OIL EXPOSURE OF FISH IN THE SALT PONDS OF RHODE ISLAND FOLLOWING THE *NORTH CAPE* OIL SPILL, AND ESTIMATION OF POTENTIAL FOR BIOLOGICAL INJURY TO WINTER FLOUNDER (*Pleuronectes americanus*)

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Introduction

Following the *North Cape* oil spill (NCOS) on January 19-21, 1996, oiling of several salt ponds along the coast of Rhode Island occurred. There are substantial data in existence to show that both the water column in several salt ponds as well as surficial sediments were contaminated (Hinga 1997). Because of this there was concern on the part of natural resource trustees that fish in the salt ponds could be adversely impacted by the spilled oil. Of special concern were winter flounder (*Pleuronectes americanus*), which use the salt ponds as spawning and nursery grounds, with spawning occurring during the winter, and coinciding with the time of the spill. This report summarizes the results of investigations conducted by the Environmental Conservation Division (ECD) of the Northwest Fisheries Science Center (NWFSC) of the National Marine Fisheries Service to assess exposure of fish to oil spilled from the barge *North Cape*, and also provides an estimation of the potential for such exposure to cause reproductive dysfunction and other types of biological injury to winter flounder. These efforts were supported by funding from the Damage Assessment Center of NOAA.

Methods

Sample collection: Field sampling was conducted during two time periods following the NCOS. From February 11 until March 3, eight scientists from NWFSC were involved in the sampling efforts. Several days were spent initially on securing sampling permits, laboratory space for performing dissections, vessels, and vehicles. We also were acquiring information on historical fishing methods and catch data, determining vessel launch sites, and determining what sampling had taken place after the spill. Field sampling started on February 16. While the presence of heavy ice on many of the ponds limited the areas that were available to sample, sampling was attempted in Point Judith Pond, Potter Pond, Cards Pond, Ninigret Pond, Quonochontaug Pond, and in the Narrow River (Figure 1). Samples were collected in all but Cards Pond and Potter

Pond. The sampling gear deployed included trawl nets, beach seines, fyke nets, minnow traps, and fish traps. Species collected were winter flounder, lobster, blue crab, and kelp crab. Fyke nets were the most useful for capturing adult winter flounder during this sampling period. A sediment grab sampler was used to collect sediment samples from all sites where fish were collected. Additionally, samples of bivalves were collected by divers and by a clam dredge operated by the Rhode Island Department of Environmental Management (DEM).

Fish were transported to the laboratory (USEPA/Narragansett) in aerated seawater and were necropsied the same day as captured. Fish were weighed, measured and otoliths were taken for age determination. Histological samples were taken from the liver, anterior and posterior kidney, spleen, gonad, gill, skin, gut, heart and brain. Bile was sampled, when present, for analyses of fluorescent aromatic compounds (FACs), which provides a semi-quantitative estimation of exposure to aromatic hydrocarbons. Liver samples were taken from each fish sampled, and if sufficient liver tissue was available, separate samples were collected for analyses of cytochrome P4501A, DNA adducts, glutathione, and organic chemistry. Plasma samples were collected from all fish which were large enough to perform venipuncture. Fish muscle tissue and stomach contents were also collected for analytical chemistry. All bile, liver, plasma, and muscle samples were frozen immediately after collection. All samples were collected under chain-of-custody (COC) procedures, and samples which have not been analyzed are being maintained in archival status under COC at the NWFSC.

The second field sampling effort started on July 10, 1996 and was concluded on August 2, 1996. Two crews of eight scientists from the ECD sampled biota and sediment in several locations throughout the salt ponds west of Narragansett Bay. In addition to the sites sampled previously, sites in Trustom Pond and Winnapaug Pond were sampled, as shown in Figure 1. The focus of this effort was to sample several fish species from each of the salt ponds. The sampling gear employed included beach

seines, gill nets, trawl nets, minnow traps, flounder traps, fyke nets and a sediment grab. Fish species collected were winter flounder, windowpane flounder (*Scopthalmus aquosus*), summer flounder (*Paralichthys dentatus*), mummichog (*Fundulus heteroclitus*), striped killifish (*Fundulus majalis*), Atlantic silversides (*Menidia menidia*), striped bass (*Morone saxatilis*), bluefish (*Pomatomus saltatrix*), oyster toadfish (*Opsanus tau*) and tautog (*Tautoga onitis*). Samples were collected using the same protocols used for the winter sampling, except that for the *Fundulus* and *Menidia* species, samples from several fish had to be composited to provide sufficient sample size for analysis. Histological samples were taken from a subset of the fish used in the composites. Facilities at the NMFS Narragansett laboratory was used for performing the necropsies during the summer sampling.

Sample analysis: Forty-eight of 105 bile samples from adult winter flounder captured in February and March 1996 were analyzed for fluorescent aromatic compounds (FACs) by high performance liquid chromatography (HPLC) with fluorescence detection, using the method of Krahn et al. (1986). This semi-quantitative procedure for measuring FACs in bile provides a rapid assessment of exposure of fish to petroleum-related aromatic compounds (ACs) and was been used extensively to evaluate exposure of fish to ACs from the *Exxon Valdez* oil spill (EVOS) in Alaska (Collier et al., 1996a). The fluorescent responses were recorded at the wavelength pairs for naphthalene (NPH) and phenanthrene (PHN), prominent constituents of ACs in petroleum. These wavelengths have been shown to be most useful for determining petroleum exposure in fish (Krahn et al., 1992). In the paragraphs below we primarily discuss the results of biliary FACs measured at PHN wavelengths, because of the very strong statistical correlation with NPH values ($r = 0.994$, $p = 0.0001$). This approach is similar to what was done for most of our EVOS data. Biliary FAC values were normalized against protein content of bile in order to partially account for variable water content of bile (Collier and Varanasi,

1991). Of the 188 bile samples collected in the summer sampling, 60 were analyzed, and these included samples from adult winter flounder, striped bass, and mummichog. All data, at both wavelengths, and with and without protein correction, are given in Appendix 1.

Results and Discussion

This report focuses on the data showing exposure of winter flounder to oil (shown in Figure 2), and an estimation of the potential for biological injury resulting from the oil exposure. The results of all analyses done, for both sampling periods and for winter flounder, striped bass, and mummichog, are presented in Table 1. Discussion of the data for striped bass and mummichog can be found in Collier et al. (1996b).

Winter sampling: The results of the bile analyses showed that many adult winter flounder in the salt ponds were exposed to petroleum following the NCOS, and the levels of exposure appeared to be substantially higher than the levels of exposure of flatfish following the EVOS. Whereas we found mean concentrations of more than 100,000 ng PHN equivalents/mg biliary protein in winter flounder following the NCOS (see Table 1, Point Judith Pond/Jerusalem), the highest such value (e.g., site mean) for any flatfish species following the EVOS was less than 15,000 (Collier et al., 1996a; Hom et al, 1996).

Specifically, there were significantly higher (as determined by ANOVA of log-transformed data) mean concentrations of biliary FACs in winter flounder from Point Judith Pond (i.e., Ram Island, Turner Pt., Jerusalem) and Ninigret Pond, areas that were oiled by the spill, compared to concentrations in fish from the Narrow River, a reference site, that was not affected by the oil spill (Table 1, Figure 2). For example, the mean concentration of biliary FACs in fish captured near Jerusalem at the mouth of Point

Judith Pond was 18-fold greater than the concentration measured in fish from Narrow River. Increased concentrations of biliary FACs were also measured in fish captured from Ram Island (14-fold greater) and Turner Point (10-fold greater), other sites within Point Judith Pond, relative to the reference fish (Table 1). Statistical evaluation of bile analyses of winter flounder captured from Quonochontaug Pond, an area that was not thought to have been substantially contaminated by the NCOS, was not done because only 2 fish were sampled. However, both fish showed concentrations of biliary FACs that were in the range of FAC concentrations found in fish from the other contaminated ponds.

Summer sampling: Overall, the results of the second set of bile analyses showed that exposure to AHs is continuing following the NCOS, though the levels of exposure were reduced from the levels seen in February. Levels of biliary FACs in winter flounder (on a protein-adjusted basis) decreased by 67% and 26% at two sites in Pt. Judith Pond (Jerusalem and Ram Island, respectively), and also decreased by 50% at the site in Quonochontaug Pond (see Table 1 and Figure 2). Sediment concentrations of AHs also decreased at these sites in Pt. Judith Pond (there have been no analyses of sediments collected from Quonochontaug Pond) during this period, to an even more marked degree. At the sediment sites near Jerusalem (sites 10, 11, and 12), levels of ACs essentially decreased by 100%, to below detection limits, and at the sites near Ram Island (sites 8 and 9) concentrations of lower molecular weight ACs dropped 87% and 49%, respectively. These proportional changes were calculated from the sediment chemistry data we submitted to the TWG in July and September of 1996, with the final submission in October, 1996. Those data are attached to this report as Appendix 2, and are discussed in Hinga (1997). Thus, although both sediment and fish bile are showing decreases in AH contamination, the rate of decrease is apparently slower in fish bile than in the sediments. This suggests that there may be another source for AH contamination of fish, such as via their diet. This question would best be addressed by

conducting analyses of the archived stomach contents samples collected from these fish. However, with the current data set, such a hypothesis cannot be tested. It does not appear likely that the relatively high levels of exposure seen in Pt. Judith Pond during the summer are primarily due to the vessel traffic around Jerusalem and Galilee, as levels of FACs in bile decreased to a greater degree in fish from the Jerusalem site as compared to fish from Ram Island, a site with much less vessel traffic.

In contrast to the decreasing trends seen in fish from the salt ponds, levels of FACs in bile of winter flounder from the reference site, Narrow River, increased 100% between February and July. As shown in Figure 2, however, levels of exposure at this site were still well below the apparent summertime exposure in fish from Pt. Judith Pond. This slight increase in fish from the Narrow River is consistent with a presumed increase in vessel traffic and increased road traffic and resultant street runoff in this area during the summer. Accordingly, the levels of FACs in bile of fish from the Narrow River are useful for estimating background PAH exposure of winter flounder in the salt pond region.

Because levels of FACs in bile decrease quickly after exposure of fish to aromatic hydrocarbons ceases [we estimate the 'biological half life' to be about 2 weeks (Collier and Varanasi, 1991; Collier and Anulacion, 1992)], the data collected in the summer and winter NCOS samplings should be considered to represent the current, on-going, exposure of the fish sampled. Thus, while some winter flounder presumably moved into and out of the salt ponds and Narrow River between the winter and summer samplings, the data presented here give an indication of the overall exposure of adult flatfish populations in the ponds during the period from February to July.

Estimation of potential for biological injury

Based on previous field and laboratory studies with winter flounder, English sole and other flatfish species, there is reason to believe that the levels of exposure of winter flounder following the NCOS, as indicated by the biliary FAC concentrations measured during the winter and early spring spawning season, are sufficient to cause a variety of biological effects, including reproductive impairment. It should be emphasized, however, that these presumed effects, which are based on the exposure assessments done under DAC funding, are only speculative. Samples of plasma and ovarian tissue are currently in archival status, and analyses of these samples would be required for a better estimation of biological injury. Confounding the estimation of injury based on exposure measurements alone is the probability that there are species differences in uptake, disposition, metabolism, and excretion of AHs, as well as differences in the sensitivity of different species to toxic effects of AHs (McCain et al. 1982; Myers and Rhodes, 1988; Collier et al., 1992; Johnson et al., 1994). Nonetheless, based on best available information, major possible impacts of the NCOS on winter flounder are described below, along with the reasons for concern that such effects may have occurred as a result of the NCOS.

Depressed plasma sex steroid levels. Studies have shown that oil exposure can cause reduced levels of reproductive steroid hormones in flatfish species that are related to winter flounder. For example, in rock sole and flathead sole exposed to Prudhoe Bay crude oil by injection at doses of 0.1-1.5 ml/kg body wt, reductions in plasma estradiol concentrations and *in vitro* ovarian estradiol concentrations were observed at all doses tested (Johnson et al. 1995). At 0.1 ml/kg, reductions were about 10-20% relative to controls, while at 0.5-1.5 ml/kg, reductions were 40-50% relative to controls. Mean biliary FAC concentrations at the different treatments ranged from about 100,000 ng NPH or PHN equivalents/mg bile at 0.1 ml/kg to about 600,000 NPH or PHN equivalents/mg bile at 1 ml/kg. These FAC-NPH levels are quite similar to those

observed in winter flounder following the NCOS; FAC-PHN levels in PBCO-treated fish are somewhat higher. However, it is difficult to quantitatively compare the results from Johnson et al (1995) to the results from the NCOS study, as we have found that laboratory studies of the effects of contaminants on plasma steroids are confounded by the stress of holding feral animals in captivity. For example, we found that the stress of treatment and handling alone resulted in a 30-35% decline in plasma steroid concentrations in control fish in the study by Johnson et al. (1995).

It is more useful to compare the NCOS results to results from other field studies following oil spills. After the EVOS, female fish were collected during the reproductive season approximately one year after the spill, thus fish sampled from contaminated areas were presumably chronically exposed to oil. In the EVOS study, depressed plasma estradiol concentrations were observed at biliary FAC concentrations substantially below those observed in the PBCO laboratory exposure (Collier et al. 1993; Sol et al. 1995; Varanasi et al. 1995). In dolly varden char, depressed plasma estradiol concentrations (about 2000 pg/ml or lower) were found in fish with PHN concentrations above about 5000 ng/mg bile protein and NPH concentrations above 50,000 ng/mg bile protein (Figure 3a). Very similar results were obtained for yellowfin sole, where depressed plasma estradiol concentrations were found in fish with PHN concentrations above about 7500 ng/mg bile protein and NPH concentrations above 50,000 ng/mg bile protein (Figure 3b).

Reduced plasma estradiol concentrations have also been associated with exposure to ACs derived from industrial sources. In English sole from urban areas in Puget Sound (Figure 4), biliary FAC-NPH levels of about 100,000 ng NPH equivalents/mg bile protein and PHN levels of about 50,000 ng PHN equivalents/mg bile protein and greater have been associated with depressed plasma estradiol concentrations in adult female sole (Johnson et al. 1988, 1993, unpublished data). Winter flounder, however, may be less sensitive to the effects of chronic AC exposure

on reproductive steroids. In a recent field survey (Johnson et al. 1994) no correlation was found between biliary FAC concentrations and plasma E2 levels in reproductively maturing female winter. Although fish with the highest plasma E2 levels generally showed low AC exposure, plasma E2 concentrations in the small number of fish with biliary FAC concentrations above 50,000 ng PHN equivalents/mg bile protein or 100,000 ng NPH equivalents/mg bile protein were within the normal range for vitellogenic female winter flounder. These different responses may be due to differences in sensitivity between winter flounder and other species which have been studied, or to differences in the timing and duration of exposure.

