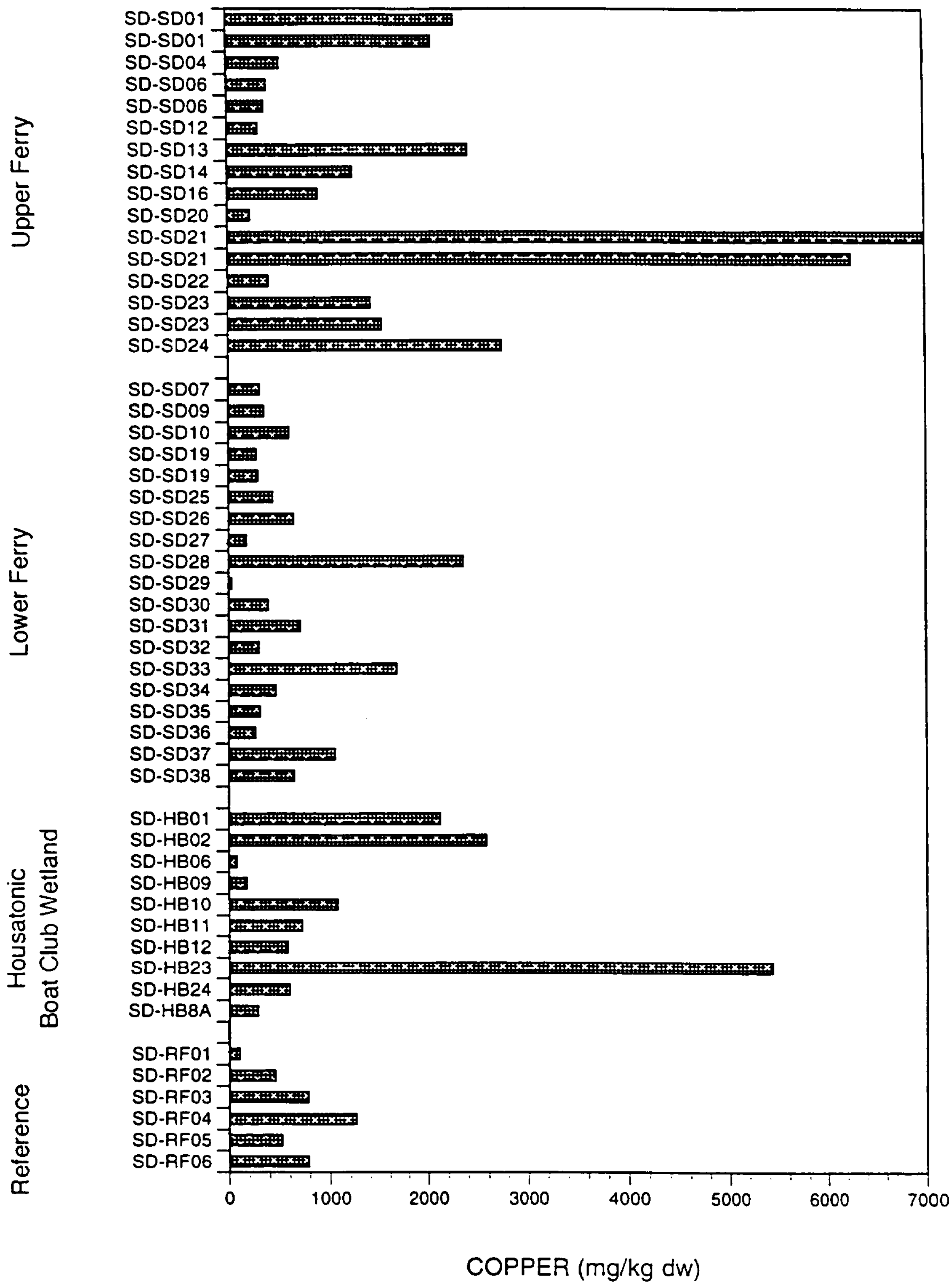

Figure 6-7. Copper concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

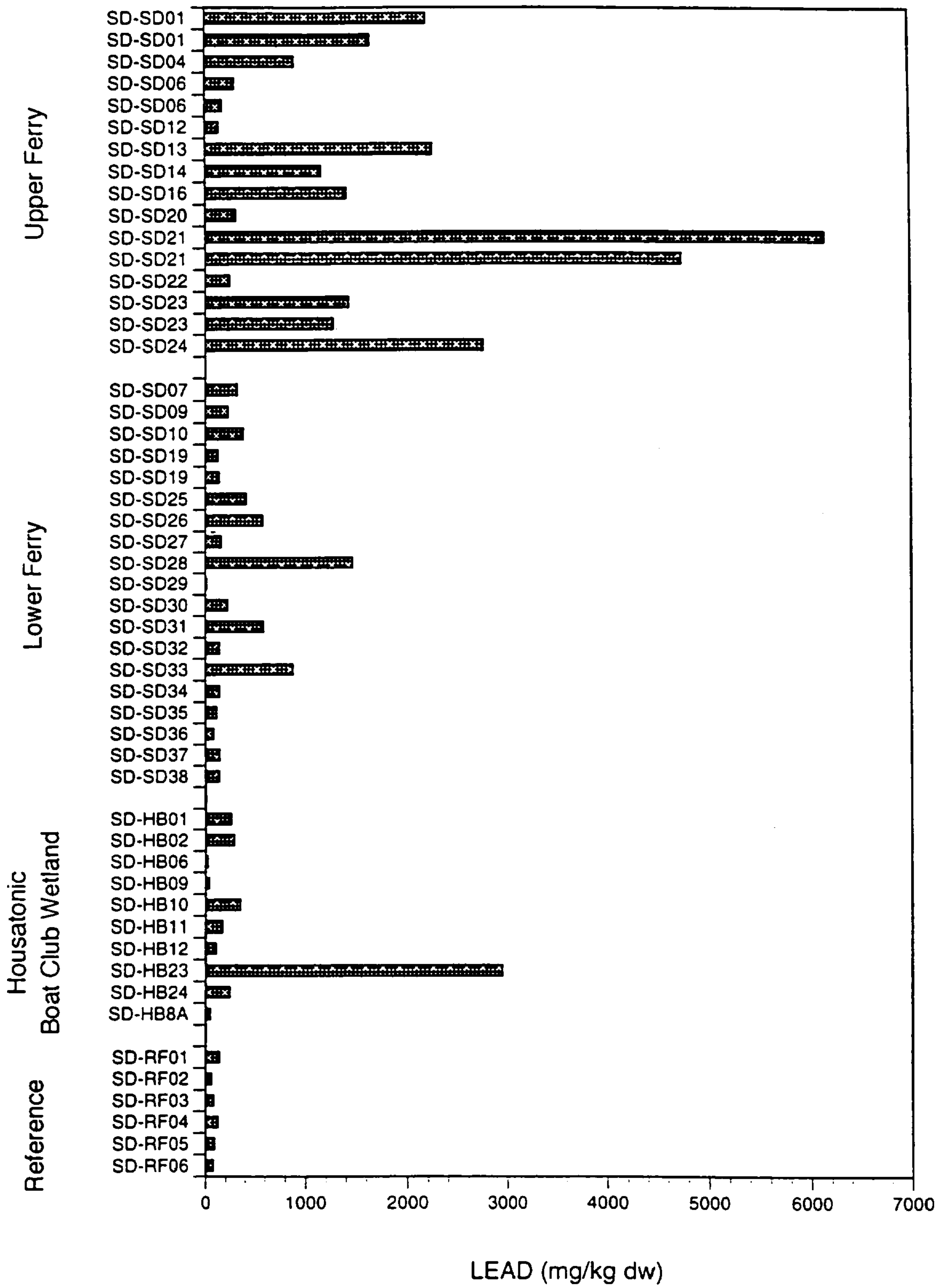

Figure 6-8. Lead concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

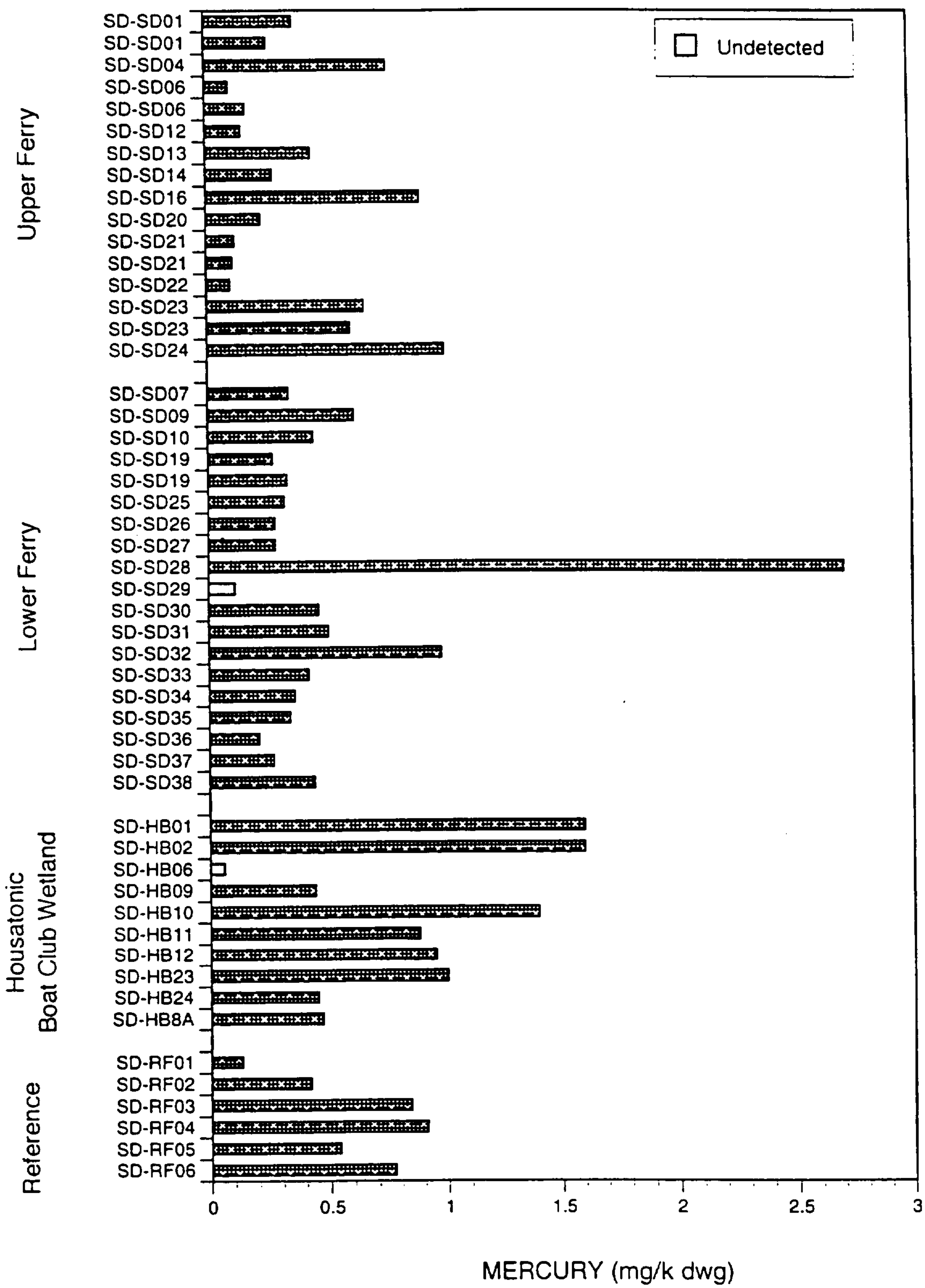

Figure 6-9. Mercury concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

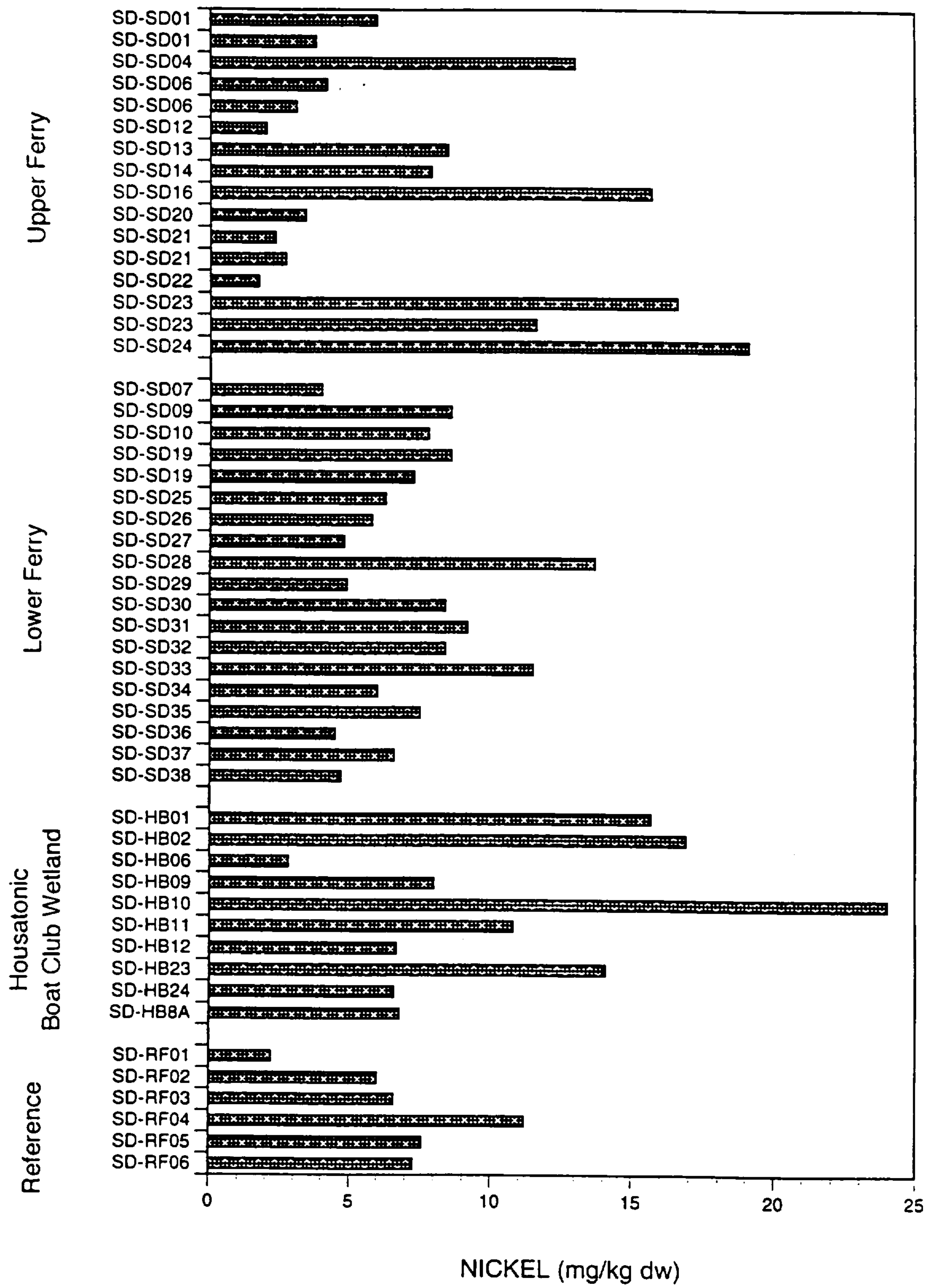

Figure 6-10. Nickel concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

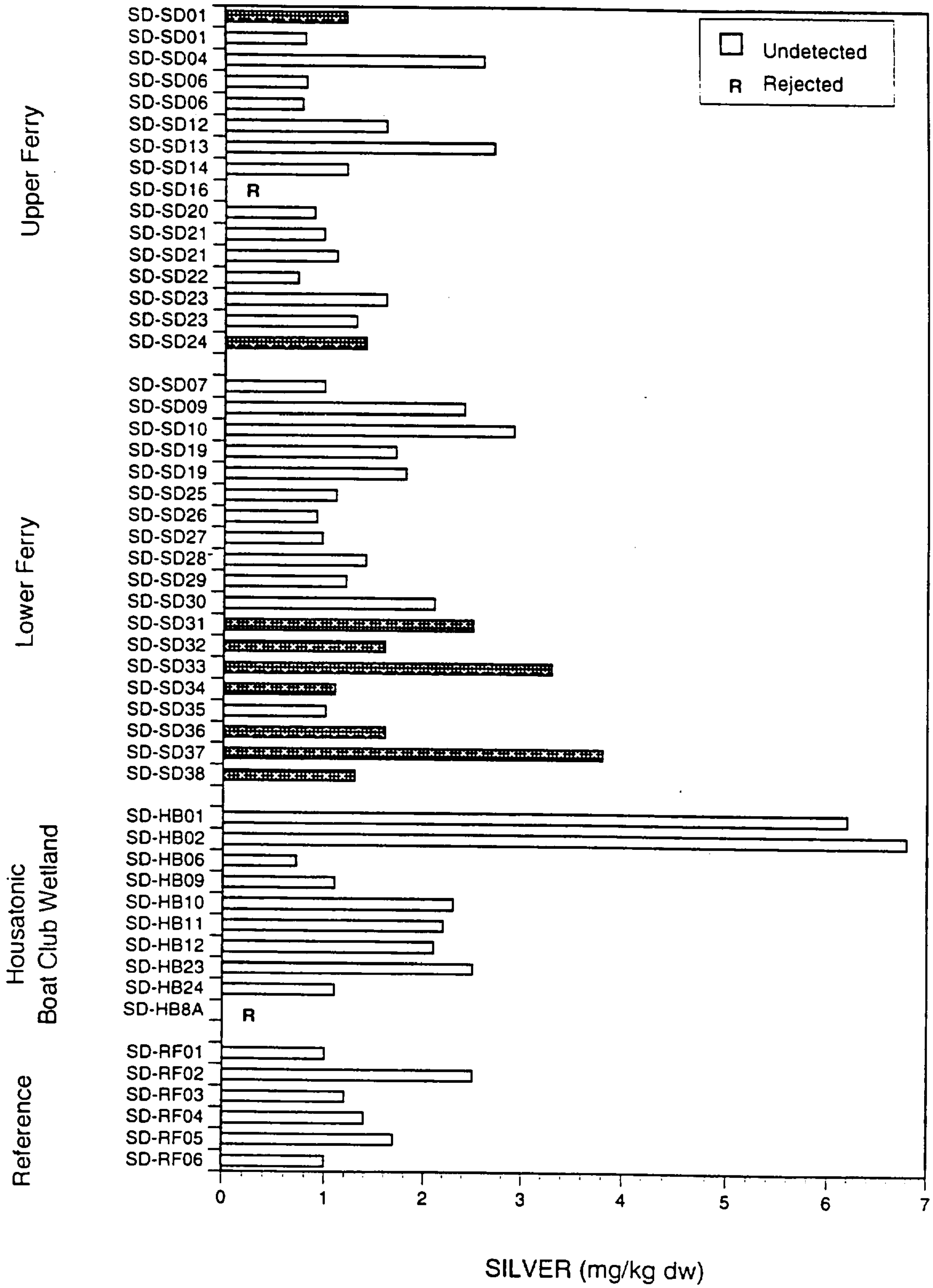

Figure 6-11. Silver concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

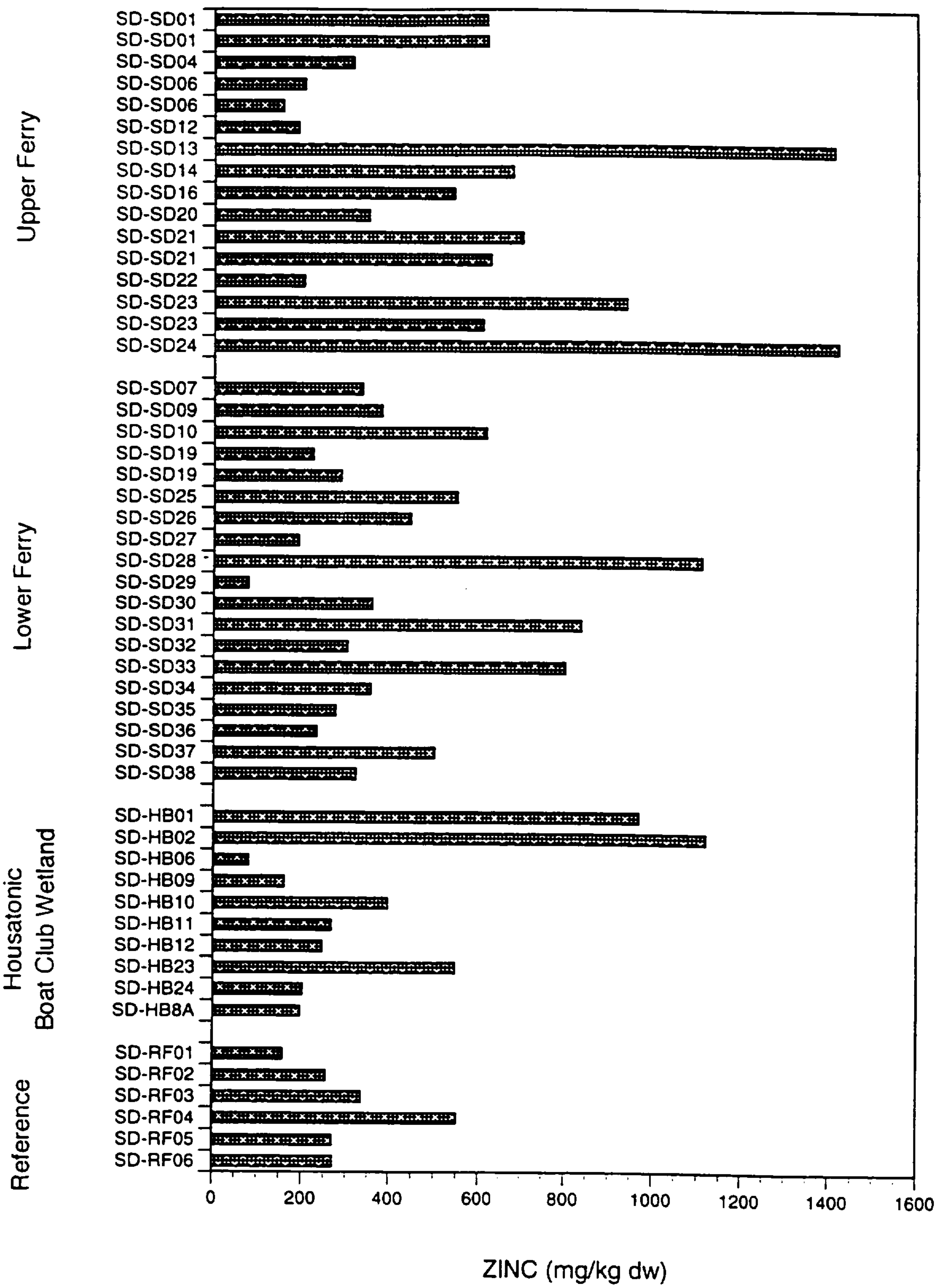

Figure 6-12. Zinc concentrations in sediment collected from the Raymark Industries site and Milford Pond and Beaver Brook Reference zones.

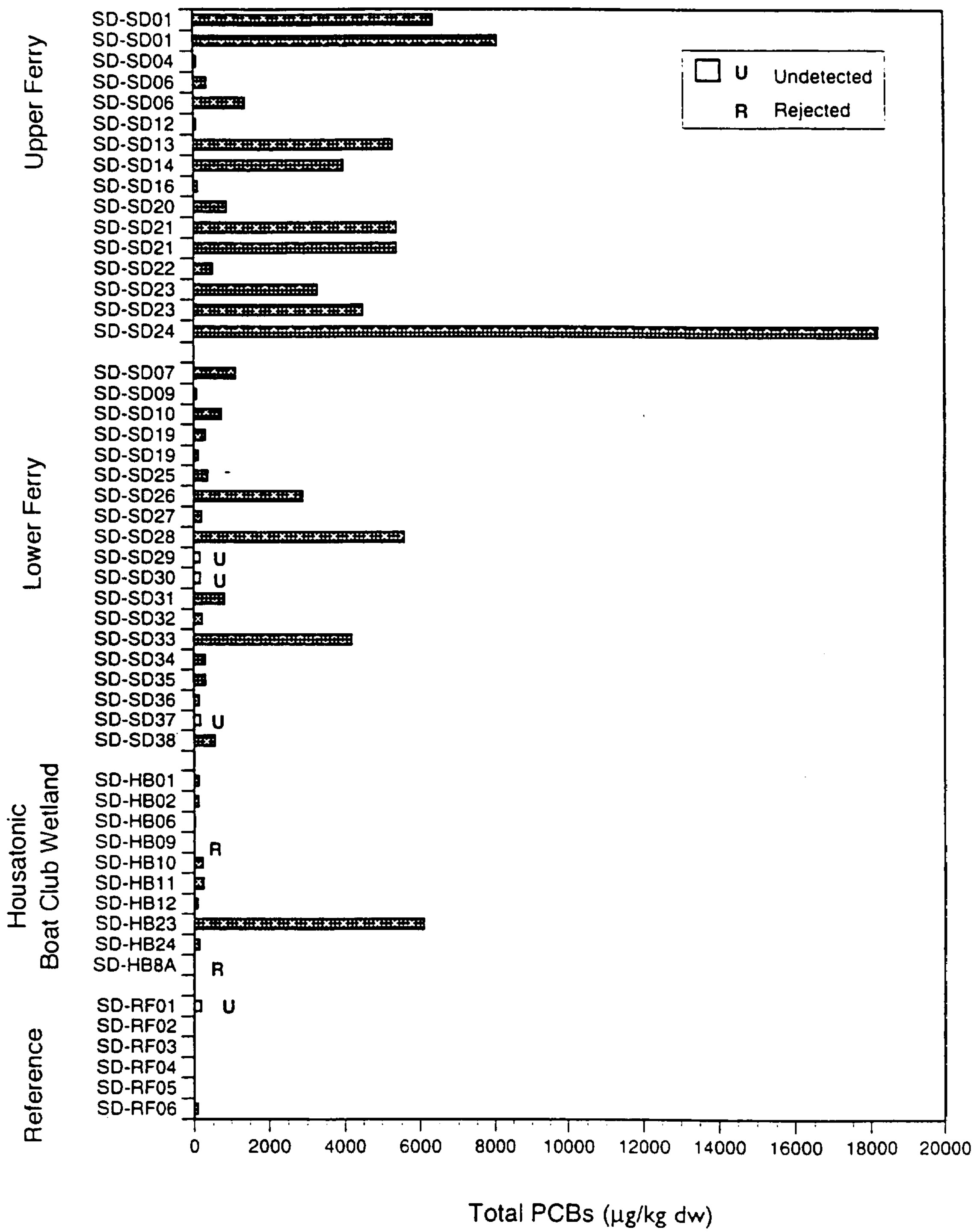

Figure 6-13. Total PCB concentrations in sediment collected from the Raymark Industries site and Milford Point and Beaver Brook Reference zones.

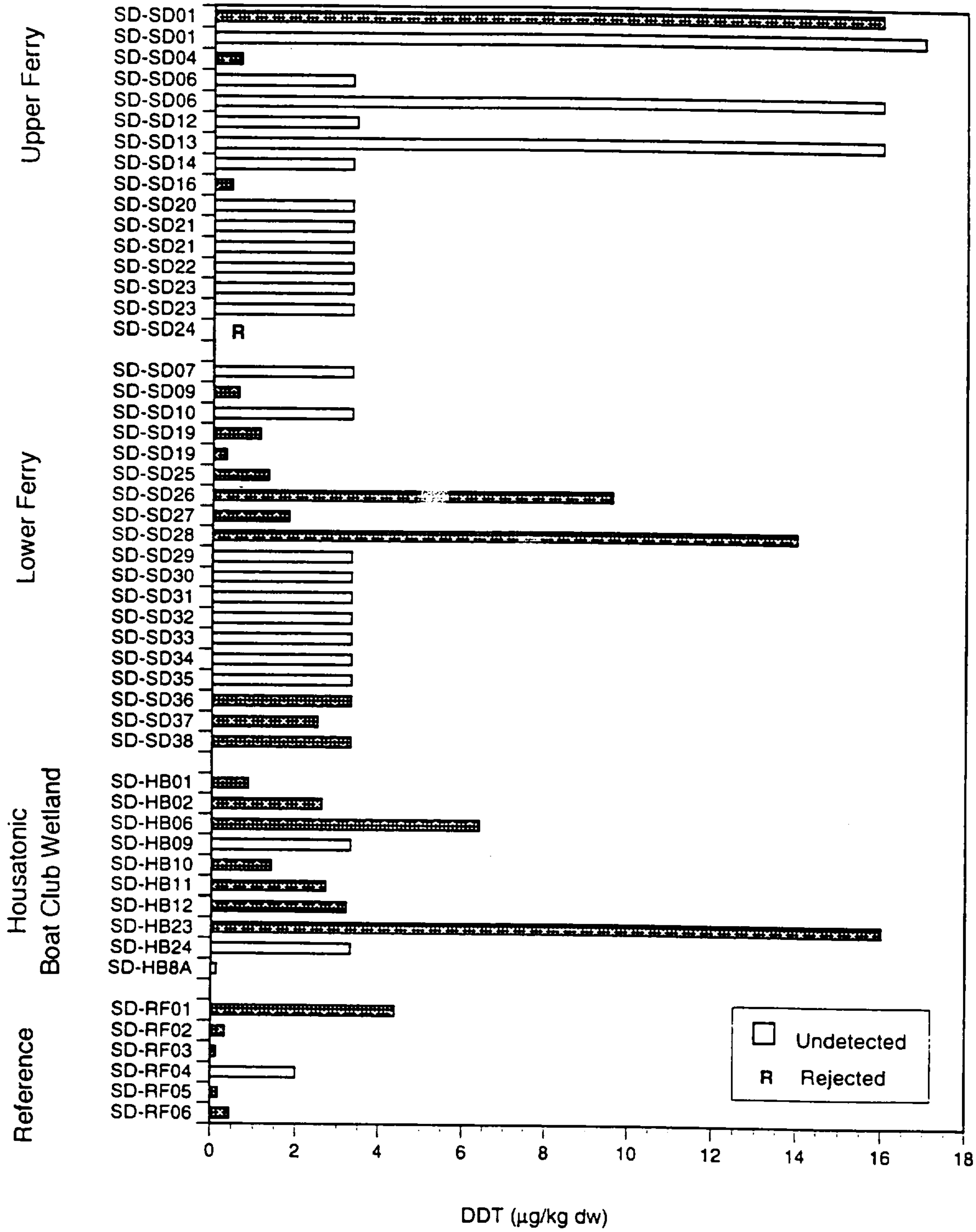

Figure 6-14. DDT concentrations in sediment collected from the Raymark Industries site and Milford Point and Beaver Brook Reference zones.

