Assessment of Damages to Natural Resources in the East Walker River from the Advanced Fuel Filtration Spill: Water, Sediment, and Fish Tissue Analysis.

U.S. FISH AND WILDLIFE SERVICE
NEVADA FISH AND WILDLIFE OFFICE
DIVISION OF ENVIRONMENTAL QUALITY
RENO, NEVADA

U.S. FISH & WILDLIFE SERVICE
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Assessment of Damages to Natural Resources in the East Walker River from the Advanced Fuel Filtration Spill: Water, Sediment, and Fish Tissue Analysis.

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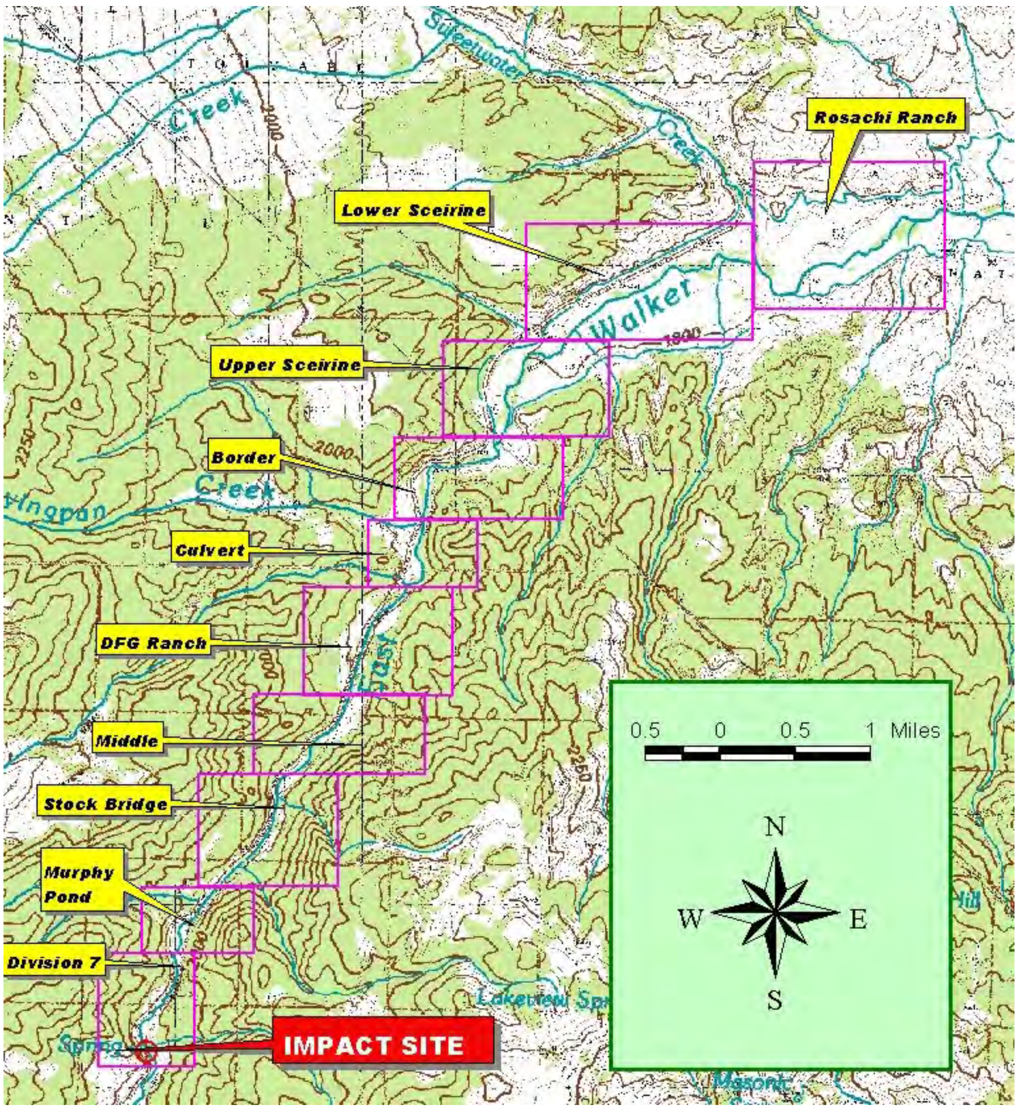
Background

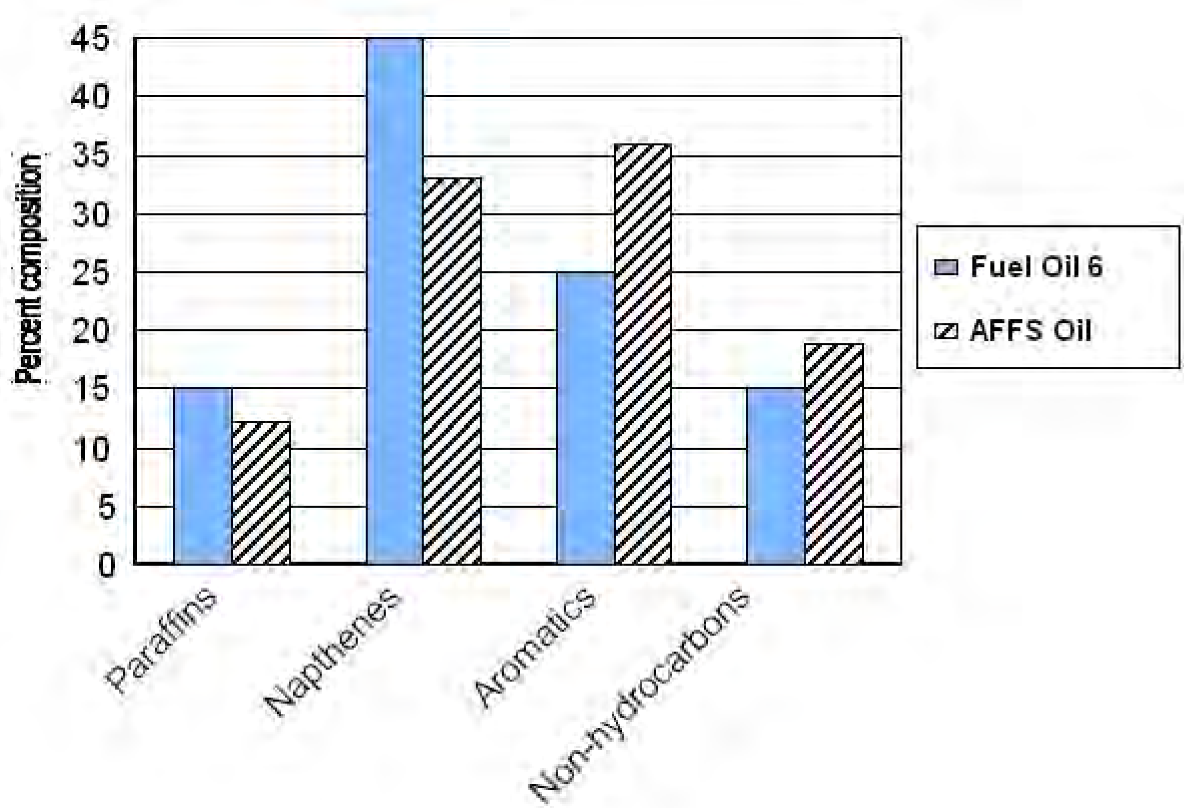
On December 30, 2000, a tanker truck operated by Advanced Fuel Filtration Systems, Inc. (AFFS) of Corona, California overturned on California State Route 182 resulting in the release of approximately 3,608 gallons of fuel oil #6, the majority of which entered into the East Walker River. The fuel visibly oiled approximately ten miles of stream habitat, seven of which were in California and three in Nevada. The impacted area was divided into ten sections (or divisions) for clean up and assessment for natural resource damages (Figure 1). The purpose of this report is to describe the ecological impacts to East Walker River using data collected on water, sediment, and fish tissue analysis of polycyclic aromatic hydrocarbons originating from the fuel oil released in the AFFS Spill.

Figure 1. Map of the area affected by the AFFS Spill in the East Walker River along with the divisions used for cleanup and assessment of natural resource damages.