Several additional laboratory studies by other researchers have documented alteration in steroid hormone concentrations or metabolism in fish, including male winter flounder, at exposure levels of 25-50 ppm of petroleum compounds in sediment, the approximate exposure range for winter flounder from the most heavily impacted salt ponds (e.g., Jerusalem, Ram Island, and Turner Point in Point Judith Pond, and Ninigret Pond). For example, male winter flounder exposed to crude oil at sediment PHN concentrations of 100-200 ppb, or total AC concentrations of 25 ppm, exhibited subtle changes in reproductive steroid metabolism, including declines in plasma concentrations of steroid glucuronides. These changes did not affect gonadal growth but could alter spawning success as these steroid metabolites are thought to act as pheromones in flatfish (Truscott et al. 1992; Idler et al. 1995). At higher exposures, concentrations of biologically active sex steroids (testosterone and 11-ketotestosterone) were also reduced (Idler et al. 1995). Although female fish were not tested in these studies, glucuronide conjugates are also major metabolites of estradiol in winter flounder (Truscott 1983). From these results, one could presume similar effects would occur in female flounder following oil exposure. In a similar experiment, female Atlantic croaker were exposed to the water-soluble fractions of diesel fuel oil (25-50 ppm) and naphthalene (0.5-1.0 ppm) for 5-10 weeks during reproductive development.

These fish exhibited decreased secretion of pituitary gonadotropins as well as a reductions in ovarian production and plasma concentrations of the female sex steroid, 17-β estradiol (Thomas and Budiantara 1995).

Altered gonadal development and inhibited spawning. Declines in plasma sex steroid concentrations are associated with both inhibited gonadal development and inhibited spawning in several studies in which fish were exposed to oil or to ACs from other sources. In English sole from urban areas in Puget Sound, elevated bile FAC levels are associated with inhibited gonadal development in female sole (Johnson et al. 1988, 1993, unpublished data); for example, in one contaminated waterway, female English sole with FAC-NPH concentrations between 100,000 and 300,000 ng equivalents/mg bile protein have about a 25% decreased likelihood of maturation compared to fish with FAC levels that are lower, while those with FAC levels of 300,000 to 500,000 NPH ng equivalents/mg bile protein have only about a 5-10% likelihood of gonadal development (Figure 5). Biliary FAC concentrations in the same range noted above have also been associated with inhibition of spawning (Casillas et al. 1991). In that study, only 40% of English sole from Eagle Harbor, a site which has sediment AC concentrations ranging from 10-100 ppm (wet wt), spawned successfully, as opposed to 80-90% spawning success for female sole from a minimally contaminated reference site. Similar to the findings on plasma E2 concentrations, inhibited gonadal development was not observed in winter flounder from Boston Harbor and Raritan Bay with biliary FAC concentrations as high as 1,000,000 ng NPH equivalents/g bile or estimated 150,000 ng NPH equivalents/mg bile protein (Johnson et al. 1994); however, no data are available on the effects of acute AC exposure on spawning ability in this species.

The resorption or deterioration (atresia) of eggs is a common reaction to exposure to oil or ACs from other sources. For example, in oil-exposed flathead sole with biliary FAC concentrations of approximately 75,000 ng PHN equivalents/mg bile protein or

300,000 ng NPH equivalents/mg bile protein, increased atresia of yolked oocytes was found; the prevalence of atresia increased by about 40% relative to control animals (Johnson et al. 1995). Winter flounder from Mystic River in Boston Harbor showed increased atresia at biliary FAC-NPH concentrations of 300,000-1,000,000 ng/g bile (no protein corrections were done in this study), as well as reductions in egg size (Johnson et al., 1994). Biliary FAC-NPH concentrations well above this range were seen in winter flounder collected in February and March from all of the salt ponds (but not the Narrow River) following the NCOS (Figure 6 and Appendix 1).

Impaired ovarian recrudescence and increased oocyte atresia were also observed in female Atlantic croaker *(Micropogonias undulatus)* exposed to the water soluble fraction of diesel fuel oil (2.5-5% by volume) or naphthalene (0.5-1.0 ppm). Both pollutants blocked sexual maturation in some fish and impaired ovarian recrudescence in others. The majority of oocytes in exposed fish were undeveloped and widespread oocyte atresia was evident at higher concentrations of these polycyclic aromatic hydrocarbons (PAH). In gravid females, exposure to these xenobiotics appeared to interfere with final oocyte maturation and spawning (Thomas and Budiantara 1995).

There is also some evidence that exposure to very low concentrations of oil may accelerate egg development. In starry flounder, exposure to concentrations of 100 to 200 ppb of the water soluble fraction of Cook Inlet crude oil for 1-3 weeks resulted in accelerated egg maturation (Whipple et al. 1978). However, in this same experiment, accelerated development was associated with a decline in egg quality, and an increased incidence of abnormal or dead eggs. The estimated decline in egg viability as a result of oil exposure was around 15-30%. Moreover, accelerated maturation could result in inappropriate timing of egg release so that food availability or environmental conditions for larval growth are sub-optimal.

Reduced embryo and larval viability. Oil exposure studies conducted during the late 1970's indicated that oil exposure may reduce egg and larval viability in winter

flounder (Kuhnhold et al. 1978). In these experiments, both direct exposure of winter flounder eggs to 100 ppb water-accommodated No. 2 fuel oil or exposure of gravid adults to 100-1000 ppb of oil in water resulted in reduced viable hatch, hatching delay, and larval abnormalities. Moreover, winter flounder exposed to ACs from other sources (e.g., industrial activities) also appear to experience reduced egg and larval viability at exposure levels comparable to those found in the NCOS fish. Winter flounder from industrial areas in Boston Harbor exhibited 10-30% declines in fertilization success, % hatch, % viable hatch, larval yolk sac lipid concentrations and yolk sac size, and larval size in comparison to reference fish (Nelson et al. 1991; Perry et al. 1991), as well as reduced egg size and increased ovarian atresia (Johnson et al. 1994). Mean biliary FAC-NPH concentrations in winter flounder from these sites ranged from 280,000 to 1,000,000 ng/g bile, or approximately 70,000 to 150,000 NPH equivalents/mg bile protein. In English sole, biliary FAC concentrations in this same range were associated with reduced fertilization success (about a 50% reduction in fertilization success compared to control animals) and a 10-15% reduction in the proportion of normal larvae produced (Casillas et al. 1991).

A variety of other studies also suggest that injury to fish embryos or larval viability may occur at exposure to aqueous concentrations of oil as low as 0.5 ppm. Capelin *(Mallotus villosus)* embryos exposed from fertilization to hatch to the water-soluble fraction of Hibernia crude oil exhibited sublethal effects at concentrations greater than or equal to 0.5 ppm. These effects included delayed or accelerated hatching, reduced size resulting from a reduction in the rate of yolk conversion, and reduced pigmentation (Paine 1989). Exposure of developing pollock (*Theragra chalcogramma*) embryos to static water-soluble fractions (WSF) of Cook Inlet crude oil in seawater at concentrations of 2 ppm and above slowed initial development, produced shorter larvae, and caused a variety of morphological abnormalities. Prehatch mortality was reduced by up to 26%, and those larvae that survived were malformed, smaller, and

had poorer survival potential than controls (Carls and Rice 1990). Unusually high proportions of abnormal herring larvae *(Clupea harengus)* were also observed following an oil spill in the Bothnian Sea, with 30-40% of larvae exhibiting notochord curvature or damage (Urho and Hudd, 1989). Similar impacts have been observed in African mudfish larvae *(Clarias gariepinus)*, exposed to petroleum refinery effluent. Exposure to 5% percent petroleum refinery effluent stimulated early hatching (approximately 16 hours after fertilization), while 50-100% effluent delayed hatching until after 25-31 hours after fertilization. Spinal flexures of larvae (abnormal larvae) was common, and larval survival declined at doses above 10% effluent (Onuoha and Nwadukwe 1990).

Oil exposure may also have a detrimental effect on metamorphosis of flatfish larvae. While specific data are unavailable for winter flounder or other flatfish, in the green tree frog *(Hyla cinerea)*, exposure to crankcase oil resulted in reduced growth at concentrations of 50-100 mg/L, and failure of metamorphosis at a concentration of 100 mg/L (Mahaney 1994).

Growth impairment in juvenile fish. Recent studies done in our laboratories on growth of juvenile English sole exposed to AC-contaminated sediments indicate significant growth impairment in fish with biliary FAC concentrations in the range of 200,000 to 500,000 NPH ng equivalents/mg bile protein or 50,000 to 120,000 PHN ng equivalents/mg bile protein (L. Kubin, unpublished data). Growth reductions did not become apparent until approximately 90 days after exposure began. Reduced growth has also been observed in juvenile pink salmon fed oil-contaminated food (Wang et al. 1993, Mortensen and Carls 1994) and in Atlantic salmon parr exposed to water-borne crude oil (Vignier et al. 1992).

Altered immune response. At sediment PHN concentrations of 0.1-0.2 ppm and total PAH concentrations of about 25 ppm and above, winter flounder showed significant declines in numbers of melanomacrophage centers in liver, which could be evidence of reduced immune response (Payne and Fancey 1989). Alterations in

immune function, including suppression of secondary immune response, have also been observed in juvenile salmon exposed to PAHs from industrial sources (Arkoosh et al. 1994).

Increased liver weight. At sediment PHN concentrations of 0.1-0.2 ppm and total PAH concentrations of 25 ppm and above winter flounder show significant increases in hepatosomatic index (Truscott et al. 1992; Payne et al. 1988), which could be due to hypertrophy or proliferation of liver cells (Heath 1987).

Potential Impacts of the NCOS on Winter Flounder Reproductive Output

Based on the data cited above, winter flounder from the salt ponds impacted by the NCOS would be likely to show a wide range of sublethal effects, leading to an overall reduction in reproductive capacity. The reasoning for this statement is given below.

Reductions in concentrations of plasma sex steroids or their metabolites have been observed at biliary FAC concentrations as low as 50,000 ng PHN equivalents/mg bile protein or 100,000 ng NPH equivalents/mg bile protein in several field and laboratory studies. As shown in Figure 7, 40% of the winter flounder sampled in the salt ponds during the winter of 1996 had FACs-PHN concentrations at or above 50,000 ng PHN equivalents/mg bile protein, and 70% of the same winter flounder had FACs-NPH concentrations at or above 100,000 ng NPH equivalents/mg bile protein. Consequently, changes in plasma sex hormone levels could be expected in a substantial proportion (up to 70%) of the winter flounder population present in the salt ponds following the NCOS. The actual proportion of winter flounder affected might be somewhat lower, however, because there is some indication that this species may be less sensitive than other flatfish to the effects of contaminants on steroid hormone levels

(Johnson et al. 1994). It should be noted, however, that those data were obtained from animals chronically exposed to industrially-derived PAHs, and flounder may respond differently to acute exposure to very high concentrations of oil, such as occurred following the NCOS. There is some evidence of this from studies with other flatfish. For example, although rock sole experienced substantial reductions in plasma E2 concentrations following acute exposure to PBCO in the laboratory (Johnson et al. 1995), no significant negative relationship was found between biliary FACs and plasma E2 concentrations in field studies with this species (Johnson et al. in press).

As noted above, in English sole exposed chronically to ACs from industrial sources, we have observed inhibition of gonadal development in fish with biliary FAC concentrations of 100,000 ng NPH equivalents/mg bile protein. However, inhibited gonadal development was not observed in winter flounder from Boston Harbor and Raritan Bay with elevated biliary FAC concentrations (Johnson et al. 1994). Moreover, because winter flounder undergo most of their gonadal development offshore, and only move into the nearshore area and salt ponds for final maturation and spawning, it is not likely winter flounder were exposed to oil spilled from the North Cape during early phases of ovarian development. Accordingly, inhibition of vitellogenesis was not considered as a factor in the overall evaluation of reproductive impairment in winter flounder as a result of the NCOS. Winter flounder in the Boston Harbor study did exhibit increased oocyte atresia, however, and this response would be expected in a high proportion of flounder exposed to oil following the NCOS, resulting in a loss in egg production.

Oil exposure may also have affected final oocyte development and spawning in some winter flounder, either by altering plasma steroid concentrations or through other mechanisms. In English sole, vitellogenic females chronically exposed to ACs, with biliary FAC levels of 70,000 to 150,000 ng NPH equivalents/mg bile protein exhibited reduced spawning ability (Casillas et al. 1991). Spawning failure was associated with

plasma estradiol concentrations of 40-50% of average concentrations in reference fish of comparable sexual maturity (Casillas et al. 1991); however, it was not clear from this study whether spawning inhibition was due to the low plasma E2 levels, or to concurrent effects of PAHs on pituitary function or maturation inducing steroids (e.g., see Thomas and Budiantara 1995). In PBCO exposure study (Johnson et al. 1995), plasma estradiol concentrations and in vitro estradiol production in female flatfish declined by 40-50% relative to controls in moderate to high dose treatments, where mean biliary FAC-NPH concentrations were at or above 500,000 NPH equivalents/mg bile protein. Comparable biliary FACs-NPH levels were found in roughly 20% of winter flounder sampled from all the salt ponds, and in 30% of flounder from Point Judith Pond (Figure 7). Because of species sensitivity issues, we cannot be certain how this level of acute oil exposure may have affected winter flounder, but there is some risk that it may have produced comparable declines in plasma hormone concentrations and associated effects on final oocyte maturation, with subsequent spawning failure. Data showing inhibited spawning in Atlantic croaker (Thomas and Budiantara 1995) and alterations in sex pheromones in winter flounder (Truscott et al. 1992; Idler et al. 1995) exposed to oil further support the possibility of spawning impairment in winter flounder impacted by the NCOS.