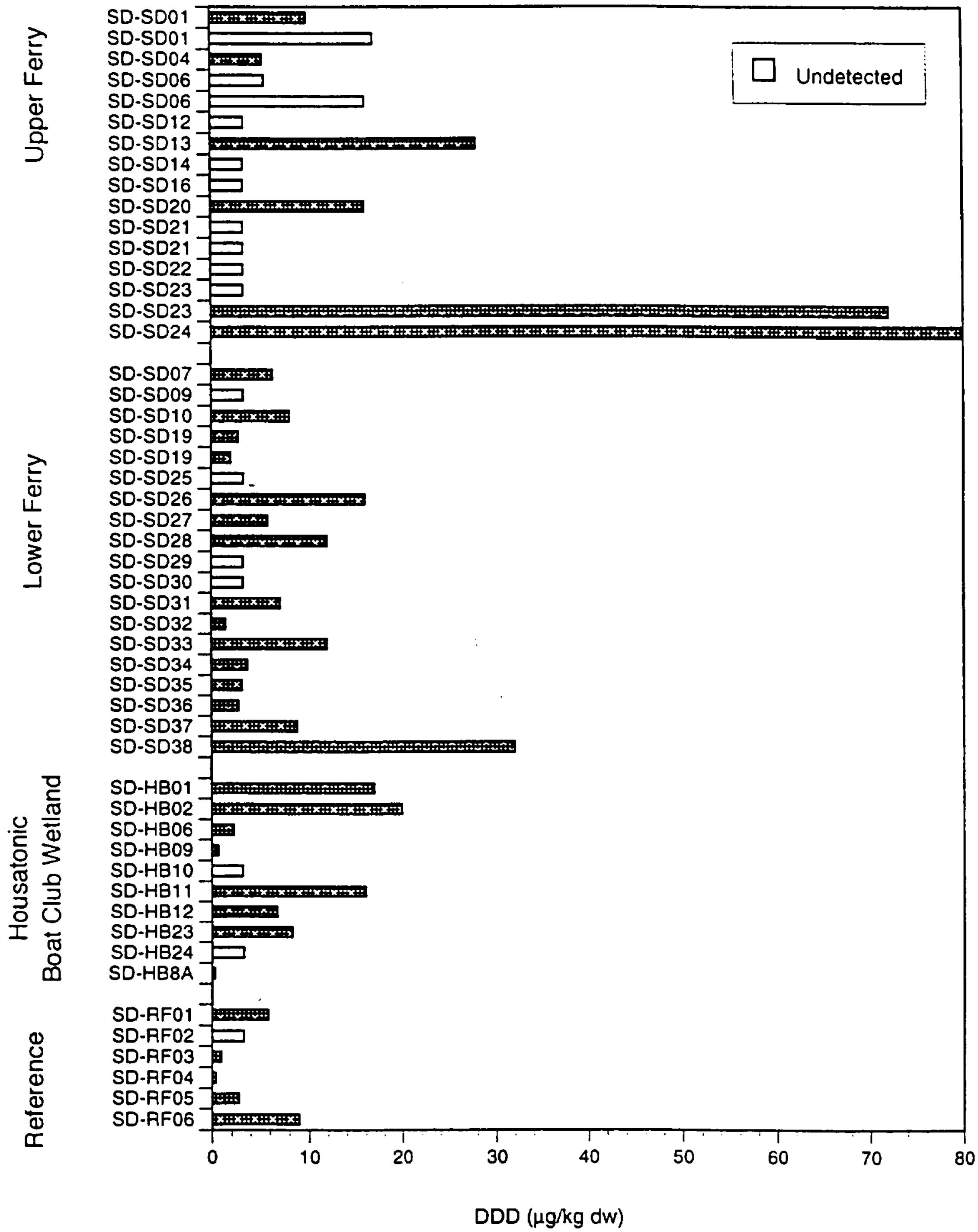

Figure 6-15. DDD concentrations in sediment collected from the Raymark Industries site and Milford Point and Beaver Brook Reference zones.

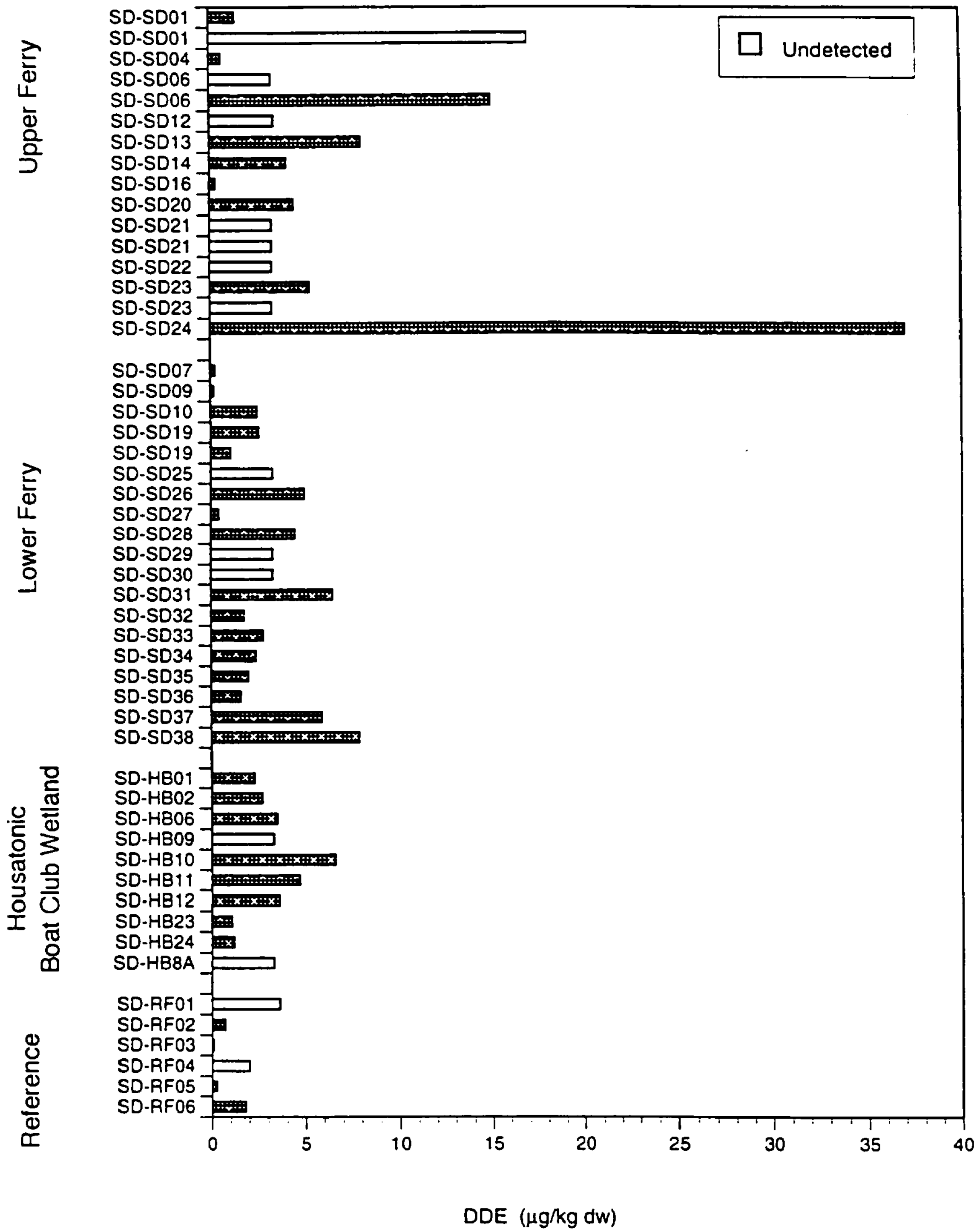

Figure 6-16. DDE concentrations in sediment collected from the Raymark Industries site and Milford Point and Beaver Brook Reference zones.

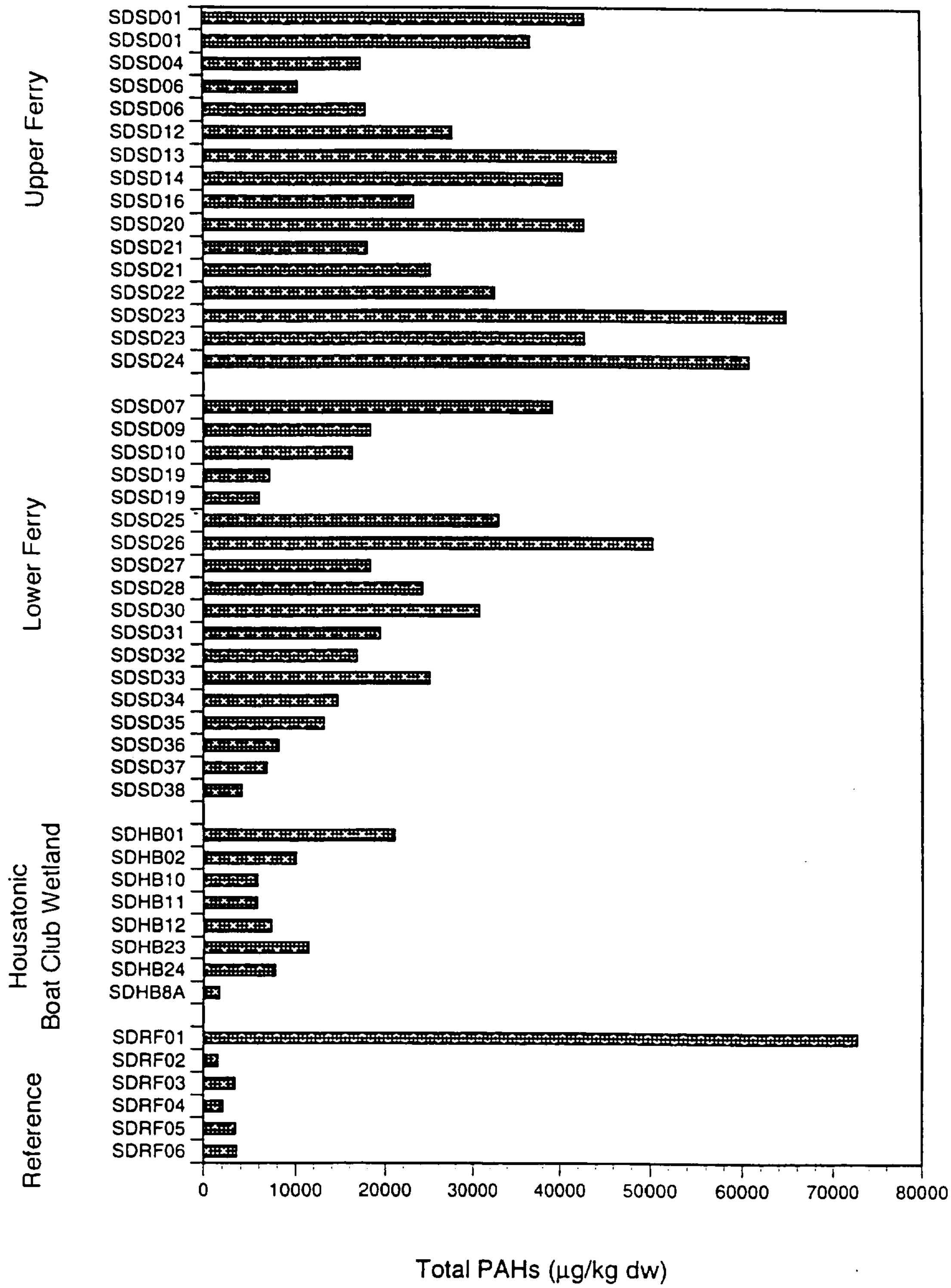

Figure 6-17. Total PAH concentrations in sediment collected from the Raymark Industries site and Milford Point and Beaver Brook Reference zones.

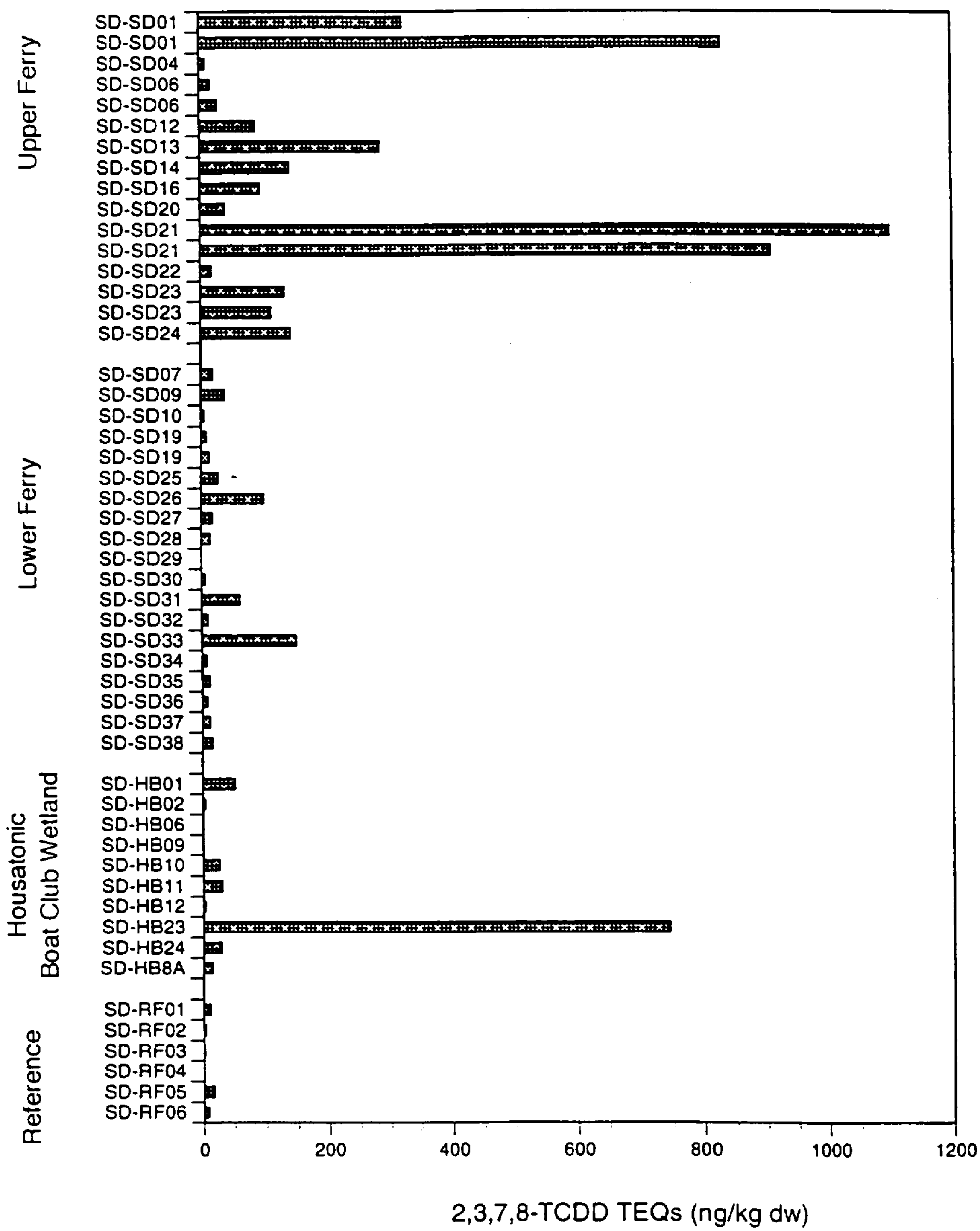

Figure 6-18. Dioxin concentrations in sediment collected from the Raymark Industries site and Milford Point and Beaver Brook Reference zones.

6.3 FOOD-WEB EXPOSURE CHARACTERIZATION

The biota tissue sampling—fish, crab, and insect tissue—represents three potential food-web transfer routes for site-related contamination. Because these tissue samples are a component of other measurement endpoints in this risk assessment, the following sections present only results of the chemical analysis of these tissues. Their use as dietary inputs to the avian food-web model was discussed previously.

6.3.1 Fish Tissue Body Burdens

The life history of the mummichog and the habitat features in the study area indicate that many reaches offer ideal habitat for the mummichog. Their presence in nearshore shallow waters and benthic feeding habits indicate likely exposure to site-related contamination. These fish could be exposed by consuming benthic organisms that have accumulated contaminants from the sediments, direct exposure to contaminated sediment and surface water, and incidental ingestion of contaminated sediments and water. Exposure could occur year-round to all life stages since the species is not known to migrate and tolerates a wide variety of salinity and temperatures. Because their home range is limited and they do not migrate, samples of mummichog should represent localized conditions.

Results from fish tissue chemical analysis are presented in **Figures 6-19 through 6-22.** Targeted and measured detection limits are compared in **Table 6-5**; observed tissue concentration ranges are summarized in **Table 6-6**. Nine metals were detected in fish tissue samples from all locations. Variability in body burdens within an area (e.g., Upper Ferry Creek) was high, possibly reflecting the extremely heterogeneous pattern of contaminant distribution. For instance, there was an order-of-magnitude range in lead levels among the four composite samples from Upper Ferry Creek. Statistical tests of mean body burdens for Upper and Lower Ferry Creek samples versus the reference area fish (Kruskal-Wallis) indicate that mean tissue levels of cadmium, copper, lead, and zinc were significantly elevated in Upper Ferry Creek fish, while silver body burdens were significantly depressed. For cadmium, copper, and lead, tissue body burdens were significantly higher in Upper Ferry Creek fish than Lower Ferry Creek fish. Lower Ferry creek fish contained significantly higher mean levels of arsenic than reference fish. Upper Ferry Creek fish also had the highest mean levels of detected PAHs and dioxin TEQs; mean body burdens were significantly greater than either the reference fish or Lower Ferry Creek fish on either a wet-weight or lipid-weight basis. Because of problems with detection limits, tissue concentrations of PCBs were not evaluated in any detail.

6.3.2 Crab Tissue Body Burdens

Results from crab-tissue chemical analysis are presented in **Figures 6-23 through 6-24.** Table 6-5 compares targeted and measured detection limits; **Table 6-7** summarizes actual measured tissue concentrations. Eight metals were detected in crab tissues from all locations. Copper and lead levels were the most elevated, particularly in the boat club wetland sample. Copper was twice the level measured in the reference sample collected from Milford Point, while lead was 14 times higher. Copper and lead were also higher than the reference concentrations in the Upper Ferry Creek sample, but not as elevated as the boat club sample. The only other substantial difference observed in body burdens of metals was that Cd levels in the sample from Upper Ferry Creek were two orders of magnitude greater than those in the reference sample. Aroclor 1260 was also detected in crab tissue. The sample from the boat club wetland contained the highest level of PCBs, greater than 20 times the concentrations detected at the reference area. Ferry Creek samples had concentrations of PCBs two to four times greater than the reference sample. A variety of high-molecular-weight PAHs were detected in crab samples from all stations. The highest levels occurred in the Upper Ferry Creek sample, followed by the Lower Ferry Creek sample. Dioxins and furans were also observed in all samples. The highest TCDD TEQ was in the boat club sample. Although this sample had a TCDD TEQ greater than the reference sample, most of the difference can be attributed to higher furan concentrations. The TCDD TEQ for the Upper Ferry Creek sample was about twice the reference values.

Because of the limited number of samples, statistical tests of crab body-burden data are extremely limited. Mean tissue body burdens of the three site-related samples (Upper & Lower Ferry Creek plus the boat club wetlands) were tested against the value obtained in the reference samples by Students *t*-test. Wet weight values were tested for trace elements while both wet-weight and lipid-normalized values were tested for the organics. The only detectable difference using this approach was in body burdens of chromium, mercury, and lead.

6.3.3 Insect Tissue Body Burdens

Results from insect-tissue chemical analysis are presented in **Figure 6-25**. Seven metals were detected in the insect composite samples. Targeted detection limits and measured detection limits are compared in Table 6-5. The actual tissue concentrations detected appear in **Table 6-8**. Levels of metals appear generally comparable between the two samples, except that lead was three times greater in the reference sample than in the sample collected at Ferry Creek. No chlorinated compounds were detected, and only two PAHs (phenanthrene and indeno-pyrene) were detected in each sample. The TCDD TEQ was about 60% greater in the Ferry Creek sample than the reference sample. This difference was largely due to dioxins: the dioxin contribution to the total TCDD TEQ in the Ferry Creek sample was twice that in the reference sample, while the TEQ contribution from the furans was similar in both samples.

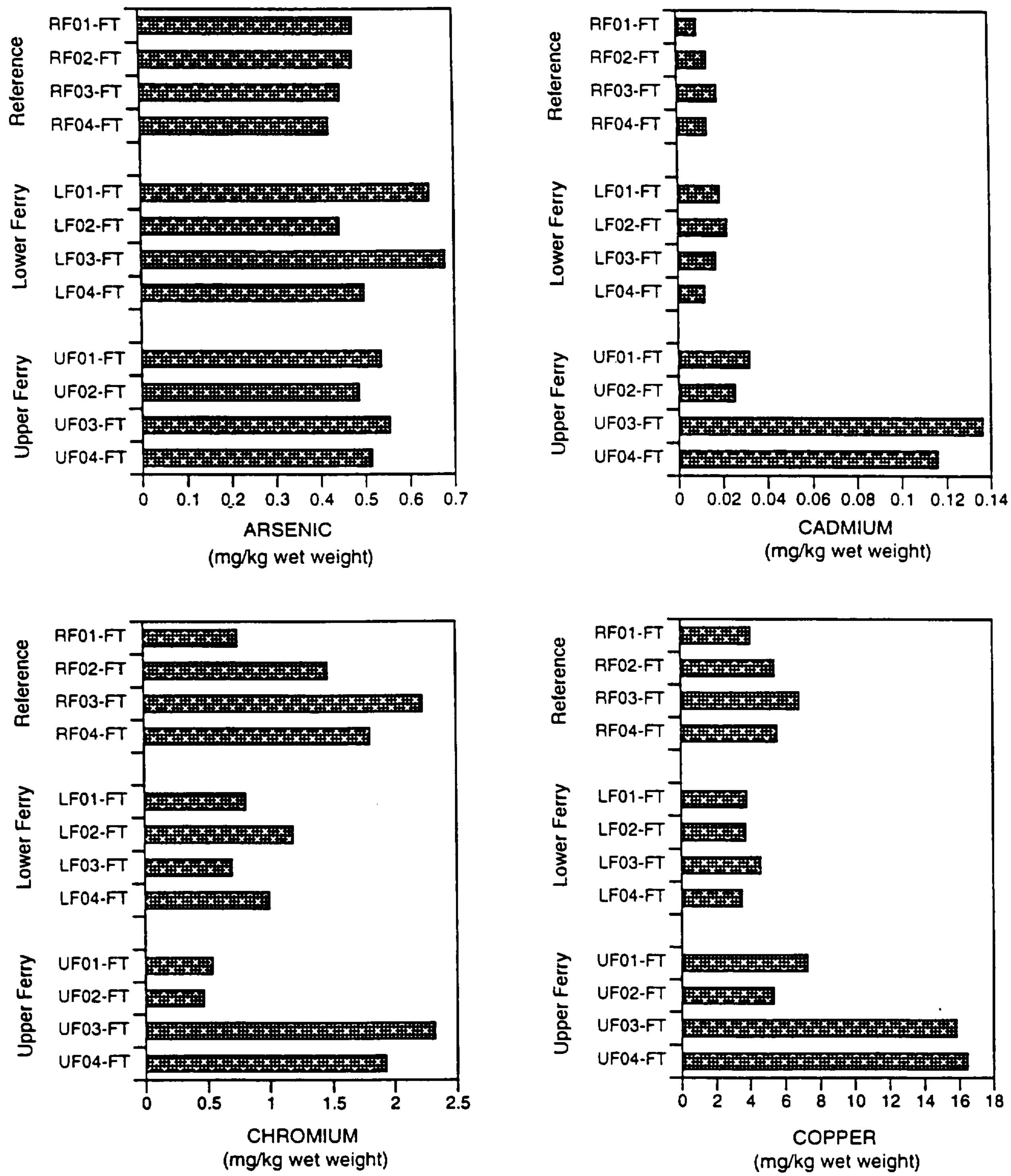

Figure 6-19. Arsenic, cadmium, chromium, and copper tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

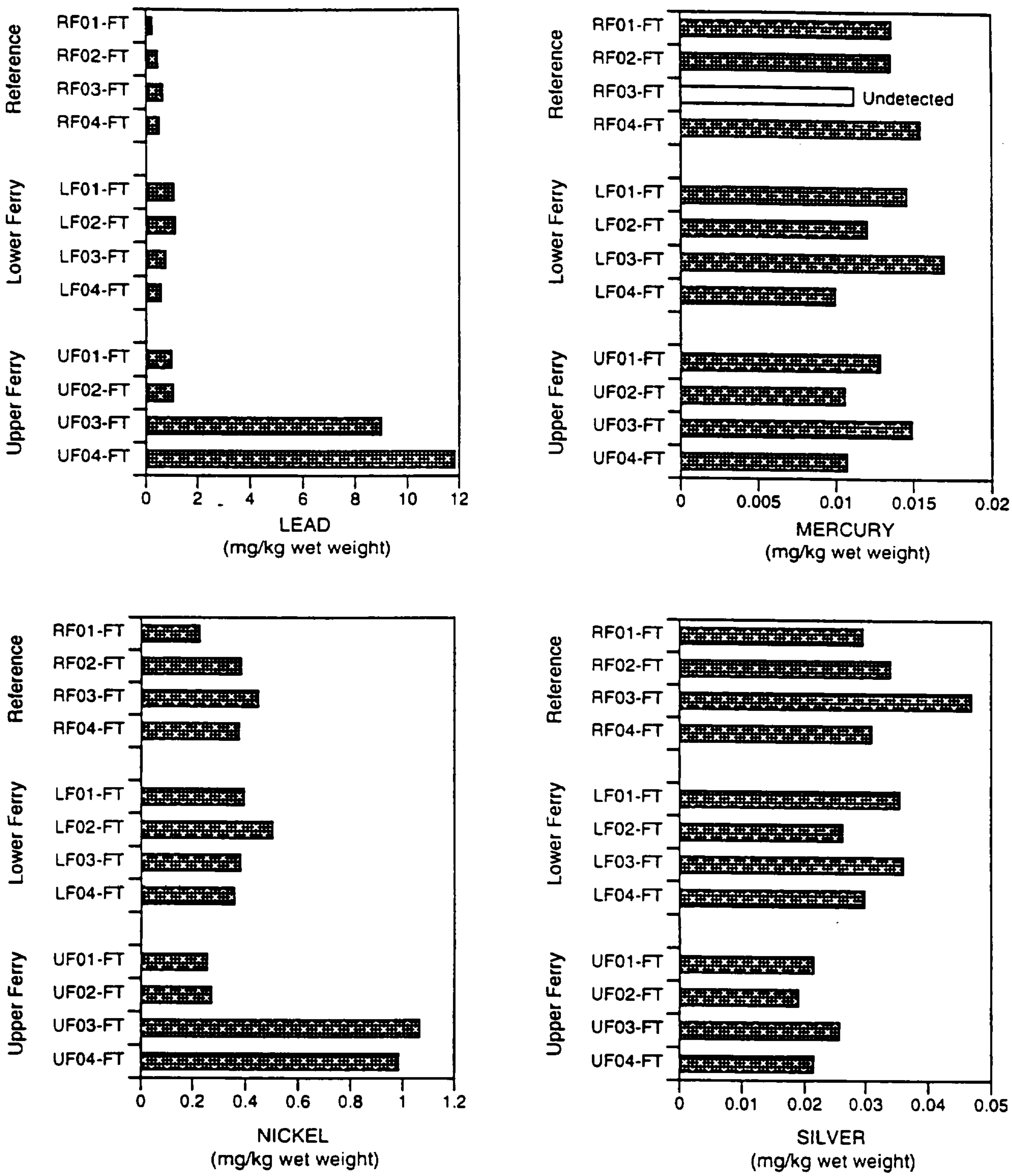

Figure 6-20. Lead, mercury, nickel, and silver tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

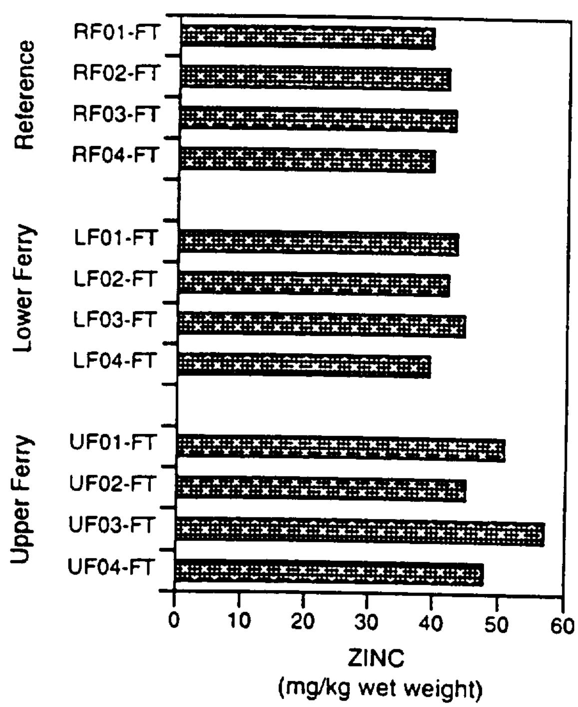

Figure 6-21. Zinc tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

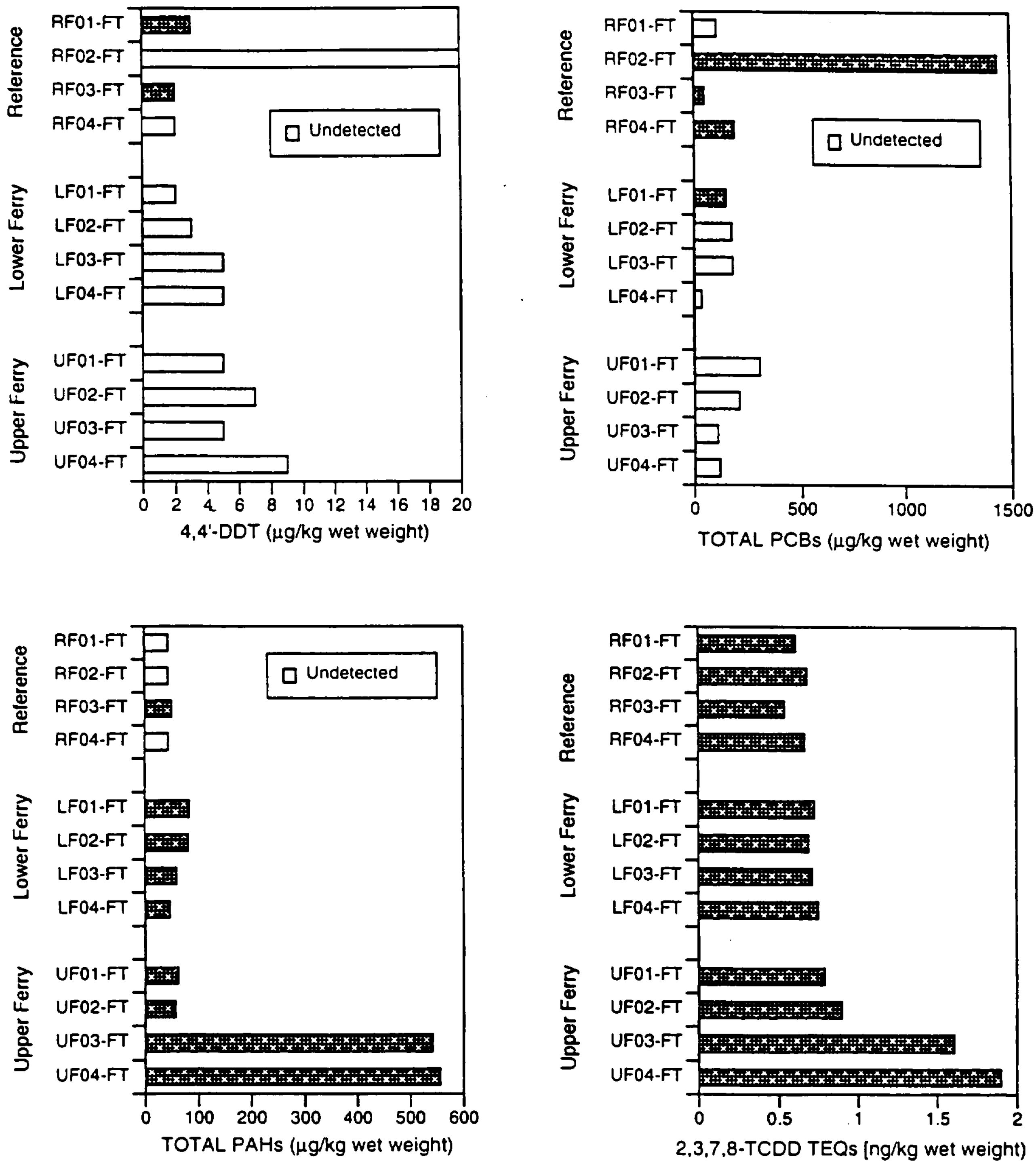

Figure 6-22. DDT, PCB, PAH and TCDD TEQ tissue concentrations in mummichog collected from Ferry Creek and Milford Point reference zones.