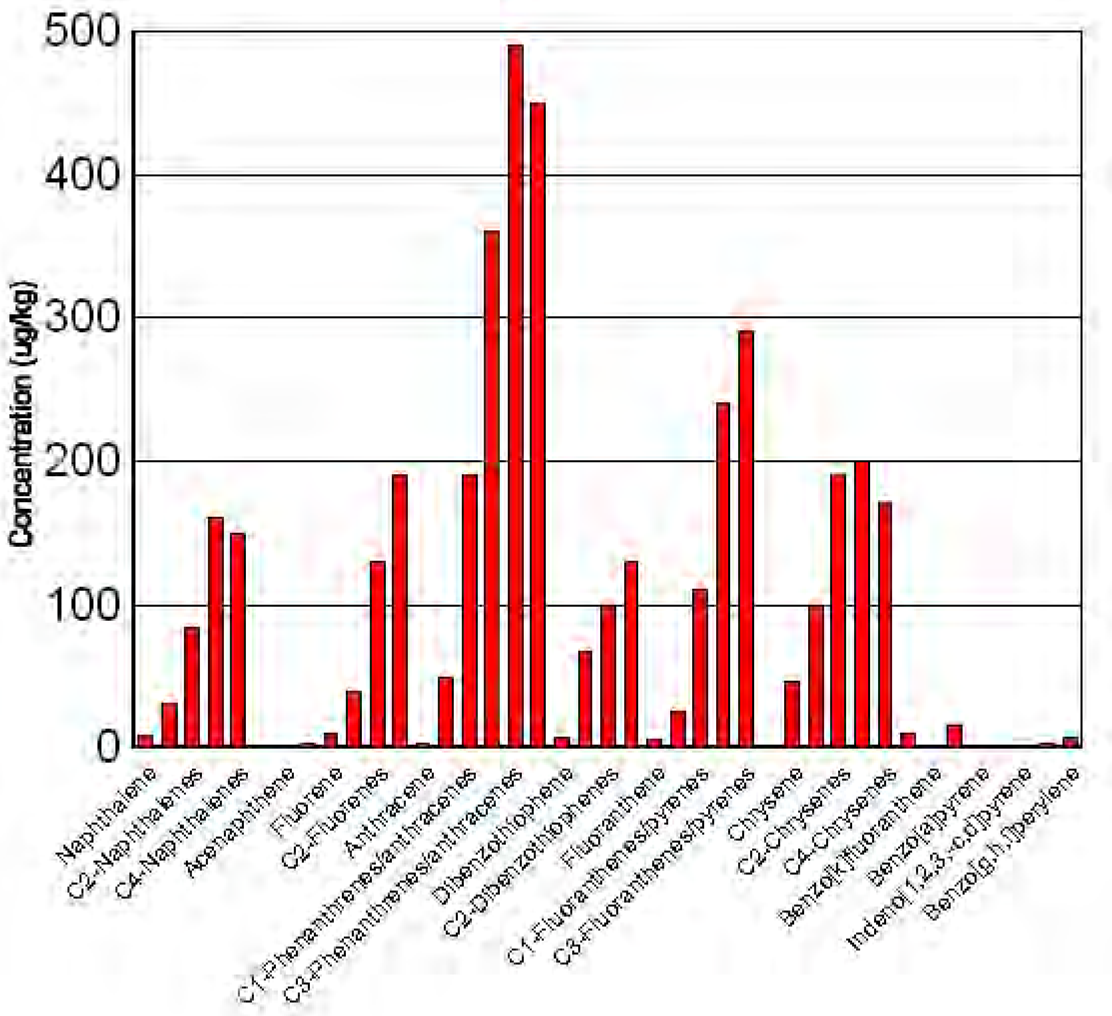
A brief description is needed on the physical properties of fuel oil #6 as well as its' environmental fate and toxicity. Fuel oils are comprised of mixtures of petroleum distillates. Fuel oil #6 has a boiling point of >400 degrees F and has the highest boiling fraction among the heavy distillates made from petroleum. Fuel oil #6 is commonly known as a "residual oil" and has a complex and variable mixture of relatively high molecular weight compounds. Fuel oil #6 contains about 15% paraffins, 45% naphthenes, 25% aromatics, and 15% non-hydrocarbon compounds; the hydrocarbons contain $\geq$30 carbon atoms (Clark et al. 1977). It consists of straight-run and cracked distillates and residuals and contains aliphatics and aromatics (Dabney 1990). A comparison to typical fuel oil #6 components revealed fuel oil #6 from the AFFS spill contained lower percentages of paraffins and naphthenes and a higher percentage of aromatics (Figure 2).

Figure 2. Percent composition of typical Fuel Oil No. 6 compared to Advanced Fuel Filtration Systems' product released into the East Walker River, December 30, 2000.



The most toxic components of fuel oils are the aromatics, such as benzene, toluene, xylene, naphthalene and others. These aromatics are relatively highly soluble in water. After the aromatic fraction, toxicity decreases from olefins through naphthenes to paraffins. Within each of these groups, the lower molecular weight hydrocarbon tends to be more acutely toxic (Curl and O'Donnell 1977). Appreciable concentrations of polycyclic aromatic hydrocarbons (PAHs) are present in residual fuels because of the common practice of using both uncracked and cracked residues in their manufacture (Irwin et al. 1997). Most blending stocks are likely to contain 5% or more of the four- to six-ring condensed aromatic hydrocarbons. The exact identities and concentrations of PAHs in a particular sample depend on the nature and amounts of blending stocks as well as the virgin and cracked residues (World Health Organization 1989). The concentrations of PAH congeners in the AFFS fuel oil #6 released into the East Walker River are shown in Figure 3.

Figure 3. Concentrations of polycyclic aromatic hydrocarbon compounds (PAHs) in Fuel Oil No.6 from the Advanced Fuel Filtration tanker truck collected January 2, 2001.



In the aquatic environment, the main concern from fuel oil #6 is in the aromatics. Fuel oil #6 contains considerable amounts of polycyclic aromatic hydrocarbons (PAHs) (Rand and Petrocelli 1985; World Health Organization 1989). Due to their relative persistence and potential for various chronic effects (like carcinogenicity), the heavier PAHs in fuel oil #6 can pose long term (chronic) hazards in contaminated soils, sediments, and groundwater. They may weather slowly, and potentially sink (depending on product density and water density) to impact benthic organisms. Short-term hazards of some of the lighter, more volatile and water soluble compounds (such as toluene, ethylbenzene, and xylenes) include potential acute toxicity to aquatic life in the water column (especially in relatively confined areas). Long-term effects are also associated with PAHs, alkyl PAHs, and alkyl benzene (such as xylene) constituents. Although PAHs, particularly heavy PAHs, do not make up a large percentage of distillate fuel oils by weight, there are some low molecular PAHs (LPAHs) in these fuel oils, including naphthalene, alkyl naphthalenes, phenanthrene, and alkyl phenanthrenes (Rand and Petrocelli 1985; World Health Organization 1989). This report summarizes the analytical results and potential impacts to natural resources in the East Walker River.

Methodology

Duplicate samples for water and sediment were collected at each site by personnel from U.S. Fish and Wildlife Service, California Department of Fish and Game, and Polaris Applied Sciences. Samples were stored on ice until delivered to the analytical laboratory for analysis of PAHs. Of the duplicate samples, one sample was submitted to Arthur D. Little Environmental Chemistry and Forensics Unit (ADL) in Cambridge, Massachusetts, and the other sample to the California Department of Fish and Game Water Pollution Control Laboratory in Rancho Cordova, California. Samples analyzed in the laboratory used U.S. Environmental Protection Agency's (EPA) modified 8270 method. Water samples were collected from the center of the river channel entering the channel downstream of the sampling location and using a fresh set of gloves at each sampling site. Sample bottles were rinsed with site water prior to collection keeping the lid in place and plunging the bottle down into the water at sampling depth. The lid was then removed and kept at sampling depth while the bottle was turned into the flowstream. Sample bottles were filled until all air was forced out. The lid was replaced while submerged, the bottle removed, and rinsate discarded downstream of the sampling point. After the rinse, the water sample was collected in the same manner as the rinse. Only fine depositional sediments were selected at each site and composited into one sample from a 10m stretch. Entrance into the sample site was the same as described under the water sample methodology as well as rinsing protocols. Surficial sediment samples were collected and placed into a chemically clean stainless steel bowl and repeated throughout the 10m stretch of the sampling site. Sediment was then mixed with a chemically cleaned stainless steel spoon and split into two sample bottles for duplicate analysis.

