Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Final Report

Hydrocarbons in Hair, Livers and Intestines of Sea Otters (*Enhydra lutris*) found Dead along the Path of the *Exxon Valdez* Oil Spill

Marine Mammal Study 6-3
Final Report

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Study History: Marine Mammal Study 6 (MM6), titled *Assessment of the Magnitude, Extent and Duration of Oil Spill Impacts on Sea Otter Populations in Alaska*, was initiated in 1989 as part of the Natural Resource Damage Assessment (NRDA). The study had a broad scope, involving more than 20 scientists over a three year period. Final results are presented in a series of 19 reports that address the various project components.

Abstract: Aliphatic and aromatic hydrocarbons were analyzed in hair, liver and intestinal samples taken from dead sea otters (*Enhydra lutris*) collected in spring and summer 1989 from Prince William Sound, the Kenai Peninsula and Kodiak Island, along the path of the *Exxon Valdez* oil spill. Hair showed significant differences in hydrocarbon concentrations among the three locations, but few significant differences were noted for liver or intestine samples. The highest concentrations of both aliphatic and aromatic hydrocarbons were measured in hair samples from Prince William Sound. Hair samples from Kenai were also relatively high, and hair samples from Kodiak had the lowest concentrations. The lower molecular weight hydrocarbons in hair samples were absent or present only at very low concentrations, indicating that the oil had weathered by the time the samples were collected. Hydrocarbon concentrations in intestine and liver samples from the three locations were generally similar and low, suggesting that uptake into the tissues was limited, or that hydrocarbons within the tissues had been metabolized by the time samples were collected.

Key Words: *Enhydra lutris*, *Exxon Valdez*, hydrocarbons, mortality, oil spill, sea otter.

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EXECUTIVE SUMMARY

Aliphatic and aromatic hydrocarbons were analyzed in hair, liver and intestinal samples taken from dead sea otters (*Enhydra lutris*) collected in spring and summer 1989 from Prince William Sound, the Kenai Peninsula and Kodiak Island, along the path of the *Exxon Valdez* oil spill. Hair showed significant differences in hydrocarbon concentrations among the three locations, but few significant differences were noted for liver or intestine samples. The highest concentrations of both aliphatic and aromatic hydrocarbons were measured in hair samples from Prince William Sound. Hair samples from Kenai were also relatively high, and hair samples from Kodiak had the lowest concentrations. The lower molecular weight hydrocarbons (C10-C14; naphthalene, C1-, C2- and C3-naphthalene) in hair samples were absent or present only at very low concentrations, indicating that the oil had weathered by the time the samples were collected. Hydrocarbon concentrations in intestine and liver samples from the three locations were generally similar and low, suggesting that uptake into the tissues was limited, or that hydrocarbons within the tissues had been metabolized by the time samples were collected.

INTRODUCTION

Following the grounding of the T/V *Exxon Valdez* on Bligh Reef in northeastern Prince William Sound (PWS) on March 24, 1989, oil spread over a linear distance of greater than 700 km and contaminated an estimated 5300 km of coastline. By March 30, 1989, oil had moved out of PWS into the Gulf of Alaska, spreading southwest along the Kenai Peninsula. An estimated 25% of the original 41.3 million liters of crude oil drifted out of PWS, reaching as far southwest as Shelikof Strait, adjacent to Kodiak Island (Galt and Payton 1990, Galt et al. 1991).

Much of the area affected by the spill was prime sea otter (*Enhydra lutris*) habitat. Sea otters are particularly vulnerable to oil contamination as the oil fouls their fur and destroys its insulating ability (Costa and Kooyman 1982; Geraci and Williams 1990). Documented acute mortality of sea otters was high, with a total of 871 sea otter carcasses recovered from the spill area (Ballachey et al. 1994). However, it is likely that a significant proportion of carcasses were not recovered, and that total mortality may have been as high as several thousand sea otters (DeGange et al. 1994).

The concentrations of hydrocarbons present in tissues of sea otters from southeast Alaska, animals which were not known to have experienced exposure to a petroleum spill, are very low (Ballachey and Kloecker 1997a). Hydrocarbon concentrations in sea otters from PWS that died within a few days of the spill and were heavily contaminated with oil on the fur when recovered are much higher than those found in the unoiled animals from southeast Alaska, or in unoiled otters recovered in PWS after the spill (Ballachey and Kloecker 1997b). The PWS oiled animals were exposed to relatively fresh oil. As the oil moved through the Gulf of Alaska, its hydrocarbon constituents changed, and exposure of sea otters in areas further from the site of the spill may have differed in incidences and concentrations of individual hydrocarbons.

We report herein the concentration and composition of petroleum hydrocarbons in samples of hair, liver and intestine taken from sea otter carcasses recovered in spring and summer 1989 from several locations along the drift route of the oil spilled from the T/V *Exxon Valdez*.

METHODS AND MATERIALS

Animals

Sea otter carcasses were recovered from sea and shore searches in western PWS, along the southeastern shore of the Kenai Peninsula, and on the northern islands of the Kodiak Archipelago. Information on the otters is presented in Table 1. External oiling of the carcasses was subjectively classified at the time of arrival at the morgue or at necropsy as light, moderate or heavy. All carcasses from PWS were classified as lightly oiled; carcasses from Kenai and Kodiak included some judged as moderately and heavily oiled. Carcasses from PWS were recovered between April 17 and May 1, 1989. Carcasses from the Kenai Peninsula were recovered between April 26 and August 8, and carcasses from the Kodiak Island area were recovered between May 26 and August 29, 1989. The exact locations and times of death of the animals were not known. Upon return to the collection centers, carcasses were frozen until necropsied in the summer of 1990.

At necropsy, samples of hair, liver, and intestine were removed using solvent-rinsed instruments and placed in specially cleaned sample containers (Eagle Picher Environmental Services, Miami, OK). Samples were kept frozen at -20°C in the dark until analyzed, within 9 months of collection.

A total of 13 hair samples were analyzed: five from PWS, two from the Kenai Peninsula, and six from Kodiak Island. A total of 15 intestinal tissue samples were analyzed: six from PWS, three from the Kenai Peninsula, and six from Kodiak Island. A total of 29 liver samples were analyzed: six from PWS, nine from the Kenai Peninsula, and 14 from Kodiak Island.

Analytical Methods

Hydrocarbon analyses were done by the Geochemical and Environmental Research Group (GERG), College Station, Texas. The tissue extraction and analytical methods used were initially developed by MacLoed et al. (1985) as modified by Wade et al. (1988, 1993) and Jackson et al. (1994). The concentrations of 28 aliphatic and 39 aromatic primary analytes were measured.

Briefly, samples weighing approximately 2 g (liver, intestine) or 10 g (hair) were used for the analysis. After the addition of internal standards (surrogates) and 50 g of anhydrous sodium sulfate, the tissue was extracted three times with dichloromethane using a tissuemizer. The extract was fractionated by alumina:silica open column chromatography. The extract was sequentially eluted from the column with pentane (aliphatic fraction) and pentane-dichloromethane (aromatic fraction). The aromatic fraction was further purified by HPLC to remove lipids.

Quality assurance for each set of 10 samples included a procedural blank and a sample spiked with all calibration analytes (matrix spike) which were carried through the entire analytical scheme. In addition, a laboratory reference oil from the T/V *Exxon Valdez* was used to confirm the identity of alkylated polyaromatic hydrocarbons when no standards were available, and act as a reference oil. All internal standards (surrogates) were added to the samples prior to extraction and were used for quantification.

Aliphatic hydrocarbons (n-C10 to n-C34 including pristane and phytane) were separated by gas chromatography in the split-less mode using a flame ionization detector. Analyte amounts were calculated using the surrogate standards.

Aromatic hydrocarbons were separated and quantified by gas chromatography-mass spectrometry (GC-MS). The mass spectral data were acquired using selected ions for each of the polyaromatic hydrocarbon analytes. The GC-MS was calibrated by injection of a standard component mixture at five concentrations ranging from 0.01 ng/μl to 1 ng/μl. Sample component concentrations were calculated from the average response factor for each analyte. Analyte identifications were based on correct retention time of the quantitation ion (molecular ion) for the specific analyte and confirmed by the ratio of the confirmation ion.

A calibration check standard was run three times during the sample runs (beginning, middle and end), with no more than 6 h between calibration checks. The calibration check was confirmed to maintain an average response factor within 10% for all analytes, with no one analyte greater than 25% of the known concentration. With each set of samples, a laboratory reference sample (oil spiked solution) was analyzed to confirm GC-MS system performance.

Analytical data are always estimates of the concentrations of the compounds being measured; however, the uncertainties of the estimated concentrations can be assessed. The minimum concentration of a substance that can be measured and reported with a specified statistical confidence that the analyte concentration is greater than zero can be determined and is sometimes termed the method detection limit (MDL). Using spiked oyster (Crassostrea virginica) tissue samples (n=7) obtained from the Gulf of Mexico, GERG estimated the MDLs of the hydrocarbon analytes at the 99% confidence level. Individual hydrocarbons detected in tissues at concentrations lower than the computed MDL were reported by GERG. Values of estimated MDLs, and concentrations of individual hydrocarbon analytes in each sample are presented in the Appendix (MDLs - Table A-1; aliphatics - Table A-2; aromatics - Table A-3).

Data Analysis

For each sample, MDLs for specific analytes were calculated as the ratio of the absolute weight MDL (ng; Table A-1) to the sample wet weight. Hydrocarbon concentrations that are above the MDL are indicated in bold-face in Tables A-2 and A-3. In Figures 1-18, MDL's for each analyte are included. MDL points for each analyte are connected by a solid line to more readily distinguish them from the data points on the graph. For Figures 1-6, showing hydrocarbon concentrations in hair samples, MDLs for each sample are included. However, for Figures 7-18 (showing intestine and liver), rather than present the MDL for each sample, we computed the mean MDL for all samples of that tissue type from otters in each area. For example, the MDLs shown in Figure 7 are the mean MDLs for all intestine samples from the PWS otters with values graphed in that figure. This use of a mean MDL for intestine and liver samples was based on the fact that, within an area and tissue type, sample weights were relatively similar, so MDLs also were similar.

Kruskal-Wallis tests were used to compare the hydrocarbon concentrations among areas, within each tissue type. MDLs were computed for each sample, based on its wet weight. All values below the MDL were treated as tied, and the average rank was assigned to ties. P-values obtained were asymptotic, relying on a Chi-square approximation ($df=2$) to the distribution of the Kruskal-Wallis statistic. If a hydrocarbon was below MDL in all groups (i.e., tied), the Kruskal-Wallis p-value was 1.00.

If the overall p-value from the Kruskal-Wallis test was less than or equal to 0.125, then Wilcoxon rank sum tests were also performed, comparing PWS to Kenai, PWS to Kodiak, and Kenai to Kodiak. This test treated all values below detection as tied, and performed all possible permutations of the ranks to obtain p-values.

RESULTS

Kruskal-Wallis and Wilcoxon p-values are presented in Tables 2 (aliphatics) and 3 (aromatics). Significant differences among areas ($p<0.04$) were obtained for analytes in hair samples. The two-way tests identified that these differences were not between PWS and Kenai, but between PWS and Kodiak, and, to a lesser extent, between Kenai and Kodiak.

Very few significant differences were detected for intestine or liver.

Hair. Generally, two of the five PWS samples had relatively high concentrations of hydrocarbons, two were intermediate and one was low (Figures 1, 4). The two "intermediate" PWS samples were similar to the two Kenai samples (Figures 2,5). The Kodiak samples included one that was similar to the "low" PWS sample, and five with even lower concentrations (Figures 3,6).

The low molecular weight n-alkanes (C10 to C14) were not detected or were present at very low concentrations (less than 6 ng/g, except for one PWS sample with a C14 concentration reported at 20 ng/g) in hair from all locations. No significant differences were identified among locations for these compounds (Table 2). However, there were statistically significant differences between PWS and Kodiak for alkanes C15-C34, pristane, phytane and UCM. Some differences in these alkanes were also noted between Kenai and Kodiak samples. In samples from PWS and Kenai, alkanes C15 to C34 were present as a series, with relatively low concentrations of C15 and C16, high concentrations of C17 through C26, and moderate concentrations of C27 through C34. Pristane and phytane were measured in approximately equal concentrations, and UCM's were relatively high in PWS and Kenai samples. The alkane series showed generally much lower concentrations in the Kodiak samples, and in three of the six Kodiak samples, many analytes were reported at zero concentration. The UCM was present in four of the six hair samples from Kodiak, but concentrations were low ($<20\ \mu g/g$).

The aromatic hydrocarbon concentrations also were much higher in the hair samples from PWS and Kenai than from Kodiak. Differences between PWS and Kodiak were identified more frequently, and were of greater significance, than differences between Kenai and Kodiak samples. PWS and Kenai samples did not differ significantly. Naphthalene, C1-naphthalene, and C2-naphthalene were relatively low in all samples, although PWS samples tended to have highest concentrations of these compounds. Concentrations of the alkylated derivatives of fluorene, phenanthrene, dibenzothiophene and chrysene were generally lower at Kodiak than at the other two locations. Three of the six Kodiak samples (those with higher concentrations of alkanes) had concentrations of C3- and C4-naphthalene, C2- and C3-fluorene, phenanthrene and its alkylated derivatives, C2- and C3-dibenzothiophene, and chrysene, C1- and C2-chrysene detected at concentrations above the MDL, although lower than PWS or Kenai. The remaining three samples from Kodiak had essentially all alkylated derivatives reported at zero concentration.

Intestine. There were essentially no significant differences in concentrations of either aliphatic or aromatic hydrocarbons among intestine samples from the three locations (Tables 2, 3). Several samples from Kodiak had relatively high levels of compounds in the C10-C17 series, but similar elevations generally were not seen in samples from other areas (Figures 7-9). Very few aromatic compounds were detected at concentrations above the MDL (Figures 10-12). Naphthalene, C1- and C2-naphthalene were reported at very low concentrations (below MDL) for all samples; C2- and C3-naphthalene were detected in only three samples (two from PWS, both below MDL, and one from Kodiak, above MDL). Alkylated derivatives of fluorene, phenanthrene, dibenzothiophene and chrysene were reported at zero concentration in all samples except that from a single PWS otter, VD294.

Liver. Similar to samples of intestine, liver showed essentially no significant differences among the three locations in concentrations of either aliphatics or aromatics (Tables 2,3). Phytane concentrations, however, tended to be lower in samples from Kodiak than from the other two areas, and UCM concentrations higher in PWS samples.

Concentrations of aliphatic compounds generally were low in all liver samples. However, one sample from Kenai (HD010) had relatively elevated concentrations of alkanes C11 to C29, and high levels of pristane and phytane, and two sampls from Kodiak (KD107 and KD2137) had elevated concentrations of the C20 to C30 series. In addition, several Kodiak samples and one PWS sample had relatively high concentrations of alkanes in the C10 to C17 range, particularly C15 and C17.

Aromatic hydrocarbons were also low in liver samples from all three locations and were generally detected at concentrations below the MDL. Naphthalene and its alklylated derivatives were detected at concentrations above the MDL in several samples from each area. A single sample, KD107, was an exception to the general pattern of aromatics: concentrations of alkylated derivatives of fluorene, phenanthrene, and dibenzothiophene were detected at levels above the MDL (most other samples were reported at zero for these compounds) and concentrations of C1- and C2-chrysene were detected, although below MDL.

DISCUSSION

The presentation and discussion of hydrocarbon data which are quantitatively less than the calculated MDL for each hydrocarbon are controversial (Rhodes 1981, Berthouex 1993). MDLs are statistical values obtained from replicate analyses of samples with known quantities of the compound of interest. In the literature, hydrocarbon concentrations which fall below the MDL are presented in various ways: as "trace", "not detected (ND)", "<MDL", zero, or some incremental number between zero and the MDL. Alternate strategies, which include simply presenting the measured concentration regardless of its relationship to the MDL, presentation of both the measured concentration and the MDL, or giving the measured concentration followed by a statistical estimate of its precision, are considered superior (Berthouex 1993, Gilbert 1987). These methods prevent the discarding of useful information which occurs with the former methods, all of which censor some of the data.

In this report, we have chosen to present all measured concentrations of hydrocarbon analytes and their MDLs, and to focus our discussion on those values that exceed the MDL. However, for data analysis using the Kruskal-Wallis nonparametric test, concentrations below MDL were treated as tied, and thus significant p-values are obtained only from data that were above MDL levels.

Because the statistical analysis was conducted for each hydrocarbon analyte, we have a large number of p-values. The most conservative approach to interpretation of these p-values would be to apply a Bonferroni correction, and only consider those values below an adjusted p (in our case, with 67 hydrocarbon analytes and assuming an initial level of significance at $p = 0.05$, the adjusted p value would be $0.05/67 = 0.0007$). We have chosen not to use the Bonferroni correction, but instead relied on observation of consistent patterns of low (<0.05) p-values, which can be interpreted in consideration of our knowledge of the constituents of oil.

As oil that is spilled into the environment ages, its individual constituent hydrocarbons are lost or changed by the action of air, water, and physical and biological processes. The compounds that would have been lost most rapidly after the spill are those of lower molecular weights, including alkanes C10 to C14, and aromatics naphthalene and its alkylated derivatives (Cretney et al. 1974, Harrison et al. 1974, NRC 1985, Payne et al. 1991). Because the three study areas vary in distance from the site of the spill (PWS is closest, and Kodiak farthest), and in time elapsed between the spill and arrival of the oil in those areas, it was thought that the composition of the oil to which sea otters were exposed may have differed. Although initial exposure may have differed, by the time of sampling for this study, our data show similar patterns of hydrocarbons in hair samples from the three areas. However, concentrations of hydrocarbons differed among areas, with PWS samples generally having the highest, and Kodiak samples the lowest, concentrations.

Although external oiling was classified (light, moderate or heavy) for all otters in this study when carcasses were delivered to morgues, classifications were subjective and it is unlikely that they were strictly comparable across areas. The lightly oiled otters recovered from PWS actually may have been called heavily oiled had they been recovered in another area. Thus, the fact that "lightly" oiled PWS otters had higher concentrations of hydrocarbons in their pelage than did lightly oiled otters from the other areas perhaps is not surprising. No hair samples were collected from otters classified as moderately or heavily oiled, presumably because the oil contamination was obvious and it was not thought that there would be a need to validate its presence.

The lower molecular weight hydrocarbons, both aliphatic and aromatic, are very low or missing from hair samples collected in all locations, presumably reflecting that sufficient time had passed since the spill for weathering of the oil on the pelage. In fact, concentrations of naphthalene measured in hair samples were actually lower than observed for any sea otter tissues, including those of non-oiled otters from a non-contaminated area in southeast Alaska (Ballachey and Kloecker 1997a).

