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PAHs IN THE AQUATIC ENVIRONMENT OF BRITISH COLUMBIA

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BY

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ABSTRACT

This report summarizes information on polycyclic aromatic hydrocarbon (PAH) compounds in the aquatic environment of British Columbia, obtained from select studies conducted by Environment Canada, Pacific and Yukon Region between 1984 and 1992. The information reflects studies conducted mainly in urban areas such as the Fraser River Estuary, Vancouver, Victoria and Esquimalt harbours, however, data for some other coastal regions and reference sites are also presented.

This report also documents the existing information on the potential sources of PAH compounds and current environmental quality guidelines governing regulatory requirements.

A general overview of the toxicity and environmental levels of these compounds in other areas of the world has been presented to provide a broader context for the British Columbia data.

RESUME

Ce rapport fournit un sommaire d'informations sur les hydrocarbures aromatiques polycycliques (PAHs) dans l'environnement de la Colombie-Britannique et est le resultat d'etudes conduites par Environnement Canada, Pacific et la Region du Yukon entre 1984 et 1992.

L'objectif de ce rapport etait de documenter les informations existantes sur les niveaux de diffusion dans l'environnment des PAHs de l'etain en Columbi-Britannique et la legislation courante et les directives controlant la diffusion de ces composes.

Une vue d'ensemble generale des niveaux de toxicite et d'environnement de ces composes dans d'autre regions dans le monde a ete fournie au lecteur afin de mettre en relief ces informations pour la Columbie-Britannique.

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EXECUTIVE SUMMARY

- Polycyclic aromatic hydrocarbons (PAHs) are organic compounds made up of hydrogen and carbon atoms with two or more benzene rings. Most PAHs are produced as by-products and released to the environment inadvertently. However, some PAHs are manufactured in North America as commercial chemicals and used mainly in the pharmaceutical, photographic, and chemical industries, as well as in the production of fungicides, insecticides, surfactants, and moth repellents. Elevated concentrations of PAHs in the environment are of concern due to their persistence and toxicity.

- PAHs have been designated as toxic substances under Section 11 of the *Canadian Environmental Protection Act* (CEPA, 1988). Many species of aquatic organisms exhibit adverse biological effects following exposure to micrograms per litre (μg/L) concentrations of PAH compounds. These include effects on growth, reproduction, immunocompetence, and survival. Due to their greater water solubility, the lower molecular weight (LMW) PAH compounds (two and three ring) generally exhibit greater acute toxicities to aquatic biota than the higher molecular weight (HMW) compounds (> four rings). However, several of the HMW compounds are carcinogenic and mutagenic. The toxicity of PAHs is also affected by environmental conditions. Toxicity to some aquatic species is increased several fold in the presence of light (phototoxicity), while the presence of high levels of organic carbon in sediments reduces the toxicity of PAHs to benthic organisms. The influence of local environmental conditions must be considered when setting and applying environmental objectives for the protection of aquatic species.

- PAHs in the aquatic environment can be degraded or transformed into new compounds by processes such as volatilization, photooxidation, and microbial degradation. The rate and extent to which PAH compounds are transformed or degraded are influenced by both the molecular structure of the compound and environmental conditions. For example, microbial degradation is favoured in oxygenated sediments and exposed tidal flats. Estuaries and harbours in urbanized and industrialized areas tend to have oxygen-depleted sediments and can serve as long term sinks for PAHs.

- Atmospheric deposition accounts for the majority of PAH input to most aquatic systems. PAHs are produced as by-products and released to the atmosphere during the combustion of organic matter, both naturally and as a result of human activity. Natural sources include forest and grass fires and volcanic eruptions. Anthropogenic sources of PAHs to the atmosphere include coal, oil and wood combustion for residential heating; transportation; aluminum smelters; steel and coking plants; municipal incinerators; agricultural, forest slash, and other open-air burning; and teepee burners at sawmills. A 1990 study conducted

for Environment Canada identified forest fires and aluminum smelters as the two main sources of PAH emissions in Canada. Forest fires accounted for 47% of the total PAH emissions to the atmosphere in 1990, while aluminum smelters accounted for 21% (LGL, 1993).

- High environmental concentrations of PAHs were found in the vicinity of the Alcan aluminum smelter in Kitimat, British Columbia. However, PAH emissions from the smelter have decreased more than 10 fold since the 1970's as a result of improvements to the process technology (Simpson, 1997). Sediment concentrations in many areas of Kitimat Arm have declined as a result of decreased PAH releases from the smelter, but concentrations within 1 km of the smelter remain high (Paine *et al*, 1996).

- Sediment concentrations in the vicinity of the Alcan smelter exceeded concentrations normally associated with adverse biological effects, however, an environmental effects monitoring program showed little evidence of adverse effects in resident communities and no sediment toxicity was observed in bioassays (Paine *et al,* 1996). The lack of adverse effects on local biological communities may be related to the fact that PAH releases from the smelter were associated with pitch globules or coal particles, rather than in solution or sorbed to suspended solids. Studies in Norway have shown that PAHs in sediments receiving discharges from an aluminum smelter are not readily available for degradation or biological uptake.

- Direct losses of PAHs to the aquatic environment occur through the use and spillage of petroleum products, coal, and creosote. These substances contain naturally high levels of PAHs. It has been estimated that the loss of PAHs from creosote-treated wood products may result in the release of up to 2000 tonnes of PAHs to soil and water each year (LGL, 1993). Other direct sources of PAHs to the aquatic environment include municipal treatment plants, industrial discharges, storm sewers, landfill leachate, and surface runoff.

- Environment Canada surveys conducted between 1984 and 1992 found high concentrations of PAH compounds in the sediments of False Creek and Vancouver, Victoria, and Esquimalt harbours. Total PAH concentrations in sediments from these areas ranged up to several thousand nanogram per gram (ng/g) (dry weight). Potential sources of PAHs to these areas include former coal gasification plants (False Creek), fuel combustion and spillage, leaching from creosote pilings, industrial discharges, atmospheric deposition, surface runoff and stormwater discharges. At some sites, multiple potential PAH sources are present in close proximity. For example, combined sewer overflows discharge to these areas and can make significant contributions to PAH concentrations in nearshore sediments. In some cases, the PAH contamination in nearshore sediments may not be associated with the current operations at that site. Historical reviews of land use along the shoreline in these areas indicated a diverse range of industrial activities since the early 1990's.

- During the late 1980's and early 1990's, the highest PAH concentrations in Vancouver Harbour were detected in sediments near several shipbuilding and repair facilities; Vancouver Shipyards (up to 85,614 ng/g), Versatile Pacific (up to 41,321 ng/g), Allied Shipyards (up to 114,880 ng/g), Rivtow (101,375 ng/g), B.C. Marine Shipbuilding/Sterling Shipyards (up to 402,530 ng/g), and Menchion's Shipyard (28,500 ng/g). As of March 2000 these facilities were closed, with the exception of Allied Shipyards and Vancouver Shipyards.

- In 1990, PAH concentrations exceeding 10,000 ng/g (dry weight) were detected in sediments throughout Victoria Harbour with the highest concentrations (>20,000 to >30,000 ng/g) occurring in sediments at the Boatbuilding Facility, the now-closed Smith Cedar Products site, Rock Bay in the Upper Harbour, and at B.C. Shipyards in the Inner Harbour.

- In 1990, the highest PAH concentration in Esquimalt Harbour sediments (63,250 ng/g) occurred in sediments collected near the Department of National Defence facility at Constance Cove. PAH concentrations in sediments throughout this area and at Dunn's Nook (site of a fuel oil jetty) exceeded 10,000 ng/g. Concentrations were also high in Plumper Bay sediments (up to 6,589 ng/g), but were much lower in sediments from the less urbanized/industrialized Fort Rodd (313 ng/g) and Upper Harbour (142 ng/g) areas.

- PAH concentrations were elevated in the vicinity of some wood preservation facilities on the lower Fraser River. Total PAH concentrations were particularly high in the vicinity of the old Kopper's International site in Burnaby (up to 19,834 ng/g) which used creosote from the 1930's until the plant closed in 1981. PAHs were also detected in the vicinity of Domtar Wood Preservers in New Westminster (up to 3,175 ng/g), which has used creosote from the 1930's to the present, and also at the Domtar/Liverpool facility (up to 330 ng/g), where creosote was not used but was stored in large tanks and transferred from ships and barges to rail cars. The Domtar/Liverpool facility was decommissioned in the early 1980's. Although creosote has not been used at Princeton Wood Preservers or B.C. Cleanwood Preservers, PAHs (407 ng/g and up to 3,743 ng/g, respectively), were detected in Fraser River sediments collected near these sites. The elevated PAH concentrations detected in sediments near B.C. Cleanwood Preservers are likely due to PAH input from surface runoff and leaching from creosote pilings, and the fact that this facility is located in Gundersen Slough, which is an area of low flushing. The PAH concentrations detected in the sediments near Princeton Wood Preservers are not considered unusually elevated in comparison to levels found elsewhere in the Fraser River.

- PAH concentrations in sediments collected from reference sites at Crescent Beach, Warn Bay (west coast of Vancouver Island), and the Queen Charlotte Islands were low (0.4 to 83 ng/g dry weight) in comparison to urban/industrialized areas. The presence of PAHs in remote areas is likely due to atmospheric deposition and boat traffic.

- PAH concentrations in sediments collected from many nearshore sites in False Creek and Vancouver, Victoria, and Esquimalt harbours in the late 1980's and early 1990's, greatly exceeded the Canadian Interim Sediment Quality Guidelines and probable effects levels (PELs) summarized in Section 3; Table 6. In some cases, the concentrations of individual PAH compounds were more than 10 fold higher than their PELs. PEL is defined as the level above which adverse effects are expected to occur frequently. It is apparent that the PAH concentrations at several locations in these regions were high enough to cause adverse environmental impacts, depending on local environmental conditions. At some sites, information on current environmental levels is not available and it is not know whether current levels exceed the ISQGs. However, at many of the facilities located in Vancouver Harbour (and at some sites in False Creek), environmental site assessments have been, or are being, conducted and are being reviewed by regulatory agencies. Remedial action will be taken where deemed necessary. In addition, the Ministry of Transport is currently in the process of conducting baseline studies for contaminated shoreline sites throughout Victoria and Esquimalt harbours. Where required, remediation and risk management actions will be undertaken.

- PAH concentrations in the hundreds of ng/g (wet weight) range were detected in mussels from most areas of Vancouver Harbour and False Creek in the late 1980's and early 1990's. Especially high concentrations (4,000 to 5,000 ng/g) were present in mussels collected from Vancouver Shipyard and Versatile Pacific Shipyard in Vancouver Harbour, and from Constance Cove (>3,500 ng/g) in Esquimalt Harbour. These levels are comparable to those detected in mussels from the highly contaminated Sydney Harbour in Nova Scotia (4,200 ng/g).

- PAH concentrations in the hundreds of ng/g (wet weight) range were detected in clams from Vancouver, Victoria, and Esquimalt harbours and in crab hepatopancreas from False Creek and Vancouver and Victoria harbours in the late 1980's and early 1990's. Concentrations in the muscle tissue of crabs were much lower than those detected in the hepatopancreas.

- In the late 1980's and early 1990's, PAH concentrations in fish from False Creek, Vancouver, Victoria and Esquimalt harbours and from the Fraser River exceeded those in fish from reference areas. Concentrations in fish were generally much lower in fish than in shellfish and sediments from the same area, and only occasionally exceeded 100 ng/g (wet weight). These levels are consistent with findings reported in other areas of the world. Fish have a more efficient mixed-function oxidase (MFO) system than do invertebrate species and, therefore, are more able to metabolize PAH compounds.

- Evidence of PAH toxicity has been observed in the aquatic environment of British Columbia. In the late 1980's, a high incidence of liver neoplasms (up to 75%) was observed in the liver of English sole (greater than 20 centimetres in length) collected in the

vicinity of the Ioco oil refinery in the Port Moody area of Vancouver Harbour. The concentrations of PAH compounds in the sediments from this area were also elevated. In the early 1990's, a decline in the frequency of liver lesions (to 30-45%) was observed and was attributed to the fact that the process effluent from the refinery no longer discharged to the harbour (Goyette *et al*, 1988; Goyette, 1991; Goyette, 1994). Concentrations of PAHs in the sediments near the refinery also declined significantly over this period. A high incidence of cancer has been reported in aquatic biota, primarily fish, from several PAH-contaminated aquatic systems throughout the world

- At virtually all areas sampled in British Columbia, the higher molecular weight compounds comprised the bulk of the total PAHs detected in sediments (>80% at most sites). The compounds detected at the highest concentrations were fluoranthene, pyrene, and benzofluoranthenes. Other high molecular weight compounds commonly detected were chrysene, benzo[a]anthracene, benzo[e]pyrene, benzo[a]pyrene, and indeno[1,2,3-c,d]pyrene. Of the lower molecular weight PAH compounds, phenanthrene made the largest contribution to the total PAH content in sediment samples. The mean percent contributions of individual PAH compounds were quite consistent throughout all areas sampled. The predominance of the four and five ring compounds, combined with the significant contribution of phenanthrene and preliminary indications of high contributions of alkylated compounds and dibenzothiophenes, suggests a combination of combustion and petroleum sources.

- The patterns of PAH compounds in mussels, clams, and oysters from all areas were quite consistent and were very similar to that observed in sediments. The PAH pattern in crabs, shrimp, and fish was less consistent and was less likely to resemble those in sediments (Figures 1 and 2). This is probably due, in part, to the fact that both crustaceans and fish metabolize PAH compounds more efficiently than do bivalve species.

1. INTRODUCTION

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds made up of hydrogen and carbon atoms. They consist of two or more aromatic (benzene) rings joined by a pair of shared carbon atoms. Parent PAH compounds contain only hydrogen and carbon atoms. Closely related compounds include PAH derivatives, which have an alkyl or other radical group attached to a ring; halogenated PAHs, which contain chlorine and bromine atoms; and heterocyclic aromatic compounds (HACs), in which one carbon atom in a ring has been replaced by nitrogen, sulphur or oxygen. Most environmental studies have focused on the parent PAH compounds and less information is available on the levels and impacts of PAH derivatives and HACs.

Most PAHs are produced and released to the atmosphere inadvertently, however, some PAHs are produced as commercial chemicals in North America. These include acenaphthene, acridine, anthracene, fluorene, naphthalene, pyrene, and quinoline. These compounds are used mainly by the pharmaceutical, photographic and chemical industries. Naphthalene is also used in the production of fungicides, insecticides, moth repellents, and surfactants (Nagpal, 1993).

PAHs are produced and released to the atmosphere during the combustion of organic matter, both naturally and as a result of human activity. Many factors affect the amount and type of PAHs produced including the type and quantity of fuel, the duration and temperature of combustion, and the presence of oxygen. Important sources of PAH releases to the atmosphere include residential heating (burning of coal, oil or wood); transportation; aluminum smelters; steel and coking plants; municipal incinerators; agricultural, forest slash, and other open-air burning; and teepee burners at sawmills. Natural sources of PAHs include forest fires, volcanic eruptions, and the natural occurrence of these compounds in coal derivatives and petroleum (NRC, 1983). In Sydney, Australia summer bush fires are thought to be a significant source of atmospheric PAHs (Freeman and Cattell, 1990). A 1990 study conducted for Environment Canada identified forest fires as the single most important source of PAHs to the environment in Canada (2010 tonnes or 47% of the total emissions). Aluminum smelters, the second most important source, contributed 925 tonnes or 21% of the total emissions (Environment Canada, 1994; LGL, 1993).

Although atmospheric deposition accounts for the majority of PAH input to aquatic systems, several sources of direct release have been identified including municipal treatment plants, storm sewers, oil refineries, industrial discharges, landfill and surface runoff. The use and spillage of petroleum products, coal, and creosote are also significant sources of PAHs to the aquatic environment due to their naturally high levels of PAHs. It has been estimated that the loss of PAHs from creosote-treated wood products may result in the release of up to 2000 tonnes of PAHs to soil and water each year (LGL, 1993).

Creosote is distilled from coal tar and contains a complex mixture of compounds, including very high concentrations of PAHs. The composition of creosote varies, from 40 to 85% according to some authors (Neff, 1979; Environment Canada, 1988; Mueller *et al*, 1989). Creosote has been used primarily as a wood preservative for treating railway ties, pilings, transmission and telephone poles. In Canada, telephone and transmission poles have not been treated with creosote since the mid-1970's (Environment Canada, 1988; Envirochem, 1991; Environment Canada, 1994). Creosote is still used for the treatment of railway ties and wood pilings, timbers and wood decking of piers and floating wharves in the marine environment. The production and use of creosote and creosote-treated structures has led to localized areas of high levels of environmental PAH contamination (Dunn and Stich, 1976; Wan, 1991; Wan, 1993).

The commercial production of creosote in Canada has decreased since the 1940's, when Canadian production was greater than 60 x 10^6 kg per year, to approximately 20 x 10^6 kg in 1990 (Envirochem, 1991). However, there is significant year to year fluctuation in the use of creosote. A 1995 pesticide use survey revealed that 2.2 x 10^6 kg of creosote was used in British Columbia in 1991 compared to 5.9 x 10^6 kg in 1995 (FRAP, 1997).

PAHs are often divided into two groups according to molecular weight. The high molecular weight (HMW) group includes the four to seven ring compounds, while the low molecular weight (LMW) group includes the two and three ring compounds. In environmental surveys, the most commonly studied high molecular weight compounds include fluoranthene, pyrene, chrysene, perylene, benzo[a]pyrene, benzo[e]pyrene, coronene, benz[a]anthracene, benzofluoranthenes, indeno[1,2,3-cd]pyrene, dibenz[a,h]anthracene, benzo[g,h,i]perylene. The most commonly studied low molecular weight compounds are naphthalene, acenaphthylene, acenaphthene, anthracene, phenanthrene, and fluorene.

The physical and chemical characteristics of these compounds and their biological effects vary with their molecular weight. The lower molecular weight compounds (three or less rings) are acutely toxic to many aquatic organisms. The higher molecular weight compounds (four or more rings) exhibit lower acute toxicity, but several are carcinogenic. PAHs have been declared toxic as defined under Section 11 of the *Canadian Environmental Protection Act (*CEPA, 1988*)*. Benzo[a]pyrene, benzo[b]fluoranthene, benzo[f]fluoranthene, benzo[k]fluoranthene, and indeno[1,2,3-c,d]pyrene have been classified as probable human carcinogens. (Environment Canada, 1994). The higher molecular weight compounds are also more persistent in the environment as they are more resistant to degradation. Resistance to oxidation, reduction, and vapourization increases with molecular weight, while aqueous solubility decreases (Nagpal, 1993; Neff, 1979; Moore and Ramamoorthy, 1984; Herbes and Schwall, 1978; Wild *et al*, 1991; Cerniglia, 1981; Cerniglia, 1984; Environmental Protection Agency, 1990).

2. PRESENCE IN THE ENVIRONMENT

2.1 Environmental Fate

2.1.1 Water and Sediments

The behaviour and ultimate fate of PAH compounds in natural waters is determined largely by their molecular weight. Upon entering aquatic systems, the hydrophobic nature of the higher molecular weight compounds results in their rapid adsorption to particulates in the water column. They eventually settle out to the bottom sediments where they can persist for long periods of time. Due to their higher solubility, the lower molecular weight PAHs are more likely to remain in the water column (Kaiser *et al,* 1985; Eganhouse and Calder, 1976; MacKay and Shiu, 1977). Smith *et al* (1991) reported that the lower molecular weight PAHs (two to three ring compounds) were primarily dissolved in the water, while the higher molecular weight PAHs (four and five ring compounds) were primarily associated with particulates. Fluoranthene and pyrene showed intermediate behaviour and were distributed between the dissolved and particulate phases.

Environmental factors can affect the partitioning of PAHs between the water column and particulate matter. Laboratory tests have shown that the solubilities of PAHs increase with temperature (Neff, 1979; Cornelissen *et al*, 1997) but are lower in marine waters than in freshwaters (Rossi and Thomas, 1981). The presence of dissolved humic matter can increase the amount of PAH which remains in the water column and, therefore, increase the distance that the PAH can be transported from the point of entry (McCarthy and Jimenez, 1985a). Johnson and Amy (1995) also reported that natural organic matter in sediments facilitates the transport of PAHs and noted that the addition of organic matter to sediments with a low natural organic carbon content results in an increase in the release of PAHs from the sediments. Similarly, Chin and Gschwend (1992) reported that organic colloids (including humic substances) in sediment pore waters could enhance the amount of PAHs in the aqueous phase and influence the transport of these compounds in the aquatic environment. Schlautman and Morgan (1993) reported that water chemistry (pH and ionic strength) can affect the binding of PAHs by dissolved humic material.

Hardy *et al* (1987) reported that potentially carcinogenic, mutagenic, and teratogenic PAHs were present in most of the sea-surface microlayer samples collected from Puget Sound. Very high concentrations were detected at some sites including Elliott Bay and Commencement Bay. Many of the samples contained high concentrations of fluoranthene, pyrene, chrysene, and benzo[a]pyrene. In samples with high PAH concentrations approximately 90 to100% of the PAH was associated with particles while, in samples with low concentrations, the PAHs were more evenly distributed between the dissolved and particulate fractions. PAHs were not detected in samples of sub-surface water collected from several sites.

A study of PAH content and sediment particle size fractions in river sediments from England revealed a bimodal distribution of organic matter content and PAH concentrations in sediment particle size fractions. The smallest and the largest size fractions contained the highest PAH levels. A linear relationship between individual and total PAH concentrations and organic matter content was observed. The proportions of individual PAH compounds remained relatively constant regardless of temporal and spatial differences in total PAH concentrations (Evans *et al*, 1990a).

In addition to adsorption and sedimentation, other processes controlling the fate of PAHs in aquatic systems include volatilization, photolysis and biodegradation.

While low molecular weight PAHs such as naphthalene volatilize readily, compounds with four or more rings have shown insignificant volatility under a variety of environmental conditions (Nagpal, 1993; Neff, 1979; Moore and Ramamoorthy, 1984; Lee *et al*, 1978; Sloof *et al*, 1989; Southworth, 1979; Lyman *et al*, 1982). Baker and Eisenreich (1990) report that the higher molecular weight compounds, which tend to be adsorbed to particulates in the water column, are less available for volatilization than are the low molecular weight compounds (such as naphthalene and phenanthrene), which may be dissolved in the water column. The amount of PAH volatilization from the water column is also determined by weather conditions (temperature and wind) and water movement (Southworth, 1979).

The sensitivity of PAH compounds to photodegradation varies. Some PAH compounds have been shown to photodegrade readily in both laboratory and field situations. Nagata and Kondo (1977), using acetone and carbon tetrachloride as solvents, concluded that anthracene, phenanthrene, and benz[a]anthracene were most likely to be photodegraded, while chrysene, fluorene, pyrene, and benzo[a]pyrene were relatively resistant to photodegradation. Solvents used in laboratory experiments have been shown to significantly influence the photosensitivity of PAHs and, therefore, care must be used when utilizing laboratory-derived photodegradation rates to predict the fate of PAH compounds in the natural environment. The presence of fulvic acid in pond water reduced the half-life of benzo[a]pyrene from 173 hours to 43 hours. The observed increase in the rate of photodegradation could be due to either increased solubility or increased photosensitivity of benzo[a]pyrene in the presence of fulvic acid. The rate of photodegradation decreased with increasing water depth due to factors such as decreased light intensity, temperature and dissolved oxygen. Photodegradation of PAHs in unexposed bottom sediments was negligible (Neff, 1979; Moore and Ramamoorthy, 1984).

Ehrhardt *et al* (1992) demonstrated that alkyl derivatives are photodegraded faster than are parent PAHs and concluded that sunlight-induced oxidation in the natural environment would result in a depletion of alkyl-substituted PAHs originating from dissolved fossil fuels. The authors suggested that the remaining mixture of non-substituted PAHs in the environment could lead to the mistaken assumption that the PAHs originated from incomplete combustion processes.

The rate of microbial degradation of PAHs in sediments is determined by a number of factors including previous exposure, chemical structure, and environmental conditions including the presence of oxygen, nutrients, temperature, pH and salinity (Atlas, 1981; Kerr and Capone, 1988; Ward and Brock, 1976; Hambrick *et al*, 1980; Maher and Aislabie, 1992; Zaidi and Imam, 1999). Low molecular weight aromatic compounds such as naphthalene are more easily degraded by bacteria than are the higher molecular weight aromatic compounds (Lee *et al*, 1978; Atlas, 1981; Herbes, 1977; Readman *et al,* 1982). In addition, the alkylation of a parent compound inhibits microbial degradation (Cerniglia and Heitkamp, 1989). There is some evidence that prior exposure to even one PAH can result in increased degradation of other PAHs (Bauer *et al*, 1988). Exposure results in the adaptation of microbial populations to PAH and results in enhanced degradation compared to cleaner sediments (Cerniglia and Heitkamp, 1989; Kerr and Capone, 1988; Shiaris, 1989b; Heitkamp and Cerniglia, 1989). The biodegradation of PAH compounds under anaerobic conditions has been observed (Mihelcic and Luthy, 1988; Rochne and Strand, 1998), however, the highest rates of degradation have been measured in oxygenated surface sediments. Under anaerobic conditions, degradation is slower. Microbial degradation would, therefore, be favoured in non-urban oxygenated estuaries and exposed tidal flats. Estuaries in urbanized and industrialized areas tend to have oxygen-depleted sediments and probably serve as long term sinks for PAHs (Cerniglia and Heitkamp, 1989; Hambrick *et al*, 1980; Bauer and Capone, 1985; Mihelcic and Luthy, 1988; Delfino and Miles, 1985; Delaune *et al*,1981). PAH degradation is stimulated in sediments containing the polychaete worm *Capitella capitata* due to the fact that the worms aerate the sediments and provide nutrients, such as nitrogen and phosphorus, that are essential for microbial growth (Kerr and Capone, 1988). Degradation rates are lowest during the cooler temperatures of winter and highest in the warmer temperatures of summer (Shiaris, 1989a). Hambrick *et al* (1980) reported that degradation rates were higher at pH 8 than at pH 5.

The source of the PAH compounds may affect their fate and behaviour in the aquatic environment. Maruya *et al* (1996) reported variations in the partitioning of PAHs between sediments and porewaters collected from various locations in San Francisco Bay. Variations were noted with location and also between samples collected in wet and dry seasons. The authors attributed these variations to the soot content of sediments and suggested that sediments with higher soot contents had a higher retention of PAHs and, therefore, a lower concentration of PAHs in porewaters. McGroddy and Farrington (1995) measured PAH concentrations in the sediments and porewaters of sediments cores collected from Boston Harbour. PAH concentrations in the porewaters were much lower than would be expected based on equilibrium partitioning models and measured partition coefficients. The authors suggested that pyrogenically derived PAH compounds associated with soot particles in the bottom sediments of Boston Harbour were less likely to partition to porewaters than were PAHs from petroleum sources. Other researchers have also reported that PAHs from combustion sources are more strongly bound to particulates than are PAHs from petroleum related sources. Combustion generated PAHs are reported to be less available for adsorption and desorption processes, partitioning into the water column and porewaters, and uptake

into biota (Prahl and Carpenter, 1983; Socha and Carpenter, 1987; Farrington *et al*, 1983b). For example, some researchers have suggested that PAHs in sediments receiving discharges from an aluminum smelter in Norway are not readily available for degradation or biological uptake (Naes and Oug, 1997; Chapman *et al*, 1995; Knutzen, 1994).

2.1.2 Atmospheric Influences

PAHs are present in the air in very small amounts (ng/m^3) in the gas phase and adsorbed onto particulates. Between 70 and 90% of the PAHs are associated with particles and most are adsorbed to particles in the respirable fraction (less than 5 μm) (Nikolauo *et al*, 1984; Pierce and Katz, 1975), however, low molecular weight compounds (lower than fluoranthene) are present mainly in the gas phase (Venkataraman *et al*, 1994).

PAHs are transported in the atmosphere and can be deposited near their point of release or in areas far removed from sources. PAHs can be present in significant concentrations in long-range transported aerosols and particulates (NRC, 1983; Neff, 1979; Lunde and Bjorseth, 1977). Long range transport of fine particulates entering the atmosphere as a result of dust storms in agricultural areas in Asia are thought to be a significant source of PAHs and other contaminants in brown snow deposited in the Canadian Arctic (Welch *et al*, 1991). Examination of sediment cores from lakes allowed Welch *et al* (1991) to determine fluxes of these pollutants. The authors concluded that the PAHs deposited during the single brown snow event monitored may have contributed greater than 10% of the total annual input of PAH to this area. Jaffrezo *et al* (1994) studied surface snow samples from the Greenland ice cap and concluded that current PAH contamination was due primarily to fossil fuel combustion with lesser inputs from biomass burning. Atmospheric deposition of PAHs to the Canadian high Arctic areas appears to have remained constant over the last 20 years (Peters *et al*, 1995).

Hites and Gschwend (1982) collected sediment cores from urban and remote areas of northeastern United States and calculated PAH fluxes to these sites. They concluded that sites near urban areas had much higher PAH fluxes areas (approximately 35 ng/cm/yr) than did remote sites (0.8 to 3 ng/cm/yr).

PAH compounds enter the aquatic environment in association with both wet and dry deposition. Analysis of rainwater and air particulates in Europe showed that the lower molecular weight PAH compounds were present in greater proportions in rainwater than were the higher molecular weight compounds (Muller, 1984).

Eisler (1987) estimated that atmospheric fallout contributed 50,000 tonnes of PAH compounds to aquatic systems annually. Eisenrich *et al* (1981) has estimated that 582 tonnes of total PAHs were deposited to the Great Lakes annually. Baker and Eisenreich (1990) measured gas and aerosol samples collected over Lake Superior in 1986. Total PAH

concentrations (2.5 to 6.3 mg/m^3) were typical of background concentrations found in continental air. The more volatile (lower molecular weight) PAHs such as fluorene, phenanthrene, fluoranthene, and pyrene were detected in the gas phase while the higher molecular weight compounds (such as indeno[1,2,3-c,d]pyrene and benzo[g,h,i]perylene were found primarily in the aerosol samples. Simcik *et al* (1996) reported that the higher molecular weight PAHs were deposited to Lake Michigan and settled out to the bottom sediments. Although particulate deposition was the main source of PAH entry to Lake Michigan, lower molecular weight PAHs associated with the gas phase also entered the lake through air-water exchange and then partitioned to the organic matter in the water column.

Particulate and gaseous PAH compounds were collected from the air in Toronto and Montreal between 1984 and 1986. Mean PAH concentrations were higher in Montreal than in Toronto and, of the compounds considered to be possible or probable carcinogens, benzo[b,k]fluoranthene was present at the highest concentrations in both cities (Dann, 1988). Environment Canada has conducted monitoring of atmospheric PAHs in several areas of Canada. The highest concentrations were found in the vicinity of sources such as aluminum smelters (up to 16,390 ng/m^3 total PAHs and 460 ng/m^3 benzo[a]pyrene). Lower, but still elevated, concentrations have been detected in urban areas which receive PAH inputs from wood burning and urban transportation (up to 1,000 ng/m^3 with mean levels of approximately 100 ng/m^3 or less). PAH concentrations are usually much lower in areas not directly influenced by local sources (low ng/m^3 range or less) (Ringuette *et al*, 1993).

Hoff and Chan (1987) measured PAH concentrations ranging from 3 pg/m^3 to 40 ng/m^3 in the particulate and gas phases of air samples collected along the United States-Canada border and the Niagara River. Concentrations were highest near urban and industrial sources. PAHs with three or less rings were present in the gas phase while the higher ring compounds were found in the particulate phase. The authors concluded that the particulates were originating from local sources, while the gas phase PAHs suggested regional or long-range transport. Similarly, Naf *et al* (1992) reported that PAHs associated with airborne particulates originating from various emission sources in Sweden were not transported great distances but were quickly deposited within a 10 to 50 km^2 area around the sources. Other researchers reported that submicron particles are important in long-range transport (Bidleman, 1988), while particles greater than 1 μm in size are deposited in the vicinity of the emission source due to gravitational settling (Broman *et al*, 1990).

Katz and Chan (1980) reported that PAH concentrations in air particulates from Hamilton, Ontario were higher than those reported for New York City and Los Angeles, probably due to the presence of coke ovens and iron and steel manufacturing facilities in the Hamilton area. The U.S. Environmental Protection Agency reported that cities with coke ovens consistently have higher benzo[a]pyrene concentrations in the air than do cities without coke ovens.

Motor vehicle exhaust has also been identified as a major contributor to atmospheric PAHs. It has been estimated that motor vehicle exhausts account for approximately one third of the PAH emissions in the United States (Bjorseth and Ramdahl, 1985). Marr *et al* (1999) reported that light-duty vehicles released significant amounts of heavier (four and five ring) compounds, while heavy-duty diesel engines were the main source of three-ring compounds such as fluoranthene and pyrene. Benzo[g,h,i]perylene was present in higher concentrations than other PAHs in air samples collected in Hamilton, Los Angeles (Gordon, 1976) and Toronto (Pierce and Katz, 1975). It was suggested that the main source of this compound was motor vehicle exhaust (Katz and Chan, 1980). Handa *et al* (1980) reported that the ratio of the atmospheric PAH level to the benzo[g,h,i]perylene level in Japan was in agreement with the PAH levels in exhausts from Japanese cars. Similarly, Aceves and Grimalt (1993) concluded that motor vehicle emissions were the main source of PAHs to aerosol samples collected in Barcelona, Spain. Gordon (1976) reported that the major source of PAHs in the well ventilated coastal areas in Los Angeles county was automobile exhaust while, in inland areas, non-automobile related sources also made significant contributions to the total PAH load. In Christchurch, New Zealand motor vehicle exhaust was also reported to be a major source of airborne particulate matter, however, during periods of heavy air pollution, domestic fires for home heating were reported to the major source (Cretney *et al*, 1985).

Many researchers reported that PAH concentrations in the ambient air are higher near emission sources (Vogt *et al*, 1987; Karlesky *et al*, 1987). However, meteorological conditions can also influence PAH concentrations in ambient air (Pierce and Katz, 1975; Nielson, 1988; Masclet *et al*, 1988). Temperature influences the PAH composition of aerosols and particulates deposited from the atmosphere (Bidleman, 1988; McVeety and Hites, 1988). At least some PAH compounds (phenanthrene, fluoranthene, and pyrene) are more strongly retained by the particulate phase in colder temperatures. This favours the adsorption of the more volatile PAHs by aerosols and snow and results in the deposition of these compounds during the Arctic winter (Hoff *et al*, 1995; Yunker *et al*, 1996).

In urban areas, where the main sources of PAHs to the air are fossil fuel combustion and motor vehicle traffic, PAH concentrations are often higher in the winter than in the summer (Katz and Chan, 1980; Prahl *et al*, 1984; Muel and Saguem, 1985). Gordon (1976) reported that PAH concentrations in airborne particulates from Los Angeles County were highest in the winter. Similarly, in Barcelona Spain, the hydrocarbon pattern in particle fractions was indicative of motor vehicle traffic. PAH concentrations were up to 10 times higher in the winter than in the summer. The authors attributed this mainly to the increased photochemical degradation of some PAH compounds during the warmer temperatures of summer (Aceves and Grimalt, 1993).

Pierce and Katz (1975) reported that, in the winter, 85 to 90% of the total PAH in aerosol samples from Toronto, Ontario was associated with particles with a diameter of less than 5 μm while, in the summer, 70 to 85% was associated with this size fraction. Examination of the PAH content of particulate matter in the atmosphere above Argentina

revealed that the greatest proportion of PAH was associated with the smallest particles, which tended to be carbonaceous. Greater amounts of PAHs were present in the winter than in the spring and summer (Cattoggio *et al*, 1989). According to Greiner *et al* (1977), PAHs adsorbed to carbonaceous particulate matter in the atmosphere are less subject to photochemical processes.

PAH photodegradation is largely influenced by the type of substrate to which these compounds are adsorbed. Behymer and Hites (1988) reported that the colour of the fly ash (determined by the amount of carbon present) was an important factor. The darker the fly ash (or the higher the carbon content) the greater the resistance to photodegradation. This was explained by the fact that the fly ash samples adsorbed most of the light and prevented it from getting to the PAH. On black fly ash particles, the half-life was in the order of several days. Korfmacher *et al* (1980) also reported that, while PAHs photolyzed readily in solution and when adsorbed on activated alumina, they were resistant to photodegradation when adsorbed on fly ash. PAHs were also more resistant to photodegradation when they were adsorbed to particulates at high concentrations compared to low concentrations, as the upper layers have been found to protect the lower layers from oxidation (Sloof *et al*, 1989; Kamens *et al*, 1988).

It has been reported that the products of PAH photooxidation (PAH nitro-derivatives) are more toxic than the parent compounds. For example, the nitro-derivatives formed when benzo[a]pyrene reacts with NO_2 have been shown to be direct mutagens according to the Ames Test (Pitts *et al*, 1978). Nitropyrene has been shown to be a potent mutagen and is largely responsible for the mutagenic activity of particulate diesel exhaust (Tokiwa *et al*, 1981; Salmeen *et al*, 1982; Grosjean *et al*, 1983). Similarly, PAH reacts with ozone to form oxygenated compounds, some of which are mutagenic (Nikolauo *et al*, 1984; Wislocki *et al*, 1976; Pitts *et al*, 1980). Moller *et al* (1982) studied the mutagenicity of airborne particulate matter deposited on street surfaces. They concluded that the mutagenic activity varied with traffic intensity and was primarily associated with the presence of PAHs.

2.1.3 Uptake into Aquatic Biota

2.1.3.1 Invertebrates

Aquatic invertebrates are good indicators of environmental levels of PAHs. The high octanol/water partition coefficients of these compounds cause them to be readily accumulated in many species of aquatic invertebrates, with bioconcentration factors increasing with the K_{ow} coefficient (Trucco *et al*, 1983; Geyer *et al*, 1991; Southworth *et al*, 1978).

Characteristics of the organism (species, feeding habits, and developmental stage) and environmental conditions (temperature, sediment grain size, and the presence of dissolved humic or organic matter, particulate matter and other chemical contaminants) can

influence PAH uptake into aquatic organisms. The route, duration and conditions of exposure are also important factors (Majewski and Scherer, 1985; Landrum and Scavia, 1983; Landrum, 1983; Korn *et al*, 1979; McCarthy *et al*, 1985; McCarthy *et al*, 1985; Curto *et al*, 1993; Landrum *et al*, 1992; Landrum, 1989; Germain *et al*, 1993).

Bivalve molluscs, particularly mussels, have been shown to readily accumulate PAHs in the environment. In laboratory experiments the uptake rates from water for both benzo[a]pyrene and fluorene were one to two orders of magnitude higher for mussels than for diatoms, while the depuration rates were similar. Bioconcentration factors in mussels were 21,428 and 394 for benzo[a]pyrene and fluorene, respectively, compared to bioconcentration factors of 636 and 11, respectively, for these compounds in diatoms (Majewski and Scherer, 1985). Similarly, Bender *et al* (1988) observed that oysters generally accumulated three times the body burdens of clams under the same conditions of exposure, and attributed this difference to a faster depuration rate in clams.

The developmental stage of the organism has been reported to be an important factor in the uptake of PAHs in some species. Mothershead and Hale (1992) exposed molting and intermolt blue crabs to high levels of PAH and reported that newly molted blue crabs accumulated much higher PAH levels in the muscle and hepatopancreas than did the intermolt crabs. The authors suggested that the higher accumulation in newly molted crabs may be due to increased water uptake and shell permeability at ecdysis or decreased PAH metabolism during molting.

The molecular weight of PAH compounds is a major determining factor in the uptake and retention of PAHs in aquatic species. Dunn (1980) reported that the more hydrophobic higher molecular weight PAH compounds showed less accumulation in the tissues of mussels relative to concentrations in sediments than did the lower molecular weight (and more soluble) compounds. Varanasi *et al* (1985) examined clams and amphipods from contaminated sediments in Puget Sound and concluded that four ring PAH compounds were more readily accumulated in these organisms than were the three or five ring PAH compounds. Tatem (1984) exposed *Rangia cuneata* (clam) and *Nereis virens* to PAH contaminated (approximately 100 μg/g) sediments from Connecticut Harbour and reported that, while both low and high molecular weight compounds were accumulated, the higher molecular weight compounds were less readily depurated and were retained throughout the study period (12 days). Similarly, Mix (1982) reported that the depuration of clams in clean seawater for a 24 hour period resulted in the loss of significant amounts of three and four ring compounds but not the five, six and seven ring compounds. Lee *et al* (1978) examined the depuration rate of PAHs in oysters and estimated the half-lives of anthracene, fluoranthene, benzo[a]anthracene, and benzo[a]pyrene to be 72, 120, 216, and 432 days, respectively. These authors also concluded that the lower molecular weight PAHs were more readily eliminated from oysters than were the higher molecular weight compounds. In comparison, Pruell *et al* (1986) reported that the half-lives of benzo[a]pyrene, benzo[a]anthracene, and fluoranthene in mussels were 15, 18, and 30 days, respectively. Sato *et al* (1992) studied PAH depuration in the clam *Mercenaria mercenaria* and observed that the lower molecular weight compounds

were more readily depurated, but that the rate of depuration was also affected by the solubility of the PAH in seawater. Clams exposed *in vitro* for 48 hours to 9 parent PAHs found in waste crankcase oil, and then allowed to depurate for 45 days, showed no significant depuration of PAHs (Tanacredi and Cardenas, 1991).

Landrum (1988) studied the uptake of PAHs into the amphipod *Pontoporeia hoyi* and reported that, for compounds less water soluble than anthracene, the uptake rate constant is inversely proportional to the mass of the organisms and directly proportional to the temperature. The depuration rate constant was inversely proportional to the octanol-water partition coefficient, the mass of the organism, and the lipid content of the organisms, and directly proportional to the temperature.

Mix *et al* (1981) and Widdows *et al* (1983) reported that the elimination of benzo[a]pyrene from mussels was biphasic with an initial period of rapid elimination followed by a longer period of slow release. They suggested that this biphasic elimination of PAHs indicated that shellfish store PAHs in two different compartments. Sato *et al* (1992) also observed a two component depuration of certain PAHs, including naphthalene, fluorene, phenanthrene, fluoranthene, pyrene, and chrysene from *Mercenaria mercenaria.* However, a single-stage depuration was observed for benzo[a]anthracene and benzo[a]pyrene.

McLeese (1982) studied uptake and excretion in marine invertebrates exposed to PAHs in water and in sediments. Clams exposed to five PAH compounds in water had relatively high uptake rates, with calculated bioconcentration factors (BCFs) ranging from 1,280 for phenanthrene to 10,000 for perylene, while excretion rates were low. Uptake and excretion patterns for the five PAH compounds were similar in clams exposed to PAH-contaminated sediments. In comparison to PAH concentrations in the surface waters, the calculated bioconcentration factors (BCFs) following sediment exposure were smaller and ranged from 890 for phenanthrene to 3,900 for triphenylene. Molecular complexity and weight of the PAH compounds affected both the BCF and the excretion rate. Increased molecular complexity and weight resulted in an increase in BCF and a decrease in percent loss over 14 days. The percent loss ranged from 80 to 100% for phenanthrene and from 20 to 40% for perylene.

Sediment and water characteristics are also important in influencing PAH uptake into aquatic organisms. For example, the availability of PAHs for uptake in aquatic organisms is influenced by their association with particulate matter. Narbonne *et al* (1992) observed that the uptake of benzo[a]pyrene in mussels was more than five times higher when sediment particles were suspended in water and suggested that the filtration rate in mussels was increased in the presence of sediment. This theory is supported by the work of Bjork and Gilek (1996) who reported that the concentration of particulate organic matter in the water influences both the partitioning of phenanthrene and the physiology of the mussels. For this reason, the authors concluded that processes such as filtration and ingestion, which are dependent on particle concentrations, must be considered when assessing contaminant uptake in filter feeding bivalves.

The presence of dissolved organic matter (DOM) in high concentrations can result in reduced PAH uptake. Oikara and Kukkonen (1990) reported that the bioaccumulation of benzo[a]pyrene by *Daphnia magna* from five lakes was inversely correlated with the DOM concentration of the waters. The authors suggested that animals in waters with low DOM concentrations may be more vulnerable to water-borne toxicity from benzo[a]pyrene and related chemicals than those in waters with a higher DOM concentration. Similarly, McCarthy *et al* (1985b) reported that PAHs bound to dissolved humic matter are less bioavailable to *Daphnia magna* than unbound PAH.

Foster and Wright (1988) reported that bioaccumulation factors for unsubstituted PAH compounds in clams (*Macoma* sp.) and *Nereis* ranged between 0.2 and 4 for sediments with organic carbon contents of more than 0.5%. More PAH was bioaccumulated by organisms exposed to coarse-grained sediments with low organic carbon contents than by organisms exposed to fine-grained sediments. Total PAH concentrations in both species paralleled the concentrations in muddy-bed sediments. The PAHs detected most frequently in the biota were those compounds present in the highest concentrations in the sediments (phenanthrene/anthracene, fluorene, pyrene, benz[a]anthracene, and chrysene).

In addition, the rate of PAH uptake is influenced by the presence of other contaminants. The accumulation of naphthalene by oysters was antagonistically affected by a simultaneous exposure to a PCB mixture, although no effect was observed on benzo[a]pyrene uptake (Fortner and Sick, 1985). Landrum (1983) reported that the uptake of both benzo[a]pyrene and anthracene by the amphipod *Pontoporea hoyi* was reduced by 50% in the presence of toluene.

Farrington *et al* (1983a) observed that PAH concentrations in bivalves and polychaetes were substantially different from PAH concentrations in sediments from the same general locations. The authors suggested that both the source and the physical-chemical form of the PAHs in the environment were important factors. PAHs from combustion sources are more strongly bound to particulates than are PAHs from petroleum related sources. Combustion generated PAHs are reported to be less available for adsorption and desorption processes, partitioning into the water column and porewaters, and for uptake into biota (McGroddy and Farrington, 1995; Prahl and Carpenter, 1983; Socha and Carpenter, 1987; Farrington *et al,* 1983a; Farrington *et al*, 1993b).

Aging of contaminated sediments in the environment can also affect the uptake of specific PAHs into aquatic organisms. Burns and Yelle-Simmons (1994) reported on the uptake of PAHs from heavily oiled sediments in the Panama area several years after an oil spill. Over a period of at least 5 years, PAHs leaching out of oiled sediments were bioaccumulated by bivalves. Organisms contained the whole range of alkylated PAHs in amounts proportional to what leached out of the sediments. In the fifth year, a change in the composition of PAH compounds being bioaccumulated at most sites was interpreted as a depletion of the most soluble and most acutely toxic compounds. The most persistent PAH

compounds in both sediments and bivalves were the dibenzothiophene, phenanthrene and chrysene series. Also, Landrum *et al* (1992) reported that when the contact time between the sediment and the PAH was increased (from 3 days to 60 days), the bioavailability of phenanthrene and pyrene to the amphipod *Diporeia* species decreased and then stabilized.

Seasonal variations in the uptake of PAH compounds in aquatic organisms have been observed. Biota-sediment accumulation factors (BSAFs) for PAHs in a coastal marsh in San Francisco Bay varied with season and along an intertidal gradient. The BSAFs were lowest during the rainy season while, during the dry season, BSAFs were lowest in the high intertidal zone closest to shore. BSAFs also varied (almost three orders of magnitude) with species and were lowest in polychaetes and highest in Asian clams. Sediment characteristics also influenced BSAFs, which decreased with increasing percent fines and with PAH concentrations on an organic carbon basis. These findings support the theory that the content of highly aromatic soot particles is an important factor. The soot particle content increased during periods of surface runoff. According to the authors, during the dry season soot particle content would likely be highest in the high intertidal zone where finer particles preferentially accumulate (Maruya *et al*, 1997).

Aquatic invertebrates accumulate PAHs from the sediments, water and food (Varanasi *et al*, 1985; Pruell *et al*, 1986; Eadie *et al*, 1983; Mix and Schaffer, 1983a and 1983b; Reichart *et al*, 1985; Neff and Anderson, 1975). Uptake studies with *Macoma* species have shown that clams concentrate PAHs from water more readily than they do from sediment. The authors suggested that the PAHs, which accumulated in the clams exposed to contaminated sediments, originated in the interstitial waters rather than from sediment particles (Roesijadi *et al*, 1978). Similarly, Landrum (1989) examined the uptake of PAH from sediments by the benthic amphipod (*Pontoporeia hoyi*) and concluded that the uptake occurs largely via the sediment interstitial water and is controlled by the desorption of PAHs from sediment particles and dissolved organic matter. However, it was suggested that uptake and assimilation from ingested particles may be significant for strongly sorbed compounds such as benzo[a]pyrene. The desorption rate from the sediments likely determines whether the major source to the organism is interstitial water or ingested particles. The bioavailability of the contaminants sorbed to the sediments decreased as the contact time between the sediment and the contaminant increased. Bioavailability was reduced despite the fact that the chemical extractability remained high. Landrum *et al* (1991) reported that the concentration of PAH in the sediments influenced the rate of PAH accumulation from sediments into amphipods (*Diporeia*). Furthermore, they concluded that it was not possible to predict the rate of accumulation through measured partitioning between the interstitial water and sediment particles.

Kaag *et al* (1997) reported that feeding habits of benthic invertebrates were important in assessing the risk of contaminated sediments. They reported that sediment ingestion was the major route of uptake for the sediment-feeding lugworm *Arenicola marina* and for the clam *Macoma balthica,* however, PAH residues in the filter-feeding mussel *Mytilus edulis* were independent of PAH concentrations in the sediments. Leppanen and Kukkonen (1998) reported that after 8 days of exposure, 61% of the body burden of PAHs in

oligochaetes had originated from ingested sediments rather than from pore water. Eadie *et al* (1983) reported that benthic filter-feeders in the Great Lakes obtain more PAH from sediments than from water in areas where PAH concentrations in sediments are high. Fortner and Sick (1985) reported that more naphthalene and benzo[a]pyrene were taken up by oysters in dissolved than in particulate form. Significant uptake from food has also been observed in larvae of clams (*Mercenaria* sp.) preying on diatoms (*Thalassiosira pseydonana*). Within a 24 hour period, 44% of the benzo[a]pyrene associated with the diatoms was transferred to the clam larvae (Dobrowsky and Epifanio, 1980). Lee *et al* (1976) reported that blue crab accumulated more benzo[a]pyrene from food than from water.

Dillon (1982) reported that the route of exposure can influence both the uptake and retention of PAH compounds in invertebrates. The laboratory exposure of aquatic crustaceans demonstrated that, in comparison with naphthalene in solution, naphthalene was obtained from the diet more efficiently and retained in the tissues for longer.

The bioaccumulation of PAH compounds in aquatic organisms is determined largely by their ability to metabolize and excrete these compounds via mixed-function oxidases (MFOs) enzymes. The metabolism of PAHs can result in the production of less toxic compounds or more reactive intermediates with higher toxicity or carcinogenicity. Cytochrome P450 (CYP or P450) system plays an important role in biotransformation.

The ability of bivalve molluscs to accumulate PAHs to high concentrations has been attributed to the belief that they lack an efficient MFO system and, as a result, they are unable to readily metabolize and excrete these compounds (Stegeman, 1980; Payne *et al*, 1983; Anderson, 1977; Vandermeulen and Penrose, 1978). However, while the MFO system is undoubtedly less active in molluscs than in vertebrates, cytochrome P450 MFO activity has been identified in molluscs and several researchers observed some metabolism of PAH compounds by bivalves (Broman *et al*, 1990; Gilewicz *et al*, 1984; Livingstone and Farrar, 1985; Michel *et al*, 1994; Stegeman, 1985; Rudolph and Rudolph, 1999).

Low MFO activity has also been reported for some species of echinoderms and annelids (Payne and May, 1979; Lee and Singer, 1980). However, McElroy (1990) reported that polychaetes exposed to benzo[a]anthracene contaminated sediment, water or diets for periods of days to weeks rapidly accumulated and metabolized this PAH, primarily to water soluble and unextractable compounds.

Crustaceans metabolize most PAH compounds to water soluble compounds via their MFO system which is more active than in bivalves but less active than in fish. Cytochrome P-450 activity has been observed in the tissues of several crustaceans including crabs, lobsters and copepods (Singer *et al*, 1980; James *et al*, 1979; James *et al*, 1980; Walters *et al*, 1979). The hepatopancreas is the major site of cytochrome P-450 dependent xenobiotic monooxygenase in crustacean species. Cytochrome P-450 and monooxygenase activities have been reported in other crustacean organs including the antennal gland (green gland) and stomach. Crustaceans are not as sensitive as fish to the induction of P-450 and

monooxygenase activity. It has been reported that the cytochrome P-450 content in the digestive gland of spiny lobster was higher

than in many other species studied, and yet the MFO activity in *in vitro* studies was lower (James *et al*, 1979; James *et al*, 1980). The fact that lobsters accumulate very high concentrations of PAHs indicates that they may have a limited ability to metabolize these compounds. No aryl hydrocarbon hydroxylase (AHH) induction was observed in lobsters exposed to petroleum for a period of up to 6 months (Payne and May, 1979).

Cytochrome P-450 MFO activity has also been observed in the digestive gland of mussels, the green gland of shrimp, pyloric caecum of starfish, larvae of aquatic insects, blood suckers, limnaed snails, annelida and cladocerans (McElroy, 1990; Stegeman, 1985; Den Besten *et al*, 1992; Den Besten *et al*, 1990; Gill *et al*, 1993; Lemaire *et al*, 1993; Winston *et al*, 1992). Mixed function oxidase (benzo[a]pyrene hydroxylase) activity and cytochrome P-450 content generally increased in polychaetes and crabs after exposure to oil, benzo[a]pyrene or PCBs (Lee *et al*, 1981).

The transfer of PAH compounds through the trophic levels has been observed by some researchers and, therefore, the presence of high concentrations of PAH compounds in aquatic invertebrate species can result in the contamination of predator organisms. McElroy and Sisson (1989) examined the trophic transfer of benzo[a]pyrene metabolites from polychaetes into winter flounder and concluded that the metabolites produced by the worms were absorbed by flounder but were less available than the parent benzo[a]pyrene. The authors also reported that metabolites accumulated through the diet may be further modified by the prey organisms. Other studies have shown that the pre-carcinogenic compound 7,8-diol benzo[a]pyrene in prey organisms such as zooplankton, crustaceans and mussels can be transferred up the food chain (Reichart *et al*, 1985; Stegeman, 1985; Winston *et al*, 1993).

Dobrowsky and Epifanio (1980) reported that when diatoms were cultured in water contaminated with benzo[a]pyrene and then fed to larvae of the hard clam (*Mercenaria* sp.), the rate of direct benzo[a]pyrene uptake from seawater by the diatoms was much greater than the rate of trophic transfer of benzo[a]pyrene from the diatoms to the clam larvae. This was attributed to the greater efficiency of direct uptake and to the larger quantity of benzo[a]pyrene available in the water. A comparison of direct uptake by bivalves with trophic transfer indicated that the processes may be equally important in accumulation of benzo[a]pyrene in natural populations of bivalves.

2.1.3.2 Fish

Bioconcentration factors in fish are influenced by a number of factors including the PAH compound, fish species, development stage, route of exposure, and environmental conditions such as temperature and the presence of sunlight, dissolved organic matter, suspended sediments and other chemical contaminants.

Uptake of naphthalene and benzo[a]pyrene in rainbow trout decreased as temperature decreased from 17° C to 8° C in association with a decrease in oxygen consumption (Black *et al*, 1991). Jimenez *et al* (1987) reported that benzo[a]pyrene uptake, metabolism, and elimination in bluegill sunfish was significantly affected by temperature. Uptake and elimination rates were lower at 13° C than at 23° C and the metabolite profiles indicate that biotransformation of benzo[a]pyrene is much slower at colder temperatures.

The presence of dissolved organic matter (DOM) and humic acid reduced the bioavailability of PAHs (Spacie *et al*, 1983; McCarthy and Jimenez, 1985b; Stein *et al*, 1984). The presence of other chemical contaminants can also influence the PAH uptake in fish. The uptake of benzo[a]pyrene in English sole was enhanced in the presence of Aroclor 1254. The formation and accumulation of toxic metabolites in sole liver was also increased in the presence of the PCB mixture (Stein *et al*, 1984; Stein *et al*, 1987). In contrast, antagonistic effects of simultaneous PCB exposure on PAH uptake in oyster have been reported by Fortner and Sick (1985).

Fish accumulate PAHs primarily by direct uptake from the water column, with uptake via the gills being of greater importance than adsorption through the skin (Balk *et al*, 1984). Although uptake of PAHs from food has been observed in some studies, this route is generally thought to be less important than direct uptake from water. For example, Southworth *et al* (1979a,1979b) examined uptake in fathead minnows directly from the water and from a food source (*Daphnia* sp.) and concluded that uptake from water was the more important route. Studies have demonstrated that adsorption of PAHs through the digestive tract in fish is inefficient (Whittle *et al*, 1977; Lemaire *et al*, 1992).

Uptake of PAHs from bottom sediments has been demonstrated in English sole under experimental conditions (Stein *et al*, 1984; Varanasi and Gmur, 1981). However, Malins *et al* (1984) concluded that English sole in Puget Sound accumulate more PAHs from ingesting benthic fauna than from the sediments. Hellou *et al* (1995) studied the bioconcentration of PAHs from sediments to muscle tissue in winter flounder. PAH concentrations in sediments ranged from those typically found in pristine areas to between 25 and 50 times higher. The lower molecular weight water soluble PAH compounds displayed the highest biota-sediment bioaccumulation factors (BSAFs). The less soluble higher

molecular weight PAHs required a much longer time to reach steady state because of their low concentration in water. Ariese *et al* (1993) reported that direct contact with the sediment was the most important factor determining uptake of PAHs in flounder. Uptake via the water and the diet were less significant.

PAH concentrations in wild fish populations (edible tissue) are usually low (ng/g wet weight). Unlike aquatic invertebrates, fish species are capable of rapidly metabolizing these compounds (Lawrence and Weber, 1984; Uthe and Musial, 1986; Veith *et al*, 1979). According to some researchers, the PAH compounds detected in fish are usually of low molecular weight (e.g. naphthalene and 2,6-methylnaphthalene). The lower water solubility of the higher molecular weight PAH compounds results in a decreased bioavailability of these compounds in natural water systems. As a result, it is the lower molecular weight PAH compounds which tend to be accumulated in aquatic biota (Hellou *et al*, 1995; Lake *et al*, 1990; DiToro *et al*, 1991; Hellou and Warren, 1997). In addition, it has been reported that the high molecular weight compounds, such as the carcinogen benzo[a]pyrene, are detected less commonly as they are more effectively metabolized by fish than the lower molecular weight compounds (Varanasi and Gmur, 1981; Hellou and Warren, 1997; Schnell *et al*, 1980; Varanasi and Stein, 1991; Malins *et al*, 1980; McCain *et al*, 1978). Varanasi *et al* (1989) reported that PAH excretion from fish was dependent on molecular size with the higher molecular weight compounds being excreted more readily. They also observed that starry flounder and rock sole depurated the PAHs rapidly in the first few days and more slowly after that. PAH concentrations in blood, muscle and urine decreased significantly within one week, while concentrations in the liver and bile of flounder decreased very little within two weeks.

The half-lives of PAHs in fish are relatively short compared to those reported for aquatic invertebrates. Spacie *et al* (1983) reported that the half-lives for ^{14}C-anthracene and ^{14}C-benzo[a]pyrene, were 17 and 67 hours, respectively, in bluegill sunfish exposed for a 5 hour period. Lemaire *et al* (1992) reported that the half-lives of benzo[a]pyrene in sea bass are 8.2, 3.5, 3.3, and 0.8 days, respectively, for liver, gallbladder, intestines and kidneys.

Schnitz *et al* (1987) reported that metabolic studies on dimethylbenzo[a]anthracene (DMBA) in rainbow trout support the theory that the primary route of PAH elimination in fish involves the metabolism of PAHs in the liver, followed by the transport of the parent compound and conjugated metabolites to the gall bladder, and subsequent excretion to the intestine.

Exposure to PAHs and many other pollutants, including 2,3,7,8-TCDD, PCBs, some organochlorine pesticides, petroleum and some industrial effluents, can result in the induction of the MFO system in the liver of many species of fish. This effect has been observed in the laboratory as well as in the natural environment (Lech *et al*, 1982; Perdu *et al*, 1993; Payne *et al*, 1985; Holdway *et al*, 1994; Stein *et al*, 1992; Collier *et al*, 1986; Livingstone *et al*, 1993; Ahokas *et al*, 1994; Lindstrom-Seppa *et al*, 1990; Goksoyr and Forlin, 1992; Forlin and Celander, 1993; Di Guilio *et al*, 1993; Stegeman *et al*, 1987). Several enzyme systems make up the mixed-function oxidases including aryl hydrocarbon

hydroxylase (AHH) (also known as benzo[a]pyrene hydroxylase), ethoxycouramin O-deethylase (ECOD), and ethyoxyresorufin O-deethylase (EROD). Exposure to PAH compounds causes AHH, ECOD, and EROD to be activated. As a result, soluble PAH metabolites in the bile and blood are excreted as water soluble compounds (Di Giulio *et al*, 1993; Varanasi *et al*, 1987; Collier *et al*, 1980; Krahn *et al*, 1980). MFO systems in fish are similar to those in mammals and are more effective in metabolizing PAHs than the MFO system in lower animals, such as bivalve molluscs (Lawrence and Weber, 1984).

In fish, CYP1A is the major cytochrome P-450 subfamily which responds to compounds such as PAHs, PCBs and dioxins. The liver is the main site of CYP1A expression and activity is localized in the hepatocytes and endothelial cells (Goksoyr and Forlin, 1992). However, CYP1A induction has been observed in other organs of fish. Atlantic cod and European flounder caged for 3 months in a contaminated Norwegian Fjord exhibited CYP1A induction in the liver and in several extrahepatic organs (biliary epithelial cells, mucosal epithelial cells in the intestine, and renal tubular epithelial cells). The most significant induction was observed at the most contaminated sites (Beyer *et al*, 1996; Husoy *et al*, 1996). Hepatic CYP1A induction was significantly correlated to PAH exposure as measured by fluorescent aromatic compounds (FACs) in the bile (Beyer *et al*, 1996). Van Veld *et al* (1990) reported that the intestine also plays an important role in the absorption and metabolism of dietary PAHs and may be a useful indicator of dietary exposure to these compounds. Similarly, a study by McElroy and Kleinow (1992) showed that the liver and intestinal mucosal cells had similar abilities to metabolize benzo[a]pyrene or 7,8-diol in the winter flounder. This provides further evidence that the intestine also plays an important role in the metabolism of dietary carcinogens in winter flounder.

Fish hepatic monooxygenase induction is often used as an indicator of the sub-lethal effects of exposure to PAHs and other chemical contaminants. The most commonly used indicator is the induction of ethoxyresorufin O-deethylase (EROD) or benzo[a]pyrene hydroxylase (B(a)PH) (also known as AHH). Lange *et al* (1992) reported that cytochrome P-450 and EROD activity in the liver of dab from the North Sea was highest at various sites within the German Bight. This finding was attributed to the high levels of PAH and PCB contamination in this area. Van Veld *et al* (1990) also reported that the levels of cytochrome P-450 and EROD were elevated in both the intestine and the liver microsomes of spot from the highly contaminated Elizabeth River. Addison *et al* (1994) reported that hepatic mono-oxygenase activity in winter flounder from Sydney Harbour in British Columbia increased with sediment PAH concentrations. In addition, they reported that cyanoethoxycourmarin O-de-ethylase activity was as sensitive an indicator of monooxygenase induction as was EROD or B[a]PH (AHH), with all three being well correlated with both cytochrome P-450 1A concentrations and sediment concentrations. Kezic *et al* (1983) reported that benzo[a]pyrene monooxygenase (B[a]PMO or AHH) activity in non-migratory fish from a river area was highly correlated to the recent pollution history in that area. Experimental fish caged for a 10 day period in various areas of the river exhibited B[a]PMO activity comparable to the natural populations of fish. The authors concluded that B[a]PMO measurement was a relevant measure of harmful pollutant potential in aquatic systems.

Induction of the cytochrome P-450 enzyme system can be influenced by a number of variables including the developmental stage and sex of the organism (Andersson and Forlin (1992). In mammals, it has been shown that males generally contain higher hepatic P-450 levels than females. However, in salmonids this appears to hold true only during the late stage of their cycle. In mature male rainbow trout several hepatic P-450 activities are higher than in adult females (Forlin, 1980; Forlin and Haux, 1985; Koivusaari *et al*, 1981; Stegeman and Chevion, 1980).

Temperature in the ambient environment also affects enzyme induction. Andersson and Koivusaari (1985) showed that induction of P-450 by PAH compounds occurred in both cold and warm acclimated fish, but the warm acclimated fish demonstrated a faster and stronger induction reaction. Kennedy *et al* (1989) reported that gulf toadfish were capable of rapidly metabolizing benzo[a]pyrene with metabolism proceeding more quickly under warmer temperatures. The major metabolite produced was benzo[a]pyrene 7,8-dihydrodiol. Metabolite production was influenced by the exposure temperature with more carcinogenic metabolites being produced at the warmer temperatures (Andersson and Forlin, 1992; Andersson *et al*, 1988).

Since PAH metabolism proceeds quite quickly in fish, parent PAH compounds do not usually accumulate to high levels in fish tissue. However, the bile of fish exposed to PAHs contains many oxygenated PAH derivatives, usually in the form of glucoronide, sulphate, or glutathione conjugates. In analysis, these compounds are normally quantitated and reported as benzo[a]pyrene equivalents. However, the major contribution to the overall benzo[a]pyrene equivalents is usually from the metabolites of the lower molecular weight compounds such as pyrene and fluoranthene, which are more readily adsorbed than are the higher molecular weight compounds (Krahn *et al*, 1987).

The exposure of fish to PAH compounds is often determined by screening the gallbladder bile for PAH metabolites. Since these compounds are usually cleared from fish quite readily, quantification of bile metabolites indicates recent exposure to PAHs. The quantification of PAH metabolites in bile is a more sensitive measure of fish PAH exposure than is the quantification of PAH compounds in tissues. For example, McDonald *et al* (1992) reported that the tissue PAH concentrations were similar in fish collected near a small scientific station and in fish from remote areas of Antarctica. However, the PAH metabolites were elevated in the bile of fish from the research station, indicating that they had been exposed to petroleum-derived PAHs. The presence of bile PAH metabolites has also been used to confirm the long-range transport of PAHs to mountain lakes and uptake into fish from those lakes and also in deep-sea fish species in a remote areas of the northwest Mediterranean Sea (Escartin and Porte, 1999a and b).

Leadly *et al* (1999) reported that, although the presence of fluorescent aromatic compounds (FACs) in the bile of fish is a useful biomarker of PAH contamination in fish, there is great deal of variability in the FAC levels detected even under controlled laboratory conditions. In the field, differences in the movements and feeding of the individual fish would contribute to even greater variability in the FAC levels detected. However, these authors also

report that FACs were a valuable way of demonstrating recent PAH exposure as FAC bile concentrations show elevation after only a few hours of exposure.

MacCubbin *et al* (1988) reported that bullheads fed PAH contaminated food in laboratory studies exhibited polar metabolites of PAH in their bile within 24 hours. Similarly, bullheads collected from the Buffalo River contained benzo[a]pyrene equivalents in their bile at concentrations 7 to 148 greater than those in fish from less contaminated areas.

The main metabolite of pyrene, 1-hydroxypyrene, accounts for a large percentage of the total metabolite profile in the bile of fish exposed to combustion related PAHs (Krahn *et al*, 1987). Ariese *et al* (1993) reported that North Sea flounders exposed to contaminated sediments exhibited a similar ratio, between 3-hydroxy benzo(a)pyrene and 1-hydroxypyrene, to that observed in English sole from polluted areas of Puget Sound (Krahn *et al*, 1987). It was suggested that different locations with comparable PAH sources could have similar PAH metabolite profiles and that 1-hydroxypyrene may, therefore, be a relevant measure for the total uptake of pyrolytic PAHs.

2.2 Biological Effects

Toxic effects in many species of aquatic organisms have been observed following exposures to μg/L concentrations of PAH compounds. According to the Environment Canada Assessment Report on PAHs (Germain *et al*, 1993), existing information on the toxicity of PAH compounds suggests that PAHs can be considered to be at ecotoxic levels in the water when concentrations reach the μg/L range.

The exposure of aquatic species to PAH compounds can result in effects on growth, reproduction, and survival.

Most of the existing information on acute toxicity of PAH compounds pertains to the lower molecular weight compounds. The solubility of these compounds in water is higher than that of the higher molecular weight compounds and, therefore, they more readily reach toxic levels in water. Although some higher molecular weight compounds are acutely toxic to aquatic organisms, their lower solubility makes it much less likely that they will reach acutely toxic levels in aquatic systems. The toxicity of PAH compounds increases as the octanol-water partition coefficients of the compounds increase (Millemann *et al*, 1984).

For many PAH compounds, acutely toxic concentrations (as measured under lab conditions) exceed the aqueous solubilities of the compounds. Fluoranthene toxicity has been demonstrated in some aquatic organisms at environmentally realistic concentrations (lower than its aqueous solubility) (Suedel *et al*, 1993; Swartz *et al*, 1990). According to Suedel and Rodgers (1996), the 48hr LC_{50} and the 10 day LC_{50} for the cladoceran *Daphnia*

magna exposed to fluoranthene were 106 µg/L and 103 µg/L, respectively. In comparison, the amphipod *Hyalella azteca* was more sensitive and exhibited a 48hr LC_{50} value of 92 µg/L and a 10 day LC_{50} value of 30 µg/L (Swartz *et al*, 1990). Exposure to fluoranthene levels of 200 and 400 µg/L affected the immunocompetence of mussels (*Mytilus edulis*) (Coles *et al*, 1994). Differences in the sensitivity of various species of aquatic organisms to PAH compounds have been noted. For example, Neff (1979) reported that crustaceans are more sensitive to fluoranthene toxicity than are polychaete worms or fish.

Weinstein (1997) studied oysters from an urbanized fluoranthene-contaminated site in South Carolina and reported that the seasonal profile of epithelial thickness was related to the body burden of fluoranthene and other PAH compounds. The oysters from this area contained PAH concentrations of up to 683 ng/g dry weight. Exposure to 5 mg/L fluoranthene in the lab also resulted in a reduction in the mean digestive epithelial thickness. The authors concluded that observations of thinning epithelial thickness in oyster populations could provide a useful indicator of fluoranthene-induced stress. In addition, Eertman *et al* (1995) reported that mussels with high fluoranthene body burdens exhibited decreased gonadal development.

Walker *et al* (1998) reported that exposure of bullfrog larvae to fluoranthene and solar ultraviolet radiation, simultaneously, caused significant effects on locomotor behaviour at 60 µg/L after 48 hours and at 40 µg/L after 96 hours. In addition, the skin of the larvae showed signs of necrosis after exposure to as little as 10 µg/L fluoranthene.

At much higher concentrations of benzo[a]pyrene (10 mg/L), Sabourin and Tullis (1981) observed significant decreases in the heart activity of mussels (*Mytilus californianus*).

Miller *et al* (1982) reported that exposure of pink shrimp (*Pandalus duorarum*) to 1 µg/L chrysene over a 28 day period, increased the incidence of molting. Fiddler crab exposed to naphthalene exhibited hyperglycemia, which is mediated by CHH (crustacean hyperglycemic hormone) from the eyestalks (Reddy *et al*, 1996).

Exposure to naphthalene had toxic effects on the hepatopancreatic cells of crayfish, however, cells were able to proliferate once exposure was terminated. This indicates that the crayfish hepatopancreas is similar to the mammalian liver in its ability to replace lost cells (Sarojini *et al*, 1993). Naphthalene also affects the vitellogenesis of crabs (Elumalai and Balasubramanian, 1999).

A chronic (lifetime) exposure of the copepod *(Eurytemora affinis)* to 10 µg/L of certain naphthalene compounds (2-MNA, d-MNA, and t-MNA) resulted in a reduced lifespan and decreased reproductive success. The production of eggs was reduced to approximately 50% of the control group as a result of exposure to 10 µg/L of any of the naphthalene compounds (Ott *et al*, 1978).

Mummichogs (*Fundulus heteroclitus*) exposed to naphthalene concentrations as low as 200 µg/L for a period of 15 days exhibited histological effects in the brain, liver and pancreas. Concentrations as low as 20 µg/L resulted in neurosensory damage after 15 days and metabolic stress (as indicated by elevated serum glucose, protein and cortisol) (DiMichele and Taylor, 1978). Similarly, mature fathead minnow exposed to up to 20 µg/L exhibited decreased reproductive output (number of eggs), egg percent hatch, and fry survival. In addition, teratogenic effects (in the form of internal hemorrhaging and eye and yolk deformities) were observed in hatched fry (Hall and Oris, 1991).