Table 6-5. Comparison of targeted detection limits with measured detection limits in fish, crab, and insect tissues.

ANALYTES	DETECTION LIMITS FOR FISH TISSUE		DETECTION LIMITS FOR CRAB TISSUE		DETECTION LIMITS FOR INSECT TISSUE	
	TARGETED	MEASURED	TARGETED	MEASURED	TARGETED	MEASURED
HEMICAL PARAMETERS						
etals in μg/kg						
Arsenic	0.5	nu	0.5	nu	0.5	0.24
Cadmium	0.02	nu	0.02	nu	0.5	0.24
Chromium	0.2	nu	0.2	nu	0.2	nu
Copper	0.05	nu	0.05	nu	0.05	nu
Lead	1.1	nu	55	nu	3.5	nu
Mercury	3	nu	592	0.02	37	0.02
Nickel	0.2	nu	0.2	nu	0.5	nu
Silver	0.02	nu	0.02	nu	0.02	nu
Zinc	0.5	nu	0.5	nu	0.5	nu
PAHs in μg/kg						
Naphthalene	na	5.0	10093	5.0	634	20
2-Methylnaphthalene	na	5.0	259	nr	16	nr
Acenaphthylene	na	5.0	259	5.0	16	20
Acenaphthene	na	5.0	7593	5.0	477	20
Fluorene	na	5.0	259	5.0	26	20
Phenanthrene	na	5.0	1296	5.0	81	nu
Anthracene	na	5.0	6111	5.0	3837	20
PAHs in μg/kg						
Fluoranthene	na	5.0	741	5.0	47	20
Benzo(b)fluoranthene	a	5.0	a	nu	a	100
Pyrene	na	5.0	37	5.0	2.3	20
Benz(a)anthracene	na	5.0	37	5.0	2.3	100
Chrysene	na	5.0	183	2.0	12	100
Benzo(a)pyrene	na	5.0	2222	nu	140	100
Dibenz(a,h)anthracene	na	5.0	37	5.0	2.3	100
DDs/PCDF in μg/kg	0.05	nu	0.01		0.01	
sticides/PCBs in μg/kg						
Total PCBs	140	10 - 600	631	10	39	40-80
Total DDT	160	2 - 20	20	2.20	1.3	8

. = not applicable
ι = no undetected values measured
= not recorded
= not listed in QAPP Table 4-2.

Table 6-6. Concentrations of trace metals, PCBs, DDTs, and PAHs in fish tissues (wet weight)

Analyte	Milford Point		Lower Ferry Creek		Upper Ferry Creek	
	Min	Max	Min	Max	Min	Max
Trace Elements(mg/kg)						
Arsenic	0.42	0.48	0.44	0.68	0.49	0.55
Cadmium	0.009	0.018	0.012	0.02	0.023	0.14
Chromium	0.75	2.23	0.70	1.19	0.46	2.32
Copper	4.09	6.82	3.54	4.62	5.34	16.45
Lead	0.24	0.64	0.57	1.13	0.98	11.83
Mercury	0.011	0.015	0.01	0.017	0.01	0.015
Nickel	0.23	0.446	0.36	0.50	0.26	1.07
Silver	0.03	0.047	0.026	0.036	0.019	0.026
Zinc	39.27	42.8	39.2	44.5	44.98	56.57
DDTs and PCBs (µg/kg)						
4,4'-DDD	5 UJ	5	5 UJ	4	2 U	5 UJ
4,4'-DDE	5 UJ	10	5 UJ	6	5 UJ	6
4,4'-DDT	2 UJ	3	2 U	5 UJ	5 U	9 J
Aroclor 1016	10 U	20U	10 U	10 U	10 U	40 UJ
Aroclor 1221	10 U	20 U	10 U	10 U	10 U	180 UJ
Aroclor 1232	10 U	20 U	10 U	40 UJ	10 U	80 UJ
Aroclor 1242	10 U	20 U	10 U	40 UJ	10 U	40 UJ
Aroclor 1248	10 U	60 U	10 U	120 UJ	20 U	100 UJ
Aroclor 1254	10 U	80 U	10 U	80 UJ	50 U	120 UJ
Aroclor 1260	20	430	10 U	50	80 U	200 UJ
PCDDs and PCDFs (ng/kg)						
Total TCDD	.07 U	.1 U	0.1 U	0.3 U	.1 U	.2 U
Total PeCDD	.1 U	.16 NJ4	0.1 U	0.2 U	.1 U	.52 NJ4
Total HxCDD	.2 U	.98 NJ4	0.2 U	0.73 NJ4	.3 U	2.9
Total HpCDD	1.1 NJ4	3.4	3.2 NJ4	4.6	1.8	20.4
Total TCDF	1.4 NJ4	3 NJ3	0.2 U	0.54	.41 NJ4	4.7 NJ4
Total PeCDF	1.9	4.1 NJ4	0.88	1.4	1.3	6.9 NJ4
Total HxCDF	.68 NJ4	1.6 NJ4	0.39 J4	1.5 NJ4	.74 NJ4	9.3
Total HpCDF	1	3.2	1.1	2.2	.57 NJ4	8.4
2,3,7,8-TCDD TEQs	**0.533**	**0.673**	**0.683**	**0.743**	**0.786**	**1.9**
PAHs (µg/kg)						
2-Methylnaphthalene	5 U	5 U	5 U	5 U	5 U	5 U
Acenaphthene	5 U	5 U	5 U	5 U	5 U	5 U
Acenaphthylene	5 U	5 U	5 U	5 U	5 U	5 U
Anthracene	5 U	5 U	5 U	5 U	5 U	8
Benzo(a)anthracene	5 U	5 U	5 U	5 U	5 U	28
Benzo(a)pyrene	5 U	5	5 U	7	5 U	46
Benzo(b)fluoranthene	5 U	7	5 U	7	5 U	114
Benzo(g,h,i)perylene	5 U	5 U	5 U	5 U	5 U	34
Benzo(k)fluoranthene	5 U	5 U	5 U	10	5 U	5 U
Chrysene	5 U	5 U	5 U	8	5 U	62
Dibenz(a,h)anthracene	5 U	5 U	5 U	5 U	5 U	7
Fluoranthene	5 U	5 U	5 U	12	7	86
Fluorene	5 U	5 U	5 U	5 U	5 U	6
Indeno(1,2,3-cd)pyrene	5 U	5	5 U	5 U	5 U	41
Naphthalene	5 U	5 U	5 U	5 U	5 U	6
Phenanthrene	5 U	5 U	5 U	7	6	55
Pyrene	5 U	5 U	6	11	7	62
Total PAHs		12	6	60	21	546
%Lipids	1.75 U	1.96	1.35 U	1.69	1.46	1.71
%Solids	22.1	22.7	19.9	21.2	21.1	21.4

U — Undetected at the concentration not greater than the value shown.
J4 — Estimate due to interferences associated with standard.
NJ4 — Estimated maximum Possible Concentration; result is considered tentative.

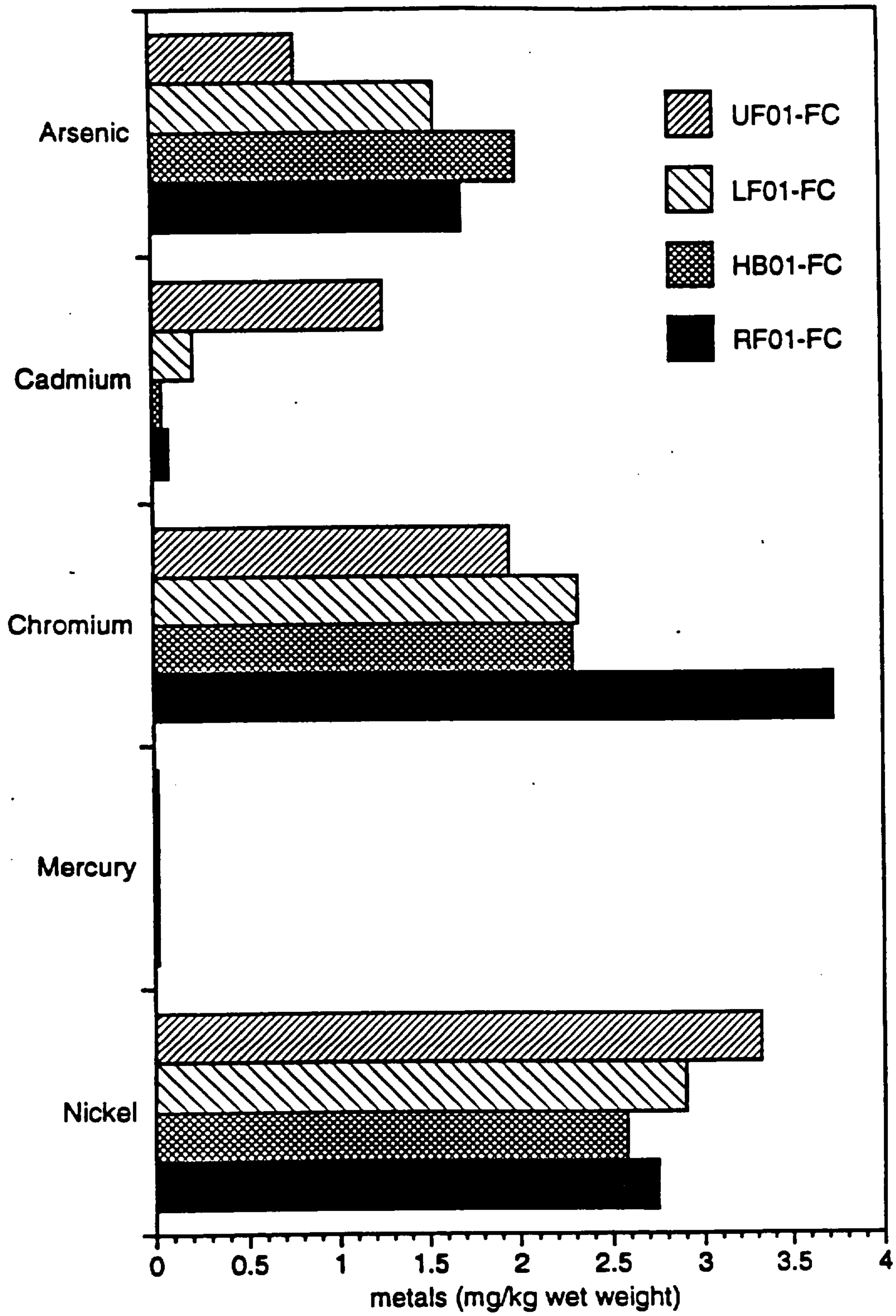

Figure 6-23. Metals concentrations in crab tissues collected from the Ferry Creek and Housatonic Boat Club Wetland and Milford Point Reference areas.

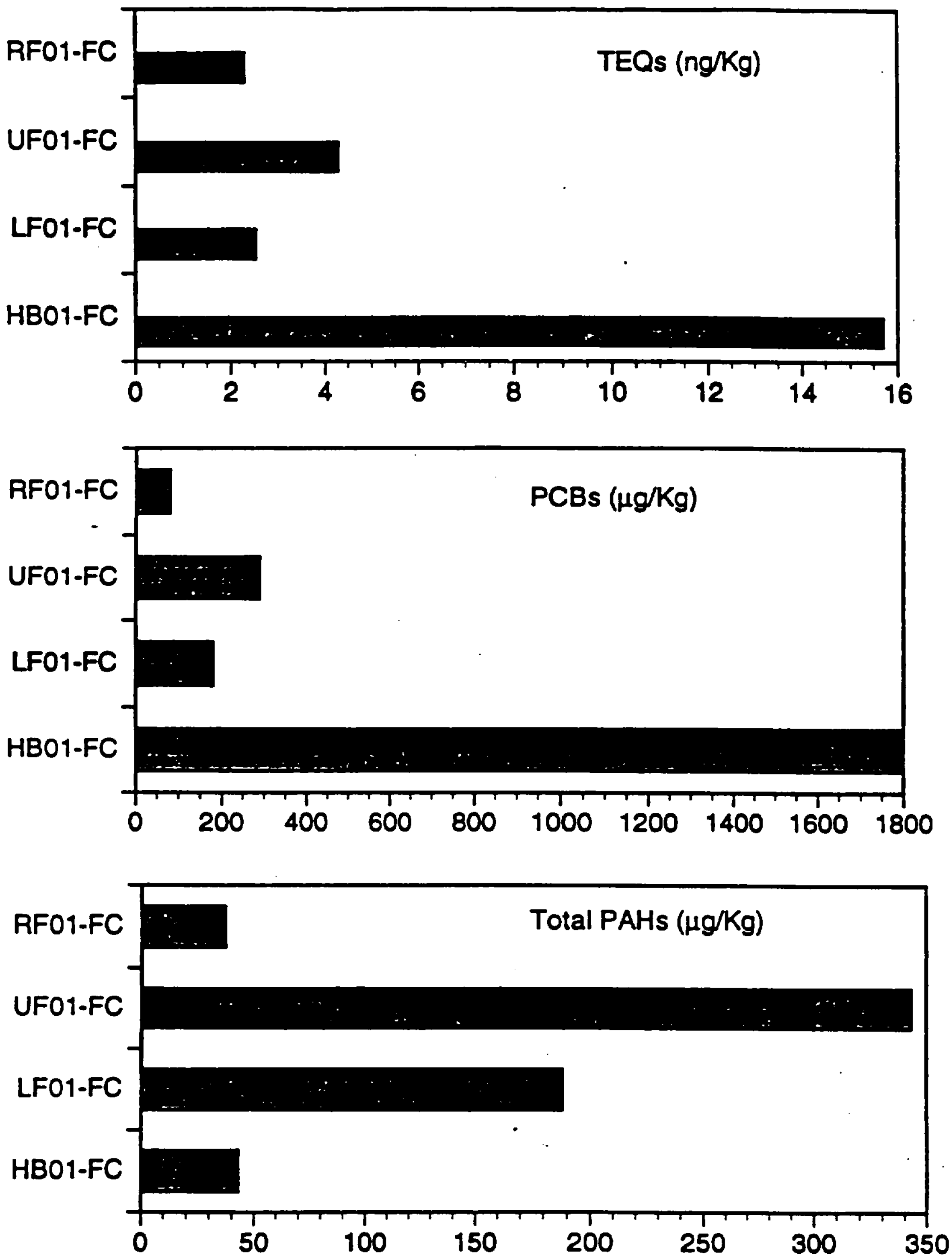

Figure 6-24. Concentrations of organics in crab tissues collected from the Ferry Creek and Housatonic Boat Club Wetland and Milford Point Reference areas.

Table 6-7. Concentrations of trace metals, PCBs, DDTs, and PAHs in crab tissues (wet weight)

Analyte	Milford Point	Boat Club wetlands	Lower Ferry Creek	Upper Ferry Creek
Trace Elements (mg/kg)				
Arsenic	1.70	2.00	1.55	0.73
Cadmium	0.09	0.05	0.22	1.26
Chromium	3.73	2.29	2.32	1.95
Copper	52.65	102.72	53.99	72.23
Lead	3.66	52.49	6.12	15.84
Mercury	0.02	0.02 U	0.02 U	0.02 U
Nickel	2.75	2.53	2.90	3.32
Silver	nr	nr	nr	nr
Zinc	23.48	27.14	27.14	27.37
DDTs and PCBs (µg/kg)				
4,4'-DDD	3 U	2 U	2 U	2 U
4,4'-DDT	2 U	20 U	3 U	5 U
4,4'-DDE	2 U	2 U	2 U	4 U
Aroclor 1016	10 U	10 U	10 U	10 U
Aroclor 1221	10 U	10 U	10 U	10 U
Aroclor 1232	10 U	10 U	10 U	10 U
Aroclor 1242	10 U	10 U	10 U	10 U
Aroclor 1248	10 U	10 U	10 U	10 U
Aroclor 1254	10 U	10 U	10 U	10 U
Aroclor 1260	60	1300	160	290
PCDDs and PCDFs (ng/kg)				
Total TCDD	0.09 NJ4	0.2 U	0.4 NJ4	0.2 U
Total PeCDD	1.3 NJ4	0.64 NJ4	1.5 NJ4	1.8 NJ4
Total HxCDD	504	3.2	8.1 NJ4	8.6
Total HpCDD	7.9	6.1	19.5 NJ4	42.8
Total TCDF	11.2 NJ4	40 NJ4	10.1 NJ4	11.7 NJ4
Total PeCDF	11 NJ4	69.1 NJ4	12.1 NJ4	17.4 NJ4
Total HxCDF	6.5 NJ4	52.1	9.7 NJ4	19 NJ4
Total HpCDF	7.3 NJ4	16.5 NJ4	6.9 NJ4	16.3
2,3,7,8-TCDD TEQs	2.29	15.7	2.52	4.28
PAHS (µg/kg)				
Naphthalene	5 J	5 UJ	6 J	5 UJ
Acenaphthylene	5 UJ	5 UJ	5 UJ	5 UJ
Acenaphthene	5 UJ	5 UJ	5 UJ	5 UJ
Fluorene	5 UJ	5 UJ	5 UJ	5 UJ
Phenanthrene	5 UJ	5 UJ	8 J	16 J
Anthracene	5 UJ	5 UJ	5 UJ	5 UJ
Fluoranthene	5 UJ	5 UJ	20 J	53 J
Pyrene	5 UJ	5 UJ	27 J	54 J
Benzo(a)anthracene	5 UJ	5 J	8 J	20 J
Chrysene	5 UJ	13 J	16 J	31 J
Benzo(b)fluoranthene	9 J	12 J	20 J	33 J
Benzo(k)fluoranthene	6 J	6 J	15 J	27 J
Benzo(a)pyrene	6 J	7 J	17 J	30 J
Indeno(1,2,3-cd)pyrene	5 J	5 UJ	20 J	35 J
Dibenz(a,h)anthracene	5 UJ	5 UJ	10 J	9 J
Benzo(g,h,i)perylene	6 J	5 UJ	21 J	44 J
Total PAHs	37	43	188	352
% Lipd	1.06	0.93	1.21	0.97
%Solids	32.7	32.2	32.2	31

nr — not reported
U — Undetected at the concentration not greater than the value shown.
NJ4 — Estimated maximum Possible Concentration; result is considered tentative.

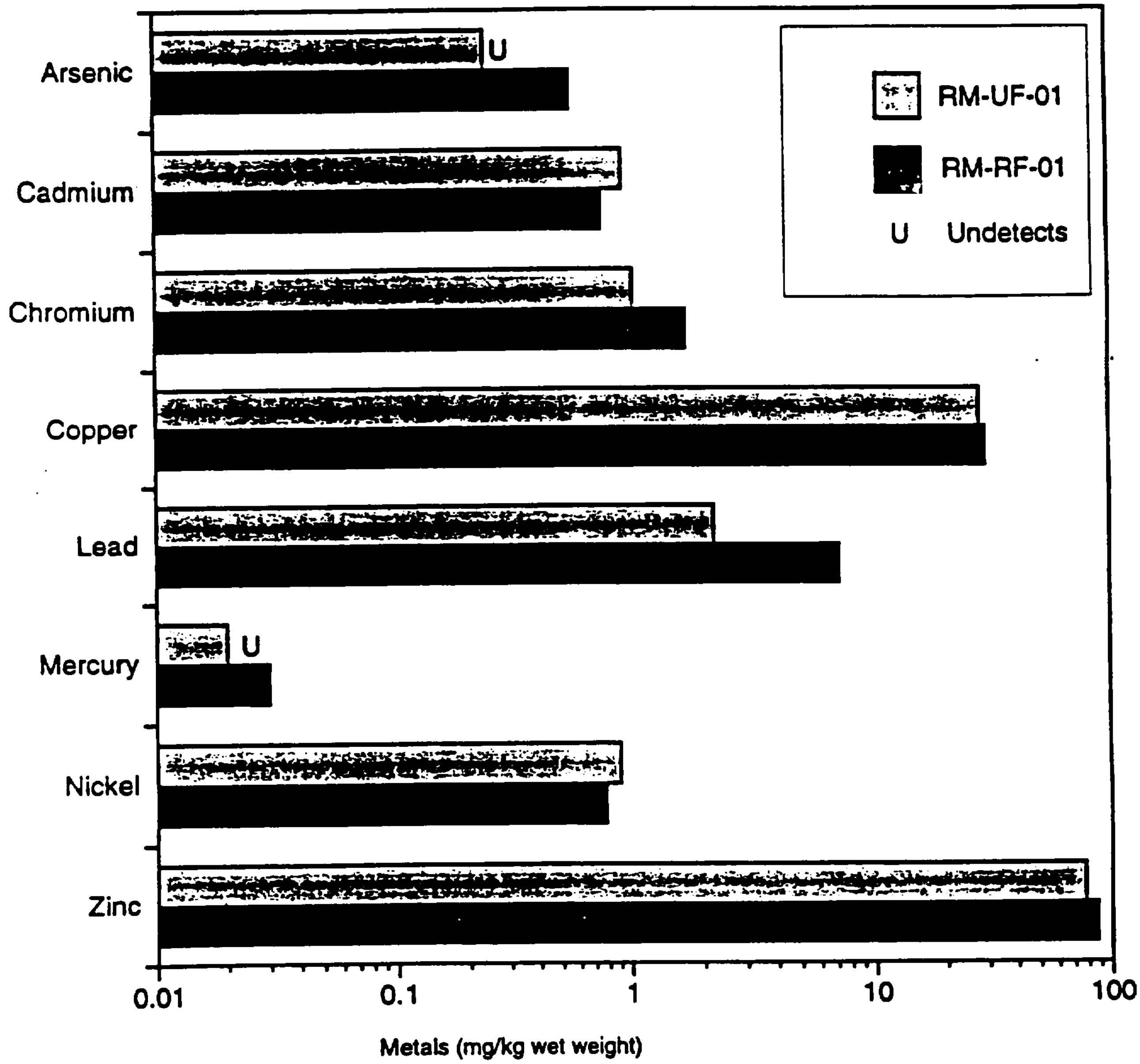

Figure 6-25. Metals concentrations in insect tissues collected from the Ferry Creek and Milford Point Reference areas.

Table 6-8. Concentrations of trace metals, PCBs, DDTs, and PAHs in insect tissue composites (wet weight).

Analyte	Milford Point	Upper Ferry Creek
Trace Elements (mg/kg)		
Arsenic	0.56	0.24 U
Cadmium	0.76	0.94
Chromium	1.73	1.04
Copper	29.69	25
Lead	7.20	2.22
Mercury	0.03 UJ	0.02 UJ
Nickel	0.78	0.90
Zinc	87.05	77.6
DDTs and PCBs (µg/kg)		
4,4'-DDD	8 U	8 U
4,4'-DDT	8 U	5 U
4,4'-DDE	8 U	8 U
Aroclor 1016	40 U	40 U
Aroclor 1221	40 U	40 U
Aroclor 1232	40 U	40 U
Aroclor 1242	40 U	40 U
Aroclor 1248	40 U	40 U
Aroclor 1254	40 U	40 U
Aroclor 1260	40 U	80 U
PCDDs and PCDFs (µg/kg)		
Total TCDD	0.8 J	0.84J
Total PeCDD	2.3 J	0.65 UJ
Total HxCDD	8 J	4.6 UJ
Total HpCDD	32.5 J	66.3 J
Total TCDF	7.2 J	3.2 J
Total PeCDF	5.1 UJ	3.7 J
Total HxCDF	4.4 UJ	5.3 UJ
Total HpCDF	2.8 UJ	13.9 J
2,3,7,8-TCDD TEQs	1.38	2.23
PAHs (µg/kg)		
Naphthalene	20 U	20 U
Acenaphthylene	20 U	20 U
Acenaphthene	20 U	20 U
Fluorene	20 U	20 U
Phenanthrene	47	26
Anthracene	20 U	20 U
Fluoranthene	20 U	20 U
Pyrene	20 U	20 U
Benzo(a)anthracene	100 U	100 U
Chrysene	100 U	100 U
Benzo(b)fluoranthene	100 U	100 U
Benzo(k)fluoranthene	108	100 U
Benzo(a)pyrene	100 U	100 U
Indeno(1,2,3-cd)pyrene	186	150
Dibenz(a,h)anthracene	100 U	100 U
Benzo(g,h,i)perylene	100 U	100 U
Total PAHs	341	176
% Lipid	12.0	7.8
%Solids	55.8	47.3

U — Undetected at the concentration not greater than the value shown.
J — Estimate

7.0 EFFECTS ASSESSMENT

Ecological effects of a contaminant on an ecosystem may be immediate or delayed, permanent or reversible, direct or indirect. Investigative methods to assess these effects may also be either direct or indirect. In this risk assessment, both direct bioassessment methods and indirect modeled approaches are used to assess the potential for, or the actual occurrence of, adverse ecological effects. The direct methods include measurements of the bioaccumulation of CoCs, toxicity tests for acute and chronic toxicity, and surveys of the benthic community with interpretive analysis of its structure. Indirect, comparative, and predictive models were used to contrast ambient exposures or doses of CoCs to benchmark values. Site-specific data from the field-sampling effort serve as inputs for the exposure portion of the models, while the effects benchmarks come from scientific literature.

7.1 SEDIMENT TOXICITY RESULTS

Toxicity from exposure to CoCs present in sediment was assessed using three bioassessment tools: two sediment-toxicity tests and a survey of the indigenous benthic community. The two sediment-toxicity tests—an amphipod test and the oyster larvae test—assessed the acute lethality of sediment by exposing test organisms to environmental samples under controlled, laboratory conditions. The survey of the indigenous benthic community established the structure of the infaunal macroinvertebrate community at each location. This section presents the results from these bioassessment measures. The complete laboratory reports for each analysis are included as Appendices A through C of this report.

7.1.1 Amphipod Acute Lethality Bioassay

The results of the 10-day *Leptocheirus plumulosus* test are summarized in **Table 7-1.** The test was considered valid since mean survival in the control sediment (92.5%) met the acceptability criterion set by ASTM (1994a). A good, broad range in response was observed which helps provide discriminatory power to the results. Survival data were transformed using an arcsine square root function and tested for normality (Shapiro-Wilk's test) and for homogeneity of variance (Bartlett's test). The transformed survival data passed both of these tests.

The lowest mean amphipod survival was 30% in the sediment sample collected from Station SD07, located below the tide gate in Ferry Creek. However, the variability among replicates of this sample was the highest observed. This may indicate poor laboratory procedure, or lack of homogeneity in the sediment replicates. Very low survival (31%) was also observed in the sample collected from Station SD21 located in Upper Ferry Creek. This sample had the second largest standard deviation among replicates. The highest mean amphipod survival results were 99% in sediment collected from RF01, the reference area in Beaver Brook, and 98% in sediment from HB06, located in the western portion of the Housatonic Boat Club wetlands.

Individual samples were identified as "toxic" by virtue of diminished survival due to responses to the CoCs in the sample. Statistical comparisons (ANOVA followed by Fisher's PLSD) were made between mean responses observed in the five laboratory replicates of each single sample versus those observed in the appropriate reference area sample(s). Because of the potential effect of grain size on amphipod survival, samples were matched based on their grain size, as defined by percent fines content. Results of these comparisons indicated that three of the nine samples were classified as toxic—SD21 from Upper Ferry Creek ($\rho<0.0001$); SD13 from Upper Ferry Creek ($\rho<0.0035$); and SD07 from Lower Ferry Creek ($\rho<0.0001$;

Table 7-1. Summary of results of the 10-day *Leptocheirus plumulosus* sediment toxicity test.

Sample	Reference sample [a]	Mean survival (%) [b]	Toxic [c]	Avoidance [d] (mean ± sd)
HB-06	RF-01	98.0	No	0.3 ± 0.1
HB-12	RF-02/03	88.0	No	0.2 ± 0.3
HB-23	RF-02/03	78.0	No	0.1 ± 0.1
SD-07	RF-01	30.0	Yes	0.4 ± 0.2
SD-10	RF-02/03	92.0	No	0.2 ± 0.1
SD-13	RF-02/03	58.0	Yes	0.3 ± 0.2
SD-19	RF-02/03	79.0	No	0.2 ± 0.1
SD-20	RF-01	77.0	No	0.2 ± 0.2
SD-21	RF-01	31.0	Yes	0.6 ± 0.3
RF-01	na	99.0	na	0.4 ± 0.2
RF-02	na	83.0	na	±
RF-03	na	78.0	na	0.1 ± 0.1
Control Sediment	na	92.5	na	0.1 ± 0.1

[a] Corresponding reference station with similar grain size.
[b] Five replicates, except for Control Sediment, which had four replicates.
[c] Statistically significant reduction in mean survival of sample replicates when compared with response of reference sample replicates.
[d] Number of amphipods on the sediment surface per jar per day (out of a maximum of 20).
na — not applicable

Table 7-1). Because sediment sampling stations were selected to encompass a range in contamination levels, it was not expected that all samples would be toxic.

Mean avoidance in the laboratory replicates of test sediments ranged from zero amphipods/jar/day in the sediment sample collected from RF02 to 0.6 amphipods/jar/day for the sample from SD21. This was one of the samples identified as toxic. Mean avoidance in the control sediment sample was 0.1 amphipods/jar/day.

The two samples with the greatest toxicity contained elevated levels of total PCBs and total PAHs. Sample SD21 from Upper Ferry Creek also had the highest TCDD TEQs and the second highest SEM/AVS ratio (7.7), which was sufficiently high to suggest that bioavailable divalent trace metals were present.

Statistical comparisons (Kruskal-Wallis with multiple contrasts) of mean survival and avoidance between the mean response observed in the three samples each from Upper Ferry Creek, Lower Ferry Creek, and the boat club wetlands versus the reference samples were also conducted. This test distinguished areas where the mean response was statistically different than that of the reference area. There were significant differences ($p=0.0003$) in survival, with the Ferry Creek areas exhibiting lower survival than either the reference or boat club wetland area samples. For the avoidance measure, differences were indicated at a p-value of 0.06, with the only distinguishable area being Upper Ferry Creek, which had significantly greater avoidance than the reference area. The highest avoidance was observed in an Upper Ferry Creek sample (SD-SD21). Avoidance of test sediments can be another indication that the nature of the test samples is noxious, distasteful, or somehow stressful to the organisms. Since avoidance would tend to lower exposures to sediments and pore water, it can be a confounding factor with the survival endpoint, although avoidance is not generally viewed as strong a response to contamination as is mortality.

7.1.2 Oyster Larvae Developmental Bioassay

The results of the *Crassostrea gigas* larval development test are presented in **Table 7-2**. The mean percent abnormality and mean percent combined mortality in the seawater control were within the criteria limits for test acceptance of 10% abnormality (ASTM 1994a) and ≤50% combined mortality (PSDDA 1989). Mean percent abnormality and mean percent combined mortality in the seawater control were 2.7% and 4.3%, respectively. There was also a broad range in responses observed which lends itself to good discriminatory ability. Survival data were transformed using an arcsine square-root function and tested for normality (Shapiro-Wilk's test) and for homogeneity of variance (Bartlett's test). The abnormality data passed both of these tests. The combined mortality data passed the test for normality but not for homogeneity of variance. ANOVA is quite robust to uneven variance, particularly when sample sizes are equal as in this case (Zar 1984). Therefore, these data were evaluated with parametric statistical tests. Tests of abnormality reflect the developmental toxicity potential of samples, while the mortality endpoint reflects acute toxicity. Because abnormal larvae are assumed to be inviable, these two counts are summed for the combined mortality figure. This value is thought to reflect the longer term, overall toxicity potential.