The aromatic compounds that generally were detected at concentrations above the MDLs in hair samples were alkylated derivatives, including C3- and C4-naphthalene, and the alkylated derivatives of fluorene, phenanthrene, dibenzothiophene, and chrysene. Typically, these derivatives showed a pattern in which the parent compound was lowest, and the C2-compound was present at a higher concentration than the C1- compound. This pattern is typical of crude oil, and strongly suggests that crude oil was the source of hydrocarbon contamination (NRC 1985, Hellou 1996).

Ballachey and Kloecker (1997b) report on intestine and liver samples from sea otter carcasses with heavy external oiling recovered in PWS about two weeks prior to the collection of PWS carcasses included in this study. Concentrations of both aliphatic and aromatic compounds in samples from the heavily oiled animals were generally much higher than concentrations observed in the lightly oiled otters. This may reflect lower exposure or, possibly, greater capacity of the less severely oiled otters to metabolize hydrocarbons that were transported into their tissues, perhaps because death following exposure was not so rapid. Quantification of either cytochrome P450 levels or of hydrocarbon metabolites in the tissues might provide greater insight into extent of exposure among animals.

The elevated levels of C10-C17 seen in livers and intestines of Kodiak otters may reflect a biogenic source. Although diets of otters in the three areas are thought to be similar, Kodiak has a greater presence of macroalgae than either PWS or Kenai (J. Bodkin, pers.

comm.). Macroalgae are a biogenic source of alkanes including C15 and C17 (Clark and Blumer 1967), and thus may contribute to observed differences among areas in sea otter tissue alkanes.

Liver samples from one Kenai otter (HD010) and two Kodiak otters (KD107 and KD2137) had concentrations and distribution of aliphatic hydrocarbons similar to patterns frequently observed for heavily oiled PWS otters (Ballachey and Kloecker 1997b). HD010 and KD107 were both classified as heavily oiled, and KD2137 was moderately oiled. It may be that exposure was greater for these otters, and the time between exposure and death shorter, than for other otters from those areas, with the consequence of higher concentrations in liver tissues.

A single liver sample, from sea otter KD107, had relatively high concentrations of alkylated derivatives present, and non-zero concentrations of C1- and C2-chrysene. These have not been reported in other tissue samples, including livers from heavily oiled PWS otters (Ballachey and Kloecker 1997b). The only tissue in which alkylated derivatives including chrysenes have been previously reported was intestine from a single heavily oiled otter in PWS Ballachey and Kloecker 1997b) and, in that case, it appeared that there had been surface contamination of the tissue rather than absorption of the hydrocarbons into the tissue. It seems likely, therefore, that the liver sample from KD107 may also have been contaminated, perhaps during the collection process.

CONCLUSIONS

Differences were observed among PWS, Kenai and Kodiak in concentrations of hydrocarbons in hair samples taken from sea otter carcasses, with PWS having the highest concentrations and Kodiak the lowest. Three sea otters from the Kodiak area, visually classified as lightly oiled, had low but detectable concentrations of hydrocarbons in their hair samples. In contrast, three additional hair samples from Kodiak, also from otters classified as lightly oiled, had extremely low concentrations, well below MDLs. This difference may have resulted from variation among animals in the actual extent of external oil contamination. However, if the classification of external oiling was accurate, this finding suggests that hair may not be useful as a tissue for sampling to evaluate oil exposure. Hydrocarbon concentrations in liver and intestine from oiled sea otters were, for many samples, not largely different from those measured in non-oiled otters, suggesting that analysis of hydrocarbon analytes in tissues also is not a useful approach to evaluating oil exposure. Uncertainties about actual exposures (amounts and duration) make interpretation of these data more difficult. Controlled studies of tissue hydrocarbon concentrations and metabolic responses to exposure to crude oil in sea otters and other mustelids would be of value. In the event of another oil spill affecting sea otters, examination and necropsies of carcasses would be most reliable for determining oil exposure.

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Table 1. Histories of sea otters from Prince William Sound (PWS), Kenai Peninsula (KP), and Kodiak Island (KI) sampled for hydrocarbons. All animals were recovered dead between April 17, 1989 and August 29, 1989. When possible ages were determined by counting dental annuli.

Otter number	Sex	Recovery location	Oiling[a]	Age (y)	Weight (kg)	Length (cm)
			PWS			
VD255	M	Latouche I.	L	4	17.6	128
VD271	M	Latouche I.	L	7	19.7	136
VD293	M	Perry I.	L	4	Unknown	133
VD294	M	Knight I.	L	2	13.4	116
VD382	M	Knight I.	L	2	15.4	121
VD451	F	Green I.	L	2	19.1	127
			KP			
HD010	F	Windy Bay	H	Unknown	14.5	Unknown
HD019	F	South Coast	H	15	13.6	127
HD020	F	Gore Point	H	12	26.4	117
HD096	F	Unknown	H	Unknown	20.4	122
HD097	F	Unknown	L	1	11.4	97
SD008	M	Resurrection Bay	L	2	20.4	119
SD031	F	Nuka Pass	L	1	10.9	98
SD035	F	Aialik P	H	1	13.2	104
SD064	M	Rocky Bay	M	Pup[b]	Unknown	Unknown
			KI			
KD042	M	Sturgeon R	H	Pup	4.5	71
KD050	F	Sturgeon R	M	9	20.9	125
KD057	F	Tugidak I.	M	Pup	4.1	71
KD078	M	Unknown	M	Pup	2.3	56
KD085	F	Unknown	L	Pup	7.3	97
KD089	F	Puale Bay	L	13	29.1	137
KD094	U	Sharatin Bay	U	Unknown	13.6	119
KD107	M	Unknown	H	Adult	22.7	109
KD110	M	Unknown	L	1	18.2	107
KD119	F	Unknown	L	Unknown	20.4	117
KD143	M	Unknown	L	Unknown	22.7	127
KD180	F	Shuyak I.	L	Pup	3.6	51
KD2137[c]	M	Unknown	M	Subadult	2.7	61
KD2188[c]	M	Unknown	H	Pup	1.4	41

[a] L = light, M = moderate, H = heavy oiling.
[b] Pup refers to <1 year.
[c] Otter number not assigned in 1989; 4 digit number refers to 1990 necropsy record number.

Table 2. Results of statistical analysis comparing aliphatic hydrocarbon concentrations in hair, intestine, and liver samples from oiled sea otters collected in Prince William Sound (PWS), the Kenai Peninsula (KP), and Kodiak Island (KI), Alaska, following the *Exxon Valdez* oil spill. The Kruskal-Wallis test was performed on all three groups. All values below MDL were treated as tied and assigned the average rank. If the overall Kruskal-Wallis p-value was less than or equal to 0.125, then the regular Wilcoxon rank sum test was also performed comparing PWS to KP, PWS to KI, and KP to KI.

HAIR (PWS n = 5, KP n = 2, KI n = 6)					
ANALYTE[a]	p Kruskal-Wallis test	n-distinct[b]	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
C10	1	1	NA[c]	NA	NA
C11	1	1	NA	NA	NA
C12	1	1	NA	NA	NA
C13	1	1	NA	NA	NA
C14	0.4493	2	NA	NA	NA
C15	0.3144	7	NA	NA	NA
C16	0.0372	11	0.3810	0.0173	0.2857
C17	0.0219	11	0.3810	0.0087	0.0714
C18	0.0158	11	0.5714	0.0087	0.0714
C19	0.0167	11	0.8571	0.0087	0.0714
C20	0.0159	9	0.8571	0.0087	0.0357
C21	0.0159	9	0.8571	0.0087	0.0357
C22	0.0159	9	0.8571	0.0087	0.0357
C23	0.0167	11	0.8571	0.0087	0.0714
C24	0.0152	9	0.8571	0.0087	0.0357
C25	0.0165	10	0.8571	0.0087	0.0714
C26	0.0159	9	0.8571	0.0087	0.0357
C27	0.0165	10	0.8571	0.0087	0.0714
C28	0.0159	9	0.8571	0.0087	0.0357
C29	0.0356	11	0.8571	0.052	0.143
C30	0.0136	9	0.3810	0.0087	0.0357
C31	0.0151	9	0.5714	0.0087	0.0357
C32	0.0136	9	0.3810	0.0087	0.0357
C33	0.0136	9	0.3810	0.0087	0.0357
C34	0.0140	8	0.5714	0.0087	0.0357
Pristane	0.0330	11	0.3810	0.017	0.0714
Phytane	0.0158	11	0.5714	0.0087	0.0714
UCM	0.0165	10	0.8571	0.0087	0.0714

Table 2. continued.

INTESTINE (PWS n = 6, KP n = 3, KI n = 6)					
ANALYTE	p Kruskal-Wallis test	n-distinct	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
C10	0.0068	6	1	0.0152	0.0714
C11	0.2005	3	NA	NA	NA
C12	0.0753	4	1	0.1818	0.3929
C13	0.2005	3	NA	NA	NA
C14	0.1049	6	0.0833	0.1818	1
C15	0.1347	7	NA	NA	NA
C16	0.4782	13	NA	NA	NA
C17	0.2535	11	NA	NA	NA
C18	0.9577	11	NA	NA	NA
C19	0.2883	12	NA	NA	NA
C20	0.3088	4	NA	NA	NA
C21	0.7165	9	NA	NA	NA
C22	0.1443	10	NA	NA	NA
C23	0.6015	13	NA	NA	NA
C24	0.1443	11	NA	NA	NA
C25	0.1347	7	NA	NA	NA
C26	0.0500	4	0.0833	1	0.0833
C27	0.5519	10	NA	NA	NA
C28	0.0702	5	0.0833	0.4545	0.2262
C29	0.1151	5	0.0833	0.4545	0.5238
C30	0.1353	2	NA	NA	NA
C31	0.0138	3	0.0833	1	0.0833
C32	1	1	NA	NA	NA
C33	1	1	NA	NA	NA
C34	1	1	NA	NA	NA
Pristane	0.1184	13	0.3810	0.0649	0.3810
Phytane	0.5117	10	NA	NA	NA
UCM	0.2223	11	NA	NA	NA

Table 2. continued.

LIVER (PWS n = 6, KP n = 9, KI n =14)					
ANALYTE	p Kruskal-Wallis test	n-distinct	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
C10	0.3486	5	NA	NA	NA
C11	0.2239	6	NA	NA	NA
C12	0.2461	6	NA	NA	NA
C13	0.4678	4	NA	NA	NA
C14	0.5233	9	NA	NA	NA
C15	0.1350	12	NA	NA	NA
C16	0.6157	22	NA	NA	NA
C17	0.5925	27	NA	NA	NA
C18	0.5722	13	NA	NA	NA
C19	0.5074	23	NA	NA	NA
C20	0.4588	8	NA	NA	NA
C21	0.6770	18	NA	NA	NA
C22	0.3273	13	NA	NA	NA
C23	0.3153	25	NA	NA	NA
C24	0.5702	14	NA	NA	NA
C25	0.6030	7	NA	NA	NA
C26	0.9229	6	NA	NA	NA
C27	0.6924	13	NA	NA	NA
C28	0.8971	7	NA	NA	NA
C29	0.5246	5	NA	NA	NA
C30	0.6214	4	NA	NA	NA
C31	0.3297	3	NA	NA	NA
C32	0.5853	2	NA	NA	NA
C33	1	1	NA	NA	NA
C34	1	1	NA	NA	NA
Pristane	0.9741	26	NA	NA	NA
Phytane	0.0111	21	0.5287	0.0225	0.0077
UCM	0.0121	17	0.0450	0.0010	0.9392

[a] Abbreviations: C10-C34: n-alkanes; UCM: unresolved complex mixture.

[b] n-distinct is the number of non-tied observations in the overall Kruskal-Wallis test.

[c] NA: p-value from the Kruskal-Wallis test was >0.125, so the Wilcoxon rank sum test was not performed.

Table 3. Results of statistical analysis comparing aromatic hydrocarbon concentrations in hair, intestine, and liver samples from oiled sea otters collected from Prince William Sound (PWS), the Kenai Peninsula (KP), and Kodiak Island (KI), Alaska, following the *Exxon Valdez* oil spill. The Kruskal-Wallis test was performed on all three groups. All values below MDL were treated as tied and assigned the average rank. If the overall Kruskal-Wallis p-value was less than or equal to 0.125, then the regular Wilcoxon rank sum test was also performed comparing PWS to KP, PWS to KI, and KP to KI.

HAIR (PWS n = 5, KP n = 2, KI n = 6)					
ANALYTE	p Kruskal-Wallis test	n-distinct[a]	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
NAP	1	1	NA[a]	NA	NA
C1N	0.0107	7	0.1905	0.0043	0.2500
C2N	0.0167	5	0.2381	0.0152	1
C3N	0.0871	9	0.3810	0.0563	0.2500
C4N	0.0542	10	0.3810	0.0303	0.2500
BIP	1	1	NA	NA	NA
ANP	1	1	NA	NA	NA
ANH	1	1	NA	NA	NA
FLU	0.1767	3	NA	NA	NA
C1F	0.0329	6	0.4286	0.0152	0.2500
C2F	0.0216	8	0.5714	0.0152	0.0357
C3F	0.0197	8	0.3810	0.0152	0.0357
PHE	0.0156	10	0.5714	0.0087	0.0714
ANT	1	1	NA	NA	NA
C1P	0.0136	9	0.3810	0.0087	0.0357
C2P	0.0136	9	0.3810	0.0087	0.0357
C3P	0.0210	9	0.3810	0.0173	0.0357
C4P	0.0111	7	0.3810	0.0065	0.0357
DIB	0.0915	6	0.7619	0.1061	0.0357
C1D	0.0285	7	0.3810	0.0281	0.0357
C2D	0.0126	8	0.3810	0.0087	0.0357

HAIR (PWS n = 5, KP n = 2, KI n = 6)					
ANALYTE	p Kruskal-Wallis test	n-distinct[a]	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
C3D	0.0197	8	0.3810	0.0152	0.0357
FLA	0.0406	8	0.3810	0.0455	0.0357
PYR	0.0254	6	0.238	0.0152	0.25
CFP	0.0177	6	0.3810	0.0152	0.0357
BAA	0.4493	2	NA	NA	NA
CHR	0.0285	7	0.3810	0.0281	0.0357
C1C	0.0285	7	0.3810	0.0281	0.0357
C2C	0.0285	7	0.3810	0.0281	0.0357
C3C	0.0177	6	0.3810	0.0152	0.0357
C4C	0.0177	6	0.3810	0.0152	0.0357
BBF	0.0595	4	0.4286	0.0606	1
BKF	0.4493	2	NA	NA	NA
BEP	0.0254	6	0.2381	0.0152	0.2500
BAP	0.4493	2	NA	NA	NA
PER	0.1767	3	NA	NA	NA
IDE	1	1	NA	NA	NA
DBN	1	1	NA	NA	NA
BEQ	0.0595	4	0.4286	0.0606	1

INTESTINE (PWS n = 6, KP n = 3, KI n = 6)					
ANALYTE	p Kruskal-Wallis test	n-distinct	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
NAP	0.7605	3	NA	NA	NA
C1N	1	1	NA	NA	NA
C2N	0.4724	2	NA	NA	NA
C3N	0.4724	2	NA	NA	NA
C4N	1	1	NA	NA	NA
BIP	1	1	NA	NA	NA
ANP	1	1	NA	NA	NA
ANH	1	1	NA	NA	NA
FLU	1	1	NA	NA	NA
C1F	1	1	NA	NA	NA
C2F	1	1	NA	NA	NA
C3F	1	1	NA	NA	NA
PHE	1	1	NA	NA	NA
ANT	1	1	NA	NA	NA
C1P	1	1	NA	NA	NA
C2P	0.4724	2	NA	NA	NA
C3P	0.4724	2	NA	NA	NA
C4P	1	1	NA	NA	NA
DIB	1	1	NA	NA	NA
C1D	1	1	NA	NA	NA
C2D	1	1	NA	NA	NA
C3D	0.4724	2	NA	NA	NA
FLA	1	1	NA	NA	NA
PYR	1	1	NA	NA	NA
CFP	1	1	NA	NA	NA
BAA	1	1	NA	NA	NA
CHR	1	1	NA	NA	NA
C1C	1	1	NA	NA	NA
C2C	1	1	NA	NA	NA
C3C	1	1	NA	NA	NA
C4C	1	1	NA	NA	NA
BBF	1	1	NA	NA	NA
BKF	1	1	NA	NA	NA
BEP	1	1	NA	NA	NA
BAP	1	1	NA	NA	NA
PER	1	1	NA	NA	NA
IDE	1	1	NA	NA	NA
DBN	1	1	NA	NA	NA
BEQ	1	1	NA	NA	NA

LIVER (PWS n = 6, KP n = 9, KI n =14)					
ANALYTE	p Kruskal-Wallis test	n-distinct	p Wilcoxon PWS-KP	p Wilcoxon PWS-KI	p Wilcoxon KP-KI
NAP	0.0603	10	0.0440	0.6992	0.0481
C1N	0.5411	12	NA	NA	NA
C2N	0.9491	11	NA	NA	NA
C3N	0.9981	10	NA	NA	NA
C4N	0.1782	4	NA	NA	NA
BIP	0.4941	3	NA	NA	NA
ANP	1	1	NA	NA	NA
ANH	0.5853	2	NA	NA	NA
FLU	1	1	NA	NA	NA
C1F	1	1	NA	NA	NA
C2F	0.5853	2	NA	NA	NA
C3F	0.5853	2	NA	NA	NA
PHE	0.8971	7	NA	NA	NA
ANT	1	1	NA	NA	NA
C1P	0.5853	2	NA	NA	NA
C2P	0.3927	3	NA	NA	NA
C3P	0.3927	3	NA	NA	NA
C4P	0.5853	2	NA	NA	NA
DIB	1	1	NA	NA	NA
C1D	0.5853	2	NA	NA	NA
C2D	0.5853	2	NA	NA	NA
C3D	0.5853	2	NA	NA	NA
FLA	0.3292	2	NA	NA	NA
PYR	1	1	NA	NA	NA
CFP	1	1	NA	NA	NA
BAA	1	1	NA	NA	NA
CHR	1	1	NA	NA	NA
C1C	1	1	NA	NA	NA
C2C	1	1	NA	NA	NA
C3C	1	1	NA	NA	NA
C4C	1	1	NA	NA	NA
BBF	1	1	NA	NA	NA
BKF	1	1	NA	NA	NA
BEP	1	1	NA	NA	NA
BAP	1	1	NA	NA	NA
PER	1	1	NA	NA	NA
IDE	1	1	NA	NA	NA
DBN	1	1	NA	NA	NA
BEQ	1	1	NA	NA	NA

[a] NA: p-value from the Kruskal-Wallis test was >0.125 so the Wilcoxon rank sum test was not performed.