Of those flounder that spawned successfully, we might expect significant declines in egg and larval viability in a high proportion of fish. At biliary FAC concentrations of about 100,000 ng NPH equivalents/mg bile protein, English sole from Eagle Harbor, a PAH-contaminated site in Puget Sound, exhibited approximately a 50% reduction in fertilization success, whereas larval viability was reduced by about 10% (Casillas et al. 1991). Studies in winter flounder from Boston Harbor show about a 10-30% reduction in larval viability (Nelson et al. 1991; Perry et al. 1991) at FACs-NPH around 300,000 [estimated to be about 70,000 corrected for protein (Johnson et al. 1994)]. Nearly 70% of flounder from all the salt ponds and 85% of flounder from Point Judith

Pond had FAC levels at or above this range in the winter sampling. If we assume a scenario in which winter flounder suffered from the combined impact of spawning impairment, reduced egg viability, and reduced larval viability, the overall reproductive output of Judith Pond winter flounder is estimated to be about 35-40% of the reproductive output of fish from unimpacted ponds. It should be noted that this estimation of impact is extrapolated from our studies linking increased exposure to reductions in reproductive outputs of English sole, so may overestimate effects on the less sensitive winter flounder. However, it is based on measurements of maternal exposure only. Thus, there may be additional effects on male reproductive capacity, as well as impacts on spawned demersal eggs, larvae, and developing or resident juveniles exposed to oiled sediments.

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References

Arkoosh, M. R., E. Clemons, M. Myers and E. Casillas. 1994. Suppression of B-cell mediated immunity in juvenile chinook salmon (*Oncorhynchus tshawytscha*) after exposure to either a polycyclic aromatic hydrocarbon or to polychlorinated biphenyls. Immunopharmacology and Immunotoxicology. 16(20) pp. 293-314

Carls, M. G. and S. D. Rice. 1990. Abnormal development and growth reductions of pollock *Theragra chalcogramma* embryos exposed to water-soluble fractions of oil. Fish. Bull. 88:29-37.

Casillas, E., Misitano, D., Johnson, L., Rhodes, L., McCain, B. and Varanasi, U. 1991. Spawning and reproductive success of female English sole *(Parophrys vetulus)* from urban and non-urban sites of Puget Sound, Washington. Mar. Env. Res. 31:99-122.

Collier, T.K. and B.F. Anulacion. 1992. Bioindicators of contaminant exposure and effects in fish removed from polluted environments in Puget Sound. PANWAT Proceedings 9:15. Richland, WA. Presented 9/26/92.

Collier, T.K. and U. Varanasi. 1991. Hepatic activities of xenobiotic metabolizing enzymes and biliary levels of xenobiotics in English sole *(Parophrys vetulus)* exposed to environmental contaminants. *Arch. Environ. Contam. Toxicol.* 20:462-473.

Collier, T.K., S.V. Singh, Y.C. Awasthi, and U. Varanasi. 1992. Hepatic xenobiotic metabolizing enzymes in two species of benthic fish showing different prevalences of contaminant-associated liver neoplasms. *Toxicol. Appl. Pharmacol.* 113:319-324.

Collier, T.K., M.M. Krahn, C.A. Krone, L.L. Johnson, M.S. Myers, S-L. Chan and U. Varanasi. 1993. Oil exposure and effects in subtidal fish following the *Exxon Valdez* oil spill. In: Proceedings 1993 International Oil Spill Conference. USCG, API, EPA, Tampa, FL, pp. 301-305.

Collier, T.K., C.A. Krone, M.M. Krahn, J.E. Stein, S.-L. Chan, and U. Varanasi. 1996a. Petroleum exposure and associated biochemical effects in subtidal fish after the *EXXON Valdez* oil spill. Am. Fish. Soc. Symp. 18:671-683.

Collier, T.K., T. Hom, B. F. Anulacion, L. P. Chicchelly, Jr., and J. E. Stein. 1996b. Concentrations of fluorescent aromatic compounds in bile of fish sampled from the salt ponds of Rhode Island five months after the barge *North Cape* oil spill. Draft report submitted to Salt Pond Technical Working Group for the North Cape oil spill. December, 1996.

Heath, A. G. 1987. Water Pollution and Fish Physiology. CRC Press, Boca Raton, FL. 245 pp.

Hinga, K.R. 1997. Concentrations over time of North Cape oil in water and sediments in Rhode Island's south shore ponds. Contract report to Industrial Economics, Inc. (Task Order # 50111). January, 1997.

Hom, T., U. Varanasi, J.E. Stein, C.A. Sloan, K.L. Tilbury and S.-L. Chan. 1996. Assessment of the exposure of subsistence fish to aromatic compounds following the Exxon Valdez oil spill. In. S.D. Rice, R.B. Spies, D.A. Wolfe and B.A. Wright, Eds., Proceedings of the Exxon Valdez Oil Spill Symposium. American Fisheries Society Symposium 18:856-866.

Idler, D.R., Y. P. So, G. L. Fletcher, and J. F. Payne. 1995. Depression of blood levels of reproductive steroids and glucuronides in male winter flounder *(Pleuronectes americanus)* exposed to small quantities of Hibernia crude, used crankcase oil, oily drilling mud and harbour sediments in the 4 months prior to spawning in late May-June. In: Proceedings Of The Fifth International Symposium On The Reproductive Physiology Of Fish. F. W. Goetz and P. Thomas, Eds. The University of Texas at Austin, 2-8 July 1995., Fish Symposium 95, Austin, TX (USA), p. 187

Johnson, L., E. Casillas, T. Collier, B. McCain, B. and U. Varanasi. 1988. Contaminant effects on ovarian development in English sole *(Parophrys vetulus)* from Puget Sound, Washington. Can. J. Fish. Aquat Sci. 45:2133-2146.

Johnson, L.L., E. Casillas, S. Sol, T. Collier, J. Stein, and U. Varanasi. 1993. Contaminant effects on reproductive success in selected benthic fish species. Mar. Env. Res. 35:165-170.

Johnson, L. L., J. E. Stein., T. K. Collier, E. Casillas, and U. Varanasi. 1994. Indicators of reproductive development in prespawning female winter flounder *(Pleuronectes americanus)* from urban and nonurban estuaries on the northeast Atlantic coast. Sci. Total Environ. 141:241-260.

Johnson, L. L., J. E. Stein, T. Hom, S. Sol, T. K. Collier, and U. Varanasi. 1995. Effects of exposure to Prudhoe Bay crude oil on reproductive function in gravid female flatfish. Environmental Sciences 3:67-81.

Johnson, L. L., D. Misitano, S. Sol, G. Nelson, B. French, G. Ylitalo, T. Hom. in press. Contaminant effects on ovarian development and spawning success in rock sole *(Lepidopsetta bilineata)* from Puget Sound, WA. Trans. Am. Fish. Soc.

Krahn M.M., L.D. Rhodes, M.S. Myers, L.K. Moore, W.D. MacLeod Jr. and D.C. Malins. 1986. Associations between metabolites of aromatic compounds in bile and the occurrence of hepatic lesions in English sole (Parophrys vetulus) from Puget Sound, Washington. *Arch. Environ. Contam. Toxicol.* 15:61-67.

Krahn, M.M., D.G. Burrows, G.M. Ylitalo, D.W. Brown, C.A. Wigren, T.K. Collier, S.-L. Chan, and U. Varanasi. 1992. Mass spectrometric analysis for aromatic

compounds in bile of fish sampled after the *EXXON Valdez* oil spill. *Environ. Sci. Technol.* 26:116-126.

Kuhnhold, W. W., D. Everich, J. J. Stegeman, J. Lake, and R. E. Wolke. 1978. Effects of low levels of hydrocarbons on embryonic, larval, and adult winter flounder (Pseudopleuronectes americanus). Proceed. Conf. Assess. Ecol. Impacts Oil Spills. Keystone, CO, 14-17 June 1978. AIBS, pp. 677-711.

Mahaney, P. A. 1994. Effects of freshwater petroleum contamination on amphibian hatching and metamorphosis. Environ. Toxicol. Chem. 13:259-265.

McCain, B.B., M.S. Myers, U. Varanasi, D.W. Brown, L.D. Rhodes, W.D. Gronlund, D.G. Elliott, W.A. Palsson, H.O. Hodgins, and D.C. Malins. 1982. Pathology of two species of flatfish from urban estuaries in Puget Sound. DOC [EPA Interagency Energy/Environment, Research and Development Program Report (EPA-600/7-82-001)], 100 pp.

Mortensen, D. G. and M. G. Carls. 1994. Effects of crude oil ingestion on growth and microstructure of juvenile pink salmon (Oncorhynchus gorbuscha) otoliths. Proc. Northeast Pacific Pink Salmon and Chum Workshop, pp. 183-184.

Myers, M.S., and L.D. Rhodes 1988. Morphologic similarities and parallels in geographic distribution of suspected toxicopathic liver lesions in: rock sole *Lepidopsetta bilineata* , starry flounder *Platichthys stellatus* , Pacific staghorn sculpin *Leptocottus armatus* , and Dover sole *Microstomus pacificus* as compared to English sole *Parophrys vetulus* from urban and non-urban embayments of Puget Sound, Washington. *Aquatic Toxicol.* 11:410-411.

Nelson, D. A., J. E. Miller, d. Rusanowsky, R. A. Greig, G. R. Sennefelder, R. Mercado-Allen, C. Kuropat, E. Gould, F. P. Thurberg and A. Calabrese. 1991. Comparative reproductive success of winter flounder in Long Island Sound: A three-year study (Biology, biochemistry, and chemistry). Estuaries 4:318-331.

Onuoha, G. C. and F. O. Nwadukwe. 1990. Influence of liquid petroleum refinery effluent on the hatching success of *Clarias gariepinus* (African mud fish) eggs. Environ. Ecol. 8:1201-1206.

Paine, M.D. 1989. Sublethal effects of Hibernia crude oil on capelin (Mallotus villosus) embryos. p. 493, RAPP. P.-V. REUN. CIEM., 191:493.

Payne, J. F., J. Kiceniuk, L. L. Fancy, U. Williams, G. L. Fletcher, A. Rahimtula, and B. Fowler. 1988. What is a safe level of polycyclic aromatic hydrocarbons for fish?: Subchronic toxicity study on winter flounder *(Pseudopleuronectes americanus).* Can. J. Fish. Aquat. Sci. 45:1983-1993.

Payne, J. F. and L. F. Fancey. 1989. Effect of polycyclic aromatic hydrocarbons on immune responses in fish: Changes in melanomacrophage centers in flounder

(*Pseudopleuronectes americanus*) exposed to hydrocarbon-contaminated sediments. Mar. Environ. Res. 28:431-435.

Perry, D. M., J. B. Hughes, and A. T. Hebert. 1991. Sublethal abnormalities in embryos of winter flounder, *Pseudopleuronectes americanus*, from Long Island Sound. Estuaries 14:306-317.

Sol, S.-Y., L. L. Johnson, T. K. Collier, M. M. Krahn, and U. Varanasi. 1995. Contaminant effects on reproduction in North Pacific flatfish. Proc. Int. Pac. Flatfish Conf., Anchorage, AK 1994 , pp. 547-560.

Thomas, P. and L. Budiantara. 1995. Reproductive life history stages sensitive to oil and naphthalene in Atlantic croaker. Mar. Environ. Res. 39:147-150.

Truscott, B. 1983. Steroid metabolism in fish. 2. Testosterone metabolites in the bile of the marine winter flounder *Pseudopleuronectes americanus* and the freshwater Atlantic salmon *Salmo salar* . Gen. Comp. Endocrinol. 51:460-470.

Truscott, B., D. R. Idler, and G. L. Fletcher. 1992. Alteration of reproductive steroids of male winter flounder (*Pleuronectes americanus*) chronically exposed to low levels of crude oil in sediments. Can. J. Fish. Aquat. Sci. 49:2190-2195.

Urho, L and R. Hudd. 1989. Sublethal effects of an oil spill on fish (herring) larvae in the Northern Quark, in the Baltic. Rapp. P.-V. Reun. Ciem. 191:494.

Varanasi, U., T. K. Collier, C. A. Krone, M. M. Krahn, L. L. Johnson, M. S. Myers, and S.-L. Chan. 1995. Assessment of oil spill impacts on fisheries resources: Measurement of hydrocarbons and their metabolites, and their effects, in important species, Exxon Valdez Oil Spill State/Federal Natural Resource Damage Assessment Final Report (Subtidal 7), National Marine Fisheries Service, National Oceanic and Atmospheric Administration, Seattle, Washington.

Vignier, V., J. H. Vandermeulen, and A. J. Fraser. 1992. Growth and food conversion by Atlantic salmon parr during 40 days exposure to crude oil. Trans. Am. Fish. Sic. 121:322-332.

Wang, S. Y., J. L. Lum, M. G. Carls, and S. D. Rice. 1993. Relationship between growth and total nucleic acids in juvenile pink salmon, Oncorhynchus gorbuscha, fed crude oil contaminated food. Can. J. Fish. Aquat. Sci. 50:996-1001.

Whipple, J. A., T. G. Yocum, D. R. Smart and M. H. Cohen. 1978. Effects of chronic concentrations of petroleum hydrocarbons on gonadal maturation in Starry Flounder, Platichthys stellatus. Proceed. Conf. Assess. Ecol. Impacts Oil Spills. Keystone, CO, 14-17 June 1978. AIBS, pp. 757-806.

Table 1. Concentrations of fluorescent aromatic compounds in bile of fish sampled from Rhode Island salt ponds and the Narrow River following the North Cape oil spill. Data shown are for measurements at phenanthrene (PHN) wavelengths only. Data for measurements at naphthalene wavelengths are given in Appendix 1.