Table 7-2. Summary of results of 48-h *Crassostrea gigas* larval development test.

Sample	Mean [a] Abnormality (%)	Toxic [b]	Mean Combined Mortality[c] (%)	Toxic [?]
HB-23	20.3 ± 3.2	Yes	83.7 ± 2.8	Yes
SD-10	12.2 ± 2.3	No	34.7 ± 1.9	No
SD-13	47.4 ± 4.1	Yes	79.4 ± 2.3	Yes
RF-02	11.7 ± 1.9	na	43.7 ± 7.2	na
Sediment Control	4.1 ± 0.7	na	3.1 ± 4.3	na
Seawater Control	2.7 ± 1.0	na	4.3 ± 10.1	na

[a] Mean of the five replicates

[b] Statistically significant increase in mean abnormality of sample replicates when compared with response of reference sample replicates.

[c] Mean combined mortality = mean abnormality + mean mortality.

Mean percent abnormality in the laboratory replicates of sediment samples ranged from 11.7% in the reference area sample (RF02) to 47.4% in the sample from Upper Ferry Creek (SD13). Average percent combined mortality (mortality plus abnormality) ranged from 34.7% in the Lower Ferry Creek sample (SD10) to 83.7% in the sample from the boat club wetlands (HB23).

Statistical comparisons (ANOVA followed by Fisher's PLSD) were made between mean responses observed in the five laboratory replicates of the single sample from each station versus those observed in the controls, and also against the mean in laboratory replicates from the reference area sample (RF02). This comparison identified those samples which, by virtue of their content of CoCs, had toxic responses significantly different from those observed in the controls. Two endpoints are examined because toxic constituents may exert either acute lethality or, if acutely non-lethal, may interfere with development to produce deformed larvae which are assumed to be non-viable. Dioxin is a good example of a toxin which tends to act through a latent, developmental mode of action. Results for mean percent abnormality and combined mortality are also presented in Table 7-2. Two of the three site-related samples were thus identified as toxic. The sample from the Housatonic Boat Club wetland, HB23, was identified as toxic by both the abnormality and combined mortality endpoints ($\rho=0.0003$ and $\rho<0.0001$, respectively). The sample from Station SD13 in Upper Ferry Creek was also identified as toxic by both measures ($\rho<0.0001$ for both). Although parametric tests are relatively robust with regard to homogeneity of variance (Zar 1984), non-parametric Kruskal-Wallis tests were also conducted to confirm results. Significant differences were again indicated at only slightly lower ρ values.

The two toxic samples that exhibited the greatest reduction in viability of larvae (HB23 and SD13) were also the samples containing some of the highest levels of total PCBs and TCDD TEQs. Both also contained above-average total PAHs. The sample from the boat club wetlands also had the greatest ratio of SEM/AVS, indicating potentially bioavailable, divalent trace elements in this sample. The remaining, non-toxic sample from the mouth of Ferry Creek (SD10) was not expected to be toxic due to lower contaminant concentrations at this locale.

Statistical comparisons (Students t test) were made between mean responses of the three site-related samples (i.e., Upper and Lower Ferry Creek plus the Housatonic Boat Club wetlands) versus the value of the mean response observed from the reference sample to further address the question of whether site-related sediments containing CoCs were capable of causing adverse ecological impacts. Despite the low statistical power enabled by only three samples in the areas of interest, differences between the mean percent abnormality or combined mortality associated with site-related samples versus the mean value observed in the reference sample were indicated at a ρ-value of 0.15.

7.2 BENTHIC INVERTEBRATE COMMUNITY STRUCTURE

Analyses of benthic community structure are often aimed primarily at pattern detection (as opposed to *a priori*, controlled, experimental testing). The objective of pattern detection is to confirm hypotheses concerning the structure of ecological communities (Ludwig & Reynolds 1988). Three basic patterns are recognized in communities: random, clumped, and uniform (Ludwig & Reynolds 1988). Randomness in a community tends to confirm environmental homogeneity and non-selective patterns. Clumping suggests that individuals are aggregated according to areas of more (or less) favorable conditions. A uniform (i.e., non-random) dispersion suggests that negative interactions between individuals (e.g., competition for food or space) may be the primary controlling distributional factor. When the unit size of the area sampled is sufficiently smaller than the clumping pattern, observational assessments are able to detect differences between investigative areas. Any differences observed are likely due to some combination of environmental stressors that creates more and less favorable habitats.

For benthic macroinvertebrate community assessments, pattern detection usually focuses on analysis of species richness, species evenness, and diversity. Species richness is simply the number of species in the community. When sample sizes between investigative areas are even, richness should be even as well (richness can be affected by the degree of sampling effort).

Species evenness refers to the equitability of how species abundance (e.g., the number of individuals, biomass, cover) is distributed among the species present. Diversity incorporates these two factors into a single index. Since diversity is a combination of two factors, it responds to changes in richness or evenness either singularly or both concurrently. Interpretation of diversity indices thus requires caution.

For this risk assessment, four sediment grabs (samples) were collected at each of the following seven stations to identify and count benthic macroinvertebrates:

- Upper Ferry Creek SD13, SD20;
- Lower Ferry Creek SD07, SD19;
- Housatonic Boat Club HB23;
- Beaver Brook RF01 (as a low-salinity station); and
- Milford Point RF02 (as a high-salinity station).

Station RF01 is located in the tidally influenced, low-salinity section of Beaver Brook and represents a reference area for comparison with Upper Ferry Creek Stations. Station RF02 is located in a tidal channel of a *Spartina* wetland near Milford Point. This station represents a reference area for comparison to Lower Ferry Creek and Housatonic Boat Club stations.

Macroinvertebrates were identified to the lowest taxon practical and enumerated. A complete listing of the species found and their occurrence is provided as Appendix C. Counts were transformed to densities in units of individuals per square meter. These data appear in **Table 7-3** as mean total abundance (density) and taxa richness (as number of species present) by station. **Table 7-4** summarizes and compares these data. Data were also summarized and compared by the following major groupings: annelids, arthropods, amphipods, insects, and molluscs (**Tables 7-5 through 7-9**). Nematodes occurred in only a very few replicates and were not considered in further analysis. All data were statistically evaluated by non-parametric Kruskal-Wallis tests versus only the appropriate reference station. All conclusions of significant difference were based on ρ values of 0.05 or better and one-way multiple comparisons.

7.2.1 Total Abundance

The total abundance, or density, of benthic organisms in sediment samples from Ferry Creek stations SD07, SD19, SD13, SD20; Housatonic Boat Club station HB23; and the reference stations in Beaver Brook (RF01) and Milford Point (RF02) are presented in Table 7-4. There was a nearly tenfold range in total mean infaunal density. Mean total density ranged from a low of 2,982 individuals/m^2 at station HB23 to 29,732 individuals/m^2 at the Beaver Brook reference station RF01.

Differences in mean total density were indicated for the Upper Ferry creek stations at a ρ value of 0.1 (0.056 for parametric ANOVA), with both stations having substantially lower density than the reference. There were no significant differences in density among the high-salinity stations of Lower Ferry Creek and the boat club wetlands. Station SD07 had the highest density, driven by *Capitella*, but also displayed high variance among the four samples.

Table 7-3. Density (individuals/m²) of benthic organisms.

	SAMPLING STATIONS						
	HB-23	SD-07	SD-19	RF-02	SD-20	SD-13	RF-01
Taxa NEMATODA	65	366		248			
ANNELIDA	1,722	9,850	3,789	4,500	9,495	13,639	11,949
Ampharetidae						22	
Capitella capitata complex		7,094				11	
Glycera spp.				11			
Hobsonia florida		409	86		205	1,443	8,128
Hypereteone heteropoda	11	463	1,012	1,033		11	
Laeonereis culveri	11	291	11		32	3,509	118
Marenzellaria viridis							334
Mediomastus ambiseta				54			
Neanthes spp.		32		43			
Neanthes succinea		161	183	129			
Neanthes virens		75					
Nereis spp.							
Oligochaeta	1,701	1,109	710	1,399	9,258	8,623	3,348
Polydora cornuta		151	280	22			
Streblospio benedicti		65	1,507	1,798		22	
ARTHROPODA	161	205	11	710	32	43	14,048
Almyracuma proximocuii							11
Balanus improvisus		151					
Cassidinidea ovalis							22
Cyathura polita		11			22	32	775
Edotea triloba		11		54			
Uca spp.	22						
Amphipods	140	22	11	625	11	11	13,230
Caprella penantis				11			
Corophium lacustre	11		11				409
Gammarus palustris	118						
Gammarus tigrinus		11			11	11	8,913
Leptocheirus plumulosus				614			3,908
Melita nitida		11					11
Melitidae				11			
Microgammarus mucronatus		11		11			

Table 7-3 continued

TAXA	SAMPLING STATIONS						
	HB-23	SD-07	SD-19	RF-02	SD-20	SD-13	RF-01
Amphipods	140	22	11	625	11	11	13,230
Microprotopus raneyi				11			
Talitridae	11						
INSECTA	689	129			75		3,735
cf. Aericotopus spp.							22
Chironomidae							22
Chironomini							65
Chironomus spp.	11				11		1,249
Clinotanypus spp.							11
Culicoides spp.	635				11		
Dicrotendipes spp.					43		1,464
Diptera pupae	11						
Empididae (Diptera) larvae	22						
Hemiptera		129					
Muscidae (Diptera) larvae	11						
Polypedilum spp.							43
Procladius spp.							614
Tanypoidini					11		
Tanypus spp.							11
Tanytarsus spp.							237
MOLLUSCA	344		65	194			
Gemma gemma				11			
Littoridinops tenuipes				86			
Hydrobia spp.	344						
Macoma balthica			43	97			
Mya arenaria			22				
Mean Total Abundance	2,982	10,550	3,865	5,652	9,602	13,682	29,732
Mean Taxa Richness (as no. of species)	7	11	7	11	5	5	16

Table 7-4. Comparison of total benthic infaunal abundance for Ferry Creek, Housatonic Boat Club, and reference stations.

Station	Reference Station [a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	2,982	± 1,092	No
SD-07	RF-02	10,560	± 3,267	No
SD-13	RF-01	13,682	± 5,757	Yes
SD-19	RF-92	3,865	± 1,582	No
SD-20	RF-01	9,602	± 3,821	Yes
Reference Station				
RF-01		29,732	±1,615	na
RF-02		5,652	± 1,202	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

7.2.2 Annelid Abundance

The mean density of annelids ranged from 1,722 individuals/m^2 at station HB23 to 13,639 individuals/m^2 at station SD13 (**Table 7-5**). Annelids represented between 40% and 99% of the total abundance of benthic organisms in the stations sampled.

Oligochaetes were the most abundant type of annelid present in the samples. The ampharetid *Hobsonia florida* was the most abundant polychaete present. The polychaete *Capitella capitata* was abundant in some grabs from station SD07. *Capitella* are known as a pollution-tolerant species characteristic of degraded, highly organically-enriched sediments.

Table 7-5 also lists results of the statistical comparisons for density of annelids found in Ferry Creek and the Housatonic Boat Club sediments relative to reference sediments. The density of annelids was not statistically lower at any stations. However, Upper Ferry Creek stations exhibited much greater variability in density of annelids than their reference station, thus imparting low power to any statistical tests. As noted above, increased abundance of annelids at SD07 was due largely to the relatively high occurrence of *Capitella*, a pollution-tolerant species.

7.2.3 Arthropod Abundance

The mean density of arthropods ranged from 11 individuals/m^2 at Lower Ferry Creek static SD19 to a high of 17,783 individuals/m^2 at the reference station RF01 (**Table 7-6**). Arthropoc composed between <1% and 60% of the total abundance of benthic organisms. Crustaceai composed between 30% and 100% of the arthropods present, and ranged in density from 1 individuals/m^2 at station SD19 to 14,048 individuals/m^2 at station RF01 (Table 7-3). Insec composed between 0% and 70% of the arthropods present, ranging from totally absent ; stations SD13, SD19 and the saline reference station RF02 to 3,735 individuals/m^2 at RF01.

Table 7-5. Comparison of annelid abundance at Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	1,722	± 649	No
SD-07	RF-02	9,850	± 3,001	No
SD-13	RF-01	13,639	± 5,763	No
SD-19	RF-02	3,789	± 1,539	No
SD-20	RF-01	9,495	± 3,352	No
Reference Station				
RF-01		11,949	± 374	na
RF-02		4,500	± 870	na

na = not applicable
[a] Corresponding reference station with similar salinity.
[b] Mean abundance of four replicate samples.
[c] Statistically significant depressions of abundance compared with reference.

Table 7-6. Comparison of arthropod abundance for Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	850	± 576	No
SD-07	RF-02	334	± 130	No
SD-13	RF-01	43	± 26	Yes
SD-19	RF-02	11	± 9	Yes
SD-20	RF-01	107	± 36	Yes
Reference Station				
RF-01		17,783	± 1,430	na
RF-02		710	± 354	na

na = not applicable
[a] Corresponding reference station with similar salinity.
[b] Mean abundance of four replicate samples.
[c] Statistically significant depressions of abundance compared with reference.

Crustaceans were the most abundant arthropods at stations SD13, SD19, RF01, and RF02, while insects dominated the arthropod abundance at HB23 and SD20. The most abundant of the benthic crustaceans were the amphipods *Gammarus palustris*, *G. trigrinus*, and *Leptocheirus plumulosus*. Amphipods are considered sensitive indicator species and are among the first to disappear in pollution-impacted areas (Lamberson et al. 1992). Gammarids and *Leptocheirus p.* are being used as test organisms in toxicity tests partly due to their sensitivity. One of the toxicity tests used in this assessment employed *Leptocheirus plumulosus* as the test species. In the native sediment samples, *L. plumulosus* was found only in samples from the two reference stations.

Results of the statistical comparisons for density of arthropods, amphipods, and insects relative to their appropriate reference stations are found in **Tables** 7-6, 7-7, **and** 7-8. The density of all arthropods was statistically lower at Upper Ferry Creek stations (SD 13 and SD20) and station SD19 in Lower Ferry Creek. Amphipod density was statistically depressed at all stations relative to their reference area. Amphipods were functionally absent in samples from Upper Ferry Creek as only one amphipod was present in the four grabs each at stations SD13 and SD20. There was only one individual observed in all grabs from SD19, and only three in all samples from station SD07. Insect density was statistically lower at both Upper Ferry Creek stations. In fact, insects were absent at station SD13. The functional absence of both insects and amphipods in Upper Ferry Creek emphasizes the degraded conditions of this locale.

Table 7-7 Comparison of amphipod abundance for Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station [a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	140	± 84	No
SD-07	RF-02	32	± 18	Yes
SD-13	RF-01	11	± 9	Yes
SD-19	RF-02	11	± 9	Yes
SD-20	RF-01	11	± 9	Yes
Reference Station				
RF-01		13,241	± 1,124	na
RF-02		646	± 331	na

na = not applicable
[a] Corresponding reference station with similar salinity.
[b] Mean abundance of four replicate samples.
[c] Statistically significant depressions of abundance compared with reference.

Table 7-8. Comparison of insect abundance at Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	Impacted[c]
HB-23	RF-02	689	± 423	na
SD-07	RF-02	129	± 100	na
SD-13	RF-01	0	± 0	Yes
SD-19	RF-02	0	± 0	na
SD-20	RF-01	75	± 34	Yes
Reference Station				
RF-01		3,735	± 256	na
RF-02		0	± 0	na

na = not applicable
[a] Corresponding reference station with similar salinity.
[b] Mean abundance of four replicate samples.
[c] Statistically significant depressions of abundance compared to reference.

7.2.4 Molluscan Abundance

Molluscs were expected only at higher-salinity stations HB23, SD19, SD07, and RF02. The mean density at these stations ranged from zero at SD07, to 65 individuals/m^2 at station SD19, to 344 individuals/m^2 at HB23. Molluscs were uncommon, representing only 0% to 11% of the total abundance of benthic organisms in these samples.

Results of the statistical comparisons for density of molluscs found in Lower Ferry Creek and the Housatonic Boat Club wetland sediments, relative to their appropriate reference stations, are found in **Table 7-9**. The absence of molluscs at station SD07 was the only statistically significant difference from the reference area. Both SD07 and SD19 are in Lower Ferry Creek, which has saline, tidal water incursions. Based on salinity alone, there is no apparent reason for the lack of molluscs at just one of these stations.

Table 7-9. Comparison of mollusc abundance for Ferry Creek, Housatonic Boat Club stations, and reference stations.

Station	Reference Station[a]	Abundance (per m^2)[b]	Standard Error	impacted[c]
HB-23	RF-02	344	±58	No
SD-07	RF-02	0		Yes
SD-13	RF-01	0		na
SD-19	RF-02	65	±65	Yes
SD-20	RF-01	0	±0	na
Reference Station				
RF-01		0	±0	na
RF-02		194	±44	na

na = not applicable

[a] Corresponding reference station with similar salinity.

[b] Mean abundance of four replicate samples.

[c] Statistically significant depressions of abundance compared with reference.

7.2.5 Taxa Diversity, Richness, and Evenness

A wide variety of indices have been developed to describe and contrast various aspects of community structure (i.e., species abundance relationships). Diversity, one of the most common indices reported, is actually composed of two elements: species richness or the total number of different species present, and species evenness or how abundance is distributed among the species. Diversity indices attempt to combine both these elements into a single value. Care must be taken in interpreting diversity indices, however, since they respond to these two separate components either in concert or independently.

For this assessment, two different indices of species richness were calculated: Those of Margalef (1958) and Menhinick (1964). Low values in both indices indicated low species richness or dominance by only a few species. Because species-richness indices are heavily influenced by sample sizes, the utility of calculated indices depends upon adequate and comparable sample sizes. An alternative to species-richness indices, when sample sizes at all locations are equal, is simply a count of the number of species present. Rarefraction is yet another species-richness procedure that calculates the probabilities of observing an expected number of species present over a range of sample sizes, using observed data from samples of varying sizes. The goal of rarefraction is to eliminate the bias to which other indices are subject when sample sizes vary. The probabilities obtained from rarefraction can be projected graphically, which then allows for interpretation at any given sample size. Although sample sizes were even in this study, rarefraction has been used to portray results in an intuitive, graphical manner.

Because species-richness indices are also overly sensitive to the presence of rare species, species evenness is another key aspect of community structure to examine. Optimally, an evenness index should be independent of the number of species present in a sample (i.e., species richness). Alatolo's evenness index tends to be independent of sample size and is relatively unaffected by species richness. It is also less sensitive to the presence of rare species. Therefore, the evenness index of Alatolo (1981) was also calculated for this effort. This index value approaches zero as a single species dominates the benthic community.

For overall species-diversity indices, the diversity numbers of Hill (1973) were calculated. For diversity indices, these numbers have intuitive appeal and are easy to interpret because they are expressed in units of species. Hill refers to them as the effective number of species present. His simplest index, the N0 value, is simply the number of species present, regardless of their abundance. As such, this is essentially a *de facto* species-richness figure. Hill's other indices, N1 and N2, represent the number of abundant and very abundant species, respectively.

Indices of diversity, richness, and evenness for benthic organisms present in sediment samples from Ferry Creek stations, SD07, SD13, SD19, SD20; Housatonic Boat Club station HB23; and the reference stations in Beaver Brook, RF01 and Milford Point, RF02 are presented in **Table 7-10**. Rarefraction curves based on mean values for each station for these samples are presented in **Figure 7-1**.

Mean species richness, as represented by the number of species present (i.e., N0), ranged from 4.5 taxa per grab at station SD13 or SD20, to 16.25 taxa per grab at the reference station RF01. There was a threefold range in Menhinick's richness index, with the lowest values observed for Upper Ferry Creek stations SD13 and SD20. Additionally, Hill's overall diversity indices of N1 and N2 indicated strong dominance by few species in Upper Ferry Creek, with only one or two species classified "very abundant" and only two or three classified as "abundant," as opposed to over six abundant species and almost five very abundant species at the reference stations. This pattern of species dominance is also reflected in the low evenness value for grabs from station SD20. Dominance by annelids in grabs from station SD07 is also indicated by the low evenness value for that station.

Upper Ferry Creek stations were compared with the lower-salinity reference station in Beaver Brook. All benthic community measures (species abundance, species richness, and density of individuals) were significantly reduced at the Upper Ferry Creek stations. These stations were dominated by three to four abundant species, and only one or two very abundant species. There was significantly lower evenness at SD20, where oligochaetes dominated: over 96% of the individuals were oligochaetes. Together with just two annelid species, these species accounted for 99% of the individuals present at this Upper Ferry Creek station.

Table 7-10. Indices of diversity, evenness, and richness for benthic community structure.

Station	Total Count	Diversity					Evenness	Richness	
		NO [a]	H' [b]	N1 [c]	λ [d]	N2 [e]	E [f]	R [g]	R [h]
HB23	2,984	14	1.33	3.77	0.39	2.59	0.58	1.62	0.26
SD07	10,551	18	1.34	3.83	0.47	2.13	0.40	1.84	0.18
SD19	3,865	10	1.56	4.77	0.26	3.81	0.75	1.09	0.16
RF02	5,643	18	1.84	6.30	0.21	4.73	0.70	1.97	0.24
SD20	9,604	9	0.21	1.23	0.93	1.08	0.33	0.87	0.09
SD13	13,684	9	0.93	2.53	0.47	2.11	0.72	0.84	0.08
RF01	2,9715	21	1.91	6.73	0.20	4.99	0.70	1.94	0.12

[a] Cumulative number of species present among all four grabs.

[b] Shannon's index. Average degree of uncertainty in predicting what species a random individual came from. Used in calculating N1.

[c] Number of abundant species. Lower value indicates an increase in dominance by fewer species

[d] Probability that two random individuals sampled are from same species. Inverse with diversity. Used in calculating N2.

[e] Number of very abundant species. Lower value indicates an increase in dominance by fewer species.

[f] Alatolo 1981

[g] Margalef 1958

[h] Menhinick 1964

Lower Ferry Creek stations and the boat club wetland station were compared with the reference station at Milford Point (RF02). Species abundance, species richness, and density of individuals were all significantly reduced at the boat club wetland station, HB23, compared with the reference, although stations in Lower Ferry Creek exhibited more erratic patterns. Richness indices of Margalef (1958) and Menhinick (1964) were both highly variable among grabs at the Lower Ferry Creek stations. Samples from SD19 had significantly reduced richness of taxa and dominance by only three abundant species. At SD07, there was a high number of individuals, but with great variability between grabs. Richness of taxa was high, but this was due to rare occurrences (as discussed above). This station also was dominated by only two very abundant and three to four abundant species. This dominance was further reflected by the significantly reduced evenness.

7.2.6 Overall Benthic Community Impacts

Results of calculations for the various benthic community diversity parameters, evenness, richness, and abundance (Table 7-10) plus rarefraction curves of Figure 7-1 clearly indicate that the benthic community present at Upper Ferry Creek stations (SD13 and SD20) is seriously degraded. These stations have depressed abundance, richness, and evenness, which all combine for significantly depressed diversity. In the rarefraction curves, this trend is indicated by the low number of species expected, less than four, regardless of sample size.

The stations HB23 and SD19 also indicate a degraded benthic community. These stations are not as severely impacted as the Upper Ferry Creek stations, but clearly are still distinct from the reference stations. The expected number of species is lower than the reference areas, confirmed by the dominance indices. There were only three to four abundant or very abundant species at these stations.

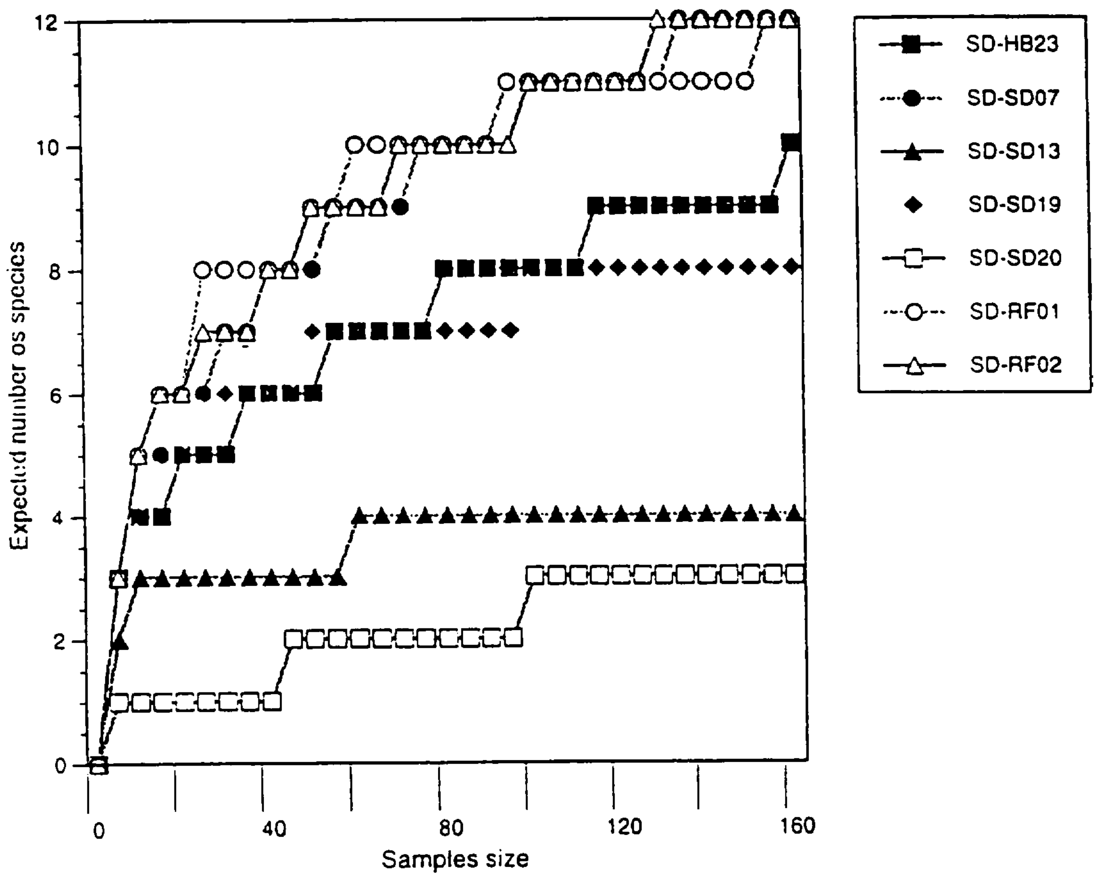

Figure 7-1. Rarefraction curves indicating number of benthic species expected for various sample sizes.

Although station SD07 plots out in the rarefraction curves (Figure 7-1) with the reference stations, as discussed above, this station is an anomaly. The number of species present at this station was comparable to the reference stations only because of the rare occurrence of one or two individuals in only one or two of the four grabs. The evenness, dominance, and richness would all suggest that diversity at the station is diminished and is comparable to HB23 or SD19. This station is also unique for the high incidence of *Capitella*, plus the relatively high TOC (5.2%) for such a low amount of fine material (34%). A mean TOC for coastal and estuarine sediments in the U.S. has been reported to be just under 2% (Long 1995). The benthic community at this station is clearly degraded, although the nature or cause of the alteration may be attributed to multiple factors (e.g., the grain size of the sediment, freshwater upwelling or discharge).

7.3 BIOACCUMULATION EFFECTS ASSESSMENT

Bioaccumulation of CoCs indicates their bioavailability from sediment (and/or water), plus their transfer through a food web. Only certain contaminants (primarily lipophilic organics) are known to biomagnify to substantially greater levels with transfer to higher levels in a food chain. Others may be transferred, but generally will not increase with each successive step up in trophic level.

The presence of CoCs in the tissues of organisms sampled represents two pathways of exposure and potential risk. The first is a risk to the organisms themselves from the possible interactions of the CoCs with their own biochemical processes. The second risk is from a dietary dosage to predatory species which may feed upon the organisms sampled (i.e., an exposure factor or route). To evaluate both these risks, tissue body burdens may be compared against benchmark (e.g., Maximum Acceptable Tissue Concentrations or MATCs) which are related to adverse impacts. In this risk assessment, the first pathway is evaluated by comparison of field-collected fish (*Fundulus*) with MATCs for fish, while the second pathway is assessed with RTV benchmarks for avian species.

7.3.1 Bioaccumulation Effects in Fish

Only marginal gross, pathological adverse effects were directly observed in fish collected in the study area. Out of the hundreds of mummichog collected, very few fish were observed to have slightly eroded fins. Because of the extremely low incidence, this observation will not be discussed further. Risk to the fish is examined essentially through comparison of body burdens with benchmark levels (i.e., MATCs).

The literature was reviewed for MATCs in fish tissue for all of the CoCs. Only six suitable MATCs were found **(Table 7-11)**. Most of the MATCs were associated with adverse reproductive success. These MATCs are compared with measured body burdens in mummichog. An attempt was made to use toxicity studies conducted with the species of concern used in this ERA, or with very closely related species. However, studies with these species could not be located. Differences between the test conditions and species studied and those that occur from the study area increase the uncertainty of applying these MATCs (see Section 9.0). However, these MATCs typically represent sensitive species and should therefore be protective of those species found in the study area.

Two of the four Upper Ferry Creek composite samples contained Cd and total PAH levels greater than the MATCs. These were the two samples (UF-03-FT and UF-04-FT) collected closest to the head of the creek. The sediment samples associated with, or adjacent to, areas

Table 7-11. Summary of MATCs used for fish tissue vs. concentrations observed in mummichog.

Analyte	Ranges in mummichog	MATC (μg/kg, ww)	Samples above MATC	Study Details	Reference
PCBs	b.d. — 590	200	RF-02-FT	MFO induction and reduced reproductive success in starry flounder eggs	Spies et al. 1985
DDT + DDE	b.d. — 15	220	NA	Concentration in eggs of winter flounder (based on LOEL of 2.2 with vertebral deformities in developing eggs and larvae)	Smith & Cole 1973
Cadmium	10 — 140	32	UF-03-FT UF-04-FT	Highest No Effect Concentration	Dillon & Gibson 1985
Mercury	10 — 20	3000	NA	NOEL for whole-body brook trout	McKim et al. 1976
Total PAHs [a]	b.d. — 546	140	UF-03-FT UF-04-FT	Concentration of total PAHs in the liver of flounder associated with normal gonadal development	Spies et al. 1985
PCDDs/ PCDFs [b]	0.52 — 1.9	50 in eggs 75 in parents	NA	No-effects thresholds for reproductive effects (mortality in embryos and young)	USEPA 1993

[a] Total PAHs include 9,10 dihydroanthracene, phenanthrene, anthracene, 1-methylphenanthrene, fluoranthene, pyrene, benzanthracene, chrysene/triphenylene, benzo(*b*)fluoranthene, benzo(*k*)fluoranthene, benzo(*e*)pyrene, benzo(*a*)pyrene, perylene, benzo(*ghi*)pyrene

[b] Ranges in fish in ng/kg TEQs.

b.d. = below detection.

trawled for these two fish composites included some of the most contaminated samples observed during this round of sampling (e.g., SD21 and SD13) and were found to be classified as toxic by the bioassessments used for this ERA. HQs calculated for Cd (against MATCs) for samples UF-03-FT and UF-04-FT are 4.4 and 3.4, respectively. For PAHs, their HQs are 3.8 and 3.9, respectively.