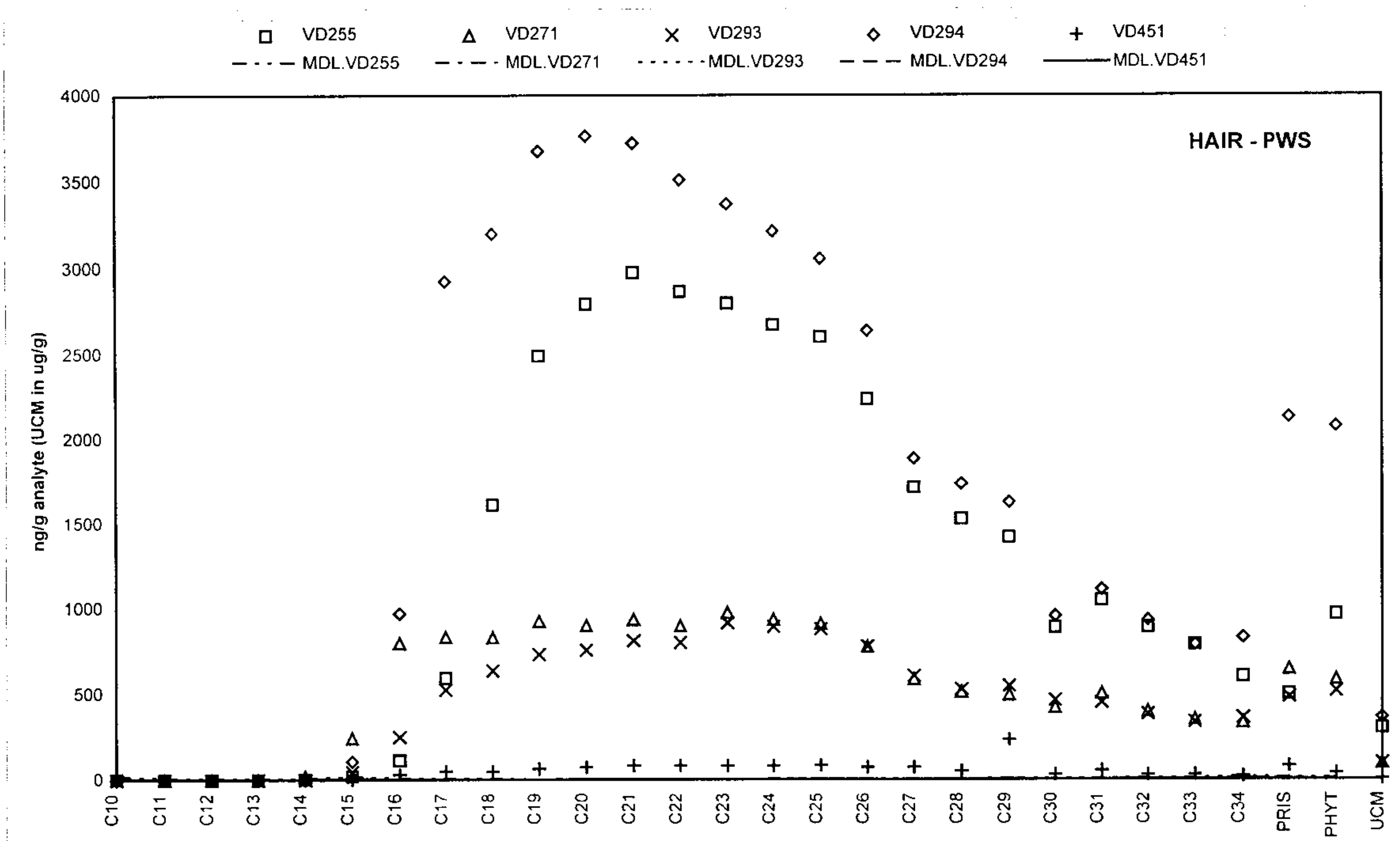

Figure 1. Aliphatic hydrocarbon concentrations in hair samples from oiled sea otters collected in PWS following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The lines indicate the MDLs for hair samples from this group. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

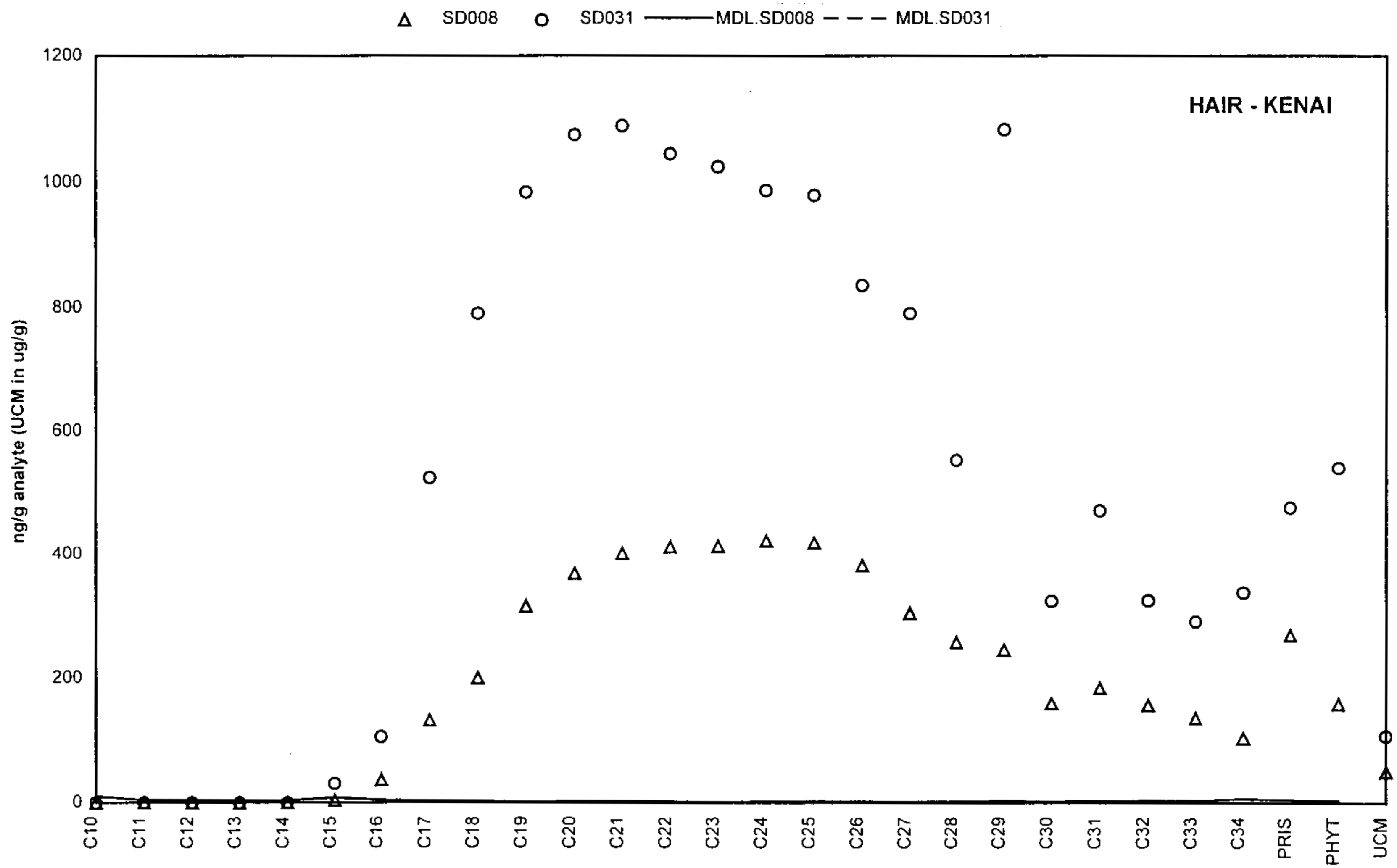

Figure 2. Aliphatic hydrocarbon concentrations in hair samples from oiled sea otters collected along the Kenai Peninsula following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The lines indicate MDLs for the samples. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

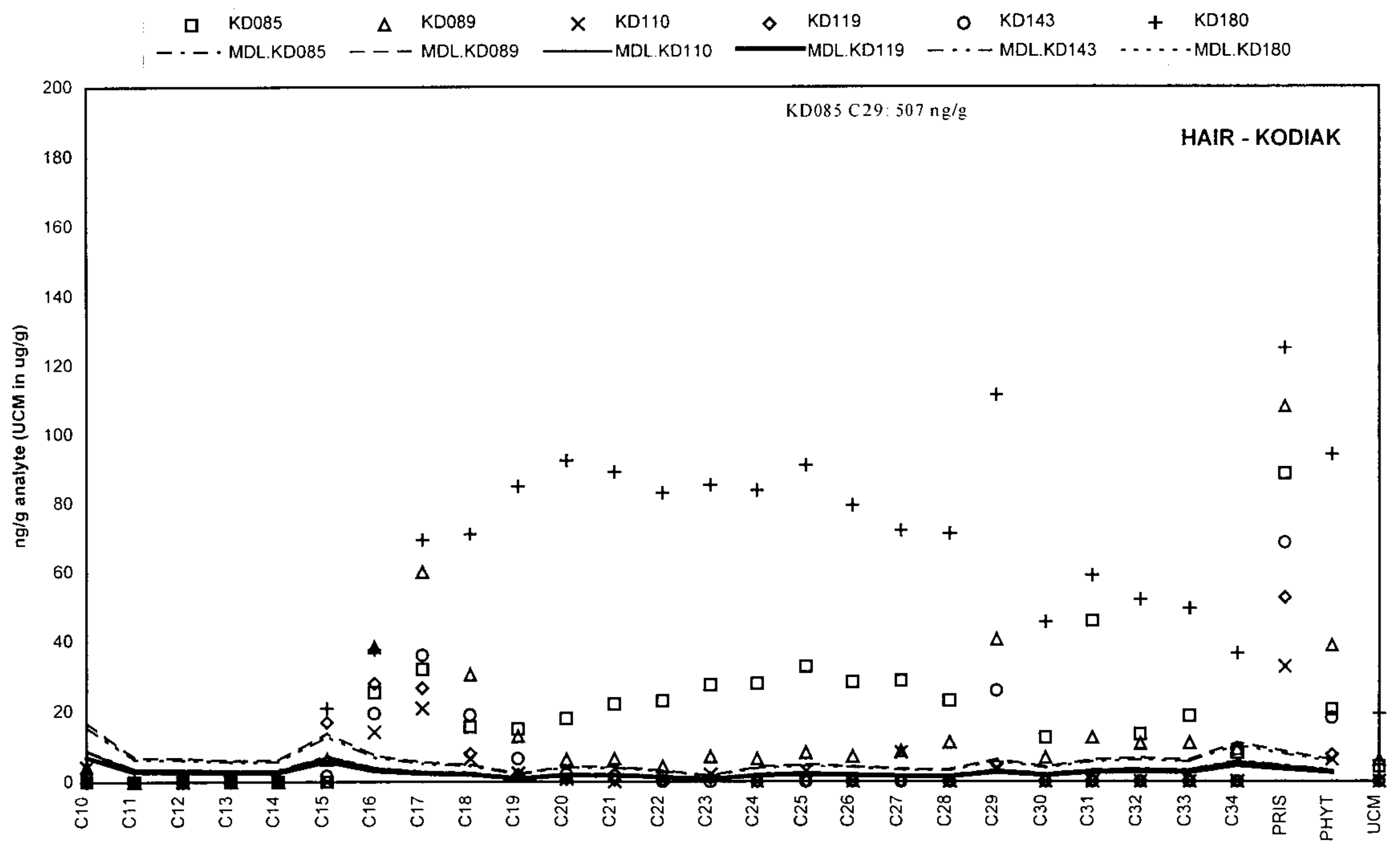

Figure 3. Aliphatic hydrocarbon concentrations in hair samples from oiled sea otters collected at Kodiak Island following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The lines indicate MDLs for the samples. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

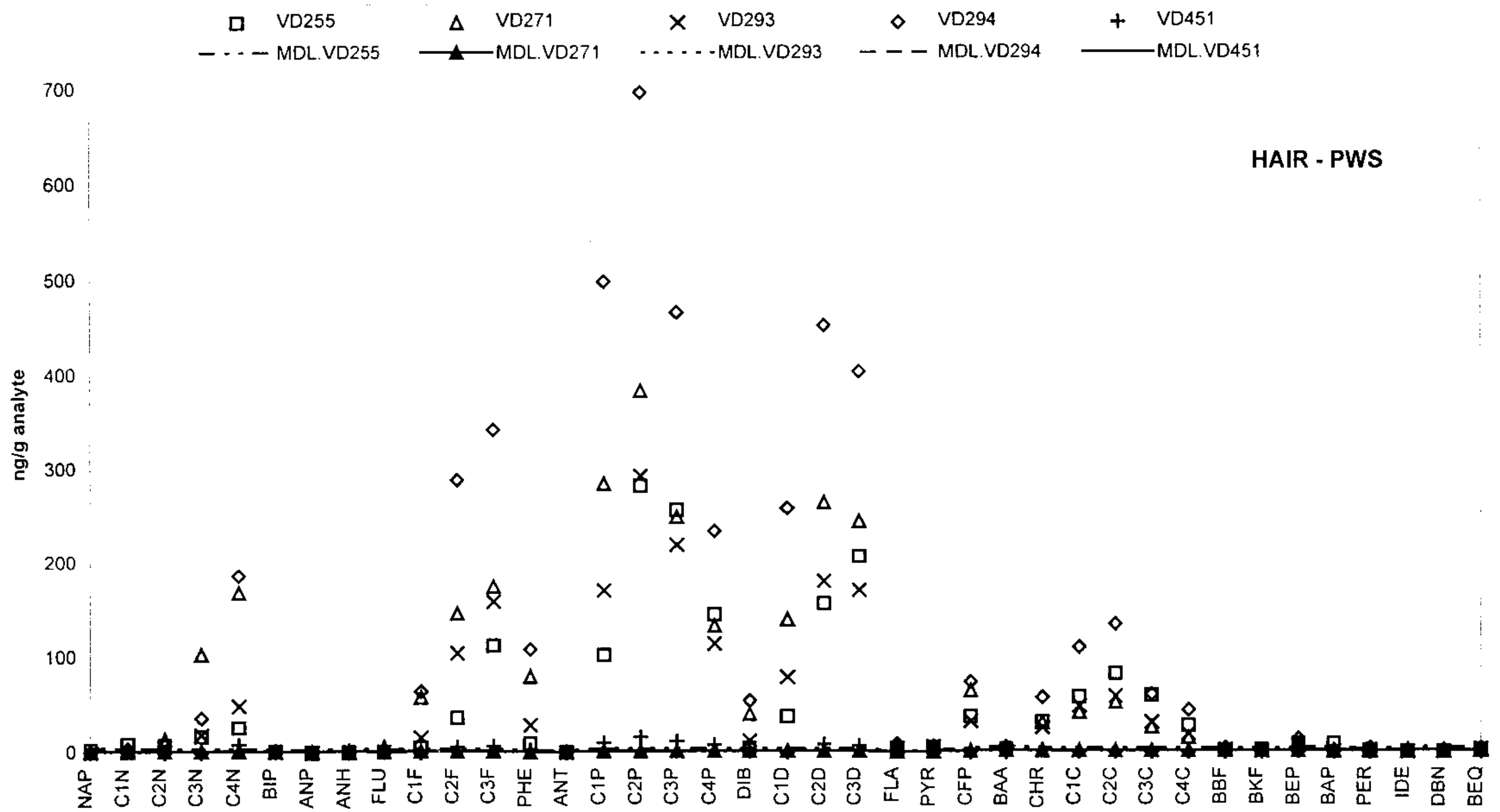

Figure 4. Aromatic hydrocarbon concentrations in hair samples from oiled sea otters collected in PWS following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for hair samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

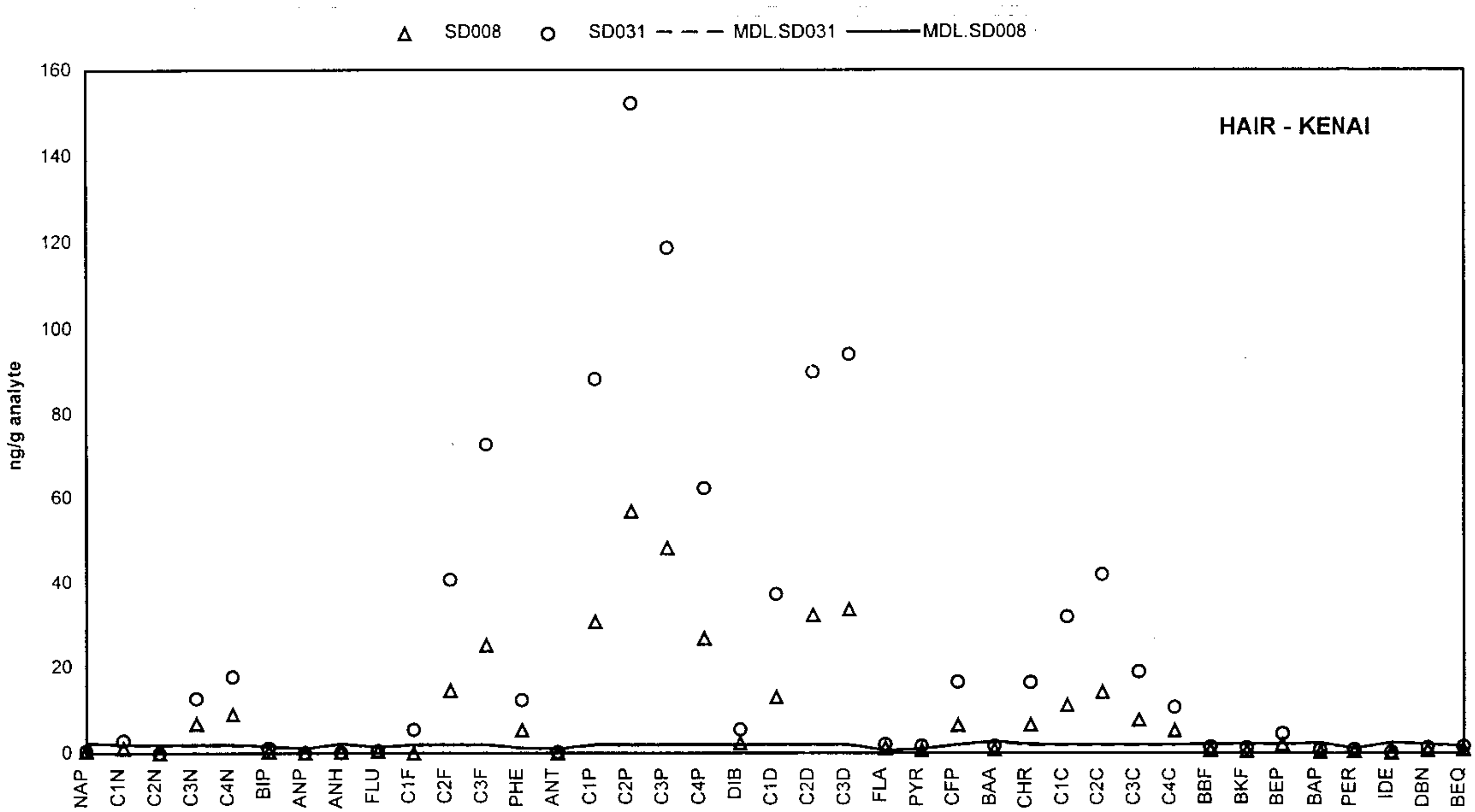

Figure 5. Aromatic hydrocarbon concentrations in hair samples from oiled sea otters collected along the Kenai Peninsula following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The lines indicate MDLs for the samples. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