Species	Site	Time	N[a]	PHN[b]	PHN/prot[c]
Winter Flounder					
	Point Judith				
	Jerusalem	Feb/Mar	8	1,100,000 ± 260,000	110,000 ± 26,000
		July	5	66,000 ± 13,000	37,000 ± 8,600
	Ram Island	Feb/Mar	10	830,000 ± 240,000	81,000 ± 12,000
		July	5	120,000 ± 20,000	60,000 ± 10000
	Turner Point	Feb/Mar	10	370,000 ± 69,000	58,000 ± 11,000
		July	•	•	•
	Ninigret Pond	Feb/Mar	14	390,000 ± 110,000	55,000 ± 11,000
		July	•	•	•
	Quonochontaug Pond	Feb/Mar	2	110,000 ± 55,000	26,000 ± 12,000
		July	6	28,000 ± 3,600	13,000 ± 2,700
	Narrow River	Feb/Mar	6	22,000 ± 11,000	6,000 ± 1,300
		July	5	19,000 ± 2,700	12,000 ± 5,500
	Winnapaug Pond	Feb/Mar	•	•	•
		July	6	20,000 ± 3,500	15,000 ± 5,700
Striped Bass					
	Point Judith				
	Ram Island	Feb/Mar	•	•	•
		July	3	38,000 ± 1,400	26,000 ± 1,100
	Turner Point	Feb/Mar	•	•	•
		July	3	42,000 ± 16,000	30,000 ± 5,600
	Quonochontaug Pond	Feb/Mar	•	•	•
		July	5	17,000 ± 4,700	6,200 ± 800

[a] N = number of samples analyzed. Numbers followed by a C indicate the number of composite samples analyzed.
[b] Fluorescence measured at phenanthrene (PHN) wavelengths. Units are ng PHN equiv/g bile. Values are mean ± SE
[c] Fluorescence corrected for protein content. Units are ng PHN equiv/mg biliary protein.

Species	Site	Time	N[a]	PHN[b]	PHN/prot[c]
Mummichog					
	Point Judith				
	Jerusalem	Feb/Mar	•	•	•
		July	2 C	53,000 ± 710	7,800 ± 400
	Ram Island	Feb/Mar	•	•	•
		July	2 C	38,000 ± 1,400	6,400 ± 22
	Turner Point	Feb/Mar	•	•	•
		July	2 C	42,000 ± 16,000	7,700 ± 1,300
	Ninigret	Feb/Mar	•	•	•
		July	2 C	21,000 ± 95	3,700 ± 210
	Ninigret 2	Feb/Mar	•	•	•
		July	2C	13,000 ± 2,300	2,800 ± 550
	Quonochontaug Pond	Feb/Mar	•	•	•
		July	1 C	10,000	10,000
	Potter Pond	Feb/Mar	•	•	•
		July	2 C	14,000 ± 440	3,000 ± 162
	Succotash Marsh	Feb/Mar	•	•	•
		July	2 C	38,000 ± 1,400	12,000 ± 800
	Trustom POND	Feb/Mar	•	•	•
		July	2 C	14,000 ± 3,400	4,700 ± 1,000
	Cards Pond	Feb/Mar	•	•	•
		July	2C	32,000 ±12,000	6,100 ± 4,000
	Narrow River	Feb/Mar	•	•	•
		July	2 C	16,000 ± 3,800	4,400 ±1,200
	Winnapaug	Feb/Mar	•	•	•
		July	1 C	12,000	4,100

[a] N = number of samples analyzed. Numbers followed by a C indicate the number of composite samples analyzed.
[b] Fluorescence measured at phenanthrene (PHN) wavelengths. Units are ng PHN equiv/g bile. Values are mean ± SE
[c] Fluorescence corrected for protein content. Units are ng PHN equiv/mg biliary protein.

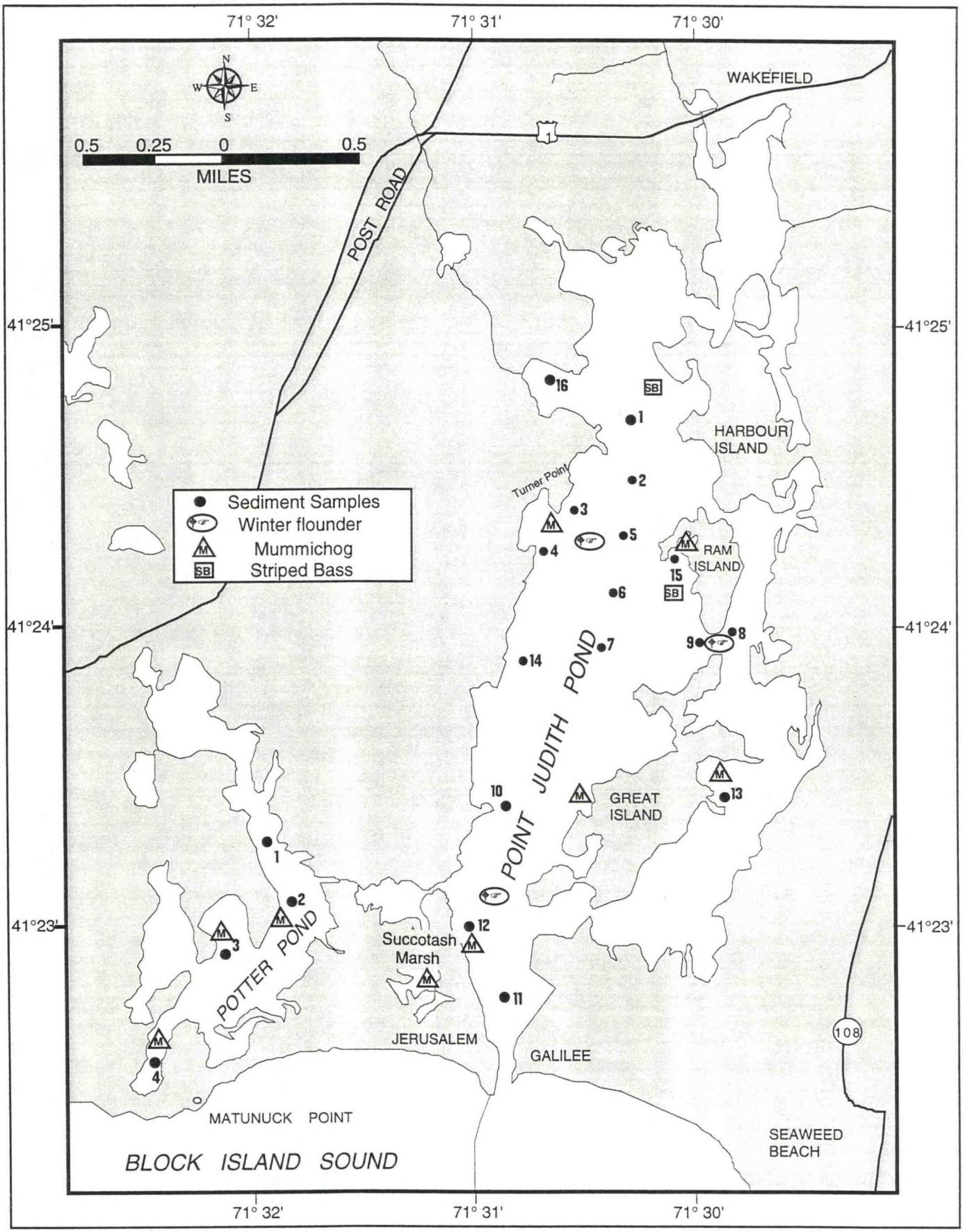


Figure 1. Fish and sediment sampling sites in Pt. Judith and Potter Ponds.

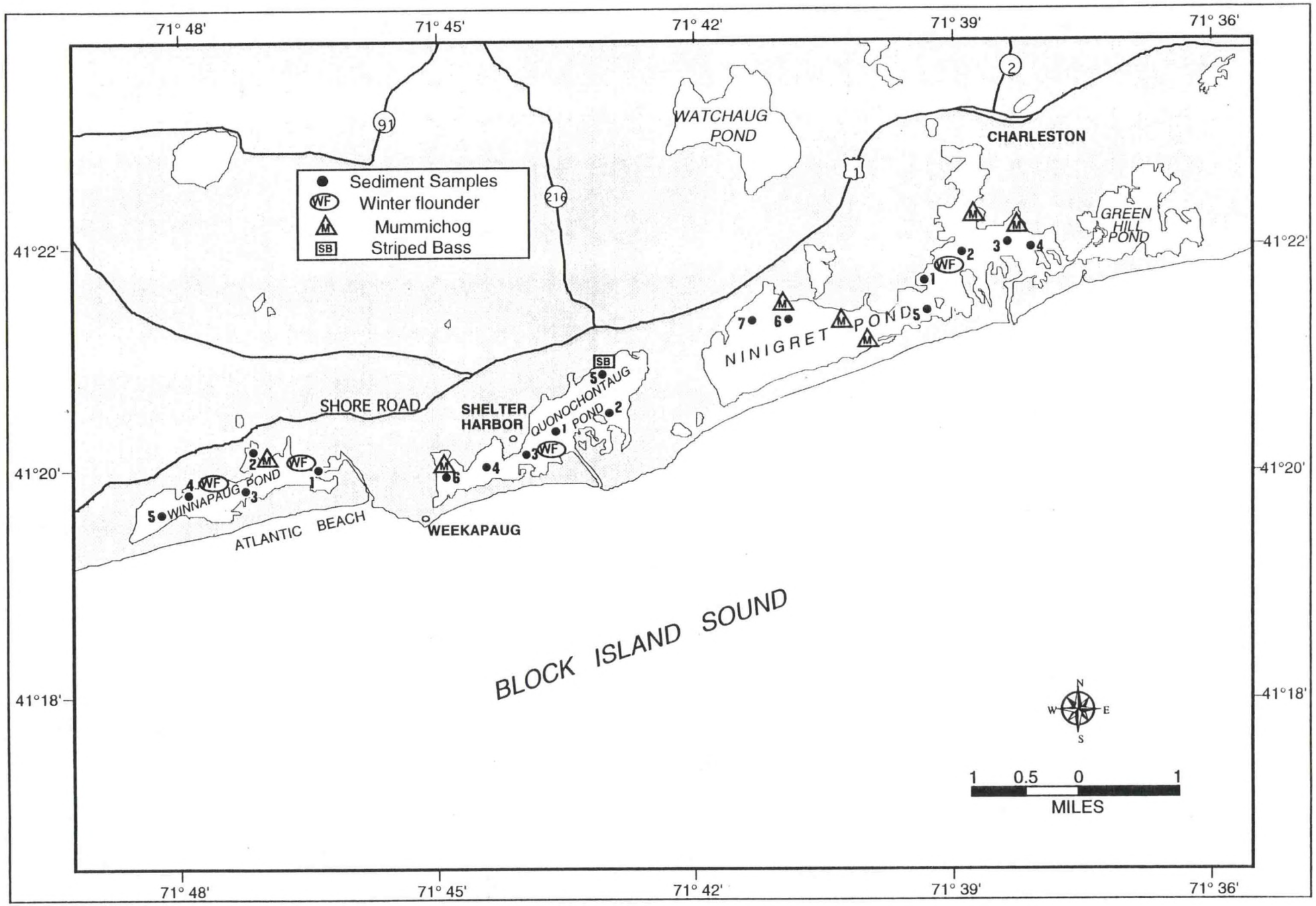


Figure 1 (cont'd). Fish and sediment sampling sites in Ninigret, Quonochontaug, and Winnapaug Ponds.

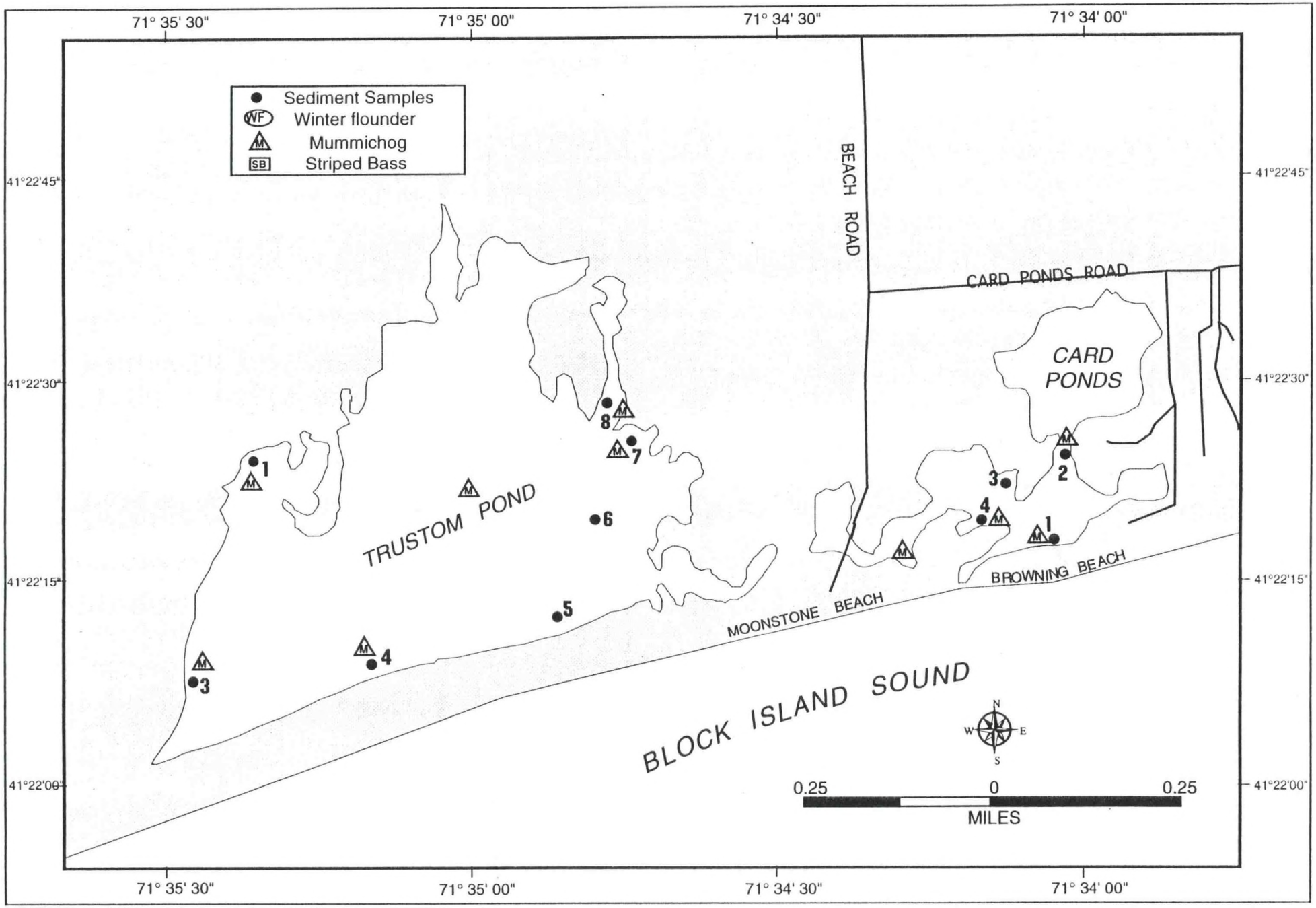


Figure 1 (cont'd). Fish and sediment sampling sites in Trustom and Card Ponds.