Fish sampling was conducted on March 11, 2001 and used a Smith-Root Type VII Backpack Electro shocker to capture fish. Two samples were collected at each site, each being composed of five suckers (*Catostomus spp*.) less than 6 inches and five trout (*Oncorhynchus mykiss* or *Salmo trutta*) less than 10 to 12 inches. Each sample was wrapped in aluminum foil and stored on ice until delivered to ADL. All samples were composited whole bodies. An additional sample of brown trout from the Border division was analyzed for muscle (filet) only and analyzed using EPA modified 8270 method.

Results and Discussion

Water

Water samples were collected at several locations (Divisions) but only Border division was sampled during all three sampling events. PAH congeners in the water column were correlated with the PAH congeners found in the AFFS oil confirming the spill as the source (Figure 4). Total PAHs (TPAH) in the water column were highest during the January sampling period immediately after the spill release with Border and Rosachi Ranch divisions having the highest concentrations among sites with 4,900 and 1,400 parts per trillion (ppt) respectively (Table 1).

Figure 4. Comparison of PAH congener concentrations between fuel oil #6 from the Advanced Fuel Filtration Systems Inc. Spill and water taken from the Border division area of the East Walker River, January 10, 2001.

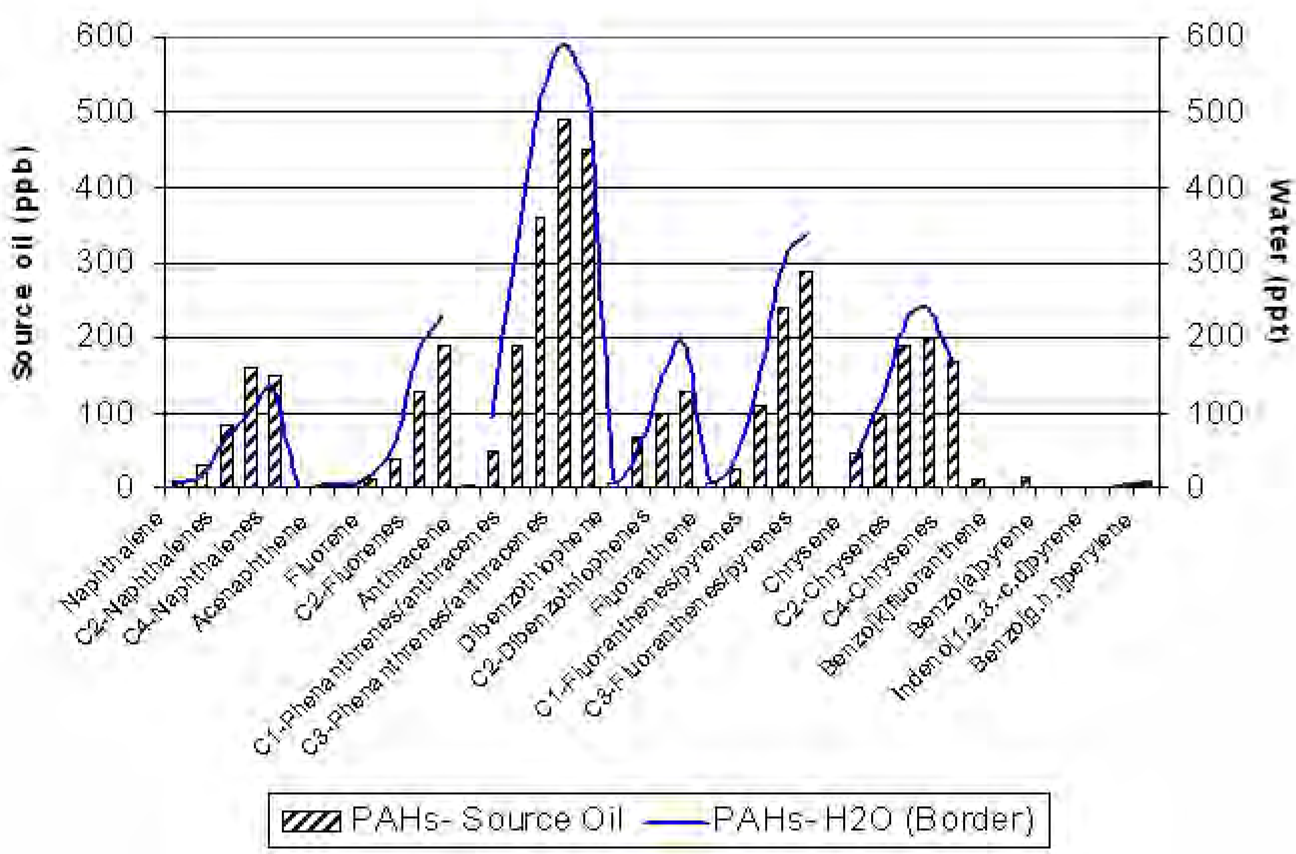


Table 1. Total polycyclic aromatic hydrocarbon (TPAH) concentrations in water at sites downstream of the Advanced Fuel Filtration Systems Spill in the East Walker River.

Location (distance from impact site)	Date	TPAH (parts per trillion)
Control	May 22, 2001	19
Murphy Pond (1.0 mi.)	January 10, 2001	310
DFG Ranch (3.7 mi.)	March 11, 2001	380 (am), 470 (pm)
	May 22, 2001	27
Border (6.0 mi.)	January 10, 2001	4,900
	March 11, 2001	360 (am), 400 (pm)
	May 22, 2001	29
Rosachi (10.4 mi.)	January 10, 2001	1,400
	May 22, 2001	30
Elbow (15.2 mi.)	May 22, 2001	32
Raccoon Beach (20.4 mi.)	May 22, 2001	34

In water, PAHs may either evaporate, disperse into the water column, incorporate into bottom sediments, concentrate in aquatic biota, or degrade through chemical oxidation and biodegradation (Suess 1976). Aqueous TPAH concentrations as low as 400 ppt cause sub-lethal responses in larvae and eggs of pacific herring (*Clupea pallasi*) (Carls et al. 1998). Aqueous TPAH concentrations of 1000 ppt can also kill pink salmon (*Oncorhynchus gorbuscha*) embryos located downstream from oil sources (Bue et al. 1996; Heintz et al. 1999). The Border and Rosachi divisions had water concentrations that exceeded these effect levels immediately after the spill event (Table 1 and Figure 5). Reductions in concentrations of TPAHs in the water column occurred by the March period but were still at or above threshold effect levels for DFG Ranch and Border divisions. The May sampling event showed that TPAHs in the water column had decreased near background concentrations for all sites compared to the control sample collected for the same period.

Low water solubilities of PAHs (0.0003 to 34 µg/L) combined with their high water-octanol partition coefficients (log K_{ow} = 3.4 to 7.6) make them tend to be more strongly associated with sediments and biota (Eisler 1987). LPAHs, with three aromatic rings or less, are more water soluble and more easily degraded. LPAHs dominated most of the PAHs in the water column at the Border Division in January(Figure 6). As mentioned previously, LPAHs are more acutely toxic than HPAHs to aquatic biota but also degrade more rapidly. The latter appears to be the case in the AFFS spill with water concentrations reduced to near background levels by May.

Figure 5. Total polycyclic aromatic hydrocarbon concentrations in water taken from sites in the East Walker River downgradient of the Advanced Fuel Filtration Systems, Inc. Fuel oil spill. January- May 2001.