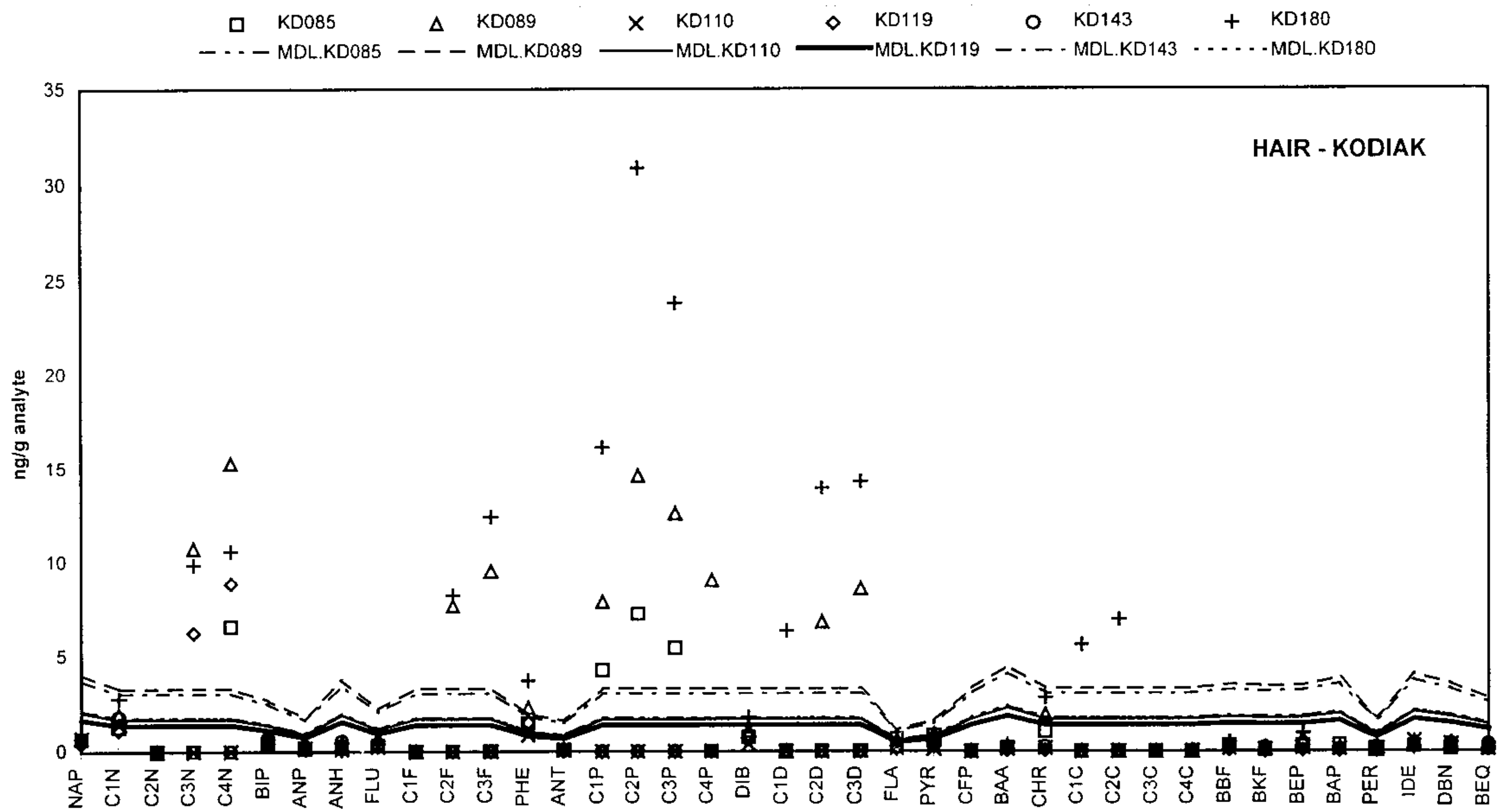

Figure 6. Aromatic hydrocarbon concentrations in hair samples from oiled sea otters collected at Kodiak Island following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The lines indicate the MDLs for the samples. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

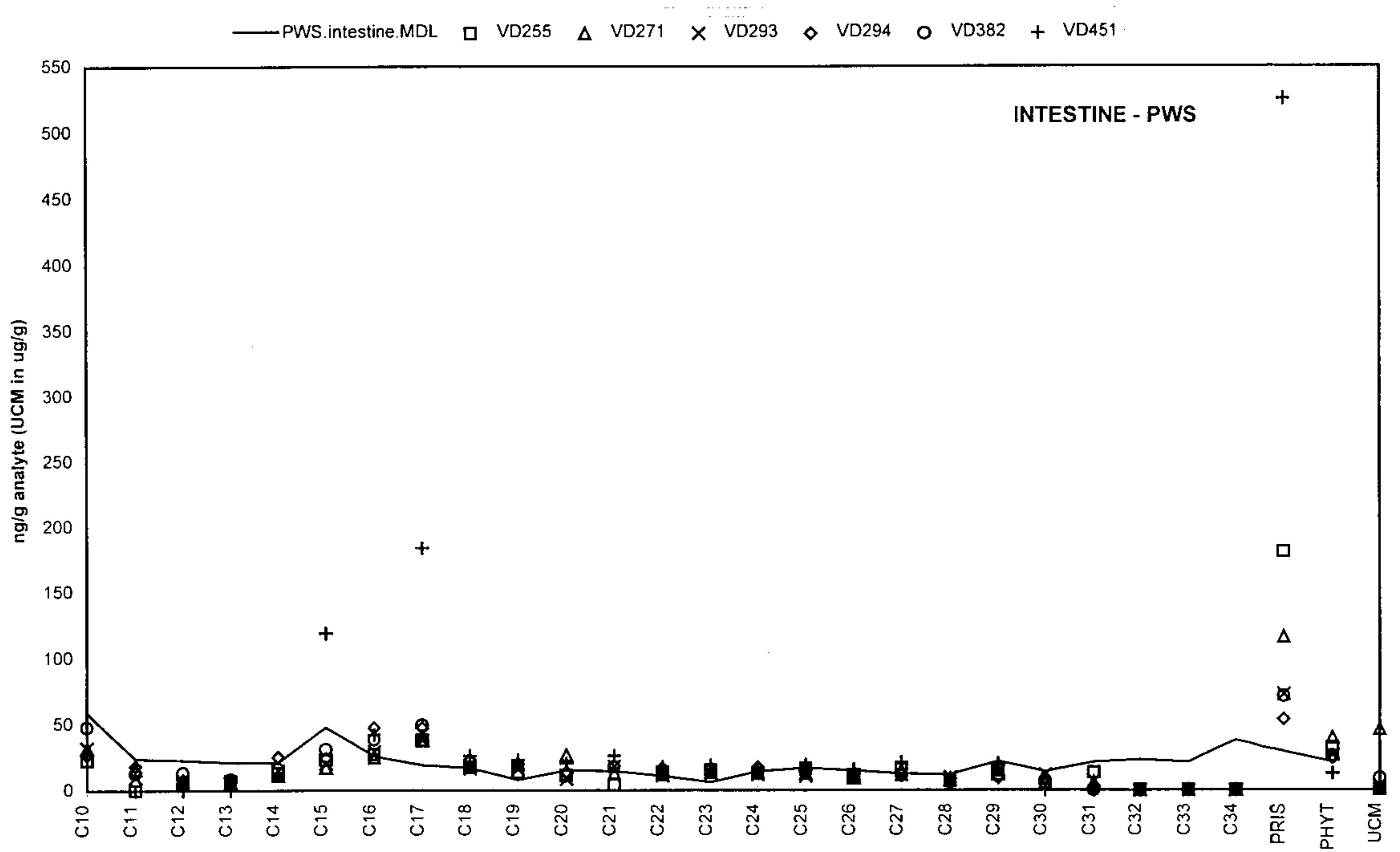

Figure 7. Aliphatic hydrocarbon concentrations in intestine samples from oiled sea otters collected in PWS following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The solid line indicates the mean MDL for intestine samples from this group. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

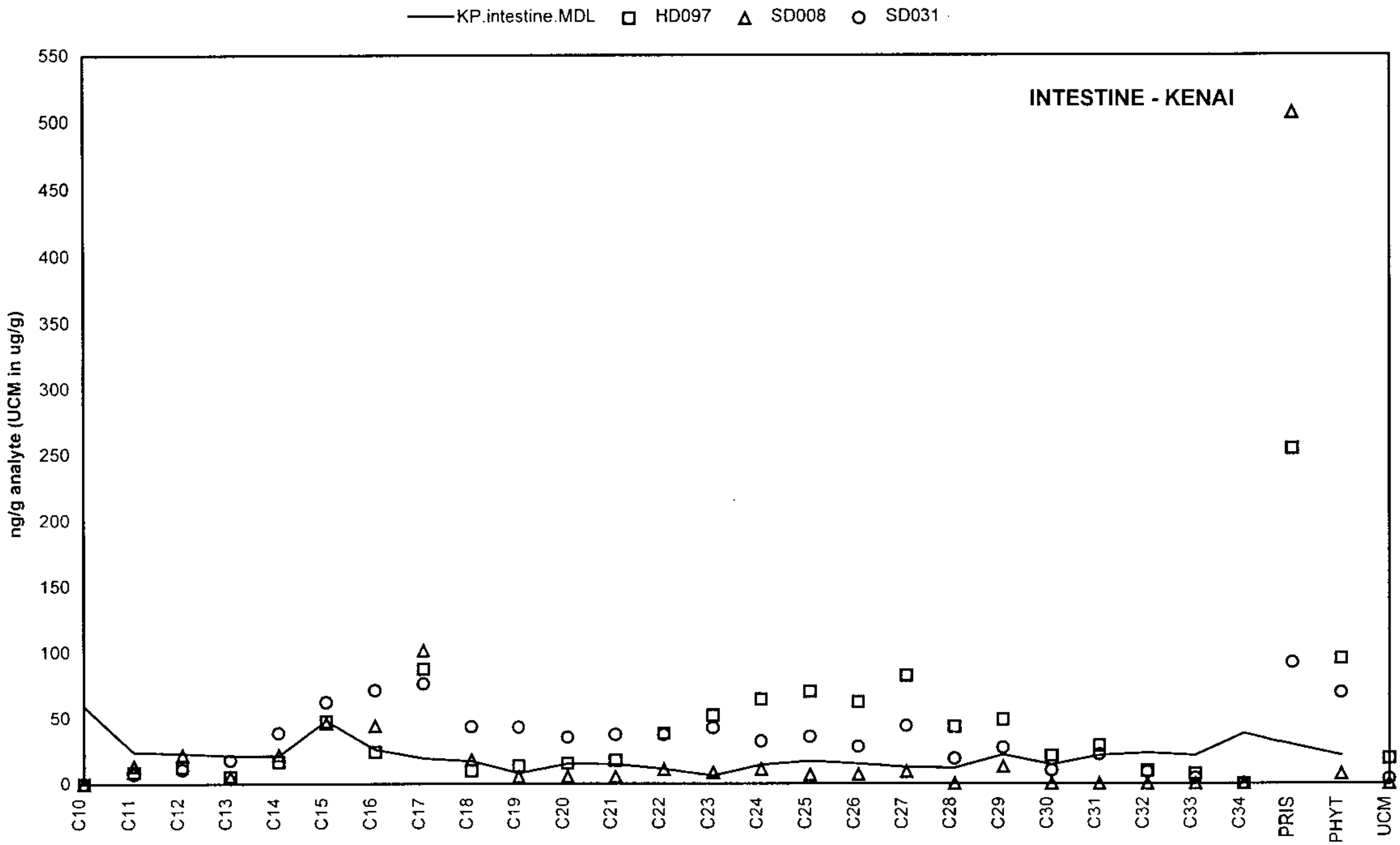

Figure 8. Aliphatic hydrocarbon concentrations in intestine samples from oiled sea otters collected along the Kenai Peninsula following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The solid line indicates the mean MDL for intestine samples from this group. Abbreviations: KP.intestine.MDL: mdl determined using the mean wet weight of the Kenai Peninsula sea otter intestine samples: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

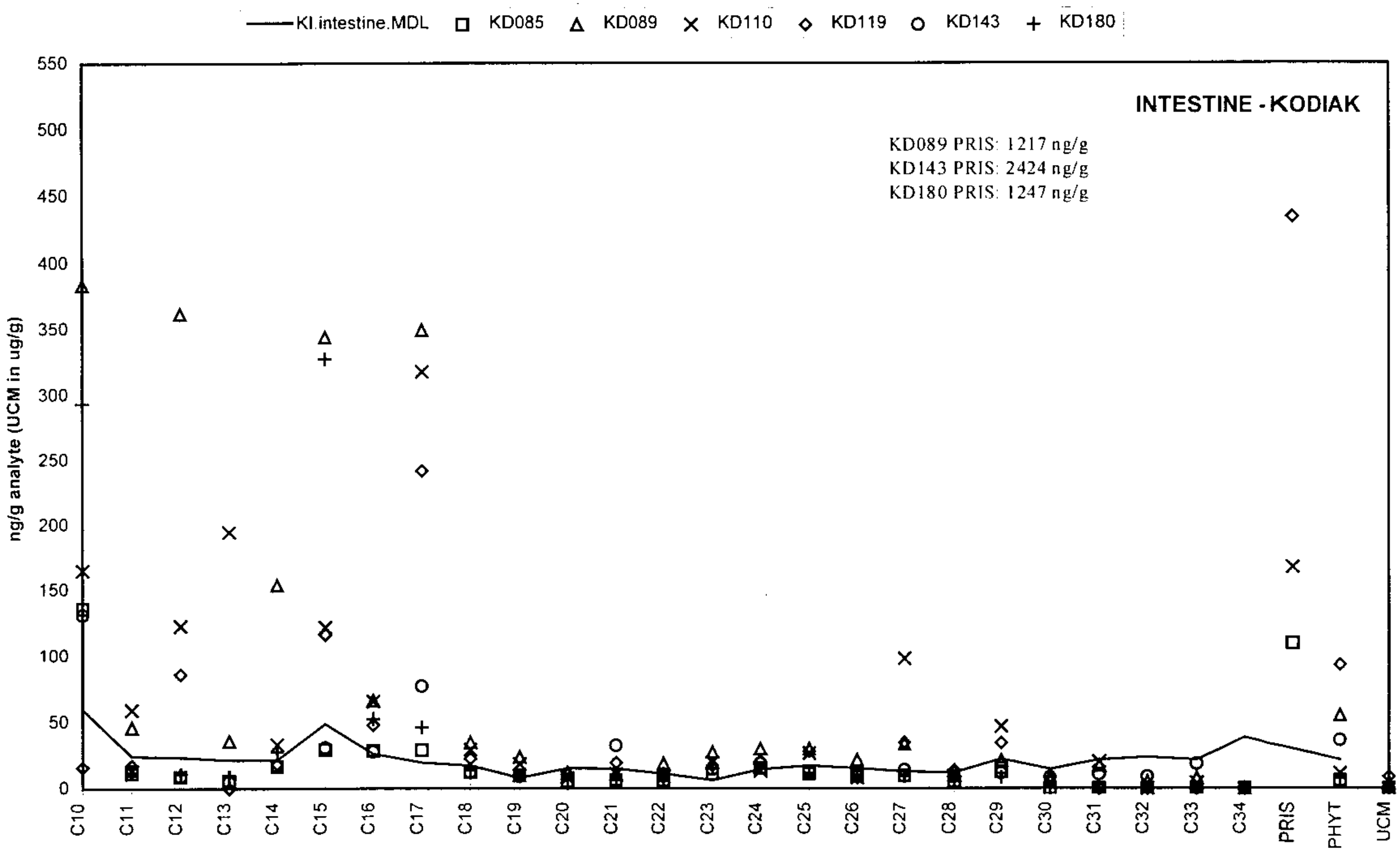

Figure 9. Aliphatic hydrocarbon concentrations in intestine samples from oiled sea otters collected at Kodiak Island following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The solid line indicates the mean MDL for intestine samples of these otters. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