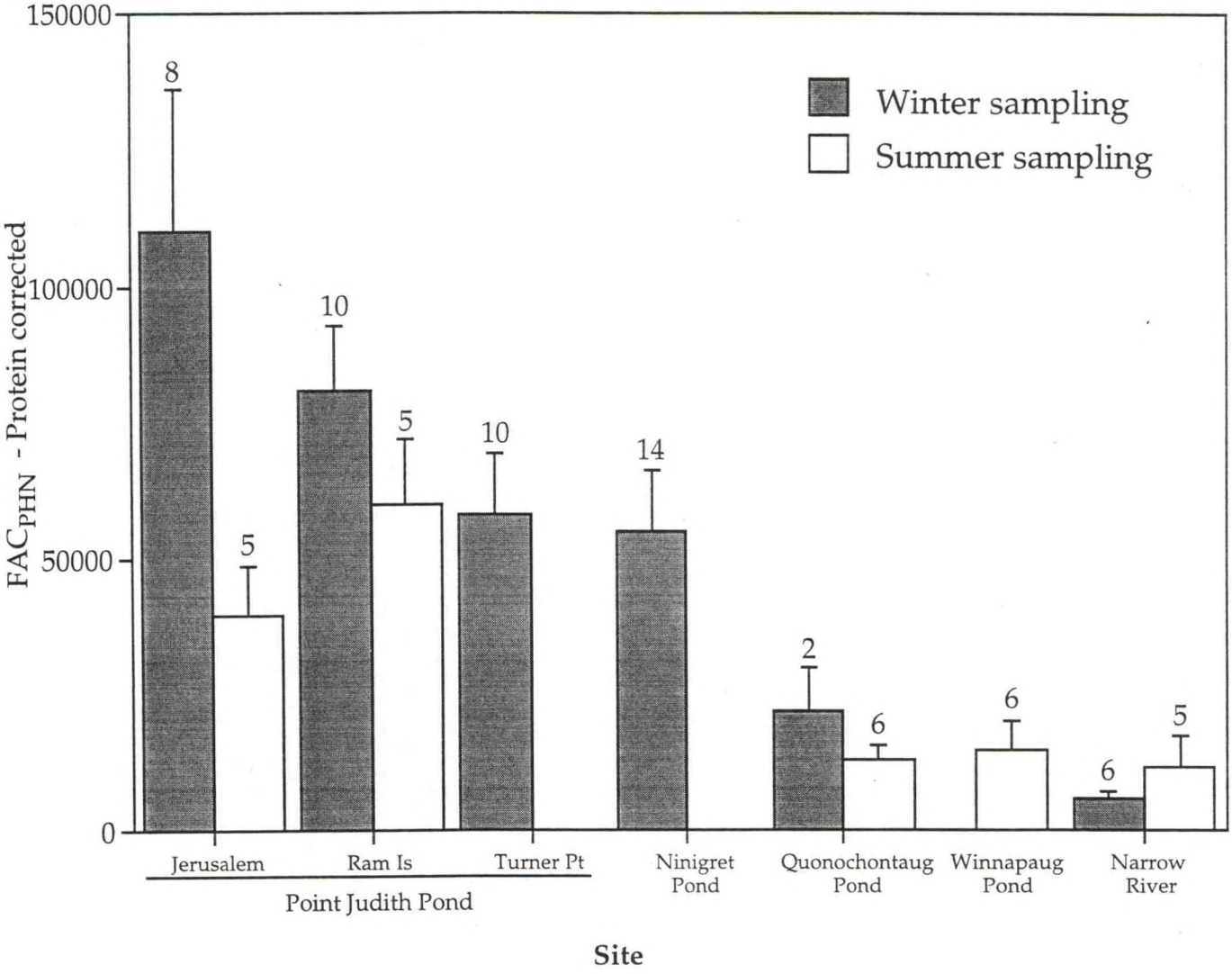


Figure 2. Mean levels of fluorescent aromatic compounds (FACs) in bile of winter flounder sampled from the salt ponds and Narrow River (reference site) in the winter and summer of 1996. Error bars denote standard error of the mean (SE), and numbers above error bar denote the number of samples analyzed. Data are for analyses done at phenanthrene (PHN) wavelengths, and corrected for protein content. Data at naphthalene (NPH) wavelengths, and without protein correction, are given in Appendix 1.

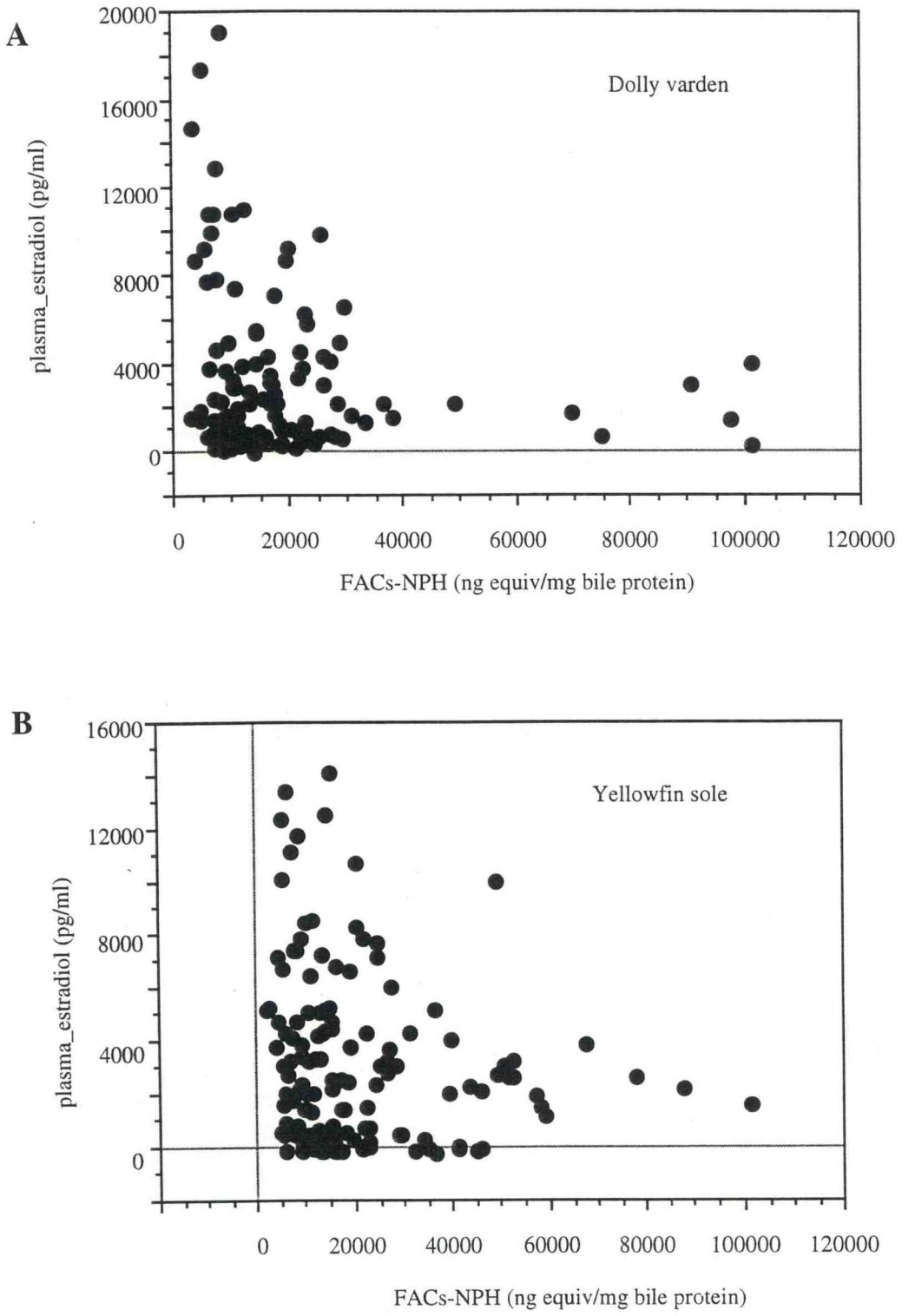


Figure 3. Relationships between plasma estradiol concentration (pg/ml) and biliary FAC levels in a) female dolly varden and b) female yellowfin sole sampled following the Exxon Valdez oil spill. Data from Varanasi et al. (1995).

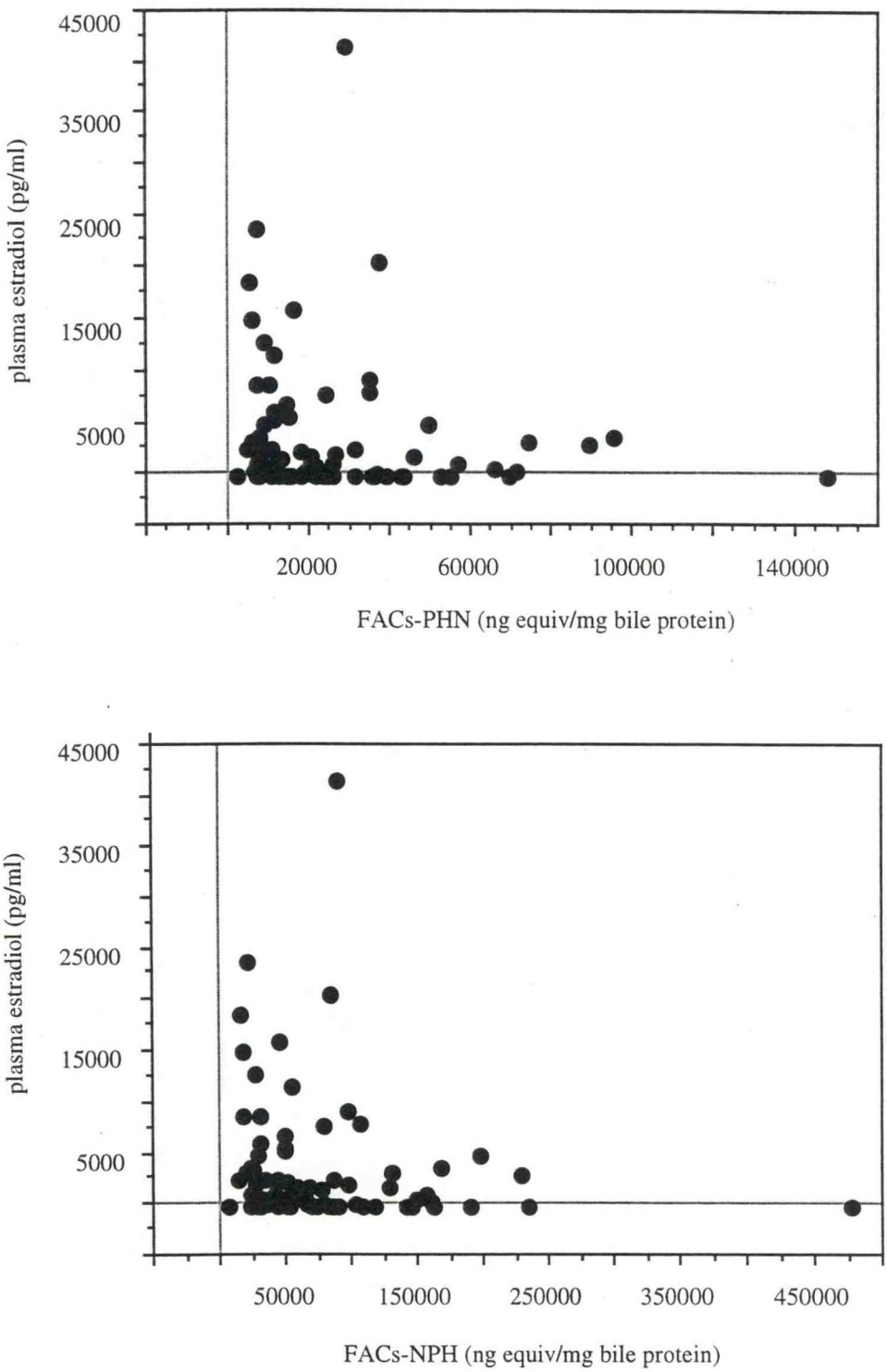
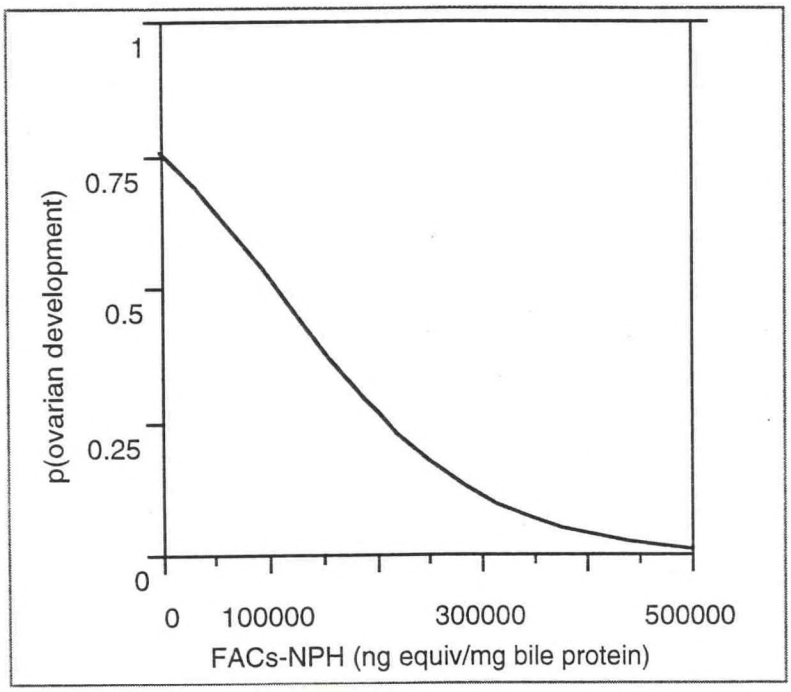


Figure 4. Relationship between plasma estradiol concentrations and biliary FAC levels in female English sole from an urban embayment in Puget Sound. From Johnson et al. (1988) and Johnson et al. (unpublished data).