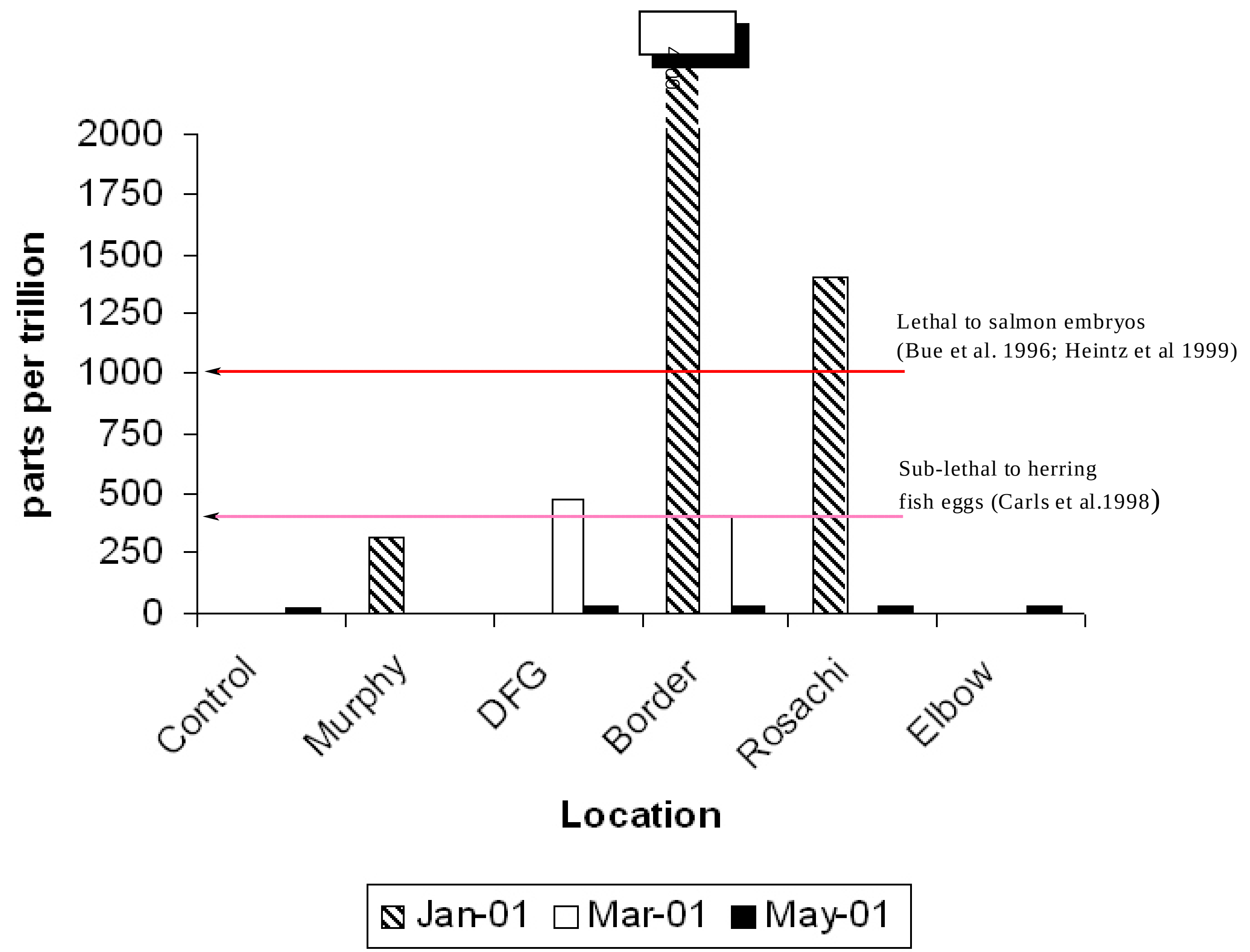
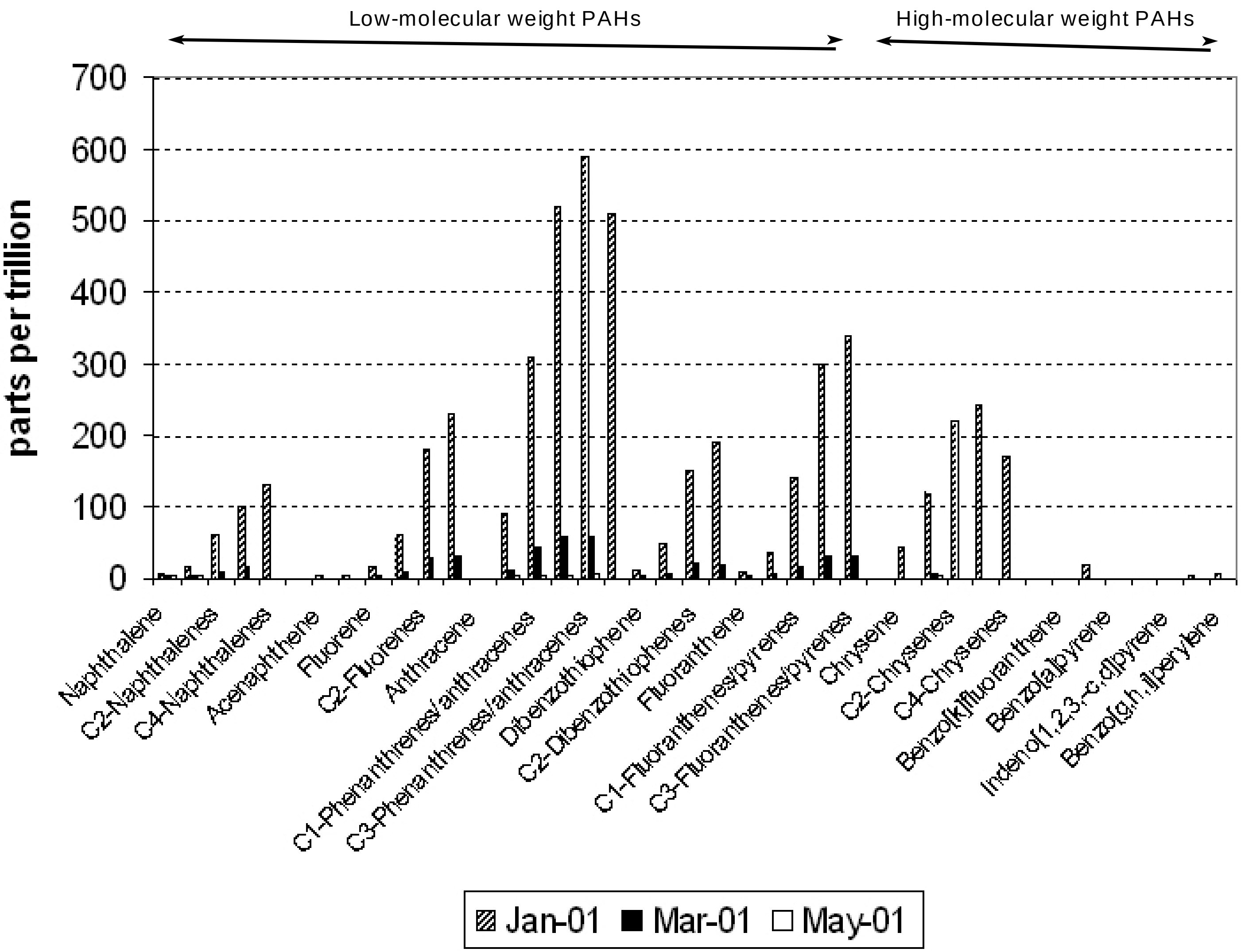


Figure 6. Concentrations of PAH congeners in water at the Border division of the East Walker River, January- May 2001.



Sediment

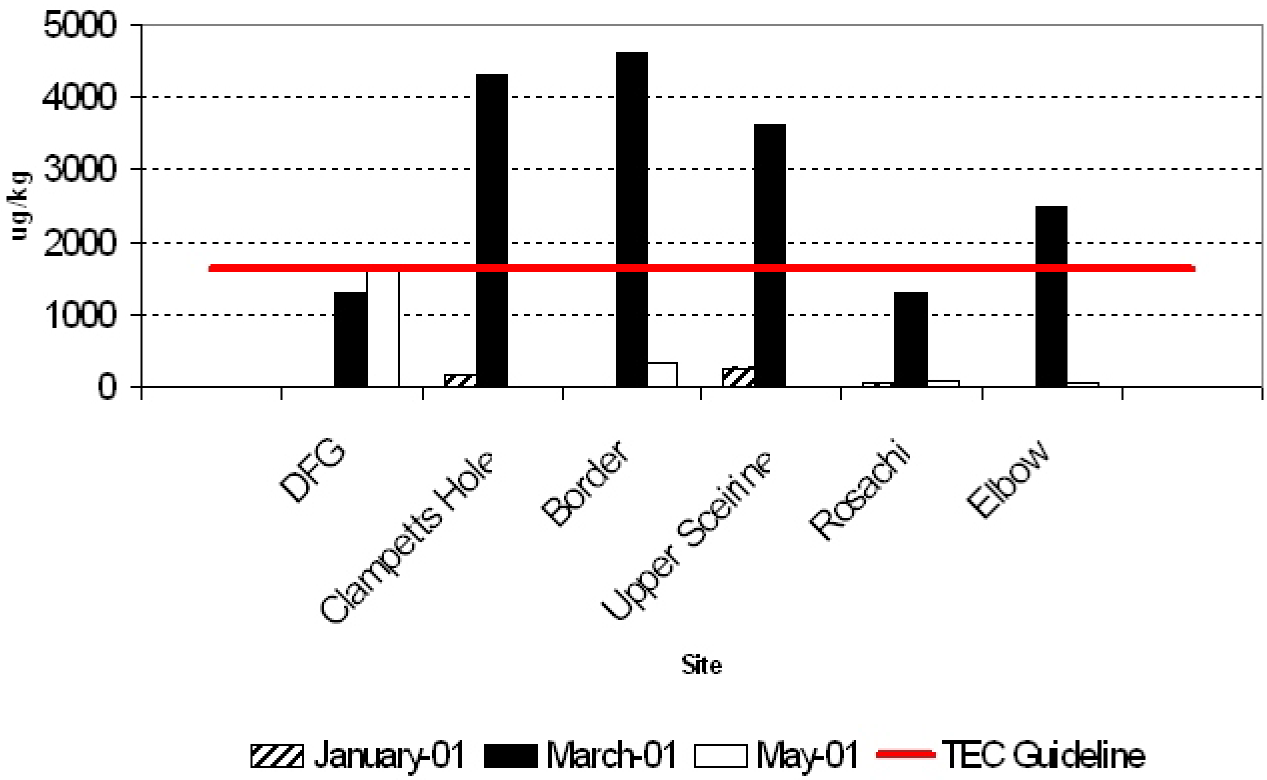
TPAH concentrations in sediments after the AFFS Spill ranged from 29 to 4,600 parts per billion (ppb) (Table 2). Highest concentrations of PAHs were observed during March. Figure 7 illustrates TPAHs in the sediments of the East Walker River downstream of the impact site exceeded the consensus-based Threshold Effect Concentration (TEC) sediment quality guideline for TPAHs developed by McDonald et al. (2000). The TEC was derived from several published sediment quality guidelines for freshwater sediments and represents the concentration below which harmful effects are unlikely to occur.