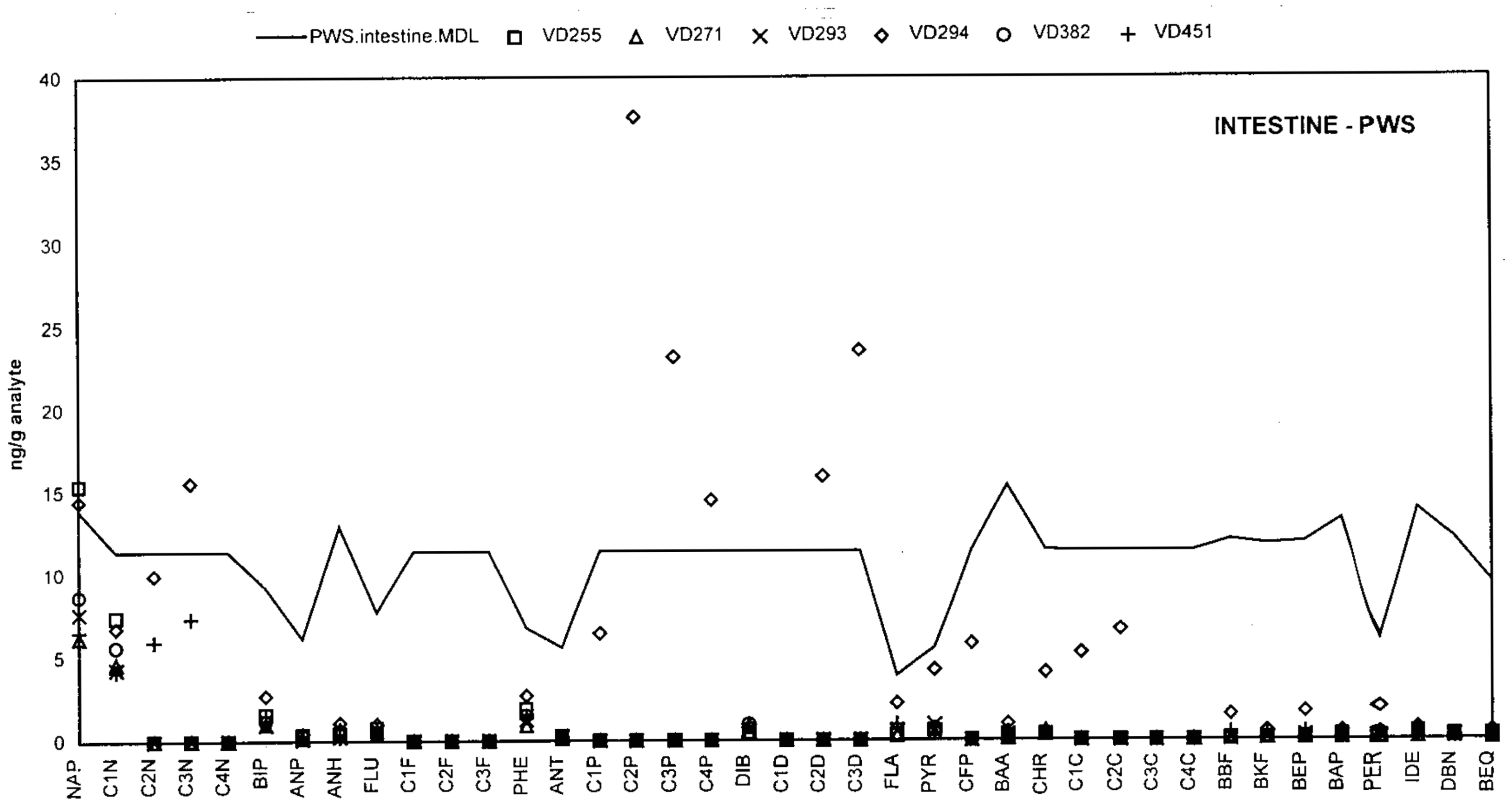

Figure 10. Aromatic hydrocarbon concentrations in intestine samples from oiled sea otters collected in PWS following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for intestine samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

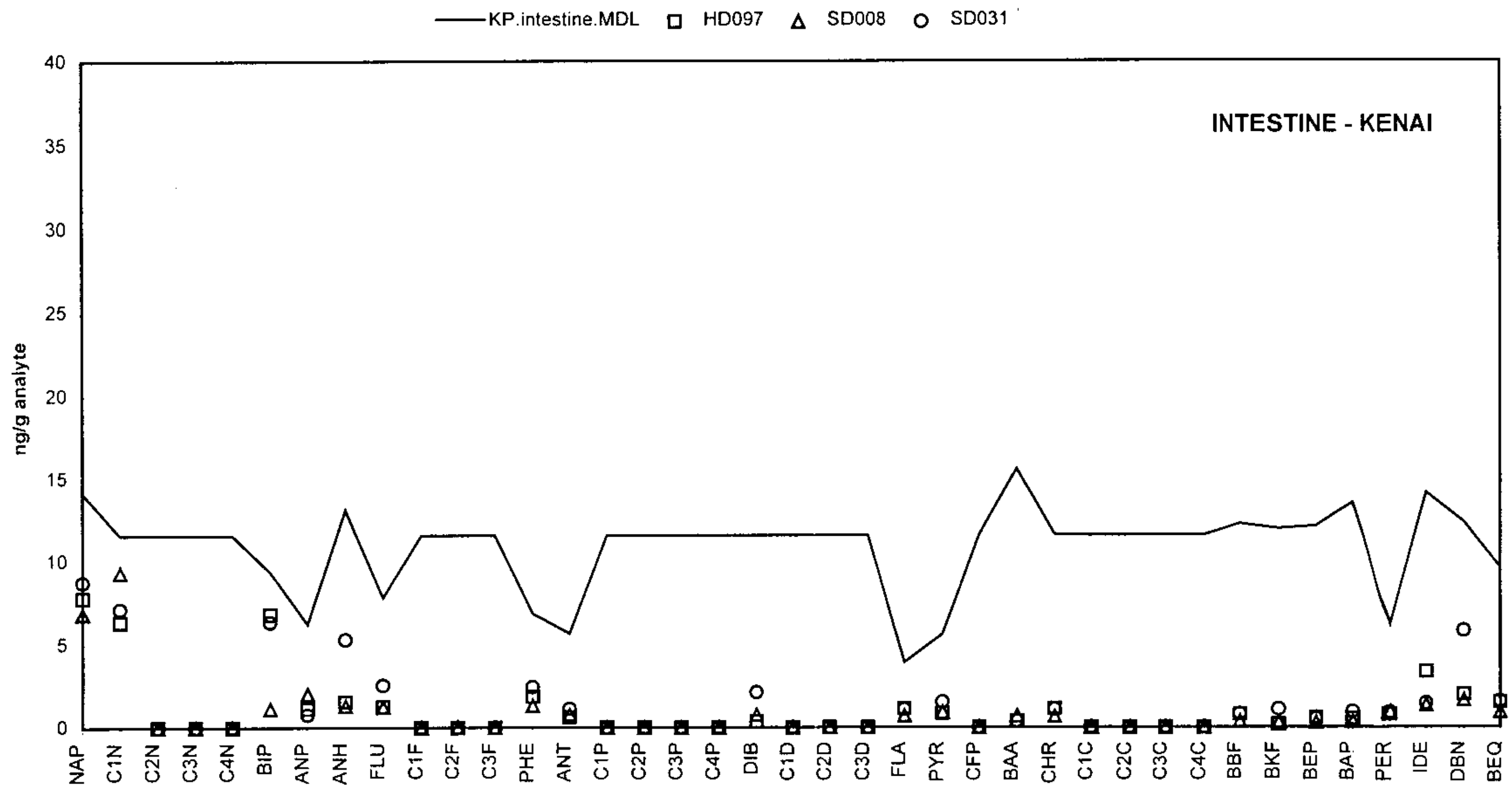

Figure 11. Aromatic hydrocarbon concentrations in intestine samples from oiled sea otters collected along the Kenai Peninsula following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for intestine samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

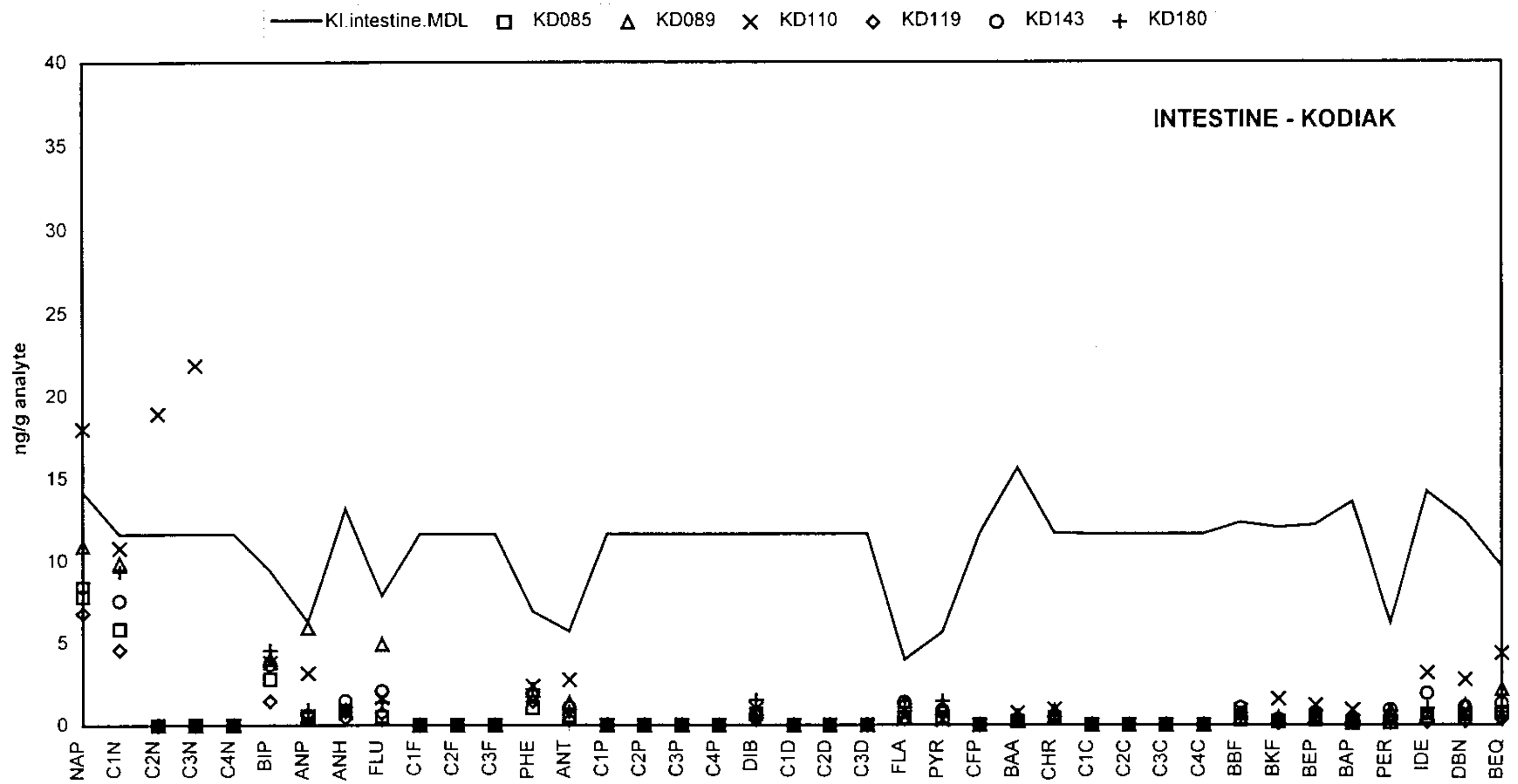

Figure 12. Aromatic hydrocarbon concentrations in intestine samples from oiled sea otters collected at Kodiak Island following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for intestine samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

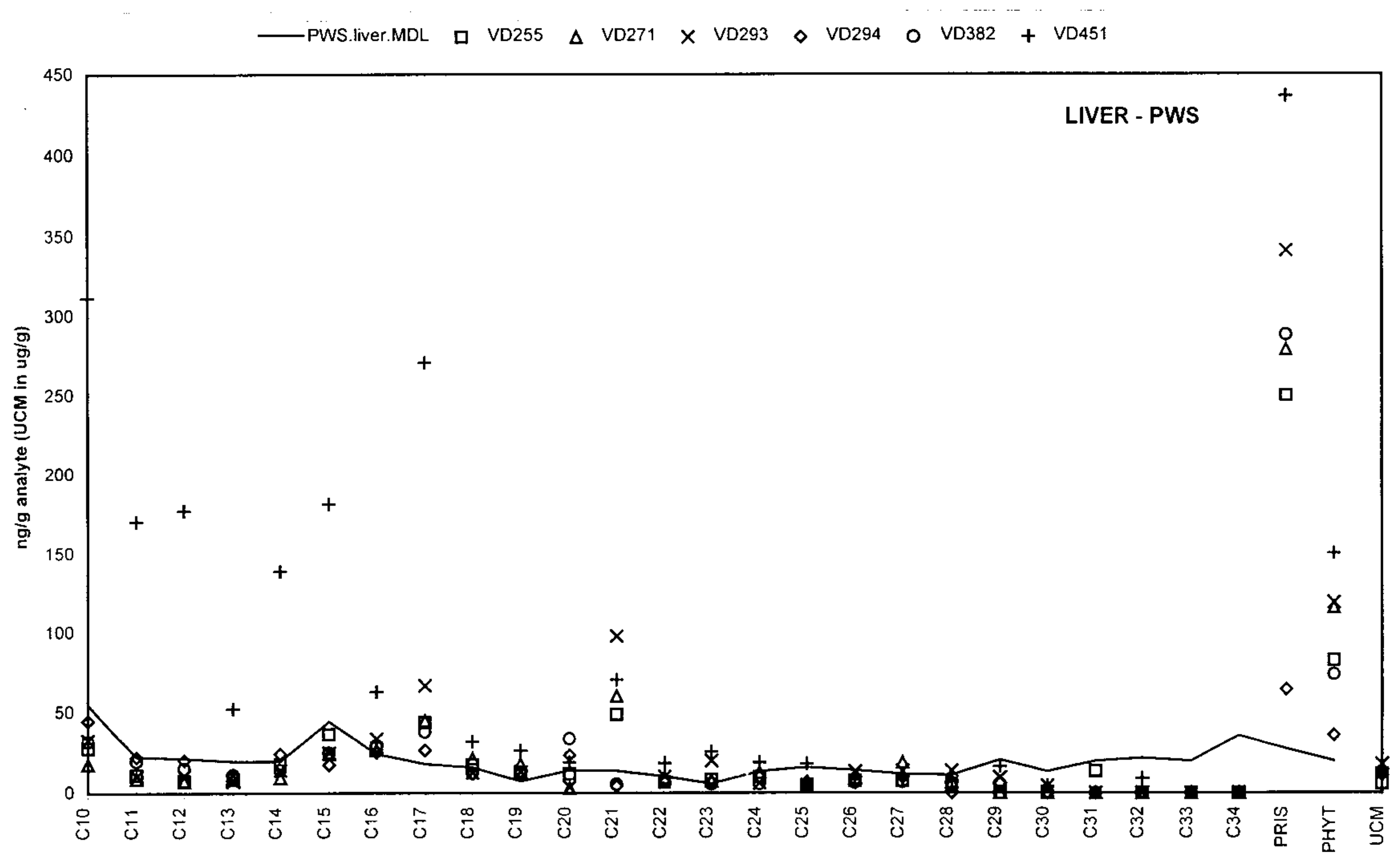

Figure 13. Aliphatic hydrocarbon concentrations in liver samples from lightly oiled sea otters collected in PWS following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The solid line indicates the mean MDL for liver samples from this group. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

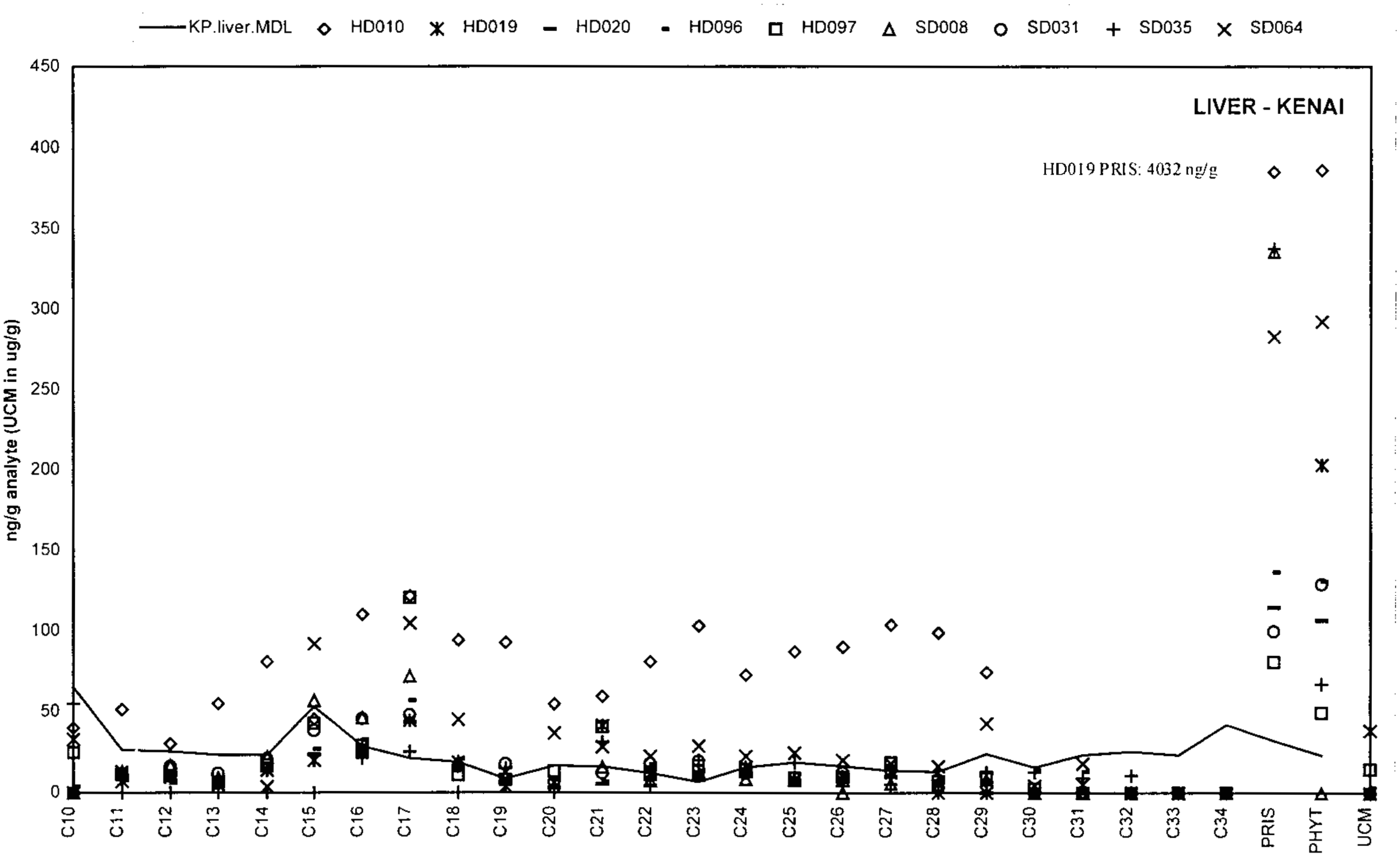

Figure 14. Aliphatic hydrocarbon concentrations in liver samples from oiled sea otters collected along the Kenai Peninsula following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The solid line indicates the mean MDL for liver samples from this group. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