A study of the toxicity of phenanthrene to marine polychaetes (*Nereis* sp.) showed that 48 hour old emergent juveniles (14 day LC_{50} of 51 µg/L) were more sensitive than were adults (14 day LC_{50} of 501 µg/L). Worm growth and reproduction were both adversely affected (Emery and Dillon, 1996).

Hardy *et al* (1987) reported that there were fewer sand sole eggs and neustonic organisms in sea surface samples collected from Puget Sound than in those from reference sites during spawning season (February and March). The hatching success of sole eggs from urban areas was 50% or less that of sole eggs at reference areas. A number of toxic effects were observed in developing organisms exposed in the laboratory to surface microlayer samples from urban bays. These effects included increased chromosomal aberrations in developing sole embryos and reductions in both the hatching success of sole larvae and the growth in trout cell cultures. The authors noted that the toxicity of the sea-surface microlayer was strongly correlated with the presence of high concentrations of PAHs and metals.

Exposure of larval zebrafish to retene at concentrations of 320 µg/L and higher for a 14 day period caused reduced growth, yolk sac edema, and mortality. The same study revealed that retene concentrations of 32 to 320 µg/L caused increased incidence of blue-sac disease in larval rainbow trout. Other effects observed in rainbow trout were yolk sac edema, subcutaneous hemorrhaging, fin erosion, opercular sloughing, reduced growth, craniofacial malformations and increased cytochrome P4501A enzyme activity (Billiard *et al*, 1999).

White *et al* (1999) reported that fathead minnow larvae two generations after exposure to the mutagen, benzo[a]pyrene, exhibited a significant decrease in survival. At the highest exposure level (1 ppb) both the larvae survival and the reproductive capacity were affected.

In general, PAH compounds are more toxic to organisms during the early developmental stages. However, carcinogenic effects of PAH compounds are more common in older organisms as these effects develop over longer time periods (Black, 1983; Hawkins *et al*, 1990).

Although the higher molecular weight PAH compounds are usually of lower acute toxicity to aquatic organisms, many of them are recognized as mutagens and/or carcinogens, including benzo[a]pyrene, dibenz[a,h]anthracene, and benzanthracenes. Other compounds, such as chrysene, have been shown to be tumour promoters (Metcalfe *et al*, 1990).

Hawkins *et al* (1990) reported that benzo[a]pyrene and 7,12 dimethylbenz[a]anthracene (DMBA) induced hepatic neoplasms in both guppy and Japanese medaka. Benzo[a]pyrene exposure (150 to 250 µg/L) resulted in hepatic neoplasms, while DMBA exposure resulted in hepatic and extrahepatic neoplasms. DMBA was a stronger carcinogen than benzo[a]pyrene and neoplasms in medaka and guppy occurred following exposures to <5 µg/L and 30 to 50 µg/L, respectively. Earlier work by Hawkins *et al* (1989) demonstrated that hepatic and extrahepatic neoplasms appeared in guppies exposed to ≥20 µg/L DMBA for 6 hours once each week over a four week period.

Exposure to PAH contaminated sediments has also been reported to cause toxic effects in aquatic organisms. Long *et al* (1995) reported that adverse effects were associated with sediments containing phenanthrene, fluoranthene and low molecular weight PAHs at concentrations of 2.25, 7.65, and 4.74 µg/g (dry weight at 1.5% organic carbon content). Other researchers reported that concentrations in the 1 to 20 µg/g dry weight range have been associated with impacts on benthic species (Steinhauer and Boehm, 1992; Misitano and Schiewe, 1990). Landrum *et al* (1991) reported that sediment concentrations in the range of 100 µg/g dry weight of total PAHs (11 compounds) caused mortality in amphipods (*Diporeia* spp.) over a 26 day exposure period. Two species of benthic amphipods (*Rhepoxinius* and *Corophium* sp.) exposed to fluoranthene contaminated sediments (0.18 % organic carbon content) exhibited 10 day LC_{50}s of 3.4 and 5.1 µg/g dry weight (Swartz *et al*, 1990).

Lotufo (1997) reported that the 4 day LC_{50}s for the estuarine copepod *(Schizopera knabeni)* exposed to sediment-associated phenanthrene and fluoranthene were 473 µg/g and >2,100 µg/g dry weight, respectively. They also reported that feeding was inhibited at concentrations less than the LC_{50} (50% decrease at 48 to 94 µg/g dry weight), as was nauplii and copepodite production (50% decrease at 38 to 64 µg/g, dry weight). Avoidance behaviour was also observed at sublethal concentrations. The authors concluded that, although mortality occurred only at very high sediment concentrations, sublethal levels would likely affect fitness, distribution and abundance of aquatic species in contaminated areas. This emphasizes the need to consider sublethal effects during the development of sediment quality criteria.

Mussels from Kitimat Harbour have a high incidence of a condition involving extensive infiltration of tissue by hyalinocytes. The incidence of the condition correlates positively with benthic sediment levels of PAHs (Brown *et al*, 1983; Cretney *et al*, 1980). However, Chapman *et al* (1995) and Paine *et al* (1996) reported that, despite the very high PAH concentrations in sediments offshore the Alcan smelter in Kitimat Arm, an environmental effects monitoring program showed little evidence of adverse effects. Few

indications of disturbances were detected in benthic infaunal, crab and bottomfish communities and sensitive toxicity tests (bioassays) showed no effects related to PAHs. The authors suggested that the limited bioavailability and lack of adverse effects on local biological communities may be related to the fact that PAH releases from the smelter were associated with pitch globules or coal particles rather than in solution or sorbed to suspended solids. Simpson (1997) suggested that, over time, PAH could become more bioavailable as a result of microbial action, particle breakdown, or other natural processes in the environment. However, examination of a Kitimat sediment core showed no evidence of weathering or biotransformation of the anthropogenically generated PAHs (Simpson *et al*, 1998).

Carman *et al* (1995) used a microcosm system to study the effects of PAHs on a benthic estuarine sedimentary salt-marsh food web. Sediments containing 0.3 to 3 mg/kg dry weight were tested, however, it is estimated that surface concentrations may have reached 27 mg/kg. Microalgae activity, physiological condition and meiofaunal community composition were affected but bacterial activity, physiological condition, abundance and meiofaunal grazing were not. The authors suggested that the chronic petroleum contamination in this coastal salt marsh over the past several decades may have allowed the resident microorganism populations to adapt to elevated PAH concentrations.

Creosote contaminated sediments have been associated with a number of toxic effects in aquatic organisms. According to Tagatz *et al* (1983) the lowest creosote sediment concentration that affected the number of benthic individuals or species in recolonization experiments was 844 µg/g dry weight for molluscs and 177 µg/g for echinoderms, annelids, and arthropod (including amphipods). Swartz *et al* (1989) reported that creosote contaminated sediment from one station in Eagle Harbour, Washington was highly toxic to the amphipod *Rhepoxynius*, however, sediments from other nearby stations (within 150 metres) were not acutely toxic. This demonstrates that sediment contamination and toxicity can be highly variable even between stations in close proximity. Total PAH concentrations were as high as 29,000 µg/kg at some sites in Eagle Harbour. Sved *et al* (1992) observed a number of effects in spot exposed to coal tar creosote contaminated sediments for 14 days including; severe fin erosion, epidermal lesions, and mortality. Goyette and Brooks (1998) investigated the spatial and temporal effects of creosote treated pilings in the marine environment. They concluded that, under worst case conditions, creosote treated wood can cause adverse effects in the marine environment and that care should be taken during the use of treated structures to minimize environmental risks. However, adverse biological impacts were significant only to a distance of 0.65 metres from the structure. Significant environmental PAH contamination was restricted to within 7.5 metres of the structure. The authors concluded that creosote tends to remain intact in the bottom sediments, even when agitated, limiting its spread from the source and its contact with local biota (Goyette, personal communication).

Some researchers have suggested that the concentration of chemicals in the interstitial waters provides a better indication of the potential sediment toxicity than do chemical concentrations in bulk sediments (Hargis *et al*, 1984; Adams *et al*, 1985). Swartz *et al* (1989) analyzed the interstitial waters from sediments collected from several sites within

Eagle Harbour and observed that 6 µg/L was the highest phenanthrene concentration at which no amphipod mortality occurred. This value is in agreement with the safe level for amphipods reported by Tetra Tech (1986).

In many studies, a strong association has been observed between the contamination of bottom sediments with PAHs in urban waterways and the prevalence of liver lesions, including neoplasms, in bottom fish (Varanasi and Stein, 1991). Such an association has been reported in several contaminated river systems in the United States including the Buffalo and Hudson rivers in New York, the Black River in Ohio, the Detroit River in Michigan, and the Elizabeth River in Virginia. Similar findings have been reported for Puget Sound in Washington State; in contaminated areas near Los Angeles, California; in Alabama; and in the Elbe River in the vicinity of the North Sea (Bowser *et al*, 1990; MacCubbin *et al*, 1990; Krahn *et al*, 1986; Malins *et al*, 1985; Schiewe *et al*, 1991; Landahl *et al*, 1990; Pritchard *et al*, 1996; Myers *et al*, 1991; Simpson, 1992).

Mummichog from a creosote contaminated site in the Elizabeth River in Virginia had a high prevalence of idiopathic hepatic lesions. Visible hepatic lesions were observed in 93% of individuals with 33% of these having hepatocellular carcinomas. Hepatic lesions were not observed at the less contaminated sites in the river (Vogelbein *et al*, 1990). In addition, Hargis *et al* (1989) reported that mummichog from the Elizabeth River had a high incidence of papillomas of the lip and mouth., while Hargis and Zwerner (1988a, 1988b) reported that five species of fish from this river had lens cataracts. Fin rot and skin ulcerations were also observed. The prevalence of all lesions was highest in areas of high sediment PAH concentrations.

Hepatic lesions were also identified in English sole from Vancouver Harbour (Goyette *et al*, 1988; Goyette, 1991; Goyette, 1994). Based on data up to 1991, the highest incidence (up to 75% of the individuals greater than 20 cm in length) of preneoplastic and neoplastic liver lesions in Vancouver Harbour English sole were observed in Port Moody Arm, an area of low tidal exchange which receives petroleum refinery and other industrial and urban discharges. At this time, maximum surface sediment concentrations were between 20,000 and 40,000 ng/g. Lesions were found in 5 to 40% of the fish collected in the outer harbour and central portion of the inner harbour. Histological studies showed no evidence of liver lesions or hepatocellular disorders in English and flathead sole from reference sites including Loughborough Inlet, Alice Arm, and Barclay Sound. The frequency of liver lesions near the refinery in Port Moody declined in 1991 (45%) and 1992 (30%). This decline was attributed to the fact that the process effluent from the refinery had been re-directed to the Greater Vancouver Regional District sewer system in 1989 (Goyette, 1991; Goyette, 1994; Goyette and Boyd, 1989).

Fish exposed to PAHs (such as benzo[a]pyrene) during laboratory tests have also exhibited tumour formation. For example, Metcalfe *et al* (1988) reported that exposure of rainbow trout to extracts from PAH contaminated sediments from Hamilton Harbour resulted in the development of hepatocellular carcinomas.

A study of English sole from several locations in Puget Sound revealed that fish with liver lesions had significantly higher bile concentrations of compounds with benzo[a]pyrene fluorescence than did fish without lesions. Bile of English sole from polluted locations contained individual metabolites from fluorene, phenanthrene, anthracene, and dimethylanthracene. Concentrations ranged from 90 to 19000 ng/g wet weight (Krahn *et al*, 1984). Several authors reported that there was a significant positive correlation between the concentrations of metabolites of aromatic compounds and total liver lesions in flatfish and other bottomfish species. Observed lesions included hepatocellular and biliary neoplasms, preneoplastic focal lesions, degenerative/necrotic lesions, and non-neoplastic proliferative lesions (Husoy *et al*, 1996; Krahn *et al*, 1986). Myers *et al* (1991b) reported that, although liver neoplasms are rare in young fish, the detection of other liver lesions in juvenile flatfish can be useful as early indicators of biological effects in fish exposed to contaminants. Juvenile starry flounder, English and rock sole collected from Puget Sound contained high incidences of several types of nonspecific degenerative liver lesions at the more highly contaminated sites. These lesions have also been induced experimentally in fish by exposure to various toxicants. The presence of lesions in all three species were positively correlated to mean bile FACs (fluorescent aromatic compounds).

Laboratory studies indicate that hepatic enzymes in fish metabolize benzo[a]pyrene to intermediate compounds that bind to DNA. The binding of chemicals or their metabolites to DNA results in the formation of the carcinogen-DNA adducts and is thought to be the first step in carcinogenicity. The presence of DNA adducts in fish is used as one measure of the genetic damage originating from exposure to environmental carcinogens (MacCubbin *et al*, 1990; Miller and Miller, 1981; Okey, 1989). Laboratory studies have shown that hepatic enzymes in fish metabolize benzo[a]pyrene to glutathione conjugates, glucuronides and sulfates. One of the major metabolites is benzo[a]pyrene-7,8-dihydrodiol (BaP-7,8-diol), which is a precursor to the suspected ultimate carcinogen, anti-benzo[a]pyrene-7,8-dihydrodiol-9,10-epoxide (anti-BaPDE), which readily forms DNA adducts (Sikka *et al*, 1990; Thakker *et al*, 1977; Steward *et al*, 1990; Grady *et al*, 1992; Pangrekar and Sikka, 1992; Varanasi *et al*, 1989).

Work by Stein *et al* (1989) and Varanasi *et al* (1989) indicated that benzo[a]pyrene DNA-adducts persist in English sole after a single exposure to benzo[a]pyrene. The ability of the fish to repair DNA damage determines the persistence of the DNA-adducts in fish tissues. Although carcinogen-DNA adducts are efficiently eliminated from mammals by a process called excision repair, this process occurs more slowly in fish (Grady *et al*, 1992; Shugart *et al*, 1987; Shugart, 1988; Shugart, 1990).

Increased levels of DNA adducts have been associated with a higher incidence of liver lesions in wild populations from PAH contaminated areas and in test fish exposed to PAHs in the laboratory. In Puget Sound, a positive correlation has been found between hepatic CYP1A induction, the prevalence of preneoplastic hepatic lesions, and the level of hepatic DNA-adducts (Myers *et al*, 1997). In addition, the laboratory exposure of English sole to PAH contaminated sediments from the Eagle Harbour area of Puget Sound, over a five week period, resulted in elevated DNA adducts and increased fluorescent aromatic compounds

(FACs) in the bile. These effects occurred in relation to the dose. Sampling of the wild population of English sole from Eagle Harbour confirmed the presence of elevated levels of DNA adducts in fish exposed in the natural environment. The authors concluded that DNA adducts are persistent in English sole and that when a significant amount of the DNA damage occurs it is not easily repaired (French *et al*, 1996).

Some species are more sensitive to the carcinogenic effects of PAHs than others. For example, brown bullhead from rivers contaminated with PAH compounds exhibit a high incidence of liver tumours, while carp from the same areas show a low or zero incidence of tumours. Lab studies have confirmed the higher susceptibility of bullhead to PAH-induced carcinogenesis. Carp metabolize benzo[a]pyrene faster than bullhead, however bullhead liver microsomes formed a higher proportion of BP-phenols and BP-quinones among the total metabolites produced than did carp liver microsomes (Sikka *et al*, 1990; Steward *et al*, 1989). Pangrekar and Sikka (1992) suggested that the formation of a relatively high proportion of toxic BP-quinones in the liver may contribute to the observed susceptability of brown bullhead liver to BP-carcinogenesis. These authors reported that both liver and kidney microsomes formed PAH metabolites, primarily 7,8-diol, 9,10-diol, 3-hydroxy-BP, and 9-hydroxy-BP. In addition to these metabolites, liver microsomes also formed a significant amount of 3,6-quinone. A significant difference between the liver and kidney microsomes was noted in the proportion of BP-quinones formed. While quinones accounted for nearly 26% of the total metabolites formed by liver microsomes, they were not detected with kidney microsomes. BP-quinones are known to cause DNA damage.

Similarly, studies have shown that starry flounder are less susceptible to hepatocarcinogenesis than are English sole. Although starry flounder and English sole accumulated similar concentrations of PAHs from the sediments, and had similar rates of benzo[a]pyrene metabolism and benzo[a]pyrene 7,8-diol formation by liver microsomes, the binding of benzo[a]pyrene metabolites to hepatic DNA was higher in English sole than in flounder. It was suggested that this difference may be associated with the higher amounts of glutathione (for conjugating metabolites) in starry flounder than in English sole (Stein *et al*, 1990; Varanasi *et al*, 1986)

Spiny lobsters exposed to benzo[a]pyrene have been shown to efficiently eliminate benzo[a]pyrene metabolite DNA adducts within 28 days of exposure. This may, in part, explain the resistance of crustaceans to chemical carcinogenesis. Benzo[a]pyrene metabolites can bind to lobster hepatopancreatic DNA, but the adducts are not as persistent as those found in carcinogen-sensitive fish species (James *et al*, 1992).

Venier and Conova (1996) reported that DNA reactive intermediates were formed in the gills of mussels treated with benzo[a]pyrene and suggested that this may indicate that PAHs can cause genetic damage in this species. Other researchers reported that exposure to benzo[a]pyrene resulted in chromosomal aberrations and micronuclei in the gill cells of mussels (Al-Sabtum and Kurelec, 1985)

Tumour development has also been observed in oysters exposed to contaminated sediments. Gardner *et al* (1992) reported that sediments containing a mixture of contaminants (PAHs, PCBs, chlorinated hydrocarbons, an aromatic amine, a nitrosamine and heavy metals) produced kidney and gastrointestinal tumours after a 30 day exposure period. Previous studies had reported tumour development in oysters exposed to contaminated sediments from Black Rock Harbour in Connecticut for 30 days. Several organ and tissue systems were affected including the kidney, intestine, gills, gonads, heart and nerves (Gardner *et al*, 1991).

Oysters exposed to contaminated sediments from the Elizabeth River in Virginia have demonstrated increased susceptibility to infectious disease (Chu and Hale, 1994). Decreased immunocompetence has also been observed in fish exposed to sediments from this river system (Weeks *et al*, 1986).

Oysters from some PAH-contaminated areas have been shown to be mutagenic (Kira and Ogata, 1989). In addition, studies have shown that oysters that were relocated to polluted waters from pristine areas develop mutagenic activity within 3 days. Pittinger *et al* (1987) reported that oysters relocated to the polluted Elizabeth River in Virginia showed an increased mutagenic activity over a 14 day period. The level of mutagenic activity in the relocated oysters was similar to that in the oysters native to the area. When oysters were relocated back to a pristine area, mutagenic activity quickly decreased and was not detected after 14 days. The authors noted that there was little association between the levels of PAHs in the tissues and the mutagenic activity.

The toxicity of PAH compounds to aquatic species is influenced by a number of environmental variables. The amount of organic matter, the ambient temperature, and the presence of sunlight are thought to be among the most important factors.

The amount of sediment organic carbon influences the biological impacts of hydrophobic organic compounds, including PAHs, by reducing their bioavailability and toxicity (Swartz *et al*, 1990; DeWitt *et al*, 1992; Oris *et al*, 1990). Weinstein and Oris (1999) reported that the presence of dissolved humic materials reduced both the bioaccumulation of phenanthrene and the phototoxicity of this compound to juvenile fathead minnow.

Korn *et al* (1979) reported that an increased sensitivity was observed in shrimp exposed to naphthalene at higher temperatures, despite the fact that toxicants were lost more rapidly at higher temperatures. Synergistic effects of naphthalene and temperature on mysid respiration have also been observed. Respiratory compensation for naphthalene toxicity was no longer effective at high temperatures and high exposure combinations, resulting in 50% mortality over a 96 hour period. Respiratory rates were affected at the lowest concentration tested (200 µg/L). The authors reported that both the size and the sex of mysids influenced the response (Smith and Hargreaves, 1985).

The effects of salinity are less clear. Sabourin (1982) studied the effect of acclimation salinity on the respiratory and circulatory responses of blue crab exposed to naphthalene. No salinity related difference was observed in the resistance of crabs to naphthalene, however, underlying responses of the respiratory and circulatory system to naphthalene are affected by salinity. The response of the oxygen transport system to naphthalene differed with salinity. Naphthalene appears to exert sublethal effects on gill epithelia by disrupting ion exchange. Compensation is a complex process and occurs via increased ventilation and blood flow (Sabourin, 1982).

Some PAH compounds, including anthracene, fluoranthene, and pyrene, exhibit photo-induced toxicity. This means that, in the presence of natural or simulated ultraviolet light, these compounds are much more toxic to a variety of species, including insect larvae, daphnids, amphibians, invertebrates, fish and algae, than in the absence of light (Newsted and Giesy, 1987; Veith *et al*, 1995; Ankley *et al*, 1994; Kagan *et al*, 1984; Kagan *et al*, 1985; Monson *et al*, 1995; Alfred and Giesy, 1985; Bowling *et al*, 1983; Oris and Giesy, 1985; Cody *et al*, 1984; Gala and Giesy, 1983). Phototoxicity is increased by both a stronger intensity and a longer duration of light exposure (Oris and Giesy, 1987; Ankley *et al*, 1995; Oris and Giesy, 1986; Hatch and Burton, 1998).

Juvenile sunfish exposed to anthracene in the presence of sunlight exhibited a 96 hr LC_{50} that was 190 to 1800 times lower than the 24 hour no effect concentration in the absence of sunlight. Simultaneous exposure to sunlight and anthracene also resulted in increased opercular ventilation rate and structural changes in the gills and epidermis (Bowling *et al*, 1983; Oris and Giesy, 1985). Holst and Giesy (1989) reported that *Daphnia magna* exposed to ultraviolet radiation and anthracene (at concentrations ranging from 6 to 22% of the aqueous solubility) suffered a 69% reduction in the production of neonates.

Pelletier *et al* (1997) exposed larval and juvenile bivalves (*Mulinia lateralis*) and juvenile mysid shrimp (*Mysidopsis bathia*) to known phototoxic PAH compounds (anthracene, fluoranthene and pyrene) simultaneously with fluorescent or ultraviolet light. The authors reported that exposure to light increased the toxicity of individual PAH compounds by 12 fold to more than 50,000 fold. Exposure to ultraviolet light usually resulted in LC_{50}s and EC50s which were below the water solubility of the PAHs. This finding suggests that low levels of PAHs could cause significant toxicity in the environment in the presence of ultraviolet light. The authors also reported that the phototoxicity of petroleum products was determined by the presence of phototoxic PAHs. Heavier oils such as Arabian Light Crude, Prudhoe Bay Crude and Fuel Oil #6 were found to be phototoxic, while the lighter Fuel Oil #2 was not phototoxic. Fewer multiple aromatic ring phototoxic compounds occur in the lighter oils. The authors suggested that exposure to ultraviolet radiation after an oil spill could potentially increase the toxicity by 2 to 100 fold. The organisms at highest risk would be those species with pelagic larvae and species living in shallow areas where ultraviolet light penetration is possible (50 metres in clear water and up to 1 metre in turbid coastal water).

Organisms in some aquatic systems may be experiencing increased mortality and reduced reproductive success due to the phototoxicity of PAH compounds. For example, Gala and Giesy (1992) reported that, since the 24 hr EC_{50} for primary production in green alga ranged from 24 to 3.3 μg/L anthracene (depending on the UVA intensity), PAH concentrations in some aquatic systems are high enough that photo-induced toxicity may pose a hazard to natural algal communities.

There is evidence that, during periods of darkness, organisms can repair part of the damage caused by phototoxicity. Oris and Giesy (1986) reported that, during periods of darkness, bluegill sunfish were able to slowly repair damage caused during exposure to anthracene and ultraviolet light. However, despite the repairs which took place during periods of darkness, the accumulation of damage caused during periods of light was sufficient to cause eventual death.

In addition, the presence of other environmental contaminants can influence the toxicity of PAH compounds to aquatic species. McCarthy *et al* (1989) reported that bluegill sunfish pre-exposed to 3-methylcholanthrene five days prior to injection with benzo[a]pyrene, exhibited double the number of DNA benzo[a]pyrene adducts compared to fish exposed to only benzo[a]pyrene. The authors suggested that multiple contaminants appear to act synergistically on DNA adduct formation and, therefore, the effects of multiple carcinogens may be greater than would be predicted based on laboratory results of exposures to single compounds.

2.3 Concentrations in the Aquatic Environment

2.3.1 General Information

2.3.1.1 Water and Sediments

Concentrations of PAH compounds in surface waters are generally low due to their low solubility in water. In particular, the higher molecular weight compounds are rarely detected in sub-surface ambient waters. PAHs are mainly associated with suspended particulate matter with only a small fraction present in dissolved form. Most of the PAHs entering aquatic systems are ultimately deposited in the bottom sediments.

Recycling of some PAHs (particularly low molecular weight compounds) between the sediments and the water column can occur, but depends on factors such as water depth and mixing conditions. A study conducted in a deep, rural lake in the United Kingdom revealed that, in the case of phenanthrene, significant recycling between the sediments and water column occurred and resulted in remobilization and diffusive release (Sanders *et al*, 1996).

Brisbane Estuary in Australia receives discharges from petroleum refineries, fertilizer plants, cement factories, sewage treatment plants and also storm runoff from urbanized centres. Kayal and Connell (1989a) reported that more than 99.9% of the total PAHs present in water samples were associated with particulate matter, with less than 0.01% of the PAHs dissolved in the water column. PAH concentrations in filtered water samples were very low with naphthalene present at the highest concentrations (19 to 26 ng/L). Compounds with molecular weights greater than benzo[a]pyrene were not detected. Total PAHs in particulate matter ranged from 2.38 to 14.78 μg/g, with fluorene and pyrene present at the highest concentrations. Water samples collected from rivers bordering large Australian cities contained total PAH concentrations ranging from less than 0.3 to 525 ng/L (Smith *et al*, 1991). Lower molecular weight compounds such as fluorene (45-525 ng/L), anthracene (20-335 ng/L) and phenanthrene (4-35 ng/L) accounted for virtually all of the PAH present. Higher molecular weight compounds such as benzo[k]fluoranthene and benzo[a]pyrene were tightly adsorbed to particulate matter and extractable concentrations were below 0.3 ng/L in most samples. Fluoranthene and pyrene concentrations ranged from 1 to 18 ng/L and were distributed between the particulate and dissolved fractions.

PAH concentrations in particulates from seawater in Antarctica ranged from 1.5 to 9.8 ng/L (mean of 7.3 ng/L). The presence of alkylated derivatives of naphthalene and phenanthrene indicated a petroleum source (Green *et al*, 1992).

PAHs were detected in microlayer and subsurface waters of Winyah Bay and North Inlet in South Carolina (Kucklick and Bidleman, 1994). The most predominant compounds were fluoranthene and pyrene. However, the authors noted that previous studies in Chesapeake Bay (Hardy *et al*, 1990) and Lake Superior (Baker and Eisenreich, 1990) had demonstrated that phenanthrene was a major component of total PAHs in waters. Total PAH concentrations in water samples from Winyah Bay and North Inlet rarely exceeded 1000 ng/L with the highest concentrations occurring near commercial boat docks and a local steel mill (Kucklick and Bidleman, 1994). In general, the results supported a previous study by Bidleman *et al* (1990) in that the highest concentrations occurred close to urban Georgetown. PAH profiles in Winyah Bay and North Inlet indicate that runoff or fallout of urban dust may be the main PAH source to this area. PAHs were enriched in the surface microlayer and were detected at concentrations 18 times greater (on average) than the concentrations in subsurface samples.

Analysis of water samples collected off the coast of Finland at depths of 22 to 230 metres revealed that PAH concentrations in water samples collected closer to bottom sediments were higher than concentrations in upper water layers. Particularly high concentrations were detected at the sediment-water interface. In water samples, pyrene was detected at the highest concentrations while the higher molecular weight 5- and 6- ring compounds accumulated in the sediments or at the sediment-water interface. The authors noted that most of the carcinogenic PAH compounds would be deposited in the bottom sediments (Kirso *et al*, 1990)

Seasonal variations in PAH concentrations in surface waters have been observed in some regions. Bouloubassi and Saliot (1991) reported that PAHs associated with particulates in water samples from the Rhone delta area of the Mediterranean Sea ranged from 420 to 6000 ng/g. Concentrations detected in the winter were higher than in the summer and were attributed to increased pyrolytic contributions of PAH-enriched particles in the winter. Examination of PAH profiles suggested that PAH contributions were mainly from fossil fuel sources in the winter, while sources in the summer appeared to be more heterogeneous. Dissolved PAHs were present at concentrations ranging from 4 to 31 ng/L in the summer and 19 to 50 ng/L in the winter. As with particulates, the profiles of dissolved PAHs indicated a fossil fuel origin in the winter and mixed sources in the summer. In contrast to most other areas, a higher proportion of PAHs were in dissolved form (>80%) than associated with particulate matter. Alkylated and sulfur-containing compounds were particularly enriched in the dissolved phase.

Dissolved PAH concentrations in the Humber Estuary area of the United Kingdom were highest in September and lowest in June (Zhou *et al*, 1996). However, a significant increase in PAH concentrations was noted off a sewage outfall in June. Fluoranthene (2 to 66 ng/L) was detected in samples from all coastal stations including some located 40 km from shore. Pyrene was also present (3 to 61 ng/L), however, concentrations were near the detection limit at most sites.

Studies worldwide have shown that the highest concentrations of PAHs occur in sediments collected from urban and industrialized harbours and waterways. The combustion of fossil fuels and organic matter and the release of uncombusted petroleum products are the major sources of PAHs to coastal sediments (Maher and Aislabie, 1992; McGroddy and Farrington, 1995).

Shiaris and Jambard-Sweet (1986) reported that sediments from Boston Harbour in Massachusetts contained total PAH concentrations (sum of 14 unsubstituted compounds) ranging from 480 to 718,000 ng/g (dry weight). Particularly high concentrations were detected in the vicinity of a raw sewage pumping station in the inner harbour. Much lower concentrations (1,000 to 5,000 ng/g) were found in the outer harbour. The most predominant PAH compounds detected were the four and five ring compounds fluoranthene, pyrene, chrysene, benzanthracene, and benzo[a]pyrene. Phenanthrene was also detected, but at lower concentrations than the four and five ring compounds. The higher molecular weight compounds dibenzanthracene, indeno[1,2,3-cd]pyrene, and benzo[g,h,i]perylene were not detected in any Boston Harbour sediment samples. Hites *et al* (1978) reported that PAH concentrations ranged from 160 to 120,000 ng/g but decreased rapidly with distance from Boston (approximately one order of magnitude for every 40 km). Sediment samples collected from the Gulf of Maine, and from deep ocean areas off the continental shelf, contained total PAH concentrations ranging from 200 to 870 ng/g and from 18 to 160 ng/g, respectively.

Bates *et al* (1987) reported that the concentrations of total four, five and six ring PAH compounds in surficial bottom sediments and suspended sediments from the main basin of Puget Sound ranged from 600 to 3,200 ng/g. Concentrations in fine-grained surficial

bottom sediments were quite uniform throughout the central basin (1000 to 1200 ng/g). However, somewhat higher concentrations (2,700 to 3,000 ng/g) were detected in samples collected in Elliott Bay, the industrial harbour in Seattle. The highest PAH concentrations on suspended sediments were detected in samples collected near Seattle (1200 to 2000 ng/g). Concentrations decreased with distance from Seattle and also with the depth of collection within the water column. The PAH pattern in the suspended sediments and the surficial bottom sediments was similar. Elevated concentrations of retene, which is found naturally in conifer resin and in coal, were present in some samples. The highest levels (480 ng/g) were detected in the Commencement Bay area where the major source is thought to be input from the Puyallup River, which runs through several coal outcrops (Barrick *et al*, 1984). In comparison, bottom sediments collected from the Seattle area contained 90 ng/g of retene. In coastal marine sediments and sediments from lakes in forested watersheds, retene concentrations are usually in the 10 to 100 ng/g range. However, pulp mills can be significant sources of retene and, in sediments downstream from pulp mills, concentrations of up to 1,600,000 ng/g have been detected (Billiard *et al*, 1999). Malins *et al* (1984) reported that, in the Puget Sound area, the highest concentrations of the carcinogenic PAH compounds benz[a]anthracene (7,600 ng/g) and benzo[a]pyrene (2,400 ng/g) were detected in Elliott Bay which receives industrial and municipal waste and urban runoff.

PAHs were detected in the thousands of ng/g concentrations throughout the Brisbane River estuary in Australia. The highest total PAH concentration (16,100 ng/g) was detected in the most highly urbanized area. Fluoranthene and pyrene were present in the highest concentrations. Benzo[a]pyrene comprised 4 to 7% of the total PAH. Mean concentrations of individual PAH compounds ranged from 30 ng/g for dibenz[a,h]anthracene to 2340 ng/g for fluoranthene (Kayal and Connell, 1989c).

Although atmospheric deposition accounts for the major input of PAHs to the aquatic environment, there are often multiple direct releases of PAHs to industrialized harbours and waterways. These include sanitary and storm sewage discharges, the use and spillage of fuel and other petroleum products, creosoted pilings and wharf structures, and industrial discharges and runoff.

Dunn and Stich (1976) reported elevated PAH concentrations in sediments collected in the vicinity of a sewage discharge near Vancouver, British Columbia. These authors reported that the increase in benzo[a]pyrene concentrations in sediments from stations closest to the outfall of the sewage treatment plant suggested that this was the major source of benzo[a]pyrene to the Fraser River Estuary.

Urban and roadway runoff contribute significant amounts of PAHs to the aquatic environment directly and through stormwater releases (MacKenzie and Hunter, 1979; Carr *et al*, 2000). PAHs are deposited on road surfaces from asphalt and tire particles, atmospheric fallout, crankcase oil and petroleum, and exhaust fumes (Hoffman *et al*, 1984; Hoffman *et al*, 1985; Hermann, 1981; Payne *et al*, 1978; Wakeham *et al*, 1980a; Eganhouse *et al*, 1981; Enzminger and Ahlert, 1987; Evans *et al*, 1990b). PAHs adsorbed to street and roof dust are mobilized by storm events and transported to aquatic systems where they are

deposited in the bottom sediments (Evans *et al*, 1990b). Urban/road runoff was thought to be the major source of PAHs to the Derwent River in England. Sediment samples collected at several locations in the late 1980's contained mean total PAH concentrations of 5,220 to 35,240 ng/g, with a maximum concentration of 209,590 ng/g. Pyrene and fluoranthene were the main compounds detected. Sediments collected in a rural location upstream contained much lower levels of PAHs (mean of 580 ng/g; maximum of 2,450 ng/g).

PAHs are major constituents of creosote and high PAH concentrations have been detected in sediments collected off wood preservation facilities utilizing creosote. In 1982, sediments obtained off a wood preservation facility in Newcastle, New Brunswick contained 400,000 to 11,000,000 ng/g PAH, while sediments from the discharge stream at a wood preservation plant in Truro, Nova Scotia contained 1,500 to 6,300,000 ng/g. At both locations the PAH compounds detected at the highest concentrations were phenanthrene, pyrene, and fluoranthene (Kieley *et al*, 1986).

Perhaps the most recognized area of high PAH contamination in Canada is Sydney Harbour in Nova Scotia. For many years a steel coking operation discharged wastes in the vicinity of Muggah Creek and very high contamination levels have been reported in this area of the harbour. In 1981, Matheson *et al* (1983) reported total PAH concentrations (based on the sum of 12 compounds) of up to 2,800,000 ng/g dry weight in sediments at the mouth of Muggah Creek. The predominant compounds detected in the sediments were phenanthrene, fluoranthene, benzo[a]anthracene and pyrene. Subsequent sampling in 1986 demonstrated that PAH concentrations had declined significantly over the 5 year period. Total PAH concentrations at the mouth of Muggah Creek were 310,000 ng/g, and the predominant compounds detected were fluoranthene, pyrene, benzo[a]pyrene, phenanthrene, benzo[e]pyrene, and benzo[b]fluoranthene. The decline in concentrations between 1981 and 1986 was attributed to the reduction in discharges from the coke plant (Kieley *et al*, 1988).

Steel mills in other areas have also resulted in high levels of PAH contamination in the environment. Simcik *et al* (1996) reported that coke and steel production were the major sources of PAH to Lake Michigan sediments, contributing approximately 600 to 800 $mg/m^2/yr$. Core samples showed that, over the last 70 years, the distribution of PAHs was identical, both vertically within each core, and also between cores taken throughout the lake. This finding implies that the major sources of PAHs to Lake Michigan sediments have not changed significantly since the beginning of the century. In Hamilton Harbour, Ontario a total PAH concentration of 1,470,000 ng/g was detected in sediments from the vicinity of two steel mills. Individual PAHs such as pyrene, fluoranthene and benzo[a]pyrene were present at high concentrations (280,000, 189,000, and 69,200 ng/g, respectively).

Aluminum smelters can also be major sources of PAHs to the environment (Bjorseth *et al*, 1979; Naes *et al*, 1994; Simpson *et al*, 1995; Ayres, 1995). Total PAH concentrations in the hundreds of thousands of ng/g dry weight have been detected in sediments near aluminum smelters in Norway. The compounds present in the highest concentrations were fluoranthene, chrysene/triphenylene, benzofluoranthenes, benzopyrenes, and benzo[g,h,i]perylene (Naes and Oug, 1997; Naes *et al*, 1994).

Similar findings were reported for sediments from the Saguenay Fjord in Quebec which received discharges from an aluminum smelter (Smith and Levy, 1990). PAH concentrations in sediments from this area increased markedly in the 1940s following a major expansion of the smelter and the implementation of a new process called the 'Soderberg' process. Martel *et al* (1987) reported that concentrations of several thousands of μg/g were present in the sediments from this area. Smith and Levy (1990) concluded that, until 1964, atmospheric deposition was the principal source of PAHs to the environment. After that time, discharges of scrubber effluents directly to water became the major PAH source until 1976, when discharges released to water were reduced and atmospheric deposition, once again, became the major input.

Similarly, the distribution of PAHs in surficial sediments in Kitimat Arm, on the northern coast of British Columbia, demonstrated that the nearby Alcan aluminum smelter was the major source of PAHs to this area. According to Simpson *et al* (1998), major sources to Kitimat Arm were atmospheric particulate emissions, aqueous effluent releases, and spills of raw materials such as coke briquettes and pencil pitch. Very high PAH concentrations were detected in sediments collected near the smelter in the 1980's, but concentrations decreased rapidly with increasing distance from the smelter (Cretney *et al*, 1983; Goyette and Wagenaar, 1995; Simpson, 1997). Cretney *et al* (1983) reported that the sediments from Kitimat Arm contained an overall mean concentration of 140 ng/g dry weight with a maximum concentration of 9,300 ng/g. PAH concentrations in age-dated cores indicated a major input of PAHs to sediments in the mid-20th century following a period of at least 150 years of constant but low PAH deposition (Cretney *et al*, 1983). PAH concentrations of up to 257,700 ng/g were detected in the Alcan Yacht Basin in 1989 (Goyette and Wagenaar, 1995). Chapman *et al* (1995) reported that the PAH concentration in some sediment samples collected in the vicinity of the aluminum smelter approached 1% and the concentrations varied over a 1000-fold range. However, they noted that PAH concentrations in surface sediments had decreased as a result of decreased PAH releases from the smelter. Paine *et al* (1996) reported that PAH concentrations in sediments from many sites in Kitimat Arm have decreased since the 1980's, however, PAH concentrations in sediments within one kilometer of the smelter remain high (typically <150 mg/kg with a maximum of 10,000,000 ng/g total PAH). Simpson (1997) reported that sediment obtained from an effluent lagoon at the Alcan smelter contained a total PAH concentration of over 10,000,000 ng/g dry weight. Sediment samples collected throughout the fjord contained PAH concentrations ranging from 1,000 to 528,000 ng/g dry weight, with concentrations exceeding 2,000 ng/g at 16 of the 25 sites sampled. The highest concentrations were found in sediments collected in close proximity to the smelter. Simpson (1997) reported that the PAH composition was characteristic of a combustion source. The 4-and 5-ring compounds were present at higher concentrations than were the 2- and 3- ring compounds and unsubstituted PAH compounds were more abundant than their alkylated homologues. Simpson *et al* (1998) reported that a sediment core from Kitimat Arm showed no compound-specific weathering or biotransformation with sediment depth. The authors suggested that this may indicate that PAHs emitted from smelters have limited chemical and biological availability.

Analysis of sediment core samples from Puget Sound indicates that PAHs had not been significantly degraded or produced in the sediments over at least the last 100 years represented by the cores. Many of the cores contain maximum PAH concentrations in the 1945 to 1960 horizons. Data from Strait of Georgia sediment cores shows similar distributions of PAH but lower concentrations (Macdonald and Crecelius, 1994).

Examination of sediment core samples from several areas throughout the world revealed a similar decline in PAH inputs in recent decades (Simcik *et al*, 1996; Hites *et al*, 1980; Gschwend and Hites, 1981; Prahl and Carpenter, 1979; Bates *et al*, 1984; Hursthouse *et al*, 1994; Heit *et al*, 1988; Barrick and Prahl, 1987; Grimmer and Bohnke, 1975; Catallo *et al*, 1995). This has led to suggestions that the change in fuel sources for residential heating from coal to natural gas may be responsible for the downward trend. Heit *et al* (1988) reported that in sediment cores from Cayuga Lake in New York State, PAH deposition around 1850 was at least an order of magnitude less than that in the period of maximum deposition (1940 to 1955). However, significantly lower inputs have occurred from the late 1960's to the present. Since coal fired power plants did not begin operation in this area until 1955, the authors concluded that this could not be the predominant historical source of PAH to sediments in this area. In fact, the decline in coal combustion at electrical utilities in New York State occurred at least 10 years after the PAH decline observed in sediment cores. The authors concluded that their observations supported the theory that the decline was attributable to the replacement of coal with petroleum and natural gas as the primary residential heating fuels. Dasch (1982) reported that the inefficiency of coal combustion during residential burning resulted in the release of much higher levels of PAHs than commercial coal burning, wood burning or automotive exhaust. Based on their observations on historical PAH deposition in sediments, Heit *et al* (1988) also suggested that PAH contributions from modern and efficient power plants utilizing either coal, petroleum or natural gas, were minor in comparison to past contributions from coal combustion for residential heating.

Elevated PAH concentrations have been found in areas which are not highly industrialized or urbanized. The Penobscot Bay region of the Gulf of Maine is relatively undeveloped, however, total PAH concentrations of up to 8,800 ng/g were detected in the sediments from this area. The authors suggested that the major source was atmospherically transported particulate combustion products which enter the bay through freshwater runoff (Johnson *et al*, 1985).

It can be difficult to determine the source of PAHs in the aquatic environment. Methods employed for distinguishing between likely sources of PAHs in environmental samples are based on the recognition of patterns in the PAH composition which are characteristic of certain sources (Lipiatou and Saliot, 1991). Steinhauer and Boehm (1992) summarized information on sources of various PAH compounds in the environment as follows:

Naphthalenes - includes the 2-ring parent compound and the alkyl-substituted homologues. These compounds are rarely found in clean sediments and

the presence of naphthalene compounds is indicative of unweathered or fresh petroleum (crude oil).

Phenanthrenes - includes the 3-ring parent compound and the alkyl-substituted homologues. These compounds can originate from petroleum, combustion and diagenetic sources, but the presence of more highly alkylated compounds indicates a petroleum source.

Dibenzothiophenes - includes the 3-ring sulfur heterocyclic parent compound and the alkyl-substituted homologues. These compounds are present in many crude oils.

4-,5-ring PAHs - The sum of the 4- and 5- ring compounds includes the high molecular weight compounds formed by combustion of fossil fuels and wood.

Σ PAHs - A comparison of the sum of the 4- and 5- ring compounds and the ΣPAHs (2- to 5-ring compounds) can provide information regarding the relative contributions of petrogenic and pyrogenic sources.

Phenanthrene/ dibenzothiophenes - The presence of dibenzothiophenes (D) indicates a petroleum source. In oiled sediments the D value approaches the phenanthrene (P) value and the ratio P/D gets closer to 1. In unoiled sediments D is not present at high concentrations and this ratio can range from 10 to 100 or more.

Naphthalene/ Phenanthrene - Phenanthrene may originate from petrogenic, pyrogenic or diagenetic sources, however, the presence of naphthalene indicates a fresh petroleum source. In sediments with crude oil contamination the N/P ratio would be much greater than 1 but decreases to less than or near 1 in unoiled sediments.

Perylene- This compound is present in sediments from diagenetic sources (Heit *et al*, 1988; Wakeham *et al*, 1980; Aizenshtat, 1973).

Fossil fuel pollution index (FFPI) - This ratio was described by Boehm & Farrington (1984) to approximate fossil fuel derived PAHs relative to total PAHs. Pyrogenic or combustion-derived PAHs are rich in 3- to 5- ring compounds, while uncombusted fossil fuels are rich in 2- and 3- ring compounds (also dibenzothiophene and its alkyl homologues). The FFPI ranges between 100 for fossil fuels and 0 for combustion PAHs.

In addition, the presence of alkyl derivatives of PAHs at higher concentrations than the parent compounds indicates a petroleum source as these compounds are found at high proportions in petroleum products (Yunker *et al*, 1996; Platt and Mackie, 1981; Pereira *et al*, 1996).

Researchers have utilized PAH patterns in sediments to determine predominant PAH sources in many aquatic systems.

Fluoranthene, which is often associated with a combustion source, was the predominant PAH in sediment cores collected from Cayuga Lake in New York State. This finding, combined with the low presence of alkylated compounds, led authors to conclude that combustion was the main source of PAH to Cayuga Lake (Heit *et al*, 1988; Laflamme and Hites, 1978). Similarly, O'Malley *et al* (1996) estimated that 50 to 80% of the PAH input to St. John's Harbour sediments is of combustion origin. The most likely source was thought to be vehicular emissions carried into the harbour via surface runoff. The remaining 20 to 50% of the total PAH input to the harbour was attributed to petroleum sources, possibly dominated by crankcase oil. The authors concluded that the dominance of three, four and five ring parental PAH compounds together with the presence of alkylated PAHs was evidence of both combustion and petroleum sources. In addition, the presence of retene and perylene suggested a lesser diagenetic source. Diagenesis has been cited as the source of some PAHs including perylene and retene (methyl-1 isopropyl-7 phenanthrene). Retene is commonly found in resins in conifers in temperate climates and can be used as a molecular marker for combustion of conifer vegetation. The main sources of these compounds are forest fires and forest soils (Lipiatou and Saliot, 1991; Ramdahl, 1983).

Hites *et al* (1978) reported that the PAH pattern observed in sediment samples collected in Massachusetts Bay also indicated a predominant combustion source, even in Boston Harbour. Although sediments from nearby Gulf of Maine and from the deep ocean areas off the continental shelf contained much lower levels of PAH compounds, the PAH patterns in sediments from these locations were also indicative of a combustion source. Shiaris and Jambard-Sweet (1986) suggested that urban runoff was a major source of PAHs to Boston Harbour.

In the highly industrialized seaport of Hampton Roads, Virginia (Elizabeth River), different sources appear to predominate in different areas of the port. In the area of maximum sediment toxicity, the lower molecular weight PAH compounds (two and three ring) were predominant. The source of the PAHs to this area was thought to be petroleum related, originating from shipbuilding and repair operations in addition to shipping and anchorage activities. In the vicinity of three creosote plants, the predominant PAHs were similar to those found in other creosote contaminated areas (phenanthrene, anthracene, pyrene, fluoranthene, benzo[b]fluoranthene, and benzoanthracene). In another region of the port, the two and three ring compounds virtually disappeared from the sediments and the higher molecular weight compounds predominated. Benzo[a]pyrene and benzo[b]fluoranthene were present at the highest concentrations followed by chrysene, pyrene, fluoranthene, and benzo[a]anthracene. This pattern indicates a high-temperature combustion source and likely sources were nearby power plants and highway runoff (Alden and Butt, 1987).

In sediments collected in the Brisbane River estuary in Australia, fluoranthene, pyrene, benzo[a]pyrene, chrysene, benzo[k]fluoranthene, benzo[e]pyrene, and benzo[a]anthracene were present at higher levels than their alkyl derivatives, indicating a

predominantly pyrolytic source. However, the presence of naphthalene and the phenanthrene/ anthracene series indicated a petroleum source as well. The authors also reported that the phenanthrene/anthracene ratio indicated that urban runoff was an important source of PAHs to this area (Kayal and Connell, 1989b).

Studies in the Lauritzen Canal area of San Francisco Bay have shown that this area is highly contaminated with PAHs and the oil storage tanks located in this area are thought to be a probable source. A maximum total PAH concentration of 30,000 ng/g was detected in this area (Pereira *et al*, 1996) compared to a mean concentration of 2,400 ng/g total PAHs in San Francisco Bay sediments (Long *et al*, 1988). The authors concluded that the predominance of the four ring compounds, such as fluoranthene, pyrene, benz[a]anthracene, and chrysene, suggested a highly weathered petroleum source. The presence of alkylated homologs of chrysene at higher concentrations than the parent compound was also indicative of a petrogenic source. It was suggested that the loading of furnace coke into ships may be the source of the elevated concentrations of anthracene compounds (benz[a]anthracene, anthracene, and 2-methylanthracene) detected in the sediments (Pereira *et al*, 1996; Boehm *et al*, 1991).

Yunker *et al* (1996) reported that the MacKenzie River input of natural PAHs and petroleum dominates anthropogenic sources into the Beaufort Sea. PAH levels in sediments from the Beaufort Sea were relatively high and consistent at all stations. This finding, combined with the fact that the alkyl forms were present at higher concentrations than were the parent compounds, led the authors to suggest a strong petrogenic source. In contrast, although PAH concentrations in the Barents Sea were much lower than in the Beaufort, it was concluded that anthropogenic contributions were greater to the Barents Sea and alkyl compounds were present at lower concentrations than their parent compounds (Yunker *et al*, 1996; Steinhauer and Boehm, 1992). Sediment sampling at a research station in the Antarctic detected PAH compounds with phenanthrene, fluoranthene and chrysene being the predominant compounds (Cripps, 1992).

PAH pattern characterizations can be useful in distinguishing between combustion versus petroleum related sources, however, more specific identification of various combustion sources is much more difficult due to the overlap in signature sources and the degradation of PAHs in the environment. Recently, however, Yunker *et al* (1996) has reported that the use of principal components analysis (PCA) can improve this capability.

2.3.1.2 Aquatic Biota

2.3.1.2.1 Aquatic Invertebrates

PAH compounds have been detected in a variety of different tissues of invertebrate species. PAH parent compounds and metabolites are found mainly in the hepatopancreas of crustaceans, however, lower levels are detected in other tissues. PAHs tend

to accumulate in the digestive glands of mussels and the pyloric caecum of starfish (Lemaire *et al*, 1993; Uthe and Musial, 1986; Moore *et al*, 1984; Michel *et al*, 1993; Den Besten *et al*, 1993; Sanborn and Malins, 1980; Williams *et al*, 1985; Uthe *et al*, 1984). Mix *et al* (1982) reported that benzo[a]pyrene is stored mainly in the somatic tissues of mussels rather than the gonad, even during spawning season. Benzo[a]pyrene in the gonad accounted for a minor portion of the whole body concentrations and did not measurably affect seasonal variation in whole body benzo[a]pyrene.

PAH concentrations in aquatic invertebrates are highest in industrialized areas. Mix and Schaffer (1983b) reported that the average total PAH concentration in mussels collected from industrialized regions in Oregon in 1979/80 was 986.2 ng/g (wet weight) compared to an average of 273 ng/g in mussels from more remote sites. The more water soluble lower molecular weight compounds were present at concentrations of 1 to 2 orders of magnitude greater than were the higher molecular weight compounds. These authors also reported that PAH concentrations were highest in marine clams from industrialized areas (551.1 ng/g) and lowest in clams from remote areas (76.3 ng/g) (Mix and Schaffer, 1983a).

Especially high PAH concentrations have been detected in marine organisms collected from harbours in the vicinity of creosote treated structures such as wharves and pilings. Eaton and Zitko (1978) reported that PAH levels in shellfish were generally higher close to creosoted structures and decreased with increasing distance from wharves and bridges. Dunn and Young (1976) reported that mussels, collected from mainland and island stations at least 1 km from piers and wharves in the Southern California Bight, contained benzo[a]pyrene concentrations at or near the limits of detection (0.1 ng/g wet weight). Mussels collected from creosoted pilings contained higher PAH concentrations (up to 8.2 ng/g) than did mussels collected near large harbours and marinas (up to 2.3 ng/g). Dunn and Stich (1976) reported that PAH concentrations in mussels collected from creosoted structures in Vancouver Harbour contained 215 ng/g wet weight, while mussels taken from nearby rocks ranged from 54 to 172 ng/g. The average PAH concentration in mussels from outer Vancouver Harbour was approximately 2 ng/g. Mussels collected from the outer harbour stations in the Spanish Banks area ranged from less than 2 to more than 8 ng/g, while mussels collected from False Creek ranged from less than 10 to more than 30 ng/g wet weight (Dunn and Stich (1976). Mussels from Sydney Harbour in Nova Scotia contained up to 4200 ng/g total PAH (O'Neill and Kieley, 1992).

Some samples of mussels collected in Lake George, New York contained detectable concentrations of PAHs: phenanthrene (1 to <60 ng/g dry weight), fluoranthene (<1 to 370 ng/g), pyrene (1 to 450 ng/g), 1-methylpyrene (<1 to 90 ng/g), perylene (<10 to 300 ng/g), and dibenzothiophene (<1 to 4 ng/g). Benz[a]anthracene, benzo[a]pyrene, and dibenzacridine were not found in any samples (Heit *et al*, 1980).

Mussels from the Finnish Archipelago Sea contained several PAH compounds including naphthalene, phenanthrene, anthracene, fluoranthene, pyrene, benzo[a]pyrene and compounds of the benz[a]anthracene/chrysene/triphenylene group. Naphthalene, phenanthrene and pyrene were detected in most samples while benzo[a]pyrene was detected

only in two samples which had been influenced by an oil spill. Concentrations of individual PAH compounds ranged from <0.5 to 109 ng/g wet weight (Raino *et al*, 1986). Much higher levels were detected in mussels collected near a ferro alloy smelter in Norway (2,785 ng/g wet weight) (Grimmer and Bohnke, 1975). The dominant PAH compound detected in these mussels was benzo[a]fluoranthene. Mussels collected near an Oslo sewage treatment plant also contained elevated PAH concentrations ranging from 534 to 1,060 ng/g wet weight (Kveseth *et al*, 1982).

In the San Francisco Bay estuary, total PAH concentrations in Asian clams (496 to 1,002 ng/g dry weight) were higher than the concentrations in bed sediments (15 to 675 ng/g) but similar to those in suspended sediments (498 to 1,059 ng/g) (Pereira *et al*, 1992). In contrast, Smith *et al* (1984) reported that PAH concentrations in clams from the uncontaminated Great Barrier Reef in Australia were close to the detection limit at most sites (0.01 to 0.07 ng/g wet weight). Clams from two sites exposed to frequent boating activity contained detectable PAH concentrations (1 to 5 ng/g) (Smith *et al*, 1984). Sediment and oyster samples collected from islands on the Rowley Shelf off Western Australia between 1986 and 1988 contained PAH concentrations of <5 ng/g dry weight and 10 to 150 ng/g wet weight, respectively. Possible sources of contamination to this area included fishing boats, commercial shipping and work boats (Pendoley, 1992).

A seasonal variation in PAH concentrations was observed in both mussels and clams from the Oregon coast, with the lowest concentrations occurring in autumn and winter and the highest concentrations occurring in spring and summer (Mix and Schaffer, 1983a and 1983b). Seasonal variations have also been observed in oysters from other areas. Marcus and Stokes (1985) also reported that elevated PAH concentrations occurred in oysters collected in the vicinity of marinas. However, these authors noted that the highest levels occurred in the cooler months, at a time when lipids and glycogen reserves were accumulating in the oysters in preparation for spawning.

Elevated PAH concentrations are often detected in the hepatopancreas of crabs collected in the vicinity of PAH sources, but concentrations in muscle tissue of crabs are usually much lower. PAHs were identified in the muscle and hepatopancreas of two crab species collected from nearshore and offshore in Newfoundland, with the highest concentrations occurring in the hepatopancreas. Phenanthrene was the predominant compound detected in both species (120 to 560 ng/g dry weight in the hepatopancreas; 40 to 55 ng/g in the muscle). Alkylated phenanthrenes, benzo[a]anthracene and chrysene were also detected in the hepatopancreas. The lower molecular weight compounds, fluoranthene and pyrene, were not detected despite the fact that these compounds were present in the sediments (Hellou *et al*, 1994). In comparison, blue crabs from the Elizabeth River in Virginia (Mothershead *et al*, 1991) contained 2,600 to 24,000 ng/g (dry weight) of total PAH in the hepatopancreas and 300 to 4,100 ng/g in the muscle. Newly molted blue crab from the Elizabeth River had higher PAH concentrations than did intermolt crab (Mothershead and Hale, 1992). Winger *et al* (1990) reported that whole body concentrations in crab from the lower Savannah River, Georgia and South Carolina ranged from below detection to 50 ng/g (wet weight). Kayal and Connell (1989a) reported that the soft tissues of crabs from the

Brisbane Estuary in Australia contained 55.5 to 123.1 ng/g of total PAH (mean of 93.1 ng/g wet weight). They concluded that, unlike fish, tissue lipid content was not the primary factor in determining PAH concentrations in crab.

Uthe and Musial (1988) concluded that lobsters can accumulate high concentrations of PAHs because they have a limited capacity to metabolize these compounds. In Sydney Harbour, Nova Scotia the presence of total PAH concentrations ranging from 23 to 1,000 ng/g (wet weight) resulted in a closure for lobster fishing in this area (Sirota *et al*, 1983). Lobsters collected in Nova Scotia, from an area contaminated with creosote, contained 750 to 22,500 ng/g in the hepatopancreas and 25 to 2,500 ng/g in the tail muscle (wet weight) (Uthe and Musial, 1986). The hepatopancreas of lobster collected near a coal coking plant in Sydney harbour in Nova Scotia contained an estimated 80 PAH compounds and halogenated aromatic compounds (HACs), most of them alkylated. Some of the compounds were suspected carcinogens including benzo[c]phenanthrene, 7-methylbenz[a]anthracene, 5-methylchrysene, benzo[a]fluoranthene, benzo[b]chrysene, and dibenzanthracenes. The benzoquinolines were also present at high levels. Alkylated phenanthrenes and alkylated fluorenes, which are suspected mutagens, were also present at significant levels (King *et al*, 1993).

Dunn and Fee (1979) reported on PAH carcinogens in commercial seafood from 15 countries. PAHs were detected in most shellfish species sampled, however, samples of fish did not contain detectable concentrations. Concentrations were less than 10 ng/g wet weight in most shellfish samples, but higher levels (up to 36 ng/g) were occasionally detected. Crab and shrimp muscle samples contained little or no benzo[a]pyrene (ND to 0.5 ng/g), however, concentrations in the tail muscle of commercial lobsters were variable (0.8 to 7.9 ng/g). Freshly caught lobsters contained less than 1 ng/g benzo[a]pyrene. Lobsters which had been kept alive for three months in a commercial tidal pond made of creosoted timber, were also examined. These lobsters contained elevated concentrations of a number of carcinogenic or tumour-promoting PAHs including benzo[a]pyrene, chrysene, benzo[a]anthracene, benzo[b]fluoranthene, dibenz[a,h]anthracene and indeno[1,2,3-c,d]pyrene. Benzo[a]pyrene concentrations of up to 2,300 ng/g in hepatopancreas and 281 ng/g in edible tail meat were reported.

2.3.1.2.2 Fish

PAH concentrations are usually low in fish tissues, compared to levels detected in bivalves from the same area, due to their ability to rapidly metabolize these compounds (Amodio-Cocchieri *et al*, 1993; Amodio-Cocchieri *et al*, 1990). For this reason, the determination of PAH concentrations in fish tissues is not considered to be an accurate reflection of PAH exposure.

Benzo[a]pyrene and phenanthrene concentrations in bullheads from the highly contaminated Black and Buffalo Rivers in the United States, were 1 and 26 ng/g, respectively. These levels are between 100 and 1000 times lower than the concentrations of these

compounds in the sediments collected from these rivers (MacCubbin *et al*, 1988). PAH concentrations were usually less than the detection limit (<15 to <45 ng/g dry weight) in the liver and muscle tissue of English sole collected from both urban and non-urban regions within Puget Sound in Washington State. PAHs (primarily benzothiophene, dibenzothiophene, pyrene and chrysene) were detected in a limited number of English sole and rock sole livers. In contaminated areas of Puget Sound, PAH compounds were detected in the muscle of some fish but these compounds were normally the low molecular weight non-carcinogenic compounds (naphthalene; 1-, 2-methylnaphthalene; acenaphthene; 2,6-dimethylnaphthalene). Eagle Harbour is highly contaminated with creosote and English sole collected from this area contained detectable concentrations of PAH compounds in the liver tissue. LMW compounds (primarily naphthalene compounds) were present at higher concentrations (7 to 103 ng/g wet weight) than were the HMW compounds (38 to 39 ng/g). The HMW compounds detected included fluorene, phenanthrene, fluoranthene, perylene and benzo[e]pyrene. Benz[a]pyrene was not detected in any samples (Malins *et al*, 1980; Malins *et al*, 1984; Malins *et al*, 1985; Malins *et al*, 1988; Varanasi and Stein, 1991; Varanasi *et al*, 1987;). Muscle tissue of several recreational sport fish species collected from Puget Sound contained total PAH concentrations ranging from less than 1 to 32 ng/g wet weight (as measured by HPLC) (Landolt *et al*, 1985).

Raino *et al* (1986) reported that fish from the Finnish Archipelago Sea contained only a few of the 14 PAH compounds analyzed for. Fluoranthene and pyrene were detected in only one third of the herring samples. Low levels (<0.5 to 27 ng/g wet weight) of fluoranthene, pyrene, phenanthrene, chrysene and compounds of the benzo[a]anthracene/chrysene/triphenylene group were detected in the muscle tissue of some fish. Benzo[a]pyrene was not detected. In addition to the compounds detected in muscle tissue, naphthalene was detected in the liver and gallbladder of some fish. Elevated total PAH concentrations were detected in the liver (118 to 445 ng/g) and gallbladder (237 to 313 ng/g) of pike, perch and burbot from the Finnish Archipelago Sea. Phenanthrene and fluoranthene were especially elevated in these organs.

PAH concentrations detected in organs such as the liver and the gall bladder are normally much higher than in the edible tissue. Fish accumulate PAH compounds primarily in the gallbladder and the liver with lower concentrations occurring in the gonads, viscera, brain and muscle (Spacie *et al*, 1983; Balk *et al*, 1984). PAHs have also been detected in fish eggs (Hall and Oris, 1991; Kuhnhold and Busch, 1978).

In highly industrialized regions, elevated PAH concentrations have been detected in the edible tissues of some fish species. Humason and Gadbois (1982) detected total PAH concentrations of 62 to 536 ng/g wet weight in the edible portions of winter flounder, windowpane and red hake from the New York Bight area of New Jersey. Phenanthrene was detected at the highest concentrations (50 to 200 ng/g range). Benzo[a]pyrene was present at concentrations ranging from 2 to 22 ng/g. Several other carcinogenic compounds were detected at lower concentrations including benzo[b]fluoranthene, benzo[a]anthracene, and chrysene.

The muscle tissue of fish collected from the Gulf of Naples contained total PAH concentrations of 94 to 1,930 ng/g wet weight, with anchovy, bogue and common sole containing the highest concentrations. The distribution of PAHs and the relative concentrations were variable in fish. A wide variety of both LMW and HMW compounds were detected and the predominant compounds were benzo[a]anthracene and benzofluoranthenes. Benzo[a]pyrene was detected in 11 of the 14 fish species tested with concentrations ranging from 3 to 44 ng/g wet weight. Sediments from this region contained primarily fluoranthene, chrysene, benzo[a]anthracene and phenanthrene (Amodio-Cocchieri *et al*, 1990). Total PAH concentrations in fish from the Ionian Sea in Italy ranged from 22 to 580 ng/g. Phenanthrene and anthracene were the compounds detected most frequently, however, the concentrations of these compounds were low (13 to 17 ng/g). Benzo[a]pyrene was present in 16% of the samples tested with concentrations ranging from 5 to 79 ng/g (average of 17 ng/g) (Amodio-Cocchieri *et al*, 1990). .

Whole body PAH concentrations in various fish species collected from the Savannah River in the southern United States ranged from less than the detection limit to 150 ng/g wet weight. Phenanthrene was present in the highest concentrations (up to 70 ng/g) (Winger *et al*, 1990).

Kayal and Connell (1989a) reported that mean total PAH concentrations in the muscle tissue of bony bream, blue catfish and sea mullett from the Brisbane River Estuary in Australia were 118.3, 94, and 137.3 ng/g wet weight, respectively. Lower molecular weight compounds appeared to be preferentially accumulated compared to the higher molecular weight compounds. The authors concluded that the tissue lipid content was the primary factor in determining PAH concentrations in fish species. Trophic level, size and age of the fish were not considered to be important factors. Other researchers reported that lipid content is an important factor in determining PAH uptake in fish. Black *et al* (1980) suggested that the higher lipid content in brown trout (2.11 % lipid) accounted for the higher PAH content in this species compared to bottom-feeding white suckers (0.18% lipid) from the same river. Akpan *et al* (1994) also reported that there was a positive correlation between the concentrations of carcinogenic compounds in fish and the lipid content in the tissues.

Hellou and Warren (1997) reported that flatfish (American plaice and yellowtail flounder) collected from the Northwest Atlantic contained a broader range of PACs (parental and alkylated PAHs and sulphur heterocycles) in the liver than in the gonad or the muscle tissue. Ratios of parental to alkylated compounds varied with the species, tissue, sampling location and season. The level of alkylated compounds in the liver showed a greater correlation with lipid content than did the parent compounds. Naphthalene was the predominant compound in all samples.

The authors also noted that smaller American plaice contained higher concentrations of PAHs in the muscle tissue than did the larger individuals, indicating that differences may exist between the uptake, elimination and/or metabolism rates between younger and mature fish (Hellou and Warren, 1997). Stronkhorst (1992) reported on trends of various chemical contaminants in flounder from two Dutch estuaries. No linear trend was

detected for PAH concentrations in either estuary, however, it was observed that PAH concentrations in the liver of flounders decreased with increasing size of fish.

2.3.2 Concentrations in the British Columbia Environment

Data on PAH concentrations in the British Columbia environment, obtained from Environment Canada sampling programs conducted by Garrett and Shrimpton between 1984 and 1992, are presented in Appendix 5. Associated quality control information is presented in Appendix 4. Sampling station coordinates are listed in Appendix 2 and site maps are located at the end of this report (pages 243 to 258). Sample characteristics information for sediments (particle size, SFR, SVR) and biota (size, sex, number of individuals, moisture content, lipid content) is located in Appendix 3. Sampling and analytical methodologies are summarized in Appendix 1.

2.3.2.1 Surface Waters and Sediments

Environment Canada surveys did not measure PAH concentrations in surface waters of British Columbia, and information available from other sources is very limited. According to the 1996 Fraser River Estuary Environmental Quality Report, water samples collected in six sloughs in the Fraser River in 1993/94 contained detectable concentrations of PAHs. The most commonly detected low molecular weight (LMW) compounds were naphthalene and phenanthrene, and the most commonly detected high molecular weight (HMW) compounds were pyrene and benzo[a]anthracene. The highest concentrations of total PAHs were detected in Gundersen Slough (average of 900 ng/L; range of 300 to 1,600 ng/L). Water samples from the other five sloughs contained from 300 to 700 ng/L total PAHs. The higher PAH concentrations in Gundersen Slough were attributed to inputs from surface runoff and leaching from creosote pilings (FREMP, 1996).

Environment Canada surveys conducted in the late 1980's and early 1990's revealed high PAH concentrations in sediments from False Creek and from Vancouver, Victoria, and Esquimalt harbours. Elevated PAH concentrations were also detected in the vicinity of some wood preservation facilities on the Fraser River. Data presented in Appendix 5.1 on a dry weight basis where obtained from surveys conducted by Garrett and Shrimpton. All sediment data are presented on a dry weight basis. Additional information on PAH concentrations in Vancouver Harbour is presented in other Environment Canada reports (Goyette and Boyd, 1989; Goyette, 1991; Goyette, 1994; Boyd and Goyette, 1993).

Environment Canada sampling in 1990 detected elevated PAH levels in sediments collected off wood preservation facilities on the lower Fraser River (Map 3) (Garrett and Shrimpton, 1992). Total PAH concentrations (5,679 to 19,834 ng/g) were particularly high in the vicinity of the old Kopper's International site in Burnaby, which used creosote from the 1930's until the plant closed in 1981. Total PAH concentrations of 861 to 3,175 ng/g

were detected in the vicinity of Domtar Wood Preservers in New Westminster, which has used creosote from the 1930's up to the present, and also at the Domtar/Liverpool facility (7 to 406 ng/g). Creosote was not used at the Domtar/Liverpool location but was stored in large tanks and transferred from ships and barges to rail cars. This facility was decommissioned in the early 1980's. PAHs were also detected in sediments at Princeton Wood Preservers in Surrey (111 to 407 ng/g) and B.C. Cleanwood Preservers in Surrey (79 to 3,643 ng/g), however, creosote has not been used at these sites. B.C. Cleanwood Preservers is located on Gundersen Slough, where elevated PAH concentrations have also been detected in surface water samples (FREMP, 1996). Gundersen Slough is a backwater area in the Main Arm of the Fraser River near Annacis Island. The accumulation of elevated concentrations in sloughs was expected as the flushing in these areas is lower than in the open areas of river. The PAH concentrations near Princeton Wood Preservers were not elevated in comparison to concentrations detected in many other areas of the Fraser River.

Swain and Walton (1993) measured PAH concentrations in sediments from several areas of the Fraser River in 1992. North Arm sites included Scott Paper (52 to 118 ng/g), Domtar Paperboard (737 to 869 ng/g), Eburne Slough (449 to 1,384 ng/g), McDonald Beach Boat Launch (569 ng/g), Celtic Boat Yard (568 to 750 ng/g), a blind channel on the south side (located about three kilometres downstream from New Westminster) (198 ng/g), and McDonald Slough (1,106 ng/g). Main Arm sites were Annacis Channel (91 to 260 ng/g), Ewen Slough (351 ng/g), Deas Slough (28 to 1,993 ng/g), a backwater area near the B.C. Ferries refit/servicing operation (941 to 1,706 ng/g), and Ladner Slough (158 to 2,833 ng/g). Likely sources in the Deas Slough and Ladner Slough areas included stormwater runoff and the many boats moored at these sites. Main Stem sites included Barnston Island (50 ng/g) and Sapperton Channel (177 ng/g). Middle Arm sediments were collected from a ditch on the South Terminal of the Vancouver Airport (west of Dinsmore Bridge) and from the Fraser River at the point where the ditch discharged. The ditch received drainage from a South Terminal machine shop. PAH concentrations in these sediments were 8,221 ng/g and 885 ng/g, respectively.

Swain and Walton (1993) concluded that, while PAH levels at most sites were low, PAH contamination in the lower end of the North Arm was widespread at concentrations which may be of concern. The higher concentrations detected in this area were attributed to the large volumes of stormwater that discharge to the North Arm. Of particular concern were the elevated concentrations of benzo[g,h,i]perylene, fluoranthene, indeno[1,2,3-c,d]pyrene, and phenanthrene) at McDonald Slough. Other PAHs present at concentrations which may be of concern at some sites were: fluoranthene, fluorene, and phenanthrene at Eburne Slough; phenanthrene, indeno[1,2,3-c,d]pyrene, and benzo[g,h,i]perylene at Deas Slough; fluoranthene, phenanthrene, and pyrene at B.C. Ferries; and acenaphthene, chrysene, fluoranthene, phenanthrene, and pyrene at Ladner Slough. The authors noted that the time of sampling for PAHs in the river was an important factor as PAH concentrations were lower in sediments collected following freshet in 1989 and 1990.

According to the 1996 Fraser River Estuary Environmental Quality Report (FREMP, 1996), PAH compounds such as pyrene, fluoranthene, phenanthrene and

benzo[a]anthracene, frequently exceeded Interim Canadian Sediment Quality Guidelines (ISQGs) for the protection of aquatic life. However, concentrations were below the probable effects levels (refer to Section 3; Table 6). The report concluded that existing information was too limited to determine whether PAH concentrations in the Fraser River sediments were increasing or decreasing. Stormwater transport of vehicular PAH emissions was identified as a primary source of PAHs to the estuary (FREMP, 1996).