One other exceedance of MATCs in mummichog tissues was observed. PCB levels in RF-02-FT, at 590 μg/kg, exceeded the MATC nearly threefold. Concentrations in the other reference area samples ranged from below detection to 80 μg/kg. No other analytes were elevated in this one sample. This is one of a few samples that experienced problems during the laboratory analytical procedure. Whether this value is an artifact of the analytical problems is unclear.

Higher trophic level, carnivorous fish species may also be at risk due to bioaccumulative compounds related to the site. To examine this issue, existing data for the white perch collected during previous field efforts were also evaluated. Because no dioxin or PAH data were available for these samples, analysis was limited to PCBs, DDTs, and Hg in white perch offal. Samples were collected from Selby Pond, near the boat club wetlands (Figure 2-1), and from Frash Pond. The maximum concentration of DDTs observed in tissue at Selby Pond, 350 μg/kg, and the maximum level of PCBs in a tissue sample from Frash Pond at 370 μg/kg (as Aroclor 1254) each exceeded their respective MATCs less than twofold (i.e., HQ of 1.75 and 1.85 for DDT and PCBs, respectively). Due to the lack of full analytical chemistry, the limited sampling locations, and tissues sampled, these data cannot be considered complete enough to adequately address bioaccumulative, trophic transfer risk to fish species. Therefore, this endpoint will not be considered further.

7.3.2 Bioaccumulation Effects in Birds

Risk from dietary exposure to bioaccumulative CoCs for two predatory avian species which may feed upon the organisms residing within areas affected by the site was evaluated using a food-web model (discussed in Section 5). Media-specific levels of CoCs were used in Equation 5-5 to estimate total dietary intake of CoCs for the black-crowned night heron and red-winged blackbird. **Table 7-12 (a-e)** presents the data on contaminants in prey items used in the food-web model for each exposure media (i.e., water, sediment crabs, fish, insects) for each area sampled (i.e., Ferry Creek, boat club wetlands, and reference). The table also indicates whether the values used were 95% upper confidence limits, maximum observed concentrations, or cases when only a single value was available (according to the data evaluation approach outlined in Section 5). These exposure data were then compared with RTVs for avian species to assess the potential for adverse effects.

The literature was reviewed for RTVs for birds for all CoCs at the Raymark facility. These NOELs and LOELs were obtained from the primary literature, EPA review documents, and on-line database (IRIS). **Table 7-13** presents the RTVs used as benchmarks in the food-web model. These RTVs are expressed as daily doses of contaminants normalized to the body weight of the test species. Values were not available for all CoCs. NOELs were available for many, but not all, CoCs. For mercury, a LOEL was used with a one-half extrapolation factor (from EPA 1993) to arrive at a NOEL value. For all other LOEL-to-NOEL conversions, one-tenth was used as the conversion factor. One analysis of avian LOEL-to-NOEL extrapolation values found that half the ratios are less than a factor of 3 (US EPA unpubl.). Therefore the factor of one-tenth used here should be adequately conservative. Data are rarely available for the wildlife species of interest, and most often must be extrapolated from other species (e.g., chicken, mallard). Because of this, the same RTVs were used for both heron and blackbirds. The RTVs were used as reported by their original authors, with no inter-species conversion other than allometric scaling to the heron and blackbird.

The results of the food-web model for black-crowned night heron, expressed as Hazard Quotients (HQs), are presented for each area in **Tables 7-14 (a-c)**. The contribution of each exposure media to the heron diet is shown, with the resulting total dietary dose. This total contaminant dose in the diet was then compared with the RTVs listed in Table 7-13 to calculate HQs for each CoC. HQs for each CoC were then summed and expressed as a Hazard Index (HI) to estimate the risk from the total cumulative dietary exposure.

Because the prey organisms included in the food-web model (and sampled from the site) represent about 75% of the diet reported for heron, a second set of risk quotients (the "adjusted" HQ) was also calculated. For the adjusted HQ, it was assumed that the contamination of the remaining 25% of the reported diet (e.g. small mammals, frogs) is the same as in the sampled and analyzed portion. The resulting adjusted HQs were about 33% greater. This is a conservative calculation which accounts for the uncertainty regarding the contaminant concentrations in the unsampled items of the reported diet of heron.

The HQ results for heron indicate that RTVs were exceeded only by Cr, and Pb. For Cr, the boat club wetlands were the only site-related area for which the HQs exceeded 1 (the adjusted HQ=1.06). Sediment was the principle media contributing to this value. Incidental sediment ingestion was estimated to equal 5% of the heron's dietary requirement. No data were available on the toxicity of Cr^{+6}, nor for the assimilation efficiency of Cr. For this

Table 7-12a. Concentrations of CoCs used as inputs to the avian food web model for each exposure r

Insect Tissue Data used in the Avian Food Web Model

	Ferry Creek				Reference area			
Inorganics (mg/kg, ww)	ncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected
Arsenic	0.24	x	na		0.25			x
Cadmium	0.94	x	na		0.78	x	na	
Chromium	1.04	x	na		1.73	x	na	
Copper	28	x	na		29.69	x	na	
Lead	2.22	x	na		7.2	x	na	
Mercury	0.01			x	0.015			x
Nickel	0.9	x	na		0.75	x	na	
Silver	nr				nr			
Zinc	77.5	x	na		87.05	x	na	
2,3,7,8-TCDD (ng/kg, ww)	2.23	x	na		1.38	x	na	
PAHs (ug/kg, ww)								
Acenaphthene	10			x	10			x
Acenaphthylene	10			x	10			x
Anthracene	10			x	10			x
Benz(a)anthracene	50			x	50			x
Benzo(a)pyrene	50			x	50			x
Benzo(b)fluoranthene	50			x	50			x
Chrysene	50			x	50			x
Dibenz(a,h)anthracene	50			x	50			x
Fluoranthene	10			x	10			x
2-Methylnaphthalene	nr				nr			
Naphthalene	10			x	10			x
Phenanthrene	26	x	na		47	x	na	
Pyrene	10			x	10			x
DDTS (ug/kg,ww)	12			x	12			x
PCBs (ug/kg, ww)	160			x	140			x

Concentrations where the value was undetected are 1/2 the detection limit

Table 7-12b. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Fish Tissue Data used in the Avian Food Web Model	Ferry Creek				Reference area			
Inorganics (mg/kg, ww)	Concentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected
Arsenic	0.6		x		0.45	x		
Cadmium	0.08		x		0.018	x		
Chromium	1.6		x		2.2	x		
Copper	11.2		x		6.5	x		
Lead	6.3		x		0.64	x		
Mercury	0.014		x		0.016	x		
Nickel	0.74		x		0.45	x		
Silver	0.03		x		0.05	x		
Zinc	49.9		x		42.6	x		
2,3,7,8-TCDD (ng/kg, ww)	1.3		x		0.67	x		
PAHs (ug/kg, ww)								
Acenaphthene	5	x			2.5	x		x
Acenaphthylene	2.5	x		x	2.5	x		x
Anthracene	6	x			2.5	x		x
Benz(a)anthracene	23	x			2.5	x		x
Benzo(a)pyrene	46	x			5	x		
Benzo(b)fluoranthene	114	x			7	x		
Chrysene	62	x			2.5	x		x
Dibenz(a,h)anthracene	7	x			2.5	x		x
Fluoranthene	86	x			2.5	x		x
2-Methylnaphthalene	2.5	x		x	2.5	x		x
Naphthalene	6	x			2.5	x		x
Phenanthrene	55	x			2.5	x		x
Pyrene	62	x			2.5	x		x
DDTS (ug/kg,ww)	11.1		x		30	x		
PCBs (ug/kg, ww)	213.7		x		1440	x		

Concentrations where the value was undetected are 1/2 the detection limit

Table 7-12c. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Sediment Data used in the Avian Food Web Model

	Ferry Creek				Housatonic Boat Club Wetland				Reference			
Inorganics (mg/kg, ww)	Concentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected
Arsenic	3.3		x		4.5		x		3.7		x	
Cadmium	1.9		x		0.67		x		0.55		x	
Chromium	66		x		140		x		121.3		x	
Copper	363.4		x		482		x		434.7	x		
Lead	250.5		x		122		x		42.1		x	
Mercury	0.19		x		0.4		x		0.38	x		
Nickel	30		x		18.5		x		14.4		x	
Silver	0.53		x		0.6		x		0.4		x	
Zinc	223.5		x		166.2		x		175.6		x	
2,3,7,8-TCDD (ng/kg, ww)	22		x		13.5		x		4.5		x	
PAHs (ug/kg)												
Acenaphthene	1794.5	x		x	825.75	x		x	192.4	x		x
Acenaphthylene	1794.5	x		x	825.75	x		x	192.4	x		x
Anthracene	1794.5	x		x	825.75	x		x	192.4	x		x
Benz(a)anthracene	1183.8		x		403.5		x		188.9		x	
Benzo(a)pyrene	1038.5		x		342.6		x		175.5		x	
Benzo(b)fluoranthene	1989.7		x		516.2		x		312.1		x	
Chrysene	1331.7		x		455.8		x		189.9	x		
Dibenz(a,h)anthracene	790.8		x		274.5		x		189.9		x	
Fluoranthene	2519.2		x		610.8		x		337		x	
Flourene	1794.5	x		x	825.75	x		x	192.4	x		x
2-Methylnaphthalene	1794.5	x		x	825.75	x		x	192.4	x		x
Naphthalene	1794.5	x		x	825.75	x		x	192.4	x		x
Phenanthrene	1087.2		x		263.3		x		189.9		x	
Pyrene	2018		x		541.8		x		268.8		x	
DDTS (ug/kg,ww)	7		x		6.5		x		3		x	
PCBs (ug/kg, ww)	625.8		x		274		x		135.9		x	

Concentrations where the value was undetected are 1/2 the detection limit

Table 7-12d. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Crab Data used in the Avian Food Web Model

Inorganics (mg/kg, ww)	Ferry Creek				Housatonic Boat Club Wetlands a				Reference a			
	Concentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected	Concentration	Maximum Value	95% UCL	Undetected
Arsenic	1.6	x			2.00	na	na	na	1.70	na	na	na
Cadmium	1.26	x			0.05	na	na	na	0.09	na	na	na
Chromium	2.32	x			2.29	na	na	na	3.73	na	na	na
Copper	72.2	x			102.72	na	na	na	52.65	na	na	na
Lead	15.8	x			52.49	na	na	na	3.66	na	na	na
Mercury	0.01	x		x	0.02	na	na	na	0.02	na	na	na
Nickel	3.3	x			2.58	na	na	na	2.75	na	na	na
Silver	nr				nr	na	na	na	nr	na	na	na
Zinc	27.4	x			27.14	na	na	na	23.49	na	na	na
2,3,7,8-TCDD (ng/kg, ww)	4.28	x			15.7	na	na	na	2.29	na	na	na
PAHs (ug/kg)												
Acenaphthene	2.5	x		x	2.5	x		x	2.5			x
Acenaphthylene	2.5	x		x	2.5	x		x	2.5			x
Anthracene	2.5	x		x	2.5	x		x	2.5			x
Benz(a)anthracene	20	x			5	x			2.5			x
Benzo(a)pyrene	30	x			7	x			6	na		na
Benzo(b)fluoranthene	33	x			12	x			9			
Chrysene	31	x			13	x			2.5			x
Dibenz(a,h)anthracene	10	x			2.5	x		x	2.5			x
Fluoranthene	53	x			2.5	x		x	2.5			x
Flourene	2.5	x			2.5	x		x	2.5			x
2-Methylnaphthalene	nr				nr				nr	na		na
Naphthalene	6	x			2.5	x		x	5	na		na
Phenanthrene	16	x			2.5	x		x	2.5			x
Pyrene	54	x			2.5	x		x	2.5			x
DDTS (ug/kg,ww)	5.5	X		X					3.5			x
PCBs (ug/kg, ww) b	170	X			1560				60	na		na

Concentrations where the value was undetected are 1/2 the detection lim

nr: not reported

na: not applicable because only one sample was collected from this area

a — Only one sample collected from this area.

b — Value is for total PCBs as determined by EPA.

Table 7-12e. Concentrations of CoCs used as inputs to the avian food web model for each exposure media.

Surface Water Data used in the Avian Food Web Model

	Ferry Creek				Housatonic Boat Club Wetland				Reference			
Inorganics (µg/L)	ncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected	oncentration	Maximum Value	95% UCL	Undetected
Arsenic	21.6		x		16.2	x			4.8	x		
Cadmium	1.2	x		x	2.3	x			0.7	x		x
Chromium	12.4		x		59.2	x			15.9	x		
Copper	121	x			138	x			17.9	x		x
Lead	13.7		x		37.2	x			3.3	x		
Mercury	0.55		x		3.5	x			6	x		
Nickel	11.7	x			1.8	x		x	1.8	x		x
Silver	1.7	x		x	1.7	x		x	1.7	x		x
Zinc	127	x			15.5	x		x	r			
2,3,7,8-TCDD (ng/L)	na				na				na			
PAHs (ug/L)												
Acenaphthene	5	x		x	5	x		x	5	x		x
Acenaphthylene	5	x		x	5	x		x	5	x		x
Anthracene	5	x		x	5	x		x	5	x		x
Benz(a)anthracene	5	x		x	5	x		x	5	x		x
Benzo(a)pyrene	5	x		x	5	x		x	5	x		x
Benzo(b)fluoranthene	5	x		x	5	x		x	5	x		x
Chrysene	5	x		x	5	x		x	5	x		x
Dibenz(a,h)anthracene	5	x		x	5	x		x	5	x		x
Fluoranthene	5	x		x	5	x		x	5	x		x
Flourene	5	x		x	5	x		x	5	x		x
2-Methylnaphthalene	5	x		x	5	x		x	5	x		x
Naphthalene	5	x		x	5	x		x	5	x		x
Phenanthrene	5	x		x	5	x		x	5	x		x
Pyrene	5	x		x	5	x		x	5	x		x
DDTS (ug/L)	0.104		x		0.15	x		x	0.15	x		x
PCBs (ug/L)	2.1		x		2.25	x		x	2.25	x		x

Concentrations where the value was undetected are 1/2 the detection limit
r: all data were rejected
na: not analyzed

Table 7-13. RTVs for use in the avian food web model and their sources.

Contaminant of Concern	Compound Tested	Test Species	Body Weight (kg)	Condition Evaluated [a]	RTV (mg/kg Bw/day)	Endpoint	Extrapolation Factor [b]	Source	Allometrically scaled species-specific NOEL BCNH (mg/kg Bw/day)	RWBB (mg/kg Bw/day)
arsenic	sodium arsenite	mallard	1	M	5.135	Chronic NOEL	NA	USFWS 1964	5.35	13.6
cadmium	cadmium chloride	mallard	1.153	R	1.45	Chronic NOEL bounded	NA	White and Finley 1978	1.58	4.02
chromium+3	CrK(SO4)2	black duck	1.25	R	1	Chronic NOEL	NA	Hasetine et al., unpub.	1.12	2.85
copper	copper oxide	chicken	0.534	G,M	28.13	Chronic NOEL bounded	NA	Mehring et al. 1960	23.8	60.3
lead	metallic	American kestrel	0.13	R	2.05			Paltee 1984	1.08	2.75
mercury		mallard	1	R	0.064	LOEL unbounded	1/2	Heinz et al. 1979	0.03	0.08
nickel	nickel sulphate	mallard	0.782	M,G	77.4	Chronic NOEL bounded	NA	Cain and Pafford 1981	74.3	188.5
silver	silver nitrate, chloride, and thiosulfate	chickens	0.4	G	12.5	Subchronic NOEL	NA	Hill and Matrone 1970	9.6	24.4
zinc	zinc carbonate	chicken	1.9	M	11.3	Chronic NOEL	NA	Gasaway and Buss 1972	14.6	37.0
Dioxin TEQs	2,3,7,8-TCDD	ringed-neck pheasants	0.121	R	0.000014	Chronic NOEL bounded	NA	Noesek et al. 1992	0.000007	0.000018
Naphthalene	TPH	mallard	1.3	M	338	Chronic LOEL	1/10	Patton and Dieter 1980	38.4	97.5
Phenanthrene	TPH	mallard	1.3	M	338	Chronic LOEL	1/10	Patton and Dieter 1980	38.4	97.5
DDTS		brown pelican	3.5	R	0.028	Chronic LOEL	1/10	EPA 1993	0.004	0.011
PCBs		pheasant	1	R	1.8	Chronic LOEL	1/10	EPA 1993	0.19	0.48

a— M: mortality R: reproduction G: growth
b — EPA, 1993: LOEL to NOEL factor of two, rather than ten, was used for Hg because the LOEL appeared to be near the threshold for dietary effects.

assessment, an RTV for Cr^{+3} and 85% assimilation was assumed. Also, speciation of Cr was not valuated; therefore, total Cr concentrations in sediment and tissues were used. The adjusted HQ for Cr also exceeded 1 for the reference area (HQ=1.32). Sediment accounted for about 75% of the estimated ingested concentration of Cr for this area.

Total ingestion of Pb calculated for both the Ferry Creek and boat club wetland areas resulted in HQs exceeding 1. The unadjusted HQs for Pb were 2.59 and 2.33 for the Ferry Creek and boat club wetland areas, respectively; whereas the adjusted HQs were 3.45 and 3.11, respectively. Fish consumption accounted for 85% of the total estimated amount of Pb ingested in the wetland area, but only about one-third of the total for the Ferry Creek area. Estimated incidental ingestion of sediment in the Ferry Creek area accounted for most (60%) of the total modeled concentration of Pb ingested.

HQs for DDTs and PCBs also exceeded 1, but only at the reference area. The adjusted HQs for Milford Point for DDTs and PCBs were 1.21 and 1.33, respectively. The fish represented nearly the entire exposure for these CoCs. For this assessment, 85% assimilation was assumed, maximum values were used, and undetected Aroclors were added to the sum of all PCBs at one-half their detection level. Also, the PCB values were suspect due to laboratory analytical concerns. The value used for total PCBs in the model was 1,440 µg/kg (from sample RF-02-FT), when in fact the highest actual detected value was 590 µg/kg as Aroclor 1260 (430 µg/kg in a lab duplicate), and the second highest detected value was only 80 µg/kg as Aroclor 1260. Aroclor 1260 was the only Aroclor detected in any fish samples; however, Aroclor 1268, a CoC, was not included in the analysis. It is also unlikely that heron feed exclusively in an area as small as that represented by the area of the fish-tissue composite collected for this assessment. These factors lead to a conservative, possible overestimate of risk due to PCBs. It is unlikely that there would be any impact to heron from exposure to these CoCs in the Milford Point wetland area.

This assessment estimated the risk associated with each CoC individually. Certain combinations of contaminants are known to have synergistic or antagonistic impacts in concert. In particular, the chlorinated compounds—DDTs, PCBs, and TCDD TEQs—are known to have certain interactions. The sum of HQs (the Hazard Index, or HI) for these chlorinated compounds therefore carries some uncertainty and may overestimate their potential cumulative impact. For instance, not all PCB congeners interfere with biological systems in a similar manner. However, a summation of these compounds allows some estimate of potential impact. For the Ferry Creek area, the HI was 0.66, and the adjusted HI was 0.85. Fish and crabs contributed the major proportion of HQs for DDTs and PCBs, while fish, crab, and sediment contributed equally to the TCDD TEQ HQ. Given that contamination of Ferry Creek is moderately widespread, and that these CoCs have similar environmental behavior (e.g., biomagnification, extreme persistence) and biological impacts (e.g., reproductive impairment), it is possible that these CoCs in combination might have cumulative impacts. It should also be noted that PCB congeneranalysis was not performed; therefore, impacts from particular congeners cannot be estimated.

Table 7-14a. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Ferry Creek

Contaminant of Concern	Fish mg/day, ww (0.133kg/day)	Crab mg/day, ww (0.036kg/day	Insects mg/day, ww (0.002kg/day	Sediment mg/day, ww (0.006kg/day	Water mg/day, ww (0.05L/day)	Total Assimilated i mg/day	Total i mg/kg Bw /day	RTV mg/kg Bw /day	Hazard Quotient	Adjusted HQ (b)
Inorganics										
arsenic	0.08	0.058	0.0005	0.020	0.00108	0.1	0.2	5.35	0.03	0.04
cadmium	0.01	0.045	0.0019	0.011	0.00006	0.06	0.1	1.58	0.04	0.06
chromium (+3)	0.21	0.084	0.0021	0.396	0.00062	0.6	0.7	1.12	0.60	0.79
copper	1.49	2.599	0.0560	2.180	0.00605	4.1	4.7	23.79	0.20	0.34
lead	0.84	0.569	0.0044	1.503	0.000685	2.5	2.8	1.08	2.59	3.45
mercury	0.00	0.000	0.0000	0.001	0.0000275	0.003	0.003	0.0334	0.10	0.13
nickel	0.10	0.119	0.0018	0.180	0.000585	0.34	0.4	74.3	0.01	0.01
silver	0.00	nr	nr	0.003	0.000085	0.01	0.007	9.60	0.0007	0.0010
zinc	6.64	0.986	0.1550	1.341	0.00635	7.8	8.8	14.6	0.60	0.80
TCDD TEQs (a)	0.17	0.154	0.0045	0.13	nr	0.39	0.4	7.22	0.06	0.08
Naphthalene	0.0008	0.00022	0.000020	0.011	0.00025	0.01	0.012	38.4	0.0003	0.0004
Phenanthrene	0.0073	0.00058	0.000052	0.0065	0.00025	0.01	0.014	38.4	0.0004	0.0005
DDTS	0.0015	0.00020	0.000024	0.0000	0.0000052	0.0015	0.0017	0.0044	0.38	0.51
PCBs	0.0284	0.00612	0.000320	0.0038	0.000105	0.03	0.037	0.188	0.20	0.26
								Hazard Inde =	4.80	6.48

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 7-14b. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Housatonic Boat Club Wetlands

Contaminant of Concern	Fish mg/day, ww (0.133kg/day)	Crab mg/day, ww (0.036kg/day	Insects mg/day, ww (0.002kg/day	Sediment mg/day, ww (0.006kg/day	Water mg/day, ww (0.05L/day)	Total Assimilated i mg/day	Total i mg/kg Bw-day	RTV mg/kg Bw-day	Hazard Quotient	Adjusted HQ (b)
Inorganics										
arsenic	nc	0.072	nc	0.027	0.00081	0.1	0.1	5.35	0.02	0.02
cadmium	nc	0.002	nc	0.004	0.000115	0.01	0.01	1.58	0.004	0.005
chromium (+3)	nc	0.082	nc	0.840	0.00296	0.8	0.9	1.12	0.79	1.06
copper	nc	3.698	nc	2.892	0.0069	4.3	4.9	23.79	0.20	0.36
lead	nc	1.889	nc	0.732	0.00186	2.2	2.5	1.08	2.33	3.11
mercury	nc	0.001	nc	0.002	0.000175	0.003	0.003	0.0334	0.09	0.12
nickel	nc	0.093	nc	0.111	0.00009	0.17	0.2	74.3	0.0026	0.0035
silver	nc	nr	nc	0.004	0.000085	0.003	0.004	9.60	0.0004	0.0005
zinc	nc	0.977	nc	0.997	0.000775	1.7	1.9	14.6	0.13	0.17
TCDD TEQs (a)	nc	0.57	nc	0.081	nr	0.55	0.6	7.22	0.09	0.11
Naphthalene	nc	0.00009	nc	0.0050	0.00025	0.005	0.005	38.4	0.0001	0.0002
Phenanthrene	nc	0.00009	nc	0.0016	0.00025	0.002	0.002	38.4	0.00005	0.00006
DDTS	nc	0	nc	0.000039	0.0000075	0.00004	0.00004	0.0044	0.01	0.01
PCBs	nc	0.056	nc	0.001644	0.0001125	0.05	0.06	0.188	0.30	0.40
								Hazard Index =	3.97	5.37

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 7-14c. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Milford Point Reference Area

Contaminant of Concern	Fish mg/day, ww (0.133kg/day)	Crab mg/day, ww (0.036kg/day	Insects mg/day, ww (0.002kg/day	Sediment mg/day, ww (0.006kg/day	Water mg/day, ww (0.05L/day)	Total Assimilated i mg/day	Total i mg/kg Bw /day	RTV mg/kg Bw /day	Hazard Quotient	Adjusted HQ (b)
arsenic	0.06384	0.061	0.0005	0.022	0.00024	0.1257952	0.14	5.35	0.03	0.04
cadmium	0.002394	0.003	0.00152	0.003	0.000035	0.0088633	0.01	1.58	0.01	0.01
chromium (+3)	0.2926	0.134	0.00346	0.728	0.000795	0.9850274	1.12	1.12	0.99	1.32
copper	0.9044	1.895	0.05938	2.608	0.000895	3.5543086	4.0	23.79	0.17	0.29
lead	0.08512	0.132	0.0144	0.253	0.000165	0.4115117	0.47	1.08	0.43	0.57
mercury	0.002128	0.001	0.00003	0.002	0.0003	0.0047277	0.005	0.0334	0.16	0.21
nickel	0.05985	0.099	0.00156	0.086	0.00009	0.2097671	0.24	74.3	0.003	0.004
silver	0.00665	nr	nr	0.002	0.000085	0.0077648	0.01	9.60	0.001	0.001
zinc	5.6924	0.845	0.1741	1.054	r	6.6005302	7.5	14.6	0.51	0.68
TCDD TEQs (a)	0.08911	0.082	0.00276	0.027	nr	0.1711135	0.19	7.22	0.03	0.04
Naphthalene	0.0003325	0.00018	0.000020	0.0012	0.00025	0.0016464	0.002	38.4	0.00005	0.00006
Phenanthrene	0.0003325	0.00009	0.000094	0.0011	0.00025	0.00162	0.002	38.4	0.00005	0.00006
DDTS	0.00399	0.00013	0.000024	0.000018	0.0000075	0.0035407	0.0040	0.0044	0.91	1.21
PCBs	0.19152	0.002	0.00028	0.00082	0.00011	0.17	0.19	0.188	1.00	1.33
								Hazard Indc =	4.21	5.68

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of 25% unsampled.

nr: analyte not reported in this media

r: concentration data rejected

Results of the HQ calculations for the red-winged black bird for the Upper Ferry Creek and reference areas are presented in **Table 7-15**. For this assessment, it was assumed that the entire food diet was insects. Red-winged blackbirds feed their nestlings primarily insects. The total dietary dosage also included water as an exposure route. Assimilation efficiencies of CoCs used were the same as those for the heron: 65% for copper, and 85% for all other CoCs. A home range factor of 90% was incorporated, as well.

The results of the food-web model for blackbirds indicate no HQs greater than 1. The modeled ingestion of chlorinated compounds (DDTs, PCBs, and TCDD TEQs) approaches only one-third of the benchmarks (i.e., HI<0.33).

Table 7-15 Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the Red-winged Black Bird.

Ferry Creek

Contaminant of Concern	Insects mg/day, ww (0.023kg/day)	Water mg/day, ww (0.01L/day)	Total (a) Assimilated mg/day	Total (b) mg/kg Bw /day	RTV mg/kg Bw /day	Hazard Quotient
Inorganics						
arsenic	0.0050	0.00022	0.0044	0.07	13.6	0.005
cadmium	0.019	0.000012	0.0165	0.28	4.02	0.069
chromium (+3)	0.022	0.00012	0.0184	0.31	2.85	0.11
copper	0.58	0.0012	0.38	6.29	60.3	0.104
lead	0.046	0.00014	0.0392	0.65	2.75	0.24
mercury	0.00021	0.0000055	0.0002	0.003	0.085	0.04
nickel	0.019	0.00012	0.0159	0.27	158.5	0.0014
silver	nr	0.000017	0.0000	0.0002	24.4	0.000010
zinc	1.60	0.0013	1.3647	22.74	37.0	0.61
TCDD TEQs (c)	0.05	nr	0.0392	0.65	18.3	0.036
Naphthalene	0.00021	0.000050	0.0002	0.0036	97.5	0.000037
Phenanthrene	0.00054	0.000050	0.0005	0.01	97.5	0.000085
DDTS	0.00025	0.0000010	0.0002	0.0035	0.011	0.31
PCBs	0.0033	0.000021	0.0028	0.05	0.48	0.099
					Hazard Index =	1.63

Milford Point Reference Area

Contaminant of Concern	Insects mg/day, ww (0.023kg/day)	Water mg/day, ww (0.01L/day)	Total Assimilated mg/day	Total mg/kg BW/day	RTV mg/kg Bw-day	Hazard Quotient
Inorganics						
arsenic	0.0052	0.000048	0.0044	0.07	13.6	0.01
cadmium	0.016	0.000007	0.0134	0.22	4.02	0.06
chromium (+3)	0.036	0.00016	0.0306	0.51	2.85	0.18
copper	0.61	0.000179	0.40	6.66	60.3	0.11
lead	0.15	0.000033	0.1267	2.11	2.75	0.77
mercury	0.00031	0.00006	0.0003	0.01	0.085	0.06
nickel	0.016	0.000018	0.0137	0.23	188.5	0.0012
silver	nr	0.000017	0.0000	0.00	24.4	0.00001
zinc	1.80	-	1.5316	25.53	37.0	0.69
TCDD TEQs (c)	0.029	nr	0.0243	0.40	18.3	0.02
Naphthalene	0.00021	0.00005	0.0002	0.004	97.5	0.00004
Phenanthrene	0.00097	0.00005	0.0009	0.01	97.5	0.0001
DDTS	0.00025	0.0000015	0.0002	0.004	0.011	0.32
PCBs	0.0029	0.0000225	0.0025	0.04	0.48	0.09
					Hazard Index =	2.30

a — Adjusted for bioavailability factor.
b — Adjusted for 90% home range factor.
c — 2,3,7,8-TCDD TEQs in ng/kg, ww
nr: analyte not reported in this media
r: concentration data rejected

.0 RISK CHARACTERIZATION

Evaluation of the contaminants of concern in the sediment of Ferry Creek, the Housatonic River near the mouth of Ferry Creek, and the wetlands associated with those areas indicate that they pose a risk to some of the assessment endpoints of this risk assessment, including the benthic community and oyster larvae survival, growth, and reproduction. Risk to benthic invertebrates from CoCs was evaluated using the sediment-quality triad approach (described below). The risk to oyster larvae was measured directly by laboratory toxicity tests, as well as inferred by comparison with benchmark values. These tests are also relevant to interpreting risk to the benthic community as a whole.

8.1 RISK TO THE BENTHIC COMMUNITY

8.1.1 Sediment Toxicity

The sediment-quality triad is a weight-of-evidence approach consisting of synoptically collected measures of bulk sediment chemistry (which are compared with benchmarks), sediment toxicity, and benthic community structure (Chapman et al. 1992). The coincident occurrence of elevated concentrations of CoCs (presented in Section 6.2), greater sediment toxicity (presented in Section 7.1), and benthic community alterations (presented in Section 7.2) act as complementary indicators of adverse impacts to the benthic community.

Under the triad weight-of-evidence approach, a station should not be assumed indicative of unacceptable risk if there is an adverse response in only one of the triad measures. Conversely, the potential for unacceptable risk cannot be dismissed when only one element indicates some potential adverse response. These situations must be interpreted cautiously and according to the site-specific situation.

Indications of adverse response in two of the three triad measures at a station are considered a likely expression of risk. Evidence of toxicity and benthic community alterations, but comparatively low concentrations of CoCs, typically indicate conditions that either the active chemical agent or stressor was not measured by the analytical chemistry; that combinations of contaminants in a mixture acted in synergy; or that environmental conditions exist such that bioavailability of contaminants was altered from the conditions in the field during the sampling and handling process.