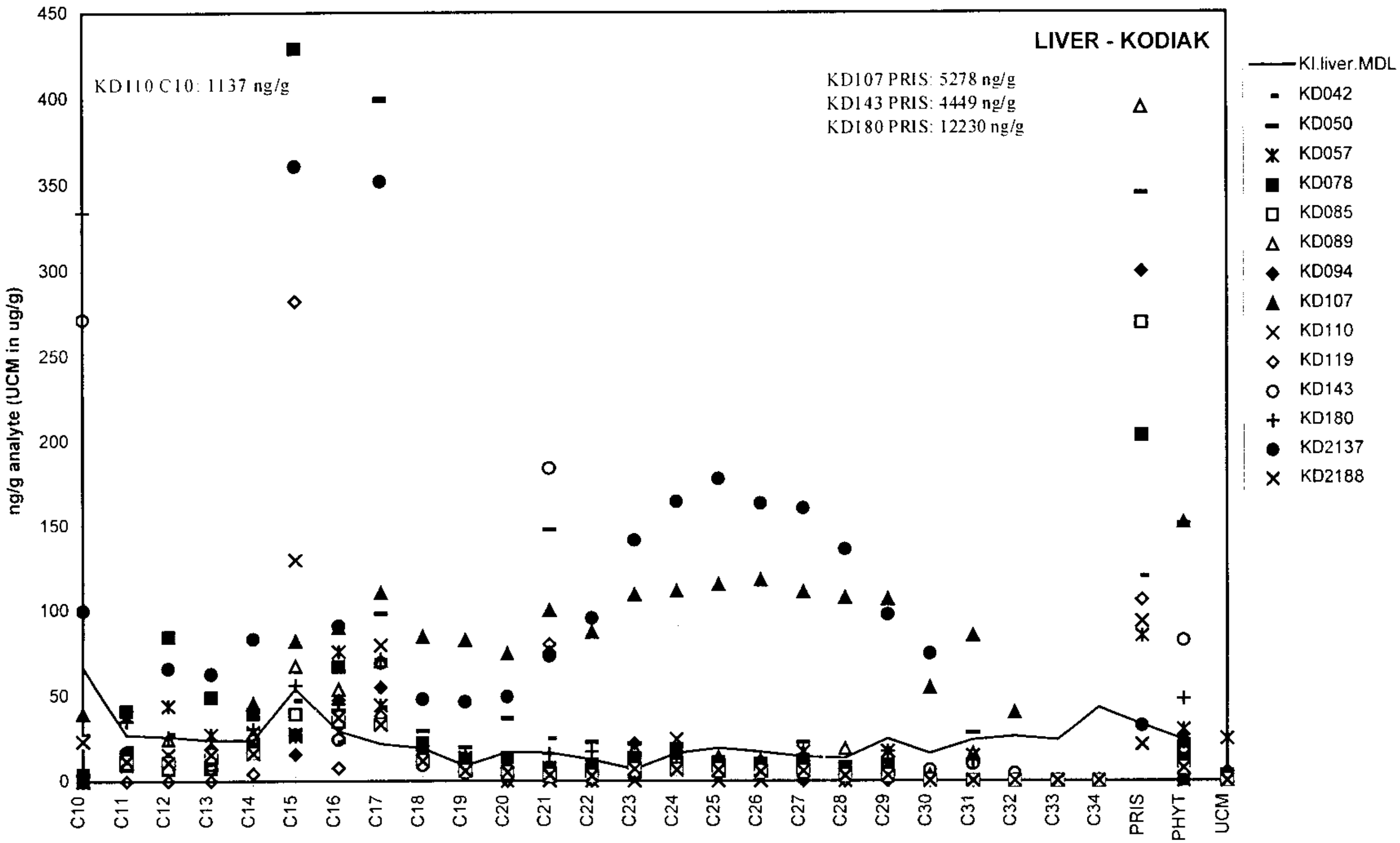

Figure 15. Aliphatic hydrocarbon concentrations in liver samples from oiled sea otters collected at Kodiak Island following the *Exxon Valdez* oil spill. Units are in nanograms per gram except UCM which is in micrograms per gram. The solid line indicates the mean MDL for liver samples from this group. Abbreviations: C10-C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture.

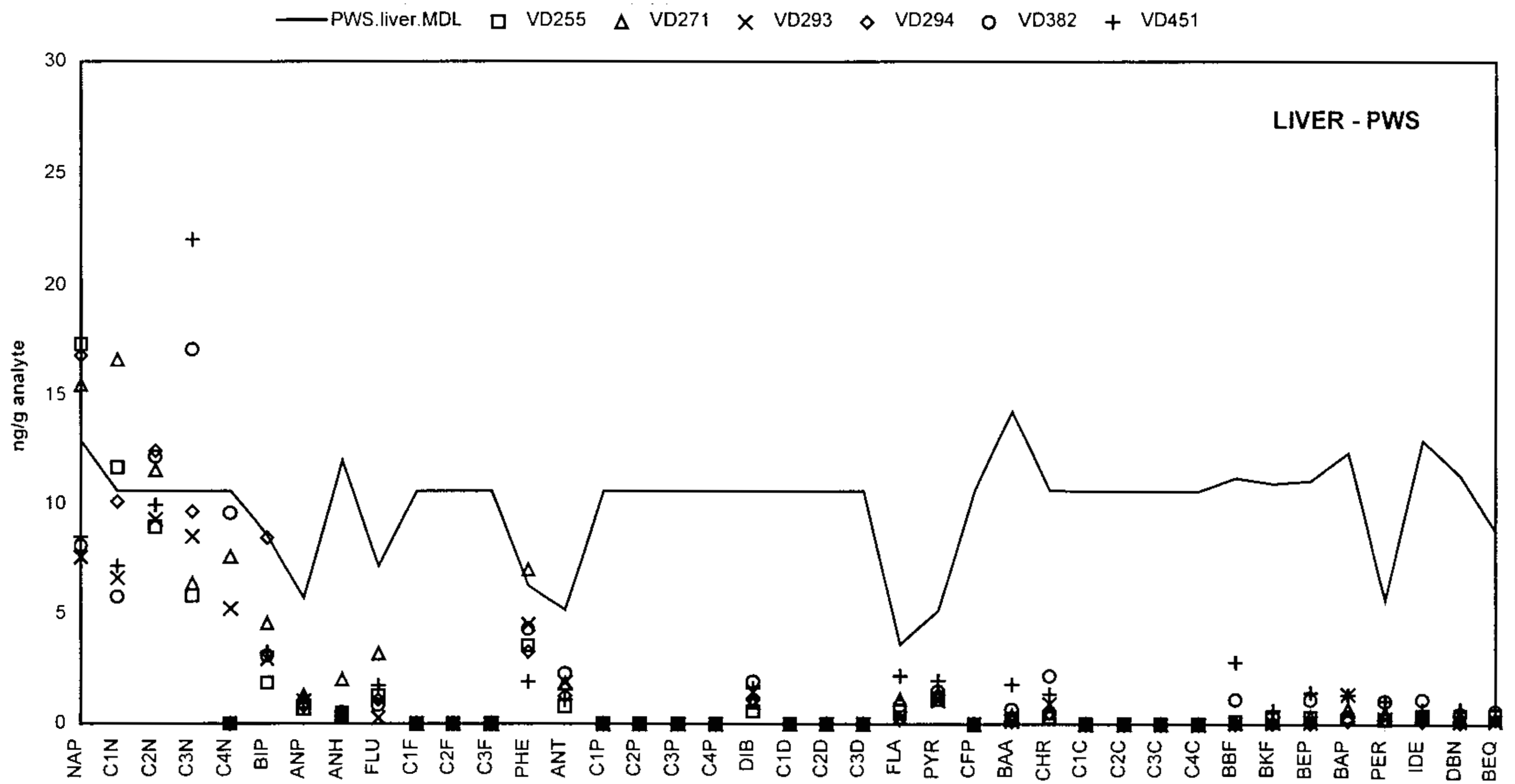

Figure 16. Aromatic hydrocarbon concentrations in liver samples from oiled sea otters collected in PWS following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for liver samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene: ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

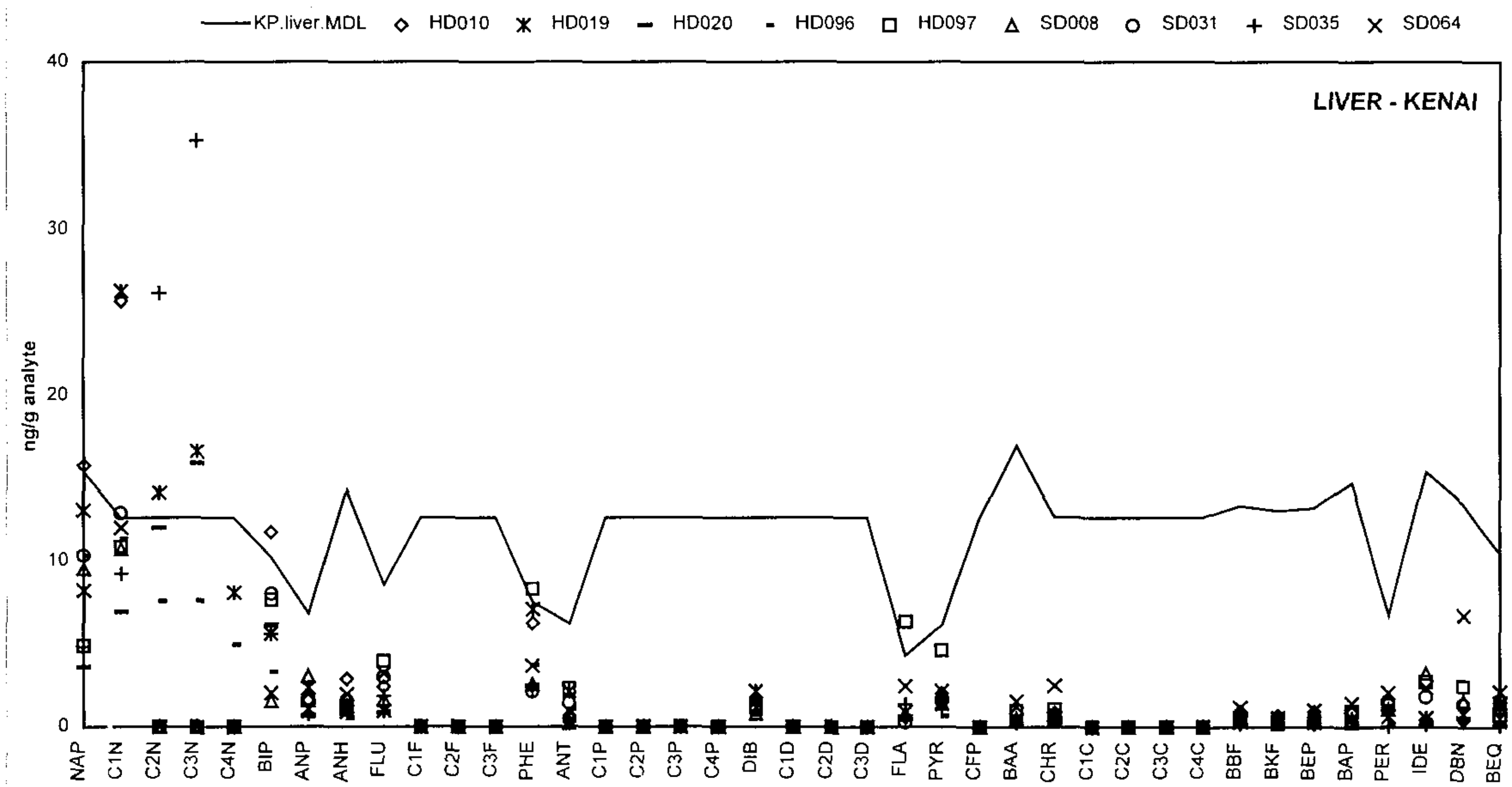

Figure 17. Aromatic hydrocarbon concentrations in liver samples from oiled sea otters collected along the Kenai Peninsula following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for liver samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

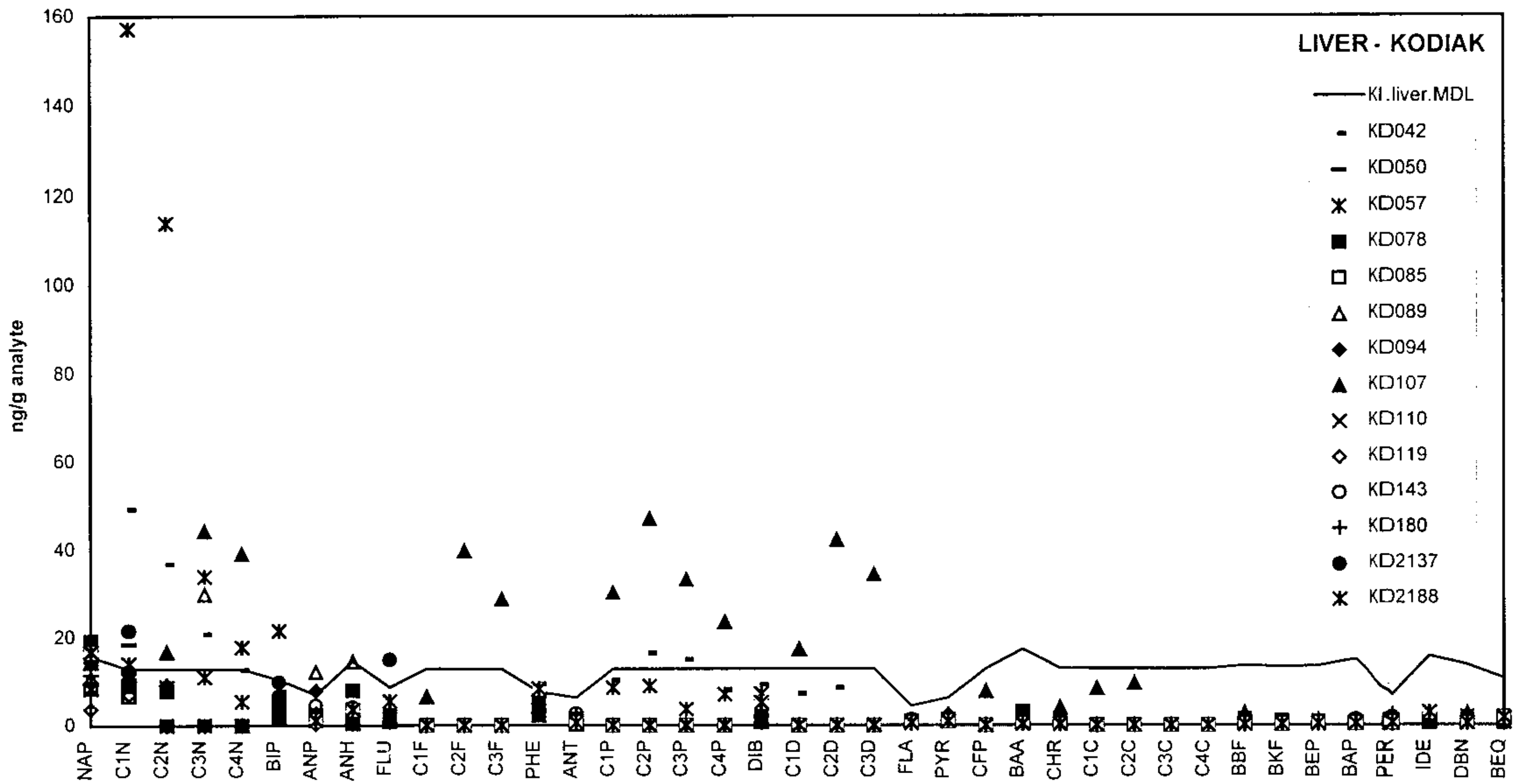

Figure 18. Aromatic hydrocarbon concentrations in liver samples from oiled sea otters collected at Kodiak Island following the *Exxon Valdez* oil spill. Units are in nanograms per gram. The solid line indicates the mean MDL for liver samples from this group. Abbreviations: NAP: naphthalene; C1N-C4N: C1-C4-methylated naphthalenes; BIP: biphenyl; ANP: acenaphthalene; ANH: acenapthene; FLU: fluorene; C1F-C3F: C1-C3-methylated fluorenes; PHE: phenanthrene; ANT: anthracene; C1P-C4P: C1-C4-phenanthrenes/anthracenes; DIB: dibenzothiophene; C1D-C3D: C1-C3-dibenzothiophenes; FLA: fluoranthene; PYR: pyrene; CFP: C1-fluoranthenes/pyrenes; BAA: benzo[a]anthracene; CHR: chrysene; C1C-C4C: C1-C4-chrysenes; BBF: benzo[b]fluoranthene; BKF: benzo[k]fluoranthene; BEP: benzo[e]pyrene; BAP: benzo[a]pyrene; PER: perylene; IDE: indeno[1,2,3-c,d]pyrene; DBN: dibenzo[a,h]anthracene; BEQ: benzo[g,h,i]perylene.

APPENDICES

Table A-1. Method detection limits (MDLs) in ng and ng/g for aliphatic and aromatic hydrocarbons analyzed by GERG.[a]

Aliphatic hydrocarbons	MDL		Aromatic hydrocarbons	MDL			MDL	
	ng	ng/g		ng	ng/g		ng	ng/g
C10	124.6	95.9	NAP	29.4	22.6	1MP	37.7	29.0
C11	50.9	39.1	C1N	--	--	DIB	--	--
C12	48.9	37.6	C2N	--	--	C1D	--	--
C13	--	--	C3N	--	--	C2D	--	--
C14	--	--	C4N	--	--	C3D	--	--
C15	101.0	77.7	1MN	32.8	25.2	FLA	8.2	6.3
C16	54.8	42.1	2MN	46.5	35.	PYR	11.7	9.0
C17	40.8	31.4	2,6MN	33.4	25.7	CFP	--	--
C18	35.9	27.6	2,3,5MN	28.6	22.0	BAA	32.4	24.9
C19	16.6	12.8	BIP	19.5	15.0	CHR	24.2	18.6
C20	31.9	24.5	ANP	13.0	10.0	C1C	--	--
C21	30.9	23.8	ANH	27.3	21.0	C2C	--	--
C22	23.3	17.9	FLU	16.3	12.5	C3C	--	--
C23	12.8	9.9	C1F	--	--	C4C	--	--
C24	30.2	23.2	C2F	--	--	BBF	25.5	19.6
C25	35.9	27.6	C3F	--	--	BLF	24.9	19.1
C26	31.8	24.5	ANT	11.8	9.1	BEF	25.2	19.4
C27	26.4	20.3	PHE	14.3	11.0	BAP	28.1	21.6
C28	25.0	19.2	C1P	--	--	PER	12.9	9.9
C29	46.1	35.5	C2P	--	--	IDE	29.4	22.6
C30	30.1	23.1	C3P	--	--	DBN	25.7	19.8
C31	--	--	C4P	--	--	BEQ	20.0	15.4
C32	48.9	37.6						
C33	--	--						
C34	80.2	61.7						
PRIS	61.7	47.5						
PHYT	--	--						
UCM	--	--						

[a] Abbreviations: C10 through C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture; NAP: naphthalene; C1N: C1-naphthalene; C2N: C2-naphthalene; C3N: C3-naphthalene; C4N: C4-naphthalene; 1MN: 1-methylnaphthalene; 2MN: 2-methylnaphthalene; 2,6MN: 2,6-dimethylnaphthalene; 2,3,5MN: 2,3,5-trimethylnaphthalene; BIP: biphenyl; ANP: acenaphthylene; ANH: acenaphthene; FLU: fluorene; C1F: C1-fluorene; C2F: C2-fluorene; C3F: C3-fluorene; ANT: anthracene; PHE: phenanthrene; C1P: C1-phenanthrene; C2P: C2-phenanthrene; C3P: C3-phenanthrene; C4P: C4-phenanthrene; 1MP: 1-methylphenanthrene; DIB: dibenzothiophene; C1D: C1-dibenzothiophene; C2D: C2-dibenzothiophene; C3D: C3-dibenzothiophene; FLA: fluoranthene; PYR: pyrene; CFP: methyl fluoranthene-pyrene; BAA: benz(a)anthracene; CHR: chrysene; C1C: C1-chrysene; C2C: C2-chrysene; C3C: C3-chrysene; C4C: C4-chrysene; BBF: benzo(b)fluoranthene; BKF: benzo(k)fluoranthene; BEP: benzo(e)pyrene; BAP: benzo(a)pyrene; PER: perylene; IDE: ideno(1,2,3-cd)pyrene; DBN: dibenzo(a,h)anthracene; BEQ: benzo(g,h,i)perylene.