Kooi (1996) reported that combined sewer overflows discharging to the Fraser River in 1994/95 commonly contained detectable concentrations of several PAH compounds including: benzo[a]pyrene; methyl-, dimethyl- and trimethylnaphthalenes; benzo[b]fluoranthene; fluoranthene; methyl- and dimethylphenanthrene. It was estimated that the annual PAH loading to the Fraser River Basin from urban runoff was 502 kg.

Sekela *et al* (1995) detected PAHs in suspended sediments collected upstream and downstream of six pulp mills in the Fraser Basin. Samples collected in the Fraser River at Shelley, Woodpecker, Marguerite, and Yale between 1992 and 1994 contained PAH concentrations ranging from 75 to 393 ng/g. Suspended sediments collected at McLure and Savona on the Thompson River contained PAH concentrations ranging from 134 to 2,287 ng/g, with the highest concentrations at Savona. Perylene, a natural PAH derived from terrestrial plant sources, was the predominant compound in samples from all sites, with the exception of Savona. On both the Thompson and the Fraser rivers, PAHs were generally found at higher concentrations downstream from pulp and paper mills than at reference sites located upstream of the mills. The authors noted that concentrations were generally higher during winter base flow periods compared to fall low flow periods. Partitioning of PAHs between the sediment and water was highly variable and appeared to be influenced by both sampling time and individual compound solubility.

Limited sampling of sediments from the Fraser River Estuary near the Iona Island sewage treatment plant by Environment Canada in 1985 and 1987 revealed total PAH concentrations of 200 to 700 ng/g (Map 3) (Garrett and Shrimpton, 1992). Harding *et al* (1988) detected concentrations of 166 to 177 ng/g PAH in sediments from the estuary region and less than 100 ng/g in sediments from Roberts Bank and Sturgeon Bank. Fanning *et al* (1989) reported that total PAH concentrations in the estuary region were less than the levels of detection (40 to 120 ng/g). Dunn and Stich (1976) observed higher benzo[a]pyrene concentrations at stations closest to the sewage treatment plant outfall and suggested that the treatment plant was the major source of benzo[a]pyrene to the Fraser River Estuary.

Swain and Walton (1994) reported that PAH concentrations in sediment samples collected from an offshore site in Boundary Bay (in the centre of the Bay near the international border) in 1993 were below the water quality objectives for Burrard Inlet (refer to Section 3; Table 4). The concentrations of some individual PAHs in the inshore (off Crescent Beach) sample slightly exceeded the long-term water quality objectives for Burrard Inlet. In addition, the concentrations of benzo(a)anthracene, fluoranthene, fluorene, and phenanthrene at this site exceeded the Canadian Interim Sediment Quality Guidelines (ISQGs) but were lower than the PEL values (Section 3; Table 6).

Historical sources of PAHs to False Creek included fuel combustion and spillage; coal use; and discharges from sawmills, wood preservation operations, shingle mills, and other industrial facilities. The east basin of False Creek was the site of most of the industrial activity, and coal gasification facilities which operated in this area from the late 1800's until the 1950's were a major PAH source. Current sources of PAHs to False Creek include leaching from creosoted pilings, surface runoff and contaminated groundwater, storm sewers, boat traffic, and atmospheric deposition. A study conducted for Environment Canada in 1992 identified several combined sewer overflows (CSOs) discharging into False Creek. CSOs discharging to the south shore of False Creek were located off Terminal Avenue in the east basin, off the Crow Street Yard just east of the Cambie Street Bridge, off Heather Street near the marina east of Monk McQueen's, off Laurel Street (about half way between the Cambie Bridge and Granville Island, and off Hemlock Street near the Granville Street Bridge. The CSO discharges to north shore of False Creek include Jervis Street (into the outer creek area), Granville Street (under the bridge), and Drake Street (west of the Cambie Street Bridge) (Environment Canada, 1992).

High PAH concentrations were detected throughout False Creek (Map 2) in the late 1980's and early 1990's. The highest levels of contamination were observed in the northeast portion and were likely associated with the historic operation of coal gasification plants and other industrial facilities in the east basin. Total PAH concentrations ranging from 26,377 to 49,250 ng/g were detected in this area, compared to levels between 10,000 and 20,000 ng/g in other areas of False Creek. Lower levels were detected in sediments collected from the outer creek area (2,316 to 4,254 ng/g) (Garrett and Shrimpton, 1992). Goyette and Boyd (1989) detected a total PAH concentration of 17,000 ng/g in sediments from the east basin in 1988 and 80,180 ng/g in 1991 (Boyd and Goyette, 1993). According to these authors, GVRD studies detected concentrations of over 330,000 ng/g in this area. Boyd and Goyette (1993) reported total PAH concentrations ranging from 3,140 to 11,870 ng/g in sediments collected from other areas within False Creek in 1991. Boyd *et al* (1998) reported that sediments collected off Monk McQueen's in False Creek in 1995 contained 16,227 ng/g total PAHs.

Past and present sources of PAHs to B.C. harbours are numerous and include fuel combustion and spillage, boat and ship traffic, marinas, industrial discharges and waste disposal, surface runoff, leaching from creosoted pilings, storm sewers, and atmospheric deposition.

Sediments collected from marinas in the Coal Harbour area of Vancouver Harbour contained high PAH concentrations (Map 1). Much of the Coal Harbour shoreline is currently undergoing re-development. However, numerous industries were located in this area in the past including shipbuilding and repair facilities, foundries, metal working operations, lumber operations, fuel transfer facilities, and a tank farm. Numerous marinas are currently located along much of the shoreline, especially adjacent to the Bayshore Inn and the Royal Vancouver Yacht Club. Floating fuel stations for boats are also located in Coal Harbour. Concentrations of several thousand ng/g (>5,000 ng/g) were present in sediments at the

Bayshore Inn Marina, in 1991, and the Royal Vancouver Yacht Club (RVYC), in 1988 and 1991 (1600 to >9,130 ng/g) (Garrett and Shrimpton, 1992). Goyette and Boyd (1989) also reported 13,300 ng/g PAHs in sediments collected from RVYC marina in 1988, and >30,000 ng/g total PAHs were detected in sediments collected near the Bayshore Marina in 1993 (Fanning *et al*, 1989). Boyd and Goyette (1993) reported total PAH concentrations of 11,780 to 117,380 ng/g in Coal Harbour sediments collected in 1991.

High concentrations of PAHs were present in sediments collected in the vicinity of several shipyards and commercial docks in Vancouver Harbour (Maps 4 to 9). The highest concentrations were detected at shipbuilding and repair facilities; Vancouver Shipyards (up to 85,614 ng/g dry weight), Versatile Pacific (up to 41,321 ng/g), Allied Shipyards (up to 114,880 ng/g), Rivtow (101,375 ng/g), Sterling Shipyard/B.C Marine Shipbuilding (up to 402,530 ng/g), Belaire Shipyards (up to 11,100) and Menchion's Shipyard (28,400 ng/g) (Garrett and Shrimpton, 1992). These concentrations were detected in the 1980's when many of the facilities were still in operation (or shortly after closure). With the exception of Allied Shipyards and Vancouver Shipyards, these shipyards have been closed for a number of years and, in many cases, the sites are being re-developed.

Elevated PAH concentrations were also detected at several commercial docks and loading facilities in Vancouver Harbour including Vancouver Wharves (up to 11,661 ng/g), Neptune Terminals (up to 8,200 ng/g), Seaboard Terminals (up to 13, 390 ng/g), Lynnterm (up to 3,712 ng/g), Vanterm (up to 2,256 ng/g), Centerm (up to 2,112 ng/g), Canada Place (up to 8,607 ng/g), United Grain Growers (5,087 ng/g), and Saskatchewan Wheat Pool (up to 6,068 ng/g) (Garrett and Shrimpton, 1992).

Sediments collected near the old L&K Lumber site contained up to12,240 ng/g of total PAHs (Garrett and Shrimpton, 1992). L&K Lumber operated a lumber operation adjacent to Vancouver Wharves from 1926 until 1984 and used pentachlorophenol for wood preservation. There is no record of creosote use at this facility. High PAH concentrations were also detected in sediments collected at the Rivtow site (up to 101,375 ng/g) located northeast of the old Sterling Shipyards site on the south shore of Vancouver Harbour (Garrett and Shrimpton, 1992).

Goyette and Boyd (1989) also reported concentrations of several thousand ng/g PAHs in sediments collected from Vancouver Harbour in the 1980's. Total PAH concentrations in sediments collected at L&K Lumber, Vancouver Wharves, Sterling Shipyards/B.C. Marine Shipbuilders and off the Clark Drive combined sewer overflow (located between United Grain Growers and Vanterm) ranged from 2,620 to 12,240 ng/g, 1,030 to 7,460 ng/g, 4,870 to 9,530 ng/g and 4,970 to17,420 ng/g, respectively. High PAH concentrations were also detected in sediments near Menchion's Shipyard (21,200 ng/g).

High PAH concentrations were also detected in sediments collected from Port Moody Arm in the vicinity of the Ioco petroleum refinery (4,040 to 36,730 ng/g). In January 1991, sediments collected nearshore at the Ioco refinery at Port Moody were about 22,000 to 24,000 ng/g, however, by September 1991 and 1992 the PAH concentration in sediments at

this location had declined to approximately 5,000 ng/g. This decline was attributed to the fact that the process effluent from the refinery, which had been discharged to Port Moody Arm, was re-directed to the Greater Vancouver Regional District sewer system in 1989 (Goyette, 1994).

Boyd and Goyette (1993) reported that total PAH concentrations ranged from 350 ng/g (Indian Arm) to 57,950 ng/g (Vancouver Shipyards) in sediments collected from the Inner Harbour, Central Harbour, Port Moody Arm and Indian Arm regions of Vancouver Harbour in1991. Sediment collected in the vicinity of the old Menchion's Shipyard site in Coal Harbour contained the highest PAH concentration (117,380 ng/g). This level was higher than those reported by Boyd and Goyette (1993) and Garrett and Shrimpton (1992) for this area in the 1980's (21,200 and 28,400 ng/g, respectively). Boyd *et al* (1998) reported that mean total PAH concentrations in sediments collected from 14 stations in Vancouver Harbour in 1995 ranged from 706 ng/g (Indian Arm) to 8,003 ng/g in Port Moody Arm.

In many cases, the PAH contamination in nearshore sediments may not be associated with the current operations at that site. Historical reviews of land use on the shores of Vancouver Harbour indicated a diverse range of industrial activities since the early 1900's. For example, the elevated PAH concentrations detected at the Vancouver Shipyards site may be associated mainly with the historic operation of a wood-preserving plant which utilized creosote at that location between 1926 and 1965. Similarly, multiple potential sources can be present in close proximity. High PAH concentrations have been detected in sediments in the vicinity of Sterling Shipyards and B.C. Marine Shipbuilders. However, the Victoria Drive combined sewer overflow (CSO) discharges to Vancouver Harbour between these two facilities. Sediments collected at the sewer overflow in 1992 contained PAH concentrations of 37,700 ng/g (Goyette and Wagenaar, 1995). A CSO also discharges off Clarke Drive between United Grain Growers and Vanterm. Elevated PAH concentrations have been detected in sediments from the vicinity of both of these facilities. Combined sewer overflows located at these sites and elsewhere in Vancouver likely make significant contributions to PAH concentrations in nearshore areas. A report prepared for Environment Canada in 1992 identified 53 untreated combined sewer overflows (CSOs) discharging to Burrard Inlet (Vancouver Harbour (south shore only), False Creek and English Bay). In addition to Victoria Drive and Clarke Drive CSOs, other sewers which discharged in the vicinity of identified areas of PAH contamination include those located in Coal Harbour off Denman Street (adjacent to the Bayshore Inn), off Burrard Street near Canada Place, and off Heatley Street and Hawks Street near Centennial and Ballantyne Piers, and off Columbia Street near Centerm. CSO discharges entering Vancouver Harbour from the north shore were not identified in this study (Environment Canada, 1992).

Goyette and Wagenaar (1995) detected elevated PAH concentrations in sediments collected at combined sewer overflows in Vancouver Harbour. Sediments collected near the Clark Drive, Victoria Drive, and Denman Street (Coal Harbour) discharges in 1992 contained 10,300, 37,300, and 7,600 ng/g total PAHs, respectively. The bulk of the PAH was associated with the solid phase of the discharge rather than the liquid portion of the effluent.

PAH concentrations exceeding 10,000 ng/g were detected in sediments collected throughout Victoria Harbour in the early 1990's. The highest concentrations (>20,000 to >30,000 ng/g) were detected at the Boatbuilding Facility, the old Smith Cedar Products site, and Rock Bay in the Upper Harbour, and near B.C. Steamships in the Inner Harbour (Maps 10a and b) (Garrett and Shrimpton, 1992).

Very high concentrations of PAHs were also detected in Esquimalt Harbour (Map 11) with the highest concentrations (up to 63,250 ng/g) occurring in sediments collected off the Department of National Defence (DND) facility at Constance Cove. Sediments from all sites in this vicinity contained greater than 10,000 ng/g and several contained between 20,000 and 30,000 ng/g. Sediments collected in the vicinity of DND facilities at Dunn's Nook, on the west shore of Esquimalt Harbour, contained over 10,000 ng/g (Garrett and Shrimpton, 1992). Dunn's Nook is the site of DND's D-jetty and F-jetty (a fuel oil jetty). DND ship repair activities have also been conducted at this location. According to Bright and Reimer (1993), sediments dredged from this area in 1986 were highly contaminated and disposal posed a problem. The sediments were deposited on DND land in Colwood and were later transferred to a secure storage facility in 1992.

Sediments from the Plumper Bay area (north of Constance Cove) contained lower levels of PAH contamination (1,579 to 6,589 ng/g) (Garrett and Shrimpton, 1992). Historical activity in the Plumper Bay area included sawmill operations, oil tanks and wharves. Sediment samples from the relatively undeveloped Upper Harbour area and from Fort Rodd (southwestern shore of the harbour) contained lower levels of PAH contamination (143 ng/g and 313 ng/g, respectively).

Sediment monitoring was also conducted in Esquimalt Harbour by Bright *et al* (1993) in the early 1990's. PAH concentrations were comparable to those detected during Environment Canada surveys, with total PAH concentrations ranging from (380 to 103,000 ng/g). In addition, these authors noted that sediments collected from offshore and center channel stations in the harbour contained lower PAH concentrations than those collected from nearshore areas. However, all sites contained elevated PAH concentrations relative to the reference site at Parry Bay (180 ng/g), which is located approximately 15 km south of Esquimalt Harbour and is relatively free of direct industrial and urban sources of contamination.

Much lower PAH concentrations were detected in sediments from the less urbanized and industrialized Ladysmith Harbour. Concentrations of total PAHs ranged from 44 to 2,083 ng/g (Map 12) (Garrett and Shrimpton, 1992).

PAH concentrations in sediments collected from reference sites (Maps 13 and 14) were very low (0.4 to 83 ng/g dry weight) in comparison to concentrations detected in sediments from urban/industrialized areas.

PAH concentrations in sediments collected from many nearshore sites in False Creek and Vancouver, Victoria, and Esquimalt harbours in the late 1980's and early 1990's greatly exceeded the Interim Canadian Sediment Quality Guidelines and probable effects levels (PELs) summarized in Section 3; Table 6. In some cases, the concentrations of individual PAH compounds were more than 10 fold higher than their PELs. PEL is defined as the level above which adverse effects are expected to occur frequently. Consequently, PAH concentrations at several locations in these regions were high enough to cause adverse environmental impacts, depending on local environmental conditions. ISQGs alone can not be used to accurately predict adverse effects on aquatic species, however, as many factors affect the bioavailability and toxicity of PAH compounds. Site specific considerations must be taken into consideration.

At some of the sites where high PAH contamination was detected by Environment Canada surveys in the late 1980's and early 1990's, more recent information on PAH levels in sediments is not available and it is not known whether current levels exceed the ISQGs. Attempts to determine changes in sediment PAH concentrations over time can be difficult due to a number of factors. The heterogeneity of the bottom sediments can cause PAH concentrations to vary widely in samples collected within metres of each other. In addition, attempts to obtain samples from the same station can be confounded by boat movement during sampling, changing shorelines as a result of new developments, and the absence of clear fixed markers on shore. Repeat sampling of sites can be especially difficult in harbours as access to sampling stations is often obstructed by the presence of large ships. As a result, variations in the location of sampling stations occurs between surveys. In addition, past dredging activity is an important factor to consider when assessing concentrations of contaminants in sediments over time. A complete dredging history for many sites was not available.

However, at many of the facilities located in Vancouver Harbour, environmental site assessments have been, or are being, conducted as a requirement to obtain approval for site modifications or re-development of the property shoreline. Site assessment reports are reviewed by provincial and federal regulatory agencies to determine whether site remediation is required prior to re-development.

Under B.C. Ministry of Environment's Criteria for Managing Contaminated Sediment in British Columbia (refer to Section 3.5), the current remedial objective for sediments is the average effects level (AEL), which is an average of the threshold effects level (TEL) and the probable effects level (PEL). The AEL is approximately equal to the EC_{20}. Sediments which are below the AEL do not require remediation. The PAH criteria used for assessing freshwater and marine/estuarine sediment sites are listed in Tables 11 and 12, respectively. At sites where the concentrations of PAH compounds and/or other contaminants exceed the provincial remedial objectives for contaminated sites, sediments may be removed to meet the AEL objective or sediment toxicity tests may be conducted to ensure that the levels of contamination will not impact aquatic life.

Site assessments are complete or in progress for Vancouver Wharves/L&K Lumber, Vancouver Shipyards/Seaspan, Versatile Pacific, B.C. Marine Shipbuilders/Rivtow, Coal Harbour, and parts of False Creek. Remedial action will be taken where considered necessary by regulatory agencies.

Similarly, the Ministry of Transport is currently in the process of conducting environmental baseline studies for contaminated shoreline sites throughout Victoria Harbour and Esquimalt Harbour. Where required, remediation and risk management actions will be undertaken.

The relative proportions of PAH compounds in British Columbia sediments are shown in Appendix 5.1. At virtually all locations sampled during Environment Canada surveys, the higher molecular weight compounds comprised the bulk of the total PAHs detected in sediment samples (greater than 80% at most sites) (Garrett and Shrimpton, 1992). Exceptions were Vancouver Wharves (37% HMW compounds), where high proportions of LMW compounds phenanthrene (25%) and fluorene (20%) were present, and Koppers International, where naphthalene contributed up to 32% of the total PAH concentration. The higher molecular weight compounds, fluoranthene, pyrene, and benzofluoranthenes, were present at the highest concentrations in all areas. Other high molecular weight PAH compounds commonly detected in sediments were chrysene, benzo[a]anthracene, benzo[e]pyrene, benzo[a]pyrene, and indeno[1,2.3-c,d]pyrene. Of the lower molecular weight PAH compounds, phenanthrene made the largest contribution to the total PAH content in sediments (Garrett and Shrimpton, 1992). Similar findings were observed in sediments collected in Vancouver Harbour by Goyette and Boyd (1989) in the 1980's.

Mean percent contributions of individual PAH compounds in sediment samples from coastal areas of B.C. are summarized in Table 1 and Figures 1 and 2. The percent contributions of the various individual PAH compounds were quite consistent throughout all B.C. coastal areas sampled. There was a predominance of the high molecular weight four and five ring compounds combined with a significant contribution from phenanthrene. This indicates a combination of sources including combustion and weathered petroleum. In addition, a limited number of samples collected from Vancouver Harbour in the early 1990's were analyzed for alkylated PAH compounds and were found to contain higher levels of the alkylated forms of naphthalene and phenanthrene/anthracene than the parent compounds. In addition, dibenzothiophenes were also detected (Goyette and Boyd, unpublished). Both of these findings indicate the presence of a petroleum source.

The Fraser River and estuary and Ladysmith Harbour sediment samples contained a higher proportion of naphthalene than did sediment samples from other locations, suggesting a fresh petroleum source at these sites. Similarly, a diagenetic source was suggested by the higher proportion of perylene in the Fraser River and estuary stations than at other sites. The presence of perylene in Fraser River sediments was also reported by Sekela *et al* (1995).

Yunker *et al* (in preparation) examined surface sediments, suspended particulates, and sediment cores from the Fraser River, Fraser basin lakes and the Strait of Georgia. They reported that the sediments from lakes nearest to large population centres indicated a combustion PAH source, likely atmospheric deposition of fuel-combustion products from Greater Vancouver. Sediments throughout the Fraser River revealed petroleum inputs, with the presence of retene at some sites indicating inputs from pulp mills, logging, road building, or wood combustion. Although an obvious influence of the Fraser River on Strait of Georgia sediments was observed, the PAH concentrations in the surface sediments from the Strait of Georgia were much higher than in the older sediments from the Fraser River system. This suggests contributions from other local sources such as the Point Roberts coal superport, municipal wastewater treatment plants and stormwater runoff. Sediments collected northward in the Strait of Georgia, towards Vancouver Harbour, showed a greater influence of combustion. Vancouver Harbour sediments contained the highest PAH contamination due to the numerous sources, however, PAH concentrations exceeded the provincial or federal sediment quality guidelines in Kamloops Lake, at most sampling sites in the Fraser River estuary and in Vancouver Harbour, and in sediment cores from the Strait of Georgia.

Table 1: Mean Percent Contributions of Individual PAH Compounds in Sediments from Coastal British Columbia
mean (range)

Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-thracene	Fluorene	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene
Fraser Estuary	7.5 (7 - 8)	0 (0 - 0)	0 (0 - 0)	0 (0 - 0)	14 (14 - 14)	1 (0 - 2)	11 (10 - 12)	12 (12 - 12)	10 (9 - 10)	7 (6 - 7)	11 (8 - 14)	5 (5 - 5)	3 (0 - 5)	0 (0 - 0)	4 (4 - 4)	ND	17 (16 - 17)
Fraser River (off wood preservation facilities)	7.9 (0 - 32)	0 (0 - 2)	3 (1 - 10)	3 (1 - 19)	16 (8 - 26)	5 (0 - 10)	19 (11 - 28)	13 (9 - 24)	6 (0 - 8)	5 (0 - 6)	8 (0 - 14)	2 (0 - 7)	2 (0 - 6)	0 (0 - 1)	2 (0 - 6)	3 (0 - 6)	9 (0 - 24)
False Creek	3 (1 - 7)	2 (0 - 3)	1 (0 - 2)	3 (2 - 5)	8 (5 - 15)	2 (1 - 3)	14 (10 - 23)	16 (12 - 20)	9 (5 - 15)	8 (4 - 11)	12 (8 - 14)	8 (5 - 11)	4 (3 - 7)	1 (1 - 2)	5 (3 - 6)	5 (4 - 7)	2 (1 - 3)
Vancouver Harbour (outer)	4	0	8	2	25	20	11	13	9	7	13	7	5	NM	5	6	6
Vancouver Harbour (inner)	3 (0 - 10)	0 (0 - 2)	2 (0 - 8)	5 (1 - 13)	11 (6 - 28)	4 (0 - 37)	19 (9 - 43)	17 (0 - 46)	9 (1 - 23)	8 (2 - 18)	12 (0 - 24)	5 (0 - 13)	3 (0 - 8)	1 (0 - 1)	3 (0 - 6)	7 (6 - 70	3 (2 - 3)
Port Moody Arm	5 (3 - 6)	2 (1 - 2)	1 (1 - 1)	3 (3 - 4)	8 (5 - 10)	2 (1 - 2)	11 (7 - 12)	22 (15 - 33)	6 (5 - 9)	3 (3 - 3)	13 (12 - 15)	6 (5 - 7)	5 (4 - 6)	1 (1 -1)	5 (3 - 6)	7 (6 - 7)	3 (2 - 3)
Coal Harbour	1 (0 - 2)	1 (0 - 1)	1 (0 - 1)	4 (1 - 6)	8 (5 - 12)	1 (1 - 2)	18 (13- 29)	22 (13-46)	9 (1 - 15)	7 (5 - 11)	14 (10 - 21)	6 (1 - 9)	4 (0 - 7)	1 (0 - 2)	4 (0 - 7)	5 (0 - 7)	2 (0 - 2)
Victoria Harbour																	
The Gorge	2 (1 - 2)	1 (0 - 1)	0 (0 - 0)	2 (2 - 2)	5 (5 - 5)	1 (1 - 1)	16 (15 - 16)	16 (15 - 16)	8 (7 - 8)	7 (6 - 7)	13 (13 - 13)	10 (9 - 10)	6 (6 - 6)	1 (1 -1)	6 (6 - 6)	7 (6 - 7)	2 (2 - 2)
Selkirk Waters	4 (2 - 7)	0 (0 - 1)	3 (1 - 7)	4 (2 - 9)	8 (6 - 17)	4 (1 - 9)	17 (5 - 24)	22 (12 - 50)	6 (5 - 7)	5 (4 - 7)	9 (7 - 12)	5 (3 - 7)	2 (0 - 4)	0 (0 - 1)	3 (0 - 6)	4 (3 - 5)	1 (0 - 2)
Upper Harbour	3 (1 - 6)	1 (0 - 1)	2 (1 - 4)	4 (2 - 4)	11 (5 - 21)	3 (1 - 6)	17 (13 - 20)	18 (12 - 33)	9 (5 - 19)	7 (5 - 8)	12 (8 - 26)	7 (4 - 8)	4 (2 - 5)	1 (0 - 1)	5 (2 - 6)	5 (3 - 6)	2 (1 - 2)
Inner Harbour	3 (1 - 5)	1 (0 - 2)	1 (1 - 3)	3 (2 - 5)	10 (6 - 17)	2 (1 - 4)	16 (11 - 20)	17 (14 - 19)	8 (5 - 11)	7 (5 - 8)	12 (7 - 14)	7 (6 - 9)	4 (2 - 5)	1 (0 - 1)	5 (2 - 6)	5 (4 - 6)	2 (1 - 3)
Outer Harbour	2	0	2	3	15	4	17	15	6	6	9	7	3	1	4	4	2
Esquimalt Harbour																	
Constance Cove	1 (1 - 2)	0 (0 - 1)	1 (1 - 2)	4 (2 - 14)	8 (6 - 11)	2 (1 - 2)	15 (9 - 19)	16 (9 - 26)	9 (7 - 17)	7 (6 - 10)	14 (10 - 18)	9 (7 - 11)	7 (3 - 8)	1 (0 - 1)	5 (4 - 9)	6 (5 - 7)	2 (1 - 6)
Plumper Bay	2 (1 - 2)	1 (1 - 1)	1 (1 - 2)	3 (2 - 6)	9 (7 - 11)	2 (1 - 3)	19 (16 - 33)	18 (18 - 18)	6 (6 - 7)	5 (5 - 6)	10 (6 - 13)	6 (3 - 6)	3 (2 - 5)	1 (0 - 1)	3 (1 - 5)	4 (2 - 6)	3 (3 - 3)
Upper Harbour	0	0	1	3	12	1	14	14	6	8	12	10	5	1	5	5	2
Ladysmith Harbour	8 (5 - 14)	0 (0 -0)	2 (1 - 3)	3 (2 - 4)	16 (13 - 19)	3 (2 - 4)	15 (10 - 18)	12 (11 - 12)	7 (6 - 8)	6 (5 - 6)	9 (6 - 11)	5 (5 - 6)	5 (4 - 6)	1 (1 - 1)	4 (3 - 5)	5 (5 - 6)	3 (2 - 5)

2.3.2.2 Aquatic Biota

2.3.2.2.1 Aquatic Invertebrates

PAH concentrations detected in aquatic invertebrate samples collected during Environment Canada surveys in British Columbia conducted by Garrett and Shrimpton between 1984 and 1992 are presented in Appendix 5.2. The highest PAH concentrations were detected in mussels, with especially high concentrations present in mussels from industrialized urban centres such as Vancouver Harbour (refer to Table 2; Maps 4 to 9). For example, concentrations of between 4,000 and 5,000 ng/g total PAHs (wet weight) were detected in mussels from Vancouver Shipyard and Versatile Pacific Shipyard in the late 1980's (Garrett and Shrimpton, 1992). These levels are comparable to the maximum concentrations (4,200 ng/g) detected in mussels from Sydney Harbour, Nova Scotia (O'Neill and Kieley, 1992).

Table 2: Average PAH Concentrations in Mussels Collected in Vancouver Harbour (1988 to 1991) (Garrett and Shrimpton, 1992)

Location	LMW Compounds	HMW Compounds	Total PAHs
	(ng/g wet weight)		
Vancouver Wharves	168	585	753
L&K Lumber	168	824	992
Vancouver Shipyard	1064	3892	5056
Versatile Pacific	72 - 1505	300 - 3353	372 - 4858
Seaboard Terminals	167 - 189	192 - 1425	982 - 1592
Lynnterm	153	289	442
Allied	118	424	542
B.C. Marine Shipbuilders	56	329	385
Canada Place	91	416	506
Menchion's Shipyard	88	321	347
Bayshore Marina	44 - 70	290 - 317	333 - 387
RVYC Marina	37 - 770	215 - 1954	252 - 2724
False Creek	27 - 68	234 - 305	261 - 373

Mussels collected from the Versatile Pacific site in 1991 contained much lower PAH concentrations (372 ng/g). It is possible that the lower concentrations detected in 1991 may be, at least in part, due to the fact that the shipyard was no longer operational in 1991. Insufficient data is available to determine whether PAH concentrations in mussels have

declined in recent years, however, mussels from all Vancouver Harbour sites sampled in 1991 contained elevated PAH concentrations (several hundred ng/g of total PAH compounds) (Garrett and Shrimpton, 1992).

High PAH concentrations were also detected in mussels collected from the Constance Cove and Plumper Bay areas of Esquimalt Harbour (>3,500 and >900 ng/g wet weight, respectively) in 1990 (Map 11). Much lower PAH concentrations (<20 to 100 ng/g) were detected in mussels from Ladysmith Harbour in 1992 (Map 12) (Garrett and Shrimpton, 1992).

At most of the sites where both mussels and sediment samples were collected, lower PAH concentrations were present in the mussels than in the sediments (Garrett and Shrimpton, 1992) (refer to Figure 1). The exceptions were the Lynnterm and Seaboard Terminals sites in Vancouver Harbour and Constance Cove and Plumper Bay sites in Esquimalt Harbour. At these locations, the PAH concentrations in mussels exceeded those detected in sediments from these sites (when concentrations were compared on a dry weight basis) (refer to Figure 1).

The percent contributions of individual PAH compounds to total PAH concentrations in aquatic invertebrates are also presented in Appendix 5.2. The patterns of PAH compounds present were similar in sediments and mussels collected from the same sites (refer to Figure 1). As with sediments, mussels from all areas contained a greater proportion of higher molecular weight (HMW) compounds than lower molecular weight (LMW) compounds, with the predominant compounds being fluoranthene (15 to 30%), pyrene (8 to 15%), chrysene (~10%) and benzofluoranthenes (~10%). Mussels generally contained a higher proportion of fluoranthene than did sediments from the same area, while sediments generally contained a higher proportion of benzo[a]pyrene than did mussels. However, mussels from almost all locations in Vancouver Harbour contained higher levels of benzo[a]pyrene than did mussels collected from wharves and pilings in the Southern California Bight (8.2 ng/g) by Dunn and Young (1976). Phenanthrene was the predominant lower molecular weight compound detected in both mussels and sediment samples (8 to 15%) (Figure 1). At most sites, lower molecular weight compounds contributed less than 30% to the total PAH burden in both sediments and mussels. In contrast, sediments from Vancouver Wharves contained predominantly LMW compounds (>60%). Particularly high levels of naphthalene, acenaphthene and, especially, fluorene were detected in the sediments from this site. It is interesting to note that the proportion of LMW compounds in the mussels collected at this site was not unusually elevated (22%), but was similar to that observed at other sites (20%). Acenaphthene, dibenz[a,h]anthracene, and perylene made virtually no contribution to total PAH concentrations in mussels, and minimal contributions to total PAH concentrations in sediments (Garrett and Shrimpton, 1992)

PAH concentrations in clams and oysters collected in British Columbia were generally lower than those detected in mussels. However, it is not possible to make species comparisons as these species were not usually collected from the same locations. The highest PAH concentrations in mussels were detected in Vancouver Harbour, however, with the

exception of bentnose clams collected at the RVYC Marina in Coal Harbour (332 ng/g total PAHs) (Map 1), clams were not obtained from Vancouver Harbour sites (Garrett and Shrimpton, 1992).

Bentnose clams from Laurel Point in Victoria Inner Harbour (Map 10a) contained the highest PAH concentrations (1,353 ng/g) (Garrett and Shrimpton, 1992). This level is comparable to the highest concentration (1579 ng/g) reported by Goyette and Wagenaar (1995) for clams (*Mya* sp.) collected near the Alcan smelter at Kitimat in 1992. Lower concentrations were detected in clams from other areas of Victoria Harbour and from Esquimalt Harbour. Bentnose clams from Selkirk Waters (Map 10b), north of the old sawmill site, contained up to 500 ng/g of total PAHs, while those collected near the Hidden Harbour Marina in the Inner Harbour contained 377 ng/g of total PAHs. Clams (*Macoma* sp.) from the Plumper Bay area of Esquimalt Harbour contained 100 to 132 ng/g PAHs (Map 11) (Garrett and Shrimpton, 1992).

Manila and littleneck clams and oysters from Nanaimo Harbour (Map 12) contained PAH concentrations ranging from 25 to 169 ng/g in clams and from 11 to 111 ng/g in oysters (Garrett and Shrimpton, 1992).

The pattern of PAH compounds in clams and oysters was very similar to that in mussels and sediments (Figure 2 (j, k, m, and s) and Appendix 5.2). Clams and oysters contained mainly HMW compounds (~80%), with the most predominant compounds being fluoranthene (20 to 40%), pyrene (16 to 24 %), chrysene (~10%) and benzofluoranthenes (~10%). Phenanthrene was the predominant LMW compound detected. As was the case in mussels, acenaphthylene, dibenz[a,h]anthracene, and perylene made only minimal contributions to the total PAH concentrations (Garrett and Shrimpton, 1992).

PAH concentrations in crab hepatopancreas were usually much higher than those in the crab muscle tissue. For example, the hepatopancreas of Dungeness crabs from Coal Harbour, False Creek, Port Moody, and Upper Victoria Harbour contained 548, 300, up to 930, up to 569 ng/g total PAH, respectively, compared to concentrations of 28, up to 29, up to 45 ng/g and less than detection, respectively, in the muscle tissue of these crabs. Dungeness crabs collected from the Fraser River Estuary in the vicinity of the Iona Island sewage treatment plant in 1986 contained up to 48.8 ng/g total PAHs in the muscle tissue and over 100 ng/g in the hepatopancreas (Garrett and Shrimpton, 1992).

Dungeness crabs collected in 1988 from the East Basin and off Monk McQueen's Restaurant in False Creek (Map 2) contained 267 ng/g and 577 to 831 ng/g total PAHs, respectively, in the hepatopancreas. Total PAH concentrations in the muscle tissue were less than 30 ng/g. Similar concentrations were present in crabs collected from the East Basin of False Creek in 1991; 300 ng/g in the hepatopancreas and less than 30 ng/g in the muscle (Garrett and Shrimpton, 1992). Goyette and Boyd (1989) reported that crabs collected from False Creek in the late 1980's contained 148 to 1,240 ng/g total PAHs in the hepatopancreas and 25 to 169 ng/g in the muscle tissue (dry weight) (38 to 322 ng/g and 5 to 32 ng/g wet weight, respectively).

PAHs were not detected in the hepatopancreas of Dungeness crabs from two sites in outer Vancouver Harbour (near the Pacific Environment Institute (PEI) and Spanish Banks; Map 4). Crabs from the inner harbour contained PAH concentrations in excess of 100 ng/g at several sites. The highest concentration (up to 930 ng/g) was detected in the hepatopancreas of crabs collected from the vicinity of the Ioco petroleum refinery in Port Moody. PAH concentrations in muscle tissue of crabs collected from Vancouver Harbour (Maps 4 to 9) were much lower and ranged from less than detection to 45 ng/g (off Ioco) (Garrett and Shrimpton, 1992). Similarly, Goyette and Boyd (1989) reported that PAH concentrations in crab hepatopancreas from the Port Moody area ranged from less than the detection limit to 996 ng/g dry weight (189 ng/g wet weight), while concentrations in the muscle tissue ranged from 10 to 20 ng/g dry weight (2.6 to 5.2 ng/g wet weight). PAHs were not detected in crabs collected from the outer harbour (PEI) or in Indian Arm.

In Dungeness crabs from Victoria Harbour (Maps 10a and b), PAH compounds were detected at concentrations ranging from less than the detection level to 11 ng/g in the muscle tissue, and from 6 to over 500 ng/g in the hepatopancreas. PAH concentrations in muscle tissue of Dungeness crabs from Esquimalt Harbour ranged from 7.3 to 16.1 ng/g, while the hepatopancreas contained 37.7 to 96.6 ng/g (Garrett and Shrimpton, 1992).

Dungeness crabs collected from the reference area at Fortune Channel (Map 13) contained only 1.2 ng/g in the hepatopancreas, however, the hepatopancreas of crabs from the reference site at Delkatla Slough in the Queen Charlotte Islands (Map 14) contained surprisingly high PAH concentrations (120 ng/g). Sediment samples from this location also contained higher PAH concentrations (36.1 to 75.3 ng/g) than did sediments from other reference sites (ND to 7.2 ng/g) (Garrett and Shrimpton, 1992). Hepatopancreas tissue from Dungeness crabs collected at a reference site at Loughborough Inlet contained 0.6 ng/g (Goyette, personal communication).

PAH concentrations in shrimp were very low, ranging from 2.0 to 27.3 ng/g, with the exception of shrimp from Agememnon Channel (Map 13) which contained 211.4 ng/g. This level of contamination was unexpected as this was considered to be a reference site. Shrimp collected from the reference site at Rivers Inlet contained only 3.3 ng/g of total PAH compounds (Garrett and Shrimpton, 1992).

Delkatla Slough and Agamemnon Channel are frequented by recreational boating traffic and would be subject to contamination associated with fuel combustion and leakage.

The pattern of PAH compounds in the tissues of crabs and shrimp were less consistent than in bivalves and was less likely to resemble those in sediment samples from the same sites (Garrett and Shrimpton, 1992) (refer to Figure 2 and Appendix 5.2). This is probably due, at least in part, to the fact that crustaceans metabolize PAH compounds more efficiently than do bivalves.

In crabs from the Fraser Estuary (Figure 2c; Map 3), virtually all of the PAH in both muscle and hepatopancreas was present as LMW compounds (primarily naphthalene) despite the fact that approximately 80% of the PAH in sediments from this site were HMW compounds. Naphthalene contributed only 7 to 10% to the total PAH concentrations in the sediments from this site (Garrett and Shrimpton, 1992).

Crab samples collected from the East Basin and off Monk McQueen's restaurant in False Creek in 1988 (Map 2), contained a wide variety of both LMW and HMW compounds in the hepatopancreas and muscle tissue (Figure 2h and j). In the hepatopancreas, greater than 60% of the PAH was present as LMW compounds, predominantly acenaphthene. In the muscle tissue, most of the PAH was present as HMW compounds (>70%). The predominant HMW compounds were the same as those found in mussels and sediments from this site (fluoranthene, pyrene, chrysene and benzofluoranthenes). The predominant LMW compounds detected in the muscle tissue were fluorene and acenaphthene, however, these compounds were detected in very low levels in sediments from this site (Stronkhurst, 1992). Goyette and Boyd (1989) also detected a wide range of LMW and HMW PAH compounds in both the hepatopancreas and muscle tissue of crabs from False Creek in the late 1980's. Crab samples collected from False Creek in 1991 (Figure 2i; Map 2) contained predominantly LMW compounds in both muscle (>80%) and hepatopancreas (100%) despite the fact that less than 20% of the PAHs in sediments were in the form of LMW compounds. Muscle tissue contained primarily naphthalene and acenaphthene, while the hepatopancreas contained primarily acenaphthylene and acenaphthene. Lower amounts of phenanthrene and fluorene were present in both tissues. None of these compounds contributed more than 8% of the total PAH compounds to sediments in this area (Garrett and Shrimpton, 1992). It is interesting that English sole collected from False Creek East Basin in 1991 also contained a higher proportion of LMW compounds than did 1988 samples (Figures 2h and i).

Crabs collected in Vancouver Harbour (Map 4 to 9) contained a variety of HMW and LMW compounds. The HMW compounds predominated in the hepatopancreas of crabs collected off Seaboard Terminals (Figure 2l) and B.C. Marine/Sterling Shipyards (Figure 2o), and the pattern of PAH compounds in these samples was similar to those in sediments from these sites. However, the LMW compounds predominated in the hepatopancreas of crabs collected off Versatile Pacific (Figure 2k) and the pattern of PAH compounds in the crabs did not closely resemble that in sediments from this site. At B.C. Marine/Sterling and Seaboard Terminals, the predominant compounds in crab hepatopancreas were similar to those in mussels. The predominant HMW compounds were fluoranthene, pyrene, chrysene, and benzo[a]anthracene, while the predominant LMW compound was phenanthrene. In crabs collected off Versatile Pacific the predominant compounds were acenaphthene, phenanthrene, and fluorene. Together these compounds accounted for approximately 60% of the total PAHs in crab hepatopancreas, despite the fact that these compounds made only minor contributions (<15% combined) to the total PAHs in sediments from this site. Muscle tissue samples were not analyzed from crabs collected at these sites (Garrett and Shrimpton, 1992).

Crabs collected off Menchion's Shipyard in Coal Harbour (Figure 2p; Map 1) contained predominantly LMW compounds in the hepatopancreas tissue (primarily

acenaphthene). The one muscle sample containing detectable PAH concentrations contained almost exclusively naphthalene. Sediment samples collected from this site in 1984 contained predominantly HMW compounds (Garrett and Shrimpton, 1992). Goyette and Boyd (1989) also reported that crab from Coal Harbour contained only LMW PAH compounds in both the muscle and hepatopancreas.

Elevated PAH concentrations detected in the hepatopancreas of crabs collected near the Ioco petroleum refinery (Figure 2n; Map 8) in 1986 were due primarily to the presence of LMW compounds, while the 1988 samples contained lower levels overall but a greater proportion of HMW compounds. The major compounds detected, in decreasing order of predominance, were phenanthrene, pyrene, chrysene, benz[a]anthracene, and fluoranthene. Only one of the 1988 muscle tissue samples contained detectable concentrations of PAH compounds. These were predominantly HMW compounds; primarily fluoranthene and pyrene. Sediments from this area contained predominantly HMW compounds (>80%) with major contributions from pyrene, fluoranthene, and benzofluoranthenes (Garrett and Shrimpton, 1992).

Crabs collected from Victoria Harbour (Maps 10a and b) in 1987 and 1990 contained primarily LMW compounds in the hepatopancreas tissue. The major compounds detected in crabs from the Selkirk Waters (Figure 2r) and Upper Harbour (Figure 2s) areas included naphthalene, acenaphthene, fluorene and phenanthrene. Crabs from the Inner Harbour area (Figure 2t) contained primarily naphthalene, acenaphthene, anthracene, and phenanthrene. LMW compounds contributed less than 25% to the total PAH concentrations in sediments from all areas of Victoria Harbour. The predominant LMW compound in sediments was phenanthrene (~10%), while other LMW compounds contributed less than 5% to the total PAHs in sediments (Garrett and Shrimpton, 1992).

Crabs from Esquimalt Harbour contained predominantly LMW compounds in both the hepatopancreas and muscle tissue (Figure 2; Map 11). In crabs from the Constance Cove area (Figure 2u), the major compounds in the hepatopancreas were phenanthrene, naphthalene, acenaphthene, and fluorene, while the muscle tissue contained mainly phenanthrene, naphthalene, and acenaphthene and also a significant amount of fluoranthene. Sediments contained approximately 15% of total PAHs as LMW compounds; primarily fluorene, pyrene, and benzofluoranthenes. Crabs from the Plumper Bay area (Figure 2v) contained greater than 90% of the total PAHs in both muscle and hepatopancreas tissue as LMW compounds. The predominant compounds in both tissues were acenaphthene and fluorene (421). The sediments from the Plumper Bay area contained less than 20% of the total PAHs as LMW compounds. The predominant compounds in the sediments were fluorene and pyrene (Garrett and Shrimpton, 1992).

The contribution of PAH compounds to total PAHs in shrimp was not consistent. While shrimp from Victoria Harbour and Plumper Bay (Esquimalt Harbour) contained 100% of the total PAHs as LMW compounds, shrimp from the Constance Cove area of Esquimalt Harbour and from Agamemnon Channel contained exclusively HMW compounds.

2.3.2.2.2 Fish

PAH concentrations in fish (whole body concentrations on a wet weight basis) collected from coastal areas of British Columbia were lower than those detected in mussels (refer to Appendix 5.3).

English sole from False Creek (Map 2) contained whole body PAH concentrations of 81 to 113 ng/g in 1988 and from 22 to 29 ng/g in 1991. In Vancouver Harbour (Maps 4 to 9), PAH concentrations in whole body of flatfish ranged from 2.7 to 164.4 ng/g, with the highest concentration being detected in starry flounder collected off Allied Shipyards. Starry flounder collected off the Ioco petroleum refinery in Port Moody Arm contained 15 ng/g of total PAHs in the liver, 1.1 ng/g in the whole body, and non-detectable levels in the muscle tissue. English sole from this location contained 21 to 51 ng/g total PAHs. Total PAH concentrations in English sole (whole body) from Victoria Harbour (Maps 10a and b) ranged from <2 ng/g to 32.4 ng/g. English sole from nearby Esquimalt Harbour (Map 11) contained 11.8 to 51.3 ng/g (Garrett and Shrimpton, 1992).

Starry flounder collected off the Iona Island Sewage Treatment Plant in the Fraser River Estuary (Map 3) contained low PAH concentrations (13 ng/g). Starry flounder and sculpin collected upstream in the Fraser River off wood treatment facilities contained higher PAH concentrations ranging, from 13.9 to 119.1 ng/g (Garrett and Shrimpton, 1992).

Fish collected from the Fraser River in 1988 rarely contained detectable PAH concentrations in muscle tissue (detection limits of 0.004 to 0.5 μg/g dry weight depending on the compound). Low concentrations of acenaphthene, fluoranthene and phenanthrene were detected in a few fish from the North Arm. The presence of PAHs in fish from the North Arm was attributed to the stormwater discharges to this region of the river. PAH were detected more frequently and at higher concentrations in liver samples than in muscle tissue despite the fact that the detection limits in liver samples were approximately five times higher. However, a statistical analysis of naphthalene (the only compound present frequently enough to permit statistical comparisons), indicated that there was no significant difference within or between species of fish collected from the North Arm and the Main Arm of the river (Swain and Walton, 1989).

In 1994, peamouth chub and starry flounder collected from the Fraser River contained detectable levels of only six to eight of the 23 PAH compounds analyzed for. Differences were observed in the concentrations of PAHs detected in fish from various reaches of the river; North Arm > Main Arm> Main Stem. PAH concentrations in the liver tissue (up to >300 ng/g wet weight) were approximately 10 times higher than in the muscle (up to >30 ng/g wet weight). PAH metabolites were detected in the bile. Concentrations of individual PAH compounds were lower in peamouth chub in 1994 (<10 ng/g) than in 1988 (5 to 200 ng/g) (Swain and Walton, 1993).

Swain and Walton (1994) reported that PAHs were present in biota samples collected from Boundary Bay in 1993 but not in samples collected in 1989. The authors attributed this to the lower detection limits used in the 1993 analysis. Sculpin (whole body samples) collected from the inshore site in 1993 contained the highest concentration of PAH (0.221 μg/g wet weight) and the greatest variety of PAH compounds. Phenanthrene was detected most commonly in the crab and fish samples (0.006-0.040 μg/g wet weight).

Sole from reference sites at Crescent Beach and St. Vincent's Bay (Map 13) contained 8.4 and 15 ng/g of total PAHs, respectively (Garrett and Shrimpton, 1992).

In whole fish samples collected from most sites, PAHs were present mainly as HMW compounds (Figure 2). The major HMW compounds detected were fluoranthene, pyrene, chrysene and, in some samples, benz[a]anthracene and benzofluoranthenes (refer to Figure 2). The patterns of PAH compounds in fish samples were not consistent from site to site and did not closely resemble those observed in sediments from the same sites (Garrett and Shrimpton, 1992).

Some fish samples contained mainly LMW compounds, however, this was usually due to high concentrations of naphthalene. This was particularly true of sculpin and starry flounder from the vicinity of wood treatment facilities along the Fraser River (Figure 2d,e,f,and g). In these fish samples, naphthalene contributed from 24 to 66% of the total PAHs. A Fraser River Estuary Report (FREMP, 1996) also stated that LMW compounds predominated in fish collected from the Fraser River. Major LMW compounds present in peamouth chub and starry flounder collected from the Fraser River in 1994 were naphthalene, phenanthrene, anthracene, acenaphthene, acenaphthylene, and fluorene. HMW compounds were also detected but were present at lower concentrations. The major HMW compounds detected were pyrene, fluoranthene, and chrysene.

Naphthalene and a predominance of LMW compounds were also observed in rock sole from Seaboard Terminals (Figure 2l), English sole in False Creek East Basin (1991 only) (Figure 2i), and English sole from Esquimalt Harbour (Figure 2v).

3. LEGISLATION, REGULATIONS, AND GUIDELINES

Current regulations and guidelines pertaining to the presence or release of PAH compounds into the aquatic environment of British Columbia are as follows.

3.1 Water Quality

In Canada, federal and provincial environmental quality guidelines for PAHs have been developed and serve as a useful tool in assessing environmental quality. Guidelines are provided for reference as one source of information in assessing environmental quality. It must be emphasized that guidelines should not be used in direct isolated comparisons with monitoring data. Site specific factors including local biophysical conditions must also be considered and guideline numbers may need to be modified to suit local aquatic conditions. For example, the bioavailability and toxicity of PAHs and other chemicals vary with environmental variables including pH, temperature, water hardness, presence of organic carbon and other toxic compounds as well as the species and life stage of the organisms.

In 1983, the Great Lakes Science Advisory Board (GLSAB) recommended that the concentration of benzo[a]pyrene in Great Lakes waters not exceed 0.01 µg/L and that the concentration of benzo[a]pyrene in sediments or prey organisms for freshwater fish not exceed 1,000 ng/g dry weight (Great Lakes Science Advisory Board, 1983).

The British Columbia Ministry of Environment, Lands and Parks (B.C. MELP) Ambient Water Quality Criteria for PAHs (Nagpal, 1993) recommend criteria for raw drinking water, ambient water, fish and shellfish, and sediment. Table 3 lists recommended criteria designed to protect freshwater life from phototoxic and long-term effects and to protect marine aquatic life from long-term effects. The recommended criteria listed in Table 3 are for sediments containing 1% organic carbon. Appropriate criteria for sediments containing organic carbon contents other than 1% should be calculated by multiplying the values shown in the table by the percent organic carbon content of the sediment.

In 1990, British Columbia Ministry of Environment, Lands, and Parks published the Coquitlam-Pitt River Area, Burrard Inlet Water Quality Assessment and Objectives (British Columbia Ministry of Environment, 1990). These objectives were established as goals which would ensure the protection of all uses of the water system and its aquatic life. They were designed to be used as tools in policy development and planning. Maximum objective levels for PAH compounds in Burrard Inlet sediments are shown in Table 4.

Table 3: BC MELP Recommended Water and Sediment Quality Criteria (fresh and marine) (Nagpal, 1993)

PAH Compound	Recommended Criteria: Water (µg/L)		Sediment (ng/g dry weight)*	
	Freshwater	Marine	Freshwater	Marine
Naphthalene	1	1	10	10
Acenaphthene	6	6	150	150
Fluorene	12	12	200	200
Anthracene	4	NR	600	NR
Phenanthrene	0.3	NR	40	NR
Acridine	3	NR	1,000	NR
Fluoranthene	4	NR	2,000	NR
Chrysene	NR	0.1	NR	200
Benz[a]anthracene	0.1	NR	200	NR
Benzo[a]pyrene	0.01	0.01	60	60

* These criteria are based on sediment containing 1% organic carbon.
NR Not recommended due to insufficient data.

Table 4: Maximum Objective Levels for PAH Compounds in Burrard Inlet Sediments (ng/g dry weight) (B.C. MELP, 1990)

LPAH Compounds	Criteria	HPAH Compounds	Criteria
naphthalene	500	pyrene	260
acenaphthylene	200	fluoranthene	170
acenaphthene	60	benzo[a]anthracene	130
fluorene	50	chrysene	140
phenanthrene	150	benzofluoranthene*	320
anthracene	100	benzo[a]pyrene	160
Total LPAH	500	indeno[1,2,3-c,d]pyrene	60
		dibenz[a,h]anthracene	60
		benzo[g,h,i]perylene	70
		Total HPAH	1,200

* Total benzofluoranthenes = benzo[b]-, benzo[j]-, and benzo[k]fluoranthene

Canadian interim guidelines for specific PAH compounds in water (Table 5) and sediments (Table 6) were published by the Canadian Council of Ministers of the Environment (CCME) in 1999 (CCME, 1999).

Table 5: Canadian Water Quality Guidelines for the Protection of Aquatic Life - PAHs (μg/L) (CCME, 1999)

LMW PAH Compounds	Guideline	HMW PAH Compounds	Guideline
Freshwater:			
Acenaphthene	5.8	Benz[a]anthracene	0.018
Acridine	4.4	Benzo[a]pyrene	0.015
Anthracene	0.012	Fluoranthene	0.04
Fluorene	3.0	Pyrene	0.025
Naphthalene	1.1		
Phenanthrene	0.4		
Quinoline	3.4		
Marine:			
Naphthalene	1.4 (interim)		
(Insufficient data was available to develop marine guidelines for other PAH compounds.)			

Table 6: Interim Canadian Sediment Quality Guidelines (ISQG) and Probable Effects Levels (PEL) for the Protection of Aquatic Life (CCME. 1999)

Substance	Marine and Estuarine Sediments (ng/g dry weight)		Freshwater Sediments	
LMW - PAHs	**ISQG**	**PEL**	**ISQG**	**PEL**
Naphthalene	34.6	391	34.6*	391*
2-methylnaphthalene	20.2	201	20.2*	201*
acenaphthylene	5.87	128	5.87*	128*
acenaphthene	6.71	88.9	6.71*	88.9*
fluorene	21.2	144	21.2*	144*
phenanthrene	86.7	544	41.9	515
anthracene	46.9	245	46.9*	245*
HMW - PAHs				
fluoranthene	113	1494	111	2355
pyrene	153	1398	53.0	875
benz[a]anthracene	74.8	693	31.7	385
chrysene	108	846	57.1	862
benzo[a]pyrene	88.8	763	31.9	782
dibenz[a,h]anthracene	6.22	135	6.22*	135*

ISQG = interim sediment quality guideline
PEL = probable effects levels. This is defined as the level above which adverse effects are expected to occur frequently.
**** = provisional***

3.2 Human Health

There are presently no Canadian guidelines for acceptable levels of PAH compounds in fish and shellfish for human consumption. Incidents of elevated PAH concentrations in commercially important species would be reviewed by Health Canada on a case by case basis.

The B.C. Ministry of Environment, Lands and Parks Ambient Water Quality Criteria for PAHs (Nagpal, 1993) recommends interim criteria for benzo[a]pyrene, as shown in Table 7, to protect consumers of fish and shellfish.

Table 7 : Recommended Maximum Benzo[a]pyrene Concentrations in Fish and Shellfish (Nagpal, 1993)

B[a]P Concentration (ng/g wet weight in edible tissue)	Safe Weekly Consumption* (g wet weight)
4	50
2	100
1	200

* These values are for a weekly consumption on a regular basis.

In 1989, Health Canada recommended that maximum benzo[a]pyrene concentrations in drinking water not exceed 0.01 μg/L (Health Canada, 1989). This recommended level was also adopted by the B.C. Ministry of Health. Similarly, in 1993 the B.C. MELP Ambient Water Quality Criteria for PAHs adopted this value as the drinking water guideline (Nagpal, 1993).

3.3 Ocean Disposal

The disposal of wastes and other materials in Canadian waters is regulated under the federal *Canadian Environmental Protection Act (*CEPA, 1988), Part VI, Ocean Dumping Regulations. In consultation with the Regional Ocean Disposal Advisory Committee (RODAC), the Ocean Disposal Control Permit Issuing Office of Environment Canada, has developed interim guidelines for sampling, analyzing and reporting proposed ocean disposal activities (Environment Canada, 1999). These interim guidelines set the

rejection/screening limit for total PAH compounds at 2.5 μg/g (2500 ng/g) dry weight in materials proposed for ocean disposal.

3.4 Use and Release

Federal and provincial legislation provide controls on the entry of PAH compounds into the environment.

Naphthalene, used in the production of fungicides, insecticides and moth repellents, and creosote-based wood preservatives are considered to be pesticides and, therefore, would be subject to both provincial and federal legislation on pest control products. The provincial *Pesticide Control Act* ensures that the sale and use of pesticides in British Columbia comply with label instructions. The federal *Pest Control Products Act* requires the registration of all pesticides used, manufactured, and sold in Canada. It also regulates these products with respect to their composition, efficacy, and package labeling. The Pest Management Regulatory Agency administers the *Pest Control Products Act* and is currently conducting a comprehensive re-evaluation of all heavy duty wood preservatives including creosote. The re-evaluation is scheduled for completion in late 2000.

In 1988, Environment Canada developed codes of practice containing recommendations for the design and operation of heavy duty wood preservation facilities in Canada. Implementation of the codes is voluntary, however, Environment Canada inspection programs conducted in 1998 found that 91% of the facilities in British Columbia had implemented the best management practices outlined in the codes compared to 62% of the facilities inn 1992 (Environment Canada, 1998).

Several of the substances which may be released to the environment as a result of the use and manufacture of heavy-duty wood preservatives, including PAHs and creosote-impregnated wastes, have been designated as toxic under Section 11 of the *Canadian Environmental Protection Act* (CEPA, 1988). Both PAHs and creosote-impregnated wastes are classified as Track 2 substances under the federal government's Toxic Substances Management Policy. While substances classified as Track 1 under this policy are targeted for virtual elimination from the environment, Track 2 substances require full lifecycle management to prevent or minimize release into the environment. Under the process established for managing toxic substances under CEPA, a risk management strategy is developed through a Strategic Options Process (SOP). In the SOP, the various stakeholders from industry, government, and non-government organizations make recommendations for the most effective options for managing the toxic substances. A report on the Strategic Options for the Management of CEPA-Toxic Substances from the Wood Preservation Sector was completed in 1999. The SOP recommendations address releases of CEPA toxic substances from chemical manufacturing, treatment of wood, use of treated wood, and the waste management of post-use treated wood. Two steering committees and nine working groups have been formed to oversee the implementation of the SOP recommendations.

The federal *Fisheries Act* subsection 36(3) prohibits the deposition of deleterious substances into waters frequented by fish.

The British Columbia *Waste Management Act* controls the handling, disposal, and release of wastes from industrial, provincial, and municipal sources. Regulations under this Act also control the transportation and disposal of contaminated waste materials. Through a permitting system, this legislation enables allowable releases to be set for pollutants discharged in wastewater and released to the atmosphere.

The federal government's *Transportation of Dangerous Goods Act* regulates the transportation of dangerous goods according to their type and classification. Commercial PAH chemicals, products containing PAHs, and PAH-contaminated wastes are covered by this legislation. Regulations under this Act are administered jointly by the Federal, Provincial and Territorial governments.

3.5 Contaminated Sites

The provincial Contaminated Sites Regulation (B.C. MELP, 1997) under the authority of the *Waste Management Act* came into effect in 1997. Under this regulation, a site can be designated as contaminated if the PAH content in the soil exceeds the concentration values listed in Table 8 or if the surface water or groundwater at the site exceed the values listed in Table 9. Similarly, remediation of a contaminated site is considered satisfactory if soil (to a depth of 3 metres) and surface water and/or groundwater on the site do not contain PAH concentrations in excess of the values listed in Tables 8 and 9. Also, the standards relating to PAH concentrations, which would trigger contaminated soil relocation agreements, are listed in Table 10.

Table 8: B.C. Contaminated Sites Regulation Generic Numerical Soil Standards for PAHs (μg/g) (B.C. MELP, 1997)

Substance	Agricultural	Urban Park	Residential	Commercial	Industrial
benz[a]anthracene	0.1	1	1	10	10
benzo[b]fluoranthene	0.1	1	1	10	10
benzo[k]fluoranthene	0.1	1	1	10	10
dibenz[a,h]anthracene	0.1	1	1	10	10
indeno[1,2,3-c,d]pyrene	0.1	1	1	10	10
naphthalene	0.1	5	5	50	50
phenanthrene	0.1	5	5	50	50
pyrene	0.1	10	10	100	100

Table 9: B.C. Contaminated Sites Regulation Generic Numerical Water Standards for PAHs (μg/L) (B.C. MELP, 1997)

Substance	Standard for Aquatic Life
acenaphthene	60
acridine	0.5
anthracene	1
benzo[a]anthracene	1
benzo[a]pyrene	0.1
fluoranthene	2
fluorene	120
naphthalene	10
phenanthrene	3
pyrene	0.2

Table 10: B.C. Contaminated Sites Regulation PAH Standards Triggering Contaminated Soil Relocation Agreements (μg/g) (B.C. MELP, 1997)

Substance	Site Relocation to Nonagricultural Land	Soil Relocation to Agricultural Land	Waste Disposal Prohibited without Authorization
benzo[a]anthracene	1	0.1	10
benzo[b]fluoranthene	1	0.1	10
benzo[k]fluoranthene	1	0.1	10
benzo[a]pyrene	1	0.1	10
dibenz[a,h]anthracene	1	0.1	10
indeno[1,2,3-c,d]pyrene	1	0.1	10
naphthalene	5	0.1	50
phenanthrene	5	0.1	50
pyrene	10	0.1	100

The Contaminated Sites Regulation contained no guidance on the management of contaminated sediments. In 1999, the Criteria for Managing Contaminated Sediment in British Columbia (pursuant to Section 26(1) of the Waste Management Act) was prepared by the B.C. Ministry of Environment, Lands and Parks (B.C. MELP, 1999). These criteria are used only at sites identified under the Contaminated Sites Regulation. The current remedial objective for sediments is the average effects level (AEL) which is an average of the threshold effects level (TEL) and the probable effects level (PEL). The AEL is approximately equal to the EC_{20}. Sediments which are below the AEL do not require remediation. At sites where contaminant levels in the sediments exceed this value (Level I), sediments may be removed to meet the AEL objective or sediment toxicity tests may be conducted to ensure that the levels of contamination will not impact aquatic life. Where contaminants levels exceed the PEL (Level II), sediments can be removed to meet the AEL objective or a full scale risk assessment for the site can be conducted. The numerical criteria for assessing freshwater and marine/estuarine sediment sites are shown in Tables 11 and 12, respectively.