Table 2. Total PAH (TPAH) concentrations in sediment at sites downstream of the Advanced Fuel Filtration Systems Spill in the East Walker River.

Location (miles downsteam from impact site)	***Date***	***TPAH (parts per billion)***
Control	May 22, 2001	25
Crash Site (0.0 mi)	January 10, 2001	130
Murphy Pond (1 mi.)	January 10, 2001	34
DFG Ranch (3.7 mi)	March 11, 2001	1,300
	May 22, 2001	1,700
Clampetts Hole in Culvert Division (4.3 mi.)	January 10, 2001	170
	March 11, 2001	4,300
Border (6mi.)	March 11, 2001	4,600
	May 22, 2001	340
Sceirine @ Bridge (7.1 mi.)	January 10, 2001	260
	March 11, 2001	3,600
Rosachi @ Bridge (10.4 mi.)	January 10, 2001	50
	March 11, 2001	1,300
	May 22, 2001	93
Elbow (15.2 mi.)	March 11, 2001	2,500
	May 22, 2001	51
Raccoon Beach (20.4 mi.)	May 22, 2001	92
Flying M Ranch (33.4 mi.)	May 22, 2001	29

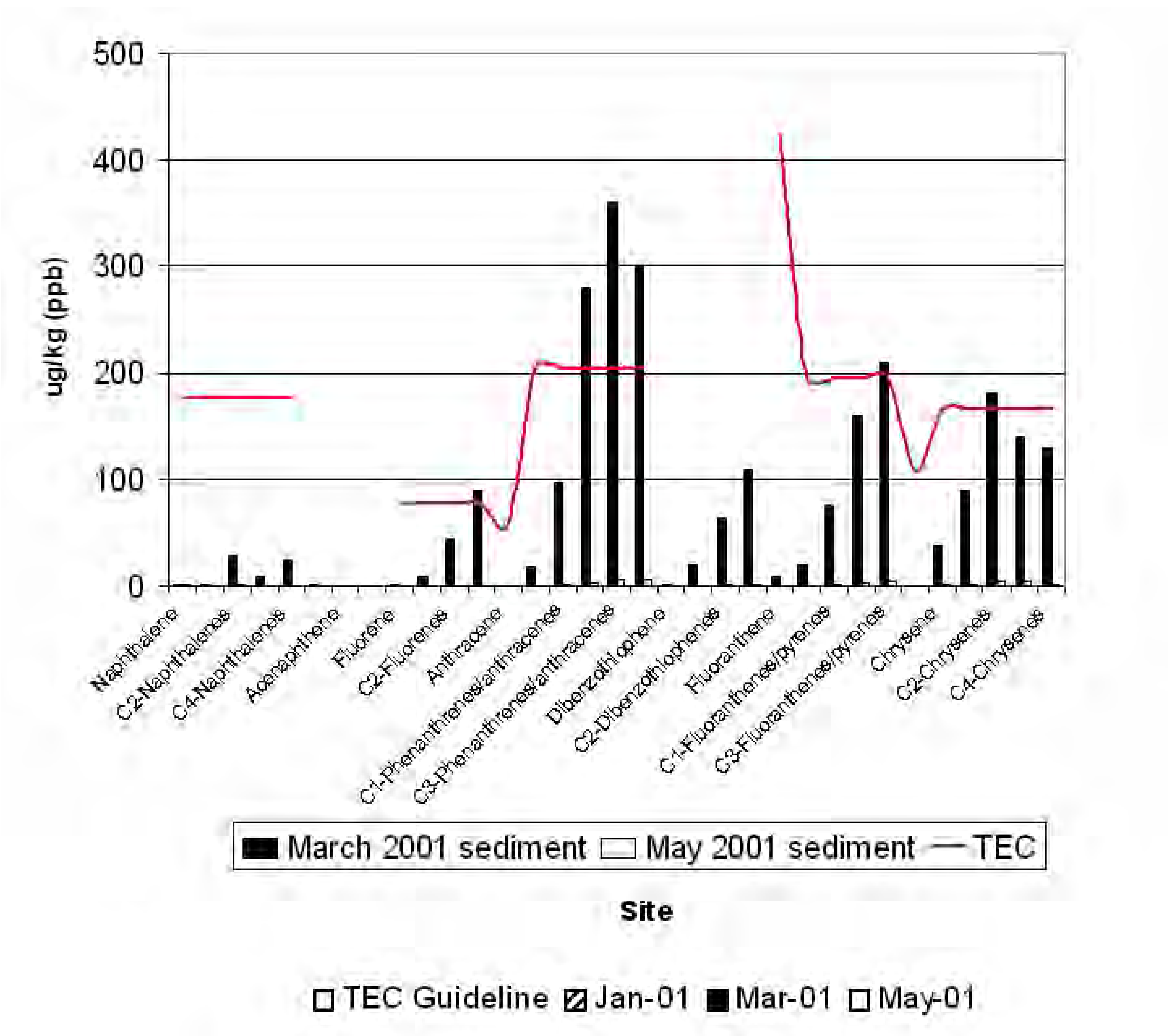
Fuel oil #6 is a heavy oil with little or no evaporation or dissolution potential (NOAA 1992a; NOAA and American Petroleum Institute 1994). As such, fuel oil #6 may be highly persistent, with the potential for long-term sediment contamination. In general, even though density of oil increases through weathering, the density will rarely increase to that of freshwater (approximately 1000 kg/m^3). However, heavy fuels such as #6 may weather to densities heavier than water since the unweathered density already exceeds 900 kg/m^3 (a typical #6 fuel oil is API 12.3 which corresponds to a density of 971 kg/m^3 at 20 to 24 degrees Celsius) (Lee et al. 1989). During a spill, the high viscosity of fuel oil #6 can often lead to the formation of "pancake" like tar globs when the temperature of the water is lower than the pour point of the oil (National Oceanic and Atmospheric Administration 1992b). These semi-solid, tar-like oils have low substrate penetrating ability, and are difficult to remove from contaminated surfaces. As a result, sediments in the East Walker River were not heavily impacted by contamination from fuel oil #6 until water temperatures increased and the fuel oil became more weathered. This explains the dramatic increase of PAH concentrations in the sediment from the March sampling event when compared to the January event (Figure 7).

Figure 7. Total PAHs in sediments downstream of the Advanced Fuel Filtration Systems Spill in the East Walker River and comparison to the Consensus-based Threshold Effect Concentration (TEC) guideline for freshwater sediment quality (McDonald et al. 2000).