Table A-2. Aliphatic hydrocarbon concentrations (ng/g) in hair, intestine and liver samples from sea otters collected from three locations in the spring and summer of 1989.[a, b]

Otter #	Lab ID	Sample wt.[c]	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
Hair		**Prince William Sound**														
VD255	22408	4.82	5.36	0.	0.	0.	2.46	20.58	**112.92**	**593.24**	**1611.46**	**2492.1**	**2795.18**	**2976.5**	**2867.23**	**2798.58**
VD271	21992	13.61	4.2	0.	0.	0.	**20.2**	**244.6**	**797.**	**834.1**	**831.6**	**925.1**	**899.9**	**935.6**	**898.7**	**975.54**
VD293	22118	10.97	0.	0.	0.	0.	0.	**45.56**	**249.68**	**526.**	**635.9**	**730.5**	**755.3**	**811.5**	**800.1**	**915.62**
VD294	22156	10.54	1.26	0.	0.	0.	3.53	**109.07**	**972.03**	**2928.05**	**3201.77**	**3679.58**	**3766.39**	**3724.80**	**3511.29**	**3370.99**
VD451	21956	11.86	0.	0.	0.	0.	0.	3.11	**30.81**	**50.**	**47.9**	**62.3**	**72.3**	**82.7**	**82.5**	**82.08**
		Kenai														
SD008	23391	11.92	0.	0.	0.	0.	0.	4.06	**36.99**	**131.91**	**199.88**	**315.52**	**368.80**	**401.2**	**411.86**	**412.84**
SD031	23341	12.8	0.	0.	0.	0.	0.	**31.02**	**105.46**	**523.52**	**790.48**	**984.02**	**1075.31**	**1089.88**	**1045.46**	**1024.76**
		Kodiak														
KD085	22974	13.65	0.	0.	0.	0.	0.	0.	**25.36**	**31.9**	**15.6**	**14.9**	**17.8**	**22.**	**22.9**	**27.48**
KD089	22497	7.26	4.46	0.	0.	0.	0.	6.37	**38.31**	**60.**	**30.4**	**12.9**	**6.3**	**6.5**	**4.4**	**7.12**
KD110	22956	14.22	4.20	0.	0.	0.	0.	0.	**14.17**	**20.8**	**6.6**	**2.4**	0.8	0.	1.1	**2.07**
KD119	22493	17.38	0.	0.	0.	0.	0.	**16.88**	**27.0**	**26.7**	**8.**	**2.**	0.7	0.5	0.4	**1.03**
KD143	22521	7.87	1.16	0.	0.	0.	0.	1.69	**19.41**	**36.**	**19.**	**6.6**	2.1	1.6	0.	0.
KD180	22583	13.5	0.	0.	0.	0.	0.	**20.87**	**37.61**	**69.4**	**71.**	**84.8**	**92.3**	**89.**	**83.**	**85.23**
Intestine		**Prince William Sound**														
VD255	22403	2.08	23.10	0.	5.94	7.36	13.20	23.29	**27.44**	**38.1**	**17.7**	**13.8**	11.4	3.8	**12.**	**15.36**
VD271	22295	2.46	32.48	16.32	7.73	5.93	11.34	17.35	**24.92**	**38.1**	**18.8**	**20.3**	**26.9**	**13.1**	**16.**	**13.81**
VD293	22124	2.24	32.47	9.84	6.9	5.78	15.22	20.4	**29.43**	**38.1**	**16.7**	**16.1**	8.6	**18.3**	**11.1**	**12.95**
VD294	22162	1.48	27.25	18.69	8.57	7.3	25.50	24.53	**47.6**	**47.5**	23.6	**20.6**	14.2	18.7	**17.**	**16.87**
VD382	21974	2.41	48.22	13.22	13.81	8.65	16.72	31.40	**38.79**	**49.6**	**21.5**	**19.3**	11.2	**18.**	**14.5**	**14.75**
VD451	21961	1.99	27.68	0.	0.	0.	11.2	**119.26**	**42.36**	**184.2**	**26.4**	**22.9**	**20.4**	**26.3**	**17.8**	**18.8**
		Kenai														
HD097	23146	2.	0.	8.90	12.95	5.46	16.89	47.65	24.48	**87.6**	9.9	**13.5**	15.4	**17.7**	**38.5**	**52.2**
SD008	23403	2.11	0.	13.58	22.12	5.04	**22.23**	46.44	**44.14**	**101.9**	**18.3**	5.2	5.3	**5.**	10.7	**8.28**
SD031	23348	2.13	0.	7.53	10.91	18.11	**39.05**	**62.62**	**71.45**	**76.6**	**43.8**	**43.3**	**35.7**	**37.6**	**37.6**	**42.72**

Otter #	Lab ID	Sample wt.[c]	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
		Kodiak														
KD085	22978	2.01	**136.07**	11.32	8.75	5.97	16.67	29.33	**28.61**	**29.**	12.3	**9.6**	5.2	6.3	6.2	**10.99**
KD089	22501	2.1	**383.76**	**46.29**	**361.95**	**35.92**	**153.93**	**344.21**	**66.28**	**349.4**	**35.**	**24.**	11.9	11.1	**18.9**	**27.7**
KD110	22960	2.16	**165.13**	**59.20**	**122.86**	**194.63**	**33.36**	**121.87**	**65.54**	**317.9**	**29.4**	**18.7**	7.9	11.	8.9	**19.8**
KD119	22487	2.29	16.44	17.68	**86.34**	0.	18.52	**116.61**	**47.95**	**241.8**	**22.7**	**9.2**	10.8	**19.6**	**11.4**	**17.36**
KD143	22527	1.84	**131.49**	13.75	8.89	5.05	16.78	31.03	28.0	**77.2**	12.	**9.2**	4.	**32.8**	9.3	**14.46**
KD180	22585	2.01	**293.55**	12.13	11.08	8.97	**28.05**	**327.75**	**52.49**	**46.2**	13.8	**10.2**	7.	6.4	7.4	**14.91**
Liver		**Prince William Sound**														
VD255	22401	1.96	27.84	11.23	7.46	8.65	17.99	36.39	27.94	**43.7**	17.6	**12.5**	12.1	**48.8**	6.5	**8.03**
VD271	22297	2.37	17.82	8.81	7.15	8.52	9.5	24.58	**26.93**	**44.7**	**21.3**	**17.9**	3.1	**60.2**	9.6	**7.39**
VD293	22129	2.42	32.89	10.44	10.93	7.38	14.18	24.81	**33.58**	**66.8**	12.5	**13.**	3.6	**98.**	**10.**	**19.92**
VD294	22160	2.31	44.97	**22.44**	20.29	11.41	**24.40**	17.48	**25.15**	**26.5**	12.	**13.2**	**23.6**	4.4	7.1	**6.81**
VD382	21971	2.37	32.05	19.83	15.23	11.28	14.29	25.10	**29.52**	**38.**	12.3	**11.9**	**33.7**	5.5	7.2	**5.51**
VD451	21959	2.18	**311.72**	**170.73**	**177.48**	**52.44**	**139.23**	**181.69**	**62.91**	**271.2**	**31.9**	**26.2**	**19.**	**70.4**	**18.3**	**25.61**
		Kenai														
HD010	21137	0.62	40.24	51.35	30.27	54.99	**80.85**	45.50	**110.17**	**121.8**	**94.2**	**92.7**	**54.7**	**59.4**	**80.9**	**103.13**
HD019	23126	2.04	0.	7.1	9.62	7.1	13.91	20.08	**28.11**	**44.4**	**18.7**	3.8	6.3	**41.3**	**11.7**	**11.67**
HD020	23153	2.07	0.	10.68	11.56	6.92	13.75	23.55	22.50	**43.4**	15.8	**8.6**	2.9	5.4	8.3	**8.45**
HD096	23119	2.35	3.94	7.79	6.10	7.88	16.05	27.03	**32.66**	**56.8**	**20.9**	**8.1**	8.2	6.9	**17.7**	**13.66**
HD097	23145	2.09	24.93	11.20	10.7	6.06	17.36	42.6	**29.27**	**120.5**	10.8	**8.**	13.3	**40.6**	**13.**	**14.01**
SD008	23401	2.	0.	12.90	16.77	9.25	22.15	**56.77**	**46.02**	**71.7**	**18.9**	**9.6**	3.5	**15.8**	7.4	**10.91**
SD031	23345	1.93	0.	11.19	16.42	12.13	21.23	38.39	**45.61**	**47.9**	16.2	**17.9**	6.8	12.3	18.2	**19.72**
SD035	23364	2.07	54.9	0.	0.	0.	0.	0.	21.52	**25.2**	0.	**15.1**	0.	**31.4**	4.8	**20.19**
SD064	25076	2.05	33.15	13.12	11.69	4.77	3.82	**91.95**	26.48	**104.7**	**45.**	**12.6**	**36.7**	**28.4**	**22.4**	**28.91**
		Kodiak														
KD042	23036	2.14	27.16	20.22	**27.89**	14.1	17.11	**47.27**	23.01	**43.1**	9.7	3.2	3.3	**24.9**	6.5	4.68
KD050	22946	1.8	3.62	17.49	9.25	10.86	21.42	26.54	**41.42**	**98.**	**29.2**	**19.7**	**36.8**	**147.6**	**22.7**	**21.83**
KD057	23006	1.87	0.	**38.39**	**44.08**	**27.42**	20.35	26.47	**75.4**	**44.3**	14.7	7.1	3.9	4.4	3.9	5.24
KD078	23010	1.37	0.	**41.3**	**84.3**	**48.9**	**39.6**	**429.**	**66.8**	**401.6**	22.2	**12.9**	13.7	7.4	9.4	**12.01**
KD085	22977	2.04	4.07	9.7	7.3	7.40	18.04	39.30	**34.72**	**33.2**	12.3	**8.3**	3.6	2.6	5.5	**13.34**

Otter #	Lab ID	Sample wt.[c]	C10	C11	C12	C13	C14	C15	C16	C17	C18	C19	C20	C21	C22	C23
KD089	22500	2.03	0.	10.98	**24.7**	10.24	**27.76**	**67.13**	**53.52**	**70.2**	**21.6**	**14.7**	6.5	3.6	8.7	**18.58**
KD094	22612	1.99	4.66	15.14	11.86	19.27	20.22	15.67	**47.54**	**54.8**	15.6	5.	7.6	**75.1**	3.7	**22.18**
KD107	22685	2.12	39.6	13.07	13.07	19.6	**45.43**	**81.81**	**89.65**	**110.2**	**84.2**	**82.2**	**74.4**	**99.9**	87.	**108.92**
KD110	22961	2.13	**1137.0**	9.53	15.52	11.23	**28.79**	27.77	**28.99**	**79.2**	**17.1**	**13.7**	0.	0.	0.	0.
KD119	22491	2.05	0.	0.	0.	0.	4.23	**282.33**	7.71	**38.4**	**18.4**	3.7	0.	**79.9**	0.	**8.00**
KD143	22526	2.05	**271.89**	13.78	11.93	7.72	17.21	27.37	24.34	**69.**	9.3	**10.**	3.5	**184.**	8.5	**13.28**
KD180	22587	1.87	**334.08**	**35.36**	26.05	12.56	**30.76**	**55.98**	**45.2**	**71.2**	18.2	**16.**	8.1	15.8	**17.2**	**7.23**
KD2137	22548	0.52	100.08	16.94	65.81	62.72	82.94	360.99	90.81	352.	48.	46.5	49.5	73.	95.2	141.34
KD2188	23023	2.18	23.33	11.77	10.75	15.56	16.27	129.56	37.15	33.1	11.6	5.9	5.1	3.3	2.8	6.81

Table A-2. Continued.

Otter #	Lab ID	Sample wt.[c]	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	PRIS	PHYT	Total	UCM[d]
Hair		**Prince William Sound**															
VD255	22408	4.82	**2672.09**	**2602.90**	**2237.28**	**1713.19**	**1528.40**	**1419.88**	**889.96**	**1049.60**	**893.05**	**790.03**	**602.51**	**500.0**	**965.46**	34140.49	302.06
VD271	21992	13.61	**934.94**	**910.6**	**776.75**	**585.46**	**512.11**	**495.16**	**420.21**	**503.70**	**400.12**	**353.06**	**333.30**	**646.6**	**586.7**	14825.24	98.56
VD293	22118	10.97	**892.12**	**878.59**	**777.34**	**605.35**	**526.53**	**546.36**	**464.55**	**450.67**	**382.35**	**336.7**	**360.87**	**483.2**	**518.3**	12693.07	98.76
VD294	22156	10.54	**3214.75**	**3058.75**	**2638.83**	**1884.74**	**1735.40**	**1625.98**	**956.38**	**1113.34**	**933.68**	**791.61**	**830.43**	**2130.08**	**2077.13**	48259.85	366.19
VD451	21956	11.86	**81.48**	**82.57**	**72.21**	**71.91**	**50.80**	**233.50**	**28.43**	**53.18**	**28.14**	**29.59**	**20.40**	**79.7**	**38.8**	1384.41	7.7
		Kenai															
SD008	2339[illegible]	11.92	**421.35**	**418.86**	**381.87**	**304.38**	**257.71**	**245.09**	**159.04**	**183.60**	**156.13**	**135.49**	**103.21**	**269.29**	**158.26**	3939.27	50.34
SD031	23341	12.8	**987.27**	**979.48**	**835.88**	**790.47**	**552.21**	**1083.55**	**324.08**	**470.83**	**325.10**	**290.89**	**337.76**	**475.79**	**539.82**	9671.08	106.85
		Kodiak															
KD085	22974	13.65	**27.79**	**32.70**	**28.31**	**28.62**	**22.98**	**506.78**	**12.57**	**45.74**	**13.47**	**18.60**	**8.14**	**88.5**	**20.4**	1032.55	4.2
KD089	22497	7.26	**6.50**	**8.26**	**7.12**	**8.67**	**11.15**	**40.46**	**6.88**	**12.48**	**10.81**	**11.00**	9.24	**108.**	**38.7**	456.02	6.2
KD110	22956	14.22	0.	**2.89**	0.	**8.27**	0.	**3.82**	0.	0.	0.	0.	0.	**32.6**	**6.3**	106.02	0.
KD119	22493	17.38	0.	0.	0.	0.	0.	**4.84**	0.	0.	0.	0.	0.	**52.6**	**7.6**	149.24	0.1
KD143	2252[illegible]	7.87	0.	0.	0.	0.	0.	**25.85**	0.	0.	0.	0.	0.	**68.6**	**18.1**	200.10	0.
KD180	22583	13.5	**83.68**	**90.92**	**79.44**	**71.99**	**71.16**	**111.40**	**45.53**	**59.06**	**51.99**	**49.37**	**36.45**	**124.9**	**94.**	1603.08	19.3
Intestine		**Prince William Sound**															
VD255	22403	2.08	12.50	16.84	**9.53**	16.10	7.10	14.72	4.22	13.28	0.	0.	0.	**181.**	**32.4**	520.17	0.
VD271	22295	2.46	**13.48**	13.06	**9.10**	15.41	7.81	12.2	5.43	5.86	0.	0.	0.	**115.9**	**39.7**	501.03	46.
VD293	22124	2.24	12.00	10.83	10.62	11.57	9.66	14.65	11.77	7.12	0.	0.	0.	**72.6**	**26.5**	429.19	2.
VD294	22162	1.48	17.63	14.6	12.87	12.87	8.54	9.30	8.67	0.	0.	0.	0.	**53.8**	24.4	480.58	0.8
VD382	21974	2.41	**13.25**	13.57	**11.09**	11.2	6.14	10.88	7.86	0.	0.	0.	0.	**71.2**	**26.2**	491.05	9.1
VD451	21961	1.99	**17.32**	**19.44**	**15.95**	21.13	9.19	20.07	0.	0.	0.	0.	0.	**525.5**	12.5	1158.39	3.9
		Kenai															
HD097	23146	2.	**64.34**	**70.20**	**62.31**	**82.44**	**43.50**	**49.06**	**21.34**	**28.83**	9.81	7.49	0.	**254.2**	**95.5**	1140.16	19.4
SD008	23403	2.11	10.93	6.79	7.22	9.13	0.	12.95	0.	0.	0.	0.	0.	506.8	7.5	869.56	0.3
SD031	23348	2.13	**32.67**	**36.02**	**28.58**	**44.50**	**19.26**	**27.74**	10.22	**22.49**	8.93	4.30	0.	92.4	69.6	923.70	3.8