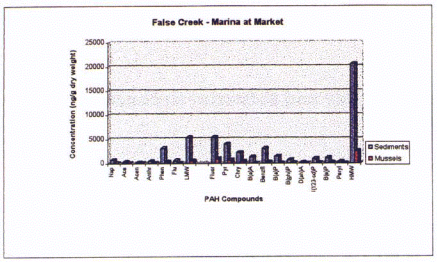
Table 11 : Numerical Criteria for Assessing Freshwater Sediment Sites (μg/g) (B.C. MELP, 1999)

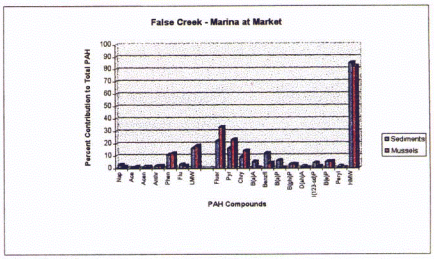
Substance	Level I Aquatic Life		Level II Aquatic Life	
	Bulk Sediment (ng/g d.w.)	Porewater (μg/L)	Bulk Sediment (ng/g d.w.)	Porewater (μg/L)
LMW - PAHs				
acenaphthene	48	6.0	89	12
acenaphthylene	67	NC	130	NC
acridine	NC	3.0	NC	6.0
anthracene	150	4.0	250	8.0
fluorene	83	12	140	24
naphthalene	210	1.0	390	2.0
2-methylnaphthalene	110	NC	200	NC
phenanthrene	280	0.30	520	0.60
Total LMW PAHs	880	NC	1,400	NC
HMW - PAHs				
benz[a]anthracene	210	0.10	390	0.20
benzofluoranthene	NC	NC	NC	NC
benzo(k)fluoranthene	NC	NC	NC	NC
benzo(g,h,i)perylene	NC	NC	NC	NC
benzo[a]pyrene	410	0.01	780	0.02
chrysene	460	NC	860	NC
dibenz[a,h]anthracene	71	NC	140	NC
fluoranthene	1,200	4.0	2,400	8.0
indeno(1,2,3c,d)pyrene	NC	NC	NC	NC
pyrene	460	NC	880	NC
Total HMW PAHs	3,700	NC	6,700	NC

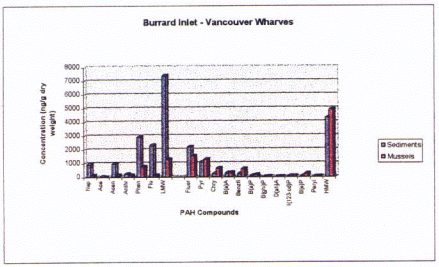
Table 12: Numerical Criteria for Assessing Marine and Estuarine Sediment Sites (μg/g) (B.C. MELP, 1999)

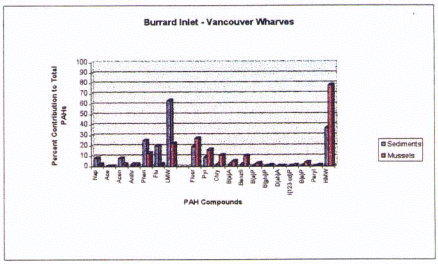
Substance	Level I Aquatic Life		Level II Aquatic Life	
	Bulk Sediment (ng/g d.w.)	Porewater (μg/L)	Bulk Sediment (ng/g d.w.)	Porewater (μg/L)
LMW - PAHs				
acenaphthene	48	6.0	89	12
acenaphthylene	67	NC	128	NC
anthracene	150	NC	250	NC
fluorene	83	12	140	24
naphthalene	210	1.0	390	2.0
2-methylnaphthalene	110	1.0	200	2.0
phenanthrene	320	NC	540	NC
Total LMW PAHs	880	NC	1,400	NC
HMW - PAHs				
benz[a]anthracene	380	NC	690	NC
benzofluoranthene	NC	NC	NC	NC
benzo(k)fluoranthene	NC	NC	NC	NC
benzo(g,h,i)perylene	NC	NC	NC	NC
benzo[a]pyrene	430	0.01	760	0.02
chrysene	480	0.10	850	0.2
dibenz[a,h]anthracene	71	NC	140	NC
fluoranthene	800	NC	1,500	NC
indeno(1,2,3c,d)pyrene	NC	NC	NC	NC
pyrene	780	NC	1,400	NC
Total HMW PAHs	9,200	NC	17,000	NC

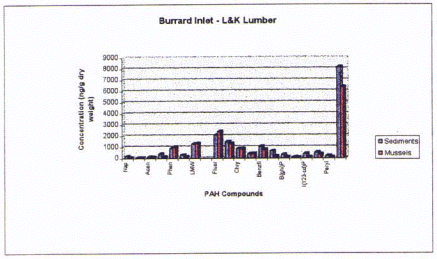
Figure 1: Comparison of PAH Concentrations and Patterns in Sediments and Mussels

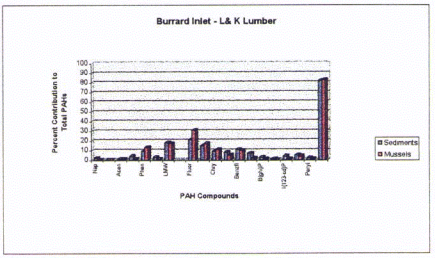


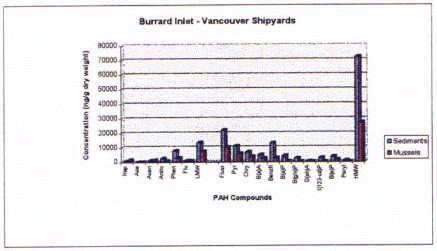












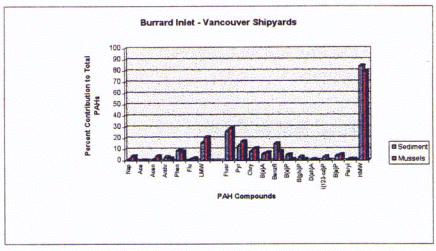
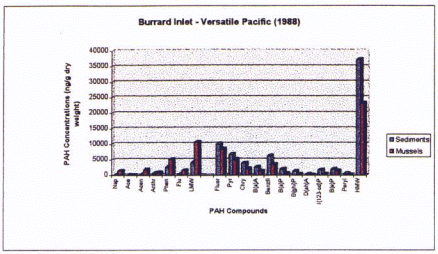
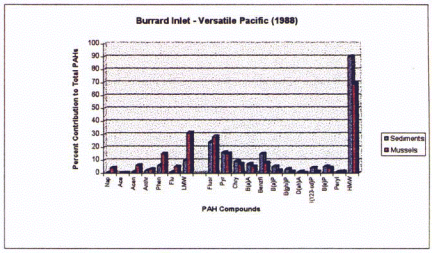
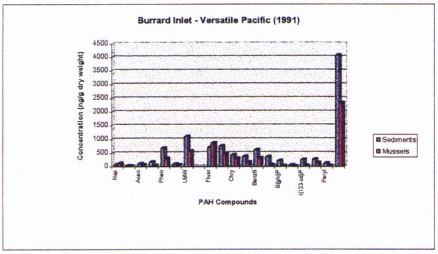
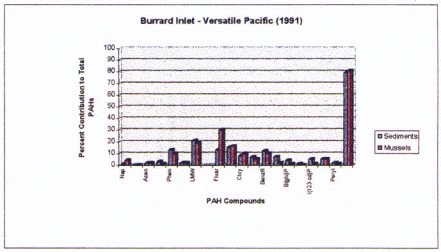


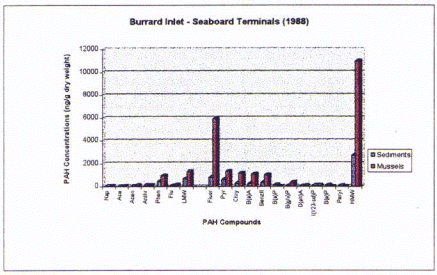
Figure 1: Comparison of PAH Concentrations and Patterns in Sediments and Mussels

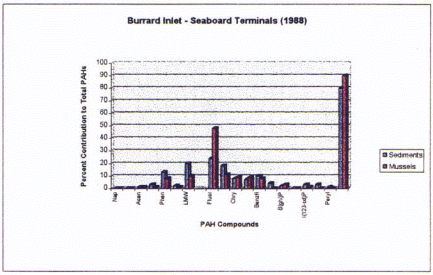


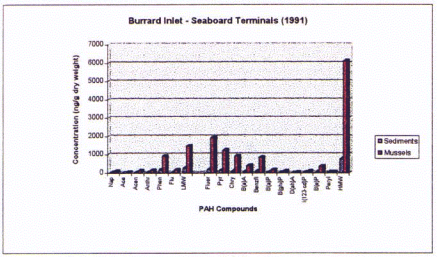












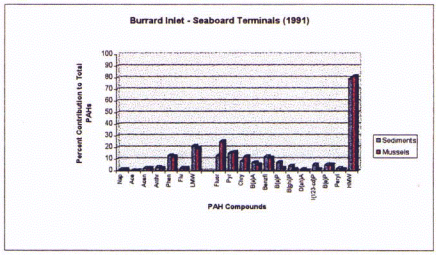
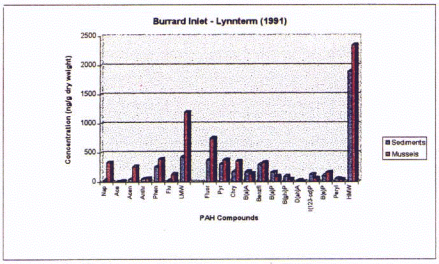
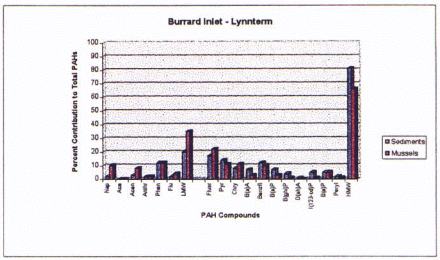
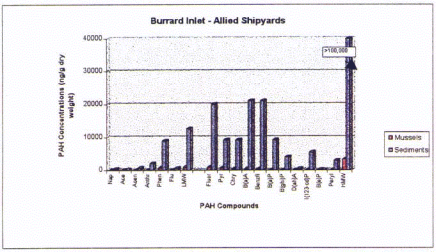
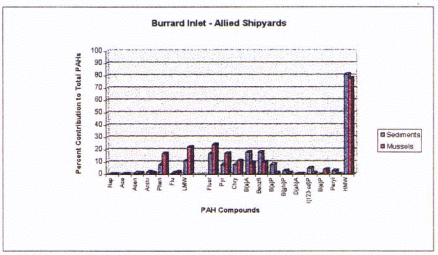


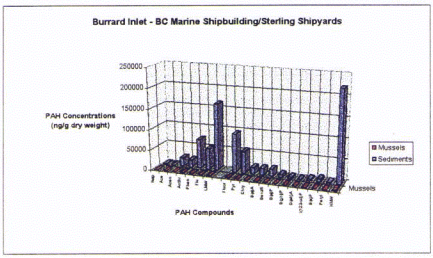
Figure 1: Comparison of PAH Concentrations and Patterns in Sediments and Mussels

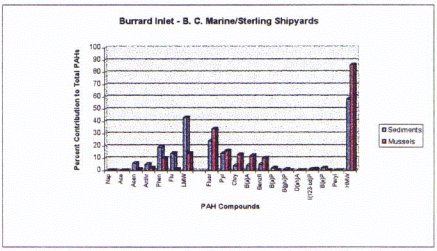


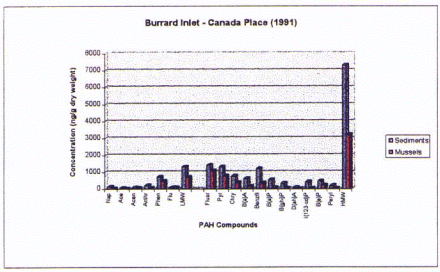












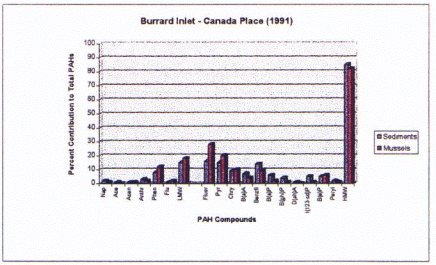
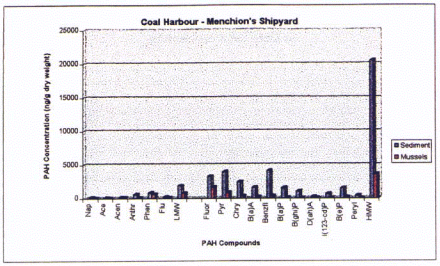
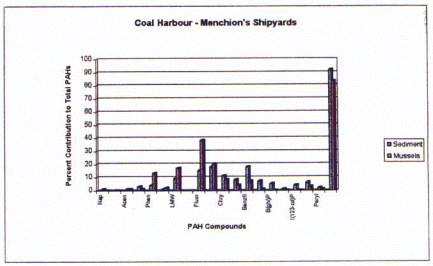
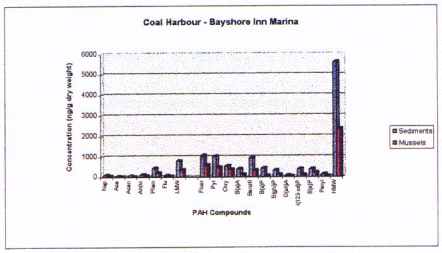
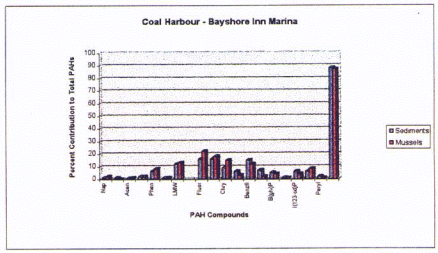


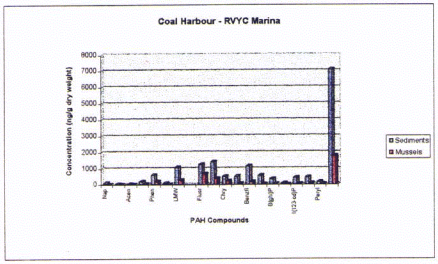
Figure 1: Comparison of PAH Concentrations and Patterns in Sediments and Mussels

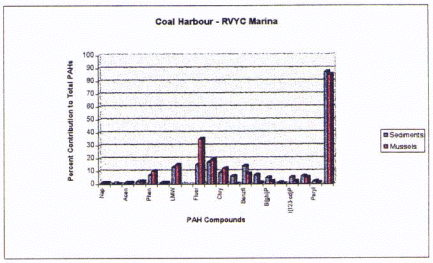


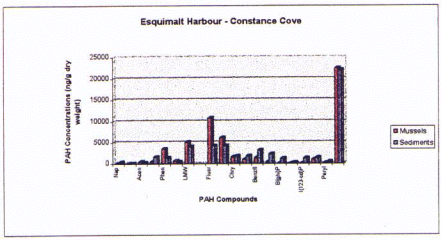












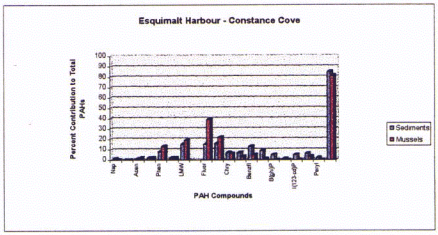
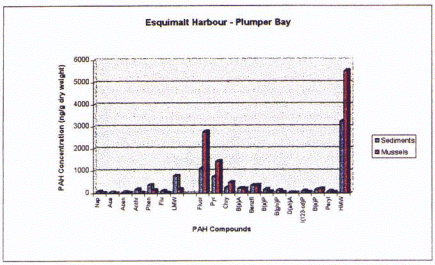
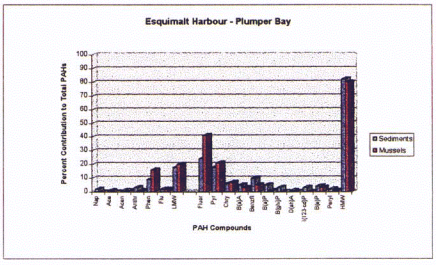
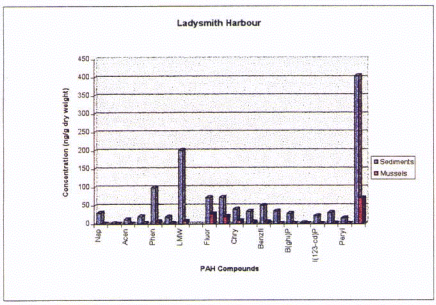


Figure 1: Comparison of PAH Concentrations and Patterns in Sediments and Mussels







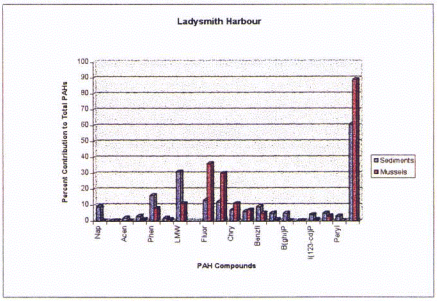
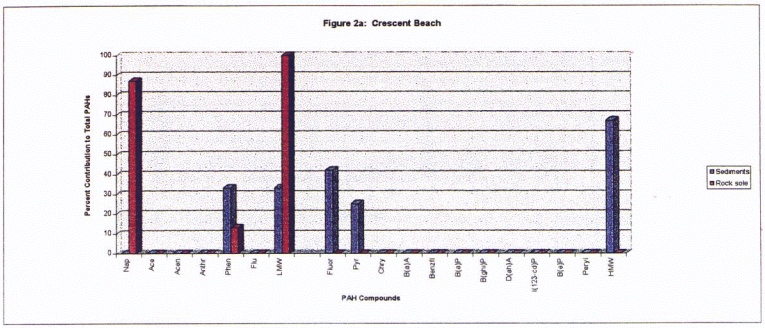
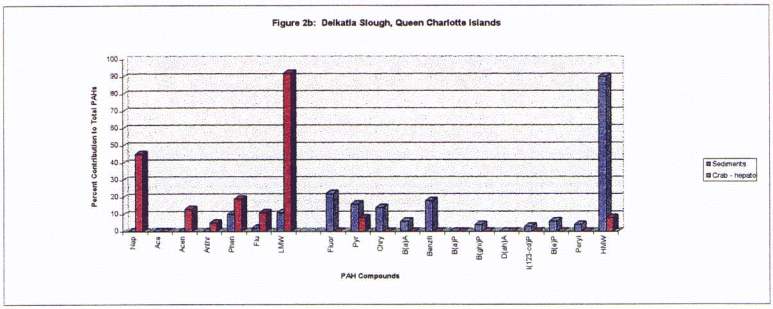
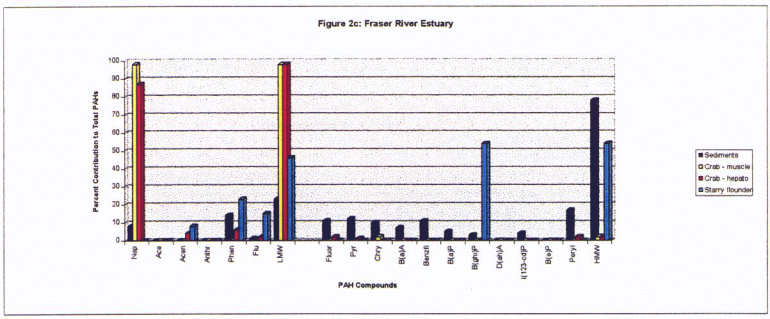


Figure 2: Percent Contribution of Individual PAH Compounds to Total PAHs in Sediments and Biota







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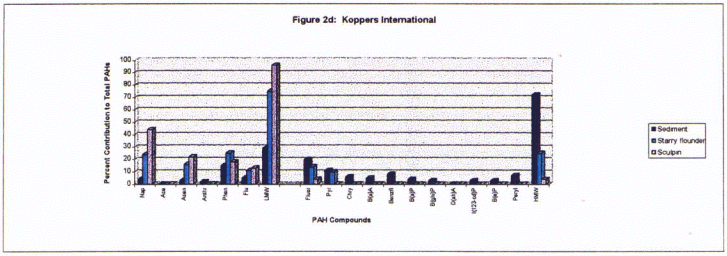

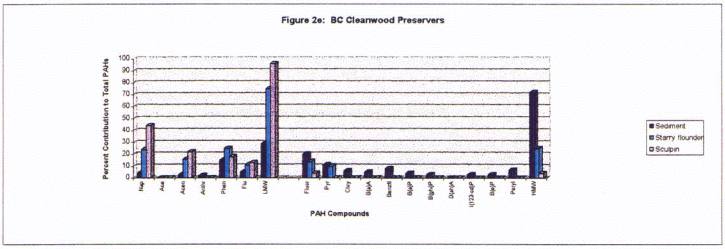

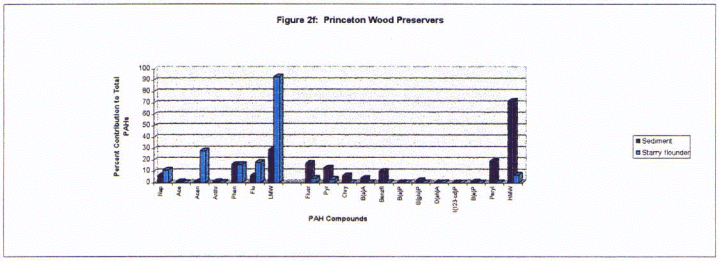

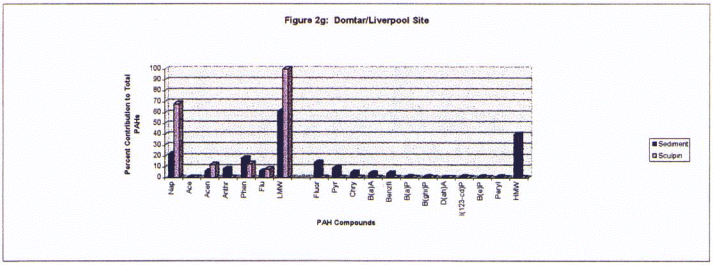

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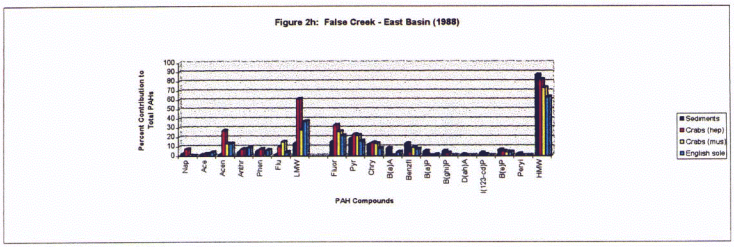
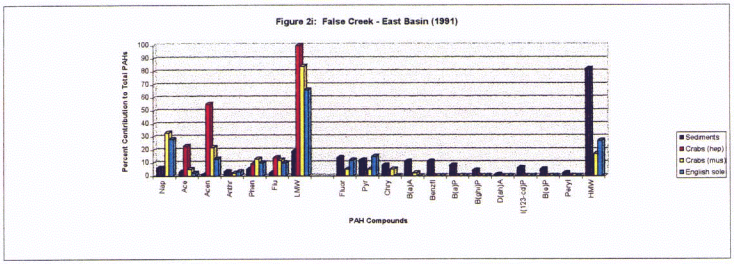
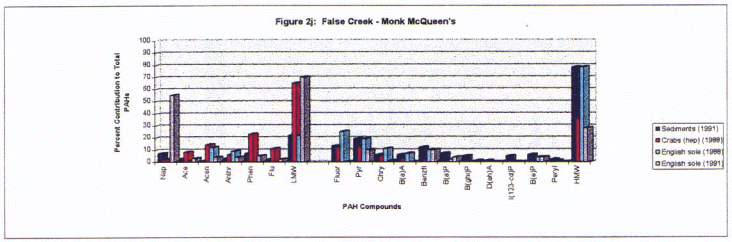






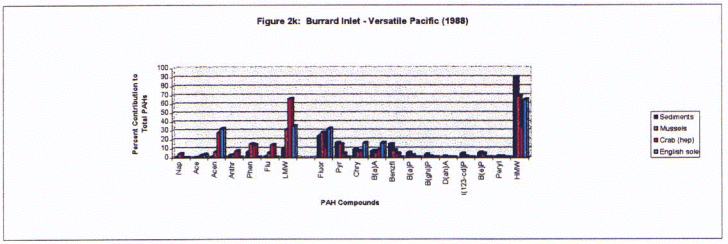
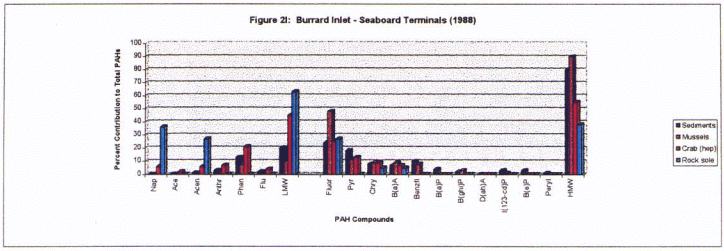
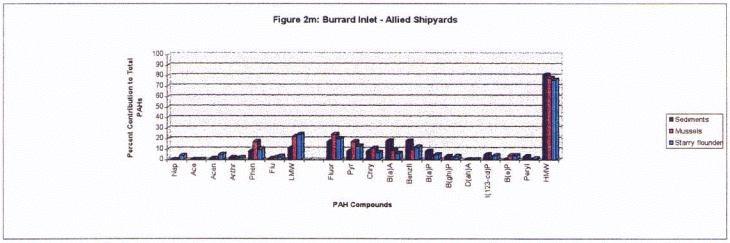
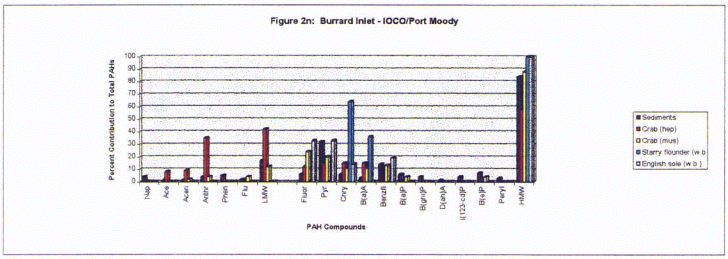


Figure 2: Percent Contribution of Individual PAH Compounds to Total PAHs in Sediments and Biota







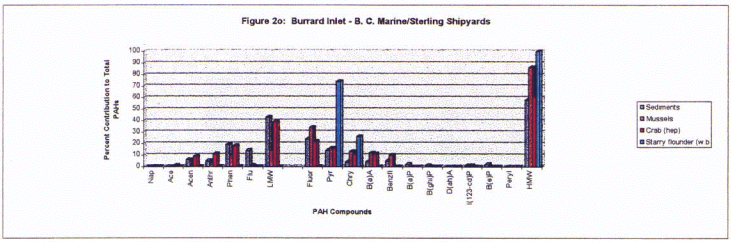
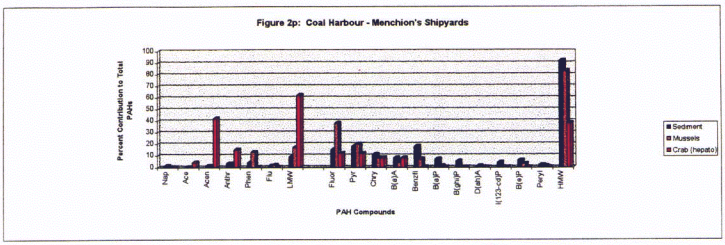
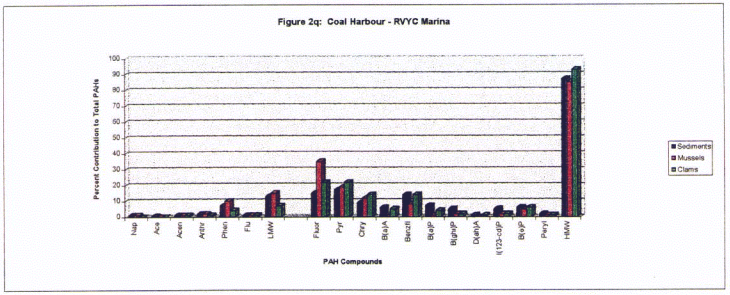
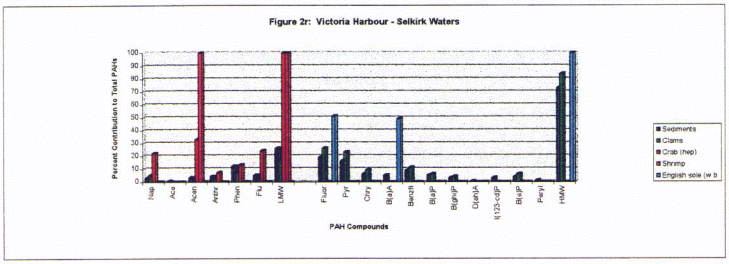


Figure 2: Percent Contribution of Individual PAH Compounds to Total PAHs in Sediments and Biota







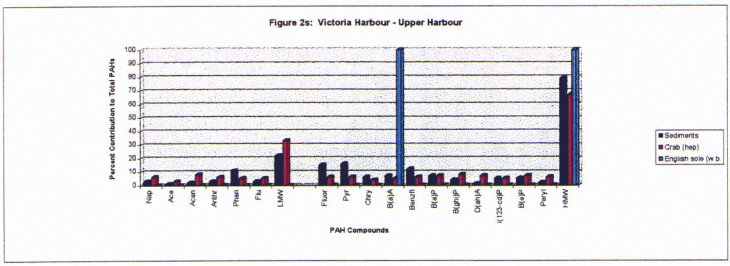
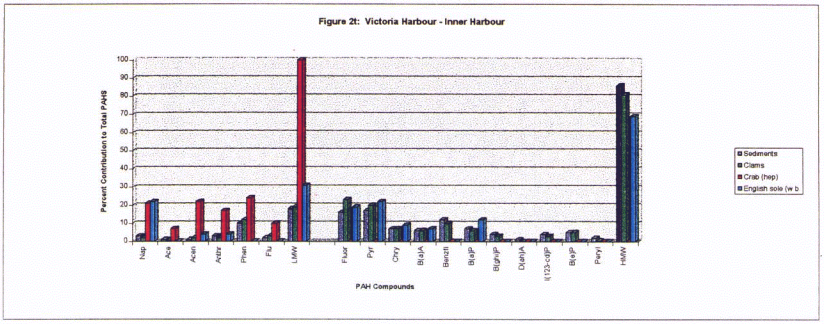
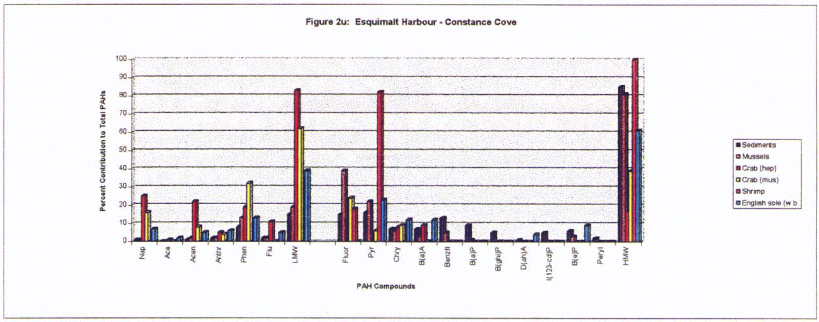
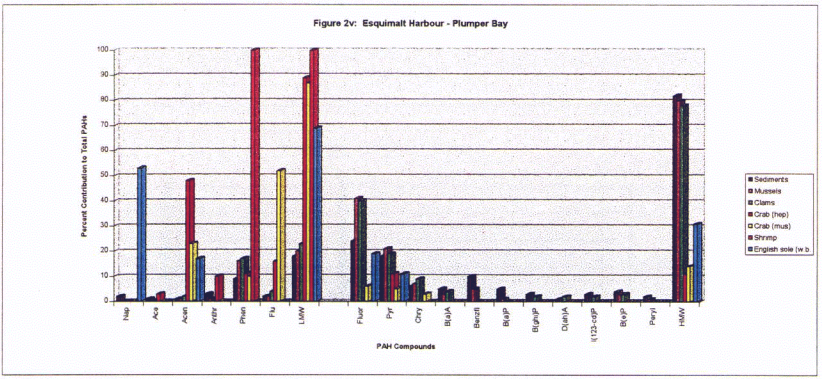


Figure 2: Percent Contribution of Individual PAH Compounds to Total PAHs in Sediments and Biota







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APPENDIX 1

SAMPLING AND ANALYTICAL METHODOLOGY

APPENDIX 1.1 Field Collection Methods

Water samples were collected at a depth of 0.5 metres using 1 litre amber glass bottles with aluminum foil cap liners. The bottles and foil cap liners had been solvent-rinsed and heat-treated. The bottles were submerged to a depth of 0.5 metres and the caps removed to allow water to enter until the bottle was filled. Samples were stored at 4☜ C until analyzed. Two samples were collected at each station and samples were composited prior to analysis. Samples were not filtered prior to analysis.

Sediment grabs were collected with a modified stainless steel Ponar Grab or a stainless steel Smith-MacIntyre grab. A minimum of three grabs were collected at each station. A relatively undisturbed sample of the top 2 cm of sediment from each grab was collected using a stainless steel spoon after carefully decanting overlying water. The surface material from each of the three grabs was composited and then thoroughly mixed in a stainless steel bucket. From the composited sample, three to four subsamples were collected for analyses for organotin compounds and other organic chemicals. Subsamples were also collected for trace metals, particle size, SVR, and SFR. Samples for organotin compounds and other organic chemicals were collected in solvent rinsed and heat-treated 125 ml glass jars with heat-treated aluminum foil liners. Samples for trace metals, particle size, SVR, and SFR were collected in a kraft paper bag, enclosed in Whirlpak ☺ bags. Samples were either frozen immediately (-20☜ C) or temporarily stored on ice in the field until samples could be transferred to lab freezers.

Fish, and some crab samples, were collected using a small otter trawl with a 3.8 cm mesh net and a 5.8 metre throat. The trawl was towed at a speed of approximately 1 to 1.5 knots. Trawl catches were sorted by species. Number of individuals, lengths, and weights were recorded and are presented in Appendix 4. At some locations crabs were also collected using crab traps. Mussels and oysters were collected by hand off rocks at low tide. At several sites mussels could not be found growing on rocks, particularly in harbour and marina locations. At these sites mussels were collected from dock structures and pilings at low tide. Clams were dug at low tide using clam shovels and garden forks.

Dissections were performed on teflon boards using sterlized stainless steel scalpels, scissors, and forceps. Tissues collected for analysis included: tail muscle from shrimp and prawns, leg muscle and hepatopancreas from crabs, dorsal muscle (skin removed, liver and gill (without gill arch) from fish, and soft tissue from bivalves. Tissues from individuals of like species and size from each location were composited. Samples were homogenized prior to analysis. Approximately 30 to 50 gram aliquots of homogenized tissue were placed in solvent-rinsed, heat treated 125 ml glass jars for organotin and lipid content analysis and in Whirlpak ☺ bags for metals analysis. The weight of each homogenized sample was recorded. Samples were kept frozen (-20☜ C) until analyzed.

APPENDIX 1.2 Analytical Methods

1.2.1 PAH Compounds

Laboratory 1 (Axys Analytical Services Ltd.)

The following information on analytical methodologies was provided by Axys Analytical Services Ltd. in Sidney, British Columbia.

Batch 342:

Materials

Solvents used were pesticide grade and distilled in glass (hexane, pentane, methanol, and dichloromethane supplied by BDH Omnisolve). A solvent blank was determined for each new solvent. Solvents were used only if blank gas chromatograms were free of interfering peaks.

Silica gel (Bio-Rad, 100-200 mesh) was heated for 10 hours at 350° C, cooled, deactivated with glass-distilled water (5% by weight) and allowed to stand at least 24 hours before use.

Anhydrous sodium sulfate (Mallinckrodt, granular) was cleaned by heating at 350° overnight.

Potassium hydroxide solution (50% w/w) was prepared by mixing equal quantities (weights) of potassium hydroxide and distilled water.

Distilled water was extracted with dichloromethane (2 X 100 mL) and hexane (100 mL) before use. Potassium hydroxide solution was extracted with dichloromethane/hexane (3/5, 3 x 100 mL) before each analysis.

Copper turnings were activated before use by standing in dilute HCl/methanol for 15 min., followed by rinsing with acetone and hexane. The copper turnings were stored in a stoppered flask under a nitrogen atmosphere.

All glassware was washed in laboratory detergent, rinsed with tap water, air dried, and baked overnight at 340° C in a forced air oven before use.

Internal standards (perdeuterated naphthalene, acenaphthene, phenanthrene, pyrene, chrysene, perylene, dibenz(a,h)anthracene and benzo(g,h,i)perylene; Merck, Sharp and Dohme) were used as received. Known quantities of the standards were dissolved in methanol to prepare an internal standard solution.

Extraction Method

Sample Size	Tissue	1-10 g wet tissue
	Sediment	25 g wet sediment

A subsample of sediment was weighted into a tared glass Petri dish and air-dried at 80° C to constant weight to determine moisture content.

Tissue samples were homogenized in a Virtis homogenizer.

A weighed sample was placed in a round-bottomed flask and methanol (100 mL), potassium hydroxide solution (10 mL, 50% w/w), an aliquot of internal standard (1.0 mL) and boiling chips were added. The mixture was heated under reflux for 1 hour, cooled 5-10 minutes and then extracted water (100 mL) added through the condenser. The solution was again heated under reflux for another 30 minutes. The solution was allowed to cool to lukewarm to settle suspended solids.

The liquid was decanted into a separatory funnel. The remaining solids in the flask were rinsed with methanol (2 x 40 mL) and these rinses added to the separatory funnel.

The digest was extracted with pentane (3 x 100 mL) by shaking the separatory funnel vigorously for 2 minutes. The aqueous layer was collected in the digestion flask and the pentane in an Erlenmeyer flask. The pentane layers were combined in another separatory funnel.

The combined pentane layers were washed with extracted water (3 x 100 mL) to remove any methanol from the pentane. The pentane layer was collected in an Erlenmeyer flask and dried over sodium sulphate for 10 - 15 minutes. The pentane extract was then evaporated to ~1 mL in a Kuderna-Danish flask in a 50° C water bath. Activated copper was added to the extract to remove sulphur. The extract was then ready for cleanup on a silica gel column.

Column Cleanup

A silica gel column (10 g. 5% deactivated) was slurry packed in pentane. The sample was loaded onto the column with rinses and eluted with pentane (25 mL, Fraction 1). The column was then eluted with dichloromethane (25 mL, Fraction 2). The eluate was collected in a small Kudera-Danish flask and subsequently concentrated to 1-2 mL. Fraction 2 contains the PAHs. The extract was transferred to a centrifuge tube with rinses for GC/MS analysis.

The sample was concentrated under a stream of nitrogen to 100 μL for GC/MS analysis.

Procedural Blanks

Procedural blanks were determined initially for each sample type and a routine procedural blank was carried through the analysis with each suite of samples. When blank levels of an analyte are detectable, the determined absolute quantities of the analyte are blank corrected.

Instrumental Analysis

Aromatic fractions were analyzed on an Incos 50 gas chromatograph/mass spectrometer (GC/MS), using a Restek Rt_x-5 column (30 m, 0.25 mm id., 0.25 μm film thickness) and the following gas chromatograph program: splitness injection at 50° C for 2 minutes, heat to 100°, after 5 minutes heat at 10° C/minute to 300° C and hold for 10 minutes. Usually 1 μL of extract was injected. Molecular ions for PAH, selected alkyl PAH and perdeuterated standards were monitored using the Multiple Ion Detection (MID) acquisition mode of the mass spectrometer.

Batches 1171 and 1187:

Summary

All sediment and tissue samples were spike with an aliquot of surrogate standard solution (perdeuterated PAHs - acenaphthene, chrysene, naphthalene, perylene, phenanthrene, pyrene, dibenz(a)anthracene, and benzo(g,h,i)perylene) prior to a base digestion extraction procedure. The digest was extracted with pentane and then separated on a silica gel column. The final extract was analyzed for PAHs by GC/MS.

Extraction Method

Sediment and Tissue

Samples were homogenized well and a subsample of sediment was dried for moisture determination. A subsample of tissue was taken for moisture determination.

Sediment sample (10 g) or tissue sample (5 g), methanol, potassium hydroxide solution, and an aliquot of surrogate standard solution were heated together under reflux for 1 hour. Extracted water was added and heating continued. When cool, the aqueous phase was extracted three times with pentane. The combined pentane extracts were washed with extracted water, dried over anhydrous sodium sulphate and concentrated in a Kuderna Danish flask. The extract was ready for fractionation on a silica gel column.

Column Cleanup

The sample extract was loaded onto a silica gel column and eluted with pentane (discarded) followed by dichloromethane. The dichloromethane fraction was concentrated in a Kuderna-Danish flask. Activated copper was added to the extract to remove sulphur. The extract was then transferred to a microvial, concentrated under a stream of nitrogen to almost dryness and an aliquot of recovery standard (benzo(b)fluoranthene d-12, fluoranthene d-10, and acenaphthylene d-8) was added. The extract was ready for analysis by GC/MS.

Instrumental Analysis

Sample extracts were analyzed for PAHs and alkylated PAHs (when required) by gas chromatography (GC) with detection by mass spectrometer (MS). Analysis of the extract was carried out using a Finnigan Incos 50 mass spectrometer equipped with a Varian 3400 gas chromatograph with a CTC autosampler and a DG 10 Data system. The chromatographic separation was carried out using a Restek$_x$-5 column (30 m, 0.25 mm i.d. x 0.25 μm film thickness). The mass spectrometer was operated in the El mode (70 Ev) using Multiple Ion Detection (MID) to enhance sensitivity, acquiring two characteristic ions for each target analyte and surrogate standard. A split/splitless injection sequence was used.

Batches 2820 and 2844

Summary

All samples were spiked with perdeuterated PAH surrogate standards (acenaphthene, chrysene, naphthalene, perylene, phenanthrene, pyrene, benzo(a)pyrene, dibenz[a,h]anthracene, and benzo[g,h,i]perylene) prior to analysis. Both sediment and tissue samples were solvent extracted on a shaker table and the extract separated on a silica gel column. Analysis was performed by GC/MS.

Extraction Methods

Sediments:

A subsample of homogenized sediment was dried for moisture determination. The sediment sample, to which an aliquot of surrogate standard had been added, was extracted with 1:1 dichloromethane:methanol by shaking on a shaker table for 30 minutes. The extraction procedure was repeated twice more with dichloromethane. The combined extracts were washed with solvent extracted distilled water to remove the methanol and dried over anhydrous sodium sulphate. The solvent was exchanged to hexane and the extract was concentrated in a Kuderna-Danish flask. Activated copper was added to the extract to remove sulphur. The extract was ready for column cleanup.

Tissues:

A subsample of homogenized tissue was dried for moisture determination. The tissue sample, to which an aliquot of surrogate standard had been added, was extracted with 1:1 dichloromethane:methanol by shaking on a shaker table for 30 minutes. The extraction procedure was repeated twice more with dichloromethane. The combined extracts were washed with solvent extracted distilled water to remove the methanol and dried over anhydrous sodium sulphate. The solvent was exchanged to hexane and the extract was concentrated in a Kuderna-Danish flask. The extract was placed on a calibrated gel permeation column and eluted with a 1:1 dichloromethane:hexane. The 125-300 mL fraction was collected and evaporated to a small volume prior to cleanup and separation on a silica gel column.

Column Cleanup

The sample extract was loaded onto a silica gel column and eluted with pentane (discarded) followed by dichloromethane (F2, retain) which contained the PAH compounds. The fraction was concentrated in a Kuderna-Danish flask and then transferred to a microvial where an aliquot of recovery standard solution was added (acenaphthylene d-8, fluoranthene d-10 and benzo[b]fluoranthene d-12). The extract was ready for analysis by GC/MS.

GC/MS Analysis

Sample extracts were analyzed by gas chromatography (GC) with detection by mass spectrometer (MS). Analysis of the extract was carried out using a Finnigan Incos 50 mass spectrometer equipped with a Varian 3400 gas chromatograph with a CTC autosampler and a DG 10 Data System. The chromatographic separation was carried out using a Restek$_x$-5 column (30 m, 0.25 mm i.d. x 0.25 μm film thickness). The mass spectrometer was operated in the El mode (70 Ev) using Multiple Ion Detection (MID) to enhance sensitivity, acquiring two characteristic ions for each target analyte and surrogate standard. A split/splitless injection sequence was used.

Laboratory 2 (Enviro-Test Laboratories)

Batches 251, 383

Sample Preparation

Sediments:

Each sediment sample was dried at room temperature for 48 hours and sieved with a #10 (2mm) sieve. Approximately 15 g was weighed into a glass extraction thimble and soxhlet extracted for 16 hours with methylene chloride. The organic extract was transferred to a 2 L separatory funnel along with 500 mL of organic free de-ionized water. The pH was adjusted to $\geq$ 10 with 6N NaOH and the sample was extracted with 3 x 100 mL methylene chloride. The organic extracts were combined and dried (base/neutral fraction). The aqueous phase was re-extracted with 3 x 100 mL methylene chloride at pH $\leq$ 2 with 6N H2S04. The organic extracts were combined and dried (acid fraction).

Because of the oily nature of the base/neutral extracts, further clean-up and fractionation was necessary prior to GC/FID and GC/MS analysis. The acid fractions were reduced to 2 mL and analyzed by GC/FID.

Tissues:

Approximately 2 g of biota was weighed into a beaker and mixed with Na2SO4. The fish sample was blended with dry ice and stored in a freezer overnight to allow the dry ice to sublime. The sample was then mixed with Na2SO4. The samples were soxhlet extracted for 16 hours with methylene chloride. Prior to acid and base/neutral partitioning, the sample extracts were concentrated to approximately 2 mL and run through a column packed with Bio-Beads SX-3 to remove interfering lipids. The first 100 mL of eluate containing the lipids was discarded. The next 130 mL of eluate was collected. The extract was poured into a separatory funnel along with 500 mL of organic free deionized water. The pH was adjusted to $\geq$10 (6N NaOH) and the sample was extracted with 3 x 100 mL methylene chloride. The organic extracts were combined and dried (base/neutral fraction). The aqueous phase was re-extracted at pH $\leq$ 2 (6N h2S)4) with 3 x 100 mL methylene chloride. The organic extracts were combined and dried (acid fraction).

Column Clean-Up

Basic alumina (Camag, activity 1) was chosen for clean-up because of its reliable success in separating saturates from aromatics. Before its use, the alumina was rinsed with ethyl ether and air dried until free-flowing.

18 g of basic alumina was added to a column (30 cm X 11 mm i.d.) and rinsed with 45 mL pentane. The base/neutral extract was added and 3 fractions collected:

Fraction 1 (saturates)	- 45 mL pentane
Fraction 2 (aromatics)	- 150 mL benzene
Fraction 3 (polar compounds)	- 150 mL methylene chloride

All three fractions were concentrated and made up to a known volume.

Method of Analysis

All samples were analyzed by GC/FID and semi-quantitated against a calibrated standard. Sediment fractions 1 and 3 were calculated against a diesel standard for total hydrocarbons. Sediment fraction 2 was calculated against a PAH calibration mix for total aromatics. The acid fractions were calculated against a diesel standard for total extractable acids. The biota extracts were also analyzed by GC/FID. The samples were concentrated to 100 - 500 μL prior to GC/MS analysis.

All fractions were then injected for GC/MS analysis. Batch software techniques were used to generate spectra and library search each sample fraction. All non-target compounds that were resolved and generated adequate spectra were library searched for identification. Those compounds searched were then manually interpreted and a confidence of identification was assigned to each compound identified.

Method of Quantitation

a.) ***Using Calibration Mixes with Anthracene-d10 as Internal Standard***

The target EPA compounds (Priority Pollutants) were analyzed and quantitated according to the EPA method 625. This is an internal standard method in which response factors for the compounds in the calibration mixes are calculated on a routine basis and updated before sample analysis. Anthracene-d10 is added to each extract and to each standard mix.

Identification of the EPA compounds were done by extracted ion methods, that is three ions for each compound were scanned within a specified retention window. If the ions are present in the right abundance they are extracted, printed out with the calculated amount. This method is very precise resulting in positive identifications and accurate quantification. Biota sample extracts were reduced to 100 µL before injection. *This reduction in volume decreases the accuracy of the results. Thus the EPA priority pollutants identified in the biota samples are semi-quantitative only.*

b.) ***Using Anthracene-d10 as an External Standard***

All the non-target compounds were quantitated against anthracene-d10. A known amount of anthracene-d10 was added to each sample and the area counts of it as well as the non-target compounds were generated (automated software program). The non-target compounds were compared directly with the anthracene-d10 added, calculated in relation to the final volume and the dry weight of the sample. All non-target compound (confidence level of 1 to 5) were calculated using this method. The accuracy of the quantitation using this method is estimated at $\pm$ 50 - 100%.

Batch 425

Method of Sample Preparation

Sediments:

Each sediment is dried at room temperature for 48 hours and sieved with a #10 (2mm) sieve. Approximately 15g is weighed into a glass extraction thimble and soxhlet extracted for 16 hours with dichloromethane (DCM). Prior to extraction the sample is spiked in the thimble with three surrogate compounds (100 µL if 20 ng/µL). The DCM is stripped to near dryness using a rotary evaporator with the water bath at 35° C and is quantitatively transferred to a 3 ½ mL vial. The remaining DCM is chased with the addition of hexane and the sample again stripped to near dryness under a nitrogen evaporator. The extract is then transferred to a scintillation vial containing vial containing 2 g of neutral alumina (Woelm Grade). The sample is gently blown with nitrogen until the alumina is free flowing. The sample (alumina) is transferred to a 9 g alumina column (30 cm x 11 mm i.d.) which is dry

packed. Three fractions are collected using 20 mL of pentane (FR. 1), 70 mL of benzene (FR. 2) and 100 mL of DCM (FR. 3). Fraction 2 (PAHs is stripped to near dryness and made up to exactly 1 mL in DCM. Mercury is added to the extract and the vial is shaken vigorously to remove interfering sulphur. A portion of the extract is transferred to an autosampler vial, internal standard (anthracene d10) added and injected onto a GC/MSD system for analysis. A second injection was made onto a GC/MS system in the TIC mode for those samples requiring additional priority pollutant analysis.

Biota:

Approximately 10 g of biota sample was weighed into a mortar containing Na2S04 and ground into the Na2S04 using a pestle. This was transferred to a soxhlet extraction thimble as in the sediment procedure and extracted for 16 hours with DCM. The DCM was removed by rotoevaporator, weighed and an aliquot of 1 mL of lipid was removed for gel permeation chromatography (GPC). A 25 minute waste was discarded and a 15 minute collect fraction was evaporated to near dryness. The DCM was chased with hexane and cleaned-up with neutral alumina as in the sediment procedure.

Selected Ion Techniques (SIM)

Using the MSD 5971 the software generates a calibration table using standards at 2 levels (0.1 ppm and 1.0 ppm). The GC/MS automatically scans for each target PAH compound, generates a selected ion chromatogram (SIC) and integrates and quantitates 3 ions for each target PAH. The GC/MS 5971 generates a calibration curve from 2 levels of standards. The target PAH are quantitated against this calibration curve to give a final concentration in μg/g (ppb), listed as amount on the chromatography.

This technique has resulted in an approximate 50 fold reduction in detection limits compared to GC/MS in the total ion mode.

Total Ion Chromatography (TIC)

Using the HP-5993 and the HP-MSD 5971 in the total ion monitoring mode, full mass spectral data is generated for each compound. The sensitivity of this equipment in the TIC mode is 50 to 100 times lower than in the SIM (Selective Ion Monitoring Mode). Consequently, detection limits are much higher (0.1 to 0.5 ppm).

Detection Limits

A general detection limit of 0.005 ppm in sediment and biota was determined for each target PAH compound using the following weights and volumes:

a.) Sediments - 15 g of sample and a 1 mL final volume

b.) Biota - 10-11 g of sample, about 1/3 of the resulting lipid cleaned-up on GPC and a 1 mL final volume

Calculations

All data was adjusted using the average surrogate recovery of terphenyl d2 fluorobiphenyl for all PAHs except naphthalene which was adjusted using naphthalene d8 surrogate recovery for each sample.

Batch 1287

Sediments:

Extraction-

Each sediment is dried at room temperature for 48 hours and sieved with a #10 (2mm) sieve. Approximately 20g is weighed into a pre-extracted glass extraction thimble and soxhlet extracted for 16 hours with 1:1 acetone/hexane (acidified with 0.5% acetic acid) The organic extract was transferred to a 2 L separatory funnel containing 500 mL of de-ionized, organic free water. The pH was adjusted to $\geq$ 10 with 6N NaOH. The sample was then extracted with methylene chloride. Enough methylene chloride was added (approximately 100 mL or more) during the first extraction to force the hexane layer into the methylene chloride. The sample was extracted twice again using 100 mL of methylene chloride for each extraction. The organic extracts (base/neutral fraction) were dried through sodium sulphate, combined and concentrated to a known volume using a rotary evaporator and a gentle stream of nitrogen.

The aqueous phase was then acidified (pH $\leq$ 2 6N H2SO4) and extracted with 3 x 100 mL of methylene chloride. Again the extracts were dried (acid fraction), combined and concentrated to a know volume.

It was obvious from the oily nature of the base/neutral extracts that further column clean-up and fractionation would be required. The acid fraction was reduced to 2 mL and analyzed by GC/FID and GC/MS.

Column Clean-up-

Basic alumina (Woelm Grade, Akt 1, fully activated from bottle) was chosen for the clean-up because of its reliable success in separating saturates from aromatics.

Many of the base/neutral extracts were extremely oily and precipitation was evident. Because of this a technique which has been used successfully for oily sludge samples was used. 3 g of basic alumina was mixed with the extracts in a vial and the sample was then placed in a fumehood and allowed to dry. This 3 g was then quantitatively added to a column (30 cm x 11 mm i.d.) containing 9 g of basic alumina. The column was eluted as follows:

Fraction 1 (Saturates)	- 30 mL pentane
Fraction 2 (Aromatics)	- 100 mL benzene
Fraction 3 (Polar compounds)	- 100 mL methylene chloride

All three fractions were concentrated and made up in a known volume of hexane. In some cases methylene chloride is added to keep the samples from precipitating.

Method of Analysis

All fractions were analyzed by GC/FID and semi-quantitated against a calibrated standard. Fractions 1 and 3 from alumina

Biota:

Approximately 10 g of biota sample was weighed into a mortar containing Na2S04 and ground into the Na2S04 using a pestle. This was transferred to a soxhlet extraction thimble as in the sediment procedure and extracted for 16 hours with DCM. The DCM was removed by rotoevaporator, weighed and an aliquot of 1 mL of lipid was removed for gel permeation chromatography (GPC). A 25 minute waste was discarded and a 15 minute collect fraction was evaporated to near dryness. The DCM was chased with hexane and cleaned-up with neutral alumina as in the sediment procedure.

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Using the MSD 5971 the software generates a calibration table using standards at 2 levels (0.1 ppm and 1.0 ppm). The GC/MS automatically scans for each target PAH compound, generates a selected ion chromatogram (SIC) and integrates and quantitates 3 ions for each target PAH. The GC/MS 5971 generates a calibration curve from 2 levels of standards. The target PAH are quantitated against this calibration curve to give a final concentration in µg/g (ppb), listed as amount on the chromatography.

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Detection Limits

A general detection limit of 0.005 ppm in sediment and biota was determined for each target PAH compound using the following weights and volumes:

a.) Sediments - 15 g of sample and a 1 mL final volume

b.) Biota - 10-11 g of sample, about 1/3 of the resulting lipid cleaned-up on GPC and a 1 mL final volume

Calculations

All data was adjusted using the average surrogate recovery of terphenyl d2 fluorobiphenyl for all PAHs except naphthalene which was adjusted using naphthalene d8 surrogate recovery for each sample.

1.2.2 Particle Size Analysis

The Environment Canada Sediment Lab conducted the particle size analysis for sediment samples from Laboratory 1 Batches 1 through 8 using the pipette method (Black, 1965). Samples were dried and passed through a series of sieves with decreasing mesh sizes for grain separation. The amount collected from each sieve was weighed and the percent composition of the total weight calculated to determine particle size distribution. Mesh sizes used for grain separation were as follows:

silt and clay	- <0.063 mm (-230 mesh)
very fine sand	- 0.063 - 0.125 mm (230 mesh)
fine sand	- 0.125 - 0.250 mm (120 mesh)
medium sand	- 0.250 - 0.500 mm (60 mesh)
coarse sand	- 0.500 - 1.000 mm (35 mesh)
very coarse sand	- 1.000 - 2.000 mm (18 mesh)
granules	- >2.00 mm (10 mesh)

Soilcon Laboratories Ltd. conducted the particle size analysis for sediment samples from Laboratory 1 Batch 9 using the following procedure.

For standard texture the following size fractions are tested for: 250, 125, 53, and 2 ☞m. Particle size analysis is done by the pipette method on air dry soil/sediment, which has passed through a 2 mm sieve (USDI, 1962; Lavkulich, 1981; Sheldrick and Wang, 1993). Organic matter is removed from a 40 g (± 0.5 g) sub-sample of soil/sediment using hydrogen peroxide. A dispersant, 0.4 N sodium pyrophosphate, and water is added to the soil/sediment to break apart any fine soil particles. The solution of soil/sediment, sodium pyrophosphate, and water is blended in an electric 'milk-shake' style mixer. The blended liquid is then transferred to a 1000 mL cylinder and brought up to volume.

The soil suspension is stirred with a plunger for a minimum of 30 seconds to ensure the sample is homogenous. Samples of the suspended soil are taken in a 20 mL volumetric pipette at predetermined time intervals dependent on the temperature of the liquid and the size of the particles one wants to measure.

Following pipette analysis, the remaining contents of the cylinder are wet sieved to determine the various sand fractions.

There is no certified reference material for soil/sediment particle size analysis. Soilcon, however, has it's own standards for particle size, which are analyzed on a regular basis. In addition, the 53 ☞m size fraction is determined both by pipetting and wet sieving. These two values must be within 5% of each other to be accepted. If the difference exceeds 5%, the sample is repeated.

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Sheldrick, B.H. and C. Wang. 1993. Particle size distribution. *In:* Martin R. Carter, ed. Soil Sampling and Methods of Analysis. Canadian Society of Soil Science. Lewis Publishers, London, pp. 499-512.

1.2.3 SFR/SVR Analysis

Sediment residue analysis was conducted at the Pacific Environmental Science Centre. Samples were oven dried and then ignited at 550° C in a muffle furnace. The loss of weight on ignition represents the sediment volatile residue (SVR), and the remaining residue represents the sediment fixed residue (SFR). Volatile residue is only an approximate measure of the organic content as results may also reflect loss of water at crystallization, loss of volatile organic matter before combustion, incomplete oxidation, and decomposition of mineral salts during combustion. For a detailed description of the residue analysis refer to APHA (1985) or Swingle and Davidson (1979).

References:

APHA/ AWAA/WPCF. 1985. Standard Methods for the Examination of Water and Wastewater. 14th Edition. Washington, D.C.

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1.2.4 Lipid Content

The following description of analytical methodology was provided by Axys Analytical Services in Sidney, British Columbia.

Gravimetric lipid analyses were carried out on extracts during either the extraction procedure for organotin compounds or the extraction procedure for PCB congeners and coplanars (many of the samples were also analyzed for PCBs). The percentage lipid was determined using a wet tissue weight.

Colourimetric lipid analyses were carried out on a small number of tissue samples. A lipid extract was prepared by homogenizing dry tissue sample with chloroform/methanol (2:1) and filtering the residue. The filtrate was made up to a volume of 100 mL.

The lipid concentration was quantified colourimetrically using the sulphophosphovanillin method of Barnes and Blackstock (1973). A portion of the lipid extract (0.5 mL) was placed in a test tube, the solvent evaporated under a stream of nitrogen, and concentrated sulphuric acid added (0.5 mL). The stoppered tubes were heated in a water bath (100℃) for 10 minutes. When cool, an aliquot (0.1 mL) of extract was transferred to a test tube, and phosphovanillin reagent (2.5 mL) was added. After 30 minutes the absorbance was measured at 520 nm against a procedural blank. A calibration curve was made with a cholesterol standard. Total lipid concentration was calculated using a conversion factor given by Barnes and Blackstock (1973) which equates 80 mg cholesterol standard with 100 mg total lipid.

Reference:

Barnes. H. and J. Blackstock. 1973. *J. Exp. Mar. Bio. Ecol.* **12**: 103-1189

APPENDIX 2

SAMPLING STATION COORDINATES

APPENDIX 2.1 Sampling Station Coordinates

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
FRASER RIVER ESTUARY				
MS-3	Off Iona Island sewage treatment plant			
	Station 1	49° 12.112′	123° 15.988′	2
FRASER RIVER				
FR-16	Koppers International	49° 13.381′	122° 55.852′	
	Station 1			2.5
	Station 2			5
	Station 3			4
FR-20	BC Cleanwood Preservers	49°11.030′	122° 54.909′	
	Station 1			5
	Station 2			13
	Station 3			4
	Station 4			5
FR-17	Domtar Wood Preservers	49° 11.280′	122° 57.780′	
	Station 1			2
	Station 2			2
	Station 3			3
	Station 4			2
FR-19	Princeton Wood Preservers	49° 11.908′	122° 54.000′	
	Station 1			1
	Station 2			5.5
	Station 3			5
	Station 4			3.5
FR-18	Domtar/Liverpool Site	49°12.723′	122° 52.995′	
	Station 1			.75
	Station 2			1.5
	Station 3			1
	Station 4			10

APPENDIX 2.1 Sampling Station Coordinates

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
FALSE CREEK				
FC-1	Marina at Market	49° 16.352'	123° 08.166'	
	Station 2			
	Station 3	49° 16.310'	123° 08.178'	3
	Station 4	49° 16.280'	123° 08.178'	6
	Station 5	49° 16.255'	123° 08.166'	4
FC-4	Outer creek - midchannel			
	Station 1	49° 16.630'	123° 08.244'	8
FC-5	At Granville Ferries			
	Station 1	49° 16.480'	123° 08.064'	7.5
FC-6	Off Granville Island Hotel			
	Station 1	49° 16.200'	123° 07.706'	6
FC-7	Off Marina at Monk McQueen's			
	Station 1	49° 16.136'	123° 07.264'	6
FC-8	Off Monk McQueen's; near Cambie Bridge			
	Station 1	49° 16.292'	123° 06.861'	7
FC-9	Inside Cambie Bridge off dumpsite			
	Station 1	49° 16.429'	123° 06.339'	9
FC-10	Northeast corner			
	Station 1	49° 16.503'	123° 06.237'	7
FC-11	East basin			
	Station 1	49° 16.495'	123° 06.327'	3

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
BURRARD INLET				
BI-1	Vancouver Outer Harbour (Pacific Environment Institute)			
	Station 2	49° 19.72'	123° 13.52'	54
BI-2	Vancouver Wharves			
	Station 4	49° 18.546'	123° 06.963'	19
BI-3	L&K Lumber			
	Station 2a	49° 18.654'	123° 06.700'	14
BI-4	Vancouver Shipyard/Seaspan			
	Station 1	49° 18.775'	123° 06.234'	8
	Station 3	49° 18.748'	123° 06.294'	20
	Station 4	49° 18.644'	123° 06.333'	8
BI-5	Versatile Pacific (was Burrard Yarrows)			
	Station 2	49° 18.500'	123° 04.684'	11
	Station 4	49° 18.543'	123° 04.774'	7
	Station 5	49° 18.367'	123° 04.663'	18
BI-7	Saskatchewan Wheat Pool			
	Station 1	49° 18.267'	123° 03.507'	14
BI-8	Neptune Terminals			
	Station 2	49° 18.203'	123° 03.077'	20
	Station 2a	49° 18.197'	123° 03.131'	15.7
BI-9	Seaboard Terminals			
	Station 1x	49° 18.061'	123° 02.621'	15.5
	Station 1xb	49° 18.075'	123° 02.684'	17
BI-10	Lynnterm			
	Station 4	48° 17.803'	123° 01.634'	15

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
BURRARD INLET cont.				
BI-11	Belaire Shipyards Station 1	49° 17.870'	123° 01.449'	8
BI-12	Allied Shipyards Station 2	49° 18.187'	123° 01.345'	9
BI-14	Boulder Rock Station 1	49° 18.20 '	122° 56.36 '	28
BI-15	Ioco Station 1	49° 17.84 '	122° 53.13 '	12
BI-16	Ioco/Port Moody Station 2	49° 17.36 '	122° 51.75 '	11
BI-17	Port Moody Station 1	49° 17.50 '	122° 55.66 '	21
BI-18	Alberta Wheat Pool Station 1	49° 17.528'	123° 01.888'	20
BI-19	Central Harbour Station 1	49° 17.95 '	123° 05.00 '	34
BI-20	Rivtow Straits Station 2	49° 17.466'	123° 03.590'	17.6
BI-21	Sterling Shipyards Station 1	49° 17.284'	123° 03.785'	2
BI-22	B.C. Marine Shipbuilders Station 1	49° 17.270'	123° 03.922'	3

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
BURRARD INLET cont.				
BI-22a	B.C. Marine/Sterling Station 1	49° 17.263'	123° 03.871'	5
BI-23	Vanterm Station 2	49° 17.345'	123° 04.305'	19-28
BI-24	United Grain Growers Station 1	49° 17.334'	123°04.633'	26-31
BI-25	Centerm Station 1	49° 17.357'	123° 05.649'	23-26
BI-26	Canada Place Station 2	49° 17.365'	123° 06.634'	18-20
Coal Harbour Area:				
CH-1	Bayshore Inn Marina			
	Station 1	49° 17.580'	123° 07.575'	3
	Station 3	49° 17.597'	123° 07.614'	2
	Station 4	49° 17.613'	123° 07.649'	6
CH-3	Royal Vancouver Yacht Club Marina			
	Station 1	49° 17.808'	123° 07.539'	2
	Station 4	49° 17.719'	123° 07.587'	6
	Station 5	49° 17.685'	123° 07.563'	6
	Station 6	49° 17.709'	123° 07.638'	5
CH-5	Menchions Shipyard Station 1	49° 17.519'	123° 07.584'	7
CH-6	Bayshore/Menchions Station 3b	49° 17.576'	123° 07.560'	6.5

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
VICTORIA HARBOUR				
The Gorge:				
VH-1	SW-7	48° 26.658'	123° 23.811'	3
VH-2	SW-8	48° 26.852'	123° 24.341'	1.5
Selkirk Waters:				
VH-3	SW-1b	48° 26.398'	123° 22.922'	4.5
VH-4	SW-2	48° 26.415'	123°22.725'	2
VH-5	SW-3	48° 26.355'	123° 22.734'	4.5
VH-6	SW-4	48° 26.278'	123° 22.728'	4.5
VH-7	SW-5	48° 26.329'	123° 22.613'	3
VH-8	SW-6	48° 26.351'	123° 22.534'	3-4
Upper Harbour:				
VH-9	UH-1	48° 26.030'	123° 22.531'	7
VH-10	UH-2	48° 26.131'	123° 22.131'	4
VH-11	UH-3	48° 26.053'	123° 22.060'	4
VH-12	UH-4	48° 26.030'	123° 22.313'	7
VH-13	UH-5	48° 25.951'	123° 22.552'	5
VH-14	UH-6 (Site 1)	48° 25.899'	123° 22.496'	4.5
VH-14a	UH-6a (Site 2)	48° 25.955'	123° 22.549'	5.5
VH-15	UH-7	48° 25.812'	123° 22.331'	6.5
VH-16	UH-8	48° 25.787'	123° 22.222'	2.5
VH-17	UH-9	48° 25.940'	123° 22.208'	7.5

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
VICTORIA HARBOUR cont.				
Inner Harbour:				
VH-18	IH-1	48° 25.575'	123° 22.416'	3
VH-19	IH-2	48° 25.521'	123° 22.343'	6.5
VH-20	IH-3	48° 25.385'	123° 22.157'	7
VH-21	IH-4	48° 25.307'	123° 22.119'	2
VH-22	IH-5	48° 25.305'	123° 22.184'	7
VH-23	IH-6	48° 25.395'	123° 22.446'	6.5
VH-23a	IH-7			
VH-24	IH-8	48° 25.384'	123° 22.655'	5
VH-25	IH-9	48° 25.372'	123° 22.802'	1.5
VH-26	IH-10	48° 25.442'	123° 23.123'	7
VH-27	IH-11	48° 25.493'	123° 22.708'	8
VH-28	IH-12	48° 25.577'	123° 22.764'	7
VH-29	IH-13	48° 25.556'	123° 22.637'	8
VH-30	IH-14	48° 25.679'	123° 23.523'	9-13
Outer Harbour:				
VH-31	OH-2	48° 24.962'	123° 23.281'	13-18

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location	Latitude	Longitude	Water Depth (m)
ESQUIMALT HARBOUR				
Upper Harbour:				
EH-1	Upper Harbour Station 1	48°27.380'	123°27.109'	1.5
Plumper Bay:				
EH-2	Station PB-1	48° 26.844'	123° 26.044'	3
EH-3	Station PB-2	48° 26.648'	123° 25.833'	4
EH-4	Trawl Site	48° 26.797'	123° 26.209'	9
EH-5	Dunn's Nook	48° 26.456'	123° 26.856'	10
EH-6	Fort Rodd	48° 25.787'	123° 26.909'	10
Constance Cove:				
EH-7	Station 1	48° 26.143'	123° 25.703'	12
EH-8	Station 6a	48° 26.221'	123° 25.756'	7.5
EH-9	Station 2	48° 26.018'	123° 25.214'	9
EH-10	Station 3	48° 26.014'	123° 25.420'	8
EH-11	Station 4	48° 25.914'	123° 25.550'	10
EH-12	Station 5	48° 26.008'	123° 25.862'	11.5
EH-13	Station 6	48° 26.014'	123° 26.206'	12
EH-14	Station 7	48° 26.032'	123° 25.641'	13

APPENDIX 2.1 Sampling Station Coordinates cont.

Sediment Samples:

Site No.	Location		Latitude	Longitude	Water Depth (m)
MS-14	***LADYSMITH HARBOUR***		49° 00′	123° 48′	NI
	LH-29	Station 29			
	LH-30	Station 30			
	LH-31	Station 31			
	LH-32	Station 32			
	LH-33	Station 33			
	LH-34	Station 34			
	LH-36	Station 36			
	LH-37	Station 37			
REFERENCE SITES					
RF-1	Crescent Beach Station 1		49° 03.358'	122° 53.199'	1
RF-5	Warn Bay Station 1		49° 15.172'	125° 45.660'	1
Queen Charlotte Islands:					
RF-9	Delkatla Slough		54°	132°	
RF-11	Tow Hill		54°	131°	

APPENDIX 2.2 Sampling Station Coordinates cont.

Biota Samples:

Site No.	Location		Latitude	Longitude
Fraser River:				
MS-3	Fraser estuary off Iona Island Sewage Treatment Plant		49°12.112'	123°15.988'
FR-16	Koppers International		49°13.381'	122° 55.852'
FR-20	BC Cleanwood Preservers		49° 11.030'	122° 54.909'
FR-17	Domtar Wood Preservers		49° 11.208'	122°57.780'
FR-19	Princeton Wood Preservers		49° 11.908'	122° 54.000'
FR-18	Domtar/Liverpool Site		49° 12.723'	122° 52.995'
False Creek Area:				
FC-1	Marina at Market			
	Station 3		49° 16.310'	123° 08.178'
	Station 4		49° 16.280'	123° 08.178'
	Station 5		49° 16.255'	123° 08.166'
FCT-1	East Basin Trawl	start	49° 16.187	123° 07.205'
		stop	49° 16.296	123° 06.888'
FCT-2	Monk McQueens Trawl			
		start	49° 16.159'	123° 07.413'
		stop	49° 16.273'	123° 06.992'

APPENDIX 2.2 Sampling Station Coordinates cont.

Biota Samples:

Site No.	Location		Latitude	Longitude
Burrard Inlet:				
SB-1	Spanish Banks Trawl			
	Trawl SBT-1	start	49° 17.84'	123° 12.35'
		stop	49° 17.73	123° 11.55'
BI-1	Vancouver Outer Harbour (Pacific Environment Institute)			
	Trawl VOT-1	start	49° 19.75'	123° 14.32'
		stop	49° 19.73'	123° 13.62'
BI-2	Vancouver Wharves			
	Station M1		49° 18.528'	123° 06.891'
	Station M2		49° 18.497'	123° 06.810'
BI-3	L&K Lumber			
	Station M1		49° 18.667'	123° 06.564'
BI-4	Vancouver Shipyard/Seaspan			
	Station M1		49° 18.703'	123° 06.353'
	Station M2		49° 18.789'	123° 06.291'
BI-5	Versatile Pacific (was Burrard Yarrows)			
	Station M1		49° 18.562'	123° 04.732'
	Station M2		49° 18.451'	123° 04.460'
	Station C1		49° 18.464'	123° 04.851'
	Trawl VCT-1	start	49° 18.259'	123° 04.758'
		stop	49° 18.166'	123° 04.418'
BI-9	Seaboard Terminals			
	Station M1		49° 18.145'	123° 02.845'
	Station M2		49° 18.079'	123° 02.653'
	Trawl ST-1	start	49° 18.048'	123° 02.945'
		stop	49° 17.931'	123° 02.545'
	Station C1		49° 18.071'	123° 02.845'
	Station C2		49° 18.059'	123° 02.564'

APPENDIX 2.2 Sampling Station Coordinates cont.

Biota Samples:

Site No.	Location		Latitude	Longitude
BURRARD INLET cont.				
BI-10	Lynnterm			
	Station M2		49° 17.824'	123° 01.706'
BI-12	Allied Shipbuilders			
	Trawl AT-1	start	49° 18.157'	123° 01.425'
		stop	49° 18.060'	123° 01.330'
	Station M1		49° 18.157'	123° 01.312'
	Station M2		49° 18.120'	123° 01.303'
BI-17	Port Moody/Ioco			
	Trawl PM/I-1a	start	49° 17.54'	122° 53.91'
		stop	49° 17.51'	122° 54.92'
	-1b	start	49° 17.51'	122° 54.92'
		stop	49° 17.54'	122° 53.91'
	-1c	start	49° 17.52'	122° 53.92'
		stop	49° 17.50'	122° 54.90'
BI-22	B.C. Shipbuilders/Sterling Shipyard			
	Trawl BCT-2	start	49° 17.400'	123° 03.716'
		stop	49° 17.474'	123° 03.952'
	Station M1		49° 17.438'	123° 03.537'
BI-26	Canada Place			
	Station M1		49° 17.308'	123° 06.840'
CH-7	Coal Harbour			
	Trawl CHT-1	start	49° 17.510'	123° 06.992'
		stop	49° 17.486'	123° 06.353'
CH-5	Menchions Shipyard			
	Station M1		49° 17.494'	123° 07.602'
	Station C1			
Coal Harbour Area:				
CH-1	Bayshore Marina			
	Station 3		49° 17.667'	123° 07.787'
	Station 5		49° 17.603'	123°07.821'
	Station 7		49 17.607'	123° 07.733'
	Station 8		49° 17.608'	123° 07.649'

APPENDIX 2.2 Sampling Station Coordinates cont.

Biota Samples:

Site No.	Location		Latitude	Longitude
Coal Harbour Area cont.:				
CH-1	Bayshore Marina cont.			
	Station 9		49° 17.597'	123° 07.620'
	Station 10		49° 17.588'	123° 07.587'
	Station 11		49° 17.573'	123° 07.579'
CH-3	Royal Vancouver Yacht Club			
	Station 1		49° 17.765'	123° 07.587'
	Station 2		49° 17.732'	123° 07.581'
	Station 3		49° 17.726'	123° 07.596'
	Station 8		49° 17.728'	123° 07.521'
Victoria Harbour:				
Selkirk Waters:				
SW-C1	Station C1		48° 26.398'	123° 22.899'
SWT-1	Trawl SWT-1	start	48° 26.404'	123° 23.119'
		stop	48° 26.404'	123° 22.911'
SWT-2	Trawl SWT-2	start	48° 26.294'	123° 22.684'
		stop	48° 26.337'	123° 22.534'
SWT-3	Trawl SWT-3	start	48° 26.349'	123° 22.843'
		stop	48° 26.192'	123° 22.652'
SW-SS1	Station SS1		48° 26.551'	123° 22.784'
SW-SS2	Station SS2		48° 26.290'	123° 23.129'
Upper Harbour:				
UHT-1	Trawl UHT-1	start	48° 26.012'	123° 22.546'
		stop	48° 25.781'	123° 22.260'
UH-C2	Station C2		48° 26.051'	123° 22.617'

APPENDIX 2.2 Sampling Station Coordinates cont.

Biota Samples:

Site No.	Location		Latitude	Longitude
Victoria Harbour cont.:				
Inner Harbour				
IH-C3	Station C3		48° 25.409'	123 22.811'
IHT-1	Trawl IHT-1	start	48° 26.012'	123 22.546'
		stop	48° 25.781'	123 22.260'
IH-SS3	Station SS3		48° 25.391'	123 22.443'
IH-C4	Station C4		48° 25.585'	123 23.505'
IH-SS4	Station SS4		48° 25.716'	123 23.708'
(same as VI-4)				
Esquimalt Harbour:				
Constance Cove				
CC-M2	Station M2		48° 26.014'	123° 26.097'
CC-C1	Station C1		48° 26.067'	123° 26.150'
CCT-1	Trawl CCT-1	start	48° 26.147'	123° 25.997'
		stop	48° 26.112'	123° 25.476'
Plumper Bay				
PBT-1	Trawl PBT-1	start	48° 27.103'	123° 26.762'
		stop	48° 26.930'	123° 26.403'
PBT-2	Trawl PBT-2	start	48° 26.930'	123° 26.268'
		stop	48° 26.641'	123° 26.250'
PBT-3	Trawl PBT-3	start	48° 27.060'	123° 26.886'
		stop	48° 26.633'	123° 26.432'
PB-M2	Station M2		48° 26.864'	123° 25.985'
PB-M3	Station M3		48° 26.809'	123° 26.027'
PB-SS5	Station SS5		48° 26.821'	123° 25.991'
Dallas Bank				
PB-SS6	Station SS6		48° 26.743'	123° 25.985'

APPENDIX 2.2 Sampling Station Coordinates cont.