Stations with differences in responses of either one or two of the three triad measures indicate some form of stress to biota. These samples require careful consideration and interpretation, however. In some cases, evaluation may involve generating new hypotheses and resampling to determine causative agents, or mitigative agents in the case of high concentrations in sediment chemistry but no apparent toxicity. The easiest interpretation, and clearest demonstration, of unacceptable risk occurs when all three measures in the sediment triad indicate adverse responses.

A tabulation of the results of the sediment-parameter triad used to assess risks to the benthic community is presented in **Table 8-1**. For this table, five key indicator CoCs were selected based on their degree of elevation above either reference samples or sediment quality guidelines, their known association with site-derived waste, and/or their concordance with adverse responses of the bioassessment endpoints noted earlier. These five CoCs are:

- copper
- lead
- total PAHs (tPAH)

- PCB Aroclor 1268
- TCDD toxicity equivalency quotients (TEQ)

Two sediment-quality benchmarks were used, both of which evaluate paired sediment chemistry and toxicity data. An Apparent Effects Threshold (AET) is the concentration of a CoC at which a "probable effect" is observed. The Threshold Effects Level (TEL) is the concentration of a CoC below which an adverse effect is unlikely. Samples with HQ_{AET}s greater than 1 were classified as clearly predictive of unacceptable risk, whereas samples with HQ_{TEL}s less than 1 would indicate a low probability of any risk.

The SEM/AVS ratio is also included in Table 8-1. A ratio less than 1 indicates sufficient AVS to sequester all of the divalent metals measured, while values greater than 1 indicate that a portion of these metals may be bioavailable and may pose potential acute toxicity. Other ligands are known to exist in the sediment, primarily organics, and are known to be influential factors affecting the bioavailability of some of these metals (NOAA 1995). Therefore, values of the AVS ratio slightly greater than 1 are not absolute predictions of acute toxicity. The greater the ratio, however, the more likely that samples could be acutely toxic. The degree to which the SEM/AVS ratio provides predictions of chronic toxicity and bioaccumulation potential is currently a topic of discussion (NOAA 1995).

Samples were considered "toxic" if statistically significant reductions in survival were observed in the laboratory in the amphipod test, relative to the response observed in the control. Statistical comparison was also made to the appropriate reference sample. Optimally, the reference sample replicates all of the characteristics of the test samples (i.e., grain size, TOC, ammonia, sulfides) except the site-related contaminants. Using the reference sample as the comparison response (instead of a laboratory control) is intended to allow for responses due to non-persistent stressors of the sediment matrix. Any response in test sediments beyond that can then be more clearly attributed to stress of site-related contamination. Although the avoidance measurement can be informative, it is given less weight independently as an indication of toxicity (Chapman, pers. commun., 1994).

Samples exhibiting either statistically significantly greater larval abnormality or combined mortality when compared with the control response were considered "toxic" in the oyster larvae bioassay.

Adverse response in benthic community structure was considered present if statistically significant reductions were present at stations when compared with the reference location for any of the following indices of community structure:

- total abundance,
- taxa evenness,
- taxa richness, and
- taxa diversity.

Samples were classified as clearly indicative of unacceptable risk if all three sediment-triad parameters indicated adverse responses. Responses from samples were classified as likely indicators of risk if two of the three parameters indicated adverse responses. Avoidance of sample sediment by amphipods was not given as great a weight as the other measures. Results from either the amphipod or oyster bioassay were used for the sediment-toxicity parameter of the sediment triad. Samples not evaluated by all sediment-triad parameters could be

Table 8-1. Summary of results of sediment quality triad analysis.

Zone	Station/ Sample	Key CoCs versus Guidelines [a]					SEM/AVS ratio [b]	Amphipod Bioassay		Oyster Larvae Bioassay		Altered Benthic Indices [c]				Classification
		Cu	Pb	Total PAHs	PCBs	TEQs		Mortality	Avoidance	Abnormality	Mortality	A	E	R	D	
Boat	HB-23	+	+	+	+	+	+	ns	ns	+	+	+	ns	ns	+++	Unacceptable risk
Club	HB-06	~	•	•	•	•	~	ns	ns	—	—	—	—	—	—	
Wetlands	HB-12	+	~	~	~	•		ns	ns	—	—	—	—	—	—	
Lower	SD-07	~	~	+	+	~		+	ns	—	—	ns	+	ns	++	Unacceptable risk
Ferry	SD-19	~	~	~	+	•	~	ns	+	—	—	ns	ns	ns	++	Potential risk
Creek	SD-10	+	~	~	+	~		ns	+	ns	ns	—	—	—	—	
Upper	SD-13	+	+	+	+	+	~	+	+	+	+	+	ns	+	+++	Unacceptable risk
Ferry	SD-21	+	+	+	+	+	+	+	+	—	—	—	—	—	—	Potential risk
Creek	SD-20	~	~	+	+	+	~	ns	+	—	—	+	+	+	+++	Potential risk

a — + indicates concentration over the AET (*i.e.*, probable effects); ~ indicates value between TEL and AET (*i.e.*, possible effects); and, • indicates below TEL (*i.e.*, improbable effects).
b — + indicates a ratio greater than 5, and ~ indicates a ratio between 1 and 5.
c — A refers to overall abundance; E to evenness; R to richness; and, D to the three diversity numbers of Hill.
—: not tested by this endpoint.
ns : no significant difference was detectable.

categorized only as potentially indicating risk. These classifications, included in Table 8-1, indicate three stations where all sediment-triad parameters clearly indicate significant, unacceptable risk to the benthic community (HB23, SD13, SD07), and three stations which potentially demonstrate conditions of significant risk (SD19, SD20, SD21).

Samples from stations HB23 at the Housatonic Boat Club, plus stations SD13 and SD07 in Ferry Creek, were all classified as adversely impacted. There were indications at those stations of statistically significant mortality following exposure to sediment; exceedance of sediment-quality guidelines in the samples; and impacted benthic community composition at the stations where those samples were collected. These samples had substantially elevated concentrations of the five indicator CoCs (copper, lead, PCBs, total PAHs, and TCDD TEQ). HQ_{AET}s for all five indicator CoCs in samples from stations SD13 and HB23 were above 1 and reached a maximum of 47. The sample from station SD07 contained PCBs and PAHs above their respective AETs, while HQ_{AET}s for TCDD TEQs, copper, and lead were all less than 1 (~0.75). These samples also had detectable levels of other CoCs, including a variety of chlorinated pesticides and chromium. The sample from station HB23 also had the highest SEM/AVS ratio of 37, indicating a fair potential for bioavailable, toxic, divalent metals. The sample from station SD-13 from Upper Ferry Creek had the clearest demonstration of adverse impacts since all sediment-triad parameters were in clear agreement; i.e., sediment analytical chemistry indicated contamination above AET benchmarks; both the amphipod and oyster toxicity bioassays indicated risk; and the benthic community was severely altered. These three stations all present significant, unacceptable risk to benthic organisms. These organisms are likely stressed by chronic lethality, reduced scope for growth, and reproductive impairment.

Samples from stations SD19, SD20, and SD21 were all classified as potentially exhibiting risk to the benthos. These samples either lacked at least one of the bioassessment measures (benthic community at SD21) or provided mixed indications. This situation somewhat limits the certainty with which definitive conclusions regarding risk can be made for these stations. However, in each case the measures available suggest the presence of significant risk. Discussions of these indications at each station follow.

Samples from station SD19 exhibited significant benthic community alterations. These alterations were characterized by reduced number of species, increased dominance by abundant species, and the near-total absence of amphipods. Amphipods are considered sensitive species (Lamberson et al. 1992), and their absence often indicates adverse impacts from chemical contamination. The amphipod toxicity test showed no significant reduction in survival, although test organisms avoided the sample. Avoidance may interfere with the survival endpoint since it tends to reduce exposure levels. However, chemical analysis of the sediment samples, when compared with sediment-quality guidelines (TELs and AETs), did not suggest substantial risk. Concentrations for all five indicator CoCs were between TELs and AETs. The maximum HQ_{AET} calculated was 0.9 for chromium. Hazard quotients were, in fact, intermediate to the two high-salinity reference stations. The oyster-larvae toxicity test was not conducted at this location. This station lies in a side channel, or inlet, on the west side of Lower Ferry Creek. Possibly, the benthic community is responding to stressors other than the CoCs associated with the site-related waste material. It is also likely that the amphipod bioassay may not provide a comprehensive, acute response to the organic contaminants present at this location (e.g., PCBs, dioxins).

The benthic community at SD20 was characterized as having reduced abundance, taxa richness, and a near absence of amphipods. Because this was the station closest to the head of the creek, the benthic community structure may partially reflect the influence of tidal fluctuations, although this would not fully explain the severely reduced abundance of insects, the depressed diversity of species, and reduced overall density. The benthic community at this station may be responding to the toxic stress of organic CoCs. This sample was not identified as toxic by the amphipod bioassay; however, the lack of statistically significant difference in responses of amphipods may be explained by the fact that some of these organic CoCs (especially the chlorinated compounds) would not have come to steady-state during a ten-day amphipod test. Therefore, the acute lethality results may not reflect the impacts to which the benthic community is responding under chronic exposures. Also, the amphipods avoided test sediments which would diminish exposure levels. Mean amphipod mortality in this sample was 23%, just beyond the rejection level for statistically significant differences from the reference value (ρ=0.069). These results certainly seem to indicate toxicity, and there clearly is some form of stress to the benthic community at this station in concordance with general contamination trends. The sediment sample from SD20 exhibited elevated concentrations of PAHs and PCBs, relative to AET sediment-quality guidelines (HQ_{AET}s of 4.7 and 6.8, respectively), plus the second highest concentration of endrin measured. This sample also had the second highest concentration of cadmium (HQ_{AET} of 2.3). The overall HI for this sample was approximately twice that of the reference station. Although the exact nature of the stress evident in the benthic community structure, and the portion of risk posed by chemical contamination, cannot be definitively determined from the available data, these data certainly suggest that the benthic community at this station is potentially at risk from exposure to CoCs.

There were four stations at which samples were analyzed for sediment chemistry and amphipod toxicity, although no survey of the benthic community was conducted. SD21, in Upper Ferry Creek, was one of these four stations. The sample from this station had statistically significant reductions in amphipod survival—the second greatest reduction observed in all the samples where the test was performed. This sample contained the highest concentrations of Cu, Pb, and TCDD TEQs, plus the second highest concentration of PCBs (HQ_{AET}s ranging from 2 to 44). The overall HI for this sample was the highest among all samples and an order of magnitude greater than those for reference samples. Based on the toxicity to amphipods and elevated concentrations of CoCs, this station was considered indicative of unacceptable risk to the benthic community, despite the lack of direct benthic community observations.

There were three additional samples not classified as adversely or potentially affected—those from stations HB06 and HB12 at the Housatonic Boat Club wetland and SD10 in Lower Ferry Creek. The sample from station HB12 was not toxic to amphipods, but did contain moderate levels of copper (HQ_{AET} of 1.5). However, the SEM/AVS ratio for this sample indicated that the copper measured would not be biologically available. Therefore, an acute response in the toxicity test would not be expected from copper. The sample from station HB06 showed neither elevated concentrations of the indicator CoCs nor statistically significant reductions in mean survival in the amphipod toxicity test. Aside from the copper in the sample from station HB12, concentrations of indicator CoCs in these two samples were generally lower than TELs, although occasionally between TELs and AETs. In contrast, the sample from station SD10 was not toxic either by the amphipod or oyster toxicity test, although it exceeded some sediment-quality guidelines. Copper, PAHs, and PCBs exceeded their respective AETs (HQ_{AET} from 1.5 to 5.8). However, the SEM/AVS ratio would suggest that divalent metals (including copper) were not biologically available in this sample.

The absence of adverse biological responses in general accordance with the sediment chemistry further substantiates the integrity of the sediment triad approach, and thereby the conclusions regarding the risk factors applied to other stations using this methodology. The sediment triad analysis indicates that chemical contaminants found in the sediment of Ferry

Creek and the wetland adjacent to the Housatonic Boat Club pose an unacceptable and significant risk to the benthic community. Stations throughout the sampling area had elevated concentrations of CoCs and adverse responses in a variety of indicators of benthic community health. The likelihood of risk was confirmed by the measurement of sediment toxicity in laboratory tests and *in situ* biological effects as measured by alterations to the benthic community structure. Samples with the greatest impacts observed in the bioassessment measures also had the largest number of CoCs present and generally the highest observed concentrations.

To further investigate the association between the biological responses observed and bulk sediment chemistry, the mean concentration of all CoCs in "toxic" samples were compared against those categorized as "non-toxic." Ratios of these means were then calculated: A ratio substantially greater than 1 would indicate a generally greater contribution to the overall contamination by that CoC. Mean toxic concentrations were also compared with AET sediment-quality guidelines. These upper thresholds of toxicity represent the level above which adverse biological responses would *always* be predicted, based on the concentration of just one CoC, as indicated by any one of the biological endpoints included in the AET database. Adverse biological responses also occur when sediment contamination is below the AET value, especially in situations of multiple, cumulative exposure to several CoCs. Results of these analyses are presented in **Table 8-2**. These analyses confirm that PCBs, dioxin TEQs, copper, and lead are the CoCs elevated to the greater degree in toxic samples. These analyses also suggest that cadmium, chlordanes, endrin, and heptachlor epoxide may appear to be potential secondary contributors to risk, according to their relative concentrations in toxic samples. The CoCs that apparently present the greatest proportion of risk, by comparison with AET guidelines, in order, are copper, PAHs, lead, PCBs, and dioxins. Hazard quotients for these mean concentrations of CoCs in the "toxic" samples, relative to AETs, ranged from 56.9 to 8.8. This analysis supports conclusions from the sediment triad that biological impacts observed are driven by exposure.

8.1.2 Potential Risk to Oyster Larvae

Oyster larval toxicity tests were conducted on sediment samples from one station each in Upper Ferry Creek (SD13), Lower Ferry Creek (SD10), and the Housatonic Boat Club wetland (HB23). Test results showed statistically significant increases in the percent of abnormally developed larvae at Stations HB23 and SD13 as well as increases in combined mortality (i.e., percent abnormality plus percent mortality). Stations HB23 and SD13 showed highly elevated concentrations of the five indicator CoCs (HQ_{AETs} from 2 to 47)—most notably Cu, Pb, and TCDD TEQs (see Tables 6-3, 6-4, and 8-2). The presence of elevated CoCs and measurable toxicity in the oyster larval toxicity test indicate that sediment from the Housatonic Boat Club wetland and Upper Ferry Creek pose an unacceptable risk to recruitment in oyster spat beds if sediment from the sample areas is transported to the beds.

8.2 *BIOACCUMULATIVE RISK*

Several of the CoCs are known to bioaccumulate or biomagnify. These types of CoCs pose the greatest risk to higher-trophic-level organisms through food-web exposures. Risks to fish and to avian species were evaluated primarily by comparing bioaccumulation of CoCs measured in tissues collected from the study areas to benchmark body-burden values associated with known or predicted toxic impacts. This sort of HQ approach identifies samples where toxic benchmarks are exceeded and adverse effects are possible. However, this approach does not define the actual occurrence or magnitude of the corresponding risk.

Table 8-2 Comparison of mean CoC concentrations in toxic samples with mean of non-toxic samples, contrasted with sediment-quality guideline values.

Analyte	Mean of non-toxic samples (n=7±SD)	Mean of toxic [a] samples (n=5±SD)	Ratio of means (toxic/ nontoxic)	TEL	AET	Ratio of toxic/ AET
Arsenic	9.2 ± 3.1	*11.8 ± 3.3*	1.3	7.2	57	0.2
Cadmium	3.0 ± 2.5	**12.5 ± 8.3**	4.2	0.68	2.7	4.6
Chromium	195 ± 88	**245 ± 158**	1.3	52	96	2.6
Copper	606 ± 332	**6030 ± 7478**	10	19	390	15.5
Lead	196 ± 128	**4566 ± 5528**	23	30	430	10.6
Mercury	0.65 ± 0.41	**0.77 ± 0.34**	1.2	0.13	0.41	1.9
Nickel	52 ± 21	**157 ± 75**	3.1	16	110	1.4
Silver	2.26 ± 0.69	**2.43 ± 0.74**	1.1	0.73	0.56	4.3
Zinc	427 ± 151	**1300 ± 567**	3.0	124	410	3.2
Total PAH	30878 ± 55007	**79339 ± 45664**	2.6	1684	~9000	8.8
Total PCB	250 ± 302	**7397 ± 5391**	30	22	130	56.9
TCDD-TEQs [b]	7.8 ± 7.7	**837 ± 1104**	108	5	25	33.5
DDE,4-4	4.8 ± 6.1	*6.3 ± 5.8*	1.3	2.1	16	0.4
DDD,4-4	6.9 ± 4.4	**24 ± 19**	3.5	1.2	16	1.5
DDT,4-4	7.1 ± 12.0	*9.0 ± 6.3*	1.3	1.2	12	0.8
Total DDT	19 ± 21	**39 ± 23**	2.1	3.9	37	1.1
Aldrin	2.0 ± 2.2	3.7 ± 2.2	1.8			
α BHC	3.2 ± 4.0	3.2 ± 2.7	1.0			
β BHC	3.1 ± 3.3	8.8 ± 3.4	2.8			
γ BHC	1.3 ± 1.4	**3.0 ± 2.4**	2.4	0.32	0.99 [c]	3.0
γ Chlordane	4.7 ± 4.4	18 ± 16	3.8			
α Chlordane	3.4 ± 2.5	14 ± 18	4.3			
Total Chlordane	8.1 ± 5.7	**32 ± 33**	4.0	2.3	4.8 [c]	6.7
Dieldrin	2.9 ± 3.4	**9.9 ± 8.0**	3.5	0.72	4.3	2.3
Endrin-A	8.1 ± 7.3	92 ± 83	11			
Heptachlor Epoxide	1.5 ± 1.1	8.0 ± 8.2	5.5			

a *Italic* entries lie between the TEL and AET, indicating possible toxicity. Entries in **bold** lie above the AET, indicating probable toxicity.

b Guidelines from Ianuzzi et al. (1995) and EPA (1993) used for TEL and AET, respectively.

c AET value not available; PEL value from MacDonald et al. (1996).

8.2.1 Potential Risk to Fish

To estimate risk to fish species within the study area, fish tissue body burdens of CoCs were compared to available MATCs. Also, measured water concentrations were compared to AWQCs.

As shown in Table 7-11, three CoCs were observed in mummichog tissues at levels that exceeded their respective MATCs—PCBs, Cd, and PAHs. This evaluation suggests that mummichog in Upper Ferry Creek, nearest the facility, could be at risk due to exposure to cadmium and PAHs. The body burdens of Cd in mummichog samples from Upper Ferry Creek (UF-04 and UF-03) resulted in HQs of 4.4 and 3.8. The MATC for total PAHs was exceeded in mummichog at UF-04 and UF-03 by factors of 3.5 and 3.4, respectively. The HQ calculated for one sample from the reference area RF02 for PCBs was almost 3. As discussed earlier, there were difficulties in the analysis of this sample, and this value may be inaccurate.

Given the magnitude of the HQs (i.e., less than 5), plus the differences in tissues analyzec from the areas of interest versus those represented by the MATC values (i.e., whole vs. eggs o liver), it cannot be stated definitively whether these HQs represent an unacceptable risk to th population of mummichog in Ferry Creek. Fish enzyme systems are quite efficient a metabolizing PAHs. Therefore, the presence of PAHs in whole-animal samples is surprising However, comparing whole-fish concentrations to an organ-specific MATC (such as live concentrations) would result in an HQ that underestimates the risk, due to the likelihood tha the concentrations in liver in sampled fish would be proportionally higher than the whole-bod concentration reported. These considerations would support the conclusion that stocks o mummichog in Upper Ferry Creek might be at risk of reproductive impairment, but the risk t the population throughout the creek cannot be stated with certainty.

A full assessment of potential impact to predatory fish, as indicated by the existing whit perch data, could not be completed because of the lack of requisite information. Therefore, n complete estimates of risk to predatory fish are possible.

Risk to fish was also evaluated by comparing surface-water sample concentrations of CoC with AWQC for the protection of aquatic life. Results of this analysis are presented in Tab 8-3. AWQC were exceeded for a number of trace elements and PCBs. Samples from SD13 Upper Ferry Creek contained the largest number of analytes exceeding their respective AWQ including PCBs, copper, chromium, lead, mercury, and zinc. The only other sample wi copper above AWQC was from HB12. Samples from this station also exceeded AWQC f chromium, lead, and mercury. Elevated surface-water concentrations of mercury we measured at many of the other stations sampled. The AWQC for mercury is based on ris from bioaccumulation of mercury, and does not indicate risk from direct exposure for aquat species. Also, the toxicity of chromium varies considerably depending on the speciation, whi was not measured in any samples. The samples with values above AWQC may indica potential risk depending on the form present. Freshwater AWQC for lead and zinc are function of the water hardness. A value of 100 mg/L calcium carbonate has been assume However, the levels observed may be close enough to the criteria that if the exact hardness the sample were known, these values may not exceed the hardness-based criteria. The on clear indication of risk is likely associated with the sample from SD13, due to the number a magnitude of exceedances.

Table 8-3. **Comparison of AWQC for CoCs with measured water concentrations (µg/L) exceeding criteria. D.L. = detection limit.**

COC	Chronic AWQC[a] Freshwater	Marine	D.L. (mg/L)	Concentration in Surface Water	Qualifier	Station[b]
Copper	12+	2.9 acute	3.8–45	121	J	SD13
				138	J	HB12
Chromium	11	50 (CrVI)	3.2	20.5	J	SD13
	210	10300 (CrIII) acute		11.1		SD21
				59.2		HB12
Lead	3.2 +	8.5	2.1 & 42	3.7		SD20
				147	J	SD13
				6.1	J	SD21
				5.9		SD21
				37.2		HB12
Mercury	0.012	0.025	0.2	0.57	J	HB23
				2.2	J	HB06
				0.29	J	SD10
				0.37	J	SD21
				0.22		SD21
				6.0	J	RF02
				2.2	J	RF03
				3.5		HB12
				1.2		SD25
				1.9		SD29
				0.80	J	SD28
				0.29	J	SD30
				0.39	J	SD01
				0.57	J	SD22
				3.3	J	SD12
				0.83	J	SD14
				0.78	J	SD06
				0.41	J	SD06
				1.2	J	SD23
				0.31	J	SD37
				0.27	J	SD32
				1.0	J	SD36
				0.47	J	SD36
Zinc	110+	86	2.6–62	127	J	SD13
Total PCBs	0.014	0.03	0.5	0.072	J	SD13

Only detected concentrations are presented.
J = estimated
[a] All AWQC are in µg/L.A; + indicates that the AWQC is hardness-dependent; the value at 100 mg/L $CaCO_3$ shown.
[b] Stations compared with freshwater criteria include 13, 20, and 21.

8.2.2 Potential Risk to Birds

Potential risk to avian receptor species was evaluated using an HQ approach, based on doses derived from a food-web model. Total daily ingestion by each receptor species and CoC was estimated for Ferry Creek, the Housatonic Boat Club wetlands, and Milford Point reference areas. The total daily dose for each CoC was compared with its RTV to calculate an HQ (total daily dose/RTV). If the HQ exceeds 1.0, that CoC is considered to pose some level of risk. The magnitude of the HQ provides an approximate, qualitative indication of the potential risk to the receptor. However, the relationship between the HQ ratio and risk is not linear, and therefore the magnitude of risk is uncertain.

Exposure of black-crowned night heron was evaluated by considering consumption of fish, crabs, terrestrial insects, and sediment. To estimate dietary exposure, fiddler crabs were collected from all sampling areas, fish were collected from Ferry Creek, and terrestrial insects were collected from upper Ferry Creek only. Dietary exposure through fish ingestion was not estimated for the Housatonic Boat Club wetlands because fish were not collected at this area since the wetlands drain completely during low tide. It was assumed that the birds spent 100% of their time feeding at each area (i.e., Ferry Creek, Housatonic Boat Club wetlands, and Milford Pond reference area), therefore a home range exposure factor of 1 was used in the food-web model.

Results of the food-web model indicate that adverse effects to the black-crowned night heron colony at Charles Island (~3.5 miles east of Ferry Creek) will not result from consumption of fish, crab, terrestrial insect, and sediment from Ferry Creek or the boat club wetlands (Tables 7-14a-c). Lead was the only CoC whose HQ exceeded 1.0 at the site-related areas but not at the reference location. The maximum HQ for lead was 3.45 for Ferry Creek, with 60% of the lead exposure coming from an assumed incidental sediment ingestion equal to 5% of the herons' dietary ingestion rate. Moreover, this assessment was based on conservative assumptions for some factors within the food-web model. For instance, despite their feeding-site fidelity, considering that this area is urbanized with houses close to Ferry Creek, it is probably not a preferred foraging area for herons that attracts large numbers of birds. Because there are several other good foraging sites near Charles Island, herons may not feed exclusively near the Raymark facility. Considering the magnitude of the HQs, plus the distance from the heron colony and the other feeding grounds within that distance, exposure to CoCs is not likely to pose substantial risk to the herons.

Exposure of red-winged blackbirds was evaluated by considering consumption of terrestrial insects that may have emerged from an aquatic life stage completed in the Ferry Creek wetlands. The assumptions employed were that red-winged blackbirds spend 90% of their time feeding in the wetlands and 10% feeding in upland areas; also, they feed their nestlings only insects. Based on the results of this assessment, the red-winged blackbird is not at risk of adverse effects from exposure to CoCs from consumption of terrestrial insects present in the wetlands along Ferry Creek. None of the HQs exceeded 1 (see Table 7-15).

.0 UNCERTAINTY ASSESSMENT

There are many uncertainties associated with an ecological risk assessment. What traditionally is referred to as "uncertainty" actually may be classified as one of two conditions: natural variability and true uncertainty. Natural variability arises from circumstances such as the heterogeneity of responses, test individuals, or ambient conditions. This form of variation in the measurements can be mathematically described. On occasion, sources of variation can be identified and controlled or minimized. True uncertainty, however, represents gaps in knowledge that cannot be mathematically described. In some cases, it may be possible to describe the direction of influence this sort of uncertainty may have on risk estimates; the magnitude of influence may even be discussed. But usually, this form of uncertainty is described qualitatively.

The overall impact of uncertainty in a risk assessment is to introduce a range of confidence about the estimates of risk ultimately derived. This confidence band can be discussed in terms of over- or underestimation of risk and its magnitude. Optimally, risk estimates should be phrased in terms of probabilities. There are circumstances in which probabilistic modeling can be used to estimate the bounds of either the variability or uncertainties. This would require numerical inputs for all aspects of the uncertainty, a situation that is not common and is resource-intensive. The following are typical categories of uncertainty factors that may have major influence in ecological risk assessments:

- extent of the chemical database used to characterize the facility;
- mathematical approximation or distribution used for exposure point concentrations;
- appropriateness of reference areas;
- strength of association between assessment and measurement endpoints;
- use of surrogate species; and
- assumptions of models, including any extrapolations required.

For the benthic community assessment endpoint, the information on chemical nature and extent of contaminants in the sediment was considered reasonable. There were sufficient data to determine an appropriate distribution function for this data. Replication of sediment grabs per station for analyzing benthic community structure was also reasonable (i.e., $n=4$ each). However, these stations had to be distributed among the four areas of interest. Since it was known that the pattern of contamination within Ferry Creek and the boat club wetlands is extremely heterogeneous, a greater number of stations within each area would have been preferable. The strength of associations between contaminant concentrations and biological measurements within a given area was diminished by the limited number of sampling stations available to characterize both the locations known to have a high degree of contamination (based on previous sampling efforts) and those known to be relatively less impacted by contamination within each of the four areas of interest.

The small number of samples tested with the amphipod test limited the ability to interpret the results. Large numbers of samples, better representing the environmental conditons, would have allowed greater confidence, or greater specificity, in statements regarding the toxicity of individual stations or even entire areas. Additionally, there was a large degree of variability associated with the toxicity measured in the laboratory replicates for two samples—SD07 and SD21. Large variation in laboratory replicates is often an indication of poor laboratory procedures. Well homogenized samples, treated equally, should in theory provide consistent results. The impact of this variability is to widen the confidence intervals about the data. The fact that it was possible to categorize these samples as toxic, given the wider confidence intervals, would tend to strengthen any estimates regarding risk. The fact that these toxicity tests, by design, incorporate factors such as cumulative impacts of multiple chemicals and bioavailability, and are a direct biological measure of effects from exposure to contaminated sediments, also strengthens the conclusions regarding risk. However, the exposure period involved with this bioassay (10 days) is generally too short to reach steady-state for many hydrophobic, organic contaminants, thereby introducing uncertainty regarding the observation of effects from these organic CoCs. Moreover, the amphipod toxicity test relies on acute lethality as its measurement parameter (as opposed to a sublethal, chronic measure of impact). Together, these two factors would tend to underestimate the potential risk when organic contaminants are involved. This is especially true for those CoCs, such as dioxins, whose primary impact is one of latent, reproductive impairment.

Data to support the measurement endpoint associated with the assessment endpoint evaluating the impacts to oyster spat are the most limited. The only direct measure was the oyster developmental test. Resource limitations made it impossible to collect replicate samples in each area of interest for this test. Again, because of the extremely heterogeneous nature of contamination within areas of interest, a single sample per area would tend to increase uncertainty (no estimate of variability can be calculated) and thereby make it more difficult to arrive at conclusions of risk. Also, seasonal difficulties made it impossible to perform the test with the eastern oyster, thus western oyster spat were used as a surrogate. While introducing additional uncertainty in interpreting the results, studies suggest that both species are expected to have similar responses (Dinnel, pers. commun., 1995). Despite any uncertainties, the oyster larvae test still provided indications of risk associated with the CoCs. Similar to the amphipod test, the fact that this endpoint provides direct, biological measures of effects from exposure to sediments contaminated by CoCs also tends to strengthen conclusions of risk. The fact that predictive approaches to estimating risk (i.e., HQs) agreed well with the responses observed with the oyster larvae test also tends to corroborate and strengthen conclusions of risk.

The assessment endpoints for fish involved comparing tissue body burdens of CoCs with benchmark values (MATCs). For predatory fish, such as the white perch, there were insufficient data (including MATCs) to derive any acceptable, complete estimate of risk. For lower-trophic-level fish, as represented by the mummichog, uncertainties in the risk estimate come from three primary sources: (1) a limited number of composite samples, (2) differences between tissues and species as represented by the mummichog and species represented by the MATCs, and (3) the potential for cumulative toxicity from multiple CoCs.

The samples of mummichog were composites of numerous individuals, but there were only four samples per area. Composite samples tend to mask the range of variability in tissue concentrations by averaging the body burdens of individual fish. This tends to broaden the confidence bands with respect to individual fish, but is more representative of the overall population conditions. Fish were collected over a range that is likely smaller than their home range. There is disagreement on the exact home range of mummichog, but 36 m was presumed for this assessment. Although this introduces some level of uncertainty about the exact sediment exposure represented by these composite samples (in the form of increased variation), this factor would result in a reasonable representation of the exposure at the population level.

There were substantial differences in the tissues represented by the MATCs. Many MATCs were tissue burdens in eggs, while the mummichog data were the whole body. Many of the organic CoCs listed in Table 7-11 are highly lipophilic and tend to accumulate in lipid-rich tissues such as eggs and liver. Concentrations for whole-animal body burdens would be less than the value for such lipid-rich tissues due to dilution by other tissues (e.g., muscle). Data presented by Stout et al. (1981) and NOAA (Mearns et al. 1988) suggest that extrapolation factors for DDT between these tissues are an order of magnitude or less. Data presented in Wiener & Spry (1994) for mercury suggest extrapolation factors between brain, liver, muscle, and whole-body concentrations in fish are approximately two- to threefold or less (as total mercury). This use of whole-body burdens in mummichog to derive HQs for CoCs whose MATCs were for eggs may derive HQs that are lower by about an order of magnitude, thus underestimating risk. However, even if levels of TCDD TEQs and DDTs in mummichog were an order of magnitude greater than those represented by whole-body burdens, they would still be less than the MATCs for these CoCs. Therefore, it is unlikely that removing the uncertainty would result in a change in conclusions of risk to the mummichog for these CoCs.