Whole-Model Test

Model	LogLikelihood	DF	ChiSquare	Prob>ChiSq
Difference	3.811541	1	7.623082	0.005763
Full	52.697399			
Reduced	56.508940			

RSquare (U)	0.0675
Observations (or Sum Wgts)	83

Figure 5. Probability (p) of ovarian development in adult female English sole (age 5+) as a function of biliary FAC-NPH level (ng equiv/mg bile protein). A similar relationship was observed for biliary FAC-PHN concentrations. Probability of ovarian development was estimated using logistic regression analysis. Data from Johnson et al. (unpublished data).

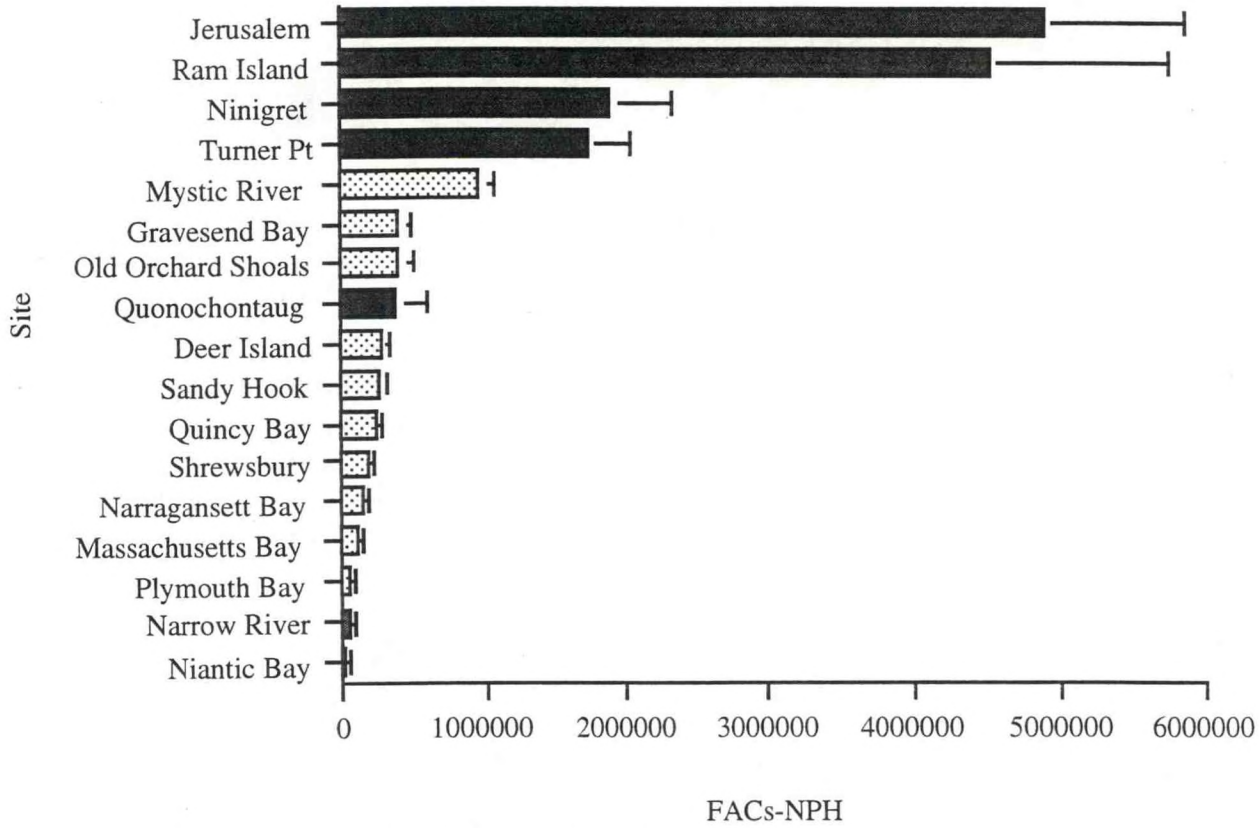
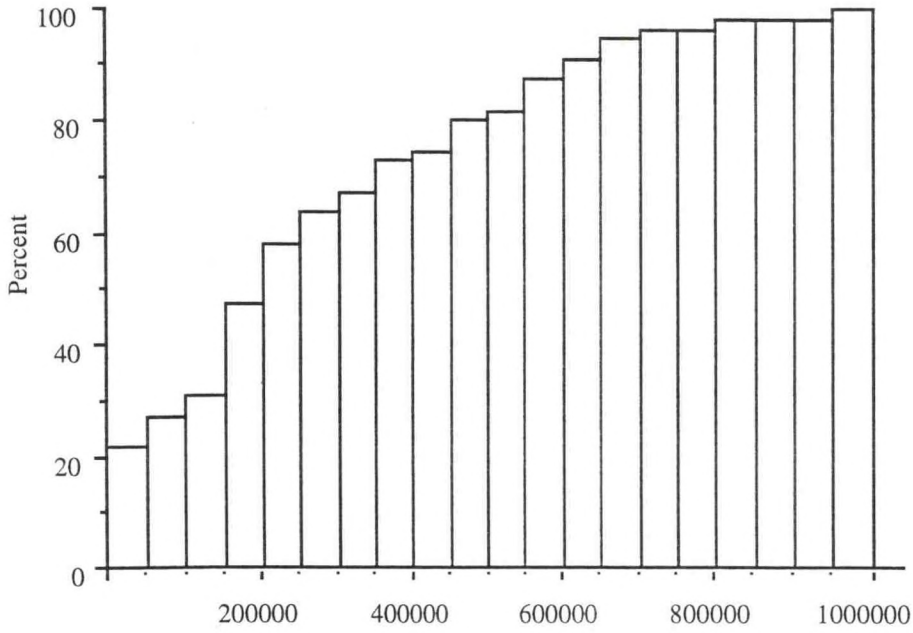


Figure 6. Biliary FAC concentrations (ng/g bile, mean ± SE, not corrected for protein content) in winter flounder from urban and non-urban embayments along the Northeast coast of the United States, as compared with biliary FAC levels in winter flounder collected in the winter following the NCOS. Data for NCOS fish at NPH wavelengths and without protein correction, are given in Appendix 1. Other data from Johnson et al. (1994).



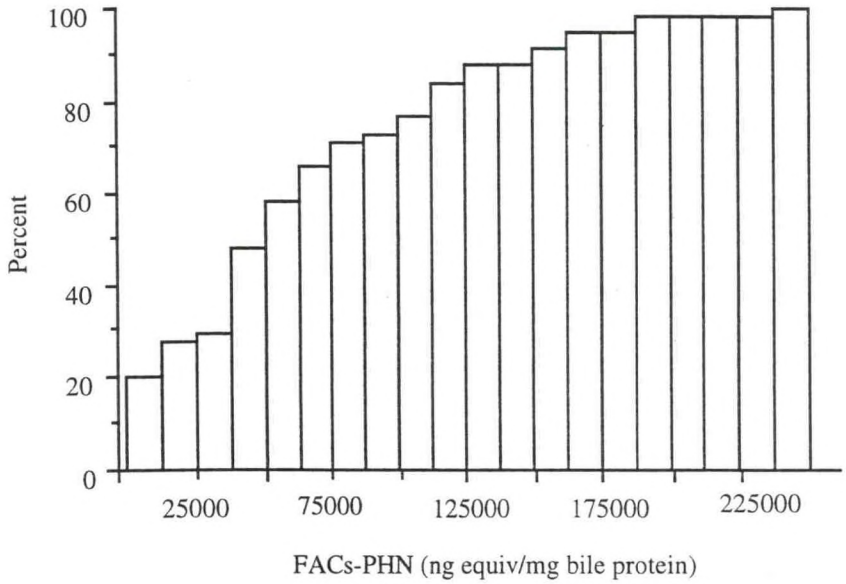


Figure 7. Frequency distributions for biliary FAC levels in winter flounder sampled in winter from the salt ponds following the NCOS. Units are ng/mg biliary protein. Data are given in Appendix 1.

APPENDIX 1

Levels of fluorescent aromatic compounds in bile of fish sampled following the *North Cape* oil spill

Appendix I. Concentrations of fluorescent aromatic compounds (FACs) in bile of individual fish sampled after the *North Cape* oil spill.

Sample ID	Species	Site	Time	FACs (ng equiv./g bile) NPH	FACs (ng equiv./g bile) PHN	FACs/Protein (ng equiv./g bile protein) NPH	FACs/Protein (ng equiv./g bile protein) PHN	Protein (mg/ml)
96-0008	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	12,000,000	2,800,000	490,000	120,000	24.3
96-0020	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	4,800,000	1,200,000	340,000	85,000	14.1
96-0026	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	1,800,000	380,000	480,000	100,000	3.7
96-0030	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	3,200,000	670,000	690,000	150,000	4.6
96-0031	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	2,400,000	450,000	140,000	26,000	17
96-0035	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	3,800,000	770,000	230,000	47,000	16.4
96-0038	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	3,400,000	740,000	210,000	46,000	16
96-0044	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	1,400,000	310,000	450,000	98,000	3.2
96-0046	Winter flounder	Pt. Judith Pond/Ram Is.	Feb/Mar	840,000	210,000	230,000	57,000	3.6
96-0049	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	2,400,000	460,000	79,000	15,000	30.9
96-0050	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	620,000	130,000	270,000	57,000	2.3
96-0057	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	3,300,000	740,000	360,000	80,000	9.3
96-0059	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	3,100,000	700,000	480,000	110,000	6.4
96-0060	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	240,000	59,000	150,000	37,000	1.6
96-0062	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	1,700,000	330,000	590,000	110,000	2.9
96-0063	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	490,000	110,000	32,000	7,200	15.3
96-0068	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	3,500,000	720,000	300,000	61,000	11.8
96-0069	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	2,800,000	630,000	170,000	39,000	16.3
96-0070	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	1,800,000	400,000	370,000	82,000	4.9
96-0071	Winter flounder	Pt. Judith Pond/Turner	Feb/Mar	730,000	130,000	330,000	60,000	2.2
96-0074	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	2,500,000	650,000	89,000	24,000	27.6
96-0075	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	9,400,000	2,500,000	680,000	180,000	13.9
96-0076	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	1,800,000	420,000	60,000	14,000	30.5
96-0077	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	4,800,000	990,000	610,000	130,000	7.9
96-0078	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	4,100,000	890,000	730,000	160,000	5.6
96-0079	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	4,400,000	890,000	560,000	110,000	8
96-0080	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	7,800,000	1,800,000	890,000	210,000	8.8
96-0081	Winter flounder	Pt. Judith Pond/Jerusalem	Feb/Mar	1,200,000	310,000	160,000	42,000	7.4
96-0084	Winter flounder	Ninigret Pond	Feb/Mar	2,800,000	840,000	170,000	51,000	16.5
96-0086	Winter flounder	Ninigret Pond	Feb/Mar	290,000	100,000	190,000	64,000	1.5
96-0088	Winter flounder	Ninigret Pond	Feb/Mar	1,700,000	440,000	170,000	42,000	10.3

Appendix I. Concentrations of fluorescent aromatic compounds (FACs) in bile of individual fish sampled after the *North Cape* oil spill.

				FACs (ng equiv./g bile)		FACs/Protein (ng equiv./g bile protein)		Protein
Sample ID	Species	Site	Time	NPH	PHN	NPH	PHN	(mg/ml)
96-0089	Winter flounder	Ninigret Pond	Feb/Mar	2,100,000	510,000	240,000	57,000	8.9
96-0092	Winter flounder	Ninigret Pond	Feb/Mar	560,000	150,000	230,000	63,000	2.4
96-0093	Winter flounder	Ninigret Pond	Feb/Mar	170,000	53,000	31,000	10,000	5.4
96-0098	Winter flounder	Ninigret Pond	Feb/Mar	350,000	91,000	170,000	46,000	2
96-0099	Winter flounder	Ninigret Pond	Feb/Mar	3,000,000	630,000	230,000	47,000	13.4
96-0100	Winter flounder	Ninigret Pond	Feb/Mar	330,000	100,000	42,000	13,000	7.9
96-0105	Winter flounder	Ninigret Pond	Feb/Mar	4,300,000	1,200,000	560,000	160,000	7.7
96-0106	Winter flounder	Ninigret Pond	Feb/Mar	1,800,000	410,000	270,000	62,000	6.6
96-0107	Winter flounder	Ninigret Pond	Feb/Mar	350,000	100,000	160,000	47,000	2.2
96-0109	Winter flounder	Narrow River	Feb/Mar	70,000	30,000	25,000	11,000	2.8
96-0110	Winter flounder	Narrow River	Feb/Mar	210,000	72,000	12,000	4,400	16.5
96-0111	Winter flounder	Narrow River	Feb/Mar	11,000	5,200	11,000	5,200	1
96-0112	Winter flounder	Narrow River	Feb/Mar	16,000	8,700	15,000	7,900	1.1
96-0115	Winter flounder	Narrow River	Feb/Mar	4,500	2,800	1,500	940	3
96-0116	Winter flounder	Narrow River	Feb/Mar	27,000	12,000	14,000	5,900	2
96-0117	Winter flounder	Quonochontaug	Feb/Mar	850,000	170,000	190,000	38,000	4.4
96-0118	Winter flounder	Quonochontaug	Feb/Mar	130,000	56,000	32,000	14,000	4.1
96-0136	Winter flounder	Pt. Judith Pond/Ram Is.	July	390,000	82,000	160,000	34,000	2.4
96-0137	Winter flounder	Pt. Judith Pond/Ram Is.	July	450,000	77,000	500,000	86,000	0.9
96-0138	Winter flounder	Pt. Judith Pond/Ram Is.	July	540,000	120,000	160,000	37,000	3.3
96-0139	Winter flounder	Pt. Judith Pond/Ram Is.	July	1,100,000	190,000	540,000	91,000	2.1
96-0140	Winter flounder	Pt. Judith Pond/Ram Is.	July	580,000	120,000	230,000	47,000	2.5
96-0148	Winter flounder	Pt. Judith Pond/Jerusalem	July	440,000	74,000	200,000	34,000	2.2
96-0149	Winter flounder	Pt. Judith Pond/Jerusalem	July	140,000	25,000	41,000	7,000	3.5
96-0150	Winter flounder	Pt. Judith Pond/Jerusalem	July	230,000	48,000	260,000	53,000	0.9
96-0151	Winter flounder	Pt. Judith Pond/Jerusalem	July	510,000	97,000	280,000	54,000	1.8
96-0152	Winter flounder	Pt. Judith Pond/Jerusalem	July	520,000	88,000	210,000	35,000	2.5
96-0175	Striped Bass	Quonochontaug	July	200,000	36,000	45,000	8,300	4.3
96-0178	Winter flounder	Quonochontaug	July	150,000	27,000	68,000	12,000	2.2
96-0179	Winter flounder	Quonochontaug	July	210,000	37,000	130,000	23,000	1.6
96-0180	Winter flounder	Quonochontaug	July	230,000	37,000	120,000	19,000	2

Appendix I. Concentrations of fluorescent aromatic compounds (FACs) in bile of individual fish sampled after the *North Cape* oil spill.