Biota Samples:

Site No.	Location		Latitude	Longitude
VI-14	***Ladysmith Harbour***		49°	123°
	Site #29			
	Site #30			
	Site #31			
	Site #32			
	Site #33			
	Site #38			
VI-13	***Nanaimo Harbour***			
	Stn. 1 - South of Nanaimo Yacht Club		49° 10.537'	123° 56.460'
	Stn 2 - North of Nanaimo Yacht Club		49° 10.708'	123° 56.581'
	Stn 3 - South of Moby Dick Motel		49° 10.790'	123° 56.617'
	Stn 4 - Petro-Can Fuel Dock		49° 11.185'	123° 56.873'
	Stn 5 - North of Air Rainbow		49° 11.437'	123° 56.830'
	Stn 6 - South of Shaft Point		49° 11.673'	123° 56.651'
	Stn 7 - Newcastle Island - across from Unique Seafoods		49° 11.092'	123° 56.412'
	Stn 8 - Newcastle Island - South tip		49° 10.637'	123° 55.957'
Reference Sites				
RF-1	Crescent Beach			
	Station 1		49° 03.358'	122° 53.199'
RF-2	St. Vincents Bay	start	49° 49.786'	124° 04.924'
	Trawl	stop	49° 49.786'	124° 03.765'
RF-3	Agamemnon Channel			
	Trawl	start	49° 45.489'	124° 00.994'
		stop	49° 45.892'	123° 59.247'
RF-6	Fortune Channel			
	Station 1		49° 11.535'	125° 46.942'
RF-7	Larkin Island, south end			
	Station 1		48° 56.380'	125° 17.471'
RF-8	Rivers Inlet			
	Station 1		51° 39'	127° 26'
RF-9	Delkatla Slough, Queen Charlotte Islands		54°	132°
	Station 1			

APPENDIX 3

SAMPLE INFORMATION

APPENDIX 3.1 **SEDIMENT CHARACTERISTICS**

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)				SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)		Silt (%)		Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
	FRASER RIVER														
MS-4	Fraser Estuary 0.6 km from Iona Sewage Treatment Plant Station 1	08-Jul-85	clay	86.3		4.1		3.2	3.8	1.4	0.7	0.5		943000	57000
MS-3	Iona Island Sewage Treatment Plant Station 1	20-Jul-87	fine sand	[	9.4	]		11.5	41.6	28.1	7.6	0.7	1.2	NA	NA
FR-16	Kopper's International	26-Sep-90													
	Station 1		clay	62.2	30.7	5.6	1	0.3	0.2					980000	20400
	Station 2		clay	63.2	29.4	5.9	1.3	0.2						977000	23300
	Station 3		clay	71.3	20.6	6.1	1.8	0.2						967000	32500
	Station 4		clay	73.9	17.1	7.8	0.9	0.3						964000	36400
FR-17	Domtar Wood Preservers	24-Sep-90													
	Station 1		clay	80	11.3	5.5	0.9	0.3						970000	29600
	Station 2		clay	75.6	14.7	6.3	3.1	0.2						971000	28900
	Station 3		clay	62.8	23.9	9.2	3.9	0.2						973000	27100
	Station 4		clay	57.1	17.4	7.8	4.9	2.2	1.9	1.6	3	0.1		973000	26600
FR-18	Domtar/Liverpool Site	26-Sep-90													
	Station 1		clay	74.8	14.2	6.7	3.3	0.4						696000	31500
	Station 2		clay	64.7	28.4	5.5	0.8	0.4	0.2					977000	23400
	Station 3		clay	65.9	28.7	4.9	1.2	0.2						978000	22400
	Station 4		very fine sand	2.1	19.5	76.6	1	0.1	0.2	0.3	0.2			992000	7710
FR-19	Princeton Wood Preservers	25-Sep-90													
	Station 1		clay	86.4	8.8	2.3	2.3	0.2						965000	35100
	Station 2		clay	91.3	6.6	1.6	0.5							962000	38300
	Station 3		clay	78.4	7	13.7	2.8	0.1						961000	38800
	Station 4		clay	71.1	21.2	6.4	0.3							970000	30200
FR-20	B.C. Cleanwood Preservers	25-Sep-90													
	Station 1		silt	19.9	40.2	37.9	1.8	0.2	0.2					983000	17000
	Station 2		silt	44.2	31.7	21	2.7	0.4						974000	26100
	Station 3		very fine sand	18.9	29.9	23.8	36.1	7.6	3.7	0.3	0.2			906000	93700
	Station 4		clay	83.7	4.3	7	2.7	0.3						940000	60100
	FALSE CREEK AREA:														
FC-1	Marina at Market														
	Station 2	12-Aug-88	fine sand	17	4.5	7.4	16.1	13.9	12.6	28.4				91000	90100
FC-4	Outer creek - midchannel														
	Station 1	04-Jun-91	medium sand	5.5	2	8.5		6.5	18.2	36.9	18.1	3.1	0.51	964000	36200
FC-5	At Granville Ferries														
	Station 1	04-Jun-91	silt	24.8	11.3	49.8		9	2.9	1.6	0.6	0.14	0	944000	55600
		16-Nov-94	clay and silt	[	62.9	]		11.6	10.9	10.9	3.2	0.5	<0.1	931000	68900
FC-6	Off Granville Island Hotel														
	Station 1	04-Jun-91	silt	26.8	9.4	43.5		11.6	6	1.8	0.62	0.27	0.41	942000	57900
	Station 2	16-Nov-94	clay and silt	[	53.1	]		10.4	13.7	15.2	3.6	1.3	2.7	934000	66000

APPENDIX 3.1 SEDIMENT CHARACTERISTICS

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)			SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)		Silt (%)	Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
	FALSE CREEK AREA cont.:B112													
FC-7	Off Marina at Monk McQueen's Station 1	04-Jun-91	silt	17.7	7.3	31.6	4.6	8.6	10.7	11.1	5.01	5.04	930000	70200
	(Lab duplicate)						NO INFORMATION						927000	72600
		16-Nov-94	clay and silt	[	72	]	6.7	8.1	7.3	3.4	2.5	<0.1	919000	81300
FC-8	Off Monk McQueen's; near Cambie Bridge Station 1	04-Jun-91	silt	19.3	10.2	42.8	5.1	7.7	7.6	4.4	1.8	1.9	921000	78800
		16-Nov-94	clay and silt	[	74.3	]	6.8	8.8	8	1.4	0.6	0.1	928000	72000
FC-9	Inside Cambie Bridge off dumpsite Station 1	04-Jun-91	silt	19.8	11.6	48.6	3.8	2.8	3.3	3.1	2.6	8.6	918000	82000
	(Lab duplicate)						NO INFORMATION						926000	73700
FC-10	Northeast corner Station 1	04-Jun-91	clay and silt	19.7	12.2	47.2	4.4	5.6	5.5	2.9	1.8	1.5	914000	86200
	(Lab duplicate)						NO INFORMATION						910000	90000
FC-11	East Basin Station 1	04-Oct-88					NO INFORMATION							
	BURRARD INLET:													
BI-1	Vancouver Outer Harbour (Pacific Environment Institute) Station 2	09-Sep-91	silt	32	10.4	54.5	2.4	0.67	0.11	0.04	0.01	0	949000	51000
	(Lab duplicate)						NO INFORMATION						949000	50800
BI-2	Vancouver Wharves Station 4	12-Sep-91	medium sand	[	1.1	]	1.2	14.4	44.6	19.6	8.5	10.6	759000	241000
	(Repeat analysis)						NO INFORMATION						938000	62300
BI-3	L & K Lumber Station 2a	12-Sep-91	very fine sand	[	40.8	]	15.9	19.6	16.7	4.8	1.1	1.1	929000	71300
	(Repeat analysis)		clay and silt	[	80.2	]	8.5	5.1	3.7	2.5	0.9	0.1	NA	NA
BI-4	Vancouver Shipyards/Seaspan Station 1	20-Aug-84					NO INFORMATION							
	Station 3	14-Sep-88	fine sand	[	23.5	]	18.9	25.3	15.8	10	2.9	3.6	926000	73900
	Station 4	12-Sep-91	coarse sand	1.73	0.44	2.7	0.99	5.5	27	40	16.2	5.6	941000	58900
BI-5	Versatile Pacific (was Burrard Yarrows) Station 2	20-Aug-84	clay and silt	[	62.3	]	9.9	8.8	8	6.9	2.3	1.8	NA	NA
	Station 4	28-Jul-88	medium sand	[	3.1	]	17.3	20.6	13.4	12.6	12.7	21	969000	31100
	Station 5	12-Sep-91	very fine sand	15.5	4.8	27.2	19.2	26.2	3.8	1.8	0.69	1.4	950000	49700
BI-7	Saskatchewan Wheat Pool Station 1	12-Sep-91	very fine sand	10.2	2.4	22.3	31.5	26.6	4.3	0.6	0.2	2.6	967000	32900

APPENDIX 3.1 SEDIMENT CHARACTERISTICS

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)			SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)		Silt (%)	Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
	BURRARD INLET cont.:													
BI-9	**Neptune Terminals**													
	Station 2	20-Aug-84					NO INFORMATION							
	Station 2a	12-Sep-91	very fine sand	[	25.2	]	24.7	28.6	17.1	3.4	1	<0.1	953000	47000
	(Lab duplicate)						NO INFORMATION						949000	50900
	(Repeat analysis)		very fine sand	9.2	2.5	21.3	21.9	29.3	13.6	1.9	0.3	0	NA	NA
BI-9	**Seaboard Terminals**													
	Station 1xb	14-Sep-88	medium sand	[	5	]	8.5	22.8	35.1	15.4	5.9	7.3	972000	27500
	Station 1x	12-Sep-91	medium sand	[	8.8	]	9.3	16.4	21.5	12.4	9.2	22.4	960000	40400
	(Repeat analysis)		medium sand	2.7	1.6	10.2	8.5	18.5	20.2	11.7	7.5	21.2	NA	NA
BI-10	**Lynnterm**													
	Station 4	11-Sep-91	fine sand	3.3	1.4	7.1	8.3	44.5	27	4.4	1	3.2	963000	37200
BI-11	**Belaire Shipyards**													
	Station 1	20-Aug-84					NO INFORMATION							
BI-12	**Allied Shipyards**													
	Station 2	14-Sep-88	very fine sand	[	34.4	]	19.9	14.1	13.4	9.3	5.3	3.6	894000	106000
BI-14	**Boulder Rock**													
	Station 1	11-Sep-91	silt	18.9	4.7	41.7	28.2	6.24	0.18	0.04	0	0	948000	51800
	(Lab duplicate)						NO INFORMATION						953000	46700
BI-15	**IOCO**													
	Station 1	10-Sep-91	medium sand	[	30	]	6	10	12	14	23	5	894000	106000
BI-16	**IOCO/Port Moody**													
	Station 2	08-Nov-89	silt and clay	[	92.4	]	2.6	2.5	1.7	0.5	0.3	<0.1	881000	119000
	(Repeat analysis)												894000	106000
BI-17	**Port Moody**													
	Station1	11-Sep-91					NO INFORMATION						912000	87700
	(Blind duplicate)						NO INFORMATION						920000	79700
BI-18	**Alberta Wheat Pool**													
	Station 1	11-Sep-91	silt	12.5	10.3	52	2.4	5.1	9.1	5	2.4	2.54	986000	11800
	(Blind duplicate)												986000	14200
BI-19	**Central Harbour**													
	Station 1	12-Sep-91	silt	20.2	6.5	34.1	15.8	16.7	2.8	0.21	0.05	5.8	951000	48900
BI-20	**Rivtow Straits**													
	Station 1	20-Aug-84					NO INFORMATION							
BI-21	**Sterling Shipyards**													
	Station 1	20-Aug-84					NO INFORMATION							
BI-22	**B.C. Marine Shipbuilders**													
	Station 1	20-Aug-84					NO INFORMATION							
BI-22a	**B. C. Marine/Sterling**													
	Station 1	14-Sep-88	fine sand	[	21.4	]	13.8	16.6	22.9	12.3	13	0	881000	119000

APPENDIX 3.1 SEDIMENT CHARACTERISTICS

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)			SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)		Silt (%)	Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
	BURRARD INLET cont.:													
BI-23	Vanterm Station 2 (Lab duplicate) (Blind duplicate)	12-Sep-91	coarse sand	5.7	2.4	13.5	4.6 NO INFORMATION NO INFORMATION	8	14.3	15.8	16.1	22.8	939000 938000 949000	61500 62200 50800
BI-24	United Grain Growers Station 1 Station 2	12-Sep-91 15-Mar-95	fine sand silt	[15	31.8	] 38.2	15.4 [	15.9	12.7 45.7	7.7	3.9]	12.6 1.1	943000 NA	57100 NA
BI-25	Centerm Station 1	12-Sep-91	fine sand	12.5	3.5	20.3	11.1	24	21.7	4	1.3	2	958000	42500
BI-26	Canada Place (Pier BC; NHB) Station 2 (Lab duplicate) (Blind duplicate)	12-Sep-91	silt	23.1	7.7	42.2	13.8	7.9	4.8	0.52	0.06	0	943000 942000 940000	57100 57800 60400
	COAL HARBOUR AREA:													
CH-1	Bayshore Inn Marina Station 1,3,4 (composite) (Lab duplicate)	25-Mar-91	silt	20.2	6.7	38.4	1.9	2.9	3.3	3.6	4.4	30.4	898000 898000	102000 102000
CH-3	Royal Vancouver Yacht Club Marina (RVYC) Station 1 (Repeat analysis) Station 4,5,6 (composite) (Blind duplicate)	16-Mar-88 25-Mar-91	medium sand fine sand	[[	11.2 18	]]	13.1 14 NO INFORMATION	12.7 32.1	32.1 31.5	18.6 3.6	6.7 <0.1	5.5 <0.1	937000 NA 921000 915000	63200 NA 79500 85500
CH-5	Menchion's Shipyard Station 1	20-Aug-84					NO INFORMATION							
CH-6	Bayshore/Menchions Station 3b	14-Sep-88	medium sand	[	23.3	]	7.5	9.8	11.1	7.9	11.7	28.7	886000	114000

APPENDIX 3.1 SEDIMENT CHARACTERISTICS

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)			SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)		Silt (%)	Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
	VICTORIA HARBOUR:													
	The Gorge:													
VH-1	Stn. SW-7; storm drains across from Aaron Point	11-Jul-90	fine sand	[	28.6	]	15.1	22	29.9	4.4	0	0	861000	139000
VH-2	Stn. SW-8; off Gorge Park	11-Jul-90	medium sand	[	13.1	]	13.7	22.3	34.3	14.9	1.7	0	868000	132000
	Selkirk Waters:													
VH-3	Stn SW-1d; off BCFP	20-Jul-87	fine sand	[	13.7	]	23.5	21.4	14.3	14.4	6.3	6.2	NA	NA
VH-4	Stn. SW-2; off old BCFP/Fletcher Challenge sawmill, west side	11-Jul-90	very fine sand	[	40.5	]	18.6	19.7	16.9	4.3	0	0	881000	119000
VH-5	Stn. SW-3; off old BCFP/Fletcher Challenge sawmill; southwest side	11-Jul-90	very fine sand	[	30.5	]	19.9	20.7	20.7	7.2	0	0	893000	107000
VH-6	Stn. SW-4; trawl site, midchannel	11-Jul-90	fine sand	[	25.4	]	15.5	19.5	23.9	15.7	0	0	854000	146000
VH-7	Stn. SW-5; south end of old BCFP/ Fletcher Challenge sawmill; off location of old dip tanks	11-Jul-90	fine sand	[	25	]	17.7	21.7	26.8	8.3	0.3	0.2	865000	135000
VH-8	Stn. SW-6; off storm drain south of sawmill site	11-Jul-90	fine sand	[	24.1	]	14.8	22.4	34.6	4.1	0	0	856000	144000
	Upper Harbour:													
VH-9	Stn. UH-1; Victoria Machinery Depot	11-Jul-90	fine sand	[	37	]	17.4	20.2	22	2.3	1.1	0	885000	115000
VH-10	Stn. UH-2; Rock Bay	11-Jul-90	silt and clay	[	52.9	]	18.1	15.3	10.9	2.8	0	0	879000	121000
VH-11	Stn. UH-3; head of Rock Bay	11-Jul-90	very fine sand	[	45.8	]	21.3	19.5	10.9	2	0.7	0	875000	125000
VH-12	Stn. UH-4; midchannel trawl site	11-Jul-90	fine sand	[	29.9	]	15.7	20.3	21	10.9	2	0.2	883000	117000
VH-13	Stn. UH-5; Smith Cedar Products	11-Jul-90	fine sand	[	23.2	]	16	22.1	23.1	13.9	1.5	0.2	879000	121000
VH-14	Stn. UH-6; Site 1	11-Jul-90	coarse sand	[	1.9	]	1.9	6	22.2	41.8	24.2	0.8	902000	98200
VH-14a	Stn. UH-6a; Site 2	11-Jul-85	NO INFORMATION											
VH-15	Stn. UH-7; Hope Point/Standard Oil	11-Jul-90	very fine sand	[	48.1	]	24	19.9	7.3	0.7	0	0	891000	109000
VH-16	Stn. UH-8; Garbage Depot/Standard Oil	11-Jul-90	very fine sand	[	43.4	]	21.7	18.2	15.3	0.4	0	0	881000	119000
VH-17	Stn. UH-9; Boatbuilding Facility	06-Mar-91	NO INFORMATION											

APPENDIX 3.1 SEDIMENT CHARACTERISTICS

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)		SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)	Silt (%)	Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
	VICTORIA HARBOUR cont.:												
	Inner Harbour:												
VH-18	Stn. IH-1; Off Songhees	11-Jul-90	very fine sand	[28.9]		27.7	24.7	13.9	4.2	2.1	0.5	936000	64400
VH-19	Stn. IH-2; West Coast Air	11-Jul-90	very fine sand	[35.6]		19.5	19.2	16.8	1.8	1.8	1.3	949000	51400
VH-20	Stn. IH-3; commercial dock at entrance to James Bay	11-Jul-90	coarse sand	[13.1]		6.9	11.5	18.1	10.3	12.2	27.9	911000	89400
VH-21	Stn. IH-4; Undersea Gardens	11-Jul-90	very fine sand	[32.5]		24.4	22.2	12.9	4.4	0.2	3.8	939000	61000
VH-21a	Stn. IH-4a; Blackball Ferries	11-Jul-85	NO INFORMATION										
VH-22	Stn. IH-5; B.C. Steamships	11-Jul-90	very fine sand	[35.8]		18.3	19	18.9	5	1.5	1.5	927000	72700
VH-23	Stn. IH-6; bay beside B.C. Steamships	11-Jul-90	very fine sand	[32.2]		24.7	25.2	12.8	4.9	0.1	0.1	915000	85000
VH-23a	Stn. IH-7; west side of Laurel Point	11-Jul-90											
VH-24	Stn. IH-8; Trotac Marine	11-Jul-90	very fine sand	[35.1]		17.3	18.9	23.6	4.3	0.4	0.4	877000	123000
VH-25	Stn. IH-9; Raymer Point/Fisherman's Wharf	11-Jul-90	fine sand	[25.2]		27.8	25.6	12.9	4.2	2.6	1.7	937000	63000
VH-26	Stn. IH-10; between Shoal Point and Fisherman's Wharf	11-Jul-90	fine sand	[11.5]		22.1	57.2	7.2	0.7	0.1	0.2	961000	38800
VH-27	Stn. IH-11; Centre Channel trawl site	11-Jul-90	medium sand	[15.6]		17.4	24.3	17.4	2.5	2.5	20.4	931000	69200
VH-28	Stn. IH-12; south side Songhees/old Seaspan site	11-Jul-90	medium sand	[10.1]		7.1	13	26.2	24.9	9.4	9.3	879000	121000
VH-29	Stn. IH-13; south side Songhees/old Shell Oil site	11-Jul-90	fine sand	[25]		20.3	27.5	17.9	5.9	3	0.4	899000	101000
VH-30	Stn. IH-14; West Bay	11-Jul-90	very fine sand	[29]		25.1	29.4	15.5	0.7	0.3	0	914000	85700
	Outer Harbour:												
VH-31	Stn. OH-2; Ogden Point Wharves	11-Jul-90	very fine sand	[27.4]		37.1	24.4	10.4	0.7	0	0	963000	37200
	ESQUIMALT HARBOUR:												
EH-1	Upper Harbour	11-Jul-90	fine sand	[14.7]		28.6	32.9	20.3	2.7	0.8	0	981000	19500
	Plumper Bay:												
EH-2	Stn. PB-1; off old wood products facility	11-Jul-90	fine sand	[11.1]		20.8	26.5	27.9	13.7	0	0	810000	190000
EH-3	Stn. PB-2; off site of old dip tank	11-Jul-90	medium sand	[26.2]		12	16.9	32.9	8.9	1.8	1.1	863000	137000
EH-4	Trawl site	11-Jul-90	very fine sand	[47.3]		17.5	16.1	16.6	0.5	0	0	927000	72600
EH-5	Dunn's Nook	11-Jul-90	very fine sand	[47.7]		16	16.6	17.8	1.9	0	0	925000	75000

APPENDIX 3.1 **SEDIMENT CHARACTERISTICS**

SITE NO.	LOCATION	DATE	MEDIAN PARTICLE SIZE	CLAY AND SILT (%)			SAND (%)					GRANULES (%)	SFR	SVR
				Clay (%)		Silt (%)	Very Fine Sand (%)	Fine Sand (%)	Medium Sand (%)	Coarse Sand (%)	Very Coarse Sand (%)			
EH-6	Fort Rodd	11-Jul-90	fine sand	[	13	]	12.7	31.5	30.5	9	3.3	<0.1	964000	36000
	Constance Cove:													
EH-7	Station 1	11-Jul-90	medium sand	[	9.4	]	5.5	16.9	43.6	15.1	8.1	1.4	928000	71600
EH-8	Station 6a; B-jetty	11-Jul-85					NO INFORMATION						920000	80300
EH-9	Station 2	11-Jul-90	fine sand	[	28	]	12.2	18.4	25.5	12.5	3.4	<0.1	904000	95900
EH-10	Station 3	11-Jul-90	fine sand	[	27.8	]	15.2	27.2	24.2	4.2	0.8	0.8	926000	74200
EH-11	Station 4	11-Jul-90	very fine	[	41.7	]	12.3	11.5	13.7	8.6	2.3	9.9	928000	71600
EH-12	Station 5	11-Jul-90	clay and silt	[	59.7	]	17.7	11.9	10.3	0.4	<0.1	<0.1	950000	50000
EH-13	Station 6	11-Jul-90	clay and silt	[	50	]	14.7	12.7	13.7	5.7	3.2	<0.1	936000	63700
EH-14	Station 7													
	Trawl site	11-Jul-90	clay and silt	[	52.8	]	13	15.3	17.3	0.5	0.3	0.8	928000	72300
	(Blind duplicate)		clay and silt	[	93.8	]	3	1.7	1.2	0.3	<0.1	<0.1	NA	NA
	REFERENCE AREAS:													
RF-1	Crescent Beach													
	Station 1	28-Aug-88	medium sand	[	1.6	]	13.4	32.6	37.2	8.7	2.9	3.7	988000	12300
RF-5	Warn Bay													
	Station 1	23-Jun-88	very coarse sand	[	1.5	]	1.9	3.3	10.8	21	29.2	32.4	906000	94100
	Queen Charlotte Islands:													
RF-9	Delkatla Slough	25-Jul-89	medium sand	[	0.2	]	3.9	22.8	41.7	16.3	4.6	10.5	NI	NI
RF-11	Tow Hill	22-Jul-89	fine sand	[	14.2	]	42.3	24	6.3	4.9	4.2	4.1	NI	NI

Clay	<0.004 mm
Silt	0.004 - 0.063mm
Silt and clay	<0.063 mm
Very fine sand	0.063 - 0.125 mm
Fine sand	0.125 - 0.25 mm
Medium sand	0.25 - 0.50 mm
Coarse sand	0.50 - 1.00 mm
Very coarse sand	1.00 - 2.00 mm
Granules	>2.00 mm

NA = Information not available

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Fraser River Estuary:										
MS-3	Fraser River off Iona Island Sewage Treatment Plant	22-Jul-97	Dungeness crab	Hepatopancreas	5	5M	NI	15.3-17.0	294.2-450.0	NI	6.33
			Dungeness crab	Muscle	5	5M	NI	15.3-17.0	294.2-450.0	NI	0.09
			Starry flounder	Whole body	8	NI	NI	22.0-25.5	119.3-179.2	NI	1.46
	Fraser River:										
FR-20	B.C. Cleanwood Preservers	25-Sep-90	Starry flounder	Whole body	38	NI	NI	6.5-12.5	4.4-24.8	83	NI
			Sculpin	Whole body	32	NI	NI	8.0-18.0	5.5-110.2	72	NI
FR-19	Princeton Wood Preservers	25-Sep-90	Starry flounder	Whole body	8	NI	NI	11.5-16.0	20.4-41.8	80	NI
FR-16	Koppers International	20-Sep-90	Starry flounder	Whole body	24	NI	NI	6.0-8.0	3.2-6.0	77	NI
FR-18	Domtar - Liverpool Site	20-Sep-90	Prickly sculpin	Whole body	7	NI	NI	9.0-16.5	3.2-62.0	76	NI
	False Creek Area:										
FC-1	Marina at Market										
	Station 3,4,5 (composite)	12-Aug-88	Mussels (large)	Soft tissue	91	NI	NI	3.8-5.5	NI	90.3	0.67/0.41
	Station 3,4,5 (composite)	25-Mar-91	Mussels (large)	Soft tissue	177	NI	NI	3.5-5.2	NI	87	1
FCT-1	East Basin Trawl	04-Oct-88	Dungeness crab	Hepatopancreas	9	6M;3F	NI	6.3-14.0	29.2-267.0	NI	8.61/7.31
		04-Oct-88	Dungeness crab	Muscle	9	6M;3F	NI	6.3-14.0	29.2-267.0	NI	0.21/0.23
		04-Oct-88	English sole	Whole body	10	NI	NI	9.8-18.8	7.4-63.6	72.4	4.56/4.0
		04-Jun-91	Dungeness crab	Muscle	7	M	NI	11.0-13.2	153.4-286.0	82/84	0.02
		04-Jun-91	Dungeness crab	Hepatopancreas	7	M	NI	11.0-13.2	153.4-286.0	71	12.9
		04-Jun-91	English sole	Whole body	9	NI	NI	14.8-19.0	32.6-54.0	80	2
FCT-2	Monk McQueen's Trawl	04-Oct-88	Dungeness crab	Hepatopancreas	56	50M;6F	NI	5.9-15.7	13.4-397.4	68	11.92/6.7
		04-Oct-88	English sole	Whole body	14	NI	NI	13.3-18.8	24.8-60.6	72.8	4.12/3.3
		06-Jun-91	English sole	Whole body	10	NI	NI	18.5-26.0	57.2-154.0	78/80	1.7

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Burrard Inlet:										
BI-1	Vancouver Outer Harbour, (Pacific Environment Institute)										
	Trawl VOH-1	23-Sep-86	Dungeness crab	Hepatopancreas			NO	INFORMATION			
SB-1	Spanish Banks Trawl	11-Oct-88	Dungeness crab	Hepatopancreas	4	M	NI	16.0-17.0	513.4-566.4	87.5	3.87
BI-2	Vancouver Wharves										
	Stations M1, M2 (composite)	29-Oct-91	Mussels (mixed sizes)	Soft tissue	82	NI	NI	0.5-4.5	NI	84/86	0.7
BI-3	L & K Lumber										
	Station M1	29-Oct-91	Mussels (small)	Soft tissue	56	NI	NI	1.5-4.0	NI	88	0.6/0.7
BI-4	Vancouver Shipyards/Seaspan										
	Stn. M1,M2 (composite)	14-Sep-88	Mussels (large)	Soft tissues	83	NI	NI	3.8-6.0	NI	90.6	1.06
BI-5	Versatile Pacific/Burrard Yarrows										
	Station M1	28-Jul-88	Mussels (small)	Soft tissue	200	NI	NI	1.8-3.6	NI	88.3	0.45
	Station M2	29-Oct-91	Mussels (small)	Soft tissue	98	NI	NI	0.2-2.0	NI	88	1.2
	Station C1	16-Sep-88	Dungeness crab	Hepatopancreas	4	3F;1M	NI	9.1-15.6	88.0-525.2	77.3	12.66
	Station VCT-1	16-Sep-88	Rock sole	Whole body	5	NI	NI	17.2-26.8	121.4-415.6	73.4	3.89/2.8
BI-9	Seaboard Terminals										
	Station M1	14-Sep-88	Mussels (mixed sizes)	Soft tissue	88	NI	NI	2.5-6.0	NI	84.8	1.02
	Stations C1,C2 (composite)	16-Sep-88	Dungeness crab	Hepatopancreas	4	NI	NI	10.0-15.0	78.0-479.8	64.2	17.15
	Trawl ST-1	16-Sep-88	Rock sole	Whole body	5	NI	NI	20.5-24.7	203.0-323.0	73.3	4.08/2.8
	Station M2	29-Oct-91	Mussels (small)	Soft tissue	87	NI	NI	0.5-2.5	NI	85/86	0.8
BI-10	Lynnterm										
	Station M2	29-Oct-91	Mussels (small)	Soft tissue	117	NI	NI	0.5-3.5	NI	86/84/85	1.4/1.4
BI-12	Allied Shipbuilders										
	Stations M1,M2 (composite)	14-Sep-88	Mussels (small)	Soft tissue	96	NI	NI	1.9-3.8	NI	NI	1.24
	Trawl AT-1	16-Sep-88	Starry flounder	Whole body	5	NI	NI	3.8-13.5	0.8-29.4	NI	1.48

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Burrard Inlet cont.:										
BI-17	Port Moody/IOCO										
	Trawl PM/IT-1	24-Sep-86	Dungeness crab	Hepatopancreas			NO	INFORMATION			
		24-Sep-86	Dungeness crab	Muscle			NO	INFORMATION			
		12-Oct-88	Dungeness crab	Muscle	7	6M;1F	NI	9.0-13.5	94.2-290.0	82	0.24
		12-Oct-88	Dungeness crab	Hepatopancreas	7	6M;1F	NI	9.0-13.5	94.2-290.0	NI	16.98
		12-Oct-88	Starry flounder	Muscle	3	NI	NI	36.4-410	>600	77.4	0.96
		12-Oct-88	Starry flounder	Liver	3	NI	NI	36.4-410	>600	NI	10.46
		12-Oct-88	English sole	Whole body	21	NI	NI	9.0-18.1	6.8-55.2	75.4	4.17
BI-22	B.C. Marine Shipbuilders/Sterling Shipyards										
	Station M1	14-Sep-88	Mussels (mixed sizes)	Soft tissue	138	NI	NI	2.3-4.6	NI	85.3/85.5	0.67
	Trawl BCT-2	16-Sep-88	Dungeness crab	Hepatopancreas	2	1M;1F	NI	14.0-15.6	397.0-472.4	NI	14.87
		16-Sep-88	Starry flounder	Whole body	5	NI	NI	20.3-28.5	161.6-385.2	74.6	2.65/1.9
BI-26	Canada Place										
	Station M1	29-Oct-91	Mussels (mixed sizes)	Soft tissue	56	NI	NI	1.0-4.5	NI	85/87	1.5
CH-5	Menchion's Shipyard										
	Station M1	28-Jul-88	Mussels (large)	Soft tissue	66	NI	NI	4.0-6.0	NI	86.9	1.05
	Coal Harbour:										
CH-6	Coal Harbour Trawl	23-Sep-86	Dungeness crab	Muscle			NO	INFORMATION			
	CHT-1	23-Sep-86	Dungeness crab	Hepatopancreas			NO	INFORMATION			
		16-Sep-88	Dungeness crab	Hepatopancreas	20	15M;5F	NI	6.8-16.0	37.6-558.4	66	12.07
		16-Sep-88	Dungeness crab	Muscle	20	15M;5F	NI	6.8-16.0	37.6-558.4	79	4.36/0.10
		16-Sep-88	Rock sole	Whole body	5	NI	NI	15.9-25.2	93.4-221.6	75.6	4.09/4.1
		16-Sep-88	Shrimp	Tail	185	NI	NI	1.7-4.0	NI	75.2	2.20

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Burrard Inlet cont.:										
	Coal Harbour cont.:										
CH-5	Menchion's Shipyard										
	Station C1	23-Sep-86	Dungeness crab	Muscle			NO	INFORMATION			
	Station C1	23-Sep-86	Dungeness crab	Hepatopancreas			NO	INFORMATION			
	Station M1	28-Jul-88	Mussels	Soft tissue	66	NI	NI	8.0-10.0	NI	NI	NI
CH-1	Bayshore Inn Marina										
	Stations 3,7,9,10 (composite)	20-Mar-89	Mussels (large)	Soft tissue	35	NI	NI	4.2-5.4	NI	92.8	0.61/0.41
	Stations 5,8,10,11 (composite)	25-Mar-91	Mussels (large)	Soft tissue	128	NI	NI	3.6-6.3	NI	0.89	88
	Stations 5,8,10,11 (composite)	25-Mar-91	Mussels (large)	Soft tissue	128	NI	NI	3.6-6.3	NI	0.92	87
CH-3	Royal Vancouver Yacht Club (RVYC) Marina										
	Station 1	17-Mar-88	Bentnose clams	Soft tissue	40	NI	NI	3.7-5.2	NI	82.2	0.68
	Stations 2,3,8 (composite)	20-Mar-89	Mussels (large)	Soft tissue	35	NI	NI	4.4-5.9	NI	91.1	0.75
	Stations 2,3,8 (composite)	25-Mar-91	Mussels (large)	Soft tissue	83	NI	NI	4.0-6.2	NI	89/90	0.4
	Victoria Harbour:										
	Selkirk Waters										
SW-C1	Station C1	20-Jul-87	Dungeness crab	Hepatopancreas	6	M	NI	16.5-18.4	341.2-550.6	68.6	12.37
	Station C1	20-Jul-87	Dungeness crab	Muscle	6	M	NI	16.5-18.4	341.2-550.6	78	0.09
SWT-1,2	Trawls SWT-1 and 2	20-Jul-87	Starry flounder	Whole body	11	NI	NI	3.8-7.2	0.6-4.0	72.3	1.56
SWT-3	Trawl SWT-3	10-Jul-90	English sole	Whole body	6	NI	NI	6.8-14.6	8.7-10.9	76.4	1.4
		10-Jul-90	Dungeness crab	Muscle	8	8M	NI	16.0-19.0	408.4-750.0	81.9	0.01
		10-Jul-90	Dungeness crab	Hepatopancreas	8	8M	NI	16.0-19.0	408.4-750.0	81.7	8.4
		10-Jul-90	Sidestripe Shrimp	Tail	97	NI	NI	7.2-10.6	3.0-10.2	74.9	0.3
SW-SS1	Stn. SS1 (off old sawmill site)	11-Jul-90	Bentnose clams	Soft tissue	20	NI	NI	2.0-5.5	NI	NI	0.4
SW-SS2	Stn. SS2 (beach at Barnfield Park)	13-Jul-90	Bentnose clams	Soft tissue	21	NI	NI	2.5-4.5	NI	NI	0.7

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Victoria Harbour cont.:										
	Upper Harbour										
UHT-1	Trawl UHT-1	10-Jul-90	English sole	Whole body	33	NI	NI	6.1-11.5	2.2-14.8	77.2	1.9
UH-C2	Station C2	11-Jul-90	Dungeness crab	Muscle	8	8M	NI	16.0-19.0	408.4-750.0	80.4	0.05
	Station C2	11-Jul-90	Dungeness crab	Hepatopancreas	8	8M	NI	16.0-19.0	408.4-750.0	77.2	12
	Inner Harbour										
IH-C3/IHT-1	Station C3 and Trawl IHT-1	10-Jul-90	Dungeness crab	Muscle	4	4M	NI	15.0-18.0	441.8-497.0	80.3	0.02
		10-Jul-90	Dungeness crab	Hepatopancreas	4	4M	NI	15.0-18.0	441.8-497.0	73/72	14
IHT-1	Trawl IHT-1	10-Jul-90	English sole	Whole body	52	NI	NI	5.4-11.3	1.4-15.8	78.7	1.0
	Trawl IHT-1	10-Jul-90	Shrimp	Tail	148	NI	NI	5.4-11.3	1.4-11.8	75.5	0.5
	Station SS3 (Laurel Point)	11-Jul-90	Bentnose clams	Soft tissue	20	NI	NI	2.0-3.5	NI	NI	0.3
IH-C4	Station C4 (West Bay)	09-Jul-90	Dungeness crab	Hepatopancreas	5	2M;4F	NI	14.5-18.0	496.0-645.2	82.9	NI
IH-SS4	Station SS4 (Hidden Harbour Marina)	11-Jul-90	Bentnose clams	Soft tissue	58	NI	NI	2.5-6.0	NI	83.5	NI
	Esquimalt Harbour:										
	Constance Cove										
CC-M1	Station M2	09-Jul-90	Mussels (mixed sizes)	Soft tissue	126	NI	NI	2.5-5.0	NI	84	1.2
CC-C1	Station C1	09-Jul-90	Dungeness crab	Muscle	9	9M	NI	14.0-19.0	405.4-752.8	83	0.5
		09-Jul-90	Dungeness crab	Hepatopancreas	9	9M	NI	14.0-19.0	405.4-752.8	83.9	5.0
CCT-1	Trawl CCT-1	09-Jul-90	English sole	Whole body	47	NI	NI	6.0-16.0	2.2-37.8	77.7	1.2
	Trawl CCT-1	09-Jul-90	Shrimp	Tail	152	NI	NI	4.5-9.5	0.6-7.0	75.6	0.3
	Plumper Bay										
PBT-1,2,3	Trawl PB-1,2,3	12-Jul-90	English sole	Whole body	44	NI	NI	4.7-11.1	0.8-11.8	78.2	1.1
	Trawl PB-1,2,3	12-Jul-90	Shrimp	Tail	92	NI	NI	5.0-11.5	0.8-8.2	73.4	0.3
	Trawl PB-1,2,3	04-Mar-91	Dungeness crab	Muscle	12	11M;1F	NI	12.0-18.0	212.2-654.2	NI	0.1
		04-Mar-91	Dungeness crab	Hepatopancreas	12	11M;1F	NI	12.0-18.0	212.2-654.2	NI	NI
PB-M2,M3	Stns. M1,M2 (adjacent old sawmill site)	09-Jul-90	Mussels (large)	Soft tissue	89	NI	NI	3.0-5.5	NI	86.3	0.9

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Victoria Harbour cont.:										
	Plumper Bay cont.:										
PB-SS5	Station SS5	09-Jul-90	Macoma clams	Soft tissue	1	NI	NI	7.5	NI	NI	0.5
PB-SS6	**Dallas Bank** Station SS6	09-Jul-90	Bentnose clams	Soft tissue	46	NI	NI	3.0-5.5	NI	80.7	0.6
	Ladysmith Harbour:										
	Site #29	20-Jan-92	Mussels	Soft tissue			NO INFORMATION				0.3
	Site #30	20-Jan-92	Mussels	Soft tissue			NO INFORMATION				2
	Site #31	20-Jan-92	Mussels	Soft tissue			NO INFORMATION				1.4
	Site #32	20-Jan-92	Mussels	Soft tissue			NO INFORMATION				2.3
	Site #33	20-Jan-92	Mussels	Soft tissue			NO INFORMATION				1.6
	Site #38	20-Jan-92	Mussels	Soft tissue			NO INFORMATION				1.6
VI-13	**Nanaimo Harbour:**										
	Station 1 - South of Nanaimo Yacht Club	20-Mar-91	Manila/ Littleneck clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Station 2- North of Nanaimo Yacht Club	20-Mar-91	Manila/ Littleneck clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Station 3 - South of Moby Dick Motel	20-Mar-91	Manila/ Littleneck clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Station 4 - Petro-Can Fuel Dock	20-Mar-91	Manila/ Littleneck clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Station 5 - North of Brechin Point Boat Ramp	20-Mar-91	Manila/ Littleneck clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Nanaimo Harbour cont.:										
	Station 6 -South of Shaft Point	20-Mar-91	Manila/ Littleneck clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
		20-Mar-91	Oysters	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Station 7 -Newcastle Island -	20-Mar-91	Clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	across from Unique Seafoods	20-Mar-91	Oysters	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Station 8 - Newcastle Island -	20-Mar-91	Clams	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	south tip	20-Mar-91	Oysters	Soft tissue	NI	NI	NI	NI	NI	NI	NI
	Reference Sites:										
RF-1	Crescent Beach CBT-1	16-Jun-91	Rock sole	Whole body	17	NI	NI	8.5-12.5	5.0-16.8	75/76	2.0/2.1
RF-2	St. Vincents Bay SVBT-1	13-Feb-88	Slender sole	Whole body	2	NI	NI	14.8-21.5	19.0-54.0	NI	1.98/1.06
RF-3	Agememnon Channel ACT-1	13-Feb-88	Rockfish	Whole body	2	NI	NI	20.0-32.0	104.0-510.0	74.9	NI
		13-Feb-88	Shrimp	Tail	10	NI	NI	1.5-3.6	NI	NI	2.85
RF-6	Fortune Channel Station 1	23-Jun-88	Dungeness crab	Hepatopancreas	7	5M;2F	NI	16.6-21.6	486.8-1036.0	77.3	3.42
RF-7	Larkin Island - south end Station 1	23-Jun-88	Mussels (M. californianus)	Soft tissue	3	NI	NI	15.9-16.0	NI	88.7	0.42

APPENDIX 3.2 BIOTA SAMPLE INFORMATION

SITE NO.	LOCATION	DATE	SPECIES	TISSUE	NO.	SEX	AGE	LENGTH (cm)	WEIGHT (g)	MOISTURE CONTENT (%)	LIPID CONTENT (%)
	Reference Sites cont.:										
RF-8	Rivers Inlet Station 1	26-Oct-89	Pink shrimp	Tail	92	NI	NI	7.0-10.0	1.2-8.2	77	0.7
RF-9	Delkatla Slough, Queen Charlotte Islands Station 1	25-Jul-89	Dungeness crab	Hepatopancreas	5	4M;1F	NI	14.0-19.5	302.0-731.8	77/78	13

NI no information was available
N/A no I.D. number assigned

APPENDIX 4

QUALITY ASSURANCE AND QUALITY CONTROL

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs
LABORATORY DUPLICATES:																				
LAB 1																				
Batch 342:																				
Sample 1	1100	170	20000	19000	69000	51000	160270	110000	58000	17000	18000	16000*	6200	3500	760	4200	6800	1800	226260	386530
Lab duplicate	1600	160	22000	16000	74000	51000	164760	77000*	48000*	15000	16000*	19000*	5700	3400	1000	3900	6800	1700	37500	202260
Batch 1171:																				
Sample 1	78	2.5	99	23	320	130	652.5	280	190	41	49	52	19	7.5	<7.6	NDR(6.6)	17	24	679.5	1332
Lab duplicate	50	NDR(1.9)	57	15	180	75	377	160	100	27	31	35	14	8.3	<5.0	NDR(5.9)	13	16	404.3	781.3
Sample 2	75	5.7	28	32	150	49	339.7	210	150	64	48	79	31	19	NDR(2.9)	14	28	42	685	1024.7
Lab duplicate	99	5	39	27	150	49	369	130	110	55	48	77	36	20	NDR(3.4)	17	28	41	562	931
Sample 3	6.1	<0.6	<2.7	NDR(2.5)	23	9.6	38.7	22	16	10	6.4	11	NDR(3.9)	NDR(5.2)	NDR(2.2)	3.7	NDR(3.8)	32	101.1	139.8
Lab duplicate	5.9	<1.1	<2.7	NDR(2.2)	21	7.1	34	18	12	5.9	5.2	10	<2.6	<4.3	<4.4	<4.8	NDR(4.0)	26	77.1	111.1
Sample 4	12	2.4	2	NDR(3.6)	26	9.8	52.2	27	23	14	9.6	18	8.2	8.6	NDR(2.7)	NDR(6.4)	7	49	164.4	216.6
Lab duplicate	15	3.2	<2.7	NDR(3.4)	25	7.7	50.9	26	22	9.2	8	17	NDR(5.4)	5.9	<2.3	NDR(4.6)	7	45	140.1	191
Sample 5	<5.2	<0.5	<0.8	NDR(1.2)	1.8	<0.8	1.8	2	1.7	<0.9	<1.0	<0.8	<0.9	<1.1	<2.0	<1.1	<0.7	1.7	5.4	7.2
Lab duplicate	<4.9	<0.4	<0.7	NDR(1.4)	1.9	<0.9	1.9	2.1	1.8	<0.9	<0.8	<1.0	<1.3	<1.4	<3.0	<1.5	<1.0	1.6	5.5	7.4
Sample 6	86	46	60	220	710	160	1282	1300	1500	680	590	1200	780	460	120	560	530	210	7930	9212
Lab duplicate	130	50	33	250	750	100	1313	1900	1900	1000	750	1300	650	380	100	440	570	190	9180	10493
Sample 7	470	44	1200	520	3100	1600	6934	3300	2300	1100	900	1300	790	410	83	430	570	190	11373	18307
Lab duplicate	440	50	1100	390	2800	1300	5880	3200	2200	880	780	1200	710	390	78	410	530	180	10558	16438
Sample 8	450	74	320	470	1600	500	3414	3200	3000	1400	1400	2800	1600	770	180	800	1000	340	16490	19904
Lab duplicate	270	62	110	410	1300	270	2422	2800	2700	1400	1300	2700	1500	780	190	810	1000	370	15550	17972
Sample 9	110	8.1	250	330	1600	490	2788.1	1400	920	770	480	600	350	150	39	160	250	72	5191	7979.1
Lab duplicate	70	5.9	190	140	1100	270	1775.9	1000	720	290	250	390	240	120	27	130	170	52	3389	5164.9
Sample 10	330	110	120	380	1200	230	2370	3400	2800	1200	1000	2200	1400	810	170	1100	1000	340	15420	17790
Lab duplicate	250	100	90	470	1200	250	2360	2300	2700	1100	1000	2100	1300	830	170	1300	970	300	14070	16430
Sample 11	440	110	160	590	1300	290	2890	3700	4300	1800	1700	3100	1900	1100	250	1200	1300	470	20820	23710
Lab duplicate	580	120	170	650	1500	340	3360	4200	4700	2000	2000	3400	2000	1100	240	1300	1300	440	22680	26040
Sample 12	61	36	19	76	240	62	494	430	460	300	190	450	210	160	36	190	180	100	2706	3200
Lab duplicate	79	48	20	80	230	50	507	440	500	280	200	450	210	170	37	190	190	110	2777	3284
Sample 13	300	100	56	240	740	140	1576	1500	1800	900	830	1200	850	450	150	430	740	200	9050	10626
Lab duplicate	520	160	140	400	1100	250	2570	2300	2000	830	780	1200	910	480	120	650	620	240	10130	12700
Sample 14	220	37	220	510	1700	230	2917	3300	2900	1600	1500	3000	2000	1200	250	1200	1300	450	18700	21617
Lab duplicate	210	51	240	720	2200	340	3761	5400	4300	2500	2800	4800	3300	1700	380	1900	2000	710	29790	33551
Batch 1187:																				
Sample 1	3	NDR(0.2)	0.7	NDR(1.2)	6	NDR(1.3)	9.7	7.7	5.2	2.6	2.4	4.9	2.1	2.7	NDR(0.6)	2.3	2.3	1.3	33.5	43.2
Lab duplicate	3.4	NDR(0.3)	0.6	1.1	5.9	1.6	12.6	7.6	5.4	2.6	2.4	5	2.1	2.4	NDR(0.5)	2.3	2.3	1.1	33.2	45.8

APPENDIX 4.1 **QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples** (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs
LAB 1 cont.:																				
Batch 2820:																				
Sample 1	1300	13	300	290	880	260	3043	920	600	370	280	420	140	58	21	77	140	63	3089	6132
Lab duplicate	2000	12	360	330	1300	320	4322	1200	770	340	270	350	120	49	17	59	120	61	3356	7678
Sample 2	170	59	27	83	200	64	603	270	390	120	150	220	190	84	20	84	120	65	1713	2316
Lab duplicate 1	150	52	78	190	590	140	1198	570	670	190	270	310	280	140	32	140	150	77	2829	4027
Lab duplicate 2	140	100	39	110	410	87	886	690	820	280	240	420	310	160	35	150	180	83	3368	4254
Sample 3	280	140	83	390	820	230	1943	1400	1700	810	930	1200	860	420	100	480	580	230	8710	10653
Lab duplicate	300	130	86	330	800	200	1846	1500	1800	980	810	1300	820	390	88	410	570	230	8898	10744
Sample 4	550	220	140	530	1400	380	3220	1700	2200	870	960	1400	1100	590	140	620	720	270	10570	13790
Lab duplicate	650	380	120	480	1300	320	3250	2100	2500	990	910	1700	1200	620	160	620	780	300	11880	15130
Sample 5	520	300	130	450	1200	370	2970	2000	2500	1300	1000	1800	1300	660	NDR(230)	630	830	320	12340	15310
Lab duplicate	580	250	98	400	910	240	2478	1400	1900	970	950	1500	860	540	140	640	650	240	9790	12266
Sample 6	880	300	99	320	830	230	2659	1400	2200	800	800	1200	820	470	NDR(150)	410	560	190	8450	11109
Lab duplicate	750	260	99	370	910	230	2619	1500	2200	900	910	1600	880	600	160	670	730	230	10380	12999
Sample 7	240	150	71	330	850	230	1871	1400	2000	870	730	1800	1200	690	150	850	840	300	10630	12501
Lab duplicate	200	150	71	290	690	170	1571	1000	1600	750	750	1400	800	530	140	640	670	240	8520	10091
Sample 8	NDR(510)	540	130	650	1100	370	2790	2800	3000	1800	1600	2800	2200	1100	270	1100	1300	500	18270	21060
Lab duplicate	610	400	120	780	1200	340	3450	2600	2900	1800	2200	3000	1900	1100	300	1400	1300	500	19000	22450
Sample 9	140	25	110	390	950	290	1905	2400	1600	990	800	1100	640	300	79	360	490	190	8949	10854
Lab duplicate	170	20	100	320	770	260	1640	1700	1300	720	690	960	600	310	80	370	450	200	7380	9020
Sample 10	28	2.7	22	24	150	28	254.7	190	140	74	70	100	46	27	7.5	31	38	34	757.5	1012.2
Lab duplicate	32	2.5	25	24	160	31	274.5	200	130	84	71	99	42	25	6.1	28	37	44	766.1	1040.6
Sample 11	35	38	16	46	150	16	303	310	360	220	160	310	170	100	24	110	130	59	1953	2256
Lab duplicate	38	22	14	46	120	16	256	190	200	130	91	200	94	63	15	65	85	42	1175	1431
Sample 12	120	53	34	130	470	58	865	1000	1100	590	330	1000	430	310	74	350	400	150	5734	6599
Lab duplicate	83	47	35	140	420	92	817	820	1100	540	330	1100	410	300	NDR(73)	370	390	150	5510	6327
Sample 13	NDR(1.6)	<0.3	<0.5	NDR(0.7)	4.2	0.7	4.9	8.5	6.1	6.1	1.8	7	NDR(0.5)	1.2	<0.4	1.4	2	2	38.1	41
Lab duplicate	NDR(1.7)	<0.7	<0.9	NDR(1.0)	7.7	NDR(0.7)	7.7	18	13	9.7	5.8	15	NDR(3.7)	3.2	<1.2	2.6	5.4	2.6	75.3	83
Sample 14	2	<0.2	<0.3	NDR(0.3)	1	NDR(0.8)	3	0.7	0.4	NDR(0.4)	<0.2	NDR(0.4)	<0.4	<0.4	<1.0	<0.4	<0.4	2	3.1	6.1
Lab duplicate	2	NDR(0.1)	<0.2	NDR(0.2)	NDR(1.0)	0.3	2.3	0.8	NDR(0.4)	<0.4	<0.4	<0.7	<0.8	NDR(1.0)	<3.0	<0.9	<0.8	2	2.8	5.1
Batch 2820b:																				
Sample 1	500	200	45	220	760	100	1825	1000	1500	690	NDR(400)	1000	470	480	NDR(82)	420	550	200	6310	8135
Lab duplicate	320	130	41	150	520	84	1245	640	940	420	NDR(260)	630	330	300	NDR(48)	260	330	120	3970	5215

APPENDIX 4.1 **QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples** (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs
LAB 2																				
Batch 383																				
Sample 1	100		100	800	*	100	1100	2400	2600	2500	*	2100	400						10000	11100
Lab duplicate	–		100	800	*	100	1000	1800	2000	2200	*	2300	300						8600	9600
Sample 2	800	100	900	4200	*	900	6900	4700	6000	2200	*	4000	1600						18500	
Lab duplicate	200	–	300	2600	*	300	3400	4500	5100	700	*	2800	400						13500	
Sample 3	–		100	700	*		800	1200	1500	1200	*	1800	500						6200	7000
Lab duplicate	200		100	600	*		900	1100	1400	1100	*	900	400						4900	5800
Batch 426																				
Sample 1	15	<5	<5	<5	26	<5	41	19	22	19	13	26	10	<5	<5	7	NA	33	149	190
Lab duplicate	14	<5	<5	<5	29	5	48	25	24	18	13	16	10	11	<5	8	NA	33	158	206
Sample 2	90	55	83	440	1700	200	2568	2600	2700	2300	1700	2000	1000	510	170	600	NA	280	13840	16408
Lab duplicate	160	85	85	460	1600	160	2550	2600	2300	2600	1800	2000	1600	630	200	500	NA	290	14520	17070
Sample 3	220	90	300	680	2500	450	4240	3600	4200	4100	2900	3200	1900	1200	220	1400	NA	480	23200	27440
Lab duplicate	410	90	190	620	2100	340	3750	3600	4300	2500	1900	3200	1900	1100	260	1300	NA	470	20530	24280
Batch 1287																				
Sample 1	–		–	1300	*	–	1300	5000	5500	100	*	200	<100						10800	12100
Lab duplicate	100		300	100	*	100	600	3000	3200	200	*	<100	<100						6400	7000
Sample 2			800	5400	*	1500	7700	13300	13000	2300	*	6000	<100						34600	42300
Lab duplicate			1600	5700	*		7300	13800	13300	2500	*	7000	<100						36600	43900
LAB 3																				
Batch 916																				
Sample 1	420	<900	<500	3570	*	<500	3990	4590	<500	2720	1600	2740	1660	<1000	<600	<900	NA	NA	13510	17500
Lab duplicate	460	<900	<500	3060	*	<500	3520	3800	<500	2790	2110	3530	1660	<1000	<600	<900	NA	NA	13910	17430
Sample 2	430	<900	<500	7300	*	<500	7730	5990	<500	1860	1100	2920	1540	<1000	<600	<900	NA	NA	13410	21140
Lab duplicate	538	<900	<500	3720	*	<500	4258	2360	<500	2300	1670	2210	1830	<1000	<600	<900	NA	NA	10370	14628
Sample 3	410	<900	540	4150	*	580	5680	3070	3050	2380	2460	5500	2660	2250	<600	2800	NA	NA	24150	29830
Lab duplicate	470	<900	520	3450	*	510	4950	2490	2500	3200	2520	4780	2910	1460	<600	1570	NA	NA	21430	26380
LAB 4																				
Batch 9390																				
Sample 1	39	29	22	140	660	64	954	930	900	570	340	730	360	240	61	240	NA	NA	4371	5325
Lab duplicate	33	22	19	93	280	44	491	560	710	470	220	640	280	210	52	200	NA	NA	3342	3833

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs		Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs
BLIND DUPLICATES																					
LAB 1																					
Batch 342																					
Original	290	48	62	230	290	83	1003		380	1900	300	160	720	300	250	40	220	380	150	4800	5803
Blind	200	39	66	250	320	96	971		470	1800	350	170	880	360	270	35	170	400	150	5055	6026
Batch 1171																					
Original	170	25	62	130	330	110	827		760	930	390	250	710	340	210	43	190	290	100	4213	5040
Blind	330	54	66	230	580	160	1420		1200	1300	550	430	750	450	280	72	290	350	130	5782	7202
Batch 2820																					
Original	650	380	120	480	1300	320	3250		2100	2500	990	910	1700	1200	620	160	620	780	300	11880	15130
Blind	520	300	130	450	1200	370	2970		2000	2500	1300	1000	1800	1300	660	NDR(230)	630	830	320	12340	15310
Original	17	1.4	24	20	110	19	191.4		170	150	72	58	100	45	29	6.6	37	37	22	726.6	918
Blind	38	3.8	66	90	410	47	654.8		570	460	280	290	490	280	160	45	220	180	82	3057	3711.8
Original	84	18	46	70	180	32	430		270	300	170	130	280	130	81	23	95	110	61	1650	2080
Blind	57	22	17	58	140	20	314		250	280	230	150	340	150	83	27	94	130	64	1798	2112
Original	57	36	25	120	300	40	578		930	940	530	350	960	380	300	63	340	370	140	5303	5881
Blind	77	43	66	150	630	110	1076		1000	1000	650	350	1000	400	310	70	330	400	140	5650	6726
Batch 2906																					
Original	220	92	190	340	1400	390	2632		2200	2400	1100	1000	2200	1500	890	210	990	1100	360	13950	16582
Blind	170	120	160	340	1300	180	2270		2400	2500	1400	1100	3300	1500	950	250	1300	1200	410	16310	18580
LAB 2																					
Batch 426																					
Orignal	990	180	1100	2500	9200	800	14770		6200	5200	9100	7300	17000	6500	2200	880	1600	NA	550	56510	71280
Blind	900	82	820	2000	10000	1000	14802		17000	11000	9000	5500	9400	6500	3500	1200	3800	NA	1300	68200	83002
Batch 1287																					
Original	–		200	1400	*	300	1900		3300	3500	200	*	300	<100						7300	9200
Blind	–		–	1300	*	–	1300		5000	5500	100	*	200	<100						10800	12100
Original	1600	5700	*			7300	13800	13300	2500	*	7000	<100							36600	43900	
Blind	2000	5500	*			7500	9000	10000	600	*									19600	27100	
LAB 3																					
Batch 916																					
Original	460	<900	<500	3060	*	<500	3520		3800	<500	2790	2110	3530	1680	<1000	<600	<900	NA	NA	13910	17430
Blind	430	<900	<500	7300	*	<500	7730		5990	<500	1880	1100	2920	1540	<1000	<600	<900	NA	NA	13410	21140

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Sediment Procedural Blanks																	
Laboratory 1																	
Batch 342:																	
Blank 3	6	<0.1	0.4	1	3	0.8	0.8	0.8	<0.1	0.1	<0.3	<0.4	<0.4	<0.5	<0.3	<0.5	<0.4
Blank 6	3	<0.08	<0.2	<0.08	<0.5	<0.07	0.3	0.5	<0.06	0.1	<0.2	<0.3	<0.3	<0.4	<0.4	<0.5	<0.4
Blank 7	3	<0.03	<0.2	<0.1	<0.5	<0.06	<0.2	<0.4	<0.1	<0.1	<0.2	<0.2	<0.4	<0.4	<0.4		
Batch 1171:																	
SBLK -																	
74	3.2	<0.6	<0.9	<0.6	NDR(1.6)	<0.5	<0.5	<0.6	<0.9	<0.6	<1.1	<1.1	<1.4	<1.1	<0.6	<1.4	<0.7
104	<6.0	<1.2	<1.8	<2.2	2.1	<0.6	<0.6	<0.8	<1.4	<0.9	<1.1	<1.1	<1.7	<1.2	<1.9	<2.5	<1.8
105	41	<4.4	11	9.1	8.3	<3.9	<2.3	<2.5	<4.5	<3.5	<7.5	<7.8	<10	<7.9	<3.5	<4.7	<3.2
106	<6.5	<1.1	<3.3	<2.6	<4.2	<1.7	<3.2	<3.2	<2.0	<1.6	<2.3	<2.4	<3.1	<2.4	<2.0	<2.0	<1.8
107	NDR(2.5)	<0.5	<1.1	<2.0	NDR(6.0)	<1.4	NDR(10)	NDR(9.2)	<1.2	<1.0	<1.2	<1.3	<1.6	<1.2	<1.1	<1.7	<1.0
108	<3.5	<1.2	<1.5	2	2.1	<1.5	<1.0	<1.0	<2.1	<1.5	<2.0	<0.3	<0.4	<2.0	<4.2	<1.6	<3.5
109	NDR(5.1)	NDR(1.4)	<1.5	2.7	7.4	NDR(2.9)	17	21	12	14	23	9.6	9.3	5.1	NDR(6.4)	4.7	7.1
110	14	<2.0	<4.0	<1.8	<1.9	<2.3	<0.6	<0.8	<2.6	<1.7	<1.3	<1.2	<1.8	<1.2	<2.4	<3.5	<2.3
111	16	<2.1	<7.6	<3.5	NDR(4.1)	<2.8	NDR(3.0)	NDR(2.4)	<4.5	<3.0	<4.3	<4.2	<5.9	<4.1	<5.7	<8.1	<5.5
120	NDR (4.4)	<2.3	<4.2	<2.6	NDR (8.5)	<2.5	NDR (4.3)	<2.0	<4.5	<3.4	<4.7	<4.5	<6.4	<4.6	<3.2	<6.9	<2.8
121	NDR(1.5)	<0.9	<3.0	<1.4	<1.0	<1.2	<0.7	<0.8	<1.4	<1.0	<1.0	<0.9	<1.3	<0.9	<0.8	<1.7	<0.8
122	3.1	<1.2	<2.2	<2.3	2.1	<0.9	<0.8	<0.8	<0.8	<1.0	<1.2	<1.6	<1.1	NDR(1.8)	7.6	<1.1	
123	NDR(3.0)	<0.8	<2.0	<0.8	1.4	<0.8	<0.6	<0.7	<0.7	<0.7	1.2	1.4	1.8	1.3	1.4	1.9	1.3
124	NDR(8.4)	<1.8	<2.8	<2.7	NDR(2.5)	<1.6	<3.0	<2.1	<3.0	<1.6	<2.0	<2.4	<3.1	<2.2	<3.4	<4.4	<3.1
126	190	<1.1	<2.1	<2.4	NDR(6.0)	<0.7	NDR(3.9)	NDR(2.8)	<0.7	NDR(3.1)	<0.8	<1.0	<1.4	<1.1	<5.8	<4.0	<4.2
Batch 1187:																	
143	<0.8	<0.1	<0.3	<0.4	<1.0	<0.3	<0.6	<0.4	<0.3	<0.4	<0.6	<0.2	<0.3	<0.2	<0.4	<0.3	<0.3
144	<0.8	<0.1	<0.3	<0.5	<1.5	<0.2	<0.9	<0.7	<0.4	<0.4	<1.5	<0.2	<0.3	<1.5	<0.3	<0.4	<0.2
150	<4.7	<0.8	<2.3	<1.2	NDR(1.4)	<1.1	NDR(1.8)	<1.0	<2.8	<2.1	<2.3	<2.4	<3.9	<2.6	<3.4	<7.1	<2.7
Batch 2820:																	
382	NDR (1.6)	<1.5	<1.0	NDR (0.8)	NDR (2.5)	NDR (1.0)	NDR (0.7)	NDR (0.8)	NDR (0.9)	NDR (0.9)	<0.6	<0.6	<0.6	<0.5	<1.5	<1.1	<1.2
551	NDR (3.1)	2.7	NDR (3.2)	NDR (3.2)	NDR (5.0	NDR (3.9)	5.3	4.7	5	NDR (4.3)	<3.2	<3.2	<3.6	<3.4	<4.4	<3.5	4.4
603	NDR (0.9)	0.4	0.4	0.7	1	NDR (0.4)	0.5	0.4	NDR (0.5)	NDR (0.7)	<0.9	NDR (2.0)	<1.0	<1.0	<2.0	<5.0	<2.0
307	NDR (1.9)	<0.9	<1.8	<2.4	5.4	<0.9	1.4	1.7	<0.7	0.7	<0.4	<0.5	<0.7	<0.5	<1.1	<1.2	<1.0
409	NDR (1.5)	NDR (1.1)	<2.5	<1.3	NDR (1.8)	<1.2	NDR (1.1)	NDR (0.8)	<1.0	NDR (1.3)	<1.4	<1.3	<1.5	<1.2	<2.5	<4.1	<1.7
313	NDR (2.8)	2.1	6.4	3.3	8.3	<1.2	3.7	3.3	4.5	2.8	6.6	NDR (1.5)	NDR (3.3)	NDR (1.5)	NDR (1.4)	<6.6	NDR (5.0)
342	NDR (1.6)	<1.5	<1.0	NDR (0.8)	NDR (2.5)	NDR (1.0)	NDR (0.7)	NDR (0.8)	NDR (0.9)	<0.5	<0.6	<0.6	<0.6	<0.5	<1.5	<1.1	<1.2
Batch 2905:																	
154	<2.3	<1.1	<2.2	<1.8	4.8	<1.6	3.7	3.8	2.2	1.8	3.8	1.7	1.9	2	1.6	<1.2	1.8

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene

Laboratory 2

Batch 383:

Two method blanks were run with this batch of samples. Compounds identified in the blanks were not listed, however, it was noted that samples had been blank corrected for any compounds detected.

Batch 426:

A method blank was run with the samples and contained no PAH compounds above the detection limit of 0.005 ug/g.

Batch 1297:

A method blank was run with the samples and contained no PAH compounds above the detection limit of 0.1 ug/g.

Laboratory 3

Batch 915:

A method blank was run with the samples and contained no PAH compounds above the detection limits (varies with the PAH compound).

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Spiked Reference Samples																	
Laboratory 1																	
NRC HS6 Marine Reference Sediment																	
Certified Conc. (S.D.):	4100 (1100)	190 (150)	230 (70)	470 (120)	3050 (600)	1130 (400)	3540 (650)	2990 (600)	1840 (300)	2050 (300)	4250 (750)	NC	2240 (400)	NC	1950 (580)	490 (160)	1780 (720)
Batch 342:																	
Determined:																	
#1	3500	100	140	390	2800	830	3800	2800	1400	1800	5300	1900	1700	470	1500	430	1700
#3	3500	100	140	420	2900	930	3800	2800	1400	1900	1800	1700	450	1800	310	1600	
Batch 1171:																	
Determined:																	
Sample #																	
Q17	4400	200	150	540	3400	820	3900	2800	1700	1800	4300	1900	2100	490	2100	410	1800
Q18	4600	260	160	470	3400	780	3800	2800	1500	2000	4000	1800	1900	470	2000	390	1600
Q19	4300	220	140	480	3200	770	3700	2700	1500	1900	4000	1800	1900	450	1900	380	1600
Q20	4300	260	140	430	3400	830	4000	2600	1800	1800	4200	1800	2000	460	1800	360	1700
Q21	4700	220	150	400	3400	840	4000	2600	1800	2000	4400	1900	2100	440	1900	360	1600
Q22	4500	300	160	600	3500	920	4100	2800	1800	1900	4100	1800	2100	500	2200	500	1800
Q23	4600	140	150	360	3600	930	3800	2800	1700	2100	5700	2000	2300	490	1900	360	1700
Q31	4200	190	140	400	3200	800	3900	2600	1600	2000	5100	1800	2100	470	21800	410	1600
Q32	4100	170	130	390	3100	800	3600	2500	1500	1800	4900	1700	1900	450	1700	330	1600
Q33	4900	140	160	470	3800	970	3700	3000	1600	1900	5000	2100	2100	530	2000	370	1700
Q35	4800	200	150	570	3500	840	5000	2800	1700	2000	4400	1900	2200	470	2000	350	1700
Q36	4400	220	130	480	3300	780	4200	2800	1700	1900	4600	1900	2000	450	2100	400	1600
Q37	4200	250	140	560	3200	720	3900	2700	1600	1900	4200	1800	1900	440	2000	400	1600
Q39	4100	220	150	420	3500	900	4000	2800	1800	1800	4800	1900	2000	460	2900	410	1700
Batch 1187:																	
NRC HS6 Marine Reference Sediment																	
Certified Conc. (S.D.):	4100 (1100)	190 (150)	230 (70)	470 (120)	3050 (600)	1130 (400)	3540 (650)	2990 (600)	1840 (300)	2050 (300)	4250 (750)	NC	2240 (400)	NC	1950 (580)	490 (160)	1780 (720)
Q70	4400	180	160	390	3200	860	3700	2700	1700	1900	4700	2000	2200	490	2000	400	1700
Q72	4400	180	190	420	3100	940	2800	2600	1700	2000	4000	2000	2200	580	2200	500	1800
Q77	4500	230	160	370	3500	920	3700	2700	1700	2100	4900	1900	2300	510	2100	470	1800
NC	Not certified for this compound																
Batch 2820:																	
NIST Marine Reference Sediment																	
SCRM 40																	
Certified	4100 +/- 1100	190 +/- 50	230 +/- 70	470 +/- 120	3000 +/- 600	1100 +/- 400	3540 +/- 650	3000 +/- 600	1800 +/- 300	2000 +/- 300	4230 +/- 750	*	2200 +/- 40	*	1950 +/- 580	490 +/- 160	1780 +/- 720
Determined	4500	250	130	520	3300	920	3900	2800	1500	1900	4000	*	1900	*	2000	420	1700
SCRM 42																	
Certified	4100 +/- 1100	190 +/- 50	230 +/- 70	470 +/- 120	3000 +/- 600	1100 +/- 400	3540 +/- 650	3000 +/- 600	1800 +/- 300	2000 +/- 300	4200 +/- 750	*	2200 +/- 40	*	1950 +/- 580	490 +/- 160	1780 +/- 720
Determined	4100	190	120	470	3300	800	3600	2600	1700	2500	4500	*	1700	*	2200	460	1600

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Spiked Reference Sediments																	
Batch 2905:																	
NIST Marine Reference Sediment HS-6																	
#SCRM 36																	
Certified	4100 +/- 1100	190 +/- 50	230 +/- 70	470 +/- 120	3000 +/- 600	1100 +/- 400	3540 +/- 650	3000 +/- 600	1800 +/- 300	2000 +/- 300	4230 +/- 750	*	2200 +/- 40	*	1950 +/- 580	490 +/- 160	1780 +/- 720
Determined	4100	340	130	480	3200	690	3800	2600	1400	1900	3900	1800	1800	450	1900	400	1600
* This reference samples is not certified for these compounds																	
Spiked Sediments																	
Batch 2820:																	
#127																	
Expected	41	42	41	49	41	43	47	43	39	42	52	45	36	36	32	36	36
Determined	43	43	39	46	44	38	48	44	40	44	55	46	37	38	34	35	37
#249																	
Expected	240	200	230	250	240	250	250	210	210	210	270	230	190	210	190	240	210
Determined	240	200	240	280	250	240	250	210	230	220	270	230	190	210	190	240	210
#278																	
Expected	240	200	230	250	240	250	250	210	210	210	270	220	190	210	180	240	210
Determined	240	200	260	270	260	290	250	230	230	250	250	260	220	240	130	300	240
#169																	
Expected	240	200	230	250	240	250	250	210	210	210	270	220	190	210	180	240	210
Determined	230	230	230	190	230	230	280	200	200	200	280	250	190	210	170	240	200
#172																	
Expected	240	200	230	250	240	250	250	210	210	210	270	230	190	210	190	240	210
Determined	220	240	210	270	210	190	280	200	190	200	270	240	180	210	190	240	200
#174																	
Expected	240	200	230	250	240	250	250	210	210	210	270	230	190	210	190	240	210
Determined	230	240	220	200	230	220	290	200	210	210	260	230	190	210	200	240	200
Laboratory 2																	
Batch 383:																	
	2-Chloro-naphthalene	**Acenaph-thylene**	**Fluoranthene**														
% Recovery	93	77	110														
Batch 426:																	
HS-5A		83	26	58	91	80	101	83	69	107	100		80		80	125	75
HS-5B		120	65	73	110	113	121	96	66	103	110		71		92	85	74
HS-5C		126	57	68	110	76	131	105	79	118	137		82		115	90	92
HS-5D		120	61	71	110	61	131	103	72	111	127		76		108	80	85
Average Recovery	83%																
Overall Recovery	92%																

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Spiked Sediments cont.																	
Laboratory 2 cont.:																	
Batch 1287:																	
	2-Chloro-naphthalene	**Acenaph-thylene**	**Fluoranthene**														
Spike A	99	98	117														
Spike B	140	98	129														
Laboratory 3																	
Batch 916:																	
Spiked Samples	–	90	89	77	[66]		–	–	75	74	64	–	48	–	62	77	64
% Recovery																	

Surrogate Recoveries for Sediment Procedural Blanks

Blank #	**Napthalene d-8**	**Acenaph-thene d-10**	**Phenanth-rene d-10**	**Pyrene d-10**	**Chrysene d-10**	**Perylene d-10**	**Dibenz(ah)-anthracene d-14**	**Benzo(ghi)-perylene d-12**
Batch 1171:								
74	39	55	62	88	81	73	74	94
104	27	39	55	71	72	77	62	70
105	13	19	36	46	55	65	63	60
106	18	28	49	60	73	71	72	74
107	22	32	66	66	80	81	77	83
108	3	25	53	54	51	66	57	68
109	21	28	55	51	46	64	55	69
110	14	22	36	45	47	100	53	64
111	16	27	47	70	54	59	34	46
120	19	28	43	48	40	59	37	65
121	18	28	46	61	69	80	75	87
122	21	26	43	51	67	62	45	53
123	31	41	65	73	87	83	465	66
124	16	26	39	49	61	51	28	48
126	15	21	35	45	48	50	22	26
Batch 1187:								
143	47	55	69	81	87	75	72	85
144	26	50	72	80	81	68	60	68
150	30	55	66	71	50	60	43	55

Batch 2820:	**Napthalene d-8**	**Acenaph-thene d-10**	**Phenanth-rene d-10**	**Pyrene d-10**	**Chrysene d-10**	**Perylene d-10**	**Dibenz(ah)-anthracene d-14**	**Benzo(ghi)-perylene d-12**	**Benzo (a) pyrene d-12**
362	12	15	29	33	40	39	34	37	35
551	32	36	49	65	48	36	25	40	36
603	73	66	65	76	51	81	35	63	69
307	15	15	24	29	36	42	36	37	-
409	11	16	33	41	44	50	28	42	43
313	11	12	18	23	21	28	13	23	-
362	12	15	29	33	40	39	34	37	35

APPENDIX 4.1 **QUALITY ASSURANCE AND QUALITY CONTROL - *Sediment Samples*** (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene		Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene

Surrogate Recoveries for Spiked Reference Sediments (ng/g)

Sample #	Napthalene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12	Benzo (a) pyrene d-12
Batch 1171:									
Q17	16	30	60	61	73	80	82	76	
Q18	17	22	38	42	55	59	62	56	
Q19	23	33	61	66	85	84	84	78	
Q20	24	37	55	44	43	64	80	68	
Q21	18	26	47	42	40	56	65	54	
Q22	14	26	52	49	56	73	110	90	
Q23	18	34	51	48	39	46	42	40	
Q31	20	32	62	60	72	79	86	74	
Q32	22	35	60	57	62	72	78	69	
Q33	41	65	72	75	67	51	45	37	
Q35	23	40	54	50	47	76	110	99	
Q36	22	32	50	44	46	64	75	84	
Q37	17	24	41	45	50	60	83	70	
Q39	17	31	41	44	51	57	53	41	
Batch 1187:									
Q70	33	59	75	72	74	69	80	69	
Q72	36	59	92	92	82	66	88	78	
Q77	20	45	62	67	65	66	87	69	
Batch 2820:									
127	22	28	46	49	61	68	80	69	64
249	35	53	75	87	88	61	55	60	64
278	46	63	61	67	51	39	17	38	43
169	11	15	28	35	43	45	40	40	41
NIST MARINE REFERENCE SEDIMENT HS-6									
SCRM 40	14	21	35	39	45	54	62	53	
SCRM 42	9	12	19	22	27	28	32	30	

APPENDIX 4.1 QUALITY ASSURANCE AND QUALITY CONTROL - Sediment Samples (ng/g dry weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene

Laboratory 2

Batch 383:

Surrogate Spiked Samples (% Recovery)

	2-bromo-phenol	naphthalene -d8	2-fluoro-biphenyl
Sterling Shipyards	107	93	76
Belair Shipyards	108	99	68
- lab duplicate	102	96	57
Site VH-14a (Stn. UH-6a)	91	65	46
- lab duplicate	96	109	74
Site VH-17 (Stn UH-9)	91	90	46
Site EH-8	91	74	53

Batch 426:

All sediment samples were spiked with a total of 2 ug of each of 3 surrogate PAH compounds.