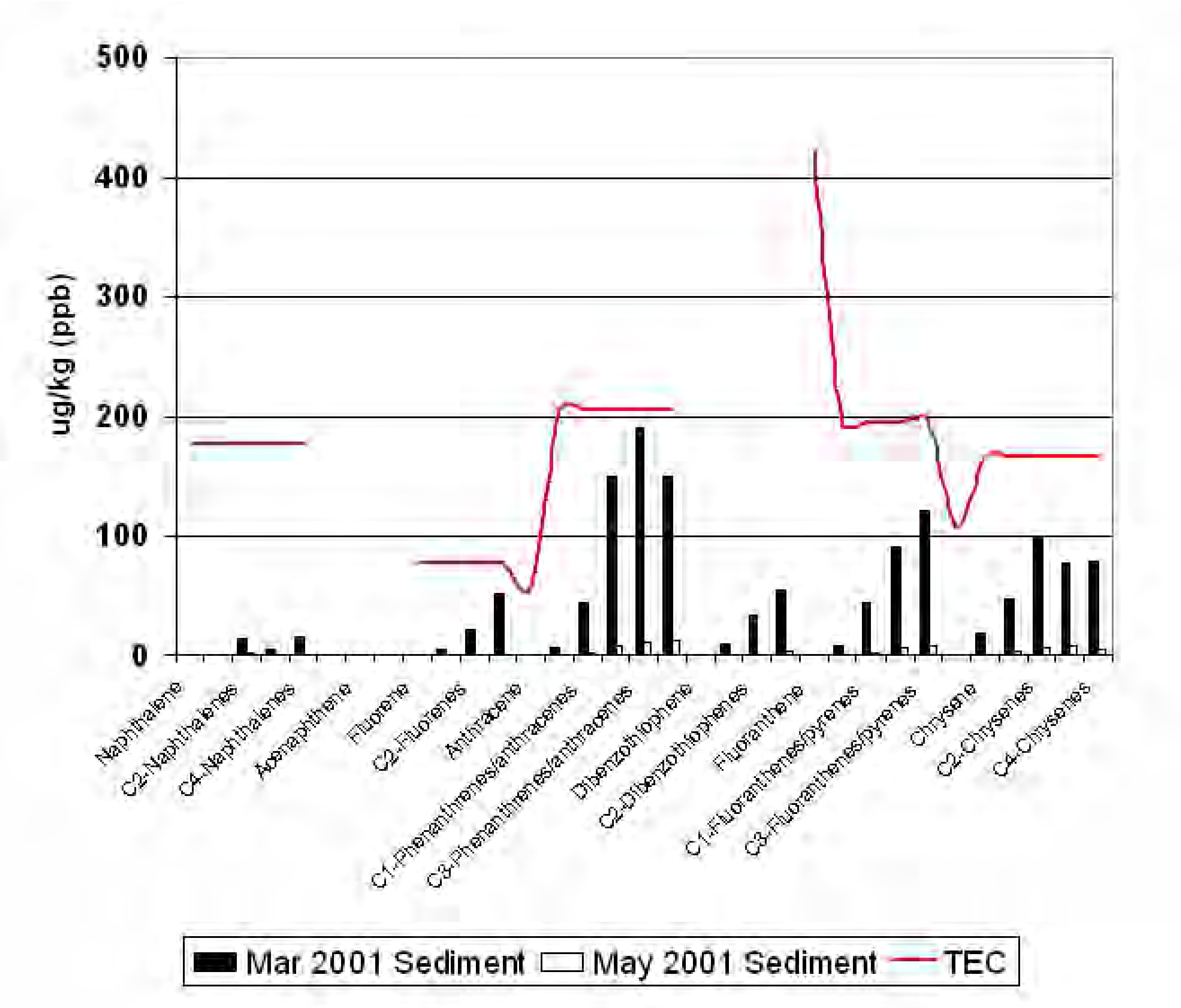
In studying individual PAH congeners in sediment samples, the Elbow site (15.2 miles downstream from the impact site) had exceeded TEC guidelines for the phenanthrene/alkylated anthracene groups (C1 to C4 phenanthrene/anthracene) and the alkylated pyrene groups (C3 and C4 fluoranthene/pyrenes) during the March period (Figure 8). However, all PAHs decreased below levels of concern by the May period.

Figure 8. PAH congener concentrations in sediment from the Elbow site of the East Walker River and comparison to the consensus-based Threshold Effect Concentration (TEC) guideline for sediment quality in freshwater sediments (McDonald et al. 2000).



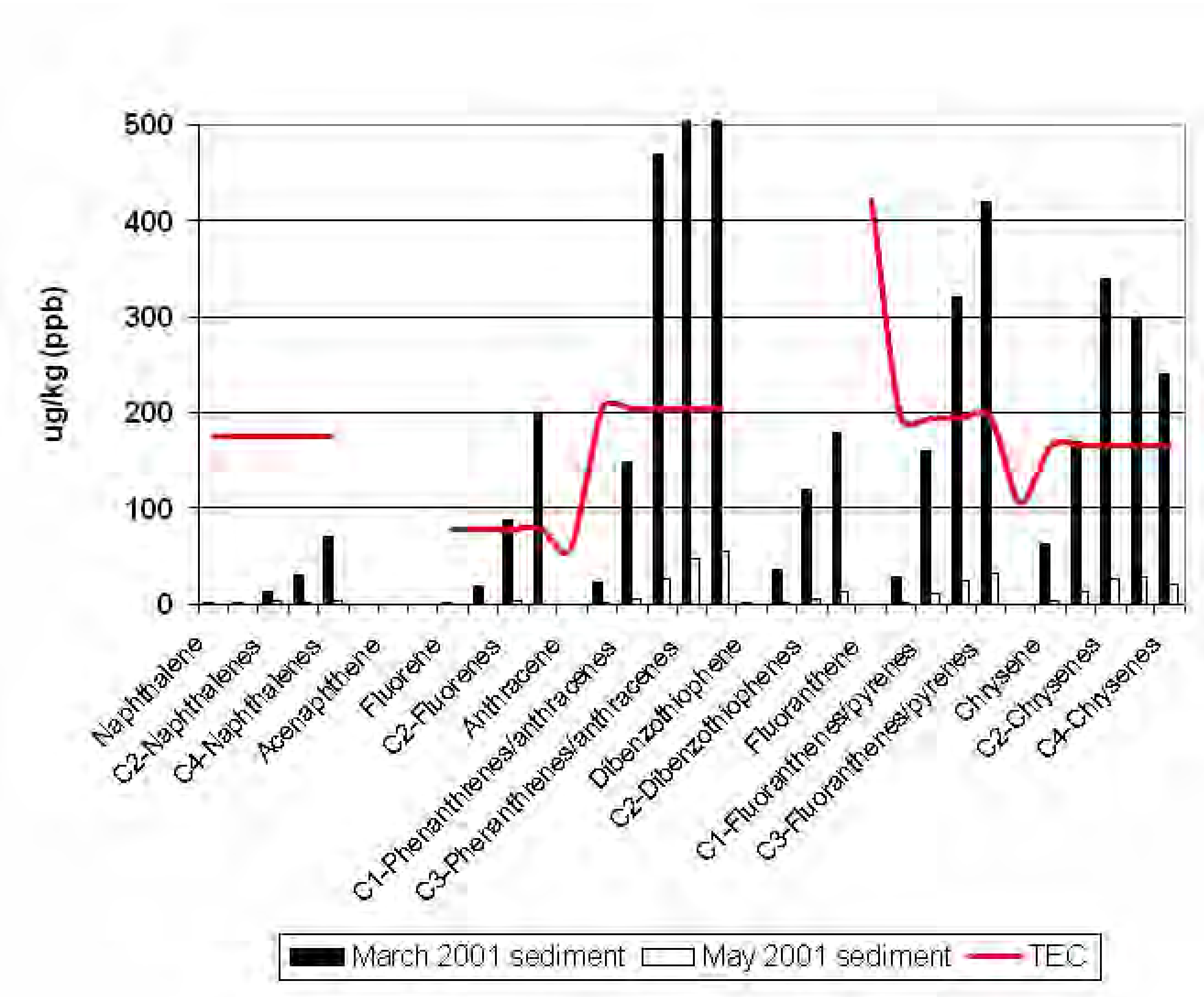
Progressing upstream towards the impact site, PAH congeners in sediment at the Rosachi division, 10.4 miles downstream of the impact site, were elevated for the March period but did not exceed established TEC guidelines (Figure 9). Furthermore, PAH congeners were reduced significantly by the May period.

Figure 9. PAH congener concentrations in sediment from the Rosachi site of the East Walker River and comparison to the consensus-based Threshold Effect Concentration (TEC) guidelines for sediment quality in freshwater sediments (McDonald et al. 2000).