Sample ID	Species	Site	Time	FACs (ng equiv./g bile)		FACs/Protein (ng equiv./g bile protein)		Protein (mg/ml)
				NPH	PHN	NPH	PHN	
96-0181	Winter flounder	Quonochontaug	July	140,000	21,000	55,000	8,400	2.5
96-0183	Winter flounder	Quonochontaug	July	170,000	29,000	66,000	11,000	2.6
96-0187	Winter flounder	Quonochontaug	July	88,000	15,000	33,000	5,700	2.7
96-0190	Striped Bass	Quonochontaug	July	110,000	11,000	52,000	4,800	2.2
96-0191	Striped Bass	Quonochontaug	July	110,000	11,000	68,000	6,200	1.7
96-0192	Striped Bass	Quonochontaug	July	130,000	16,000	61,000	7,800	2.1
96-0193	Striped Bass	Quonochontaug	July	130,000	13,000	42,000	4,000	3.2
96-1202	Striped Bass	Pt. Judith Pond/Ram Is.	July	720,000	140,000	140,000	28,000	5
96-1203	Striped Bass	Pt. Judith Pond/Ram Is.	July	940,000	160,000	140,000	25,000	6.5
96-1204	Striped Bass	Pt. Judith Pond/Ram Is.	July	860,000	160,000	140,000	25,000	6.1
96-1205	Striped Bass	Pt. Judith Pond/Turner	July	990,000	160,000	120,000	20,000	8
96-1206	Striped Bass	Pt. Judith Pond/Turner	July	650,000	110,000	170,000	30,000	3.7
96-1208	Striped Bass	Pt. Judith Pond/Turner	July	1,100,000	160,000	260,000	40,000	4
96-1219	Winter flounder	Winnapaug	July	210,000	31,000	230,000	35,000	0.9
96-1221	Winter flounder	Winnapaug	July	190,000	27,000	210,000	30,000	0.9
96-1222	Winter flounder	Winnapaug	July	200,000	26,000	54,000	6,900	3.7
96-1226	Winter flounder	Narrow River	July	150,000	30,000	170,000	33,000	0.9
96-1227	Winter flounder	Narrow River	July	110,000	16,000	18,000	2,600	6.1
96-1244	Winter flounder	Narrow River	July	100,000	15,000	74,000	12,000	1.3
96-1246	Winter flounder	Narrow River	July	120,000	16,000	89,000	13,000	1.3
96-1250	Winter flounder	Narrow River	July	92,000	16,000	17,000	3,100	5.3
96-1253	Winter flounder	Winnapaug	July	96,000	14,000	68,000	9,900	1.4
96-1255	Winter flounder	Winnapaug	July	98,000	11,000	26,000	3,000	3.8
96-CP05	mummichog	Pt. Judith Pond/Turner	July	210,000	27,000	51,000	6,400	4.2
96-CP06	mummichog	Pt. Judith Pond/Jerusalem	July	430,000	54,000	59,000	7,400	7.3
96-CP07	mummichog	Pt. Judith Pond/Turner	July	430,000	58,000	67,000	9,100	6.4
96-CP11	mummichog	Pt. Judith Pond/Ram Is.	July	270,000	39,000	44,000	6,500	6.1
96-CP12	mummichog	Pt. Judith Pond/Ram Is.	July	240,000	37,000	43,000	6,400	5.7
96-CP19	mummichog	Ninigret/1	July	150,000	21,000	27,000	3,900	5.3
96-CP21	mummichog	Ninigret/1	July	130,000	21,000	22,000	3,500	6
96-CP26	mummichog	Ninigret/2	July	67,000	11,000	14,000	2,300	4.8

Appendix I. Concentrations of fluorescent aromatic compounds (FACs) in bile of individual fish sampled after the *North Cape* oil spill.

				FACs (ng equiv./g bile)		FACs/Protein (ng equiv./g bile protein)		Protein
Sample ID	Species	Site	Time	NPH	PHN	NPH	PHN	(mg/ml)
96-CP27	mummichog	Ninigret/2	July	62,000	16,000	14,000	3,400	4.6
96-CP36	mummichog	Quonochontaug	July	48,000	10,000	8,700	1,800	5.5
96-CP39	mummichog	Quonochontaug	July	100,000	20,000	11,000	2,100	9.5
96-CP44	mummichog	Card	July	410,000	44,000	94,000	10,000	4.4
96-CP48	mummichog	Trustom	July	88,000	17,000	29,000	5,700	3
96-CP51	mummichog	Trustom	July	59,000	10,000	21,000	3,700	2.8
96-CP53	mummichog	Potter	July	89,000	13,000	19,000	2,900	4.7
96-CP56	mummichog	Pt. Judith Pond/Jerusalem	July	340,000	52,000	53,000	8,200	6.4
96-CP62	mummichog	Potter	July	94,000	14,000	21,000	3,200	4.5
96-CP65	Winter Flounder	Winnapaug	July	110,000	13,000	27,000	3,200	3.9
96-CP67	mummichog	Winnapaug	July	62,000	12,000	21,000	4,100	2.9
96-CP68	mummichog	Narrow River	July	120,000	20,000	35,000	5,600	3.5
96-CP70	mummichog	Narrow River	July	54,000	12,000	15,000	3,200	3.7
96-CP78	mummichog	Succotash Salt Marsh	July	270,000	38,000	95,000	13,000	2.8
96-CP79	mummichog	Succotash Salt Marsh	July	270,000	38,000	85,000	12,000	3.2

APPENDIX 2

Data, case narratives, and cover memo for analyses of aromatic compounds in sediments following the *North Cape* oil spill

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE

Northwest Fisheries Science Center
2725 Montlake Boulevard East
Seattle, Washington 98112

October 15, 1996

Dr. Jacqueline Michel
Research Planning, Inc.
P.O. Box 328
Columbia, SC 29202

Dear Jacqui:

The data and case narratives are enclosed for the analyses conducted to measure aromatic compounds in sediments collected from the salt ponds affected by the Rhode Island (*North Cape*) oil spill as part of the Damage Assessment Center's study. Please call me (206-860-3326) if you have any questions.

Sincerely,

Margaret M Krahn

Margaret M. Krahn, Ph. D.
Manager
Environmental Chemistry Branch

cc. John Stein - F/NWC2
Tracy Collier - F/NWC2
Don Brown - F/NWC2

CASE NARRATIVE

Sediment Analyses for the North Cape Oil Spill Damage Assessment

Semivolatile Organics—Sampling #1—2/96

Calibrations

The calibration data used to quantitate the analytes (Tables 1J and 1K) met the initial and continuing calibration criteria detailed in the "Commencement Bay Quality Assurance Plan, 12/95" (QAP).

Method Blank Analysis

The criteria in the QAP for method blanks (Tables 1E & 1F) were met (no more than 4 analytes to exceed 3 X MDL; Table 1L).

Surrogate Recoveries

Surrogate recoveries for samples analyzed by GC/MS for ACs (Table 1A) were within the guidelines detailed in the QA Plan (50-125% recovery).

SRM Analyses

An aliquot of NIST tissue SRM 1941a was analyzed with each of the sample sets, and the results (Tables 1E & 1F) met the criteria in the QA plan (>70% of concentrations for the certified analytes that were present in NIST SRM 1941a in concentrations greater than 10 times the MDL were within 35% of either end of the NIST certified value ± 95% confidence interval. Noncertified values for the other analytes in the SRM are also shown in the tables.

Sample Duplicates/Replicates

One sample was analyzed in duplicate (Tables 1H & 1I) and the criteria in the QAP were met, except for ACY and C4PHN. The concentration of ACY and certain individual C4 compounds that contribute to "C4PHN" were so low that they were not detected in one sample but were detected in the duplicate--in these cases the RSD may be >50%, but is meaningless.

Reanalyses

There is no plan to reanalyze any samples.

Barge North Cape Oil Spill Study

Analyses for Aromatic Contaminants
Table 1 Notes

The "less than" symbol (<) indicates that the analyte was not detected in concentrations above the stated value.

Results were determined by gas chromatography/mass spectrometry (GC/MS) using scan mode.

The concentrations of the analytes from naphthalene through C4-naphthalene were calculated using naphthalene-d8 as the surrogate standard; analytes from acenaphthylene through fluoranthene/C2-pyrene were calculated using acenaphthene-d10 as the surrogate standard; and analytes from benz[a]anthracene through benzo[ghi]perylene were calculated using benzo[a]pyrene-d12 as the surrogate standard.

Response factors for the parent (non-alkyls substituted compounds) are also used as the response factors for the corresponding alkyl substituted homologs.

Concentrations of ACs are rounded to two significant figures.

LACs, or low molecular weight ACs, are determined by summing the calculated (nonrounded) concentrations of 2 and 3-ring ACs, from naphthalene through the C4-phenanthrenes, and are then rounded to two significant figures. HACs, or high molecular weight ACs, are determined by summing the calculated (nonrounded) concentrations of 4 through 6-ring ACs, from fluoranthene through benzo[ghi]perylene, and are then rounded to two significant figures. ACs below the detection limit are counted as zero when summing concentrations.

The percent recoveries of the surrogate standards were calculated using phenanthrene-d10 to correct for the fraction of the total extract used for the HPLC clean-up step.

Set # and Sample # designations are intended for internal lab use and identification only. Site name, station, and jar number represent official sample identification designations, as given by those groups providing the samples.

The sample weight used to calculate concentrations for the method blank is the mean sample weight calculated for the field samples in the same set.

Table 1A-p1: Sample information for sediments analyzed for aromatic hydrocarbons as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample#	Station	Jar #	Date Collected	Dry Wt. (%)	Sample Wt. (g)	DNPH Recovery (%)	DACE Recovery (%)	DBAP Recovery (%)
Point Judith Pond									
NC386	115-46	1	JAR 1 OF 3	2/23/96	42.51	9.96	97	100	103
NC386	115-47	2	JAR 1 OF 3	2/23/96	43.69	10.03	93	99	111
NC386	115-48	3	JAR 1 OF 3	2/23/96	34.49	10.06	92	97	111
NCRR	115-49	4	JAR 1 OF 3	2/23/96	41.60	10.22	86	94	106
NC386	115-50	5	JAR 1 OF 3	2/23/96	34.60	10.20	95	101	116
NC386	115-51	6	JAR 1 OF 3	2/23/96	27.63	10.45	90	102	113
NC386	115-52	7	JAR 1 OF 3	2/23/96	35.03	10.14	87	95	112
NC386	115-53	8	JAR 1 OF 3	2/23/96	28.28	10.10	98	102	121
NC386	115-54	9	JAR 1 OF 3	2/23/96	28.47	10.05	90	98	117
NC388	115-71	10	JAR 1 OF 3	2/23/96	68.40	10.06	96	100	106
NC388	115-72	11	JAR 1 OF 3	2/23/96	80.80	10.17	107	108	108
NC388	115-73	12	JAR 1 OF 3	2/23/96	69.30	10.06	93	99	104
NC388	115-78	9	JAR 1 OF 3	2/23/96	31.40	10.08	89	97	106
Ninigret Pond									
NC388	115-74	1	JAR 2 OF 3	2/23/96	21.10	10.04	100	102	109
NC388	115-75	2	JAR 1 OF 3	2/23/96	23.90	10.08	92	98	109
NC388	115-76	3	JAR 1 OF 3	2/23/96	39.00	10.14	91	98	106
NC388	115-77	4	JAR 1 OF 3	2/23/96	32.50	10.03	90	97	107

DNPH = naphthalene-d8; DACE = acenaphthene-d10; DBAP = benzo[a]pyrene-d12.

Table 1B-p1: Concentrations (ng/g, dry weight) of low molecular weight aromatic hydrocarbons in sediments analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Sample #	NPH	C1NPH	C2NPH	C3NPH	C4NPH	ACY	ACE	FLU	C1FLU	C2FLU	C3FLU	DBT	C1DBT	C2DBT	C3DBT	C4DBT
Point Judith Pond																
115-46	15	21	50	93	100	< 1.7	< 2.8	11	29	71	< 2.3	5	21	96	110	27
115-47	17	60	410	1100	750	1.5	7.2	30	220	540	310	17	140	430	410	130
115-48	27	120	640	1400	870	< 1.6	8.4	49	280	610	290	26	160	450	410	130
115-49	25	210	1600	3900	2600	< 1.8	24	95	690	1700	870	54	420	1200	1100	400
115-50	31	100	590	1500	1000	2.2	9.5	45	300	710	350	26	180	550	460	150
115-51	33	220	1800	4800	3100	< 2	26	110	840	2100	1100	66	530	1600	1500	520
115-52	40	250	2800	6200	3900	< 1.5	42	170	1100	2700	1400	99	700	2000	1900	660
115-53	20	37	74	140	160	2.9	< 3.4	15	40	120	15	5.3	37	160	160	40
115-54	27	100	610	1700	1400	3.4	13	56	370	1000	540	30	240	810	760	250
115-71	4.1	23	170	430	270	< 0.89	2.4	12	88	190	170	7.7	63	260	300	84
115-72	< 0.77	< 0.77	< 0.77	< 0.77	< 0.77	< 0.84	< 1.4	< 1.2	< 1.2	< 1.2	< 1.2	< 0.72	< 0.72	< 0.72	< 0.72	< 0.72
115-73	5.5	31	270	700	460	< 0.91	4.5	18	130	320	290	11	100	460	520	150
115-78	27	100	640	1800	1000	< 2.3	11	48	360	700	430	29	230	720	670	170
Ninigret Pond																
115-74	14	38	160	360	200	< 3.1	< 5.2	22	110	160	< 4.2	18	92	220	170	12
115-75	21	160	1300	4000	2500	< 2.7	20	90	760	1800	1300	68	610	2200	2200	670
115-76	10	49	410	1400	940	< 1.8	6	28	250	630	520	22	220	830	890	250
115-77	16	98	750	2300	1400	< 2	10	49	430	980	800	37	360	1300	1400	410

NPH = naphthalene; C1NPH = C1-naphthalenes; C2NPH = C2-naphthalenes; C3NPH = C3-naphthalenes; C4NPH = C4-naphthalenes; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; C1FLU = C1-fluorenes; C2FLU = C2-fluorenes; C3FLU = C3-fluorenes; DBT = dibenzothiophene; C1DBT = C1-dibenzothiophenes; C2DBT = C2-dibenzothiophenes; C3DBT = C3-dibenzothiophenes; C4DBT = C4-dibenzothiophenes.