	Naphthalene -d8	2-fluoro-biphenyl	Terphenyl d14
% Recovery (average of 23 samples)	55	70	114
Relative S.D.	31	30	21

Batch 1287:

	2-fluoro-biphenyl	naphthalene -d8	4-bromo-phenol
Menchion's Shipyard	111	99	96
B.C. Marine Shipyard	105	97	109
- lab duplicate (1)	101	88	114
- lab duplicate (2)	98	84	81
Vanc. Shipy/Seaspan	92	82	97
Neptune	78	113	116
Burrard Yarrows	80	70	95
- lab duplicate	91	69	90
Average % Recovery	96.1	85.5	98
Standard Deviation	10.6	12.5	10.8

APPENDIX 4.1 SURROGATE STANDARD RECOVERIES FOR PAH ANALYSIS (% Recoveries)

	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-10	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12	Benzo(a) pyrene d-12
Samples:									
Batch 342									
No information available									
Batch 1171									
S-419	19	30	52	53	62	62	54	55	
S-420	20	35	57	56	58	66	65	64	
S-414	21	34	59	66	76	76	74	72	
(Lab duplicate)	17	27	44	51	59	63	60	58	
S-415	15	25	43	42	46	56	55	54	
S-416	10	21	34	45	61	60	61	47	
S-417	22	31	50	52	57	63	62	59	
S-418	17	25	42	43	54	59	58	55	
S-421	14	25	49	46	54	64	64	61	
S-422	23	40	55	58	67	75	110	81	
S-423	22	35	39	49	68	66	62	48	
S-424	22	36	69	59	51	63	58	57	
(Lab duplicate)	18	32	61	55	50	62	57	54	
S-425	25	50	65	67	54	55	29	37	
S-426	14	28	57	59	74	79	78	77	
(Lab duplicate)	23	35	60	60	69	76	71	71	
S-427	24	41	37	38	35	69	78	61	
S-428	24	35	34	29	32	65	70	60	
(Lab duplicate)	16	35	50	59	76	70	70	54	
S-514	16	47	57	66	72	64	85	70	
(Lab duplicate)	23	54	43	50	56	66	99	74	
S-429	18	29	53	48	47	65	57	62	
(Blind duplicate)	16	33	52	52	56	66	72	61	
S-430	22	29	33	53	58	71	73	63	
(Lab duplicate)	26	28	45	44	63	60	72	62	
S-431	18	33	34	32	31	64	120	97	
S-432	20	36	54	53	63	65	78	59	
S-433	22	44	68	62	78	76	120	92	
S-434	18	31	50	51	73	72	120	76	
S-435	22	32	50	50	56	67	71	60	
S-436	23	29	32	29	40	62	77	64	
S-437	29	42	68	61	79	84	130	100	
S-438	20	33	60	57	58	72	81	70	
S-439	32	49	76	70	74	79	86	81	
(Lab duplicate)	18	29	42	31	39	61	65	53	
S-440	17	28	52	48	50	66	75	71	
S-441	24	36	45	61	100	70	66	45	
S-442	19	31	54	53	46	51	40	43	
S-444	20	31	52	54	76	77	110	82	
S-445	28	44	55	61	57	59	51	48	
S-448			NOT ANALYZED						
S-449	18	29	56	56	63	68	64	61	
S-450	26	37	64	66	82	83	85	78	
S-451	38	57	74	67	68	85	89	73	
S-452	33	50	66	59	48	61	61	60	
(Lab duplicate)	22	47	64	58	54	71	81	72	
S-453	32	49	60	59	52	72	72	69	
S-454	12	18	35	37	47	57	61	53	
S-455	15	22	41	38	43	54	61	52	
S-457			NOT ANALYZED						
(Lab duplicate)			NOT ANALYZED						
S-446	20	41	53	49	45	60	51	46	
S-447	16	31	40	40	32	37	33	34	
S-456			NOT ANALYZED						
S-461	18	35	54	60	66	71	62	65	
S-462	20	32	51	54	57	70	60	66	
S-463	20	32	55	62	70	76	70	72	

APPENDIX 4.1 SURROGATE STANDARD RECOVERIES FOR PAH ANALYSIS (% Recoveries)

	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-10	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12	Benzo(a) pyrene d-12
Samples:									
Batch 1171 cont.:									
S-464	20	31	49	52	59	70	59	64	
(Lab duplicate)	27	41	65	70	69	76	65	70	
S-465	22	35	53	57	63	64	37	46	
S-466	18	30	49	55	66	71	61	64	
(Lab duplicate)	19	28	44	50	57	65	57	60	
S-467	13	24	43	43	44	64	82	75	
S-468	14	28	53	56	57	73	91	88	
S-469	8	26	53	58	64	70	65	66	
(Lab duplicate)	18	30	51	56	65	68	40	49	
S-470	18	27	44	47	57	54	29	36	
S-471	21	24	38	36	50	55	52	52	
S-472	14	28	55	61	64	68	57	59	
(Lab duplicate)	20	28	49	50	62	61	40	46	
S-477	38	53	48	65	48	42	17	30	
S-478	30	48	47	64	50	45	21	32	
S-479	32	51	55	75	57	51	21	34	
S-480	47	62	57	77	61	55	29	44	
Lab duplicate)	44	61	51	67	46	42	19	31	
S-483	16	25	39	40	46	57	73	64	
S-482	18	32	50	53	61	68	63	51	
S-481	17	29	45	49	60	70	82	65	
(Lab duplicate)	20	30	48	48	56	70	87	72	
Batch 1187									
LH-3	41	64	73	81	78	75	75	75	
LH-7	29	61	76	78	78	74	76	72	
LH-9	45	63	75	78	79	72	74	70	
LH-33	43	63	76	77	73	71	76	73	
(Lab duplicate)	21	44	71	79	76	74	78	74	
LH-39	37	63	89	98	100	80	100	88	
LH-34	32	56	68	77	76	71	78	73	
LH-13	27	58	86	93	99	82	100	92	
LH-19	41	64	100	110	110	71	90	80	
Batch 2820									
S-496	25	53	66	84	57	48	33	44	51
S-494	32	55	66	86	76	52	36	46	56
S-495	27	53	62	83	57	51	34	42	53
(Lab duplicate)	20	49	66	82	56	53	36	44	54
S-497	21	50	60	84	61	43	22	32	48
S-500	18	48	67	95	96	65	51	58	68
S-507	6	9	23	26	42	48	33	23	
S-506	14	21	38	41	45	55	51	48	
(Lab duplicate)	20	27	47	54	65	75	85	80	
S-505	14	18	32	36	44	54	51	51	
S-508	17	31	51	63	78	71	89	80	71
S-509	15	27	48	58	70	69	82	77	67
S-504	18	33	47	54	65	65	86	75	63
S-510	35	53	76	85	87	81	100	95	83
S-511	9	20	36	46	60	50	45	48	48
(Lab duplicate)	12	21	33	40	53	50	52	54	47
S-490	13	18	27	31	43	37	34	32	
(Lab duplicate)	13	20	27	31	33	35	40	40	
S-491	10	14	23	29	40	36	34	29	
(Lab duplicate)	15	23	29	36	40	44	57	53	
S-492	10	14	23	26	35	32	35	29	
(Lab duplicate)	13	21	29	35	36	40	55	48	
S-493	24	34	48	48	46	56	84	58	
S-489	10	13	24	26	32	33	33	30	

APPENDIX 4.1 SURROGATE STANDARD RECOVERIES FOR PAH ANALYSIS (% Recoveries)

	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-10	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12	Benzo(a) pyrene d-12
Samples:									
Batch 1171 cont.:									
(Lab duplicate)	12	20	29	34	39	39	47	44	
S-482	32	41	48	56	73	64	80	73	62
(Blind duplicate)	25	36	49	55	68	71	81	74	68
S-481	25	30	41	44	58	57	69	62	55
(Lab duplicate)	27	39	52	57	76	68	82	74	66
S-483	20	28	37	40	46	51	62	57	46
S-520	31	40	53	74	74	72	49	79	65
(Lab duplicate)	43	57	53	64	44	46	23	48	43

Batch 2905

No information available

Laboratory 2

No information available

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
Laboratory Duplicates																						
Laboratory 1																						
Batch 342:																						
Sample 1	<4	<0.6	<1	<0.6	<5	<1	ND	<2	<2	<1	<0.6	<2	<0.8	<0.8	<1	<0.9	<0.8	<0.5	ND	ND	1	342
Lab duplicate	46	<0.4	<1	<0.6	<6	<1	46	<2	<2	0.8	<0.4	<0.6	<0.4	<0.7	<0.7	<0.8	<0.4	<0.4	0.8	46.8	1	342
Sample 2	100	<0.6	4	<1	7	<2	111	3	2	NDR(0.2)	NDR(0.2)	<0.8	<0.8	<2	<0.8	<2	<0.7	<0.8	5	116	1	342
Lab duplicate	130	<0.8	6	<2	9	5	150	<2	<2	<1	<1	<1	<1	<0.9	<0.8	<1	<1	<1	ND	150	1	342
Sample 3	<5	<0.3	3	<2	<5	2	5	8	6	3	<2	5	<1	<2	<4	<3	2	<1	24	29	1	342
Lab duplicate	<5	<0.2	2	<2	<6	3	5	3	3	2	<1	<0.9	<1	<1	<2	<1	<1	<2	8	13	1	342
Sample 4	<4	<0.3	<0.5	<0.4	<2	<0.4	ND	<0.8	<0.6	<0.4	NDR(0.2)	<0.3	<0.4	<0.5	<0.5	<0.6	<0.3	<0.4	ND	ND	1	342
Lab duplicate	<4	<0.4	<0.7	<0.3	<2	<0.5	ND	<2	<2	<1	<1	<0.9	<0.5	<0.3	<0.3	<0.8	<0.4	<0.4	ND	ND	1	342
Sample 5	<3	0.8	5	7	73	10	95.6	210	110	43	23	38	4	2	<0.8	2	18	3	453	548.6	1	342
Lab duplicate	<3	0.6	5	8	75	9	97.6	220	110	45	24	39	5	3	<0.9	3	17	2	468	565.6	1	342
Sample 6	<10	0.3	<0.4	<2	<6	<0.6	0.3	49	40	30	18	43	13	<6	<3	10	14	4	221	221.3	1	342
Lab duplicate	<11	<0.2	<0.5	<2	<6	<0.5	ND	39	32	22	14	31	10	<6	<3	8	11	2	169	169	1	342
Batch 1171:																						
Sample 1	27	2.8	5.1	9	37	8	88.9	130	110	45	NDR(27)	57	26	17	3.2	NDR(18)	29	NDR(7.3)	417.2	506.1	1	1171
Lab duplicate	26	2.3	5.9	10	36	7.1	87.3	130	110	45	NDR(29)	62	30	16	2.5	NDR(19)	31	NDR(8.3)	426.5	513.8	1	1171
Sample 2	<8.0	<1.5	<3.5	<0.6	<6.5	<3.5	ND	<3.5	<2.5	<2.8	<0.7	<2.5	<3.7	<3.7	<5.8	<2.4	<2.9	<2.8	ND	ND	1	1171
Lab duplicate	<7.5	<1.2	<2.6	<0.9	<5.0	<3.0	ND	<2.3	<2.0	<2.0	<0.6	<1.3	<2.0	<1.8	<2.8	<1.9	<1.5	<1.5	ND	ND	1	1171
Sample 3	<13	<0.6	<4.0	<1.5	<8.5	<3.0	ND	<5.6	<4.8	<3.0	2.3	<4.5	<2.5	<3.8	<2.5	<3.5	<1.9	<1.9	2.3	2.3	1	1171
Lab duplicate	<17	<0.6	<4.5	NDR(2.2)	<11	<3.0	NDR (2.2)	<13	<9.6	<6.7	5.4	<8.5	<2.2	<4.5	<2.2	<4.2	<3.5	<1.7	5.4	5.4	1	1171
Sample 4	12	<0.6	2.9	<1.3	<4.8	<3.0	14.9	<1.7	<1.5	<0.4	<0.4	<0.4	<0.7	<0.3	<0.5	<0.4	<0.5	NDR(1.8)	ND	14.9	1	1171
Lab duplicate	9	<0.5	2.3	<1.0	<4.3	<2.0	11.3	<1.7	<1.2	<0.6	<0.7	<0.4	<0.6	<0.3	<0.4	<0.4	<0.4	<0.4	ND	11.3	1	1171
Sample 5	<8.0	<0.3	1.2	<1.0	2.8	NDR(1.2)	4	2	NDR(2.1)	1.3	NDR(1.4)	NDR(1.1)	NDR(1.3)	NDR(8.6)	<1.0	NDR(1.7)	NDR(1.7)	<0.5	3.3	7.3	1	1171
Lab duplicate	3.8	<0.5	<1.7	0.9	3.3	<2.0	8	2.3	1.4	<0.6	<0.9	<0.8	<1.2	<0.8	<1.4	<1.2	<0.9	<0.9	3.7	11.7	1	1171
Sample 6	<8.2	<1.0	<2.4	<1.0	<4.0	<2.0	ND	<1.4	3.5	<1.9	<1.0	<2.5	<1.1	<2.1	<2.0	<1.4	<0.9	<1.7	3.5	3.5	1	1171
Lab duplicate	<10	<1.0	<2.4	<1.0	<4.0	<1.9	ND	1.7	3.1	<1.9	<1.0	<2.5	<1.0	<2.1	<0.7	<1.4	<0.9	<0.7	4.8	4.8	1	1171

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
Laboratory Duplicates																						
Laboratory 1																						
Batch 1171 cont.																						
Sample 7	NQ	<0.9	2.3	<0.8	3.2	6.2	11.7	2	1.4	1	<0.6	NDR(1.4)	<1.4	<0.9	<1.6	<1.2	<0.8	<0.9	4.4	16.1	1	1171
Lab duplicate	<2.2	<0.4	1.9	<0.6	NDR(2.4)	4	5.9	NDR(1.4)	NDR(1.1)	NDR(0.7)	<0.5	<1.0	<1.6	<0.9	<1.7	<1.2	<1.0	<1.1	ND	5.9	1	1171
Sample 8	<6.2	<0.5	12	7	140	15	174	360	190	64	25	43	6.4	3.7	<2.1	5	25	5.6	727.7	901.7	1	1171
Lab duplicate	<6.0	<0.5	13	7.5	130	15	158	360	180	63	25	44	6.3	3.3	<1.3	4	25	5.4	716	874	1	1171
Sample 9	4.8	<0.6	13	6.9	150	19	193.7	380	200	67	25	49	NDR(5.5)	NDR(3.4)	<1.6	NDR(4.0)	27	NDR(4.7)	748	941.7	1	1171
Lab duplicate	4.4	<0.7	11	7.4	130	16	168.8	330	170	55	21	41	NDR(5.5)	NDR(2.6)	<1.0	NDR(3.3)	22	NDR(1.8)	639	807.8	1	1171
Batch 1187:																						
Sample 1	3.2	<0.7	1.3	3.3	23	2.8	33.6	80	44	27	NDR(10)	19	5.1	5	<1.1	4.2	12	NDR(6.2)	196.3	229.9	1	1187
Lab duplicate	3	<0.7	1.3	4.4	28	3.2	39.9	96	53	33	NDR(12)	23	NDR(6.0)	5.7	<0.9	4.4	14	4.8	233.9	273.8	1	1187
Sample 2	<2.0	<0.6	<0.8	1.1	<5.6	<1.9	1.1	10	6.1	4.1	3.8	NDR(4.0)	<3.5	<2.7	<3.1	<3.1	<4.0	<2.9	24	25.1	1	1187
Lab duplicate	<2.5	<0.4	<0.7	<1.1	3.9	<1.7	3.9	5.7	4.2	<4.0	<3.9	<3.7	<1.2	<1.1	<1.4	<1.4	<1.7	<1.0	9.9	13.8	1	1187
Sample 3	<2.6	0.4	0.9	1	6.2	1.5	10	27	18	7.8	4.1	8	1.1	NDR(1.0)	NDR(0.7)	1.2	3.6	0.9	71.7	81.7	1	1187
Lab duplicate	<3.0	0.4	0.8	0.9	6	1.6	9.7	25	17	7.3	4.2	8.2	1.1	NDR(0.6)	NDR(0.6)	1.3	3.4	0.8	68.3	78	1	1187
Sample 4	<5	<1	1	<2	11	2	14	18	12	4	2	NDR(2)	<1	<2	<2	<2	<1	<1	36	50	1	1187
Lab duplicate	<6	<1	1	2	11	3	17	19	12	5	2	NDR(3)	<1	<1	<1	<1	NDR(2)	<1	38	55	1	1187
Sample 5	<26	<1	2	<2	10	3	15	29	18	15	8	19	<2	<1	<1	<1	7	<2	96	111	1	1187
Lab duplicate	<34	<1	2	<1	9	4	15	25	17	14	7	19	<2	<2	<1	<2	6	<2	88	103	1	1187
Sample 6	<26	<1	2	<1	4	2	8	11	7	5	3	NDR(2)	<1	<1	<1	<1	<1	<1	26	34	1	1187
Lab duplicate	<34	<1	1	<1	4	2	7	10	6	4	3	NDR(2)	<1	<1	<1	<1	<1	<1	23	30	1	1187
Sample 7	<36	<1	<1	<1	2	<2	2	4	4	1	<1	NDR(2)	<1	<1	<1	<1	<1	<1	9	11	1	1187
Lab duplicate	<32	<1	<1	<1	3	2	5	8	5	2	2	NDR(5)	<1	<1	<1	<1	<2	<1	17	22	1	1187

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
Laboratory Duplicates																						
Laboratory 1																						
Batch 2820:																						
Sample 1	6.4	0.9	4.1	0.9	3.8	2.6	18.7	2.5	2.6	1.2	0.9	NDR(1.4)	<0.6	<0.7	<0.4	<1.1	<0.5	<0.3	7.2	25.9	1	2820
Lab duplicate	5.6	0.8	3.8	NDR(0.7)	1.5	1.8	13.5	NDR(1.1)	NDR(1.7)	0.6	NDR(0.4)	NDR(0.8)	<0.4	<0.4	<0.5	<0.4	<0.4	<0.2	0.6	14.1	1	2820
Sample 2	17	1.2	16	17	96	18	165.2	190	110	77	39	73	31	5.8	NDR(2.1)	6.7	31	6.1	569.6	734.8	1	2820
Lab duplicate	17	1.5	15	19	100	18	170.5	210	120	84	42	78	15	6.3	NDR(2.0)	7.3	33	5.8	601.4	771.9	1	2820
Sample 3	7.2	2.4	7.1	5.4	8.6	3.5	34.2	<3.1	<4.7	<4.5	<5.5	NDR(2.0)	<0.3	<0.8	<0.6	<0.9	<0.4	<0.1	1.4	34.6	1	2820
Lab duplicate	8.2	2.9	8.8	6.8	9.1	3.5	39.3	<3.1	<3.1	<5.0	<5.7	NDR(1.9)	<0.1	<0.7	<0.6	<0.9	<0.3	<0.1	1.6	36.6	1	2820
Batch 2844:																						
Sample 1	15	<0.41	7.5	NDR (0.72	6.2	4.5	33.2	1.4	NDR (1.2)	<0.46	<0.49	<0.98	<1.1	<1.1	<1.5	<1.3	<1.0	<1.1	1.3	34.6	1	2844
Lab duplicate	16	<0.33	8.1	NDR (0.76	6.3	4.6	35	1.6	NDR (1.3)	<0.25	<0.27	<0.63	<0.72	<0.71	<0.96	<0.86	<0.67	<0.64	1.6	36.6	1	2844
Laboratory 2																						
Batch 251:																						
Sample 1	<20	<20	21	<20	<20	<20	21	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	21	2	251
Lab duplicate	<20	<20	20	<20	<20	<20	20	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	30	2	251
Batch 425:																						
Sample 1	17	<5	4	<5	54	10	85	110	53	35	7	16	<5	<5	<5	<5	N/A	<5	221	306	2	425
Lab duplicate	10	<5	5	8	61	9	93	130	59	44	5	15	<5	<5	<5	<5	N/A	<5	253	346	2	425

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
SPIKED REFERENCE TISSUES																	
Laboratory 1																	
Batch 1171:																	
Expected:	2350	2030	2320	2540	2370	2480	2530	2100	2090	2080	2670	2250	1900	2080	1850	2430	2060
Determined:																	
1171-T-SPM-#																	
22	2700	1800	2400	2800	2500	2000	2800	2300	2400	1800	2900	2900	2400	2100	2000	2600	2200
2	2500	1600	2400	2700	2500	2500	2700	2200	2200	1700	2600	2200	2200	2000	2300	2400	2100
3	2500	1800	2400	2600	2400	2500	2600	2100	2100	1700	2600	2200	2200	2000	2000	2500	2100
16	2800	1700	2600	3100	2500	2300	2700	2300	2300	1800	2300	2400	2200	2200	2200	2600	2300
23	2800	1600	2500	3100	2500	2300	2700	2200	2400	1800	2500	2400	2200	2100	2100	2600	2300
24	2800	1500	2400	2800	2500	2300	2700	2200	2300	1900	2500	2400	2300	2200	2200	2600	2300
25	2700	1500	2600	3000	2600	2300	2700	2300	2200	1800	2600	2500	2200	2100	2000	2400	2300
35	2400	1500	2300	2700	2400	2400	2400	2000	2200	1600	2200	2400	2100	2200	1500	2000	2000
Batch 1187:																	
Expected:	2350	2030	2320	2540	2370	2480	2530	2100	2090	2080	2670	2250	1900	2080	1850	2430	2060
Determined:																	
1187-T-SPM-#																	
26	2800	1700	2500	3200	2600	2300	2700	2200	2400	1900	2600	2500	2500	2100	2400	2600	2300
29	2800	1800	2700	3100	2800	2200	2900	2400	2400	1900	2700	2600	2600	2400	1900	2600	2500
30	2900	1800	2700	3200	2800	2100	3000	2500	2500	2000	3000	2800	2600	2300	2600	2600	2500
Batch 2820:																	
SPM 126																	
Expected	220	190	220	240	220	230	240	200	200	200	250	210	180	200	200	170	190
Determined	220	170	200	240	220	230	250	190	190	210	270	210	170	200	220	190	190
SPM 168																	
Expected	240	200	230	250	240	250	250	210	210	210	260	230	190	210	240	190	210
Determined	220	200	230	270	240	250	240	210	240	210	270	230	190	220	240	200	200
SPM 175																	
Expected	240	200	230	250	240	250	250	210	210	210	270	220	190	210	240	180	210
Determined	230	250	220	290	220	220	300	210	250	210	300	230	190	150	240	270	210
% Recovery	96	125	96	116	92	88	120	100	119	100	111	105	100	71	100	150	100

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Laboratory 1 cont.																	
Batch 2820 cont.																	
SPM 214 I																	
Expected	240	200	230	250	240	250	250	210	210	210	270	220	190	210	240	180	210
Determined	270	230	260	300	260	210	270	230	230	230	300	250	200	230	240	210	220
% Recovery	113	115	113	120	108	84	108	110	110	110	111	114	105	110	100	117	105
Batch 2844																	
SPM 251																	
Expected	240	200	230	250	240	250	250	210	210	210	270	220	190	210	180	240	210
Determined	240	180	250	290	250	240	250	220	240	220	250	240	190	200	180	240	210
% Recovery	100	90	109	116	104	96	100	105	114	105	93	109	100	95	100	100	100

Laboratory 2

Batch 251:

Compound	Spike Level (ug/g)	% Recovery
Benzo(a)pyrene	0.047	66
Dibenzo(ah)-anthracene	0.075	65
Benzo(ghi)-perylene	0.027	54

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs
External Blind Duplicates																				
Laboratory 1																				
Batch 342:																				
Original	<5	<0.1	1	NDR(0.1)	3	2	6	<0.6	<1	<0.2	<0.3	<0.3	<0.5	7	<0.7	<1	<0.4	<0.6	7	10
Blind	<5	<0.3	<3	<1	<3	<0.6	ND	<1	<1	0.7	0.4	<0.7	<0.7	<0.6	<0.3	<0.4	<0.6	<0.7	1.1	1.1
Batch 1171:																				
Original	33	19	46	32	31	27	188	32	33	25	29	36	38	46	37	30	40	35	381	569
Blind	14	NDR(2.1)	48	7.8	9	14	92.8	NDR(6.8)	NDR(6.0)	NDR(1.8)	<0.1	<1.1	<0.5	<0.4	<0.4	<0.5	<0.7	<0.4	ND	92.8
Original	<11	<0.6	<2.6	<1.8	<10	<2.7	ND	<6.5	<6.5	<3.7	<3.5	<5.8	<2.0	<4.0	<1.8	<3.8	<2.9	<1.8	ND	ND
Blind	6.2	<1.0	1.2	1.2	<8.0	<3.1	8.6	5.3	6	2.4	2	NDR(5.1)	3.3	<1.8	<1.2	<2.2	NDR(2.4)	<1.0	19	27.6
Original	9	<0.5	2.3	<1.0	<4.3	<2.0	11.3	<1.7	<1.2	<0.6	<0.7	<0.4	<0.6	<0.3	<0.4	<0.4	<0.4	<0.4	ND	11.3
Blind	15	<0.7	NDR(4.5)	<0.9	<3.1	<2.1	15	2.3	1.5	<0.6	<0.7	<0.4	<0.7	<0.6	<1.1	<1.0	<0.5	<0.5	ND	15
Original	<6.0	<0.5	13	7.5	130	15	165.5	360	180	63	25	44	6.3	3.3	<1.3	4	25	5.4	716	881.5
Blind	4.8	<0.6	13	6.9	150	19	193.7	380	200	67	25	49	NDR(5.5)	NDR(3.4)	<1.6	NDR(4.0)	27	NDR(4.7)	748	916.8
Lab duplicate	4.4	<0.7	11	7.4	130	16	168.8	330	170	55	21	41	NDR(5.5)	NDR(2.6)	<1.0	NDR(3.3)	22	NDR(1.8)	ND	168.8
Batch 2820:																				
Original	6.4	1.7	1.7	3	5.4	1.9	20.1	9.2	11	3.6	NDR(3.5)	NDR(5.5)	2.3	<1.6	<0.4	NDR(2.1)	2.2	NDR(0.7)	28.3	48.4
Blind	9.6	NDR(1.6)	4.5	NDR(1.0)	1.9	3.3	19.3	1	1.5	<0.6	<0.6	<0.6	<0.7	<1.6	NDR(1.7)	<2.1	<0.6	<0.7	2.5	21.8
Original	5.6	1.4	1.8	1.9	2.4	1.2	14.3	NDR(3.3)	5	NDR(1.8)	NDR(1.1)	5.5	2	<2.4	<0.6	NDR(1.4)	2.3	NDR(0.5)	14.6	29.1
Blind	270	1.2	1.6	1.8	3.1	1.4	279.1	6.3	8.6	4.5	NDR (3.1)	NDR (5.1)	NDR (1.8)	2.3	NDR (1.8)	NDR (2.0)	NDR (3.1)	NDR (1.2)	21.7	300.8
Original	37	1.9	30	7.8	42	15	133.7	83	40	42	18	38	11	5.6	NDR(2.4)	NDR(6.9)	19	NDR(4.7)	256.6	390.3
Blind	48	2.1	37	8	59	19	173.1	110	57	50	NDR(21)	48	13	6.7	NDR(2.1)	8.5	23	5.3	321.5	494.6
Laboratory 2																				
Batch 425:																				
Original	17	<5	4	<5	54	10	85	110	53	35	7	16	<5	<5	<5	<5	N/A	<5	221	306
Lab duplicate	10	<5	5	8	61	9	93	130	59	44	5	15	<5	<5	<5	<5	N/A	<5	253	346
Blind	5	<5	6	<5	49	9	69	96	46	41	9	13	<5	<5	<5	<5	N/A	6	211	280

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Tissue Procedural Blanks																	
Laboratory 1																	
Batch 342:																	
#3	6	<0.1	0.4	0.8	3	1	0.8	0.8	<0.1	0.1	<0.3	<0.4	<0.4	<0.5	<0.3	<0.5	<0.4
#6	3	<0.08	<0.2	<0.08	<0.5	<0.07	0.3	0.5	<0.06	0.1	<0.2	<0.3	<0.4	<0.4	<0.4	<0.5	<0.4
#7	3	<0.3	<0.2	<0.1	<0.5	<0.06	<0.2	<0.4	<0.1	<0.1	<0.1	<0.2	<0.2	<0.3	<0.4	<0.4	<0.4
Batch 1171:																	
Blank #																	
128	11	1.3	4.5	3.7	8.6	<0.6	3.9	3.6	<0.6	3.9	5.1	<1.8	<2.3	3.5	3.3	<3.7	4.7
129	5.8	2.3	3.8	4	5.4	1.1	2.4	2.1	<0.4	2.1	2.3	<1.2	<1.5	2.6	2	<1.6	2.6
130	<3.0	<0.5	<0.4	<0.3	<0.9	<0.3	<0.6	<0.6	<0.6	<0.4	<0.4	<0.5	<0.6	<0.9	<0.6	<0.7	<0.6
134	5.8	<0.6	1.1	1.9	4.3	1.1	1.1	<0.8	1.5	<0.5	<0.6	<0.6	<0.8	<0.6	<0.9	<0.9	<0.7
135	2.6	1.3	1.5	2.4	3.7	1.7	1.3	1.2	<0.4	<0.8	<1.0	<1.2	<1.6	<1.2	<0.3	2.7	1.8
136	7.2	<0.7	<2.5	2	2.4	<0.7	1.3	1.3	<0.6	<0.5	<0.3	<0.4	<0.5	<0.4	<1.2	<0.8	<0.9
138	2.8	<0.4	<1.9	1.7	1.9	<0.7	<0.9	<0.8	<0.6	<0.5	<0.3	<0.4	<0.5	<0.4	<0.7	<0.6	<0.5
139	NDR(2.4)	<0.4	<0.7	1.1	1.8	<0.2	<0.9	<0.8	<0.4	<0.3	<0.7	<0.8	<1.1	<0.8	<0.8	<0.8	<0.6
140	NDR(1.5)	<0.3	<0.8	NDR(2.8)	<0.5	<0.5	<0.8	<0.8	<0.5	<0.3	<0.9	<1.1	<1.4	<1.0	<1.1	<1.8	<0.8
149	<1.1	<0.4	<1.0	<0.7	<1.0	<0.6	<1.2	<0.5	<0.8	<0.6	<0.9	<0.9	<1.5	<1.0	<1.6	<3.2	<1.3
Batch 1187:																	
BLK #																	
141	<3.3	<0.5	<2.5	<1.4	<3.3	<0.8	<3.3	<2.3	<2.4	<2.6	<3.5	<2.2	<2.0	<1.6	<2.4	<1.9	<1.8
142	NDR(1.6)	<0.2	<0.3	<0.6	NDR(1.3)	<0.4	<0.7	<0.4	<0.2	<0.4	<0.6	<0.2	<0.3	<0.2	<0.6	<0.4	<0.3
Batch 2820:																	
361	<1.0	<0.2	<0.1	<0.3	<0.5	<0.2	<0.2	<0.2	<0.1	NDR(0.1)	<0.1	<0.1	<0.1	<0.1	<0.2	<0.4	<0.2
408	NDR (0.7)	NDR (0.4)	<0.3	1.3	3.8	<0.5	NDR (0.3)	NDR (0.3)	<0.3	<0.3	<0.4	<0.4	<0.5	<0.5	<0.4	<0.9	<0.3
417	NDR (1.0)	0.2	<0.7	0.4	0.9	0.3	0.6	0.3	NDR (0.2)	NDR (0.4)	<0.5	<0.5	<0.6	<0.6	1.9	<1.7	1.7
506	2.3	NDR (1.1)	1.2	1.3	0.9	NDR (0.5)	NDR (0.4)	0.3	NDR (0.3)	NDR (0.3)	NDR (0.7)	<0.2	NDR (0.3)	NDR (0.3)	<0.8	NDR (0.9)	<0.6
Batch 2844:																	
BLK 554	<0.49	<0.51	<0.81	<1.0	NDR (0.63	<0.45	<0.24	<0.26	<0.64	<0.61	<0.93	<0.98	<1.1	<0.9	<1.2	<1.1	<0.98

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples (ng/g wet weight)

	Naptha-lene	Acenaph-thylene	Acenaph-thene	Fluorene	Phenan-threne	Anthra-cene	Fluor-anthene	Pyrene	Benz(a)an-thracene	Chrysene	Benzofluor-anthenes	Benzo(e)-pyrene	Benzo(a)-pyrene	Perylene	Ideno(123-cd)pyrene	Dibenz(ah)-anthracene	Benzo(ghi)-perylene
Laboratory 2																	
Batch 251:																	
Method blanks contained background levels of naphthalene. Background amounts were consistent and were subtracted from any positive values detected in the samples.																	
Batch 425:																	
Method Blank	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5	<5

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples

Surrogate Recoveries

Tissue Procedural Blanks (% Recoveries)

	Naphthalene D-8	Acenaphthalene D-10	Phenanthrene D-10	Pyrene D-10	Chyrsene D-12	Perylene D-12	Dibenz(a,h)-anthracene D-14	Benzo(g,h,i)-perylene D-12
Laboratory 1								
Batch 1171								
Blank #								
128	11	26	37	41	31	31	19	28
129	12	27	53	64	58	55	27	51
131	22	36	49	66	59	63	52	60
134	55	64	86	84	89	85	89	86
135	60	69	89	86	90	83	85	87
136	14	24	59	72	81	72	75	40
138	28	44	78	78	83	74	75	75
139	35	50	87	86	86	81	84	85
140	36	52	81	79	73	71	68	79
141	10	36	62	71	75	70	71	76
142	29	40	67	80	82	74	72	81
149	43	50	63	74	54	61	43	55

	Naphthalene D-8	Acenaphthalene D-10	Phenanthrene D-10	Pyrene D-10	Chyrsene D-12	Perylene D-12	Dibenz(a,h)-anthracene D-14	Benzo(g,h,i)-perylene D-12	Benzo(a) pyrene D-12
Batch 2820									
#361	39	53	65	84	78	82	56	74	83
#408	36	44	55	78	83	80	37	79	82
#417	24	46	86	110	98	82	46	26	81
#506	26	39	63	80	100	66	59	69	70
Batch 2844									
#554	29	34	56	92	91	80	72	100	72

Spike Reference Tissue Recoveries (% Recoveries)

	Naphthalene d-8	Acenaphthene d-10	Phenanthrene d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12
Laboratory 1								
Batch 1171								
1171-T-SPM-#								
22	39	70	85	75	66	69	100	110
2	30	41	52	42	31	44	87	41
3	34	51	65	54	40	57	53	53
16	32	56	79	76	63	72	57	61
23	23	62	88	80	71	84	65	63
24	24	62	82	76	64	74	70	73
25	33	55	69	64	57	66	52	50
26	25	52	75	69	61	63	58	59
29	39	58	68	65	63	65	78	76
30	36	59	69	70	72	66	70	64
35	43	55	58	69	78	66	84	58

	Naphthalene d-8	Acenaphthene d-10	Phenanthrene d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-12	Benzo(ghi)-perylene d-12	Benzo(a) pyrene d-12
Batch 2820									
#126	54	76	67	82	90	69	104	46	69
#168	51	67	81	90	92	78	85	80	82
#175	63	70	89	100	140	110	72	53	80
#214	35	62	77	77	110	56	74	69	58
Batch 2844									
#251	44	65	86	100	96	83	59	72	81

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples

Samples (% Recoveries)	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12
Laboratory 1								
Batch 342								
No information available								
Batch 1171								
Vict. Hbr; Trawl SWT-3.								
D. crab - muscle	30	45	60	58	56	55	47	51
D. crab - hepato.	46	81	83	86	110	99	130	96
Eng. sole - w. body	41	59	78	62	48	62	57	57
Shrimp - w. body	61	74	89	82	87	80	86	90
Vict. Hbr; Stn. SS1								
Clams - soft tissue	52	67	84	77	79	80	92	86
Vict. Hbr., Stn. SS2								
Clams - soft tissue	44	63	88	80	82	79	89	84
(Lab duplicate)	62	75	92	85	87	81	91	84
Vict. Hbr., Stn. C2								
D. crab - muscle	29	39	44	45	36	35	17	32
(Lab duplicate)	13	40	51	54	39	37	21	32
D. crab - hepato.	51	64	77	70	52	71	66	65
(Blind duplicate)	67	74	80	84	100	90	120	100
Vict. Hbr., Trawl UHT-1								
E. sole - w. body	36	46	54	48	35	42	31	37
(Lab duplicate)	24	46	54	52	40	42	25	35
Vict. Hbr., Stn C3 & Trawl IHT-1								
D. crab - muscle	19	32	34	38	35	35	28	32
D. crab - hepato.	44	57	68	56	40	57	57	39
Vict. Hbr., Trawl IHT-1								
E. sole - w. body	33	54	63	57	45	56	45	47
(Blind duplicate)	63	75	95	84	85	92	95	88
Shrimp - tail	39	50	75	83	93	82	87	81
(Lab duplicate)	49	61	83	84	90	85	92	86
(Blind duplicate)	23	43	68	65	60	55	40	51
Vict. Hbr., Stn. SS3								
B. clams - soft tissue	27	55	78	77	73	59	32	46
Vict. Hbr., Stn. SS4								
B. clams - soft tissue	30	60	87	86	95	83	79	73
Esq. Hbr., Con. Cove,Stn. C1								
D. crab - muscle	34	51	59	66	49	55	44	55
(Lab duplicate)	36	57	80	74	74	74	72	76
D. crab - hepato.	41	60	64	64	54	64	42	38
Esq. Hbr. Con. Cove, Trawl CCT-1								
E. sole - w. body	42	61	80	66	46	67	63	62
Shrimp - tails	36	61	83	77	79	72	70	69
(Lab duplicate)	18	51	78	74	72	70	65	63
Esq. Hbr. Con. Cove, Stn. M2								
Mussels - soft tissue	44	69	86	80	84	85	120	110
Esq. Hbr., P. Bay, Trawl PBT-1,2,3								
D. crab - muscle	<10	18	50	63	56	49	53	53
(Lab duplicate)	14	35	48	57	52	46	55	55
D. crab - hepato.	6	68	82	80	82	88	110	99
E. sole - w. body	60	69	87	79	83	86	78	71
Shrimp - tails	33	55	80	76	76	70	68	62
Esq. Hbr., P. Bay, Stns. M1,M2								
Mussels - soft tissue	46	67	87	76	77	75	67	63
(Lab duplicate)	50	73	90	79	78	74	69	66
(Blind duplicate)	26	52	77	70	68	62	55	54
(Lab duplicate)	20	44	70	68	69	62	61	59
Esq. Hbr., P. Bay, Stn. SS5								
M. clams - soft tissue	48	56	70	74	70	67	75	78
Esq. Hbr., Dallas Bank, Stn. SS6								
M. clams - soft tissue	23	47	61	64	50	48	45	53

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples

Batch 1187

	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12
Esq. Hbr. P. Bay, Trawl PBT-1,2,3								
D. crab - hepato.	6	68	82	80	82	88	110	99
Burrard I., Bayshore, Stn. 3,7,9,10								
Mussels - soft tissue	27	65	88	80	82	81	100	92
False Creek at Market, Stn. 3,4,5								
Mussels - soft tissue	21	50	59	71	67	66	75	70
RVYC, Stn. 2,3,8								
Mussels - soft tissue	25	61	87	79	82	75	86	76
(Lab duplicate)	36	68	91	85	91	83	92	81

Batch 2620

	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12	Benzo(a) pyrene d-12
Vancouver Wharves, Stn. M1,M2									
Mussels - soft tissue	49	71	83	93	95	78	74	79	81
(Lab duplicate)	56	74	78	89	91	79	77	79	81
L&K Lumber, Stn M1									
Mussels - soft tissue	50	72	80	88	89	78	74	79	80
Versatile Pacific, Stn. M2									
Mussels - soft tissue	46	65	74	84	76	70	59	64	71
Seaboard Terminals, Stn. M1									
Mussels - soft tissue	54	72	80	87	83	71	62	69	73
Lynnterm, Stn. M2									
Mussels - soft tissue	62	64	68	76	110	65	54	61	65
(Blind duplicate)	93	87	93	100	130	85	80	86	90
Canada Place, Stn. M1									
Mussels - soft tissue	60	78	80	110	93	82	86	89	84
Bayshore Inn, Stn. 5,8,10,11									
Mussels - soft tissue	77	80	66	75	73	69	53	60	71
False Creek Market, Stn. 3,4,5									
Mussels - soft tissue	77	82	74	82	72	77	65	75	79
False Creek, East Basin, FCT-1									
D. crab - muscle	43	66	96	110	110	99	80	60	110
(Lab duplicate)	29	58	83	100	120	87	83	94	87
(Blind duplicate)	28	47	64	74	89	54	43	55	57
D. crab - hepato.	27	27	21	35	88	48	52	37	49
E. sole - w. body	52	68	88	89	130	81	88	77	87
(Blind duplicate)	28	47	64	74	89	67	54	43	55
False Creek, Monk McQ., FCT-2									
E. sole - whole body	61	81	80	80	110	72	87	90	73
River's Inlet									
Pink Shrimp - tail	23	46	61	74	90	60	52	61	63
Q.C.I., Delkatla Slough - RF-9									
D. crab - hepato.	43	76	82	89	120	86	100	110	90
Vict. Hbr., West Bay, Stn. C4									
D. crab - hepato.	61	85	51	77	83	47	30	27	53
(Lab duplicate)	63	86	56	98	101	62	38	33	70
Crescent Beach, Trawl CBT-1									
Rock sole - whole body	51	78	85	90	120	74	94	100	75

APPENDIX 4.2 QUALITY ASSURANCE AND QUALITY CONTROL - Biota Samples

	Naptha-lene d-8	Acenaph-thene d-10	Phenan-threne d-10	Pyrene d-10	Chrysene d-12	Perylene d-12	Dibenz(ah)-anthracene d-14	Benzo(ghi)-perylene d-12	Benzo(a) pyrene d-12
Batch 2488									
Fraser R., BC Cleanwood Preser.									
Starry flounder - whole body	54	57	69	86	75	56	35	45	57
Sculpin - whole body	40	58	69	83	55	52	38	52	54
(Lab duplicate)	43	61	69	92	84	69	43	54	66
Fraser R., Princeton Wood Preser.									
Starry flounder - whole body	65	67	80	110	110	84	69	77	83
Fraser R., Koppers Int'l									
Starry flounder - whole body	43	58	73	98	96	79	51	64	79
Sculpin - whole body	44	54	75	99	100	80	61	76	81

Laboratory 2

Batch 425

All samples were spiked with 2 ug of each of 3 surrogate PAH compounds.

	Naphthalene -d8	2-Fluoro-biphenyl	Terphenyl -d14
% Recovery	69	95	90
Standard deviation	31	25	6

APPENDIX 5

ENVIRONMENTAL CONCENTRATIONS OF PAH COMPOUNDS

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FRASER RIVER																						
MS-4		**Fraser estuary 0.6 km from Iona Sewage Treatment Plant**																						
		Station 1																						
	31-Jul-85	200	NA	NA	100	*	NA	300	200	NA	NA	NA	100	100	NA	NA	NA	NA	NA	400	700	2	383
		29%	–	–	14%	–	–	43%	29%	–	–	–	14%	14%	–	–	–	–	–	57%			
MS-3		**Iona Island sewage treatment plant**																						
		Station 1																						
	20-Jul-87	15	<5	<5	<5	26	<5	41	19	22	19	13	26	10	<5	<5	7	NA	33	149	190	2	425
		8%	0%	0%	0%	14%	0%	22%	10%	12%	10%	7%	14%	5%	0%	0%	4%	–	17%	78%			
		(Lab duplicate)																						
		14	<5	<5	<5	29	5	48	25	24	18	13	16	10	11	<5	8	NA	33	158	206	2	425
		7%	0%	0%	0%	14%	2%	23%	12%	12%	9%	6%	8%	5%	5%	0%	4%	–	16%	77%			
FR-16		**Koppers International**																						
		Station 1																						
	26-Sep-90	1300	13	300	290	880	260	3043	920	600	370	280	420	140	58	21	77	140	63	3089	6132	1	2820
		21%	0%	5%	5%	14%	4%	50%	15%	10%	6%	5%	7%	2%	1%	0%	1%	2%	1%	50%			
		(Lab duplicate)																						
		2000	12	360	330	1300	320	4322	1200	770	340	270	350	120	49	17	59	120	61	3356	7678	1	2820
		26%	0%	5%	4%	17%	4%	56%	16%	10%	4%	4%	5%	2%	1%	0%	1%	2%	1%	44%			
		Station 2																						
	26-Sep-90	1600	9.5	260	210	920	220	3439.5	830	510	230	200	210	76	28	10	34	65	47	2240	5679.5	1	2820
		32%	0%	5%	4%	16%	4%	61%	15%	9%	4%	4%	4%	1%	0%	0%	1%	1%	1%	39%			
		Station 3																						
	26-Sep-90	4300	24	1700	720	3900	990	11634	1800	1400	430	420	340	140	41	15	56	100	73	4815	16449	1	2820
		26%	0%	10%	4%	24%	6%	71%	11%	9%	3%	3%	2%	1%	0%	0%	0%	1%	0%	29%			
		Station 4																						
	26-Sep-90	1300	47	930	3700	3400	2000	11377	3000	1800	1100	760	810	280	120	37	140	260	150	8457	19834	1	2820
		7%	0%	5%	19%	17%	10%	57%	15%	9%	6%	4%	4%	1%	1%	0%	1%	1%	1%	43%			
FR-17		**Domtar Wood Preservers**																						
		Station 1																						
	24-Sep-90	32	3.9	51	300	620	170	1176.9	730	440	200	180	210	71	27	<2.2	28	66	46	1998	3174.9	1	1171
		1%	0%	2%	9%	20%	5%	37%	23%	14%	6%	6%	7%	2%	1%	0%	1%	2%	1%	63%			
		Station 2																						
	24-Sep-90	22	2.4	13	17	110	32	196.4	200	140	66	46	86	29	15	<2.5	13	30	40	665	861.4	1	1171
		3%	0%	2%	2%	13%	4%	23%	23%	16%	8%	5%	10%	3%	2%	0%	2%	3%	5%	77%			
		Station 3																						
	24-Sep-90	37	1.7	18	37	170	45	308.7	170	160	80	64	89	50	23	NDR(5.9)	22	36	41	735	1043.7	1	1171
		4%	0%	2%	4%	16%	4%	30%	16%	15%	8%	6%	9%	5%	2%	–	2%	3%	4%	70%			
		Station 4																						
	24-Sep-90	75	5.7	28	32	150	49	339.7	210	150	64	48	79	31	19	NDR(2.9)	14	28	42	685	1024.7	1	1171
		7%	1%	3%	3%	15%	5%	33%	20%	15%	6%	5%	8%	3%	2%	–	1%	3%	4%	67%			
		(Lab duplicate)																						
		99	5	39	27	150	49	369	130	110	55	48	77	36	20	NDR(3.4)	17	28	41	562	931	1	1171
		11%	1%	4%	3%	16%	5%	40%	14%	12%	6%	5%	8%	4%	2%	–	2%	3%	4%	60%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FRASER RIVER cont.																						
FR-18		**Domtar/Liverpool Site**																						
		Station 1																						
	26-Sep-90		11	1	4.4	5.8	46	7.5	75.7	81	77	30	22	37	13	12	<5.2	NDR(5.6)	17	41	330	405.7	1	1171
			3%	0%	1%	1%	11%	2%	18%	20%	19%	7%	5%	9%	3%	3%	0%	–	4%	10%	81%			
		Station 2																						
	26-Sep-90		27	4.5	5.3	16	39	6	99.8	59	44	26	21	30	7.9	7.7	<2.0	NDR(4.0)	14	43	252.6	352.4	1	1171
			8%	1%	2%	5%	11%	2%	28%	17%	12%	7%	6%	9%	2%	2%	0%	–	4%	12%	72%			
		Station 3																						
	26-Sep-90		7.8	1.1	2.8	12	42	7	72.7	79	61	26	19	30	9.6	5.8	<3.6	NDR(2.5)	12	35	277.4	350.1	1	1171
			2%	0%	1%	3%	12%	2%	21%	23%	17%	7%	5%	9%	3%	2%	0%	–	3%	10%	79%			
		Station 4																						
	26-Sep-90		<5.2	<0.5	<0.8	NDR(1.2)	1.8	<0.8	1.8	2	1.7	<0.9	<1.0	<0.8	<0.9	<1.1	<2.0	<1.1	<0.7	1.7	5.4	7.2	1	1171
			0%	0%	0%	–	25%	0%	25%	28%	24%	0%	0%	0%	0%	0%	0%	0%	0%	24%	75%			
		(Lab duplicate)																						
			<4.9	<0.4	<0.7	NDR(1.4)	1.9	<0.9	1.9	2.1	1.8	<0.9	<0.8	<1.0	<1.3	<1.4	<3.0	<1.5	<1.0	1.6	5.5	7.4	1	1171
			0%	0%	0%	–	26%	0%	26%	28%	24%	0%	0%	0%	0%	0%	0%	0%	0%	22%	74%			
FR-19		**Princeton Wood Preservers**																						
		Station 1																						
	25-Sep-90		6.1	<0.8	<2.7	NDR(2.5)	23	9.6	38.7	22	16	10	6.4	11	NDR(3.9)	NDR(5.2)	NDR(2.2)	3.7	NDR(3.8)	32	101.1	139.8	1	1171
			4%	0%	0%	–	16%	7%	28%	16%	11%	7%	5%	8%	–	–	–	3%	–	23%	72%			
		(Lab duplicate)																						
			5.9	<1.1	<2.7	NDR(2.2)	21	7.1	34	18	12	5.9	5.2	10	<2.6	<4.3	<4.4	<4.8	NDR(4.0)	26	77.1	111.1	1	1171
			5%	0%	0%	–	19%	6%	31%	16%	11%	5%	5%	9%	0%	0%	0%	0%	–	23%	69%			
		Station 2																						
			8	<1.2	<3.0	2.3	23	6.8	40.1	27	21	8.6	6.7	16	<2.6	<4.8	<5.4	<5.4	NDR(6.3)	28	107.3	147.4	1	1171
			5%	0%	0%	2%	16%	5%	27%	18%	14%	6%	5%	11%	0%	0%	0%	0%	–	19%	73%			
		Station 3																						
			22	NDR(2.6)	13	9.8	61	22	127.8	89	57	25	14	37	NDR(16)	15	NDR(3.8)	NDR(14)	NDR(16)	42	279	406.8	1	1171
			5%	–	3%	2%	15%	5%	31%	22%	14%	6%	3%	9%	–	4%	–	–	–	10%	69%			
		Station 4																						
			12	2.4	2	NDR(3.6)	26	9.8	52.2	27	23	14	9.6	18	8.2	8.6	NDR(2.7)	NDR(6.4)	7	49	164.4	216.6	1	1171
			6%	1%	1%	–	12%	5%	24%	12%	11%	6%	4%	8%	4%	4%	–	–	3%	23%	76%			
		(Lab duplicate)																						
			15	3.2	<2.7	NDR(3.4)	25	7.7	50.9	26	22	9.2	8	17	NDR(5.4)	5.9	<2.3	NDR(4.6)	7	45	140.1	191	1	1171
			8%	2%	0%	–	13%	4%	27%	14%	12%	5%	4%	9%	–	3%	0%	–	4%	24%	73%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naphthalene	Acenaphthylene	Acenaphthene	Anthracene	Phenanthrene	Fluorene	Total LMW PAHs	Fluoranthene	Pyrene	Chrysene	Benz(a)anthracene	Benzofluoranthenes	Benzo(a)pyrene	Benzo(ghi)perylene	Dibenz(ah)anthracene	Indeno(123-cd)pyrene	Benzo(e)pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FRASER RIVER cont.																						
FR-20		**B.C. Clearwood Preservers**																						
		Station 1																						
	25-Sep-90		5.5	<0.8	3.4	1.8	14	5.7	30.4	14	10	3.5	4	NDR(5.4)	<1.7	3.2	<7.6	<2.9	NDR(2.3)	14	48.7	79.1	1	1171
			7%	0%	4%	2%	18%	7%	38%	18%	13%	4%	5%	–	0%	4%	0%	0%	–	18%	62%			
		Station 2																						
	25-Sep-90		78	2.5	99	23	320	130	652.5	280	190	41	49	52	19	7.5	<7.6	NDR(8.6)	17	24	679.5	1332	1	1171
			6%	0%	7%	2%	24%	10%	49%	21%	14%	3%	4%	4%	1%	1%	0%	–	1%	2%	51%			
		(Lab duplicate)																						
			50	NDR(1.9)	57	15	180	75	377	160	100	27	31	35	14	8.3	<5.0	NDR(5.9)	13	16	404.3	781.3	1	1171
			6%	–	7%	2%	23%	10%	48%	20%	13%	3%	4%	4%	2%	1%	0%	–	2%	2%	52%			
		Station 3																						
	25-Sep-90		75	5.2	33	40	360	75	588.2	770	570	260	180	440	230	160	26	170	180	69	3055	3643.2	1	1171
			2%	0%	1%	1%	10%	2%	16%	21%	16%	7%	5%	12%	6%	4%	1%	5%	5%	2%	84%			
		Station 4																						
	25-Sep-90		18	5.5	12	23	190	38	286.5	420	350	180	110	330	170	130	NDR(13)	130	140	82	2042	2328.5	1	1171
			1%	0%	1%	1%	8%	2%	12%	18%	15%	8%	5%	14%	7%	6%	–	6%	6%	4%	88%			
		FALSE CREEK																						
FC-1		**Marina at Market**																						
		Station 2																						
	12-Aug-88		90	55	83	440	1700	200	2568	2600	2700	2300	1700	2000	1000	510	170	600	NA	260	13840	16408	2	425
			1%	0%	1%	3%	10%	1%	16%	16%	16%	14%	10%	12%	6%	3%	1%	4%	–	2%	84%			
		(Lab duplicate)																						
			160	85	85	460	1600	160	2550	2600	2300	2600	1600	2000	1600	630	200	500	NA	290	14520	17070	2	425
			1%	0%	0%	3%	9%	1%	15%	15%	13%	15%	11%	12%	9%	4%	1%	3%	–	2%	85%			
		Stations 3,4,5 (composite)																						
	25-Mar-91		280	72	160	360	1400	270	2542	4000	3000	1500	1100	2000	1100	510	120	630	810	260	15030	17572	1	1171
			2%	0%	1%	2%	8%	2%	14%	23%	17%	9%	6%	11%	6%	3%	1%	4%	5%	1%	86%			
		(Repeat analysis)																						
			1100	560	190	530	4900	870	8150	6800	5000	2900	1500	4100	1700	920	240	1200	1400	370	26130	34280	1	2820
			3%	2%	1%	2%	14%	3%	24%	20%	15%	8%	4%	12%	5%	3%	1%	4%	4%	1%	76%			
FC-4		**Outer Creek midchannel**																						
		Station 1																						
	04-Jun-91		170	59	27	83	200	64	603	270	390	120	150	220	190	84	20	84	120	65	1713	2316	1	2820
			7%	3%	1%	4%	9%	3%	26%	12%	17%	5%	6%	9%	8%	4%	1%	4%	5%	3%	74%			
		(Lab duplicate)																						
			150	52	76	190	590	140	1198	570	670	190	270	310	280	140	32	140	150	77	2829	4027	1	2820
			4%	1%	2%	5%	15%	3%	30%	14%	17%	5%	7%	8%	7%	3%	1%	3%	4%	2%	70%			
		(Replicate)																						
			140	100	39	110	410	87	886	890	820	280	240	420	310	160	35	150	180	83	3368	4254	1	2820
			3%	2%	1%	3%	10%	2%	21%	16%	19%	7%	6%	10%	7%	4%	1%	4%	4%	2%	79%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FALSE CREEK cont.																						
FC-5		**At Granville Ferries**																						
		Station 1																						
	04-Jun-91		280	140	83	390	820	230	1943	1400	1700	810	930	1200	880	420	100	480	580	230	8710	10653	1	2820
			3%	1%	1%	4%	8%	2%	18%	13%	16%	8%	9%	11%	8%	4%	1%	5%	5%	2%	82%			
		(Lab duplicate)																						
			300	130	86	330	800	200	1846	1500	1800	980	810	1300	820	390	88	410	570	230	8898	10744	1	2820
			3%	1%	1%	3%	7%	2%	17%	14%	17%	9%	8%	12%	8%	4%	1%	4%	5%	2%	83%			
FC-6		**Off Granville Island Hotel**																						
		Station 1																						
	04-Jun-91		550	220	140	530	1400	380	3220	1700	2200	870	960	1400	1100	590	140	620	720	270	10570	13790	1	2820
			4%	2%	1%	4%	10%	3%	23%	12%	16%	6%	7%	10%	8%	4%	1%	4%	5%	2%	77%			
		(Replicate)																						
			850	380	120	480	1300	320	3250	2100	2500	990	910	1700	1200	620	160	620	780	300	11880	15130	1	2820
			4%	3%	1%	3%	9%	2%	21%	14%	17%	7%	6%	11%	8%	4%	1%	4%	5%	2%	79%			
		(Blind duplicate)																						
			520	300	130	450	1200	370	2970	2000	2500	1300	1000	1800	1300	660	NDR(230)	630	830	320	12340	15310	1	2820
			3%	2%	1%	3%	8%	2%	19%	13%	16%	8%	7%	12%	8%	4%	–	4%	5%	2%	81%			
		(Lab duplicate)																						
			580	250	98	400	910	240	2478	1400	1900	970	950	1500	860	540	140	640	650	240	9790	12268	1	2820
			5%	2%	1%	3%	7%	2%	20%	11%	15%	8%	8%	12%	7%	4%	1%	5%	5%	2%	80%			
FC-7		**Off Monk McQueen's**																						
		Station 1																						
	04-Jun-91		680	300	99	320	830	230	2859	1400	2200	800	600	1200	820	470	NDR(150)	410	560	190	8450	11109	1	2820
			6%	3%	1%	3%	7%	2%	24%	13%	20%	5%	5%	11%	7%	4%	–	4%	5%	2%	76%			
		(Lab duplicate)																						
			750	260	99	370	910	230	2619	1500	2200	900	910	1600	880	600	160	670	730	230	10380	12999	1	2820
			6%	2%	1%	3%	7%	2%	20%	12%	17%	7%	7%	12%	7%	5%	1%	5%	6%	2%	80%			
FC-8		**Off Monk McQueen's; near Cambie Bridge**																						
		Station 1																						
	04-Jun-91		240	150	71	330	850	230	1871	1400	2000	870	730	1800	1200	690	150	650	840	300	10630	12501	1	2820
			2%	1%	1%	3%	7%	2%	15%	11%	16%	7%	6%	14%	10%	6%	1%	5%	7%	2%	85%			
		(Lab duplicate)																						
			200	150	71	290	690	170	1571	1000	1600	750	750	1400	800	530	140	640	670	240	8520	10091	1	2820
			2%	1%	1%	3%	7%	2%	16%	10%	16%	7%	7%	14%	8%	5%	1%	6%	7%	2%	84%			
FC-9		**Inside Cambie Bridge off dumpsite**																						
		Station 1																						
	04-Jun-91		NDR(510)	540	130	650	1100	370	2790	2800	3000	1600	1600	2800	2200	1100	270	1100	1300	500	18270	21060	1	2820
			–	3%	1%	3%	5%	2%	13%	13%	14%	8%	8%	13%	10%	5%	1%	5%	6%	2%	87%			
		(Lab duplicate)																						
			610	400	120	780	1200	340	3450	2800	2900	1800	2200	3000	1900	1100	300	1400	1300	500	19000	22450	1	2820
			3%	2%	1%	3%	5%	2%	15%	12%	13%	8%	10%	13%	8%	5%	1%	6%	6%	2%	85%			
FC-10		**Northeast corner**																						
		Station 1																						
	04-Jun-91		2800	1300	340	1400	2600	760	9200	6800	5900	3800	5400	5200	3700	2200	620	3100	2400	930	40050	49250	1	2820
			6%	3%	1%	3%	5%	2%	19%	14%	12%	8%	11%	11%	8%	4%	1%	6%	5%	2%	81%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naphthalene	Acenaphthylene	Acenaphthene	Anthracene	Phenanthrene	Fluorene	Total LMW PAHs	Fluoranthene	Pyrene	Chrysene	Benz(a)anthracene	Benzofluoranthenes	Benzo(a)pyrene	Benzo(ghi)perylene	Dibenz(ah)anthracene	Indeno(123-cd)pyrene	Benzo(e)pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FALSE CREEK cont.																						
FC-11		East Basin																						
		Station 1																						
	04-Oct-88		500	97	150	1100	1400	290	3537	3900	4700	3100	2000	3300	1300	1300	380	780	1600	480	22840	26377	1	342
			2%	0%	1%	4%	5%	1%	13%	15%	18%	12%	8%	13%	5%	5%	1%	3%	6%	2%	87%			
		(Split sample)	400	270	120	830	1600	290	3510	4100	4700	3000	2500	3600	3400	2000	700	1900	NA	850	26950	30460	2	425
			1%	1%	0%	3%	5%	1%	12%	13%	15%	10%	8%	12%	11%	7%	2%	6%	–	3%	88%			
		BURRARD INLET																						
BI-1		Vancouver Outer Harbour (Pacific Environment Institute)																						
		Station 2																						
	09/09/1991		54	13	16	37	130	23	273	160	190	140	110	200	100	80	NDR(16)	80	85	92	1237	1510	1	2820b
			4%	1%	1%	2%	9%	2%	18%	11%	13%	9%	7%	13%	7%	5%	–	5%	6%	6%	82%			
BI-2		Vancouver Wharves																						
		Station 4																						
	12-Sep-91		930	22	970	230	2900	2300	7352	2200	1100	240	280	220	93	NDR(22)	10	57	83	26	4309	11661	1	2820
			8%	0%	8%	2%	25%	20%	63%	19%	9%	2%	2%	2%	1%	–	0%	0%	1%	0%	37%			
BI-3		L&K Lumber																						
		Station 2a																						
	12-Sep-91		140	25	110	390	950	290	1905	2400	1600	990	800	1100	640	300	79	360	490	190	8949	10854	1	2820
			1%	0%	1%	4%	9%	3%	18%	22%	15%	9%	7%	10%	6%	3%	1%	3%	5%	2%	82%			
		(Lab duplicate)	170	20	100	320	770	260	1640	1700	1300	720	690	960	600	310	80	370	450	200	7380	9020	1	2820
			2%	0%	1%	4%	9%	3%	18%	19%	14%	8%	8%	11%	7%	3%	1%	4%	5%	2%	82%			
BI-4		Vancouver Shipyards/Seaspan																						
		Station 1																						
	19-Aug-84		300	NA	300	1000	*	400	2000	2600	2500	400	*	800	200	NA	NA	NA	NA	NA	6500	8500	2	1287
			4%	–	4%	12%	–	5%	24%	31%	29%	5%	–	9%	2%	–	–	–	–	–	76%			
		Station 3																						
	14-Sep-88		750	34	1000	2600	7900	1100	13384	22000	11000	6800	4800	13000	4100	2400	530	2900	3700	1000	72230	85614	1	342
			1%	0%	1%	3%	9%	1%	16%	26%	13%	8%	6%	15%	5%	3%	1%	3%	4%	1%	84%			
		(Split sample)	990	180	1100	2500	9200	800	14770	6200	5200	9100	7300	17000	6500	2200	860	1600	NA	550	56510	71280	2	425
			1%	0%	2%	4%	13%	1%	21%	9%	7%	13%	10%	24%	9%	3%	1%	2%	–	1%	79%			
		(Blind duplicate)	900	82	820	2000	10000	1000	14802	17000	11000	9000	5500	9400	6500	3500	1200	3800	NA	1300	68200	83002	2	425
			1%	0%	1%	2%	12%	1%	18%	20%	13%	11%	7%	11%	8%	4%	1%	5%	–	2%	82%			
		(Repeat analysis using TIM)	NDR(450)	<14	1500	NDR(1700	5000	1900	8400	10000	5500	5300	5100	8100	3500	2400	430	2500	2400	940	46170	54570	1	342
			–	–	3%	–	9%	3%	15%	18%	10%	10%	9%	15%	6%	4%	1%	5%	4%	2%	85%			
		Station 4																						
	12-Sep-91		31	7.7	32	550	730	420	1770.7	1000	590	170	180	160	100	40	NDR(10)	46	85	29	2380	4150.7	1	2820
			1%	0%	1%	13%	18%	10%	43%	24%	14%	4%	4%	4%	2%	1%	–	1%	2%	1%	57%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont																						
BI-5		**Versatile Pacific (was Burrard Yarrows)**																						
		Station 2																						
	19-Aug-84	–	–	NA	200	1400	*	300	1900	3300	3500	200	*	300	<100	NA	NA	NA	NA	NA	7300	9200	2	1287
					2%	15%	–	3%	21%	36%	38%	2%	–	3%	0%	–	–	–	–	–	79%			
		(Blind duplicate)	–	–	–	1300	*	–	1300	5000	5500	100	*	200	<100	NA	NA	NA	NA	NA	10800	12100	2	1287
			–	NA	–	11%	–	–	11%	41%	45%	1%	–	2%	0%	–	–	–	–	–	89%			
		(Lab duplicate)	100	NA	300	100	*	100	600	3000	3200	200	*	<100	<100	NA	NA	NA	NA	NA	6400	7000	2	1287
			1%	–	4%	1%	–	1%	9%	43%	46%	3%	–	0%	0%	–	–	–	–	–	91%			
		Station 4																						
	28-Jul-88	170	51	250	670	2600	380	4121	10000	6700	3900	2700	6200	2000	1300	260	1700	1900	540	37200	41321	1	342
		0%	0%	1%	2%	8%	1%	10%	24%	16%	9%	7%	15%	5%	3%	1%	4%	5%	1%	90%			
		Station 5																						
	12-Sep-91	68	17	99	160	660	83	1087	690	750	420	370	600	350	210	54	240	260	120	4064	5151	1	2820
		1%	0%	2%	3%	13%	2%	21%	13%	15%	8%	7%	12%	7%	4%	1%	5%	5%	2%	79%			
BI-7		**Saskatchewan Wheat Pool**																						
		Station 1																						
	12-Sep-91	180	50	51	110	520	89	1000	1000	1000	580	600	650	380	170	58	210	260	180	5088	6088	1	2820
		3%	1%	1%	2%	9%	1%	16%	16%	16%	10%	10%	11%	6%	3%	1%	3%	4%	3%	84%			
BI-8		**Neptune Terminals**																						
		Station 2																						
	19-Aug-84	800	NA	NA	1500	*	NA	2300	2000	2500	400	*	900	100	NA	NA	NA	NA	NA	NA	5900	8200	2	1287
		10%	–	–	18%	–	–	28%	24%	30%	5%	–	11%	1%	–	–	–	–	–	–	72%			
		Station 2a																						
	12-Sep-91	280	8	NDR(69)	75	660	180	1203	430	360	290	200	320	130	93	28	99	130	83	2163	3386	1	2820
		8%	0%	–	2%	20%	5%	36%	13%	11%	9%	6%	10%	4%	3%	1%	3%	4%	2%	64%			
BI-9		**Seaboard Terminals**																						
		Station 1xb																						
	14-Sep-88	14	0.6	36	110	450	60	670.6	800	610	270	250	340	150	57	15	88	100	50	2730	3400.6	1	342
		0%	0%	1%	3%	13%	2%	20%	24%	18%	8%	7%	10%	4%	2%	0%	3%	3%	1%	80%			
		Station 1x+C377																						
	12-Sep-91	28	2.7	22	24	150	28	254.7	190	140	74	70	100	46	27	7.5	31	38	34	757.5	1012.2	1	2820
		3%	0%	2%	2%	15%	3%	25%	19%	14%	7%	7%	10%	5%	3%	1%	3%	4%	3%	75%			
		(Lab duplicate)																						
		32	2.5	25	24	160	31	274.5	200	130	84	71	99	42	25	6.1	28	37	44	768.1	1040.6	1	2820
		3%	0%	2%	2%	15%	3%	26%	19%	12%	8%	7%	10%	4%	2%	1%	3%	4%	4%	74%			
BI-10		**Lynnterm**																						
		Station 4																						
	11-Sep-91	17	1.4	24	20	110	19	191.4	170	150	72	58	100	45	29	6.6	37	37	22	726.6	918	1	2820
		2%	0%	3%	2%	12%	2%	21%	19%	16%	8%	6%	11%	5%	3%	1%	4%	4%	2%	79%			
		(Blind duplicate)																						
		38	3.8	66	90	410	47	654.8	570	460	280	290	490	280	160	45	220	180	82	3057	3711.8	1	2820
		1%	0%	2%	2%	11%	1%	18%	15%	12%	8%	8%	13%	8%	4%	1%	6%	5%	2%	82%			

APPENDIX 5.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-11		**Belaire Shipyards** Station 1+C776																						
	18-Aug-84		100	NA	100	800	*	100	1100	2400	2600	2500	*	2100	400	NA	NA	NA	NA	NA	10000	11100	2	383
			1%	–	1%	7%	–	1%	10%	22%	23%	23%	–	19%	4%	–	–	–	–	–	90%			
		(Lab duplicate)																						
			–	NA	100	800	*	100	1000	1800	2000	2200	*	2300	300	NA	NA	NA	NA	NA	8600	9600	2	383
			–	–	1%	8%	–	1%	10%	19%	21%	23%	–	24%	3%	–	–	–	–	–	90%			
BI-12		**Allied Shipyards** *Station 2*																						
	14-Sep-88		280	120	640	2000	8900	580	12520	20000	9200	9200	21000	21000	9200	4000	460	5400	NA	2900	102360	114880	2	425
			0%	0%	1%	2%	8%	1%	11%	17%	8%	8%	18%	18%	8%	3%	0%	5%	–	3%	89%			
BI-14		**Boulder Rock** Station 1																						
	11-Sep-91		92	28	25	110	310	54	619	430	500	340	260	520	250	180	45	200	210	110	3045	3664	1	2820b
			3%	1%	1%	3%	8%	1%	17%	12%	14%	9%	7%	14%	7%	5%	1%	5%	6%	3%	83%			
BI-15		**IOCO** Station 1																						
	10-Sep-91		500	200	45	220	780	100	1825	1000	1500	690	NDR(400)	1000	470	480	NDR(82)	420	550	200	6310	8135	1	2820b
			6%	2%	1%	3%	9%	1%	22%	12%	18%	8%	–	12%	6%	6%	–	5%	7%	2%	78%			
		(Lab duplicate)																						
			320	130	41	150	520	84	1245	640	940	420	NDR(260)	630	330	300	NDR(48)	260	330	120	3970	5215	1	2820b
			6%	2%	1%	3%	10%	2%	24%	12%	18%	8%	–	12%	6%	6%	–	5%	6%	2%	76%			
BI-16		**IOCO/Port Moody** *Station 2*																						
	08-Nov-89		290	48	62	230	290	83	1003	380	1900	300	160	720	300	250	40	220	380	150	4800	5803	1	342
			5%	1%	1%	4%	5%	1%	17%	7%	33%	5%	3%	12%	5%	4%	1%	4%	7%	3%	83%			
		(Blind duplicate)																						
			200	39	66	250	320	96	971	470	1800	350	170	880	360	270	35	170	400	150	5055	6026	1	342
			3%	1%	1%	4%	5%	2%	16%	8%	30%	6%	3%	15%	6%	4%	1%	3%	7%	2%	84%			
BI-17		**Port Moody** Station 1																						
	11-Sep-91		180	68	36	130	400	67	881	520	670	420	NDR(300)	640	320	270	NDR(52)	270	300	140	3550	4431	1	2820b
			4%	2%	1%	3%	9%	2%	20%	12%	15%	9%	–	14%	7%	6%	–	6%	7%	3%	80%			
BI-18		**Alberta Wheat Pool** Station 1																						
	12-Sep-91		10	1.9	2.3	5.5	24	3.5	47.2	30	27	19	16	30	14	11	NDR(2.1)	13	13	43	216	263.2	1	2820
			4%	1%	1%	2%	9%	1%	18%	11%	10%	7%	6%	11%	5%	4%	–	5%	5%	16%	82%			
BI-19		**Central Harbour** Station 1																						
	12-Sep-91		46	10	23	53	210	40	382	300	310	250	180	340	150	100	NDR(22)	120	130	78	1958	2340	1	2820b
			2%	0%	1%	2%	9%	2%	16%	13%	13%	11%	8%	15%	6%	4%	–	5%	6%	3%	84%			