The maximum body burden of PCBs observed in a composite sample of mummichog was in a sample from the reference area. This concentration was flagged as an estimate during quality checks of the data, and was noted as having problems associated with the laboratory analysis. No other analytes were elevated in this sample, and the next-highest body burden observed in reference samples was almost an order of magnitude lower. The nature of this anomalously high PCB level in a reference sample represents another uncertainty factor.

The impact of joint-action toxicity that may occur in circumstances with multiple CoCs is an uncertainty that cannot be addressed in detail. There is very little information that describes the joint-action toxicity of multiple contaminants from broad chemical classes with different modes of toxic action in fish. The common assumption is that toxicity is additive. Although it is known that this is a poor model for general joint-action toxicity, the state of knowledge in wildlife toxicology does not provide a better alternative.

In terms of breadth and possibly magnitude, the greatest degree of uncertainty connected with this ecological risk assessment is associated with the avian food-web models. There were numerous inputs to these models for which assumptions or estimates had to be made. For each of these unknowns, conservative estimates or assumptions were used, which would generally tend to overestimate risk.

There is disagreement among sources referenced about the amount of feeding by blackbirds in a wetland once nesting has started (90% was assumed). Also, it was assumed that the insects fed to nestlings were the same species and the same relative proportions as those caught by net and analyzed for CoC content.

There was no site-specific information on the degree to which heron from the Charles Island colony feed exclusively within the areas sampled (100% was assumed). Black-crowned night heron are opportunistic, general predators; therefore their diet can change dramatically (US EPA 1995). One study of birds on the coastline indicates a diet of 80% fish with the remainder composed primarily of annelids (chiefly *Nereis virens*), crustaceans, and a few insects. Yet another study in an inland marsh indicates a diet of only 30% fish, composed mostly of young birds (primarily gull chicks), beetles, and other terrestrial prey (US EPA 1995). Diet is apparently dependent on local availability of prey. These feeding studies are also based on small sample sizes. Factors such as these obviously lead to higher uncertainties in estimates of doses.

Very limited data on assimilation efficiency of contaminants were available. The maximum value encountered, 85%, was applied to all CoCs (except copper, for which a maximum of 65% was available). Compared with assimilation-efficiency factors reviewed for other taxa (e.g., fish), these assumptions appear to be high and thus may be overly conservative. Assimilation values observed in fish and other taxa are apparently on the order of 55% to 65% for hydrophobic organic contaminants, and lower for super-hydrophobics such as dioxins and some PCBs (Gobas et al. 1988; Barber et al. 1991; Nichols, pers. commun., 1997).

The only RTVs available were for species other than those species of concern (the lowest values encountered in the literature were used). Some RTVs required extrapolation factors to arrive at NOEL levels. Extrapolation factors for species-to-species comparisons generally fall within an order of magnitude (US EPA unpubl.). This would correspond to, at most, an order of magnitude uncertainty in the effect estimate, as expressed by HQs. Because HQs estimate effects at the level of individuals, the ultimate risk to the population would not necessarily correspond to an order-of-magnitude range. For instance, if only a small percentage of individuals from the Charles Island colony received their entire diet from within the study area, those individuals may be at risk, whereas the colony as a whole would not.

There is considerable difference in the toxicity between different states of chromium. Cr^{+6} generally has an order-of-magnitude lower thresholds of toxicity than those for Cr^{+3}. The benchmark for Cr in the avian food-web model was for Cr^{+3}. Comparison of total Cr concentration with this benchmark may underestimate toxicity from Cr exposure. There is added uncertainty to this comparison, however, in that all parties involved agreed not to expend limited resources on speciation of Cr in samples. Since the actual ratio of Cr^{+6} to Cr^{+3} is unknown, there is uncertainty in the dose. An order-of-magnitude decrease in the RTV for Cr would result in HQs exceeding 1 for both the heron and the blackbird. However, because the HQ for Cr for heron was driven by sediment ingestion, which itself was estimated, and the largest HQ for Cr was observed at the reference site, interpretations of risk would still be uncertain. Likewise, the greater HQ for Cr was observed for the reference site.

There is variability and uncertainty associated with all of the analytical results associated with this risk assessment. This is particularly illustrated by the analysis of PCB in crab tissues. Analytical labs may use different techniques to quantify the results of chromatography analysis. For instance, the peak height of a response curve versus the area under the curve might be used to quantify the response. Different peaks and a different number of peaks in a chromatogram may be selected to compare against pure standards to determine which Aroclor mixture is present and at what quantity. These factors and more lead to discrepancies in which value is finally reported for a concentration. In the case of the crab tissues, the original lab reported total PCB concentrations which were on average 70% greater than EPA's interpretation of the same chromatograms. The EPA calculations were the values used in the avian food-web model calculations.

The crab samples were the only tissue samples to be analyzed so as to allow quantification of Aroclor 1268. Omission of Aroclor 1268 in other tissue samples would tend to underestimate the concentration of total PCBs. However, not all PCBs are equally reactive in biological systems (Zabel et al. 1995). Since Aroclor 1268 is dominated by nonaclors, which may have very low biological activity, there is not necessarily a corresponding underestimation of risk.

While all of the factors discussed above add uncertainty to the assessment of risk, any conclusions of risk made in this assessment are substantiated by the fact that evaluations which have taken different approaches to arrive at the same conclusion. This convergence of results and accordance among measurement endpoints from a variety of perspectives reinforces the conclusions that have been made.

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1.0 ACRONYMS

AET	Apparent Effects Threshold
Ag	silver
ANOVA	analysis of variance
As	arsenic
ASTM	American Society for Testing and Materials
AVS	acid volatile sulfide
AWQC	ambient water quality criterion
BJ	bioavailability factor
BSAF	biota sediment accumulation factor
Cd	Cadmium
cm	centimeter
CoC	contaminant of concern
Cr	Chromium
Cu	Copper
DDD	dichloro-diphenyl-dichloro-ethane
DDE	
DDT	dichloro-diphenyl-trichloro-ethane
EPA	U.S. Environmental Protection Agency
ERA	ecological risk assessment
EVS	EVS Environment Consultants, Inc.
Fe	iron
g	gram
Hg	mercury
HQ	Hazard Quotient
HR	home range exposure factor
in	inch
km	kilometer
K_{OC}	organic carbon partitioning coefficient
L	liter
lb	pound
LOAEL	lowest observed adverse effects level
LOEL	lowest observed effects level
m	meter
MATC	maximum acceptable tissue concentrations
mm	millimeter
Ni	nickel
NOEL	no observed effects level
oz	ounce

PAH	polynuclear aromatic hydrocarbon
Pb	lead
PCB	polychlorinated biphenyl
PCDD	polychlorodizenso-p-dioxins
PCDF	polychlorodibenzo-p-furans
PSDDA	Puget Sound Dredged Disposal Analysis
PEL	permissible exposure levels
PLSD	possible least significant difference
ppm	parts per million
ppt	parts per thousand
QA/QC	quality assurance/quality control
QQ	Quantile-Quantile
RA	risk assessment
RI	remedial investigation
SAP	sampling and analysis plan
SEM	simultaneously extracted metals
SEM/AVS	simultaneously extracted metals/acid volatile sulfide
TEF	toxic equivalency factor
TEL	Threshold Effect Level
TEQ	toxic equivalency quotient
TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
TEQ	toxicity equivalency quotient
TOC	total organic carbon
TRV	toxicity reference value
UCL	upper confidence level
VOC	volatile organic compound
Zn	zinc

EVS CONSULTANTS

Amphipod Survival and Emergence Data

Client:	Raymark	Test Species:	*Leptocheirus plumulosus*
Project #:	9/575-29.1	Date Initiated:	August 29, 1995
Work Order:	9500632	Date Terminated:	September 8, 1995
Test Type:	10-d static	Number of Test Organisms:	20

Sample ID	Rep	No. Survivors	No. Emerged Days 1-10	Survival Mean (out of 20)	Survival S.D.[1]	Mean Survival (%)	Emergence (#/jar/day) Mean	Emergence (#/jar/day) S.D.[1]
RM-HB-06-AM	A	19	4	19.6	0.5	98.0	0.3	0.1
	B	20	2					
	C	19	2					
	D	20	3					
	E	20	2					
RM-HB-12-AM	A	17	1	17.6	0.5	88.0	0.2	0.3 CHM
	B	18	7					
	C	17	1					
	D	18	0					
	E	18	3					
RM-HB-23-AM	A	14	2	15.6	2.4	78.0	0.1	0.1
	B	19	1					
	C	13	1					
	D	17	2					
	E	15	1					
RM-RF-02-AM	A	18	0	16.6	0.9	83.0	0.0	0.0
	B	16	1					
	C	17	0					
	D	16	0					
	E	16	0					
RM-RF-03-AM	A	17	0	15.6	2.1	78.0	0.1	0.1
	B	16	0					
	C	14	1					
	D	18	2					
	E	13	0					
RM-SD-07-AM	A	1	7	6.0	6.1	30.0	0.4	0.2 CHM
	B	0	1					
	C	13	4					
	D	4	4					
	E	12	2					

[1]S.D. = Standard Deviation.

C. McPherson
Oct 10/95

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EVS CONSULTANTS

Amphipod Survival and Emergence Data

Client:	Raymark	Test Species:	*Leptocheirus plumulosus*
Project #:	9/575-29.1	Date Initiated:	August 29, 1995
Work Order:	9500632	Date Terminated:	September 8, 1995
Test Type:	10-d static		
		Number of Test Organisms:	20

Sample ID	Rep	No. Survivors	No. Emerged Days 1-10	Survival Mean (out of 20)	Survival S.D.[1]	Mean Survival (%)	Emergence (#/jar/day) Mean	Emergence (#/jar/day) S.
RM-SD-10-AM	A	18	1	18.4	0.9	92.0	0.2	(
	B	19	2					
	C	19	1					
	D	17	3					
	E	19	3					
SM-SD-13-AM	A	9	2	11.6	3.4	58.0	0.3	
	B	17	3					
	C	13	4					
	D	10	0					
	E	9	5					
RM-SD-19-AM	A	19	1	15.8	1.9	79.0	0.2	
	B	15	1					
	C	14	4					
	D	15	2					
	E	16	3					
RM-SD-20-AM	A	15	0	15.4	1.7	77.0	0.2	
	B	13	4					
	C	17	0					
	D	17	4					
	E	15	4					
RM-SD-21-AM	A	10	4	6.2	5.0	31.0	0.6	
	B	2	6					
	C	3	11					
	D	13	5					
	E	3	3					
RM-SD-RF-01-AM	A	20	4	19.8	0.4	99.0	0.4	
	B	19	7					
	C	20	4					
	D	20	6					
	E	20	1					

[1]S.D. = Standard Deviation.

C. McPhee
Oct 10/95

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APPENDIX A
10-d Leptocheirus plumulosus Sediment Toxicity Test Raw Data

TAXA	HB-23	HB-23	HB-23	HB-23	RF-02	RF-02
NEMATODA			6		3	4
AMPHARETIDAE						
CAPITELLA CAPITATA COMPLEX						
GLYCERA SPP.						
HOBSONIA FLORIDA					1	
HYPERETEONE HETEROPODA				1	20	25
LAEONEREIS CULVERI				1		
MARENZELLARIA VIRIDIS						
MEDIOMASTUS AMBISETA						
NEANTHES SPP.						3
NEANTHES SUCCINEA					4	4
NEANTHES VIRENS						
NEREIS SPP.						
OLIGOCHAETA	42	94	17	5	20	32
POLYDORA CORNUTA						
STREBLOSPIO BENEDICTI					30	8
ALMYRACUMA PROXIMOCULI						
BALANUS IMPROVISUS						
CAPRELLA PENANTIS					1	
CASSIDINIDEA OVALIS						
COROPHIUM LACUSTRE		1				
CYATHURA POLITA						
EDOTEA TRILOBA						1
GAMMARUS PALUSTRIS	1	9	1			
GAMMARUS TIGRINUS						
LEPTOCHEIRUS PLUMOSUS					1	
MELITA NITIDA						
MELITIDAE						
MICROPROTOPUS RANEYI						
MUCROGAMMARUS MUCRONATUS						1
TALITRIDAE				1		
UCA SPP.		1	1			
GEMMA GEMMA					1	
LITTORIDINOPS TENUIPES					5	2
HYDROBIA TOTTEUS	7	7	5	13		
MACOMA BALTHICA					2	3
MYA ARENARIA						

TAXA	HB-23	HB-23	HB-23	HB-23	RF-02	RF-02
cf. AERICOTOPUS SPP.						
CHIRONOMIDAE						
CHIRONOMINI						
CHIRONOMUS SPP.				1		
CLINOTANYPUS SPP.						
CULICOIDES SPP.	1	51	4	3		
DICROTENDIPES SPP.						
DIPTERA PUPAE	1					
EMPIDIDAE (DIPTERA) LARVAE		2				
HEMIPTERA						
MUSCIDAE (DIPTERA) LARVAE		1				
POLYPEDILUM SPP.						
PROCLADIUS SPP.						
TANYPOIDINI SPP.						
TANYPUS SPP.						
TANYTARSUS SPP.						
TOTAL ABUNDANCE	52	166	28	25	85	79

TAXA	RF-02	RF-02	SD-07	SD-07	SD-07	SD-07
NEMATODA	6	10	4		30	
AMPHARETIDAE						
CAPITELLA CAPITATA COMPLEX			47	124	364	124
GLYCERA SPP.		1				
HOBSONIA FLORIDA			3	15	6	14
HYPERETEONE HETEROPODA	24	27	2	10	18	13
LAEONEREIS CULVERI			2	8	14	3
MARENZELLARIA VIRIDIS						
MEDIOMASTUS AMBISETA		5				
NEANTHES SPP.	1		1			2
NEANTHES SUCCINEA	2	2	1	9	2	3
NEANTHES VIRENS			1		5	1
NEREIS SPP.						
OLIGOCHAETA	48	30	11	10	71	11
POLYDORA CORNUTA		2		9	3	2
STREBLOSPIO BENEDICTI	14	115	1	1	4	
ALMYRACUMA PROXIMOCULI						
BALANUS IMPROVISUS						14
CAPRELLA PENANTIS						
CASSIDINIDEA OVALIS						
COROPHIUM LACUSTRE						
CYATHURA POLITA				1		
EDOTEA TRILOBA		4		1		
GAMMARUS PALUSTRIS						
GAMMARUS TIGRINUS				1		
LEPTOCHEIRUS PLUMOSUS	18	38				
MELITA NITIDA				1		
MELITIDAE	1					
MICROPROTOPUS RANEYI	1					
MUCROGAMMARUS MUCRONATUS						1
TALITRIDAE						
UCA SPP.						
GEMMA GEMMA						
LITTORIDINOPS TENUIPES		1				
HYDROBIA TOTTEUS						
MACOMA BALTHICA	2	2				
MYA ARENARIA						

TAXA	RF-02	RF-02	SD-07	SD-07	SD-07	SD-07
cf. AERICOTOPUS SPP.						
CHIRONOMIDAE						
CHIRONOMINI						
CHIRONOMUS SPP.						
CLINOTANYPUS SPP.						
CULICOIDES SPP.						
DICROTENDIPES SPP.						
DIPTERA PUPAE						
EMPIDIDAE (DIPTERA) LARVAE						
HEMIPTERA					12	
MUSCIDAE (DIPTERA) LARVAE						
POLYPEDILUM SPP.						
PROCLADIUS SPP.						
TANYPOIDINI SPP.						
TANYPUS SPP.						
TANYTARSUS SPP.						
TOTAL ABUNDANCE	111	227	69	190	499	188

TAXA	RF-01	RF-01	RF-01	RF-01	SD-13	SD-13
NEMATODA						
AMPHARETIDAE						2
CAPITELLA CAPITATA COMPLEX						1
GLYCERA SPP.						
HOBSONIA FLORIDA	202	164	287	102	47	4
HYPERETEONE HETEROPODA						
LAEONEREIS CULVERI	2	2	5	2	140	19
MARENZELLARIA VIRIDIS	7	16	1	7		
MEDIOMASTUS AMBISETA						
NEANTHES SPP.						
NEANTHES SUCCINEA						
NEANTHES VIRENS						
NEREIS SPP.	1	1				
OLIGOCHAETA	74	94	7	136	85	13
POLYDORA CORNUTA						
STREBLOSPIO BENEDICTI						
ALMYRACUMA PROXIMOCULI	1					
BALANUS IMPROVISUS						
CAPRELLA PENANTIS						
CASSIDINIDEA OVALIS	1	1				
COROPHIUM LACUSTRE	11	12	11	4		
CYATHURA POLITA	15	34	15	8	2	1
EDOTEA TRILOBA						
GAMMARUS PALUSTRIS						
GAMMARUS TIGRINUS	191	232	272	133	1	
LEPTOCHEIRUS PLUMOSUS	98	108	70	87		
MELITA NITIDA				1		
MELITIDAE						
MICROPROTOPUS RANEYI						
MUCROGAMMARUS MUCRONATUS						
TALITRIDAE						
UCA SPP.						
GEMMA GEMMA						
LITTORIDINOPS TENUIPES						
HYDROBIA TOTTEUS						
MACOMA BALTHICA						
MYA ARENARIA						

TAXA	RF-01	RF-01	RF-01	RF-01	SD-13	SD-13
cf. AERICOTOPUS SPP.			2			
CHIRONOMIDAE		1	1			
CHIRONOMINI	2	3		1		
CHIRONOMUS SPP.	44	23	29	20		
CLINOTANYPUS SPP.		1				
CULICOIDES SPP.						
DICROTENDIPES SPP.	41	23	41	31		
DIPTERA PUPAE						
EMPIDIDAE (DIPTERA) LARVAE						
HEMIPTERA						
MUSCIDAE (DIPTERA) LARVAE						
POLYPEDILUM SPP.	1		2	1		
PROCLADIUS SPP.	11	23	13	10		
TANYPOIDINI SPP.						
TANYPUS SPP.	1					
TANYTARSUS SPP.	5	7	4	6		
TOTAL ABUNDANCE	708	745	760	549	275	40

TAXA	SD-13	SD-13	SD-19	SD-19	SD-19	SD-19
NEMATODA						
AMPHARETIDAE						
CAPITELLA CAPITATA COMPLEX						
GLYCERA SPP.						
HOBSONIA FLORIDA	57	26	1	2	5	
HYPERETEONE HETEROPODA		1	21	5	59	9
LAEONEREIS CULVERI	69	98				1
MARENZELLARIA VIRIDIS						
MEDIOMASTUS AMBISETA						
NEANTHES SPP.						
NEANTHES SUCCINEA			3	1	9	4
NEANTHES VIRENS						
NEREIS SPP.						
OLIGOCHAETA	15	688	47	5	6	8
POLYDORA CORNUTA				1	20	5
STREBLOSPIO BENEDICTI		2	9		121	10
ALMYRACUMA PROXIMOCULI						
BALANUS IMPROVISUS						
CAPRELLA PENANTIS						
CASSIDINIDEA OVALIS						
COROPHIUM LACUSTRE					1	
CYATHURA POLITA						
EDOTEA TRILOBA						
GAMMARUS PALUSTRIS						
GAMMARUS TIGRINUS						
LEPTOCHEIRUS PLUMOSUS						
MELITA NITIDA						
MELITIDAE						
MICROPROTOPUS RANEYI						
MUCROGAMMARUS MUCRONATUS						
TALITRIDAE						
UCA SPP.						
GEMMA GEMMA						
LITTORIDINOPS TENUIPES						
HYDROBIA TOTTEUS						
MACOMA BALTHICA				1	3	
MYA ARENARIA					2	

TAXA	SD-13	SD-13	SD-19	SD-19	SD-19	SD-19
cf. AERICOTOPUS SPP.						
CHIRONOMIDAE						
CHIRONOMINI						
CHIRONOMUS SPP.						
CLINOTANYPUS SPP.						
CULICOIDES SPP.						
DICROTENDIPES SPP.						
DIPTERA PUPAE						
EMPIDIDAE (DIPTERA) LARVAE						
HEMIPTERA						
MUSCIDAE (DIPTERA) LARVAE						
POLYPEDILUM SPP.						
PROCLADIUS SPP.						
TANYPOIDINI SPP.						
TANYPUS SPP.						
TANYTARSUS SPP.						
TOTAL ABUNDANCE	141	815	81	15	226	37

TAXA	SD-20	SD-20	SD-20	SD-20	TAXON	
NEMATODA						
AMPHARETIDAE					2	
CAPITELLA CAPITATA COMPLEX					660	
GLYCERA SPP.					1	
HOBSONIA FLORIDA	5	1	5	8	955	
HYPERETEONE HETEROPODA					235	
LAEONEREIS CULVERI	1		2		369	
MARENZELLARIA VIRIDIS					31	
MEDIOMASTUS AMBISETA					5	
NEANTHES SPP.					7	
NEANTHES SUCCINEA					44	
NEANTHES VIRENS					7	
NEREIS SPP.					2	
OLIGOCHAETA	524	36	257	43	2429	
POLYDORA CORNUTA					42	
STREBLOSPIO BENEDICTI					315	
ALMYRACUMA PROXIMOCULI					1	
BALANUS IMPROVISUS					14	
CAPRELLA PENANTIS					1	
CASSIDINIDEA OVALIS					2	
COROPHIUM LACUSTRE					40	
CYATHURA POLITA			1	1	78	
EDOTEA TRILOBA					6	
GAMMARUS PALUSTRIS					11	
GAMMARUS TIGRINUS			1		831	
LEPTOCHEIRUS PLUMOSUS					420	
MELITA NITIDA					2	
MELITIDAE					1	
MICROPROTOPUS RANEYI					1	
MUCROGAMMARUS MUCRONATUS					2	
TALITRIDAE					1	
UCA SPP.					2	
GEMMA GEMMA					1	
LITTORIDINOPS TENUIPES					8	
HYDROBIA TOTTEUS					32	
MACOMA BALTHICA					13	
MYA ARENARIA					2	

TAXA	SD-20	SD-20	SD-20	SD-20	TAXON	
cf. AERICOTOPUS SPP.					2	
CHIRONOMIDAE					2	
CHIRONOMINI					6	
CHIRONOMUS SPP.		1			118	
CLINOTANYPUS SPP.						
CULICOIDES SPP.				1	60	
DICROTENDIPES SPP.		3		1	140	
DIPTERA PUPAE					1	
EMPIDIDAE (DIPTERA) LARVAE					2	
HEMIPTERA					12	
MUSCIDAE (DIPTERA) LARVAE					1	
POLYPEDILUM SPP.					4	
PROCLADIUS SPP.					57	
TANYPOIDINI SPP.				1	1	
TANYPUS SPP.					1	
TANYTARSUS SPP.					22	
TOTAL ABUNDANCE	530	41	266	55	7002	250.107

APPENDIX B
48-h *Crassostrea gigas* Larval Development Test Raw Data

EVS CONSULTANTS - 10-d SEDIMENT TOXICITY TESTS
SEDIMENT DESCRIPTION AND CHARACTERIZATION

Client: Raymark
EVS Project No.: 9/575-29.1
EVS W.O. No.: 9500632

Day 0: Aug 29, 1995
Day 10: September 8, 1995
Test Species: Leptocheirus plumulosus

SAMPLE I.D.	COLOUR	GRAIN SIZE	SMELL	SHELLS/ DEBRIS	OTHER OBSERVATIONS	TECH. INITIAL
RM-SD-RF-01-AM	black	mud	slight Petroleum	twigs (small amount)		ART
RM-HB 06 AM	Grey	Sand	none	Small Rocks		RAA
RM-RF-02-AM	grey-black	mud	slight petroleum	none		ART
Negative sediment	grey-black	silt	none	none		ART

Be descriptive when you characterize the sediments. Colour and grain size information must be complete. If the sediment has an odour, describe the type of smell. Note any shells or debris that are present. Be sure to record anything else in the Observations section.

C. McPherson
Oct 5/95

sediment.doc

EVS CONSULTANTS

Amphipod Survival and Emergence Data

Client:	Raymark	Test Species:	*Leptocheirus plumulosus*
Project #:	9/575-29.1	Date Initiated:	August 29, 1995
Work Order:	9500632	Date Terminated:	September 8, 1995
Test Type:	10-d static	Number of Test Organisms:	20

Sample ID	Rep	No. Survivors	No. Emerged Days 1-10	Survival Mean (out of 20)	Survival S.D.[1]	Mean Survival (%)	Emergence (#/jar/day) Mean	Emergence (#/jar/day) S.D.[1]
Negative Control[2]	A	20	1	18.5	1.7	92.5	0.1	0.1
	B	19	0					
	C	16	0					
	D	19	1					

[1]S.D. = Standard Deviation.
[2]Replicate E was accidentally dropped prior to test termination.

C. McPherson
Oct 10/95

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EVS CONSULTANTS - 10-d SEDIMENT TOXICITY TESTS
SEDIMENT DESCRIPTION AND CHARACTERIZATION

Client: Raymark
EVS Project No.: 91575-~~09.T~~ AT 29.1
EVS W.O. No.: 9500632

Day 0: aug 29, 1995
Day 10: September 8, 1995
Test Species: Leptocheirus plumulosus

SAMPLE I.D.	COLOUR	GRAIN SIZE	SMELL	SHELLS/ DEBRIS	OTHER OBSERVATIONS	TECH. INITIAL
RM-HB-23-AM	Black	Silt	Hydrogen Sulfide	grass, Leaves		RAK
RM-SD-07-AM	Black	mud	strong Hydrogen Sulfide	Leaves, Twigs		RAK
RM-SD-19-AM	Brown/Black	mud	Hydrogen sulfide	grass, rocks		ART
RM-SD-21-AM	Black with Tan Streaks	sand/mud	slight Hydrogen Sulfide	Leaves, grass		RAK
RM-RF-03AM	Black	Silt	strong Hydrogen Sulfide	Some grass		RAK
RM-SD-13-AM	Black	Mud	strong Hydrogen sulfide	grass, twigs		ART
RM-SD-10AM	Black	Fine Silt	slight Hydrogen	grass, Twigs Leaves		RAK
RM-SD-20-AM	Brown Black	Mud	Slight Petroleum	grass, twigs		ART
RM-HB-12AM	Black	Heavy mud	strong Hydrogen Sulfide	twigs Leaves		RAK

Be descriptive when you characterize the sediments. Colour and grain size information must be complete. If the sediment has an odour, describe the type of smell.

APPENDIX C

Raw Counts
of
Benthic Organisms

ASL

RESULTS OF ANALYSIS - Water

File No. F4029r

		Negative Control 95 09 22	Control Sediment 95 09 22	RM-RF-02 -OY 95 09 22	RM-HB-23 -OY 95 09 22	RM-SD-10 -OY 95 09 22
Nutrients						
Ammonia Nitrogen	N	0.02	0.02	0.09	0.04	0.28
Inorganic Parameters						
Sulphide	S	<0.02	<0.02	0.06	0.05	<0.02

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. F4029r

		RM-SD-13 -0Y 95 09 22
Nutrients		
Ammonia Nitrogen	N	0.28
Inorganic Parameters		
Sulphide	S	<0.02

Results are expressed as milligrams per litre except where noted.
< = Less than the detection limit indicated.

RESULTS OF ANALYSIS - Water

File No. F3564

	Ammonia Nitrogen N	Sulphide S
Negative Control Day 10 1995 Sep 8	4.51	<0.02
RM-HB-06 AM Day 10 1995 Sep 8	<0.02	<0.02
RM-HB-12 AM Day 10 1995 Sep 8	1.95	<0.02
RM-HB-23 AM Day 10 1995 Sep 8	0.06	<0.02
RM-RF-~~24~~ 02 AM Day 10 1995 Sep 8	0.98	<0.02
RM-RF-03 AM Day 10 1995 Sep 8	0.86	<0.02
RM-SD-21 AM Day-10 1995 Sep 8	2.44	<0.02
RM-SD-~~07~~ 20 AM Day 10 1995 Sep 8	0.20	<0.02
RM-SD-13 AM Day 10 1995 Sep 8	4.55	<0.02
RM-SD-RF 01AM Day 10 1995 Sep 8	3.21	<0.02
RM-SD-19 AM Day 10 1995 Sep 8	0.33	<0.02
RM-SD-07 AM Day 10 1995 Sep 8	4.59	0.02
RM-SD-10 AM Day 10 1995 Sep 8	5.70	<0.02

< = Less than the detection limit indicated.
Results are expressed as milligrams per litre.

ASL

RESULTS OF ANALYSIS - Water

File No. F3911

	Ammonia Nitrogen N	Sulphide S
Neg Control Day 0	0.03	<0.02
Control Sediment Day 0	0.04	<0.02
RM-SD-13 -OY Day 0	0.37	0.04
RM-SD-10 -OY Day 0	0.45	0.05
RM-RF-02 -OY Day 0	0.14	0.03
RM-MB-23 -OY Day 0	0.21	<0.02

Results are expressed as milligrams per litre.
< = Less than the detection limit indicated.

EVS CONSULTANTS
SEDIMENT DESCRIPTION AND CHARACTERIZATION

Client: Ray Marks
EVS Project No.: 9/575-29.2
EVS W.O. No.: 9500633

Test Species: C. gigas
Test Type/Duration: 48hr.
Day 0: Sept 20/95

Sample I.D.	Colour	Grain Size	Smell	Shells/ Debris	Other Observations	Tech. Initial
RM-SD-10-04	Black	Fine.	Sulpher	Organics	→ grass & Twigs & leaves	[illegible]
RM-HB-23-04	Brown to Black	Fine clay-silt	NA	Organics	→ grass & small roots	[illegible]
RM-RF-02-~~04~~ OY AT	Dark Grey	silt and fine sand	sulphur	None	Fine layer of what looks like a greyish mould on top of sed.	[illegible]
RM-SD-13-~~04~~ OY AT	Black	Very fine	sulphur	Lots of organics leaf litter	Roots. Rootlets.	[illegible]

Be descriptive when you characterize the sediments. Colour and grain size information must be complete. If the sediment has an odour, describe the type of smell. Note any shells or debris that are present. Be sure to record anything else in the Observations section.

Data Certified By: C. McPherson

Date Certified: Oct 6/95

RESULTS OF ANALYSIS - Water

File No. F3306

	Ammonia Nitrogen N	Sulphide S
Control Sediment Day 0 1995 Aug 29 11:00	3.02	0.02
RM-SD-RF -01-AM Day 0 1995 Aug 29 11:00	2.51	0.03
RM-RF-02 -AM Day 0 1995 Aug 29 11:00	0.42	0.08
RM-RF-03 -AM Day 0 1995 Aug 29 11:00	0.93	0.03
RM-HB-06 -AM Day 0 1995 Aug 29 11:00	0.80	0.06
RM-HB-12 -AM Day 0 1995 Aug 29 11:00	2.28	0.04
RM-HB-23 -AM Day-0 1995 Aug 29	0.74	0.04
RM-SD-07 -AM Day 0 1995 Aug 29 11:00	3.15	0.07
RM-SD-10 -AM Day 0 1995 Aug 29 11:00	3.30	0.07
RM-SD-13 -AM Day 0 1995 Aug 29 11:00	2.31	0.04
RM-SD-19 -AM Day 0 1995 Aug 29 11:00	1.81	<0.02
RM-SD-20 -AM Day 0 1995 Aug 29 11:00	0.61	0.03
RM-SD-21 -AM Day 0 1995 Aug 29 11:00	1.83	0.06

Results are expressed as milligrams per litre.
< = Less than the detection limit indicated.