Otter #	Lab ID	Sample wt.[c]	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	PRIS	PHYT	Total	UCM[d]
		Kodiak															
KD085	22978	2.01	**15.15**	11.2	8.75	9.6	5.33	15.25	0.	0.	0.	0.	0.	**109.5**	6.2	497.29	0.
KD089	22501	2.1	**30.07**	**29.97**	**21.7**	**33.69**	**13.43**	21.18	8.49	17.09	5.31	7.86	0.	**1217.6**	**55.3**	3332.01	3.6
KD110	22960	2.16	13.30	**26.81**	8.22	**98.19**	9.54	**46.91**	4.44	20.34	0.	4.11	0.	**167.7**	11.4	1587.16	0.1
KD119	22487	2.29	**20.38**	**28.46**	11.43	**34.72**	**13.58**	**34.5**	4.86	0.	0.	0.	0.	**434.5**	**93.4**	1312.22	8.9
KD143	22527	1.84	**19.04**	13.21	12.49	14.15	8.95	11.65	8.63	10.82	8.96	18.90	0.	**2424.9**	**36.5**	2982.16	0.
KD180	22585	2.01	**15.54**	11.65	8.19	9.13	4.93	8.29	0.	0.	0.	0.	0.	**1247.4**	7.8	2152.86	0.
Liver		**Prince William Sound**															
VD255	22401	1.96	9.85	4.56	7.57	7.46	4.97	0.	0.	13.56	0.	0.	0.	**250.**	**82.6**	667.35	5.6
VD271	22297	2.37	**12.84**	3.8	9.24	**18.90**	6.68	0.	0.	0.	0.	0.	0.	**279.**	**116.1**	714.07	14.6
VD293	22129	2.42	6.09	4.85	**13.32**	**13.70**	**13.73**	9.50	4.39	0.	0.	0.	0.	**341.**	**119.2**	883.83	17.7
VD294	22160	2.31	9.69	6.92	6.28	9.48	0.	6.07	0.	0.	0.	0.	0.	**64.3**	**35.7**	398.20	11.1
VD382	21971	2.37	5.7	4.98	6.47	6.78	5.94	5.51	0.	0.	0.	0.	0.	**288.4**	**73.8**	659.02	13.
VD451	21959	2.18	**18.81**	**17.96**	7.97	8.5	7.01	16.26	4.24	0.	9.03	0.	0.	**436.3**	**150.4**	2235.29	15.
		Kenai															
HD010	21137	0.62	**72.66**	**87.15**	**90.13**	**103.77**	**98.98**	**74.37**	0.	0.	0.	0.	0.	**385.2**	**386.4**	2318.87	0.
HD019	23126	2.04	**16.03**	7.80	10.33	12.76	0.	0.	0.	5.30	0.	0.	0.	**4032.1**	**203.1**	4510.6	0.
HD020	23153	2.07	10.35	8.03	7.71	9.93	6.97	0.	0.	0.	0.	0.	0.	**114.7**	**106.8**	446.31	2.1
HD096	23119	2.35	**14.29**	5.46	11.45	**14.08**	8.72	6.51	**14.13**	13.16	0.	0.	0.	**136.6**	**131.1**	589.20	3.4
HD097	23145	2.09	14.33	9.12	9.62	**18.63**	4.71	9.93	2.61	0.	0.	0.	0.	**80.9**	**49.5**	561.70	14.7
SD008	23401	2.	8.58	8.05	0.	5.72	3.81	8.16	0.	0.	0.	0.	0.	**335.9**	0.	671.89	0.
SD031	23345	1.93	12.19	9.75	12.51	**14.20**	8.16	10.18	0.	0.	0.	0.	0.	**99.9**	**129.2**	580.09	0.
SD035	23364	2.07	12.58	**18.71**	4.44	5.39	10.68	12.58	12.87	9.14	10.81	0.	0.	**337.7**	**67.3**	675.30	0.
SD064	25076	2.05	**22.68**	**24.56**	**20.21**	**17.98**	**16.45**	**42.66**	4.41	18.13	0.	0.	0.	**282.9**	**292.4**	1206.07	38.5
		Kodiak															
KD042	23036	2.14	4.78	4.99	5.20	9.26	4.99	2.81	2.42	1.92	0.	0.	0.	**119.8**	**23.7**	452.01	0.
KD050	22946	1.8	**21.31**	11.85	12.26	**22.55**	10.5	10.60	0.	**28.11**	0.	0.	0.	**345.1**	**151.2**	1119.91	0.
KD057	23006	1.87	7.23	5.56	5.97	**17.09**	6.92	8.6	0.	0.	0.	0.	0.	**84.8**	**30.1**	481.91	1.4
KD078	23010	1.37	6.89	10.75	10.02	12.11	5.64	4.49	0.	0.	0.	0.	0.	**203.3**	11.2	1453.51	2.8
KD085	22977	2.04	**15.92**	10.96	9.61	6.31	3.82	6.82	0.	0.	0.	0.	0.	**269.3**	18.8	540.90	0.

Otter #	Lab ID	Sample wt.[c]	C24	C25	C26	C27	C28	C29	C30	C31	C32	C33	C34	PRIS	PHYT	Total	UCM[d]
KD089	22500	2.03	**16.99**	14.04	11.93	**15.2**	**18.89**	7.71	3.20	16.09	0.	0.	0.	**394.9**	**26.3**	863.45	2.5
KD094	22612	1.99	7.03	5.09	6.17	0.	3.46	0.	0.	0.	0.	0.	0.	**299.6**	22.2	661.89	5.1
KD107	22685	2.12	**111.18**	**114.95**	**117.63**	**110.65**	**107.31**	**106.34**	**54.38**	**84.87**	**40.**	0.	0.	**5277.7**	**152.**	7226.04	0.
KD110	22961	2.13	**24.5**	0.	0.	10.45	0.	17.31	0.	14.58	0.	0.	0.	**93.4**	0.	1529.07	24.6
KD119	22491	2.05	7.90	6.62	6.08	5.66	0.	13.55	0.	0.	0.	0.	0.	**106.1**	17.7	606.28	5.5
KD143	22526	2.05	12.44	6.64	10.65	9.59	7.27	9.28	6.40	9.92	4.27	0.	0.	**4448.6**	**82.1**	5279.00	0.
KD180	22587	1.87	**17.00**	10.38	6.82	9.98	7.74	17.41	0.	11.83	0.	0.	0.	**12229.6**	**47.9**	13052.38	1.1
KD2137	22548	0.52	**164.2**	**177.72**	**163.23**	**160.44**	**136.08**	**97.44**	**74.34**	0.	0.	0.	0.	32.4	0.	2591.67	0.
KD2188	23023	2.18	6.39	6.29	5.34	5.76	3.25	3.04	0.	0.	0.	0.	0.	21.3	7.5	371.87	0.

[a] Reported by GERG, NRDA Hydrocarbon Data, Catalogs 6540, 6556, 6641.

[b] Abbreviations: C10 through C34: n-alkanes; PRIS: pristane; PHYT: phytane; UCM: unresolved complex mixture; Total: total aliphatic (not including the UCM).

[c] Sample wet weight, in grams.

[d] $\mu g/g$.

Table A-3. Aromatic hydrocarbon concentrations (ng/g) in hair, intestine and liver samples from sea otters collected from three locations in the spring and summer of 1989.[a, b].

Otter #	Lab ID	Sample wt.[c]	NAP	C1N	C2N	C3N	C4N	BIP	ANP	ANH	FLU	C1F	C2F	C3F	PHE	ANT	C1P	C2P	C3P	C4P	DIB
Hair		**Prince William Sound**																			
VD255	22408	4.82	3.43	**9.74**	**8.58**	**17.57**	**26.76**	1.89	0.26	0.48	0.49	**5.44**	**37.24**	**112.9**	**9.8**	0.17	**102.63**	**282.88**	**257.**	**145.72**	4.78
VD271	21992	13.61	1.08	**4.26**	**14.86**	**103.82**	**168.9**	1.24	0.15	0.32	**6.39**	**58.73**	**146.83**	**175.28**	**80.39**	0.4	**285.29**	**383.67**	**249.66**	**133.91**	**41.18**
VD293	22118	10.97	0.92	**2.82**	**6.65**	**19.16**	**49.65**	0.68	0.23	0.28	1.08	**16.23**	**104.89**	**158.98**	**29.1**	0.2	**170.93**	**293.53**	**219.71**	**115.06**	**12.6**
VD294	22156	10.54	0.96	**4.98**	**8.54**	**37.21**	**187.15**	1.	0.1	0.43	**2.2**	**64.9**	**289.11**	**342.77**	**108.76**	0.63	**498.88**	**697.53**	**466.92**	**234.74**	**54.94**
VD451	21956	11.86	1.25	**4.43**	0.	0	**8.89**	1.08	0.27	0.14	0.54	0.	**6.47**	**6.94**	**3.3**	0.04	**10.21**	**16.85**	**12.55**	**8.12**	1.65
		Kenai																			
SD008	23391	11.92	0.53	1.13	0.	**6.82**	**9.01**	0.34	0.09	0.21	0.37	0.	**14.55**	**25.16**	**5.3**	0.03	**30.72**	**56.82**	**48.16**	**26.78**	**2.3**
SD031	23341	12.8	0.61	**2.92**	0.	**12.76**	**17.8**	1.12	0.08	0.11	0.49	**5.48**	**40.77**	**72.78**	**12.36**	0.2	**88.19**	**152.21**	**118.7**	**62.32**	5.55
		Kodiak																			
KD085	22974	13.65	0.67	1.3	0.	0.	**6.6**	0.45	0.13	0.26	0.32	0.	0.	0.	**1.49**	0.08	**4.26**	**7.26**	**5.44**	0.	0.74
KD089	22497	7.26	0.77	1.97	0.	**10.77**	**15.32**	0.79	0.3	0.42	0.73	0.	**7.69**	**9.55**	**2.32**	0.11	**7.91**	**14.63**	**12.6**	**9.06**	1.09
KD110	22956	14.22	0.72	1.4	0.	0.	0.	0.35	0.19	0.14	0.26	0.	0.	0.	0.86	0.08	0.	0.	0.	0.	0.38
KD119	22493	17.38	0.44	1.13	0.	**6.27**	**8.9**	0.36	0.16	0.11	0.28	0.	0.	0.	**1.51**	0.03	0.	0.	0.	0.	0.83
KD143	22521	7.87	0.58	1.82	0.	0.	0.	0.69	0.27	0.55	0.34	0.	0.	0.	1.51	0.08	0.	0.	0.	0.	0.66
KD180	22583	13.5	0.71	**2.8**	0.	**5.9**	**10.63**	0.5	0.25	0.26	0.48	0.	**8.26**	**12.43**	**3.72**	0.04	**16.15**	**30.9**	**23.84**	0.	**1.79**
Intestine		**Prince William Sound**																			
VD255	22403	2.08	**15.44**	7.44	0.	0.	0.	1.61	0.37	0.46	0.77	0.	0.	0.	1.92	0.29	0.	0.	0.	0.	0.45
VD271	22295	2.46	6.22	4.68	0	0.	0.	1.01	0.2	0.73	0.38	0.	0.	0.	0.93	0.14	0	0.	0.	0.	0.43
VD293	22124	2.24	7.67	4.34	0.	0.	0.	0.98	0.11	0.25	0.59	0.	0.	0.	1.25	0.27	0.	0.	0.	0.	0.57
VD294	22162	1.48	14.48	6.8	9.99	15.59	0.	2.73	0.44	1.09	1.05	0.	0.	0.	2.72	0.23	6.45	**37.59**	**23.2**	14.51	0.82
VD382	21974	2.41	8.72	5.66	0.	0.	0.	1.19	0.32	0.44	0.52	0.	0.	0.	1.51	0.2	0.	0.	0.	0.	0.97
VD451	21961	1.99	6.58	4.23	5.96	7.34	0.	1.55	0.24	0.22	0.59	0.	0.	0.	1.36	0.28	0.	0.	0.	0.	0.79

Otter #	Lab ID	Sample wt.[c]	NAP	C1N	C2N	C3N	C4N	BIP	ANP	ANH	FLU	C1F	C2F	C3F	PHE	ANT	C1P	C2P	C3P	C4P	DIB
		Kenai																			
HD097	23146	2.	7.81	6.36	0.	0.	0.	6.83	1.14	1.56	1.27	0.	0.	0.	1.88	0.62	0.	0.	0.	0.	0.34
SD008	23403	2.11	6.86	9.31	0.	0.	0.	1.14	2.04	1.31	1.23	0.	0.	0.	1.32	0.79	0.	0.	0.	0.	0.76
SD031	23348	2.13	8.76	7.15	0.	0.	0.	6.38	0.79	5.32	2.57	0.	0.	0.	2.47	1.13	0.	0.	0.	0.	2.15
		Kodiak																			
KD085	22978	2.01	7.83	5.83	0.	0.	0.	2.79	0.42	0.89	0.51	0.	0.	0.	1.01	0.55	0.	0.	0.	0.	0.66
KD089	22501	2.1	10.92	9.88	0.	0.	0.	4.04	5.9	0.91	4.93	0.	0.	0.	2.12	1.35	0.	0.	0.	0.	0.85
KD110	22960	2.16	**18.04**	10.8	**18.95**	**21.9**	0.	3.82	3.16	0.76	1.66	0.	0.	0.	2.37	2.76	0.	0.	0.	0.	0.99
KD119	22487	2.29	6.82	4.6	0	0.	0.	1.46	0.69	0.43	0.73	0.	0.	0.	1.43	0.32	0.	0.	0.	0.	0.33
KD143	22527	1.84	8.45	7.58	0.	0.	0.	3.69	0.58	1.48	2.07	0.	0.	0.	1.87	1.07	0.	0.	0.	0.	0.53
KD180	22585	2.01	8.77	9.37	0.	0.	0.	4.54	0.91	0.82	1.38	0.	0.	0.	2.17	0.81	0.	0.	0.	0.	1.5
Liver		**Prince William Sound**																			
VD255	22401	1.96	**17.34**	11.7	8.96	5.83	0.	1.86	0.67	0.36	1.27	0.	0.	0.	3.56	0.78	0.	0.	0.	0.	0.58
VD271	22297	2.37	**15.48**	**16.64**	**11.57**	6.4	7.62	4.57	1.27	2.02	3.2	0.	0.	0.	**7.03**	1.84	0.	0.	0.	0.	0.98
VD293	22129	2.42	7.59	6.64	9.31	8.54	5.23	2.94	1.03	0.49	0.26	0.	0.	0.	4.51	1.88	0.	0.	0.	0.	1.46
VD294	22160	2.31	**16.83**	10.13	**12.46**	9.67	0.	**8.48**	0.8	0.36	1.08	0.	0.	0.	3.28	1.27	0.	0.	0.	0.	1.11
VD382	21971	2.37	8.13	5.78	**12.2**	**17.11**	9.61	3.1	0.96	0.53	0.85	0.	0.	0.	4.32	2.3	0.	0.	0.	0.	1.94
VD431	21959	2.18	8.52	7.19	9.96	**22.05**	0.	3.26	1.06	0.45	1.74	0.	0.	0.	1.93	1.09	0.	0.	0.	0.	1.62
		Kenai																			
HD010	21137	0.62	15.8	25.73	0.	0.	0.	11.74	1.58	2.89	2.41	0.	0.	0.	6.23	0.67	0.	0.	0.	0.	1.64
HD019	23126	2.04	13.07	**26.32**	**14.11**	**16.64**	8.08	5.61	2.34	0.9	0.96	0.	0.	0.	**7.06**	2.11	0.	0.	0.	0.	2.14
HD020	23153	2.07	3.61	6.92	**12.**	**15.92**	0.	6.12	0.63	1.54	0.84	0.	0.	0.	2.47	0.43	0.	0.	0.	0.	1.54
HD096	23119	2.35	10.33	**11.36**	7.56	7.59	4.97	3.3	0.62	0.53	0.91	0.	0.	0.	3.69	1.04	0.	0.	0.	0.	0.81
HD097	23145	2.09	4.9	10.88	0	0.	0.	7.64	1.56	1.06	3.95	0.	0.	0.	**8.27**	2.28	0.	0.	0.	0.	1.34
SD008	23401	2.	9.51	10.72	0.	0.	0.	1.54	3.04	1.27	1.64	0.	0.	0.	2.55	0.21	0.	0.	0.	0.	0.8
SD031	23345	1.93	10.36	**12.91**	0.	0.	0.	8.01	1.69	1.61	3.	0.	0.	0.	2.13	1.45	0.	0.	0.	0.	1.02
SD035	23364	2.07	4.82	9.22	**26.2**	**35.3**	0.	5.58	0.76	0.82	1.83	0.	0.	0.	2.28	0.26	0.	0.	0.	0.	1.76

Otter #	Lab ID	Sample wt.[c]	NAP	C1N	C2N	C3N	C4N	BIP	ANP	ANH	FLU	C1F	C2F	C3F	PHE	ANT	C1P	C2P	C3P	C4P	DIB
SD064	25076	2.05	8.21	**12.02**	0.	0.	0.	2.03	1.07	1.95	3.22	0.	0.	0.	3.66	0.89	0.	0.	0.	0.	1.17
		Kodiak																			
KD042	23036	2.14	**14.09**	**49.26**	**36.86**	**20.84**	**12.73**	7.75	1.68	1.37	3.48	0.	0.	0.	**9.44**	0.93	10.24	**16.45**	**15.03**	8.04	9.29
KD050	22946	1.8	**18.63**	**18.53**	0.	0.	0.	3.47	3.04	0.6	1.75	0.	0.	0.	6.62	1.91	0.	0.	0.	0.	3.
KD057	23006	1.87	**15.89**	**14.15**	8.84	11.02	5.46	2.68	1.42	0.64	2.09	0	0.	0.	3.26	1.02	8.56	8.98	3.71	7.07	7.17
KD078	23010	1.37	19.27	9.14	7.77	0.	0.	1.82	2.44	7.94	2.76	0.	0.	0.	3.35	0.18	0.	0.	0.	0.	1.11
KD085	22977	2.04	8.53	6.62	0.	0.	0.	4.97	2.52	1.48	0.79	0.	0.	0.	2.39	0.88	0.	0.	0.	0.	1.42
KD089	22500	2.03	10.91	9.32	**16.86**	**29.96**	0.	7.43	12.24	**14.51**	2.2	0.	0.	0.	2.31	0.34	0.	0.	0.	0.	0.8
KD094	22612	1.99	**15.72**	11.88	9.35	0.	0.	1.71	7.99	3.84	0.76	0.	0.	0.	2.8	1.25	0.	0.	0.	0.	1.85
KD107	22685	2.12	**14.45**	**11.7**	**16.8**	**44.3**	**39.14**	2.03	1.68	0.49	1.09	6.49	**39.75**	**28.84**	**8.21**	0.71	**30.33**	**47.07**	**33.24**	**23.53**	3.82
KD110	22961	2.13	8.4	9.43	0.	0.	0.	4.51	2.35	1.4	1.57	0.	0.	0.	2.32	1.64	0.	0.	0.	0.	0.94
KD119	22491	2.05	3.76	7.11	0.	0.	0.	3.97	0.36	0.47	1.15	0.	0.	0.	3.04	1.44	0.	0.	0.	0.	0.53
KD143	22526	2.05	8.56	**12.44**	0.	0.	0.	6.7	4.61	1.57	1.93	0.	0.	0.	5.51	2.76	0.	0.	0.	0.	0.68
KD180	22587	1.87	11.56	10.34	0.	0.	0.	6.64	2.76	2.61	1.73	0.	0.	0.	3.37	2.24	0.	0.	0.	0.	2.33
KD2137	22548	0.52	19.38	21.65	0.	0.	0.	9.96	?.	4.13	14.99	0.	0.	0.	4.97	1.62	0.	0.	0.	0.	1.71
KD2188	23023	2.18	**16.87**	**157.17**	**113.97**	**33.92**	**17.81**	**21.57**	1.21	3.65	5.51	0.	0.	0.	**8.37**	0.62	0.	0.	0.	0.	5.18