APPENDIX 5.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-20		Rivtow Station 1																						
	29-Jul-88		2000	95	240	5400	8200	1500	17435	22000	18000	9200	9300	12000	4600	1500	540	2500	3300	1000	83940	101375	1	342
			2%	0%	0%	5%	8%	1%	17%	22%	18%	9%	9%	12%	5%	1%	1%	2%	3%	1%	83%			
BI-21		Sterling Shipyards Station1																						
	20-Aug-84		800	100	900	4200	*	900	6900	4700	6000	2200	*	4000	1600						18500	25400	2	383
			3%	0%	4%	17%	–	4%	27%	19%	24%	9%	–	16%	6%	0%	0%	0%	0%	0%	73%			
		(Lab duplicate)																						
			200	–	300	2600	*	300	3400	4500	5100	700	*	2800	400						13500	16900	2	383
			1%	–	2%	15%	–	2%	20%	27%	30%	4%	–	17%	2%	0%	0%	0%	0%	0%	80%			
		(Split sample)																						
			420	<900	<500	3570	*	<500	3990	4590	<500	2720	1800	2740	1880	<1000	<800	<900	NA	NA	13510	17500	3	915
			2%	0%	0%	20%	–	0%	23%	26%	0%	16%	9%	16%	11%	0%	0%	0%	–	–	77%			
		(Lab duplicate)																						
			460	<900	<500	3060	*	<500	3520	3800	<500	2790	2110	3530	1680	<1000	<600	<900	NA	NA	13910	17430	3	915
			3%	0%	0%	18%	–	0%	20%	22%	0%	16%	12%	20%	10%	0%	0%	0%	–	–	80%			
		(Blind duplicate)																						
			430	<900	<500	7300	*	<500	7730	5990	<500	1860	1100	2920	1540	<1000	<600	<900	NA	NA	13410	21140	3	915
			2%	0%	0%	35%	–	0%	37%	28%	0%	9%	5%	14%	7%	0%	0%	0%	–	–	63%			
		(Lab duplicate)																						
			538	<900	<500	3720	*	<500	4258	2360	<500	2300	1670	2210	1830	<1000	<600	<900	NA	NA	10370	14628	3	915
			4%	0%	0%	25%	–	0%	29%	16%	0%	16%	11%	15%	13%	0%	0%	0%	–	–	71%			
BI-22		B.C. Marine Shipbuilders Station 1																						
	20-Aug-84		NA	NA	800	5400	*	1500	7700	13300	13000	2300	*	6000	<100	NA	NA	NA	NA	NA	34600	42300	2	1287
			–	–	2%	13%	–	4%	18%	31%	31%	5%	–	14%	0%	–	–	–	–	–	82%			
		(Lab duplicate)																						
			NA	NA	1600	5700	*	NA	7300	13800	13300	2500	*	7000	<100	NA	NA	NA	NA	NA	36600	43900	2	1287
			–	–	4%	13%	–	–	17%	31%	30%	6%	–	16%	0%	–	–	–	–	–	83%			
		(Blind duplicate)																						
			NA	NA	2000	5500	*	NA	7500	9000	10000	600	*	NA	NA	NA	NA	NA	NA	NA	19600	27100	2	1287
			–	–	7%	20%	–	–	28%	33%	37%	2%	–	–	–	–	–	–	–	–	72%			
BI-22a		B.C. Marine/Sterling Station 1																						
	14-Sep-88		1100	170	20000	19000	69000	51000	180270	110000	58000	17000	18000	16000	6200	3500	760	4200	6800	1800	242260	402530	1	342
			0%	0%	5%	5%	17%	13%	40%	27%	14%	4%	4%	4%	2%	1%	0%	1%	2%	0%	60%			
		(Lab duplicate)																						
			1600	160	22000	16000	74000	51000	164760	77000	48000	15000	16000	19000	5700	3400	1000	3900	6800	1700	197500	362260	1	342
			0%	0%	6%	4%	20%	14%	45%	21%	13%	4%	4%	5%	2%	1%	0%	1%	2%	0%	55%			
		(Split sample)																						
			720	760	29000	12000	101000	30000	173480	81000	47000	17000	17000	12000	5700	2000	1500	2900	NA	1300	187400	360880	2	425
			0%	0%	8%	3%	28%	8%	48%	22%	13%	5%	5%	3%	2%	1%	0%	1%	–	0%	52%			
		(Repeat analysis using TIM)																						
			810	380	23000	NA**	NA**	48000	72190	NA**	NA**	13000	17000	13000	4500	2800	520	2500	4000	1100	58420	130610	1	342
			1%	0%	18%	–	–	37%	55%	–	–	10%	13%	10%	3%	2%	0%	2%	3%	1%	45%			
		(Lab duplicate)																						
			580	140	20000	NA**	NA**	48000	68720	NA**	NA**	14000	16000	15000	5600	2600	650	2500	4800	1500	62850	131370	1	342
			0%	0%	15%	–	–	37%	52%	–	–	11%	12%	11%	4%	2%	0%	2%	4%	1%	48%			

APPENDIX 5.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-23		Vanterm																						
		Station 2																						
	12-Sep-91		35	38	16	48	150	16	303	310	360	220	160	310	170	100	24	110	130	59	1953	2256	1	2820
			2%	2%	1%	2%	7%	1%	13%	14%	16%	10%	7%	14%	8%	4%	1%	5%	6%	3%	87%			
		(Lab duplicate)																						
			38	22	14	46	120	16	256	190	200	130	91	200	94	63	15	65	85	42	1175	1431	1	2820
			3%	2%	1%	3%	8%	1%	18%	13%	14%	9%	6%	14%	7%	4%	1%	5%	6%	3%	82%			
BI-24		United Grain Growers																						
		Station 1																						
	12-Sep-90		140	18	110	130	450	110	958	790	760	440	350	650	300	190	49	240	250	110	4129	5087	1	2820
			3%	0%	2%	3%	9%	2%	19%	16%	15%	9%	7%	13%	6%	4%	1%	5%	5%	2%	81%			
BI-25		Centerm																						
		Station 1																						
	12-Sep-91		84	18	46	70	180	32	430	270	300	170	130	280	130	81	23	95	110	61	1650	2080	1	2820
			4%	1%	2%	3%	9%	2%	21%	13%	14%	8%	6%	13%	6%	4%	1%	5%	5%	3%	79%			
		(Blind duplicate)																						
			57	22	17	58	140	20	314	250	280	230	150	340	150	83	27	94	130	64	1798	2112	1	2820
			3%	1%	1%	3%	7%	1%	15%	12%	13%	11%	7%	16%	7%	4%	1%	4%	6%	3%	85%			
BI-26		Canada Place (Pier BC; NHB)																						
		Station 2																						
	12-Sep-91		140	54	77	220	720	90	1301	1400	1300	760	610	1200	540	330	86	410	470	200	7306	8607	1	2820
			2%	1%	1%	3%	8%	1%	15%	16%	15%	9%	7%	14%	6%	4%	1%	5%	5%	2%	85%			
		Coal Harbour:																						
CH-1		Bayshore Inn Marina																						
		Stations 1,3,4 (composite)																						
	25-Mar-91		150	16	30	94	360	61	711	1200	1100	430	460	850	510	350	NDR(63)	460	390	130	5880	6591	1	1171
			2%	0%	0%	1%	5%	1%	11%	18%	17%	7%	7%	13%	8%	5%	–	7%	6%	2%	89%			
		(Repeat analysis)																						
			57	36	25	120	300	40	578	930	940	530	350	960	380	300	63	340	370	140	5303	5881	1	2820
			1%	1%	0%	2%	5%	1%	10%	16%	16%	9%	6%	16%	6%	5%	1%	6%	6%	2%	90%			
		(Blind duplicate)																						
			77	43	66	150	630	110	1076	1000	1000	650	350	1000	400	310	70	330	400	140	5650	6726	1	2820
			1%	1%	1%	2%	9%	2%	16%	15%	15%	10%	5%	15%	6%	5%	1%	5%	6%	2%	84%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
		Coal Harbour cont.:																						
CH-3		**Royal Vancouver Yacht Club Marina**																						
		Station 1																						
	16-Mar-88		23	6	18	51	190	32	320	370	290	190	120	330	150	80	<20	93	120	39	1782	2102	1	342
			1%	0%	1%	2%	9%	2%	15%	18%	14%	9%	6%	16%	7%	4%	0%	4%	6%	2%	85%			
		(Split sample)																						
			22	6	10	29	150	16	233	280	250	200	150	250	170	120	34	110	NA	40	1604	1837	2	425
			1%	0%	1%	2%	8%	1%	13%	15%	14%	11%	8%	14%	9%	7%	2%	6%	–	2%	87%			
		Stations 4,5,6 (composite)																						
	25-Mar-91		86	48	60	220	710	160	1282	1300	1500	680	590	1200	780	460	120	580	530	210	7930	9212	1	1171
			1%	0%	1%	2%	8%	2%	14%	14%	16%	7%	6%	13%	8%	5%	1%	6%	6%	2%	86%			
		(Lab duplicate)																						
			130	50	33	250	750	100	1313	1900	1900	1000	750	1300	650	380	100	440	570	190	9180	10493	1	1171
			1%	0%	0%	2%	7%	1%	13%	18%	18%	10%	7%	12%	6%	4%	1%	4%	5%	2%	87%			
		(Repeat analysis)																						
			120	53	34	130	470	58	865	1000	1100	590	330	1000	430	310	74	350	400	150	5734	6599	1	2820
			2%	1%	1%	2%	7%	1%	13%	15%	17%	9%	5%	15%	7%	5%	1%	5%	6%	2%	87%			
		(Lab duplicate)																						
			83	47	35	140	420	92	817	820	1100	540	330	1100	410	300	NDR(73)	370	390	150	5510	6327	1	2820
			1%	1%	1%	2%	7%	1%	13%	13%	17%	9%	5%	17%	6%	5%	–	6%	6%	2%	87%			
CH-5		**Menchion's Shipyard**																						
		Station 1																						
	20-Aug-84		NA	500	NA	2800	*	400	3500	7300	13000	300	*	4000	300						24900	28400	2	1287
			–	2%	–	9%	–	1%	12%	26%	46%	1%	–	14%	1%	0%	0%	0%	0%	0%	88%			
CH-6		**Bayshore/Menchion's**																						
		Station 3b																						
	14-Sep-88		120	48	98	550	890	180	1884	3200	3700	2200	1300	4800	1600	1100	180	1200	1700	440	21420	23304	1	342
			1%	0%	0%	2%	4%	1%	8%	14%	16%	9%	6%	21%	7%	5%	1%	5%	7%	2%	92%			
		(Repeat analysis by TIM)																						
			120	72	110	590	810	180	1882	3300	4200	2600	1900	3400	1500	1000	NDR(210)	660	1200	340	20100	21982	1	342
			1%	0%	1%	3%	4%	1%	9%	15%	19%	12%	9%	15%	7%	5%	–	3%	5%	2%	91%			
		(Split sample)																						
			220	90	300	680	2500	450	4240	3600	4200	4100	2900	3200	1900	1200	220	1400	NA	480	23200	27440	2	425
			1%	0%	1%	2%	9%	2%	15%	13%	15%	15%	11%	12%	7%	4%	1%	5%	–	2%	85%			
		(Lab duplicate)																						
			410	90	190	620	2100	340	3750	3600	4300	2500	1900	3200	1900	1100	260	1300	NA	470	20530	24280	2	425
			2%	0%	1%	3%	9%	1%	15%	15%	18%	10%	8%	13%	8%	5%	1%	5%	–	2%	85%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR																						
		The Gorge :																						
VH-1		Station SW-7; off storm drains across from Aaron Pt																						
	11-Jul-90		130	43	26	120	360	62	741	1000	1100	450	400	880	590	430	76	420	440	150	5936	6677	1	1171
			2%	1%	0%	2%	5%	1%	11%	15%	16%	7%	6%	13%	9%	6%	1%	6%	7%	2%	89%			
VH-2		Station SW-8; off Gorge Park																						
	11-Jul-90		76	33	29	210	410	62	820	1400	1300	710	620	1200	890	560	110	540	540	200	8070	8890	1	1171
			1%	0%	0%	2%	5%	1%	9%	16%	15%	8%	7%	13%	10%	6%	1%	6%	6%	2%	91%			
		Selkirk Waters :																						
VH-3		Station SW-1b; off BCFP sawmill																						
	07/20/1987		130	9	22	38	110	25	334	100	960	130	100	200	60	7	<5	9	NA	8	1574	1908	2	425
			7%	0%	1%	2%	6%	1%	18%	5%	50%	7%	5%	10%	3%	0%	0%	0%	–	0%	82%			
VH-4		Station SW-2; off old BCFP/Fletcher Challenge sawmill, west side																						
	11-Jul-90		470	44	1200	520	3100	1600	6934	3300	2300	1100	900	1300	790	410	83	430	570	190	11373	18307	1	1171
			3%	0%	7%	3%	17%	9%	38%	18%	13%	6%	5%	7%	4%	2%	0%	2%	3%	1%	62%			
		(Lab duplicate)																						
			440	50	1100	390	2600	1300	5880	3200	2200	880	780	1200	710	390	78	410	530	180	10558	16438	1	1171
			3%	0%	7%	2%	16%	8%	36%	19%	13%	5%	5%	7%	4%	2%	0%	2%	3%	1%	64%			
VH-5		Station SW-3; off old BCFP/Fletcher Challenge sawmill, southwest side																						
	11-Jul-90		270	27	390	220	650	440	1997	1700	1300	360	310	500	270	170	34	160	230	82	5116	7113	1	1171
			4%	0%	5%	3%	9%	6%	28%	24%	18%	5%	4%	7%	4%	2%	0%	2%	3%	1%	72%			
VH-6		Station SW-4 ; trawl site, midchannel																						
	11-Jul-90		300	94	170	1400	1200	500	3664	2400	1900	1100	1100	1800	1100	600	NDR(140)	930	750	260	11940	15604	1	1171
			2%	1%	1%	9%	8%	3%	23%	15%	12%	7%	7%	12%	7%	4%	–	6%	5%	2%	77%			
VH-7		Station SW-5; south end of old BCFP/Fletcher Challenge sawmill, off location of old dip tanks																						
	11-Jul-90		620	91	240	330	2300	490	4071	2800	2900	930	700	1100	610	340	76	340	510	130	10436	14507	1	1171
			4%	1%	2%	2%	16%	3%	28%	19%	20%	6%	5%	8%	4%	2%	1%	2%	4%	1%	72%			
VH-8		Station SW-6; off storm drain south of sawmill site																						
	11-Jul-90		480	85	240	390	1600	450	3245	3500	3200	1200	1000	1800	1000	730	130	670	840	270	14340	17585	1	1171
			3%	0%	1%	2%	9%	3%	18%	20%	18%	7%	6%	10%	6%	4%	1%	4%	5%	2%	82%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR cont.																						
		Upper Harbour :																						
VH-9		Station UH-1; Victoria Machinery Depot																						
	11-Jul-90		820	140	120	360	1200	310	2950	2200	2600	980	800	1500	1000	640	130	580	740	270	11440	14390	1	1171
			6%	1%	1%	3%	8%	2%	21%	15%	18%	7%	6%	10%	7%	4%	1%	4%	5%	2%	79%			
VH-10		Station UH-2; Rock Bay																						
	11-Jul-90		920	230	600	850	3800	1100	7500	3500	4400	1600	1900	2800	1900	1100	250	1200	1100	390	20140	27640	1	1171
			3%	1%	2%	3%	14%	4%	27%	13%	16%	6%	7%	10%	7%	4%	1%	4%	4%	1%	73%			
VH-11		Station UH-3; head of Rock Bay																						
	11-Jul-90		200	73	220	320	1700	420	2933	2800	1900	670	740	1200	770	530	NDR(100)	730	490	160	9790	12723	1	1171
			2%	1%	2%	3%	13%	3%	23%	20%	15%	5%	6%	9%	6%	4%	–	6%	4%	1%	77%			
VH-12		Station UH-4 ; midchannel trawl site																						
	11-Jul-90		450	74	320	470	1600	500	3414	3200	3000	1400	1400	2800	1600	770	180	800	1000	340	16490	19904	1	1171
			2%	0%	2%	2%	8%	3%	17%	16%	15%	7%	7%	14%	8%	4%	1%	4%	5%	2%	83%			
		(Lab duplicate)																						
			270	62	110	410	1300	270	2422	2800	2700	1400	1300	2700	1500	780	190	810	1000	370	15550	17972	1	1171
			2%	0%	1%	2%	7%	2%	13%	16%	15%	8%	7%	15%	8%	4%	1%	5%	6%	2%	87%			
VH-13		Station UH-5b; off Point Ellice (old Smith Cedar Products site)																						
	11-Jul-90		750	73	290	570	2000	470	4153	3700	3900	1900	1300	3300	1600	850	NDR(180)	740	1300	340	18930	23083	1	1171
			3%	0%	1%	2%	9%	2%	18%	16%	17%	8%	6%	14%	7%	4%	–	3%	6%	1%	82%			
VH-14		Station UH-6; Site 1																						
	11-Jul-90		110	8.1	250	330	1600	490	2788.1	1400	920	770	480	600	350	150	39	180	250	72	5191	7979.1	1	1171
			1%	0%	3%	4%	20%	6%	35%	18%	12%	10%	6%	8%	4%	2%	0%	2%	3%	1%	65%			
		(Lab duplicate)																						
			70	5.9	190	140	1100	270	1775.9	1000	720	290	250	390	240	120	27	130	170	52	3389	5164.9	1	1171
			1%	0%	4%	3%	21%	5%	34%	19%	14%	6%	5%	8%	5%	2%	1%	3%	3%	1%	66%			
VH-14a		Station UH-6a; Site 2																						
	07/11/1985		–	NA	100	700	*	NA	800	1200	1500	1200	*	1800	500	NA	NA	NA	NA	NA	6200	7000	2	383
			–	–	1%	10%	–	–	11%	17%	21%	17%	–	26%	7%	–	–	–	–	–	89%			
		(Lab duplicate)																						
			200	NA	100	600	*	NA	900	1100	1400	1100	*	900	400	NA	NA	NA	NA	NA	4900	5800	2	383
			3%	–	2%	10%	–	–	16%	19%	24%	19%	–	16%	7%	–	–	–	–	–	84%			
VH-15		Station UH-7; Hope Pt/Standard Oil																						
	11-Jul-90		600	160	200	630	1600	450	3640	NDR(3300)	3500	2000	1400	2800	1400	810	200	1100	1000	380	14590	18230	1	1171
			3%	1%	1%	3%	9%	2%	20%	–	19%	11%	8%	15%	8%	4%	1%	6%	5%	2%	80%			
VH-16		Station UH-8; Garbage Depot/Standard Oil																						
	11-Jul-90		330	110	120	360	1200	230	2370	3400	2800	1200	1000	2200	1400	810	170	1100	1000	340	15420	17790	1	1171
			2%	1%	1%	2%	7%	1%	13%	19%	16%	7%	6%	12%	8%	5%	1%	6%	6%	2%	87%			
		(Lab duplicate)																						
			250	100	90	470	1200	250	2360	2300	2700	1100	1000	2100	1300	830	170	1300	970	300	14070	16430	1	1171
			2%	1%	1%	3%	7%	2%	14%	14%	16%	7%	6%	13%	8%	5%	1%	8%	6%	2%	86%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR cont.																						
		Upper Harbour cont.:																						
VH-17		Station UH-9; Boatbuilding Facility																						
	07/11/1985		200	NA	200	800	*	NA	1200	1500	2200	900	*	600	300	NA	NA	NA	NA	NA	5500	6700	2	383
			3%	–	3%	12%	–	–	18%	22%	33%	13%	–	9%	4%	–	–	–	–	–	82%			
	06-Mar-91		440	110	160	590	1300	290	2890	3700	4300	1800	1700	3100	1900	1100	250	1200	1300	470	20820	23710	1	1171
			2%	0%	1%	2%	5%	1%	12%	16%	18%	8%	7%	13%	8%	5%	1%	5%	5%	2%	88%			
		(Lab duplicate)																						
			580	120	170	650	1500	340	3360	4200	4700	2000	2000	3400	2000	1100	240	1300	1300	440	22680	26040	1	1171
			2%	0%	1%	2%	6%	1%	13%	16%	18%	8%	8%	13%	8%	4%	1%	5%	5%	2%	87%			
		Inner Harbour :																						
VH-18		Station IH-1; off Songhees																						
	11-Jul-90		170	25	62	130	330	110	827	760	930	390	250	710	340	210	43	190	290	100	4213	5040	1	1171
			3%	0%	1%	3%	7%	2%	16%	15%	18%	8%	5%	14%	7%	4%	1%	4%	6%	2%	84%			
		(Blind duplicate)																						
			330	54	66	230	580	160	1420	1200	1300	550	430	750	450	260	72	290	350	130	5782	7202	1	1171
			5%	1%	1%	3%	8%	2%	20%	17%	18%	8%	6%	10%	6%	4%	1%	4%	5%	2%	80%			
VH-19		Station IH-2; West Coast Air																						
	11-Jul-90		61	36	19	76	240	62	494	430	460	300	190	450	210	160	36	190	180	100	2706	3200	1	1171
			2%	1%	1%	2%	8%	2%	15%	13%	14%	9%	6%	14%	7%	5%	1%	6%	6%	3%	85%			
		(Lab duplicate)																						
			79	48	20	80	230	50	507	440	500	280	200	450	210	170	37	190	190	110	2777	3284	1	1171
			2%	1%	1%	2%	7%	2%	15%	13%	15%	9%	6%	14%	6%	5%	1%	6%	6%	3%	85%			
VH-20		Station IH-3; commercial dock at entrance to James Bay																						
	11-Jul-90		220	56	77	170	490	170	1183	1200	1200	550	430	910	420	260	61	320	340	120	5811	6994	1	1171
			3%	1%	1%	2%	7%	2%	17%	17%	17%	8%	6%	13%	6%	4%	1%	5%	5%	2%	83%			
VH-21		Station IH-4; Undersea Gardens																						
	11-Jul-90		550	160	150	460	1300	400	3020	2200	2800	990	900	2100	1200	650	170	750	750	250	12760	15780	1	1171
			3%	1%	1%	3%	8%	3%	19%	14%	18%	6%	6%	13%	8%	4%	1%	5%	5%	2%	81%			
Vh-22		Station IH-5; B.C. Steamships																						
	11-Jul-90		1200	120	700	1400	4500	1100	9020	3000	4300	1400	1600	1800	2100	970	250	1000	1000	430	17850	26870	1	1171
			4%	0%	3%	5%	17%	4%	34%	11%	16%	5%	6%	7%	8%	4%	1%	4%	4%	2%	66%			
VH-23		Station IH-6; bay beside B.C. Steamships																						
	11-Jul-90		1500	360	540	1300	3800	1200	8700	4400	4800	2000	2100	3100	2200	1100	300	1400	1400	510	23310	32010	1	1171
			5%	1%	2%	4%	12%	4%	27%	14%	15%	6%	7%	10%	7%	3%	1%	4%	4%	2%	73%			
VH-23a		Station IH-7; west side of Laurel Point																						
	11-Jul-90		270	120	57	230	660	180	1517	1000	1300	450	430	820	500	300	84	330	380	140	5734	7251	1	1171
			4%	2%	1%	3%	9%	2%	21%	14%	18%	6%	6%	11%	7%	4%	1%	5%	5%	2%	79%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR cont.																						
		Inner Harbour cont.:																						
VH-24		Station IH-8; Trotac Marine																						
	11-Jul-90		530	170	170	560	1700	490	3620	2900	4000	2300	1200	2800	1200	780	190	950	1100	320	17740	21360	1	1171
			2%	1%	1%	3%	8%	2%	17%	14%	19%	11%	6%	13%	6%	4%	1%	4%	5%	1%	83%			
VH-25		Station IH-9; Raymur Point/Fisherman's Wharf																						
	11-Jul-90		550	93	190	350	2100	330	3613	3200	3000	1000	830	1400	910	570	120	580	650	200	12460	16073	1	1171
			3%	1%	1%	2%	13%	2%	22%	20%	19%	6%	5%	9%	6%	4%	1%	4%	4%	1%	78%			
VH-26		Station IH-10; between Shoal Point and Fisherman's Wharf																						
	11-Jul-90		220	32	120	430	1200	270	2272	1800	1700	580	610	800	500	180	39	190	330	110	6839	9111	1	1171
			2%	0%	1%	5%	13%	3%	25%	20%	19%	6%	7%	9%	5%	2%	0%	2%	4%	1%	75%			
VH-27		Station IH-11; Centre Channel trawl site																						
	11-Jul-90		300	100	56	240	740	140	1576	1500	1800	900	830	1200	850	450	150	430	740	200	9050	10626	1	1171
			3%	1%	1%	2%	7%	1%	15%	14%	17%	8%	8%	11%	8%	4%	1%	4%	7%	2%	85%			
		(Lab duplicate)																						
			520	160	140	400	1100	250	2570	2300	2000	830	780	1200	910	480	120	650	620	240	10130	12700	1	1171
			4%	1%	1%	3%	9%	2%	20%	18%	16%	7%	6%	9%	7%	4%	1%	5%	5%	2%	80%			
VH-28		Station IH-12; south side Songhees/old Seaspan site																						
	11-Jul-90		150	47	150	300	1900	280	2827	3200	2600	1000	960	1900	1200	650	140	690	730	270	13340	16167	1	1171
			1%	0%	1%	2%	12%	2%	17%	20%	16%	6%	6%	12%	7%	4%	1%	4%	5%	2%	83%			
VH-29		Station IH-13; south side Songhees/old Shell Oil site																						
	11-Jul-90		420	360	98	430	1200	250	2758	2300	3300	1400	1200	2600	1700	980	220	1100	1200	470	16470	19228	1	1171
			2%	2%	1%	2%	6%	1%	14%	12%	17%	7%	6%	14%	9%	5%	1%	6%	6%	2%	86%			
VH-30		Station IH-14; West Bay																						
	11-Jul-90		60	13	14	48	170	42	347	430	390	200	170	370	220	100	NDR(15)	110	150	69	2209	2556	1	1171
			2%	1%	1%	2%	7%	2%	14%	17%	15%	8%	7%	14%	9%	4%	–	4%	6%	3%	86%			
		Outer Harbour:																						
VH-31		Station OH-2; off Ogden Point Wharves																						
	11-Jul-90		450	80	380	620	2900	750	5180	3400	3000	1100	1200	1700	1300	830	180	780	720	300	14290	19470	1	1171
			2%	0%	2%	3%	15%	4%	27%	17%	15%	6%	6%	9%	7%	3%	1%	4%	4%	2%	73%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naphtha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		ESQUIMALT HARBOUR																						
		Upper Harbour																						
EH-1	11-Jul-90		<27	2.7	21	55	200	23	301.7	240	240	110	140	200	170	93	16	95	86	41	1431	1732.7	1	1171
			0%	0%	1%	3%	12%	1%	17%	14%	14%	6%	8%	12%	10%	5%	1%	5%	5%	2%	83%			
		Plumper Bay :																						
EH-2		Station PB-1; off wood products facility																						
	11-Jul-90		90	33	100	380	700	190	1493	2200	1200	380	340	420	190	110	<18	98	160	NDR(39)	5096	6589	1	1171
			1%	1%	2%	6%	11%	3%	23%	33%	18%	6%	5%	6%	3%	2%	0%	1%	2%	–	77%			
EH-3		Station PB-2; site of old dip tank																						
	11-Jul-90		90	32	35	87	270	56	570	860	700	280	210	410	210	130	32	120	160	130	3242	3812	1	1171
			2%	1%	1%	2%	7%	1%	15%	23%	18%	7%	6%	11%	6%	3%	1%	3%	4%	3%	85%			
EH-4		Trawl site																						
	11-Jul-90		37	19	10	36	120	27	249	250	280	98	80	200	93	85	18	79	93	54	1330	1579	1	2905
			2%	1%	1%	2%	8%	2%	16%	16%	18%	6%	5%	13%	6%	5%	1%	5%	6%	3%	84%			
EH-5		Dunn's Nook Station 1																						
	11-Jul-90		200	57	73	750	800	290	2170	1200	1700	790	570	1500	760	390	100	430	620	190	8250	10420	1	2905
			2%	1%	1%	7%	8%	3%	21%	12%	16%	8%	5%	14%	7%	4%	1%	4%	6%	2%	79%			
EH-6		Fort Rodd Station 1																						
	11-Jul-90		10	3.3	3.1	6.3	25	7.5	55.2	43	46	25	18	45	17	13	<2.3	13	19	19	258	313.2	1	1171
			3%	1%	1%	2%	8%	2%	18%	14%	15%	8%	6%	14%	5%	4%	0%	4%	6%	6%	82%			
		Constance Cove:																						
EH-7		Station 1																						
	11-Jul-90		850	120	540	1400	5700	980	9590	11000	11000	4200	4300	7300	5600	2600	560	2900	3200	1000	53660	63250	1	1171
			1%	0%	1%	2%	9%	2%	15%	17%	17%	7%	7%	12%	9%	4%	1%	5%	5%	2%	85%			
EH-8		B-jetty (6a)																						
	07/11/1985		NA	NA	170	1400	*	200	1770	2400	3200	2100	*	2100	900	NA	NA	NA	NA	NA	10700	12470	2	383
			–	–	1%	11%	–	2%	14%	19%	26%	17%	–	17%	7%	–	–	–	–	–	86%			
		(Split sample)																						
			410	<900	540	4150	*	580	5680	3070	3050	2380	2460	5500	2660	2250	<600	2800	NA	NA	24150	29830	3	915
			1%	0%	2%	14%	–	2%	19%	10%	10%	8%	8%	18%	9%	8%	0%	9%	–	–	81%			
		(Lab duplicate)																						
			470	<900	520	3450	*	510	4950	2490	2500	3200	2520	4780	2910	1460	<600	1570	NA	NA	21430	26380	3	915
			2%	0%	2%	13%	–	2%	19%	9%	9%	12%	10%	18%	11%	6%	0%	6%	–	–	81%			
EH-9		Station 2																						
	11-Jul-90		360	23	140	360	880	220	1983	2600	2500	1000	1200	2100	1400	680	160	810	860	290	13600	15583	1	1171
			2%	0%	1%	2%	6%	1%	13%	17%	16%	6%	8%	13%	9%	4%	1%	5%	6%	2%	87%			

APPENDIX 6.1 **PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)**

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		ESQUIMALT HARBOUR cont.																						
		Constance Cove cont.:																						
EH-10		Station 3																						
	11-Jul-90		220	37	220	510	1700	230	2917	3300	2900	1800	1500	3000	2000	1200	250	1200	1300	450	18700	21617	1	1171
			1%	0%	1%	2%	8%	1%	13%	15%	13%	7%	7%	14%	9%	6%	1%	6%	6%	2%	87%			
		(Lab duplicate)																						
			210	51	240	720	2200	340	3761	5400	4300	2500	2800	4800	3300	1700	380	1900	2000	710	29790	33551	1	1171
			1%	0%	1%	2%	7%	1%	11%	16%	13%	7%	8%	14%	10%	5%	1%	6%	6%	2%	89%			
EH-11		Station 4																						
	11-Jul-90		180	39	150	320	1400	180	2269	2200	2300	1100	1000	1900	1400	830	170	860	900	320	12980	15249	1	1171
			1%	0%	1%	2%	9%	1%	15%	14%	15%	7%	7%	12%	9%	5%	1%	6%	6%	2%	85%			
EH-12		Station 5																						
	11-Jul-90		270	47	100	310	820	210	1757	1600	2100	930	840	1700	1000	560	130	630	730	270	10490	12247	1	1171
			2%	0%	1%	3%	7%	2%	14%	13%	17%	8%	7%	14%	8%	5%	1%	5%	6%	2%	86%			
EH-13		Station 6																						
	11-Jul-90		370	58	420	910	3400	690	5848	5300	5600	2100	2100	3100	2100	960	220	1100	1400	450	24430	30278	1	1171
			1%	0%	1%	3%	11%	2%	19%	18%	18%	7%	7%	10%	7%	3%	1%	4%	5%	1%	81%			
EH-14	11-Jul-90	Station 7																						
			140	79	160	250	1500	300	2429	2100	2200	1100	920	2100	1400	840	200	920	1000	350	13130	15559	1	2905
			1%	1%	1%	2%	10%	2%	16%	13%	14%	7%	6%	13%	9%	5%	1%	6%	6%	2%	84%			
		(Lab duplicate)																						
			220	92	190	340	1400	390	2632	2200	2400	1100	1000	2200	1500	890	210	990	1100	360	13950	16582	1	2905
			1%	1%	1%	2%	8%	2%	16%	13%	14%	7%	6%	13%	9%	5%	1%	6%	7%	2%	84%			
		(Blind duplicate)																						
			170	120	160	340	1300	180	2270	2400	2500	1400	1100	3300	1500	950	250	1300	1200	410	16310	18580	1	2820
			1%	1%	1%	2%	7%	1%	12%	13%	13%	8%	6%	18%	8%	5%	1%	7%	6%	2%	88%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
VI-14	LADYSMITH HARBOUR																							
		Site #29																						
	01/20/1992		8.7	0.5	1.5	2.8	20	3.6	37.1	21	16	9.4	7	7.9	6.7	7.8	NDR(1.5)	5.6	7.5	6.2	95.1	132.2	1	1187
			7%	0%	1%	2%	15%	3%	28%	16%	12%	7%	5%	6%	5%	6%	–	4%	6%	5%	72%			
		Site #30																						
	01/20/1992		19	NDR(1.0)	3.8	7.4	42	7.1	79.3	50	34	19	17	28	15	14	NDR(3.2)	12	15	8.6	212.6	291.9	1	1187
			7%	–	1%	3%	14%	2%	27%	17%	12%	7%	6%	10%	5%	5%	–	4%	5%	3%	73%			
		Site #31																						
	01/20/1992		28	0.7	3.7	7.1	47	NDR(5.4)	84.5	43	30	18	15	24	13	12	NDR(2.9)	9.1	14	6.9	185	269.5	1	1187
			10%	0%	1%	3%	17%	–	31%	16%	11%	7%	6%	9%	5%	4%	–	3%	5%	3%	69%			
		Site #32																						
	01/20/1992		3	NDR(0.2)	0.7	NDR(1.2)	6	NDR(1.3)	9.7	7.7	5.2	2.6	2.4	4.9	2.1	2.7	NDR(0.6)	2.3	2.3	1.3	33.5	43.2	1	1187
			7%	–	2%	–	14%	–	22%	18%	12%	6%	6%	11%	5%	6%	–	5%	5%	3%	78%			
		(Lab duplicate)																						
			3.4	NDR(0.3)	0.6	1.1	5.9	1.6	12.6	7.6	5.4	2.6	2.4	5	2.1	2.4	NDR(0.5)	2.3	2.3	1.1	33.2	45.8	1	1187
			7%	–	1%	2%	13%	3%	28%	17%	12%	6%	5%	11%	5%	5%	–	5%	5%	2%	72%			
		Site #33																						
	01/20/1992		130	6.1	22	46	210	46	460.1	150	160	110	78	120	91	70	12	61	76	45	973	1433.1	1	1187
			9%	0%	2%	3%	15%	3%	32%	10%	11%	8%	5%	8%	6%	5%	1%	4%	5%	3%	68%			
		Site #34																						
	01/20/1992		15	0.6	3.9	6.9	42	8.3	76.7	48	35	19	14	27	16	15	NDR(1.8)	11	16	9.3	210.3	287	1	1187
			5%	0%	1%	2%	15%	3%	27%	17%	12%	7%	5%	9%	6%	5%	–	4%	6%	3%	73%			
		Site #36																						
	01/20/1992		41	0.4	4.6	8.4	58	9.4	121.8	37	32	18	15	21	14	13	NDR(2.0)	8.4	15	6.7	180.1	301.9	1	1187
			14%	0%	2%	3%	19%	3%	40%	12%	11%	6%	5%	7%	5%	4%	–	3%	5%	2%	60%			
		Site #37																						
	01/20/1992		150	4.8	57	81	370	78	740.8	220	260	120	120	170	120	93	15	68	100	56	1342	2082.8	1	1187
			7%	0%	3%	4%	18%	4%	36%	11%	12%	6%	6%	8%	6%	4%	1%	3%	5%	3%	64%			

APPENDIX 6.1 PA H CONCENTRATIONS IN SEDIMENTS FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g dry weight)

Site No.	Date	Location	Naphtha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Benz(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		REFERENCE SITES																						
RF-1		**Crescent Beach**																						
		Station 1																						
	18-Jun-91		NDR(1.4)	<0.8	<1.1	NDR(1.1)	3.5	<0.7	3.5	4.5	2.7	NDR(2.2)	NDR(1.6)	NDR(4.7)	NDR(1.0)	NDR(0.9)	<1.3	<1.0	NDR(1.0)	NDR(1.2)	7.2	10.7	1	2820
			–	0%	0%	–	33%	0%	33%	42%	25%	–	–	–	–	–	0%	0%	–	–	67%			
RF-5		**Warn Bay**																						
		Station 1																						
	06/23/1988		<3	<0.1	<0.1	<0.4	<2	<0.3	ND	<1	<0.5	0.4	<0.3	<0.2	<0.2	<0.3	<0.3	<0.2	<0.2	<0.3	0.4	0.4	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
		(Split sample)																						
			3	5	<5	<5	22	5	35	<5	<5	<5	<5	<5	<5	<5	<5	<5	NA	<5	ND	35	2	425
			9%	14%	0%	0%	63%	14%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	–	0%	0%			
		Queen Charlotte Islands:																						
RF-9		**Delkatla Slough**																						
	07/25/1989		NDR(1.6)	<0.3	<0.5	NDR(0.7)	4.2	0.7	4.9	8.5	6.1	6.1	1.8	7	NDR(0.5)	1.2	<0.4	1.4	2	2	36.1	41	1	2820
			–	0%	0%	–	10%	2%	12%	21%	15%	15%	4%	17%	–	3%	0%	3%	5%	5%	88%			
		(Lab duplicate)																						
			NDR(1.7)	<0.7	<0.9	NDR(1.0)	7.7	NDR(0.7)	7.7	18	13	9.7	5.8	15	NDR(3.7)	3.2	<1.2	2.6	5.4	2.6	75.3	83	1	2820
			–	0%	0%	–	9%	–	9%	22%	16%	12%	7%	18%	–	4%	0%	3%	7%	3%	91%			
RF-11	07/28/1989	**Tow Hill**																						
			2	<0.2	<0.3	NDR(0.3)	1	NDR(0.8)	3	0.7	0.4	NDR(0.4)	<0.2	NDR(0.4)	<0.4	<0.4	<1.0	<0.4	<0.4	2	3.1	6.1	1	2820
			33%	0%	0%	–	16%	–	49%	11%	7%	–	0%	–	0%	0%	0%	0%	0%	33%	51%			
		(Lab duplicate)																						
			2	NDR(0.1)	<0.2	NDR(0.2)	NDR(1.0)	0.3	2.3	0.8	NDR(0.4)	<0.4	<0.4	<0.7	<0.8	NDR(1.0)	<3.0	<0.9	<0.8	2	2.8	5.1	1	2820
			39%	–	0%	–	–	6%	45%	16%	–	0%	0%	0%	0%	–	0%	0%	0%	39%	55%			

ND Not detected
NA Sample was not analzed for this compound
NDR A peak was detected but did not meet quantification criteria. Maximum value given in brackets.
* Value represents a combination of anthracene and phenanthrene
TIM Analysis was conducted by total ion method. All other samples analysed by select ion method.

NOTE: Values have been blank corrected where required.

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF *INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)***

			Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	*Fluorene*	Total LMW PAHs	*Fluor-anthene*	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
Site No.	***Date***	**Location**																						
	FRASER RIVER																							
MS-3		**Fraser estuary off Iona Island Sewage Treatment Plant**																						
		Dungeness crab - Muscle																						
	22-Jul-87		<4	<0.6	<1	<0.6	<5	<1	ND	<2	<2	<1	<0.6	<2	<0.8	<0.8	<1	<0.9	<0.8	<0.5	ND	ND	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Lab duplicate)																						
			46	<0.4	<1	<0.6	<6	<1	46	<2	<2	0.8	<0.4	<0.6	<0.4	<0.7	<0.7	<0.8	<0.4	<0.4	0.8	46.8	1	342
			98%	0%	0%	0%	0%	0%	98%	0%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	2%			
		Dungeness crab - Hepatopancreas																						
	22-Jul-87		100	<0.6	4	<1	7	<2	111	3	2	NDR(0.2)	NDR(0.2)	<0.8	<0.8	<2	<0.8	<2	<0.7	<0.8	5	116	1	342
			86%	0%	3%	0%	6%	0%	96%	3%	2%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%			
		(Lab duplicate)																						
			130	<0.8	6	<2	9	5	150	<2	<2	<1	<1	<1	<1	<0.9	<0.8	<1	<1	<1	ND	150	1	342
			87%	0%	4%	0%	6%	3%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		Starry flounder - Whole body																						
	22-Jul-87		<5	<0.1	1	NDR(0.1)	3	2	6	<0.6	<1	<0.2	<0.3	<0.3	<0.5	7	<0.7	<1	<0.4	<0.6	7	7	1	342
			0%	0%	14%	0%	43%	29%	86%	0%	0%	0%	0%	0%	0%	15%	0%	0%	0%	0%	15%			
		(Blind duplicate)																						
			<5	<0.3	<3	<1	<3	<0.6	ND	<1	<1	0.7	0.4	<0.7	<0.7	<0.6	<0.3	<0.4	<0.6	<0.7	1.1	1.1	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	64%	36%	0%	0%	0%	0%	0%	0%	0%	100%			
FR-16		**Koppers International (abandoned site)**																						
		Starry flounder - whole body																						
	26-Sep-90		36	<0.44	28	2.7	21	12	99.7	9.4	7.1	1.7	1.2	NDR (1.7)	<0.76	<0.85	<0.95	<0.79	<0.7	<0.7	19.4	119.1	1	2844
			30%	0%	24%	2%	18%	10%	84%	8%	6%	1%	1%	0%	0%	0%	0%	0%	0%	0%	16%			
FR-18		**Domtar - Liverpool Site**																						
		Prickly sculpin - whole body																						
	20-Sep-90		9.4	<0.27	1.6	<0.24	1.6	1.1	13.9	NDR (0.42)	NDR (0.62)	<0.3	<0.32	<0.45	<0.51	<0.67	<0.82	<0.82	<0.48	<0.49	ND	13.9	1	2844
			68%	0%	12%	0%	13%	8%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
FR-19		***Princeton Wood Preservers***																						
		Starry flounder - whole body																						
	25-Sep-90		11	<0.31	10	NDR (0.59)	5.7	6.2	32.9	1.5	1	<0.33	<0.35	<0.63	<0.72	<0.77	<1.0	<0.94	<0.67	<0.66	2.5	35.4	1	2844
			31%	0%	28%	0%	16%	18%	93%	4%	3%	0%	0%	0%	0%	0%	0%	0%	0%	0%	7%			
FR-20		**B.C. Cleanwood Preservers**																						
		Starry flounder - whole body																						
	25-Sep-90		6.9	<0.31	4.7	NDR (0.99)	7.4	3.1	22.1	4.2	3	NDR (2.1)	NDR (1.2)	NDR (1.2)	<1.2	NDR (1.5)	NDR (1.8)	<1.5	<1.0	<1.1	7.2	29.3	1	2844
			24%	0%	16%	0%	25%	11%	75%	14%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	25%			
		Sculpin - whole body																						
	25-Sep-90		15	<0.41	7.5	NDR (0.72)	6.2	4.5	33.2	1.4	NDR (1.2)	<0.46	<0.49	<0.98	<1.1	<1.1	<1.5	<1.3	<1.0	<1.1	1.4	34.6	1	2844
			43%	0%	22%	0%	18%	13%	96%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%			
		(Lab duplicate)																						
			16	<0.33	8.1	NDR (0.76)	6.3	4.6	35	1.6	NDR (1.3)	<0.25	<0.27	<0.63	<0.72	<0.71	<0.96	<0.86	<0.67	<0.64	1.6	36.6	1	2844
			44%	0%	22%	0%	17%	13%	96%	4%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	4%			

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FALSE CREEK																						
FC-1		**False Creek Marina at Market**																						
		Stations 3,4,5 (composite)																						
		Mussels (large) - Soft tissues																						
	12-Aug-88		<13	0.9	3	2	17	4	28.9	100	50	32	12	20	2	3	<0.6	2	12	1	234	260.9	1	342
			0%	0%	1%	1%	7%	2%	10%	38%	19%	12%	5%	8%	1%	1%	0%	1%	5%	0%	90%			
		Mussels (large) - Soft tissues																						
	25-Mar-91		NDR(6.3)	3.4	4.1	6.3	44	7.3	65.1	120	88	38	NDR(18)	NDR(33)	NDR(13)	13	NDR(7.2)	NDR(9.4)	20	NDR(5.9)	279	344.1	1	1187
			0%	1%	1%	2%	13%	2%	19%	35%	26%	11%	0%	0%	0%	4%	0%	0%	6%	0%	81%			
		(Repeat analysis)																						
			6.6	3	3.7	5	44	7.4	69.7	120	82	65	NDR(16)	33	NDR (7.3)	8.2	<1.0	8.2	17	<1.3	331.4	401.1	1	2820
			2%	0%	1%	1%	11%	2%	17%	30%	20%	16%	0%	8%	0%	2%	0%	2%	4%	0%	83%			
FCT-1		**East Basin Trawl EBT-1**																						
		Dungeness crab - Hepatopancreas																						
	04-Oct-88		19	5	73	19	19	28	163	32	30	14	14	7	3	<2	<1	<2	4	<2	104	267	1	342
			7%	2%	27%	7%	7%	10%	61%	12%	11%	5%	5%	3%	1%	0%	0%	0%	1%	0%	39%			
		Dungeness crab - Muscle																						
	04-Oct-88		<5	<0.3	3	<2	<5	2	5	8	6	3	<2	5	<1	<2	<4	<3	2	<1	24	29	1	342
			0%	0%	10%	0%	0%	7%	17%	28%	21%	10%	0%	17%	0%	0%	0%	0%	7%	0%	83%			
		(Lab duplicate)																						
			<5	<0.2	2	<2	<6	3	5	3	3	2	<1	<0.9	<1	<1	<2	<1	<1	<2	8	13	1	342
			0%	0%	15%	0%	0%	23%	38%	23%	23%	15%	0%	0%	0%	0%	0%	0%	0%	0%	62%			
		English sole - Whole body																						
	04-Oct-88		<26	5	15	10	7	5	42	25	18	9	5	8	1	<2	<2	<1	5	<0.9	71	113	1	342
			0%	4%	13%	9%	6%	4%	37%	22%	16%	8%	4%	7%	1%	0%	0%	0%	4%	0%	63%			
		Dungeness crab - Muscle																						
	04-Jun-91		6.4	0.9	4.1	0.9	3.8	2.6	18.7	2.5	2.6	1.2	0.9	NDR(1.4)	<0.6	<0.7	<0.4	<1.1	<0.5	<0.3	7.2	25.9	1	2820
			25%	3%	16%	3%	15%	10%	72%	10%	10%	5%	3%	0%	0%	0%	0%	0%	0%	0%	28%			
		(Lab duplicate)																						
			5.6	0.8	3.8	NDR(0.7)	1.5	1.8	13.5	NDR(1 1)	NDR(1.7)	0.6	NDR(0.4)	NDR(0.8)	<0.4	<0.4	<0.5	<0.4	<0.4	<0.2	0.6	14.1	1	2820
			40%	6%	27%	0%	11%	13%	96%	0%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	4%			
		Dungeness crab - Hepatopancreas																						
	04-Jun-91		NDR(48)	45	110	NDR(23)	17	28	200	NDR(19)	NDR(5.1)	<1.2	NDR(6.5)	NDR(4.5)	<1.3	NDR(2.5)	NDR(3.5)	NDR(4.4)	<1.0	<1.2	ND	200	1	2820
			0%	23%	55%	0%	9%	14%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	04-Jun-91	English sole - Whole body																						
			6.4	1.7	1.7	3	5.4	1.9	20.1	9.2	11	3.6	NDR(3.5)	NDR(5.5)	2.3	<1.6	<0.4	NDR(2.1)	2.2	NDR(0.7)	28.3	48.4	1	2820
			13%	4%	4%	6%	11%	4%	42%	19%	23%	0%	0%	0%	5%	0%	0%	0%	5%	0%	58%			
		(Blind duplicate)																						
			9.6	NDR(1.6)	4.5	NDR(1.0)	1.9	3.3	19.3	1	1.5	<0.6	<0.6	<0.6	<0.7	<1.6	NDR(1.7)	<2.1	<0.6	<0.7	2.5	21.8	1	2820
			44%	0%	21%	0%	9%	15%	89%	5%	7%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL *PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)***

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-antheres	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		FALSE CREEK cont.																						
FCT-2		**Monk McQueen's Trawl MMT-1**																						
		Dungeness crab - Hepatopancreas																						
	04-Oct-88		<26	43	86	43	130	60	362	74	77	23	18	13	4	<3	<1	<1	6	<2	215	577	1	342
			0%	7%	15%	7%	23%	10%	63%	13%	13%	4%	3%	2%	1%	0%	0%	0%	1%	0%	37%			
		(Split sample)																						
			36	67	110	43	190	100	546	89	100	43	28	10	7	<5	<5	<5	N/A	10	285	831	2	425
			4%	8%	13%	5%	23%	12%	66%	11%	12%	5%	3%	1%	1%	0%	0%	0%	0%	1%	34%			
		English sole - Whole body																						
	04-Oct-88		<15	1	10	7	<6	<2	18	20	15	9	6	8	2	<0.7	<0.9	<0.5	3	<0.9	63	81	1	342
			0%	0%	12%	9%	0%	0%	22%	25%	19%	11%	7%	10%	2%	0%	0%	0%	4%	0%	78%			
		English sole - Whole body																						
	06-Jun-91		5.6	1.4	1.8	1.9	2.4	1.2	14.3	NDR(3.3)	5	NDR(1.8)	NDR(1.1)	5.5	2	<2.4	<0.6	NDR(1.4)	2.3	NDR(0.5)	14.8	29.1	1	2820
			19%	5%	6%	7%	8%	4%	49%	0%	17%	0%	0%	19%	7%	0%	0%	0%	8%	0%	51%			
		(Blind duplicate)																						
			270	1.2	1.6	1.8	3.1	1.4	279.1	6.3	8.6	4.5	NDR (3.1)	NDR (5.1)	NDR (1.8)	2.3	NDR (1.8)	NDR (2.0)	NDR (3.1)	NDR (1.2)	21.7	300.8	1	2820
			90%	0%	1%	1%	1%	0%	93%	2%	3%	1%	0%	0%	0%	1%	0%	0%	0%	0%	7%			
		BURRARD INLET																						
BI-1		**Vancouver Outer Harbour (Pacific Environment Institute)**																						
		Trawl VOHT-1																						
		Dungeness crab - Hepatopancreas																						
	22-Sep-88		<20	<20	<20	<20	<20	<20	ND	<20	<20	<20	<20	<20	<20	<80	<80	<80	NA	NA	ND	ND	2	251
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
SB-1		**Spanish Banks Trawl**																						
		Trawl SBT-1																						
		Dungeness crab - Hepatopancreas																						
	11-Oct-88		<4	<0.3	<0.5	<0.4	<2	<0.4	ND	<0.8	<0.6	<0.4	NDR(0.2)	<0.3	<0.4	<0.5	<0.5	<0.6	<0.3	<0.4	ND	ND	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Lab duplicate)																						
			<4	<0.4	<0.7	<0.3	<2	<0.5	ND	<2	<2	<1	<1	<0.9	<0.5	<0.3	<0.3	<0.8	<0.4	<0.4	ND	ND	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
BI-2		**Vancouver Wharves**																						
		Stations M1,M2 (composite)																						
		Mussels - Soft tissue																						
	29-Oct-91		17	1.2	16	17	96	18	165.2	190	110	77	39	73	31	5.8	NDR(2.1)	6.7	31	6.1	569.6	734.8	1	2820
			2%	0%	2%	2%	13%	2%	22%	26%	15%	10%	5%	10%	4%	1%	0%	1%	4%	1%	78%			
		(Lab duplicate)																						
			17	1.5	15	19	100	18	170.5	210	120	84	42	78	15	6.3	NDR(2.0)	7.3	33	5.8	601.4	771.9	1	2820
			2%	0%	2%	2%	13%	2%	22%	27%	16%	11%	5%	10%	2%	1%	0%	1%	4%	1%	78%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-3		**L&K Lumber**																						
		Station M1																						
		Mussels - Soft tissue																						
	29-Oct-91		3.9	1.1	7.8	14	130	11	167.8	310	170	110	50	97	17	8	2.5	8.5	44	6.8	823.8	991.6	1	2820
			0%	0%	1%	1%	13%	1%	17%	31%	17%	11%	5%	10%	2%	1%	0%	1%	4%	1%	83%			
BI-4		**Vancouver Shipyard**																						
		Stations M1,M2 (composite)																						
		Mussels - Soft tissue																						
	14-Sep-88		190	4	180	72	370	100	916	1300	740	490	310	380	48	24	8	22	210	31	3543	4459	1	342
			4%	0%	4%	2%	8%	2%	21%	29%	17%	11%	7%	8%	1%	1%	0%	0%	5%	1%	79%			
		(Repeat analysis by TIM)																						
			250	<8.4	300	110	520	230	1410	1900	830	390	400	340	54	37	18	30	190	33	4220	5630	1	342
			4%	0%	5%	2%	9%	4%	25%	34%	15%	7%	7%	6%	1%	1%	0%	1%	3%	1%	75%			
		(Split sample)																						
			130	14	150	59	430	83	866	1500	800	680	340	420	82	<5	23	48	N/A	21	3914	4780	2	425
			3%	0%	3%	1%	9%	2%	18%	31%	17%	14%	7%	9%	2%	0%	0%	1%	0%	0%	82%			
BI-5		**Versatile Pacific (was Burrard Yarrows)**																						
		Station M1																						
		Mussels - Soft tissue																						
	28-Jul-88		180	6	230	110	660	200	1386	1100	660	270	170	450	78	29	<7	41	180	25	3003	4389	1	342
			4%	0%	5%	3%	15%	5%	32%	25%	15%	6%	4%	10%	2%	1%	0%	1%	4%	1%	68%			
		(TIM)																						
			210	NDR(13)	340	93	720	260	1623	1600	760	350	280	340	91	49	NDR(16)	41	160	33	3704	5327	1	342
			4%	0%	6%	2%	14%	5%	30%	30%	14%	7%	5%	6%	2%	1%	0%	1%	3%	1%	70%			
		Station M2																						
		Mussels - Soft tissue																						
	29-Oct-91		15	NDR(0.7)	6.2	5.2	38	7.3	71.7	110	58	38	20	39	7.9	3.5	<1.1	3.4	18	2.3	300.1	371.8	1	2820
			4%	0%	2%	1%	10%	2%	19%	30%	16%	10%	5%	10%	2%	1%	0%	1%	5%	1%	81%			
		Station C1																						
		Dungeness crab - Hepatopancreas																						
	16-Sep-88		<13	2	24	6	12	12	56	9	3	6	8	3	<2	<0.8	<1	<0.7	<2	<2	29	85	1	342
			0%	2%	28%	7%	14%	14%	66%	11%	4%	7%	9%	4%	0%	0%	0%	0%	0%	0%	34%			
		(Split sample)																						
			37	10	29	25	120	27	248	53	22	35	26	14	<5	<5	<5	<5	N/A	<5	150	398	2	425
			9%	3%	7%	6%	30%	7%	62%	13%	6%	9%	7%	4%	0%	0%	0%	0%	0%	0%	38%			
		Trawl VCT-1																						
		Rock sole - Whole body																						
	16-Sep-88		<13	0.2	2	<2	<6	<2	2.2	2	<2	1	1	<0.3	<0.5	<0.4	<2	<0.4	<0.5	<0.6	4	6.2	1	342
			0%	3%	32%	0%	0%	0%	35%	32%	0%	16%	16%	0%	0%	0%	0%	0%	0%	0%	65%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naphtha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-9		**Seaboard Terminals**																						
		Station M1																						
		Mussels - Soft tissues																						
	14-Sep-88		5	2	11	13	120	16	167	770	170	150	140	130	NDR(2)	48	6	11	NDR(30)	<0.4	1425	1592	1	342
			0%	0%	1%	1%	8%	1%	10%	48%	11%	9%	9%	8%	0	3%	0%	1%	0%	0%	90%			
		Station C1, C2 (composite)																						
		Dungeness crab - Hepatopancreas																						
	16-Sep-88		6	2	6	7	23	4	48	27	14	10	8	<0.2	<0.3	<0.5	<3	<0.4	<21	<0.4	59	107	1	342
			6%	2%	6%	7%	21%	4%	45%	25%	13%	9%	7%	0%	0%	0%	0%	0%	0%	0%	55%			
		Trawl ST-1																						
		Rock sole - Whole body																						
	16-Sep-88		4	<0.1	3	<1	<3	<1	7	3	<1	0.6	0.6	<0.3	<0.5	<0.5	<0.6	<0.5	<4	<0.6	4.2	11.2	1	342
			36%	0%	27%	0%	0%	0%	63%	27%	0%	5%	5%	0%	0%	0%	0%	0%	0%	0%	38%			
		Station M2																						
		Mussels - Soft tissue																						
	29-Oct-91		13	1.4	16	19	120	20	189.4	250	160	120	52	110	21	11	3.5	12	46	6.8	792.3	981.7	1	2820
			1%	0%	2%	2%	12%	2%	19%	25%	16%	12%	5%	11%	2%	1%	0%	1%	5%	1%	81%			
BI-10		**Lynnterm**																						
		Station M2																						
		Mussels - Soft tissue																						
	29-Oct-91		37	1.9	30	7.8	42	15	133.7	83	40	42	18	38	11	5.6	NDR(2.4)	NDR(6.9)	19	NDR(4.7)	256.6	390.3	1	2820
			9%	0%	8%	2%	11%	4%	34%	21%	10%	11%	5%	10%	3%	1%	0%	0%	5%	0%	66%			
		(Blind duplicate)																						
			48	2.1	37	8	59	19	173.1	110	57	50	NDR(21)	48	13	6.7	NDR(2.1)	8.5	23	5.3	321.5	494.6	1	2820
			10%	0%	7%	2%	12%	4%	35%	22%	12%	10%	0%	10%	3%	1%	0%	2%	5%	1%	65%			
BI-12		**Allied Shipbuilders**																						
		Stations M1,M2 (composite)																						
		Mussels - Soft tissues																						
	14-Sep-88		<7	0.5	4	7	94	12	117.5	130	91	62	46	52	8	5	<1	5	21	2	424	541.5	1	342
			0%	0%	1%	1%	17%	2%	22%	24%	17%	11%	9%	10%	1%	1%	0%	1%	4%	0%	78%			
		Trawl AT-1																						
		Starry flounder - Whole body																						
	14-Sep-88		6	0.4	8	4	16	5	39.4	33	21	12	10	20	8	5	<1	7	7	2	125	164.4	1	342
			4%	0%	5%	2%	10%	3%	24%	20%	13%	7%	6%	12%	5%	3%	0%	4%	4%	1%	76%			

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-17		Port Moody/Ioco Trawl																						
		Trawl PM/IT (a,b, &c)																						
	24-Sep-86	Dungeness crab - Hepatopancreas	80 63%	<20 0%	46 37%	<20 0%	Trace (10) 0%	Trace (10) 0%	126 100%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	126	2	251
	24-Sep-86	Dungeness crab - Hepatopancreas	24 3%	Trace (10) 0%	180 19%	76 8%	270 29%	170 18%	720 77%	110 12%	100 11%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	210 23%	930	2	251
	24-Sep-86	Dungeness crab - Hepatopancreas	Trace (10) 0%	Trace (10) 0%	130 82%	<20 0%	<20 0%	29 18%	159 100%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	159	2	251
	24-Sep-86	Dungeness crab - Muscle	<20 0%	Trace (6) 0%	<20 0%	<20 0%	<20 0%	<20 0%	Trace (6) 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251
	24-Sep-86	Dungeness crab - Muscle	<20 0%	Trace (10) 0%	Trace (10) 0%	<20 0%	<20 0%	<20 0%	Trace (20) 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251
	24-Sep-86	Dungeness crab - Muscle	<20 0%	Trace (10) 0%	Trace (5) 0%	<20 0%	<20 0%	<20 0%	Trace (15) 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251
	12-Oct-88	Dungeness crab - Muscle	<7 0%	0.2 0%	1 2%	2 4%	<6 0%	2 4%	5.2 12%	11 24%	9 20%	5 11%	5 11%	6 13%	2 4%	<1 0%	<1 0%	<1 0%	2 4%	<0.8 0%	40 88%	45.2	1	342
	12-Oct-88	Dungeness crab - Muscle	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	ND 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251
	12-Oct-88	Dungeness crab - Muscle	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	ND 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251
	12-Oct-88	Dungeness crab - Muscle	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	ND 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251
	12-Oct-88	Dungeness crab - Hepatopancreas	<7 0%	2 8%	NDR 0%	9 35%	<6 0%	<2 0%	11 42%	3 12%	4 15%	4 15%	4 15%	<1 0%	<2 0%	<0.8 0%	<0.9 0%	<0.6 0%	<2 0%	<2 0%	15 58%	26	1	342
	12-Oct-88	Dungeness crab - Hepatopancreas	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	ND 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<20 0%	<60 0%	<60 0%	<60 0%	NA 0%	NA 0%	ND 0%	ND	2	251

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

Site No.	Date	Location	Naphtha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		BURRARD INLET cont.																						
BI-17		**Port Moody/Ioco Trawl cont.**																						
		Starry flounder - Muscle																						
	12-Oct-88		<3	<0.4	<2	<0.4	<2	<0.6	ND	<1	<1	<0.6	<0.3	<0.4	<0.4	<0.7	<0.5	<0.6	<0.4	<0.4	ND	ND	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		Starry flounder - Liver																						
	12-Oct-88		<7	0.4	7	3	<6	<2	10.4	3	<1	0.6	1	<0.6	<0.9	<0.7	<2	<0.6	<0.9	<1	4.6	15	1	342
			0%	3%	47%	20%	0%	0%	69%	20%	0%	4%	7%	0%	0%	0%	0%	0%	0%	0%	31%			
		Starry flounder - Whole body																						
	12-Oct-88		<5	<0.3	<3	<1	<3	<0.6	ND	<1	<1	0.7	0.4	<0.7	<0.7	<0.6	<0.3	<0.4	<0.6	<0.7	1.1	1.1	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	0%	64%	36%	0%	0%	0%	0%	0%	0%	0%	100%			
		English sole - Whole body																						
	12-Oct-88		18	<5	<5	<5	16	5	39	7	5	<5	<5	<5	<5	<5	<5	<5	N/A	<5	12	51	2	425
			35%	0%	0%	0%	31%	10%	76%	14%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	24%			
		(Split sample)																						
			<9	<0.1	<0.8	<2	<6	<1	ND	7	7	3	<1	4	<0.4	<2	<0.9	<0.4	<2	<0.4	21	21	1	342
			0%	0%	0%	0%	0%	0%	0%	33%	33%	14%	0%	19%	0%	0%	0%	0%	0%	0%	100%			
BI-22		**B.C. Marine Shipbuilders/Sterling Shipyards**																						
		Station M1																						
		Mussels - soft tissues																						
	14-Sep-88		<3	0.5	5	8	39	5	55.5	130	60	49	48	38	NDR(2)	NDR(2)	<0.6	4	NDR(30)	NDR(2)	329	384.5	1	342
			0%	0%	1%	2%	10%	1%	14%	34%	16%	13%	12%	10%	0%	0%	0%	1%	0%	0%	86%			
		Trawl BCT-2																						
		Dungeness crab - Hepatopancreas																						
	16-Sep-88		<3	0.5	4	5	8	<1	17.5	10	7	5	5	<0.6	<0.9	<0.6	<1	<0.6	<23	<1	27	44.5	1	342
			0%	1%	9%	11%	18%	0%	39%	22%	16%	11%	11%	0%	0%	0%	0%	0%	0%	0%	61%			
		Starry flounder - Whole body																						
	16-Oct-88		<3	<0.1	<0.5	<1	<3	<1	ND	<1	2	0.7	<0.3	<0.1	<0.2	<0.6	<0.9	<0.6	<13	<0.2	2.7	2.7	1	342
			0%	0%	0%	0%	0%	0%	0%	0%	74%	26%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
BI-26		**Canada Place**																						
		Station M1																						
		Mussels - soft tissues																						
	29-Oct-91		4.4	1.1	6.7	8	61	9.7	90.9	140	99	52	22	48	10	4.7	1.6	4.7	28	5.5	415.5	506.4	1	2820
			1%	0%	1%	2%	12%	2%	18%	28%	20%	10%	4%	9%	2%	1%	0%	1%	6%	1%	82%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		Coal Harbour:																						
CH-1		**Bayshore Inn Marina**																						
		Stations M3,7,9,10 (composite)																						
		Mussels (large) - Soft tissue																						
	20-Mar-89		<13	1	1	7	54	7	70	110	86	41	14	32	3	7	<0.7	3	21	<0.7	317	387	1	342
			0%	0%	0%	2%	14%	2%	18%	28%	22%	11%	4%	8%	1%	2%	0%	1%	5%	0%	82%			
		Stations M5,8,10,11 (composite)																						
		Mussels (large) - Soft tissue																						
	25-Mar-91		7.3	1.2	2.4	7.3	31	4.9	54.1	97	74	41	NDR(17)	42	NDR(6.5)	15	NDR(2.7)	12	31	NDR(10)	312	366.1	1	1187
			2%	0%	1%	2%	8%	1%	15%	26%	20%	11%	0%	11%	0%	4%	0%	3%	8%	0%	85%			
		(Repeat analysis)																						
			3.7	0.8	1.6	3.2	21	2.7	33	54	46	53	14	39	8.6	12	3.5	12	22	3.3	267.4	300.4	1	2820
			1%	0%	1%	1%	7%	1%	11%	18%	15%	18%	5%	13%	3%	4%	1%	4%	7%	1%	89%			
CH-3		**Royal Vancouver Yacht Club Marina**																						
		Station SS-C5131																						
	17-Mar-88	'Bentnose clams - Soft tissue																						
			<5	0.8	2	3	14	3	22.8	74	74	45	18	45	12	8	2	7	21	3	309	331.8	1	342
			0%	0%	1%	1%	4%	1%	7%	22%	22%	14%	5%	14%	4%	2%	1%	2%	6%	1%	93%			
		Station 2,3,8 (composite)																						
	20-Mar-89	Mussels (large) - Soft tissue																						
			5	5	27	170	480	83	770	880	520	280	83	150	24	<5	9	15	N/A	13	1954	2724	2	425
			0%	0%	1%	6%	18%	3%	28%	32%	19%	10%	3%	6%	1%	0%	0%	1%	0%	0%	72%			
		Station 2,3,8 (composite)																						
	25-Mar-91	Mussels - Soft tissue																						
			3.2	<0.7	1.3	3.3	23	2.8	33.6	80	44	27	NDR(10)	19	5.1	5	<1.1	4.2	12	NDR(6.2)	196.3	229.9	1	1187
			1%	0%	1%	1%	10%	1%	15%	35%	19%	12%	0%	8%	2%	2%	0%	2%	5%	0%	85%			
		(Lab duplicate)																						
			3	<0.7	1.3	4.4	28	3.2	39.9	96	53	33	NDR(12)	23	NDR(6.0)	5.7	<0.9	4.4	14	4.8	233.9	273.8	1	1187
			1%	0%	0%	2%	10%	1%	15%	35%	19%	12%	0%	8%	0%	2%	0%	2%	5%	2%	85%			
CH-5		**Menchion's Shipyard**																						
		Station C1																						
		Dungeness crab - Muscle																						
	23-Sep-86		<20	<20	<20	<20	<20	<20	ND	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	ND	2	251
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		Dungeness crab - Hepatopancreas																						
	23-Sep-86	Sample 1																						
			<20	<20	21	<20	<20	<20	21	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	21	2	251
			0%	0%	100%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Lab duplicate)																						
			<20	<20	20	<20	<20	<20	20	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	20	2	251
			0%	0%	100%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		Sample 2																						
			Trace (10)	<20	33	<20	Trace (15)	Trace (10)	33	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	33	2	251
			0%	0%	100%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			