BIVALVE LARVAL DEVELOPMENT TOXICITY TEST RAW DATA RECORD

Client: Raymark
Project Number: 9/575−29.2
Work Order Number: 9500633
Test Species: *Crassostrea gigas*
Book: 7 Page: 71−78

Date Initiated: Sept. 20, 1995
Date Terminated: Sept. 22, 1995

Initial Density: 30000 embryos/L
Aliquot Size:(mL) 10
Test Volume:(mL) 1000

Sample ID	Rep/ Conc.	Normal Larvae	Abnormal Larvae	Total Larvae	% Abnormal Larvae	Mean % Abnormal	Mean Net % Abnormal	% Combined Mortality	Mean % Combined Mortality	Mean % Net Combined Mortality
Control Sediment	A	306	11	317	3.5	4.1	NA	−2.0	3.1	−1.3
	B	283	14	297	4.7			5.7		
	C	273	12	285	4.2			9.0		
	D	299	15	314	4.8			0.3		
	E	292	10	302	3.3			2.7		
Control Seawater[1]	A	239	7	246	2.8	2.7	NA	20.3	4.3	0.0
	B	291	12	303	3.8			3.0		
	C	323	4	327	1.1			−7.7		
	D	295	9	303	2.8			1.8		
	E	288	10	297	3.2			4.2		

NA = Not Applicable

[1] Due to the variability between replicates, the backup vials were counted to confirm the original counts. Therefore, the normal and abnormal larvae values consist of the average of the original and backup counts.

C. McPherson
Oct 4/95

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BIVALVE LARVAL DEVELOPMENT TOXICITY TEST RAW DATA RECORD

Client: Raymark
Project Number: 9/575-29.2
Work Order Number: 9500633
Test Species: *Crassostrea gigas*
Book: 7 Page: 71-78

Date Initiated: Sept. 20, 1995
Date Terminated: Sept. 22, 1995

Initial Density: 30000 embryos/L
Aliquot Size:(mL) 10
Test Volume:(mL) 1000

Sample ID	Rep/ Conc.	Normal Larvae	Abnormal Larvae	Total Larvae	% Abnormal Larvae	Mean % Abnormal	Mean Net % Abnormal	% Combined Mortality	Mean % Combined Mortality	Mean % Net Combined Mortality
Reference Toxicant (SDS in mg/L)	10.0 A	0	1	1	100.0	100.0	100.0	100.0	100.0	100.0
	B	0	3	3	100.0			100.0		
	5.6 A	0	24	24	100.0	100.0	100.0	100.0	100.0	100.0
	B	0	23	23	100.0			100.0		
	3.2 A	11	67	78	85.9	89.6	89.3	96.3	97.7	97.6
	B	3	53	56	94.6			99.0		
	1.8 A	202	34	236	14.4	15.0	12.6	32.7	31.0	27.9
	B	212	39	251	15.5			29.3		
	1.0 A	246	11	257	4.3	4.6	1.9	18.0	9.5	5.4
	B	297	15	312	4.8			1.0		

C. McPherson
Oct 4/95

BIVALVE LARVAL DEVELOPMENT TOXICITY TEST RAW DATA RECORD

Client: Raymark
Project Number: 9/575-29.2
Work Order Number: 9500633
Test Species: *Crassostrea gigas*
Book: 7 Page: 71-78

Date Initiated: Sept. 20, 1995
Date Terminated: Sept. 22, 1995

Initial Density: 30000 embryos/L
Aliquot Size:(mL) 10
Test Volume:(mL) 1000

Sample ID	Rep/ Conc.	Normal Larvae	Abnormal Larvae	Total Larvae	% Abnormal Larvae	Mean % Abnormal	Mean Net % Abnormal	% Combined Mortality	Mean % Combined Mortality	Mean % Net Combined Mortality
RM-SD-10-OY	A	206	22	228	9.6	12.2 CdM	NA	31.3	34.7	31.8
	B	193	25	218	11.5			35.7		
	C	194	33	227	14.5			35.3		
	D	192	33	225	14.7			36.0		
	E	194	23	217	10.6			35.3		
RM-RF-02-OY	A	186	20	206	9.7	11.5	NA	38.0	43.7	41.1
	B	148	23	171	13.5			50.7		
	C	180	20	200	10.0			40.0		
	D	143	23	166	13.9			52.3		
	E	188	24	212	11.3			37.3		
RM-HB-23-OY	A	45	10	55	18.2	20.2	NA	85.0	83.7	82.9
	B	45	12	57	21.1			85.0		
	C	58	17	75	22.7			80.7		
	D	58	11	69	15.9			80.7		
	E	39	12	51	23.5			87.0		

NA = Not Applicable

C. McPherson
Oct 4/95

H:\user\lab1\9500633oysters.wk1

BIVALVE LARVAL DEVELOPMENT TOXICITY TEST RAW DATA RECORD

Client: Raymark
Project Number: 9/575-29.2
Work Order Number: 9500633
Test Species: *Crassostrea gigas*
Book: 7 Page: 71-78

Date Initiated: Sept. 20, 1995
Date Terminated: Sept. 22, 1995

Initial Density: 30000 embryos/L
Aliquot Size:(mL) 10
Test Volume:(mL) 1000

Sample ID	Rep/ Conc.	Normal Larvae	Abnormal Larvae	Total Larvae	% Abnormal Larvae	Mean % Abnormal	Mean Net % Abnormal	% Combined Mortality	Mean % Combined Mortality	Mean % Net Combined Mortality
RM-SD-13-OY	A	61	61	122	50.0	47.4	NA	79.7	79.3	78.4
	B	70	51	121	42.1			76.7		
	C	52	58	110	52.7			82.7		
	D	61	52	113	46.0			79.7		
	E	66	57	123	46.3			78.0		

NA = Not Applicable

C. McPherson
Oct 4/95

Science Applications International Corporation
An Employee-Owned Company

February 13, 1998

Memorandum

To: Susan Svirsky, Tim Prior, Ken Finkelstein
From: Greg Tracey
Subject: ERA Avian Food Chain model.

Dear Raymarkers,

No that I've got all the spreadsheets from Ken I have had a chance to go through Tim's comments and figure out what's going on and what to fix so we can complete the assessment with the new data. Included in the discussion below are some discrepencies that I have discovered, which may explain some of Tim's comments (in italics).

1. The revision seems to have corrected the previous comments related to typographical errors and omissions in the basic food-web model formula 5-1, and the lack of mathematical division using body weights in the use of the formula in Tables 7-14a, b, c and 7-15 (previous General Comment 1 and 2 plus Specific Comments 1a-e and 3).

The values used in Table 7-14a do not agree with those listed in Table 5-1: Intake rates used in for sediment = .006 kg/d ww, but reported as 0.01. Also, intake rate for water used = .050 but reported as 0.054. Since there was no comments on Table 5-1 calculations, I have assumed those are the correct numbers.

a. However, after checking a few of the calculations, it appears that a new math error has cropped up in the calculations for the Red-winged Black Bird, Table 7-15, page 131. It appears that the HR (Home Range) Factor was applied in both the second column, "Insects," and the fifth column, "Total." I believe the HR Factor should have been applied to the "Insects" column and the third column, "Water," or just to the fifth column, but not both as this underestimates the dose.

It looks like the HR factor was only applied to the total. However, the values used in Table 7-15 do not agree with those listed in Table 5-1: Intake rates used in for total food = .0207 kg/d ww, but reported as 0.023 kg/day. The Table heading is also misleading since consumption of insects (0.012, Table 5-1) is only half of the total food estimate. Also, intake rate forBCNH water used = .050 but reported as 0.054. Also, intake rate forRWBB water used = .01 but reported as 0.008. Again, since there was no comments on Table 5-1 calculations, I have assumed those are the correct numbers.

Environmental Testing Center, 165 Dean Knauss Drive, Narragansett, Rhode Island 02882 (401) 782-1900 • FAX: (401) 782-2330
Other SAIC Offices Albuquerque, Boston, Colorado Springs, Dayton, Huntsville, Las Vegas, Los Angeles, McLean, Oak Ridge, Orlando, Palo Alto, Seattle, Tucson

b. The revision now clarifies the bioavailabilty factor term, BF (Specific Comment 1-e). A bioavailability factor of 65% for copper and 85% for all other contaminants is now used instead of the 100% assumption used in the draft (see page 56. Sect. 5.2 for explanation and Tables 7-14a-c and 7-15 for application).

Confirmed.

2. The revision addresses previous General Comment 3 regarding the apparent 25% under representation of the full daily dietary (prey) requirement of the Black-crowned Night Heron in a slightly different, but acceptable, manner than we had proposed.

a. However, the revision makes this correction by providing an "adjusted HQ" column in Tables 7-14a, b, and c, which is calculated by multiplying the previous, underestimated, Hazard Quotient columns by 1.33 for the missing 25%. This method of adjustment now probably overestimates the dose to some degree by also upwardly adjusting the contribution of the water and, perhaps more significantly, the sediment fractions of the dose. I'd suggest that the 1.33 adjustment factor be applied only to the "prey" or food component of the dose; i.e., fish, crab and insect in the first three columns of Tables 7-14a, b, and c.

This change has been made and is also changed in Table 5-1, with footnote.

b. The 1.33 adjustment seems to be uniformly applied to the BCNH HQ's for all contaminants except copper in Tables 7-14a, b, and c. The copper values seem to be adjusted by a factor of 1.7. I'm not sure why.

This problem is a non-issue when solution 2a is implemented.

3. The revision adds an "allometric scaling" adjustment of the report's literature-derived Reference Toxicity Doses, RTV's (page 124, Sect 7.3.2 and Table 7-13, page 125), which was not in the draft. The adjusted RTV's are then used in Tables 7-14a-c and 7-15 to calculate the HQ's shown in the last two columns of those Tables.

The data used in the spreadsheet for Tables 7-14a-c and 7-15 is the same body wt (kg) as reported in Table 5-1, and would seem needed to get the CoC intake rate into the same units as the RTV benchmark.

I found no further explanation of the method of calculating the scaling factor. Checking several of the values given in Table 7-13 suggests they are calculated with the body-weight based "physiological scaling factor" method described in Equation 4, page 5 of the 1995 revision of the Oakridge National Laboratory's Toxicological Benchmarks for Wildlife, D.M. Opresko et al., June 1995 as follows:

$$NOAEL_{wildlife} = NOAEL_{test} (BW_{test}/BW_{wildlife})^{1/3}$$

However, the more recent revision of the Oakridge National Lab Benchmarks for Wildlife, B.E. Sample, et al., June 1996, changes the power function to 1/4, and, more importantly, no longer recommends using this body size scaling factor for birds based on their review of recent literature. Based on that recommendation, I'd suggest we do the same.

I have revised Table 7-13 to adjust the test RTV only for the extrapolation factor; hence there is no longer a species-specific NOEL, just one for birds.

In any case, the 0.121 kg body weight for the test species (adult hen ring-necked pheasants) for the Dioxin TEQ RTV in Table 7-13, pg. 125, is an error. It should be around 1 kg. Someone skimmed the referenced study, Nosek, et al., and saw figures that are in that report depicting % change in body weights over time that ranged up to approx. 121%. Nosek, et al. (pg. 188) state the initial body weights of the birds was 0.9-1.3 kg.

I have adjusted Table 7-13 to show 1.0 kg for the adult hen ring-necked pheasant body weight.

4. As indicated in the attached copy of our previous comments, we had offered a number of additional, primarily editorial, suggestions. Many of these have been incorporated in the revision. Some were not included.

5. As you indicated that you were going to have additional evaluations made on the TCDD's/TCDF's in Ferry Creek fish, I tried to do some check-calculations to evaluate how these were handled in the revised document. I didn't get far. I can't tell what TEF's were used or how the TEQ's where calculated. I think this difficulty is due to the lack of full data set; i.e., I only seem to be able to find the "total" TCDD'S, PeTCDD'S, HxTCDD'S, etc. in the report, and I haven't found any discussion of TEF's, etc.

I got the TEF table from Steve Stadola at EPA, and used his formulas to calculate the Total Toxicity Equivalency Quotient. All analytes listed in his table were available in the new data set.

6. The Tables containing most of these evaluations in the ERA are in what appears to be handwritten, non-electronic form. This makes it impossible to do any re-writing or recalculation for you. I will fax you copies of three Tables on which I've penciled in some initial thoughts on how they might be edited. These ideas are draft, and may need to be changed as the editing progresses.

Revisions to electronic versions of tables on the included disk are suffixed with "r" after the table name, e.g. Table 7-15 old is "Tab7-15.xls", whereas the revised Table is "Tab7-15r.xls". Note that the new tables are linked together so there aren't any mathematical roll-up errors.

Using the revised input exposure parameter and RTV data in the attached Tables and the site chemistry measured at fish sampling locations, I have drafted a new Table 3.3-1 for the Night Heron exposure scenario for inclusion in the PRG document. As it turned out, two of the fish sampling locations were not evaluated for the TIE (due to non-toxic sediments) hence chemistry data was not collected. There may be data available from the Tetra Tech NUS part of the study. The PCB and dioxin data used was the sum of homolog concentrations and TEQs reported in Table sA-1-1 and A-1-3 of the PRG document.

cc:
M. Penko, USACE
M. Worthy, ENSR

Table 5-1. Avian food web exposure parameters.

SPECIES	INTAKE RATES (kg/day wet weight)[a]						HOME RANGE	BIOAVAILABILITY FACTOR	BODY WEIGHT (kg)
	ORGANISMS			TOTAL FOOD*	INCIDENTAL SEDIMENT	WATER[b] (L/day)			
	FISH	CRUSTACEANS	TERRESTRIAL INSECTS						
Red-winged blackbird	na		0.012	0.023	na	0.008	0.9	COC specific	0.054
Black-crowned night heron[c]	0.177	0.048	0.003	0.172	0.01	0.054	1	COC specific	0.883

(a) Dry to wet weight conversions used mean percent moisture of 78.7% for fish, 68% for crabs, 48% for insects, and 44.5% for sediment.
(b) Values for dietary requirements were derived from allometric equations of Nagy presented in Section 5.
(c) 1.33 adjustment factor be applied only to the "prey" or food component of the dose
to adjust for 25% under representation of the full daily dietary (prey) requirement of the Black-crowned Night Heron

Table 7-13. RTVs for use in the avian food web model and their sources.

Contaminant of Concern	Compound Tested	Test Species: Common name	Body Weight, kg	Condition Evaluated[a]	RTV (mg/kg Bw/day)	Endpoint	Extrapolation Factor[b]	Source	Adjusted NOEL (mg/kg Bw/day)
arsenic	sodium arsenite	mallard	1	M	5.135	Chronic NOEL	1	USFWS 1964	5.14
cadmium	cadmium chloride	mallard	1.153	R	1.45	Chronic NOEL	1	White and Finley 1978	1.45
chromium+3	CrK(SO4)2	black duck	1.25	R	1	Chronic NOEL	1	Hasetine et al., unpub.	1.00
copper	copper oxide	chicken	0.534	G,M	28.13	Chronic NOEL	1	Mehring et al 1960	28.13
lead	metallic	American kestrel	0.13	R	2.05		1	Paltee 1984	2.05
mercury		mallard	1	R	0.064	LOEL unbounded	0.5	Heinz et al. 1979	0.03
nickel	nickel sulphate	mallard	0.782	M,G	77.4	Chronic NOEL	1	Cain and Pafford 1981	77.40
silver	silver nitrate, chloride, and thiosulfate	chickens	0.4	G	12.5	Subchronic NOEL	1	Hill and Matrone 1970	12.50
zinc	zinc carbonate	chicken	1.9	M	11.3	Chronic NOEL	1	Gasaway and Buss 1972	11.30
Dioxin TEQs	2,3,7,8-TCDD	ringed-neck pheasants	1.0	R	0.000014	Chronic NOEL	1	Noesek et al. 1992	0.000014
Naphthalene	TPH	mallard	1.3	M	338	Chronic LOEL	0.1	Patton and Dieter 1980	33.80
Phenanthrene	TPH	mallard	1.3	M	338	Chronic LOEL	0.1	Patton and Dieter 1980	33.80
DDTS		brown pelican	3.5	R	0.028	Chronic LOEL	0.1	EPA 1993	0.00
PCBs		pheasant	1	R	1.8	Chronic LOEL	0.1	EPA 1993	0.18

a— M: mortality R: reproduction G: growth

b — EPA, 1993: LOEL to NOEL factor of two, rather than ten, was used for Hg because the LOEL appeared to be near the threshold for dietary effects

Table 7-14a. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Ferry Creek

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated (mg/day)	Total Assimilated (mg/kg Bw/day)	RTV (mg/kg Bw/day)	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water				
Arsenic	0.11	0.0766	0.0006	0.0330	0.0012	0.2	0.2	5.14	0.04
Cadmium	0.01	0.0603	0.0025	0.0190	0.0001	0.08	0.09	1.45	0.064
Chromium (+3)	0.28	0.1111	0.0028	0.6600	0.0007	0.9	1.0	1.00	1.02
Copper	1.98	3.4569	0.0745	3.6340	0.0065	5.9	6.7	28.13	0.24
Lead	1.11	0.7565	0.0059	2.5050	0.0007	3.7	4.2	2.05	2.06
Mercury	0.00	0.0005	0.0000	0.0019	0.0000	0.004	0.005	0.0320	0.15
Nickel	0.13	0.1580	0.0024	0.3000	0.0006	0.50	0.6	77.4	0.0074
Silver	0.01	nr	nr	0.0053	0.0001	0.009	0.010	12.50	0.0008
Zinc	8.83	1.3119	0.2062	2.2350	0.0069	10.7	12.1	11.3	1.07
TCDD TEQs (a)	0.23	0.2049	0.0059	0.2200	nr	0.56	0.6	14.00	0.05
Naphthalene	0.00	0.0003	0.0000	0.0179	0.0003	0.017	0.019	33.8	0.0006
Phenanthrene	0.01	0.0008	0.0001	0.0109	0.0003	0.018	0.021	33.8	0.00062
DDTS	0.00	0.0003	0.0000	0.0001	0.0000	0.00198	0.00225	0.0028	0.80
PCBs	0.04	0.0081	0.0004	0.0063	0.0001	0.04	0.05	0.180	0.28
								Hazard Index	5.78

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 7-14b. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Housatonic Boat Club Wetlands

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated	Total Assimilated	RTV	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water	(mg/day)	(mg/kg Bw/day)	(mg/kg Bw/day)	
Arsenic	nc	0.0956	nc	0.0450	0.0009	0.1	0.1	5.14	0.03
Cadmium	nc	0.0025	nc	0.0067	0.0001	0.01	0.01	1.45	0.006
Chromium (+3)	nc	0.1095	nc	1.4000	0.0032	1.3	1.5	1.00	1.46
Copper	nc	4.9181	nc	4.8200	0.0075	6.3	7.2	28.13	0.26
Lead	nc	2.5130	nc	1.2200	0.0020	3.2	3.6	2.05	1.75
Mercury	nc	0.0008	nc	0.0040	0.0002	0.004	0.005	0.0320	0.15
Nickel	nc	0.1233	nc	0.1850	0.0001	0.26	0.3	77.4	0.0038
Silver	nc	nr	nc	0.0060	0.0001	0.005	0.006	12.50	0.0005
Zinc	nc	1.2997	nc	1.6620	0.0008	2.5	2.9	11.3	0.25
TCDD TEQs (a)	nc	0.7517	nc	0.1350	nr	0.75	0.9	14.00	0.06
Naphthalene	nc	0.0001	nc	0.0083	0.0003	0.007	0.008	33.8	0.0002
Phenanthrene	nc	0.0001	nc	0.0026	0.0003	0.003	0.003	33.8	0.00009
DDTS	nc	0.0000	nc	0.0001	0.0000	0.00006	0.00007	0.0028	0.03
PCBs	nc	0.0747	nc	0.0027	0.0001	0.07	0.07	0.180	0.41
								Hazard Index	4.40

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 7-14c. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the black-crowned night heron.

Milford Point Reference Area

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated (mg/day)	Total Assimilated (mg/kg Bw/day)	RTV (mg/kg Bw/day)	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water				
Arsenic	0.08	0.0814	0.0007	0.0370	0.0003	0.2	0.2	5.14	0.04
Cadmium	0.00	0.0042	0.0020	0.0055	0.0000	0.01	0.01	1.45	0.010
Chromium (+3)	0.39	0.1785	0.0046	1.2130	0.0009	1.5	1.7	1.00	1.72
Copper	1.20	2.5207	0.0790	4.3470	0.0010	5.3	6.0	28.13	0.21
Lead	0.11	0.1754	0.0192	0.4210	0.0002	0.6	0.7	2.05	0.34
Mercury	0.00	0.0011	0.0000	0.0038	0.0003	0.007	0.008	0.0320	0.24
Nickel	0.08	0.1315	0.0021	0.1440	0.0001	0.30	0.3	77.4	0.0044
Silver	0.01	nr	nr	0.0040	0.0001	0.011	0.012	12.50	0.0010
Zinc	7.57	1.1242	0.2316	1.7560	r	9.1	10.3	11.3	0.91
TCDD TEQs (a)	0.12	0.1096	0.0037	0.0450	nr	0.24	0.3	14.00	0.02
Naphthalene	0.00	0.0002	0.0000	0.0019	0.0003	0.002	0.003	33.8	0.0001
Phenanthrene	0.00	0.0001	0.0001	0.0019	0.0003	0.002	0.003	33.8	0.00008
DDTS	0.01	0.0002	0.0000	0.0000	0.0000	0.00471	0.00534	0.0028	1.91
PCBs	0.25	0.0029	0.0004	0.0014	0.0001	0.22	0.25	0.180	1.39
								Hazard Index	6.76

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of 25% unsampled.

nr: analyte not reported in this media

r: concentration data rejected

Table 7-15. Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the red-winged Black Bird.

Ferry Creek

Contaminant of Concern	Dietary Intake, (mg/day)		Total Assimilated[a] (mg/day)	Total Assimilated[b] (mg/kg Bw/day)	RTV (mg/kg Bw/day)	Hazard Quotient
	Insects	Water				
Arsenic	0.01	0.0000	0.0	0.1	5.14	0.02
Cadmium	0.02	0.0037	0.02	0.36	1.45	0.248
Chromium (+3)	0.02	0.0002	0.0	0.3	1.00	0.34
Copper	0.64	0.0021	0.4	7.0	28.13	0.25
Lead	0.05	0.0208	0.1	1.0	2.05	0.50
Mercury	0.00	0.0024	0.002	0.037	0.0320	1.15
Nickel	0.02	0.0001	0.02	0.3	77.4	0.0038
Silver	nr	0.0020	0.002	0.029	12.50	0.0023
Zinc	1.78	0.0003	1.5	25.3	11.3	2.24
TCDD TEQs[c]	0.05	nr	0.04	0.7	14.00	0.05
Naphthalene	0.00	0.0009	0.001	0.015	33.8	0.0005
Phenanthrene	0.00	0.0009	0.001	0.021	33.8	0.00061
DDTS	0.00	0.0000	0.00023	0.00391	0.0028	1.40
PCBs	0.00	0.0000	0.00	0.05	0.180	0.29
					Hazard Index	6.48

a — Adjusted for bioavailability factor.

b — Adjusted for 90% home range factor.

c – 2,3,7,8-TCDD TEQs in ng/kg, ww

nr: analyte not reported in this media

r: concentration data rejected

Table 7-15, (con't). Ingestion rates and doses of CoCs, by media, with Hazard Quotient calculations for the red-winged Black Bird.

Milford Point Reference Area

Contaminant of Concern	Dietary Intake, (mg/day)		Total Assimilated[a] (mg/day)	Total Assimilated[b] (mg/kg Bw/day)	RTV (mg/kg Bw/day)	Hazard Quotient
	Insects	Water				
Arsenic	0.0058	0	0.0049	0.08	5.14	0.02
Cadmium	0.017	0.0008256	0.0156	0.26	1.45	0.18
Chromium (+3)	0.040	0.00012	0.0339	0.57	1.00	0.57
Copper	0.68	0.0027348	0.45	7.43	28.13	0.26
Lead	0.17	0.0030788	0.1434	2.39	2.05	1.17
Mercury	0.00035	0.0005676	0.0008	0.01	0.0320	0.40
Nickel	0.018	0.001032	0.0161	0.27	77.4	0.0035
Silver	nr	0.0003096	0.0003	0.00	12.50	0.00035
Zinc	2.00	r	1.7018	28.36	11.3	2.51
TCDD TEQs[c]	0.032	nr	0.0270	0.45	14.00	0.03
Naphthalene	0.00023	0.00086	0.0009	0.015	33.8	0.00046
Phenanthrene	0.00108	0.00086	0.0016	0.03	33.8	0.0008
DDTS	0.00028	0	0.0002	0.004	0.0028	1.40
PCBs	0.0032	0	0.0027	0.05	0.180	0.25
					Hazard Index	6.79

a — Adjusted for bioavailability factor.
b — Adjusted for 90% home range factor.
c – 2,3,7,8-TCDD TEQs in ng/kg, ww
nr: analyte not reported in this media
r: concentration data rejected

Table 3-3.1. Ingestion rates and doses of CoC's by media, with Hazard Quotient calculations for the black-crowned night heron.

A. Upper Ferry Creek (MF03)

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated		RTV	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water	(mg/day)	(mg/kg Bw/day)	(mg/kg Bw/day)	
Arsenic	nr	nr	nr	nr	nr	nr	nr	5.14	nr
Cadmium	nr	nr	nr	nr	nr	nr	nr	1.45	nr
Chromium (+3)	nr	nr	nr	nr	nr	nr	nr	1.00	nr
Copper	nr	nr	nr	nr	nr	nr	nr	28.13	nr
Lead	nr	nr	nr	nr	nr	nr	nr	2.05	nr
Mercury	nr	nr	nr	nr	nr	nr	nr	0.0320	nr
Nickel	nr	nr	nr	nr	nr	nr	nr	77.4	nr
Silver	nr	nr	nr	nr	nr	nr	nr	12.50	nr
Zinc	nr	nr	nr	nr	nr	nr	nr	11.3	nr
TCDD TEQs (a)	0.0002	nr	nr	nr	nr	0.0002	0.0002	14.00	0.00001
Naphthalene	nr	nr	nr	nr	nr	nr	nr	33.8	nr
Phenanthrene	nr	nr	nr	nr	nr	nr	nr	33.8	nr
DDTs	nr	nr	nr	nr	nr	nr	nr	0.0028	nr
PCBs	0.09	nr	nr	nr	nr	0.08	0.09	0.180	0.47
								Hazard Index	0.47

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 3-3.1 (con't). Ingestion rates and doses of CoCs by media, with Hazard Quotient calculations for the black-crowned night hero

B. Middle Ferry Creek (A3SD10)

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated		RTV	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water	(mg/day)	(mg/kg Bw/day)	(mg/kg Bw/day)	
Arsenic	nr	nr	nr	0.24	nr	0.2	0.2	5.14	0.04
Cadmium	nr	nr	nr	0.08	nr	0.07	0.08	1.45	0.055
Chromium (+3)	nr	nr	nr	4.63	nr	3.9	4.5	1.00	4.46
Copper	nr	nr	nr	25.5	nr	21.7	24.5	28.13	0.87
Lead	nr	nr	nr	32.9	nr	28.0	31.7	2.05	15.45
Mercury	nr	nr	nr	0.004	nr	0.004	0.004	0.0320	0.13
Nickel	nr	nr	nr	3.17	nr	2.69	3.1	77.4	0.0394
Silver	nr	nr	nr	0.02	nr	0.017	0.019	12.50	0.0015
Zinc	nr	nr	nr	13.4	nr	11.4	12.9	11.3	1.14
TCDD TEQs (a)	0.0003	nr	nr	0.01	nr	0.0055	0.0063	14.00	0.00045
Naphthalene	nr	nr	nr	0.01	nr	0.009	0.010	33.8	0.0003
Phenanthrene	nr	nr	nr	0.01	nr	0.007	0.008	33.8	0.00022
DDTs	nr	nr	nr	nr	nr	nr	nr	0.0028	nr
PCBs	0.10	nr	nr	0.29	nr	0.33	0.38	0.180	2.09
								Hazard Index	24.28

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 3-3.1 (con't). Ingestion rates and doses of CoCs by media, with Hazard Quotient calculations for the black-crowned night heron

C. Lower Ferry Creek (SD26)

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated		RTV	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water	(mg/day)	(mg/kg Bw/day)	(mg/kg Bw/day)	
Arsenic	nr	nr	nr	nr	nr	nr	nr	5.14	nr
Cadmium	nr	nr	nr	nr	nr	nr	nr	1.45	nr
Chromium (+3)	nr	nr	nr	nr	nr	nr	nr	1.00	nr
Copper	nr	nr	nr	nr	nr	nr	nr	28.13	nr
Lead	nr	nr	nr	nr	nr	nr	nr	2.05	nr
Mercury	nr	nr	nr	nr	nr	nr	nr	0.0320	nr
Nickel	nr	nr	nr	nr	nr	nr	nr	77.4	nr
Silver	nr	nr	nr	nr	nr	nr	nr	12.50	nr
Zinc	nr	nr	nr	nr	nr	nr	nr	11.3	nr
TCDD TEQs (a)	0.0002	nr	nr	nr	nr	0.0002	0.0002	14.00	0.00001
Naphthalene	nr	nr	nr	nr	nr	nr	nr	33.8	nr
Phenanthrene	nr	nr	nr	nr	nr	nr	nr	33.8	nr
DDTs	nr	nr	nr	nr	nr	nr	nr	0.0028	nr
PCBs	0.09	nr	nr	nr	nr	0.08	0.09	0.180	0.47
								Hazard Index	0.47

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media

Table 3-3.1 (con't). Ingestion rates and doses of CoCs by media, with Hazard Quotient calculations for the black-crowned night heron

D. Great Meadows Reference Area (GM08)

Contaminant of Concern	Dietary Intake, (mg/day)					Total Assimilated		RTV	Hazard Quotient
	Fish	Crab	Insects	Sediment	Water	(mg/day)	(mg/kg Bw/day)	(mg/kg Bw/day)	
Arsenic	nr	nr	nr	0.18	nr	0.2	0.2	5.14	0.03
Cadmium	nr	nr	nr	0.02	nr	0.01	0.01	1.45	0.010
Chromium (+3)	nr	nr	nr	2.31	nr	2.0	2.2	1.00	2.22
Copper	nr	nr	nr	6.6	nr	5.6	6.4	28.13	0.23
Lead	nr	nr	nr	1.6	nr	1.3	1.5	2.05	0.74
Mercury	nr	nr	nr	0.012	nr	0.010	0.012	0.0320	0.36
Nickel	nr	nr	nr	0.37	nr	0.32	0.4	77.4	0.0047
Silver	nr	nr	nr	0.03	nr	0.026	0.029	12.50	0.0023
Zinc	nr	nr	nr	2.9	nr	2.5	2.8	11.3	0.25
TCDD TEQs (a)	0.0003	nr	nr	0.0001	nr	0.0004	0.0004	14.00	0.00003
Naphthalene	nr	nr	nr	0.01	nr	0.006	0.006	33.8	0.0002
Phenanthrene	nr	nr	nr	0.001	nr	0.001	0.001	[illegible]8	0.00003
DDTs	nr	nr	nr	nr	nr	nr	nr	0.0028	nr
PCBs	0.10	nr	nr	0.003	nr	0.08	0.10	0.180	0.53
								Hazard Index	4.39

a — 2,3,7,8-TCDD TEQs in ng/kg, ww

b — Hazard Quotient is adjusted to account for 100% of diet, assuming equal contamination of the 25% unsampled.

nr: analyte not reported in this media