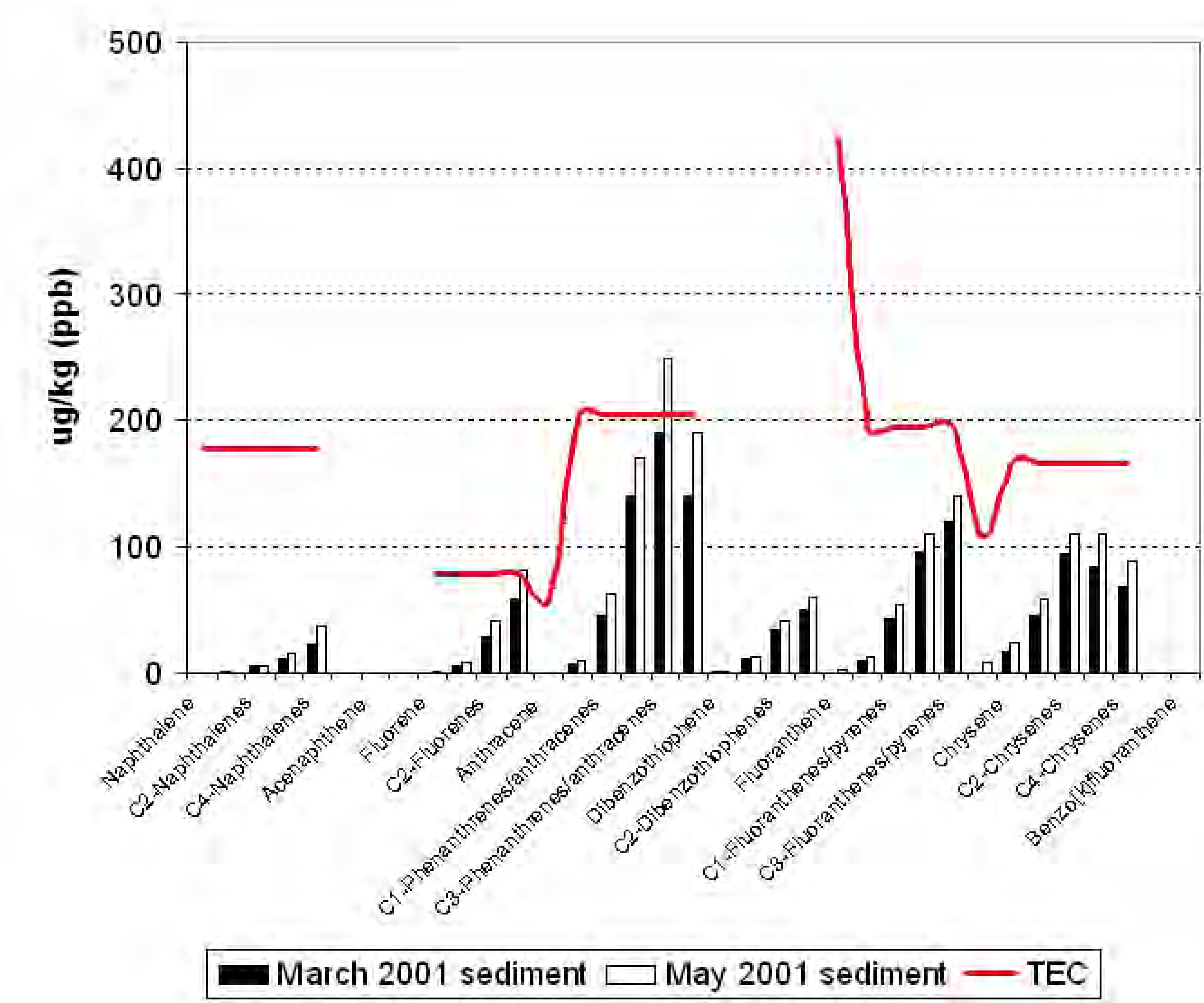
The Border division, 6.0 miles downstream of the impact site, was the most heavily impacted among sites for the March period (Table 2) and had congeners that exceeded the TEC sediment guidelines for fluorenes, phenanthrenes, fluoranthenes, and chrysenes. In particular, concentrations were highest for butylnapthalene (C4 napthalene), ethyl- and propylflourenes, phenanthrene/alkylated anthracene groups (C1 to C4 phenanthrene/anthracene), alkylated pyrene groups (C3 and C4 fluoranthene/pyrenes), and the chrysene groups (Figure 10). However, by the May period all PAHs decreased below TEC guidelines.

Figure 10. PAH congener concentrations in sediment from the Border division of the East Walker River and comparison to consensus-based Threshold Effect Concentration (TEC) guidelines for sediment quality in freshwater sediments (McDonald et al. 2000).



The DFG division, 3.7 miles downstream of the impact site, had PAH congener concentrations below established TEC guidelines for the March period. However, PAH congener concentrations during the May period were greater than March levels and was opposite of downstream siteswhich had reductions during the May period (Table 2). The propyl phenanthrene/alkylated anthracene group (C3 phenanthrene/anthracene) was the only PAH congener that exceeded the TEC guidelines for the May period. Increases of PAHs in the sediments observed from the May event could be from upstream sources that were mobilized by higher flows and deposited in this section. In addition, the river corridor appears to have higher sinuosity in this section compared to the other sites. The sinuosity combined with higher incidence of riparian pool habitats in this section may have made PAH contaminated sediments more likely to be captured and retained.

Figure 11. PAH congener concentrations in sediment from the DFG Ranch division of the East Walker River and comparison to consensus-based Threshold Effect Concentration (TEC) guidelines for sediment quality in freshwater sediments (McDonald et al. 2000).



Fish Tissue

The East Walker River provides habitat to several species of fish. Brown trout and rainbow trout are the primary salmonids along with mountain whitefish (*Prosopium williamsonii*). Other species include Tahoe sucker (*Catostomus tahoensis*), mountain sucker *(Catostomus platyrhynchus*), Lahontan redside shiner (*Richardsonius egregius*), tui chub (*Gila bicolor*), Lahontan speckled dace (*Rhinichthys osculus*), common carp (*Cyprinus carpio*), and Sacramento perch (*Archoplites interruptus*). Lahontan cutthroat trout (*Oncorhynthus clarki henshawi*), a federally endangered species, are for the most part extirpated from the stream but will be occasionally present from occupied headwater streams in the watershed. Fish samples for analysis of PAHs were collected only during the March sampling period and represented two feeding guilds: predatory (trout) and bottom-feeders (sucker). Table 3 summarizes the TPAH results for fish tissues.

Table 3. Total polycyclic aromatic hydrocarbon (TPAH) concentrations in fish collected from sites downstream of the AFFS spill in the East Walker River, March11, 2001.

Location	Fish Species (matrix)	TPAH concentration (ppb)
DFG Ranch	trout (whole body)	86
	sucker (whole body)	2,600
Border	trout (whole body)	260
	trout (muscle)	30
	sucker (whole body)	700
Rosachi Ranch	trout (whole body)	80
	sucker (whole body)	200

Fish tissue concentrations were highest in suckers for all sites. This is expected because suckers are bottom-feeding fish that scavenge the substrate feeding on algae and detrital material and are more exposed to PAH-contaminated sediments. Conversely, trout are predatory drift-feeders obtaining most of their diet from the mid to upper water column. As such, their exposure to PAH contaminated sediment is limited and uptake would primarily be through PAH in the water column or through PAH-contaminated food items. Looking at the potential bioaccumulation from sediment to fish, bioaccumulation factors (BAF), calculated by dividing concentrations in the fish by concentrations in the sediment, ranged from 0.15 to 2.0 for suckers and 0.05 to 0.06 for trout. These BAF's indicate low rates of uptake and retention of PAHs by fish in the East Walker River. This is not surprising because fish rapidly metabolize and excrete PAHs. Because of rapid metabolization of PAHs, fish tissue concentrations of the original, untransformed parent PAH compounds do not provide a useful measure of exposure to fish (Varanasi et al., 1989).

Instead, concentrations of PAHs in sediment are a useful measure of exposure because exposure to PAH-contaminated sediment has been linked to adverse effects in fish.

Other Oil-related Damages to Biota

Indirect impacts can occur to biota from physical and chemical exposure to fuel oil #6. The following is a summary of suspected and known effects that occurred to invertebrates, fish, birds, and mammals in the area of the East Walker River impacted by the AFFS spill.