APPENDIX 5.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naphtha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		Coal Habour cont.:																						
CH-6		**Menchion's Shipyard Cont.**																						
		Station M1																						
		Mussels (large) - Soft tissues																						
	28-Jul-88		<3	0.6	5	7	73	10	95.6	210	110	43	23	38	4	2	<0.8	2	18	3	453	548.6	1	342
			0%	0%	1%	1%	13%	2%	17%	38%	20%	8%	4%	7%	1%	0%	0%	0%	3%	1%	83%			
		(Lab duplicate)																						
			<3	0.6	5	6	75	9	97.6	220	110	45	24	39	5	3	<0.9	3	17	2	468	565.6	1	342
			0%	0%	1%	1%	13%	2%	17%	39%	19%	8%	4%	7%	1%	1%	0%	1%	3%	0%	83%			
		(Split sample)																						
			17	<5	4	<5	54	10	85	110	53	35	7	18	<5	<5	<5	<5	N/A	<5	221	306	2	425
			6%	0%	1%	0%	18%	3%	28%	36%	17%	11%	2%	5%	0%	0%	0%	0%	0%	0%	72%			
		(Lab duplicate)																						
			10	<5	5	6	61	9	93	130	59	44	5	15	<5	<5	<5	<5	N/A	<5	253	346	2	425
			3%	0%	1%	2%	18%	3%	27%	38%	17%	13%	1%	4%	0%	0%	0%	0%	0%	0%	73%			
		(Blind duplicate)																						
			5	<5	6	<5	49	9	69	98	48	41	9	13	<5	<5	<5	<5	N/A	6	211	280	2	425
			2%	0%	2%	0%	18%	3%	25%	34%	16%	15%	3%	5%	0%	0%	0%	0%	0%	2%	75%			
CH-7		**Coal Harbour Trawl**																						
		CHT-1																						
		Dungeness crab - Muscle																						
	23-Sep-88		<20	<20	28	<20	<20	Trace (10)	28	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	28	2	251
			0%	0%	100%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%				
		Dungeness crab - Hepatopancreas																						
	23-Sep-88		21	<20	460	<20	<20	67	548	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	548	2	251
			4%	0%	84%	0%	0%	12%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	16-Sep-88	Dungeness crab - Hepatopancreas																						
			<13	1	11	4	<6	<2	16	3	3	2	2	<0.3	<0.5	<0.6	<0.4	<0.5	<0.5	<0.6	10	26	1	342
			0%	4%	42%	15%	0%	0%	62%	12%	12%	8%	8%	0%	0%	0%	0%	0%	0%	0%	38%			
	16-Sep-88	Dungeness crab - Muscle																						
			33	<0.2	<1	<2	<6	<2	33	<2	<2	0.3	0.7	<0.5	<0.7	<1	<1	<1	<0.7	<0.8	1	34	1	342
			97%	0%	0%	0%	0%	0%	97%	0%	0%	1%	2%	0%	0%	0%	0%	0%	0%	0%	3%			
	16-Sep-88	Dungeness crab - Muscle																						
			<20	<20	<20	<20	<20	<20	ND	<20	<20	<20	<20	<20	<20	<60	<60	<60	NA	NA	ND	ND	2	251
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	18-Sep-88	Shrimp - Tail																						
			5	0.3	6	<1	<3	<1	11.3	5	7	2	2	<0.4	<0.6	<1	<2	<1	<17	<0.7	16	27.3	1	342
			18%	1%	22%	0%	0%	0%	41%	18%	26%	7%	7%	0%	0%	0%	0%	0%	0%	0%	59%			
		Rock sole - Whole body																						
	16-Sep-88		<3	0.4	5	4	4	<1	13.4	17	15	6	5	NDR(0.1)	3	<1	<0.8	1	<12	<0.2	47	60.4	1	342
			0%	1%	8%	7%	7%	0%	22%	28%	25%	10%	8%	0%	5%	0%	0%	2%	0%	0%	78%			
		(TIM)																						
			NDR(7.6)	<1	5.1	7.5	4	NDR(4.6)	16.6	16	14	5.5	7.5	NDR(29)	NDR(75)	6.6	<3	NDR(4)	NDR(6.6)	NDR(16)	49.6	66.2	1	342
			0%	0%	8%	11%	6%	0%	25%	24%	21%	8%	11%	0%	0%	10%	0%	0%	0%	0%	75%			
		(Split sample)																						
			20	<5	4	5	14	7	50	15	11	7	5	6	<5	<5	<5	<5	N/A	8	52	102	2	425
			20%	0%	4%	5%	14%	7%	49%	15%	11%	7%	5%	6%	0%	0%	0%	0%	0%	8%	51%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR																						
		Selkirk Waters																						
SW-C1		Station C1																						
		Dungeness crab - muscle																						
	20-Jul-87		<7	<0.3	<0.7	<0.5	<2	<0.9	ND	<0.8	<1	0.4	<0.3	<0.5	<0.5	<1	<0.4	<0.4	<0.5	<0.5	0.4	0.4	1	342
			0%	0%	#VALUE!	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
		Dungeness crab - hepatopancreas																						
	20-Jul-87		11	0.9	14	2	4	5	36.9	5	4	0.8	1	<0.9	<2	<1	<0.9	<1	<1	<2	10.8	47.7	1	342
			23%	2%	29%	4%	8%	10%	77%	10%	8%	2%	2%	0%	0%	0%	0%	0%	0%	0%	23%			
SWT-1/2		Trawls SWT-1 and SWT-2																						
		Starry flounder - whole body																						
	20-Jul-87		6	0.4	4	1	4	2	17.4	6	4	2	1	2	<0.5	<1	<1	<1	<0.5	<0.6	15	32.4	1	342
			19%	1%	12%	3%	12%	6%	54%	19%	12%	6%	3%	6%	0%	0%	0%	0%	0%	0%	46%			
SWT-3		Trawl SWT-3																						
		Dungeness crab - muscle																						
	12-Jul-90		<7.0	<1.0	<2.3	<0.5	<6.5	<4	ND	<3	<2	<1.2	NDR(1.4)	<0.9	<1.3	<1.6	<0.7	<1.6	<1.0	<1.0	ND	ND	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		Dungeness crab - hepatopancreas																						
	12-Jul-90		15	<2.0	22	4.7	9	16	66.7	NDR(14)	NDR(9.0)	NDR(5.3)	<0.4	<2.2	<1.8	<2.0	<3.0	<2.0	<1.6	<1.4	ND	66.7	1	1171
			22%	0%	33%	7%	13%	24%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	10-Jul-90	English sole - whole body																						
			<12	<1.0	<5.0	<1.0	<8.0	<3.3	ND	3.5	<4.2	<2.7	3.3	<4.3	<2.2	<2.8	<1.0	<2.9	<1.7	<1.7	6.8	6.8	1	1171
			0%	0%	0%	0%	0%	0%	0%	51%	0%	0%	49%	0%	0%	0%	0%	0%	0%	0%	100%			
	10-Jul-90	Shrimp - tail													0%									
		NDR(5.0)	<0.6	2	<1.5	<3.4	<2.6	2	<2.1	<1.8	<0.6	<0.7	<1.1	<1.7	<1.3	<2.4	NDR(1.4)	<1.3	<1.3	ND	2	1	1171	
			0%	0%	100%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
SW-SS1		Station SS1 (off old sawmill site)																						
	11-Jul-90	Bentnose clams - soft tissue																						
			21	<2.1	5.2	5.7	26	6.1	64	100	94	34	NDR(22)	43	23	15	<4.2	NDR(16)	24	NDR(6.4)	333	397	1	1171
			5%	0%	1%	1%	7%	2%	16%	25%	24%	9%	0%	11%	6%	4%	0%	0%	6%	0%	84%			
SW-SS2		Station SS2 (beach at Bamfield Park)																						
	13-Jul-90	Clams - soft tissue																						
			27	2.8	5.1	9	37	8	88.9	130	110	45	NDR(27)	57	26	17	3.2	NDR(18)	29	NDR(7.3)	417.2	506.1	1	1171
			5%	1%	1%	2%	7%	2%	18%	26%	22%	9%	0%	11%	5%	3%	1%	0%	6%	0%	82%			
		(Lab duplicate)																						
			26	2.3	5.9	10	36	7.1	87.3	130	110	45	NDR(29)	62	30	16	2.5	NDR(19)	31	NDR(8.3)	426.5	513.8	1	1171
			5%	0%	1%	2%	7%	1%	17%	25%	21%	9%	0%	12%	6%	3%	0%	0%	6%	0%	83%			

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR cont.																						
		Upper Harbour																						
UH-C2		Station C2																						
		Dungeness crab - muscle																						
	10-Jul-90		<8.0	<1.5	<3.5	<0.6	<6.5	<3.5	ND	<3.5	<2.5	<2.8	<0.7	<2.5	<3.7	<3.7	<5.8	<2.4	<2.9	<2.8	ND	ND	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Lab duplicate)	<7.5	<1.2	<2.6	<0.9	<5.0	<3.0	ND	<2.3	<2.0	<2.0	<0.6	<1.3	<2.0	<1.8	<2.8	<1.9	<1.5	<1.5	ND	ND	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		Dungeness crab - hepatopancreas																						
	10-Jul-90		33	19	46	32	31	27	188	32	33	25	29	36	38	46	37	30	40	35	381	569	1	1171
			6%	3%	6%	6%	5%	5%	33%	6%	6%	4%	5%	6%	7%	8%	7%	5%	7%	6%	67%			
		(Blind duplicate)	14	NDR(2.1)	48	7.8	9	14	92.8	NDR(6.8)	NDR(6.0)	NDR(1.6)	<0.1	<1.1	<0.5	<0.4	<0.4	<0.5	<0.7	<0.4	ND	92.8	1	1171
			15%	0%	52%	8%	10%	15%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
UHT-1		Trawl UHT-1																						
		English sole - whole body																						
	10-Jul-90		<13	<0.6	<4.0	<1.5	<6.5	<3.0	ND	<5.6	<4.8	<3.0	2.3	<4.5	<2.5	<3.8	<2.5	<3.5	<1.9	<1.9	2.3	2.3	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
		(Lab duplicate)	<17	<0.6	<4.5	NDR(2.2)	<11	<3.0	NDR (2.2)	<13	<9.6	<6.7	5.4	<8.5	<2.2	<4.5	<2.2	<4.2	<3.5	<1.7	5.4	5.4	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
		Inner Harbour																						
IT-C3/IHT-1		Station C3 and Trawl IHT-1																						
	10-Jul-90	Dungeness crab - muscle																						
			<14	<1.5	<3.9	<2.5	11	<2.7	11	<5.0	<1.5	<3.7	<0.6	<2.6	<4.0	<2.8	<1.8	<3.0	<3.1	<3.1	ND	11	1	1171
			0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	10-Jul-90	Dungeness crab - hepatopancreas																						
			<15	<1.5	12	<1.6	<9.5	<6.2	ND	<4.6	<3.5	<2.5	3.4	<3.5	<2.1	<2.5	<2.1	<2.8	<1.6	<1.6	3.4	3.4	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%			
IHT-1		Trawl IHT-1																						
	10-Jul-90	English sole - whole body																						
			<11	<0.6	<2.6	<1.8	<10	<2.7	ND	<6.5	<6.5	<3.7	<3.5	<5.8	<2.0	<4.0	<1.8	<3.8	<2.9	<1.6	ND	ND	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Blind duplicate)	6.2	<1.0	1.2	1.2	<8.0	<3.1	8.6	5.3	6	2.4	2	NDR(5.1)	3.3	<1.8	<1.2	<2.2	NDR(2.4)	<1.0	19	27.6	1	1171
			22%	0%	4%	4%	0%	0%	31%	19%	22%	9%	7%	0%	12%	0%	0%	0%	0%	0%	69%			
	10-Jul-90	Shrimp - tail																						
			12	<0.6	2.9	<1.3	<4.8	<3.0	14.9	<1.7	<1.5	<0.4	<0.4	<0.4	0%	<0.3	<0.5	<0.4	<0.5	NDR(1.8)	ND	14.9	1	1171
			81%	0%	19%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Lab duplicate)	9	<0.5	2.3	<1.0	<4.3	<2.0	11.3	<1.7	<1.2	<0.6	<0.7	<0.4	<0.6	<0.3	<0.4	<0.4	<0.4	<0.4	ND	11.3	1	1171
			80%	0%	20%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Blind duplicate)	15	<0.7	NDR(4.5)	<0.9	<3.1	<2.1	15	2.3	1.5	<0.6	<0.7	<0.4	<0.7	<0.6	<1.1	<1.0	<0.5	<0.5	ND	15	1	1171
			100%	0%	0%	0%	0%	0%	100%	15%	10%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		VICTORIA HARBOUR cont.																						
		Inner Harbour cont.																						
IH-SS3		Station SS3 (Laurel Point)																						
	11-Jul-90	Bentnose clams - soft tissue																						
			40	7	17	28	120	22	234	260	270	100	86	150	84	40	NDR(8.2)	41	72	16	1119	1353	1	1171
			3%	1%	1%	2%	9%	2%	17%	19%	20%	7%	6%	11%	6%	3%	0%	3%	5%	1%	83%			
IH-C4		Station C4 (West Bay)																						
		Dungeness crab - Hepatopancreas																						
	09-Jul-91		7.2	2.4	7.1	5.4	8.6	3.5	34.2	<3.1	<4.7	<4.5	<5.5	NDR(2.0)	<0.3	<0.8	<0.6	<0.9	<0.4	<0.1	ND	34.2	1	2820
			21%	7%	21%	16%	25%	10%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		(Lab duplicate)																						
			8.2	2.9	8.8	6.8	9.1	3.5	39.3	<3.1	<3.1	<5.0	<5.7	NDR(1.9)	<0.1	<0.7	<0.6	<0.9	<0.3	<0.1	ND	39.3	1	2820
			21%	7%	22%	17%	23%	9%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
IH-SS4		Station SS4 (Hidden Harbour Marina)																						
	10-Jul-90	Bentnose clams - soft tissue																						
			<8.5	<0.8	6.5	5.9	56	11	79.4	100	71	24	17	33	17	8.4	NDR(1.6)	11	16	NDR(3.9)	297.4	376.8	1	1171
			0%	0%	2%	2%	15%	3%	21%	27%	19%	6%	5%	9%	5%	2%	0%	3%	4%	0%	79%			
		ESQUIMALT HARBOUR																						
		Constance Cove																						
CC-C1		Station C1																						
	09-Jul-90	Dungeness crab - muscle																						
			<6.0	<0.3	1.2	<1.0	2.8	NDR(1.2)	4	2	NDR(2.1)	1.3	NDR(1.4)	NDR(1.1)	NDR(1.3)	NDR(6.6)	<1.0	NDR(1.7)	NDR(1.7)	<0.5	3.3	7.3	1	1171
			0%	0%	16%	0%	38%	0%	55%	27%	0%	18%	0%	0%	0%	0%	0%	0%	0%	0%	45%			
		(Lab duplicate)																						
			3.8	<0.5	<1.7	0.9	3.3	<2.0	8	2.3	1.4	<0.8	<0.9	<0.8	<1.2	<0.8	<1.4	<1.2	<0.9	<0.9	3.7	11.7	1	1171
			32%	0%	0%	0%	28%	0%	68%	20%	12%	0%	0%	0%	0%	0%	0%	0%	0%	0%	32%			
	09-Jul-90	Dungeness crab - hepatopancreas																						
			24	1.2	21	5.1	18	11	80.3	NDR(32)	NDR(24)	7.3	9	NDR(11)	NDR(4.1)	NDR(2.9)	NDR(1.8)	NDR(2.5)	NDR(4.4)	NDR(1.8)	16.3	96.6	1	1171
			25%	1%	22%	5%	19%	11%	83%	0%	0%	8%	9%	0%	0%	0%	0%	0%	0%	0%	17%			
CCT-1		Trawl CCT-1																						
	09-Jul-90	English sole - whole body																						
			3.8	1	2.7	3	6.9	2.6	20	NDR(11)	12	6.2	6.2	NDR(9.5)	NDR(4.6)	NDR(3.6)	2.3	NDR(3.0)	4.6	NDR(2.5)	31.3	51.3	1	1171
			7%	2%	5%	6%	13%	5%	39%	0%	23%	12%	12%	0%	0%	0%	4%	0%	9%	0%	61%			
	09-Jul-90	Shrimp - tail																						
			<8.2	<1.0	<2.4	<1.0	<4.0	<2.0	ND	<1.4	3.5	<1.9	<1.0	<2.5	<1.1	<2.1	<2.0	<1.4	<0.9	<1.7	3.5	3.5	1	1171
			0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
		(Lab duplicate)																						
			<10	<1.0	<2.4	<1.0	<4.0	<1.9	ND	1.7	3.1	<1.9	<1.0	<2.5	<1.0	<2.1	<0.7	<1.4	<0.9	<0.7	4.8	4.8	1	1171
			0%	0%	0%	0%	0%	0%	0%	35%	65%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%			
CC-M1		Station M2																						
	09-Jul-90	Mussels - soft tissue																						
			10	2.4	57	61	460	80	670.4	1400	790	210	120	180	46	12	3.3	13	120	16	2910.3	3580.7	1	1171
			0%	0%	2%	2%	13%	2%	19%	39%	22%	6%	3%	5%	1%	0%	0%	0%	3%	0%	81%			

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

Site No.	Date	Location	Naphtha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
		ESQUIMALT HARBOUR cont.																						
		Plumper Bay																						
PBT-1,2,3		Trawl PB1,2,3																						
	04-Mar-91	Dungeness crab - muscle																						
		NQ	<0.9	2.3	<0.8	3.2	8.2	11.7	2	1.4	1	<0.6	NDR(1.4)	<1.4	<0.9	<1.6	<1.2	<0.8	<0.9	4.4	16.1	1	1171
		0%	0%	14%	0%	20%	39%	73%	12%	9%	6%	0%	0%	0%	0%	0%	0%	0%	0%	27%			
		(Lab duplicate)																						
		<2.2	<0.4	1.9	<0.8	NDR(2.4)	4	5.9	NDR(1.4)	NDR(1.1)	NDR(0.7)	<0.5	<1.0	<1.6	<0.9	<1.7	<1.2	<1.0	<1.1	ND	5.9	1	1171
		0%	0%	32%	0%	0%	68%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
	04-Mar-91	Dungeness crab - hepatopancreas																						
		NDR(46)	1.2	18	3.7	4.3	6.2	33.4	NDR(5.3)	4.3	<0.7	<0.8	NDR(1.6)	<0.9	<0.7	<0.6	NDR(3.5)	NDR(1.3)	<1.2	4.3	37.7	1	1187
		0%	3%	48%	10%	11%	16%	89%	0%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	11%			
	12-Jul-90	English sole - whole body																						
		6.2	<0.6	2	<2.0	<7.5	<4.0	8.2	2.3	1.3	<1.0	<1.5	<1.0	<1.1	<0.9	<1.3	<1.2	<0.9	<0.8	3.6	11.8	1	1171
		53%	0%	17%	0%	0%	0%	69%	19%	11%	0%	0%	0%	0%	0%	0%	0%	0%	0%	31%			
	12-Jul-90	Shrimp - tail																						
		<14	<0.4	<2.0	<0.6	2.5	<1.2	2.5	<1.8	<1.3	<0.4	<0.6	<0.3	<0.5	<0.6	<0.6	<0.7	<0.3	<0.3	ND	2.5	1	1171
		0%	0%	0%	0%	100%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
		ESQUIMALT HARBOUR cont.																						
		Plumper Bay cont.																						
PB-M2,M3		Stations M1,M2 (adjacent old sawmill site)																						
		Mussels - soft tissue																						
	09-Jul-90	<6.2	<0.5	12	7	140	15	174	360	190	64	25	43	6.4	3.7	<2.1	5	25	5.6	727.7	901.7	1	1171
		0%	0%	1%	1%	16%	2%	19%	40%	21%	7%	3%	5%	1%	0%	0%	1%	3%	1%	81%			
		(Lab duplicate)																						
		<6.0	<0.5	13	0%	130	15	158	360	180	63	25	44	6.3	3.3	<1.3	4	25	5.4	716	874	1	1171
		0%	0%	1%	0%	15%	2%	18%	41%	21%	7%	3%	5%	1%	0%	0%	0%	3%	1%	82%			
		(Blind duplicate)																						
		4.8	<0.6	13	6.9	150	19	193.7	380	200	67	25	49	NDR(5.5)	NDR(3.4)	<1.6	NDR(4.0)	27	NDR(4.7)	748	941.7	1	1171
		1%	0%	1%	0%	16%	2%	21%	40%	21%	7%	3%	5%	0%	0%	0%	0%	3%	0%	79%			
		(Lab duplicate)												0%										
		4.4	<0.7	11	7.4	130	16	168.8	330	170	55	21	41	NDR(5.5)	NDR(2.6)	<1.0	NDR(3.3)	22	NDR(1.8)	639	807.8	1	1171
		1%	0%	1%	0%	16%	2%	21%	41%	21%	7%	3%	5%	0%	0%	0%	0%	3%	0%	79%			
		Station SS5																						
		Macoma clams - soft tissue																						
	09-Jul-90	<6.0	<0.5	2.2	NDR(1.2)	15	3.5	20.7	43	16	10	6.7	NDR(7.8)	NDR(3.0)	NDR(3.1)	NDR(3.4)	3.8	NDR(3.7)	NDR(2.6)	79.5	100.2	1	1171
		0%	0%	2%	0%	15%	3%	21%	43%	16%	10%	7%	0%	0%	0%	0%	4%	0%	0%	79%			
		Dallas Bank																						
PB-SS5		Station SS6																						
		Macoma clams - soft tissue																						
	09-Jul-90	<6.0	0.8	2.7	NDR(3.0)	24	4.7	32.2	49	27	10	NDR(6.0)	NDR(12)	NDR(5.2)	3.7	3.4	NDR(2.7)	6.2	NDR(2.2)	99.3	131.5	1	1171
		0%	1%	2%	0%	18%	4%	24%	37%	21%	8%	0%	0%	0%	3%	3%	0%	5%	0%	76%			

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

		Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
Site No.	**Date**	**Location**																					
VI-14		**LADYSMITH HARBOUR**																					
		Site #29																					
		Mussels - Soft tissue																					
	20-Jan-92	<2.0	<0.6	<0.8	1.1	<5.6	<1.9	1.1	10	8.1	4.1	3.8	NDR(4.0)	<3.5	<2.7	<3.1	<3.1	<4.0	<2.9	24	25.1	1	1187
		0%	0%	0%	4%	0%	0%	4%	40%	24%	16%	15%	0%	0%	0%	0%	0%	0%	0%	96%			
		(Lab duplicate)																					
		<2.5	<0.4	<0.7	<1.1	3.9	<1.7	3.9	5.7	4.2	<4.0	<3.9	<3.7	<1.2	<1.1	<1.4	<1.4	<1.7	<1.0	9.9	13.8	1	1187
		0%	0%	0%	0%	28%	0%	28%	41%	30%	0%	0%	0%	0%	0%	0%	0%	0%	0%	72%			
		Site #30																					
		Mussels - Soft tissue																					
		<3.2	<0.7	<1.1	1.6	7.7	<2.2	9.3	39	26	14	10	NDR(12)	NDR(4.2)	2.2	<3.3	<4.0	7.2	2.1	100.5	109.8	1	1187
		0%	0%	0%	1%	7%	0%	8%	36%	24%	13%	9%	0%	0%	2%	0%	0%	7%	2%	92%			
		Site #31																					
		Mussels - Soft tissue																					
		<2.9	<0.4	<0.8	<1.1	4.2	<1.6	4.2	22	15	7.4	4	NDR(5.5)	<3.0	<2.0	<1.1	<3.3	NDR(2.3)	<1.4	48.4	52.6	1	1187
		0%	0%	0%	0%	8%	0%	8%	42%	29%	14%	8%	0%	0%	0%	0%	0%	0%	0%	92%			
		Site #32																					
		Mussels - Soft tissue																					
		<2.6	<0.1	0.8	1	8.1	1.4	11.3	36	34	12	4.1	10	NDR(2.5)	NDR(1.1)	NDR(0.8)	NDR(1.4)	6.2	NDR(1.0)	102.3	113.6	1	1187
		0%	0%	1%	1%	7%	1%	10%	32%	30%	11%	4%	9%	0%	0%	0%	0%	5%	0%	90%			
		Site #33																					
		Mussels - Soft tissue																					
		<2.6	0.4	0.9	1	6.2	1.5	10	27	18	7.8	4.1	8	1.1	NDR(1.0)	NDR(0.7)	1.2	3.6	0.9	71.7	81.7	1	1187
		0%	0%	1%	1%	8%	2%	12%	33%	22%	10%	5%	10%	1%	0%	0%	1%	4%	1%	88%			
		(Lab duplicate)																					
		<3.0	0.4	0.8	0.9	6	1.6	9.7	25	17	7.3	4.2	8.2	1.1	NDR(0.6)	NDR(0.6)	1.3	3.4	0.8	ND	9.7	1	1187
		0%	4%	8%	9%	62%	16%	100%	258%	175%	75%	43%	85%	11%	0%	0%	13%	35%	8%	0%			
		Site #38																					
		Mussels - Soft tissue																					
		<2.0	0.3	0.8	1	5.9	1.1	9.1	31	21	8.2	4.6	9	1.9	NDR(0.9)	0.6	1.2	3.8	NDR(0.5)	81.3	90.4	1	1187
		0%	0%	1%	1%	7%	1%	10%	34%	23%	9%	5%	10%	2%	0%	1%	1%	4%	0%	90%			

APPENDIX 5.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
VI-13	NANAIMO HARBOUR																							
		South of Nanaimo Yacht Club																						
		Manila/Littleneck clams - Soft tissue																						
	20-Mar-91		<9	<1	<1	<2	6	2	8	13	9	5	3	NDR(4)	<2	<2	<4	<3	<2	<2	30	38	1	1187
			0%	0%	0%	0	16%	5%	21%	34%	24%	13%	8%	0%	0%	0%	0%	0%	0%	0%	79%			
		North of Nanaimo Yacht Club																						
		Manila/Littleneck clams - Soft tissue																						
	20-Mar-91		<10	<1	2	2	11	3	18	22	16	11	4	NDR(4)	<2	<2	<3	<3	<2	<2	53	71	1	1187
			0%	0%	3%	3%	15%	4%	25%	31%	23%	15%	6%	0%	0%	0%	0%	0%	0%	0%	75%			
		South of Moby Dick Motel																						
		Manila/Littleneck clams -Soft tissue																						
	20-Mar-91		<5	<1	1	<2	11	2	14	18	12	4	2	NDR(2)	<1	<2	<2	<2	<1	<1	36	50	1	1187
			0%	0%	2%	0%	22%	4%	28%	36%	24%	8%	4%	0%	0%	0%	0%	0%	0%	0%	72%			
		(Lab duplicate)																						
			<6	<1	1	2	11	3	17	19	12	5	2	NDR(3)	<1	<1	<1	<1	NDR(2)	<1	38	55	1	1187
			0%	0%	2%	4%	20%	5%	31%	35%	22%	9%	4%	0%	0%	0%	0%	0%	0%	0%	69%			
		Petro-Can Fuel Dock																						
		Manila/Littleneck clams - Soft tissue																						
	20-Mar-91		<8	<1	3	5	34	5	47	44	33	15	6	16	NDR(4)	NDR(3)	<1	NDR(4)	6	NDR(2)	122	169	1	1187
			0%	0%	2%	3%	20%	3%	28%	26%	20%	9%	4%	9%	0%	0%	0%	0%	5%	0%	72%			
		North of Air Rainbow																						
		Manila/Littleneck clams - Soft tissue																						
	20-Mar-91		<26	<1	2	3	20	5	30	35	23	13	9	16	6	<3	<1	<3	<1	<2	102	132	1	1187
			0%	0%	2%	2%	15%	4%	23%	27%	17%	10%	7%	12%	5%	0%	0%	0%	0%	0%	77%			
		South of Shaft Point																						
		Manila clams/Littleneck clams - Soft tissue																						
	20-Mar-91		<26	<1	<1	<1	4	2	6	9	6	4	3	3	<1	<1	<1	<1	<1	<1	25	31	1	1187
			0%	0%	0%	0%	13%	6%	19%	29%	19%	13%	10%	10%	0%	0%	0%	0%	0%	0%	81%			
		Oysters - Soft tissue																						
	20-Mar-91		<19	<1	2	<1	6	3	11	14	9	7	4	9	<1	<1	<1	<1	4	<1	47	58	1	1187
			0%	0%	3%	0%	10%	5%	19%	24%	16%	12%	7%	16%	0%	0%	0%	0%	7%	0%	81%			
		Newcastle Island - across from Unique Seafoods																						
		Clams - Soft tissue																						
	20-Mar-91		<24	<1	<1	<1	9	3	12	8	5	<3	<3	<3	<1	<1	<1	<1	<2	<1	13	25	1	1187
			0%	0%	0%	0%	36%	12%	48%	32%	20%	0%	0%	0%	0%	0%	0%	0%	0%	0%	52%			
		Oysters - Soft tissue																						
	20-Mar-91		<26	<1	2	<2	10	3	15	29	18	15	8	19	<2	<1	<1	<1	7	<2	96	111	1	1187
			0%	0%	2%	0%	9%	3%	14%	26%	16%	14%	7%	17%	0%	0%	0%	0%	6%	0%	86%			
		(Lab duplicate)																						
			<34	<1	2	<1	9	4	15	25	17	14	7	19	<2	<2	<1	<2	6	<2	88	103	1	1187
			0%	0%	2%	0%	9%	4%	15%	24%	17%	14%	7%	18%	0%	0%	0%	0%	6%	0%	85%			

APPENDIX 6.2 **PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)**

Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
VI-13	**NANAIMO HARBOUR cont.**																							
		Newcastle Island - South tip																						
		Clams - Soft tissue																						
	20-Mar-91	<26	<1	2	<1	4	2	8	11	7	5	3	NDR(2)	<1	<1	<1	<1	<1	<1	26	34	1	1187
		0%	0%	6%	0%	12%	6%	24%	32%	21%	15%	9%	0%	0%	0%	0%	0%	0%	0%	76%			
		(Lab duplicate)																						
		<34	<1	1	<1	4	2	7	10	6	4	3	NDR(2)	<1	<1	<1	<1	<1	<1	23	30	1	1187
		0%	0%	3%	0%	13%	7%	23%	33%	20%	13%	10%	0%	0%	0%	0%	0%	0%	0%	77%			
		Oysters - Soft tissue																						
	20-Mar-91	<36	<1	<1	<1	2	<2	2	4	4	1	<1	NDR(2)	<1	<1	<1	<1	<1	<1	9	11	1	1187
		0%	0%	0%	0%	18%	0%	18%	36%	36%	9%	0%	0%	0%	0%	0%	0%	0%	0%	82%			
		(Lab duplicate)																						
		<32	<1	<1	<1	3	2	5	8	5	2	2	NDR(5)	<1	<1	<1	<1	<2	<1	17	22	1	1187
		0%	0%	0%	0%	14%	9%	23%	36%	23%	9%	9%	0%	0%	0%	0%	0%	0%	0%	77%			
	REFERENCE SITES																							
RF-1		**Crescent Beach**																						
	18-Jun-91	Rock sole - Whole body																						
		7.3	<0.6	<0.7	<0.4	1.1	<0.9	8.4	NDR(0.5)	<0.3	<0.2	<0.2	<0.3	<0.2	<0.4	<0.2	<0.5	<0.2	<0.2	ND	8.4	1	2820
		87%	0%	0%	0%	13%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%			
RF-2		**St. Vincent's Bay**																						
		Slender sole - Whole body																						
	13-Feb-88	<19	<0.1	<0.8	<1	<6	<1	ND	6	4	3	<1	2	<0.9	<0.3	<0.3	<0.2	<1	<0.9	15	15	1	342
		0%	0%	0%	0%	0%	0%	0%	40%	27%	20%	0%	13%	0%	0%	0%	0%	0%	0%	100%			
RF-3		**Agememnon Channel**																						
		Striped Shrimp - tail																						
	13-Feb-88	<26	0.4	<0.8	<1	0%	<0.5	0.4	44	34	29	15	41	15	<6	<4	12	16	5	211	211.4	1	342
		0%	0%	0%	0%	0%	0%	0%	21%	16%	14%	7%	19%	7%	0%	0%	6%	8%	2%	100%			
RF-6		**Fortune Channel**																						
		Dungeness Crab - Hepatopancreas																						
	23-Jun-88	<26	<0.1	<0.8	<0.1	<0.4	<1	ND	<2	<2	0.6	<1	<0.2	<0.4	<0.6	<0.8	<0.4	<0.4	<0.4	0.6	0.6	1	342
		0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%			

APPENDIX 6.2 PA H CONCENTRATIONS IN AQUATIC BIOTA FROM BRITISH COLUMBIA AND PERCENT CONTRIBUTION OF INDIVIDUAL PAH COMPOUNDS TO TOTAL PAH CONCENTRATIONS (ng/g wet weight)

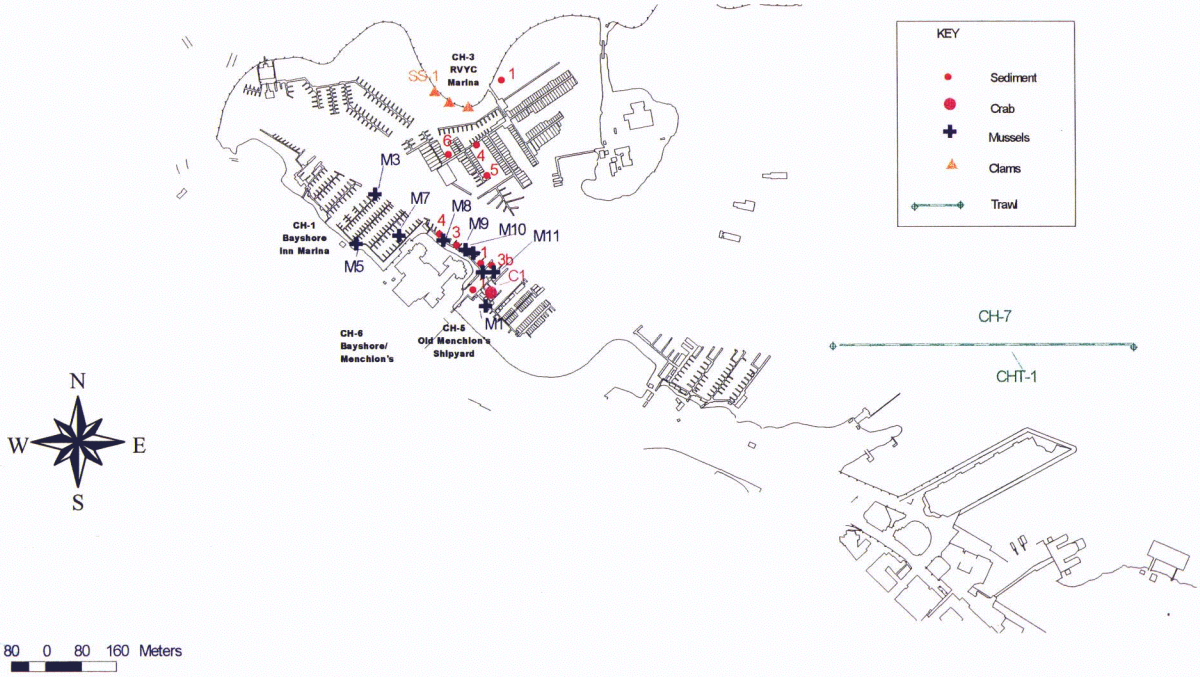
Site No.	Date	Location	Naptha-lene	Acenaph-thylene	Acenaph-thene	Anthra-cene	Phenan-threne	Fluorene	Total LMW PAHs	Fluor-anthene	Pyrene	Chrysene	Bena(a)an-thracene	Benzofluor-anthenes	Benzo(a)-pyrene	Benzo(ghi)-perylene	Dibenz(ah) anthracene	Indeno(123-cd)pyrene	Benzo(e)-pyrene	Perylene	Total HMW PAHs	Total PAHs	Lab No.	Batch No.
	REFERENCE SITES cont.																							
RF-8		**Rivers Inlet**																						
		Pink shrimp - tail																						
	26-Oct-89		NDR(9.1)	<0.5	<0.6	<0.4	2	<0.8	2	0.7	0.6	NDR(0.4)	<0.3	<0.3	<0.3	<0.4	<0.5	<0.5	<0.3	<0.4	1.3	3.3	1	2820
			0%	0%	0%	0%	61%	0%	61%	21%	18%	0%	0%	0%	0%	0%	0%	0%	0%	0%	39%			
RF-7		**Larkin Island**																						
		Mussels (large) - Soft tissue																						
	23-Jun-88		<10	0.3	<0.4	<2	<6	<0.6	0.3	49	40	30	18	43	13	<6	<3	10	14	4	221	221.3	1	342
			0%	0%	0%	0%	0%	0%	0%	22%	18%	14%	8%	19%	6%	0%	0%	5%	6%	2%	100%			
		(Lab duplicate)																						
			<11	<0.2	<0.5	<2	<6	<0.5	ND	39	32	22	14	31	10	<6	<3	8	11	2	169	169	1	342
			0%	0%	0%	0	0%	0%	0%	23%	19%	13%	8%	18%	6%	0%	0%	5%	7%	1%	100%			
		Queen Charlotte Islands:																						
RF-9		**Delkatla Slough**																						
		Dungeness crab - Hepatopancreas																						
	25-Jul-89		54	NDR(5.1)	15	5.6	23	13	110.6	NDR(12)	9.4	NDR(9.9)	NDR(6.6)	NDR(3.7)	<2.2	<4.1	<3.2	<5.4	<2.0	<2.3	9.4	120	1	2820
			45%	0%	13%	0%	19%	11%	92%	0%	8%	0%	0%	0%	0%	0%	0%	0%	0%	0%	8%			

ND Not Detected
N/A Sample was not analyzed for this compound.
NDR A peak was detected but did not meet quantification criteria. Maximum value given in brackets.
TIM Analysis conducted by total ion method. All other samples analysed by select ion method.

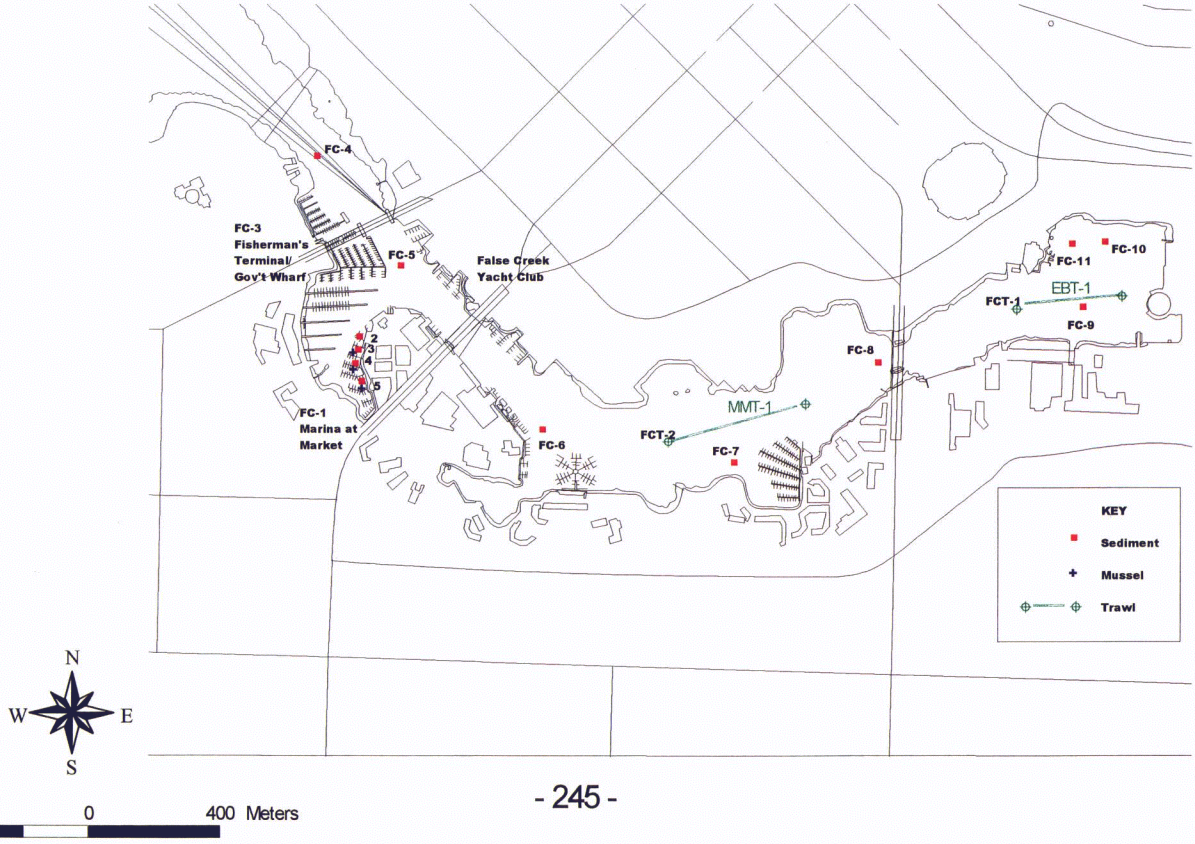
NOTE: Values have been blank corrected where required.

LOCATION MAPS

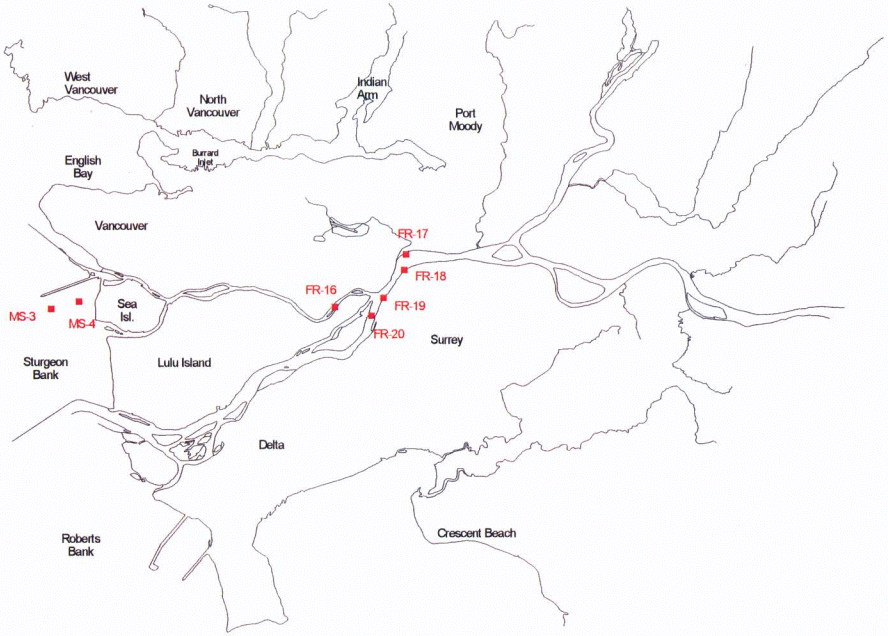
Map 1 : Coal Harbour Sampling Locations (CH-1-CH-7)

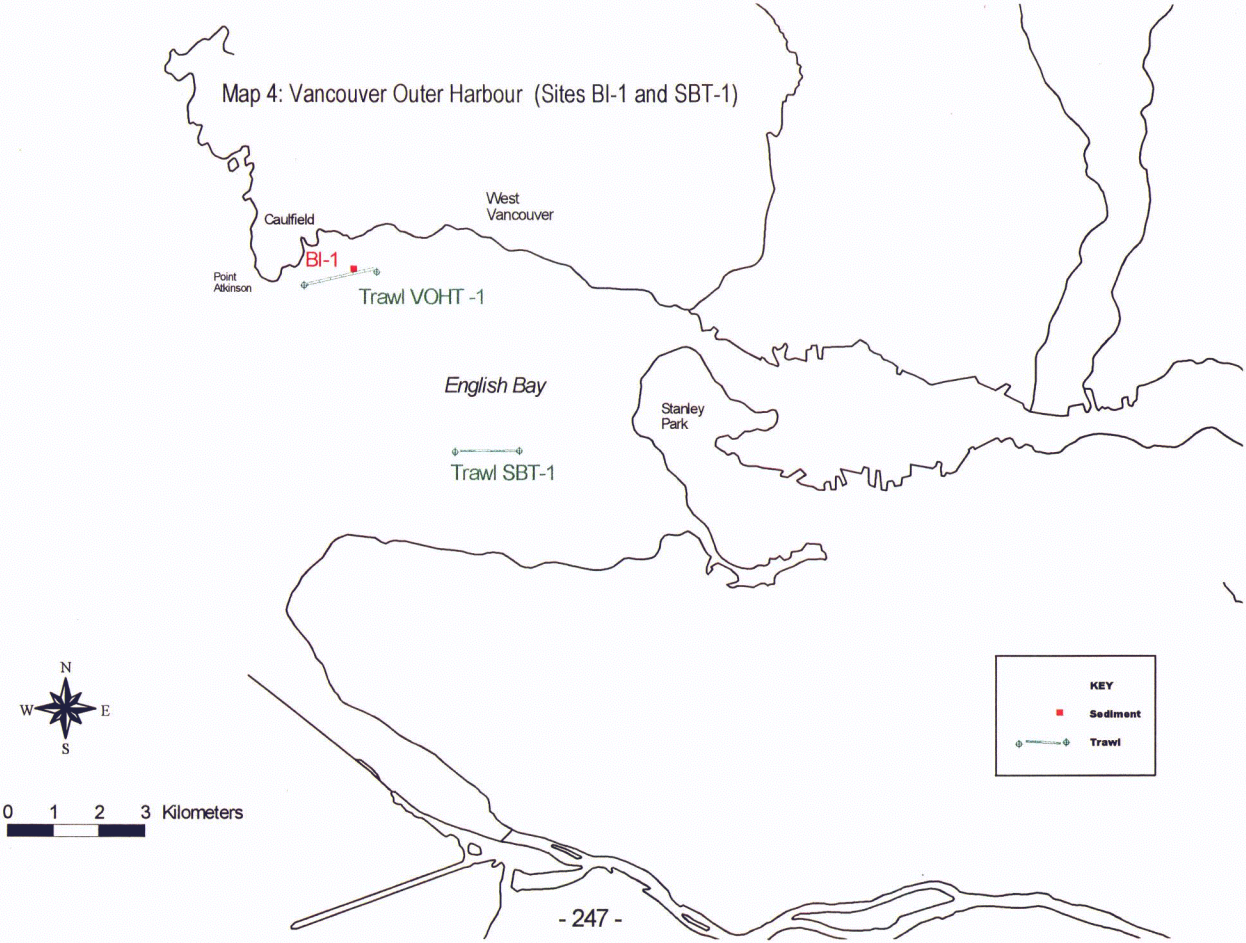


Map 2 : False Creek (FC-1 to FC-11) Sampling Locations

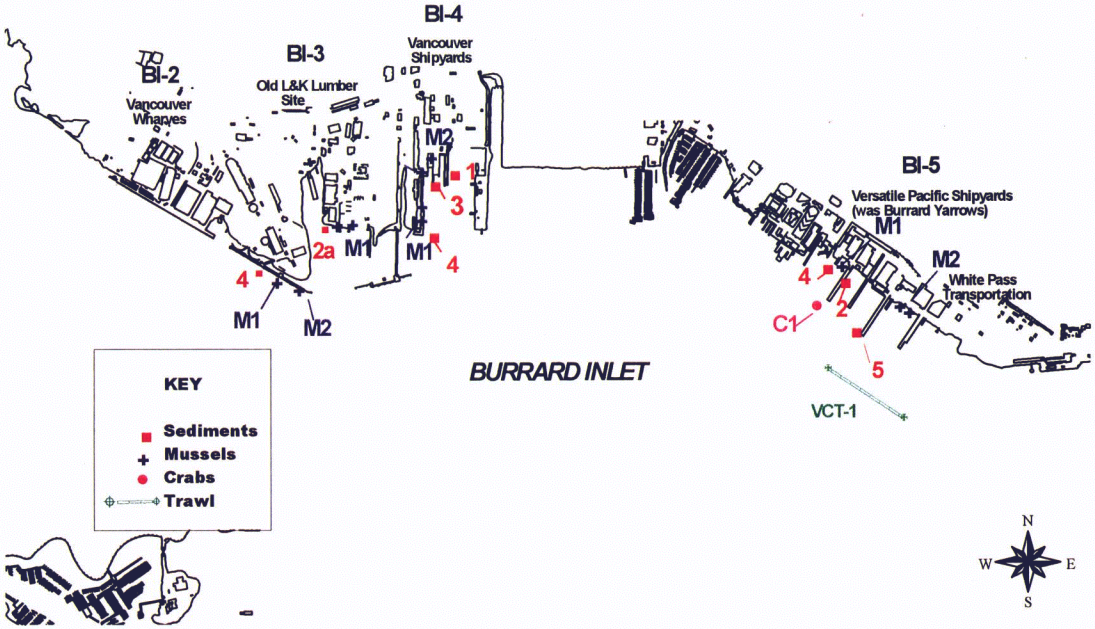


Map 3: Lower Fraser River (Sites FR-16 to 20) and Mainland (Sites MS-3 and 4)

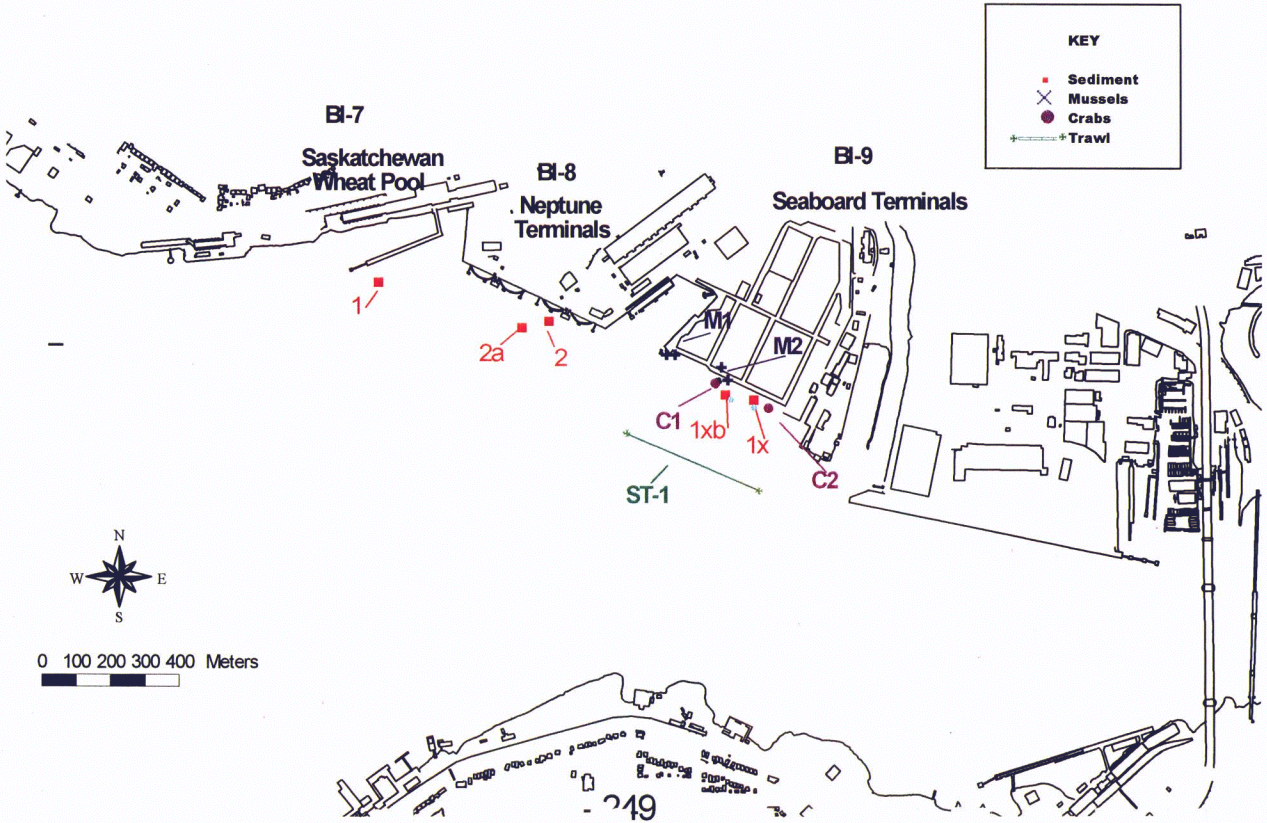



Map 4: Vancouver Outer Harbour (Sites BI-1 and SBT-1)
Caulfield
West Vancouver
BI-1
Point Atkinson
Trawl VOHT -1
English Bay
Stanley Park
Trawl SBT-1
N
W
E
S
0 1 2 3 Kilometers
KEY
Sediment
Trawl

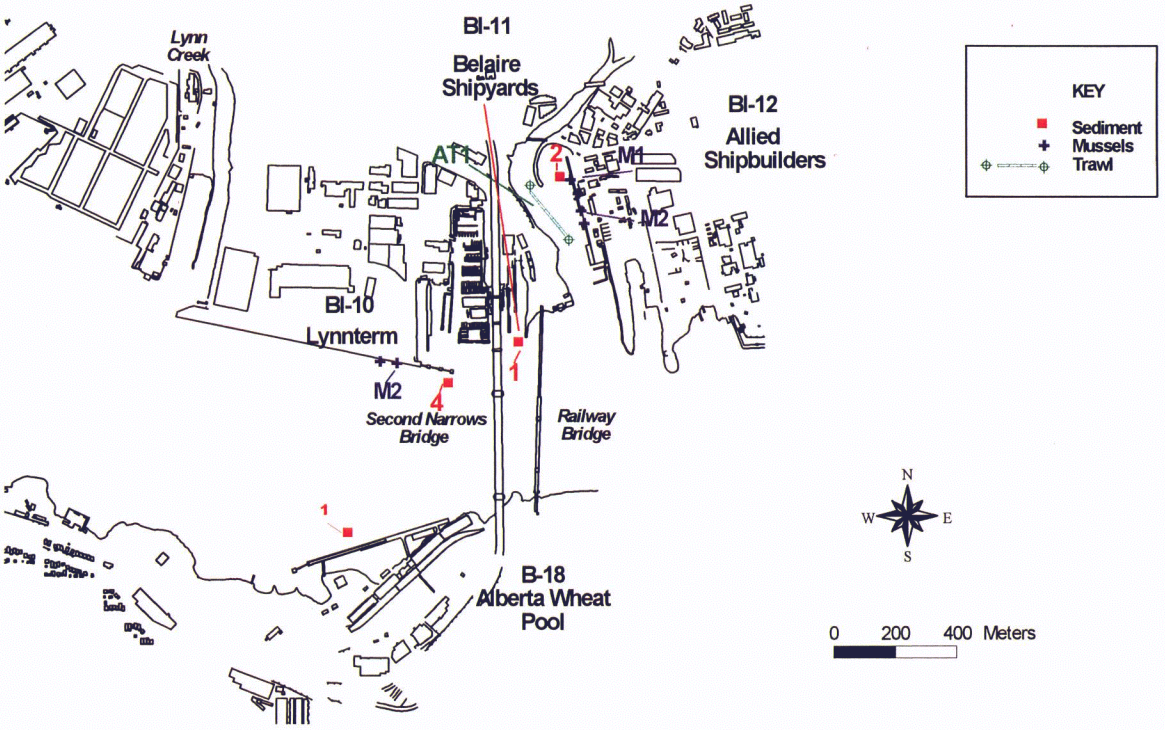
Map 5: Burrard Inlet (Sites BI-2 to BI-5) - Sediment and Biota Stations



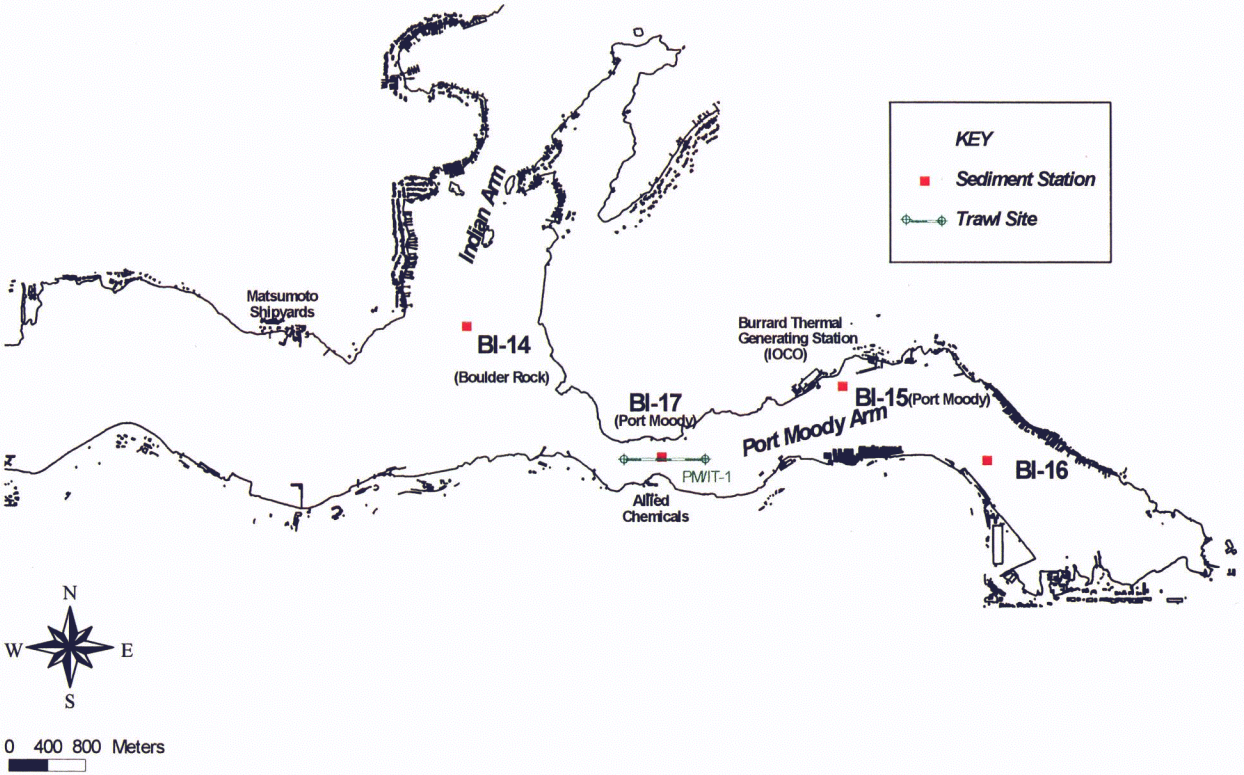
Map 6: Burrard Inlet (Sites BI-7, BI-8, and BI-9)



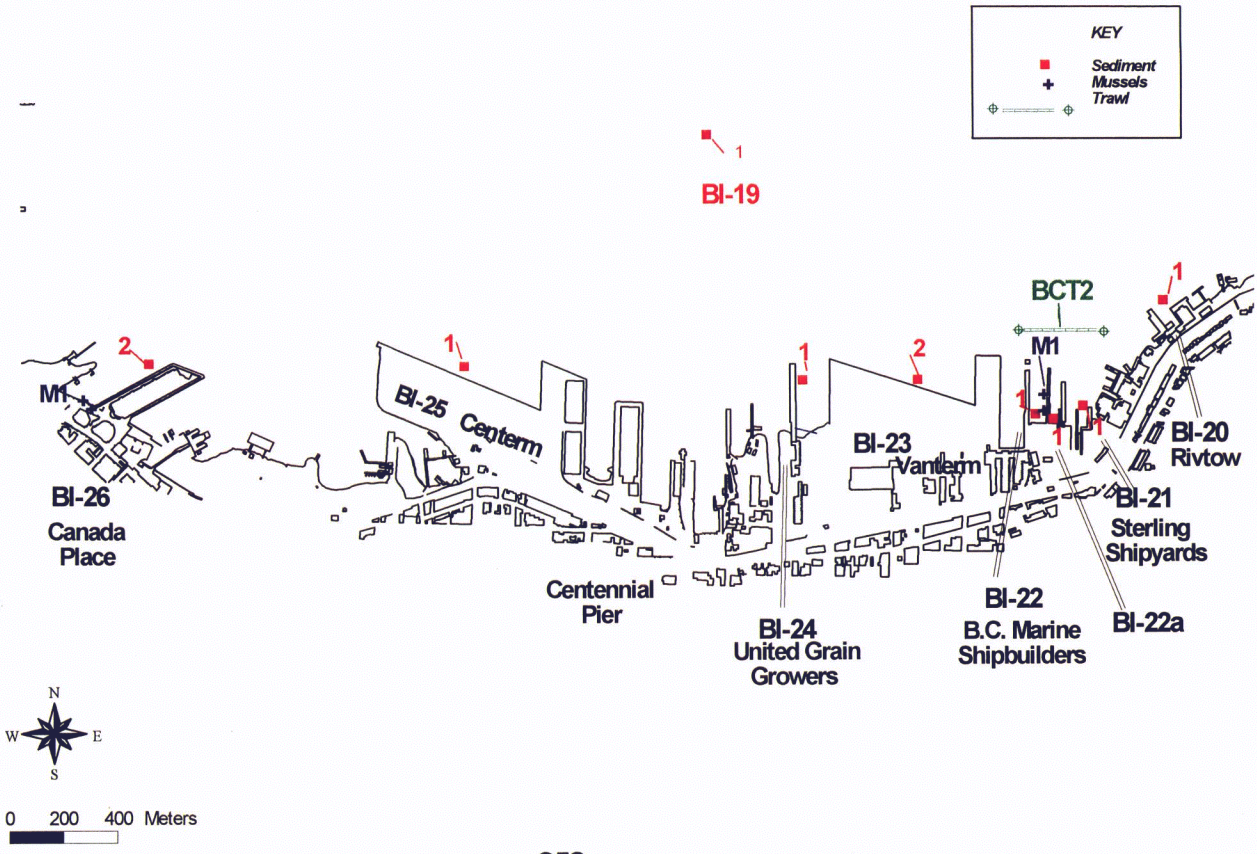
Map 7: Burrard Inlet (Sites BI-10, 11, 12 and 18)



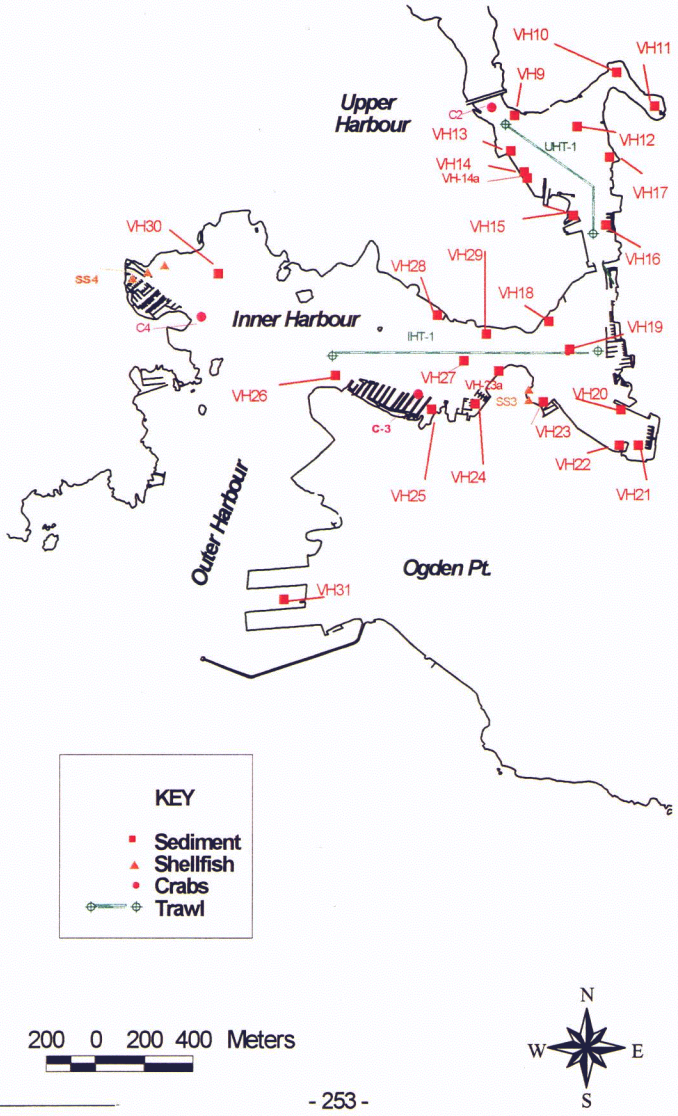
Map 8 : Burrard Inlet (Sites BI-14 to BI-17)



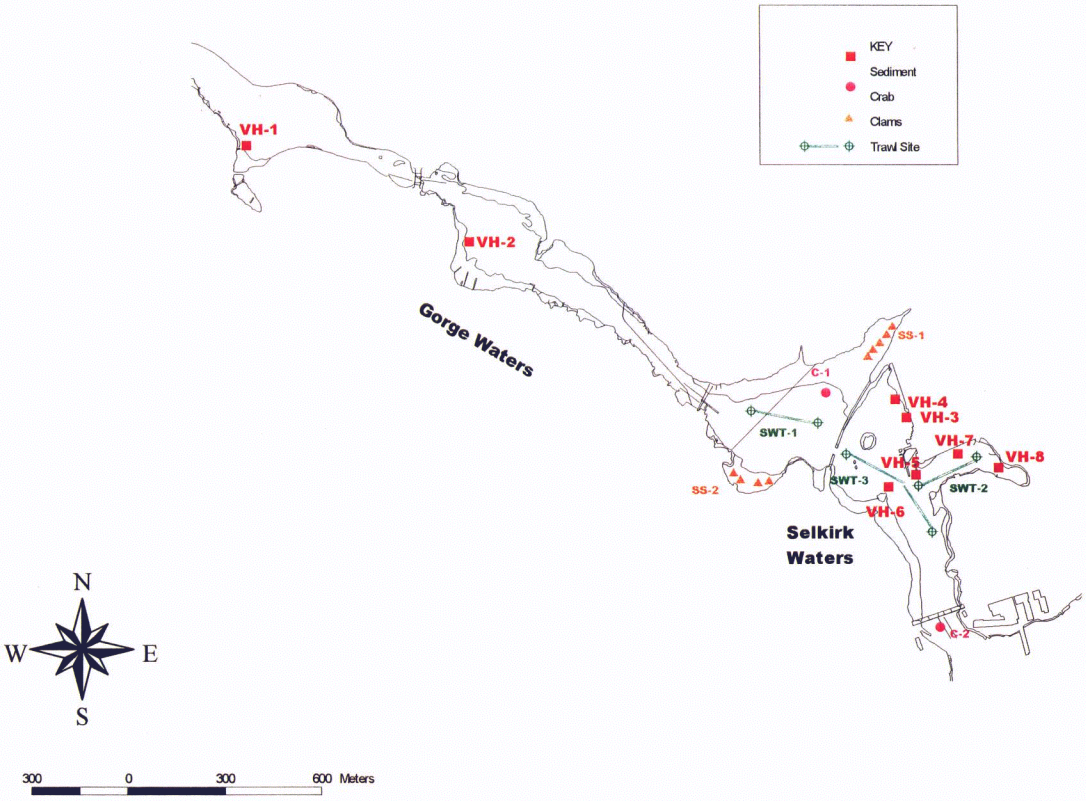
Map 9: Burrard Inlet (Sites BI-19 to BI-26)

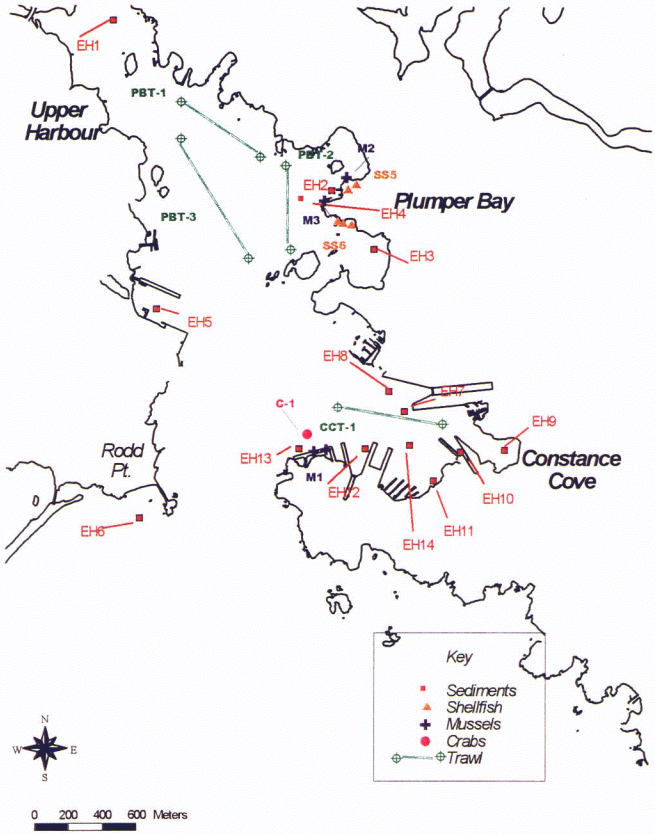


Map 10a : Victoria Harbour - Upper, Inner and Outer Harbour

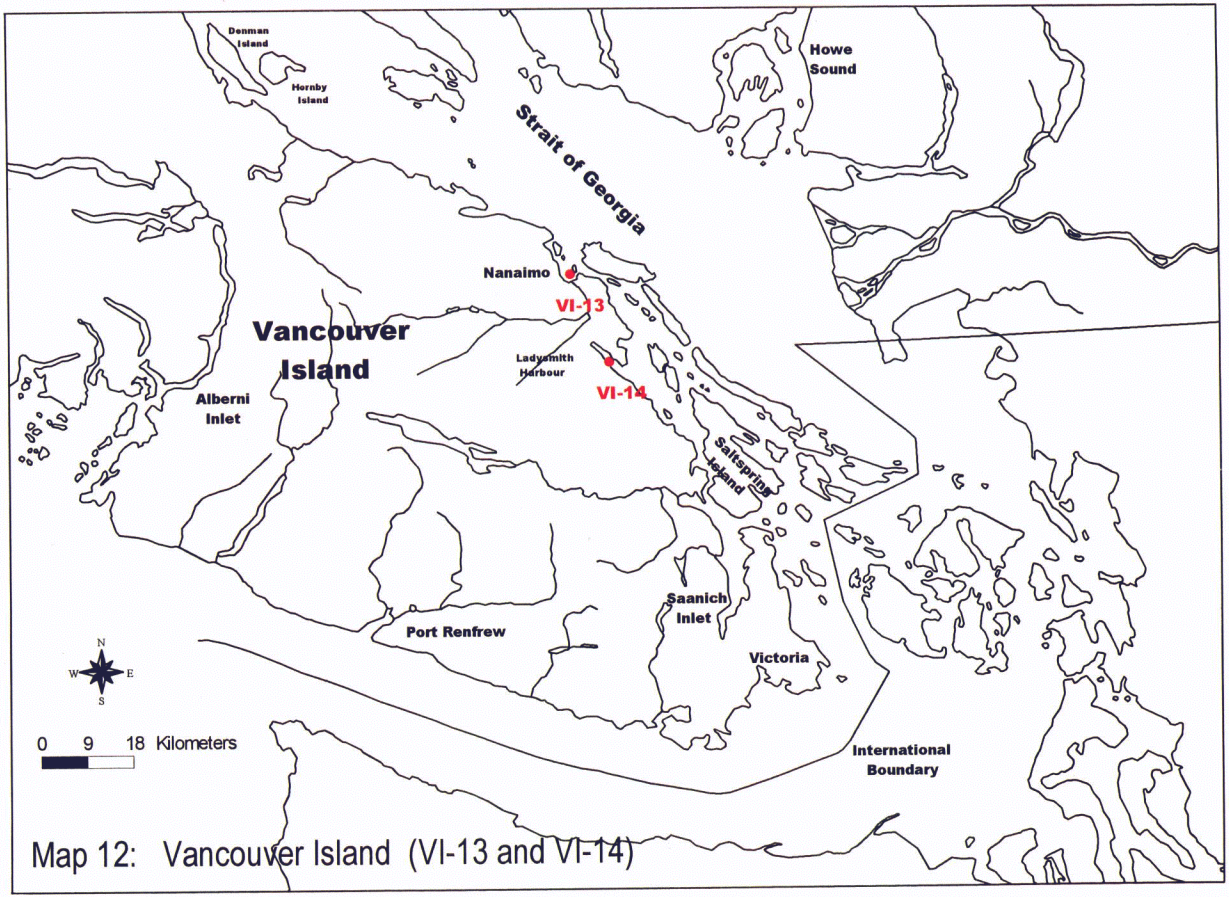


Map 10b : Victoria Harbour (Selkirk and Gorge Waters)



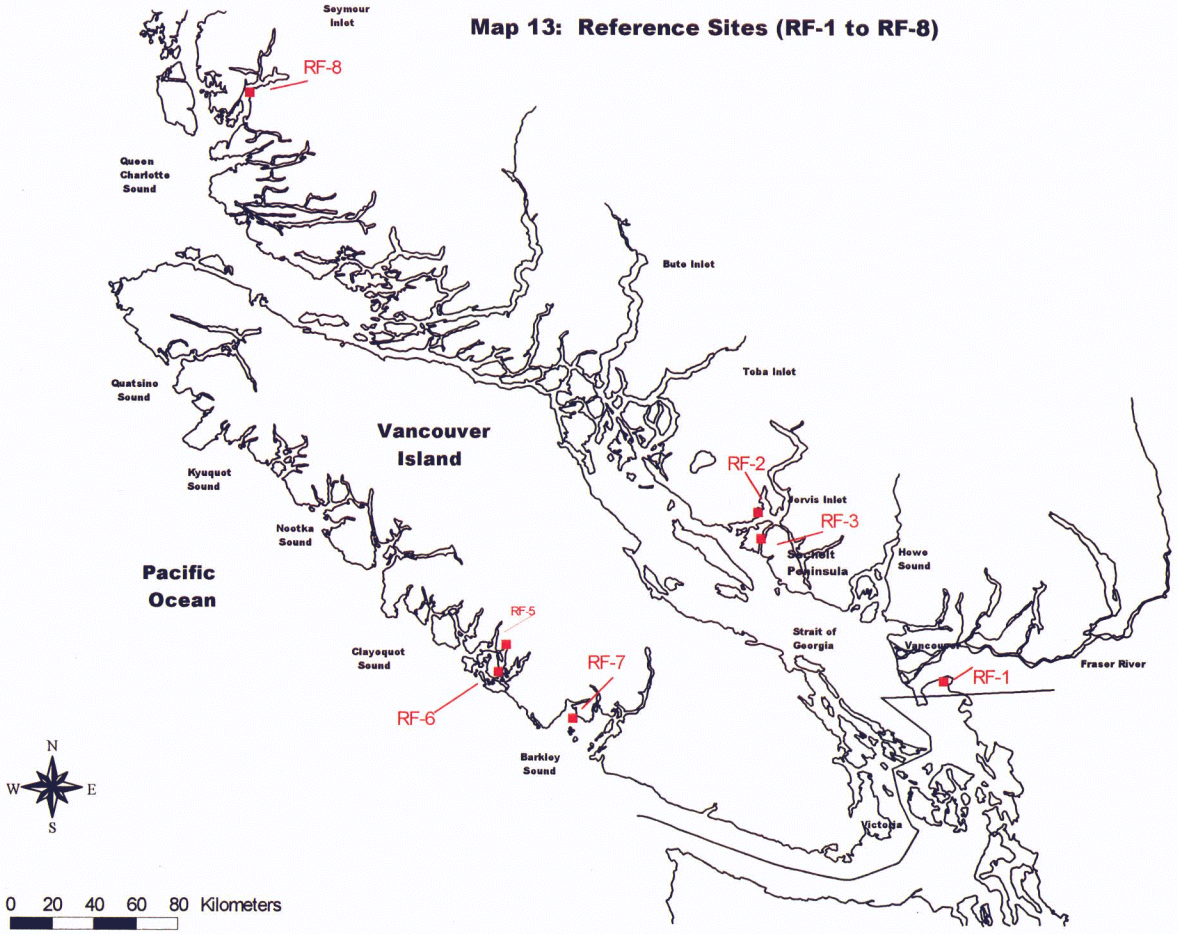


Map 11: Esquimalt Harbour



Map 12: Vancouver Island (VI-13 and VI-14)

Map 13: Reference Sites (RF-1 to RF-8)



Map 14 : Queen Charlotte Islands Reference Sites