Negative effects to benthic aquatic invertebrates likely occurred immediately after the spill. Effects that can occur to benthic organisms from exposure to PAHs in the sediment include; inhibited reproduction, delayed emergence, sediment avoidance, and mortality (Eisler 1987; Landrum et al. 1991). In a study of PAH toxicity to the amphipod *Diporeia*, the mechanism identified as most likely responsible for observed acute toxic responses to PAHs was narcosis (Landrum et al. 1991). Generally, aquatic invertebrates are less able to metabolize PAHs than aquatic vertebrates, although metabolic rates vary widely within and between phyla (Meador et al. 1995). Thus, invertebrates tend to be susceptible to PAHs due to acute lethality by narcosis more so than for other organisms which actively metabolize these compounds. An additional effect of exposure to PAHs includes inhibited reproduction of daphnids and delayed emergence of larval midges (Finger et al. 1985).

Approximately 21 dead fish were collected during the response period. Fish can readily assimilate PAHs from contaminated food (Maccubbin et al. 1985; Malins et al. 1985a, 1985b). However, as stated previously, fish can rapidly metabolize PAHs. Other negative effects can occur to fish from exposure to petroleum products. These impacts include reproductive impairment, immune dysfunction, increased incidence of liver lesions, and other histopathological endpoints (Malins et al. 1987; Johnson et al. 1988; Varanasi et al. 1992, Baumann et al. 1996). Fin erosion and liver abnormalities have also been observed in fish exposed to extracts from PAH-contaminated sediments (Fabacher et al. 1991). Other studies report sub-lethal effects on the cellular immune system (reduced macrophage activities) in fish exposed to PAH-contaminated sediments, that could result in increased susceptibility to disease (Weeks and Warinner 1984, 1986; Weeks et al. 1986). The most common diseases generally affect the liver, although cataracts and pollution-related disorders of the skin and gills may also occur (O'Connor and Huggett 1988). Also, fish exposed to PAHs may be induced to produce higher levels of enzymes capable of transforming PAHs to more excretable, but occasionally more carcinogenic, metabolites (O'Connor and Huggett 1988).

Birds can be affected from exposure through external oiling, ingestion, and egg oiling. External oiling disrupts feather structure, causes matting of feathers, and eye irritation and death often results from exposure to cold water and drowning (Albers 1977). Birds observed alive but oiled during the spill response included; Canada geese (*Branta canadensis*), common merganser (*Mergus merganser*), great blue heron (*Ardea herodias*), and the Federally threatened bald eagle *(Haliaeetus leucocephalus*). Also during the response period, one Virginia rail (*Rallus limicola*) and two American dipper *(Cinclus mexicanus*) carcasses were found coated with oil. Both of these species depend heavily on water habitats and are not very common for the East Walker River area. The discovery of these carcasses in this area indicate that many more individuals of these species were exposed. Fuel oil #6 also was likely ingested by birds through feather preening, drinking, eating contaminated food, and inhalation of fumes. Ingestion of the oil would seldom result in direct mortality but promotes death from starvation, disease, and predators (Albers 1976). Contaminated nest material and oiled plumage can transfer oil to the shell surface of bird eggs which are very sensitive to petroleum products like fuel oil #6. Small quantities can cause death, especially during early stages of incubation.

Mortalities to mammals observed from exposure to oil released within the upper 10 miles of the AFFS Spill zone included; mink (*Mustela vison*) and beaver (*Castor canadensis*). Mammals can be affected from oil exposure through external oiling, ingestion, skin and eye irritation (Albers 1992). Oiled fur becomes matted and loses its ability to trap air or water along with its insulation properties and as in birds, exposure to cold water can result in death. Ingestion of oil can produce sub-lethal effects that include gastrointestinal hemorrhaging, renal failure, liver toxicity, and blood disorders (Albers 1992). Reductions in prey-base items (i.e., vegetation, invertebrates, and fish) affected by oil can alter foraging behavior in mammals dependent on them. Studies on river otter *(Lutra canadensi*s) populations in Prince William Sound, Alaska and impacts from the *Exxon Valdez* spill demonstrated that river otters significantly changed their diet and habitat selection as a result of the spill, and in some cases these changes were not evident until a year after the spill (Bowyer et al., 1994; Bowyer et al., 1995).

Summary and Conclusions

In terms of impacts to natural resources, PAHs vary substantially in their toxicity to aquatic organisms. LPAHs such as naphthalene, fluorene, phenanthrene, and anthracene are acutely toxic to aquatic organisms. The majority of PAHs released to the East Walker River were LPAHs. Acute lethality increases with increasing alkyl substitution on the lower molecular weight compounds (Van Luik 1984). Many of the HPAHs, such as chrysene and benzo(a)pyrene, are less acutely lethal but demonstrably carcinogenic, mutagenic, or teratogenic to a wide variety of organisms including fish, amphibians, birds, and mammals (Moore and Ramamoorthy 1984; Eisler 1987).

Water concentrations of PAH's in the East Walker River were above concentrations associated with mortality of salmon embryos during the January 2001 period and above concentrations associated with sub-lethal effects to herring eggs during the March 2001 period. However, concentrations were reduced enough in the water column by May 2001 to no longer pose an immediate threat to fish. Areas of the East Walker River had high enough concentrations of PAHs to impact reproductive success of fish as well as recruitment after the spill event. This is confirmed with data collected in an extensive fish survey of the East Walker River in 2001 by the California Department of Fish and Game and the Nevada Division of Wildlife (Hampton et al.: in prep.). Results showed the potential reduction of juvenile age classes and recruitment of rainbow trout and mountain whitefish.

Once water temperatures and flows in the East Walker River increased after January, sediment concentrations of PAHs became elevated. Total PAH concentrations in the sediments were above a level at which harmful effects are unlikely to be observed.

Total PAH concentrations in sediment exceeded the consensus-based TEC guideline established for freshwater sediments at the Border, Sceirine, and Elbow divisions during the March 2001 period. Total PAH concentrations in the sediment during the May 2001 period were below the TEC guideline at all sites with the exception of the DFG Ranch division. Fish surveys conducted by the Nevada Division of Wildlife showed significant numbers of young fish detected on surveys in the past. In 2001, however, almost no young rainbow trout were found (Hampton et al.: in prep.). Rainbow trout spawn in spring, shortly after the time of the spill event. The reduction of the juvenile age class is consistent with known toxicological effects of oil on fish eggs and PAH concentrations detected in sediment samples during the spring spawning period (March). In addition, fish density per mile for mountain whitefish was significantly reduced for both California and Nevada sites (Hampton et al., in prep.). Mountain whitefish are bottom-oriented predators which feed mostly on small aquatic insects (Sigler 1951, Pontius and Parker 1973, Ellison 1980) by stirring up the bottom with their tail and pectoral fins and feeding on the exposed insects (T.L. Taylor, Entrix, Inc., pers. comm. 1990., as cited in Moyle 2002). Therefore, life history characteristics of mountain whitefish made them more susceptible to effects of sediment contamination from the spill event.

Sediment at most sites sampled during March 2001 consisted mostly of LPAHs. Individual TEC guidelines were exceeded at the Border and Elbow divisions during this time period. PAH congener concentrations did decrease below their specific TEC guidelines by the May 2001 period at all sites with the exception of the DFG Ranch division which actually had increases in PAH congeners and exceeded the TEC sediment guideline for phenanthrene. Over time LPAHs in sediments may convert to HPAHs and may persist where they are subjected to burial, resuspension, and degradation reactions. The available literature suggests that microbes degrade HPAHs slower than LPAHs. Half-lives for these compounds range from months to years. Furthermore, biodegradation probably occurs more slowly in aquatic systems than in soil (Clement Associates 1985). However, concentrations found in sediments suggest that significant degradation of PAHs occurred at most sites downstream of the impact site by May 2001 with the exception of the DFG Ranch division. Sites further upstream of the DFG Ranch division towards the impact site may have had similar increases in PAH concentrations as well during the May 2001 sampling event, but these sites were not sampled.

Fish tissue concentrations of PAHs indicated uptake into tissues from diet and exposure to PAH-contaminated sediments. PAH concentrations were highest for suckers who spend a majority of their time at the sediment/water interface and feed directly at the substrate where PAH concentrations were greatest. However, fish rapidly metabolize PAHs as evidenced by calculated BAF's. Therefore, determined fish tissue concentrations of the original, untransformed parent PAH compounds in fish do not provide a useful measure of exposure to fish and cannot provide a definitive assessment of damage to fish. Instead, determining concentrations of PAHs in sediment is a useful measure of exposure because exposure to PAH-contaminated sediment has been linked to adverse effects in fish.

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