Table 1C-p1: Concentrations (ng/g, dry weight) of low and high molecular weight aromatic hydrocarbons in sediments analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Sample #	PHN	C1PHN	C2PHN	C3PHN	C4PHN	LACs	FLA	PYR	C1PYR	C2PYR	BAA	CHR[1]	BBF	BKF[1]	BAP	IDP	DBA	BZP	HACs
Point Judith Pond																			
115-46	61	110	260	250	8	1300	120	110	85	36	36	57	57	52	52	33	2.7	37	680
115-47	160	710	1300	830	45	7600	130	170	190	130	30	59	48	44	42	32	1.3	35	910
115-48	220	850	1300	840	8.7	8700	160	200	220	130	41	82	59	56	47	35	3.8	41	1100
115-49	450	2200	3700	2300	170	24000	230	340	450	340	56	110	65	62	53	42	4.2	41	1800
115-50	240	950	1700	1000	50	9900	260	300	290	180	73	130	110	98	99	88	14	81	1700
115-51	520	2700	4800	3000	200	30000	270	430	610	450	65	160	97	73	75	58	4.6	58	2300
115-52	800	3600	6100	3800	310	39000	290	490	740	550	61	130	65	68	56	41	5.4	41	2500
115-53	81	180	440	340	3.9	2100	170	170	120	60	45	80	92	64	70	50	9	57	990
115-54	240	1200	2300	1500	82	13000	230	300	380	240	67	150	89	88	75	62	4.7	57	1700
115-71	64	320	740	550	14	3800	40	60	110	88	11	22	12	11	10	7.8	< 0.72	8.5	380
115-72	< 0.74	< 0.74	< 0.74	< 0.74	< 0.74	0	1.9	2.2	< 0.65	< 0.65	< 0.73	< 0.68	< 0.68	< 0.62	< 0.66	< 0.73	< 0.72	< 0.68	4.1
115-73	94	530	1300	930	31	6400	71	100	190	150	18	49	20	17	15	9.8	< 0.75	9.4	640
115-78	240	1100	2100	1200	23	12000	240	290	340	230	80	140	110	97	91	68	12	71	1800
Ninigret Pond																			
115-74	160	470	740	360	< 2.7	3300	130	140	110	28	37	64	58	53	56	40	2.8	43	760
115-75	590	3400	6700	4100	160	33000	200	390	750	620	42	100	57	48	49	39	3	38	2300
115-76	180	1200	2600	1600	51	12000	88	160	310	240	21	55	27	20	22	14	< 1.4	15	980
115-77	340	1900	4000	2500	93	19000	130	240	460	390	27	69	43	23	29	23	< 1.5	23	1500

PHN = phenanthrene; C1PHN = C1-phenanthrenes/anthracenes; C2PHN = C2-phenanthrenes/anthracenes; C3PHN = C3-phenanthrenes/anthracenes; C4PHN = C4-phenanthrenes/anthracenes; FLA = fluoranthene; PYR = pyrene; C1PYR = C1-fluoranthenes/pyrenes; C2PYR = C2-fluoranthenes/pyrenes; BAA = benz[a]anthracene; CHR = chrysene + triphenylene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene + benzo[j]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

LACs = NPH + C1NPH + C2NPH + C3NPH + C4NPH + ACY + ACE + FLU + C1FLU + C2FLU + C3FLU + DBT + C1DBT + C2DBT + C3DBT + C4DBT + PHN + C1PHN + C1PHN + C2PHN + C3PHN + C4PHN.
HACs = FLA + PYR + C1PYR + C2PYR + BAA + CHR + BBF + BKF + BAP + IDP + DBA + BZP.

[1] Chrysene (CHR) and triphenylene, as well as benzo[k]fluoranthene (BKF) and benzo[j]fluoranthene, are not resolved by our gas chromatographic procedure, whereas these compounds are resolved by the NIST procedure. In addition, the two pairs of compounds have very similar mass spectra, and we report each pair's combined concentrations as "CHR" and "BKF" respectively.

Table 1D-p1: QA: Sample information for method blanks and Standard Reference Material (SRM 1941a) analyzed for aromatic hydrocarbons as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	Sample Wt. (g)	Dry Wt. (%)	DNPH Recovery (%)	DACE Recovery (%)	DBAP Recovery (%)
Method Blank						
NC386	115-56	10.13	35.10	106	107	103
NCRR	115-56B	10.13	35.10	108	106	107
NC387	115-68	10.08	37.60	100	100	95
NC388	115-80	10.08	45.80	99	102	99
	Average†	10.11	38.40	103	104	101
	Standard Deviation†	0.03	4.39	3.72	2.74	4.61
	Relative Standard Deviation	0.2%	11.4%	3.6%	2.6%	4.6%
SRM 1941a						
NC386	115-55	2.11	50.16	98	101	114
NCRR	115-55B	2.11	50.16	101	105	115
NC387	115-67	2.06	49.69	92	96	111
NC388	115-79	2.45	50.91	98	103	112
	Average†	2.18	50.23	97	101	113
	Standard Deviation†	0.16	0.44	3.01	3.27	1.46
	Relative Standard Deviation	7.1%	0.9%	3.1%	3.2%	1.3%

DNPH = naphthalene-d8; DACE = acenaphthene-d10; DBAP = benzo[a]pyrene-d12.

Final

† In a previous report (dated 10/15/96), the averages and standard deviations for this table (1D) were incorrectly calculated. The correct values are displayed in this version (dated on or after 11/1/96).

Table 1E-p1: QA: Concentrations (ng/g, dry weight) of low molecular weight aromatic hydrocarbons in method blanks and Standard Reference Material (SRM 1941a) analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #		NPH	C1NPH	C2NPH	C3NPH	C4NPH	ACY	ACE	FLU	C1FLU	C2FLU	C3FLU	DBT	C1DBT	C2DBT	C3DBT	C4DBT
Method Blank																		
NC386	115-56		4.5	< 1.5	< 1.5	< 1.5	< 1.5	< 1.8	< 3	< 2.5	< 2.5	< 2.5	< 2.5	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
NCrr	115-56B		4.5	< 1.7	< 1.7	< 1.7	< 1.7	< 1.9	< 3.2	< 2.6	< 2.6	< 2.6	< 2.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.6
NC387	115-68		3.2	< 1.5	< 1.5	< 1.5	< 1.5	< 1.8	< 2.9	< 2.5	< 2.5	< 2.5	< 2.5	< 1.5	< 1.5	< 1.5	< 1.5	< 1.5
NC388	115-80		< 1.4	< 1.4	< 1.4	< 1.4	< 1.4	< 1.5	< 2.5	< 2	< 2	< 2	< 2	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3
		Average*	3.04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Standard	Deviation	1.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative	Standard	Deviation	60.1%	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
SRM 1941a																		
NC386	115-55		950	270	220	150	< 4.9	30	32	78	49	< 7.5	< 7.5	47	66	81	43	< 4.7
NCrr	115-55B		970	300	250	160	7.5	37	37	81	47	< 8.5	< 8.5	55	59	89	58	< 5.2
NC387	115-67		1000	300	230	120	< 5.5	30	34	88	36	< 8.7	< 8.7	55	60	80	47	< 5.3
NC388	115-79		1000	310	270	150	< 4.9	34	38	77	51	< 7.1	< 7.1	56	59	87	36	< 4.4
		Average*	989.77	294.48	241.23	144.59	1.87	32.95	35.32	80.97	45.67	0.00	0.00	53.38	60.80	84.32	46.10	0.00
	Standard	Deviation	31.70	15.87	17.54	12.35	3.24	3.07	2.14	4.30	5.70	0.00	0.00	3.72	3.14	4.02	7.88	0.00
Relative	Standard	Deviation	3.2%	5.4%	7.3%	8.5%	173.2%	9.3%	0.1%	5.3%	12.5%	?	?	7.0%	5.2%	4.8%	17.1%	?

SRM 1941a	CC	1010	---	---	---	---	37§	41§	97.3	---	---	---	70§	---	---	---	---
Certified	95% CI	140							8.6								
Concentrations	UCL	1553							143								
(ng/g, dry wt)	LCL	566							58								

CC is the certified concentration; 95% CI is the 95% confidence interval; UCL is the upper control limit ([CC + 95% CI] + 35%); LCL is the lower control limit ([CC - 95% CI] - 35%).

§ACY, ACE, and DBT concentrations are reported as noncertified values.

NPH = naphthalene; C1NPH = C1-naphthalenes; C2NPH = C2-naphthalenes; C3NPH = C3-naphthalenes; C4NPH = C4-naphthalenes; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; C1FLU = C1-fluorenes; C2FLU = C2-fluorenes; C3FLU = C3-fluorenes; DBT = dibenzothiophene; C1DBT = C1-dibenzothiophenes; C2DBT = C2-dibenzothiophenes; C3DBT = C3-dibenzothiophenes; C4DBT = C4-dibenzothiophenes.

* When an analyte was detected in some, but not all of the method blanks or SRMs, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the method blanks or SRMs, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1F-p1: QA: Concentrations (ng/g, dry weight) of low and high molecular weight aromatic hydrocarbons in method blanks and Standard Reference Material (SRM 1941a) analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #		PHN	C1PHN	C2PHN	C3PHN	C4PHN	FLA	PYR	C1PYR	C2PYR	BAA	CHR[†]	BBF	BKF[†]	BAP	IDP	DBA	BZP
Method Blank																			
NC386	115-56		< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.4	< 1.3	< 1.4	< 1.4	< 1.7	< 1.5	< 1.7	< 1.4	< 1.6	< 2	< 1.9	< 1.8
NCrr	115-56B		< 1.6	< 1.6	< 1.6	< 1.6	< 1.6	< 1.4	< 1.4	< 1.4	< 1.4	< 1.6	< 1.4	< 1.5	< 1.4	< 1.5	< 1.8	< 1.7	< 1.5
NC387	115-68		< 1.5	< 1.5	< 1.5	< 1.5	< 1.5	< 1.3	< 1.3	< 1.3	< 1.3	< 1.8	< 1.5	< 1.9	< 1.4	< 1.6	< 2.2	< 2	< 1.8
NC388	115-80		< 1.3	< 1.3	< 1.3	< 1.3	< 1.3	< 1.2	< 1.1	< 1.2	< 1.2	< 1.3	< 1.2	< 1.2	< 1.1	< 1.2	< 1.3	< 1.3	< 1.2
		Average*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Standard	Deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative	Standard	Deviation	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
SRM 1941a																			
NC386	115-55		510	360	280	120	< 4.8	990	790	420	200	360	500	620	580	490	480	83	440
NCrr	115-55B		510	350	300	120	< 5.3	940	770	430	220	390	540	690	560	520	490	88	470
NC387	115-67		530	360	270	96	< 5.5	1000	840	430	180	390	530	720	620	540	580	66	480
NC388	115-79		510	360	310	120	< 4.6	1000	820	440	220	410	570	710	560	540	470	85	490
		Average*	514.80	353.79	287.17	116.18	0.00	992.49	805.77	428.51	203.46	387.12	535.09	682.98	580.11	521.92	505.80	80.43	469.50
	Standard	Deviation	8.99	4.61	16.54	11.94	0.00	36.39	27.63	10.49	17.99	20.08	25.73	38.23	22.59	17.10	43.81	8.36	19.99
Relative	Standard	Deviation	1.7%	1.3%	5.8%	10.3%	?	3.7%	3.4%	2.4%	8.8%	5.2%	4.8%	5.6%	3.9%	3.3%	8.7%	10.4%	4.3%

SRM 1941a	CC	489	---	---	---	---	981	811	---	---	427	380	740	361	628	501	73.9	525
Certified	95% CI	23					78	24			25	24	110	18	52	72	9.7	67
Concentrations	UCL	691					1430	1127			610	545	1148	512	918	774	113	799
(ng/g, dry wt)	LCL	303					587	512			261	231	410	223	374	279	42	298

CC is the certified concentration; 95% CI is the 95% confidence interval; UCL is the upper control limit ([CC + 95% CI] + 35%); LCL is the lower control limit ([CC - 95% CI] - 35%).

PHN = phenanthrene; C1PHN = C1-phenanthrenes/anthracenes; C2PHN = C2-phenanthrenes/anthracenes; C3PHN = C3-phenanthrenes/anthracenes; C4PHN = C4-phenanthrenes/anthracenes; FLA = fluoranthene; PYR = pyrene; C1PYR = C1 fluoranthenes/pyrenes; C2PYR = C2 fluoranthenes/pyrenes; BAA = benz[a]anthracene; CHR = chrysene + triphenylene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene + benzo[j]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

[†] Chrysene (CHR) and triphenylene, as well as benzo[k]fluoranthene (BKF) and benzo[j]fluoranthene, are not resolved by our gas chromatographic procedure, whereas these compounds are resolved by the NIST procedure. In addition, the two pairs of compounds have very similar mass spectra, and we report each pair's combined concentrations as "CHR" and "BKF" respectively. Thus, our reported values for CHR and BKF may exceed the NIST upper control limit.

* When an analyte was detected in some, but not all of the method blanks or SRMs, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the method blanks or SRMs, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1G-p1: QA: Sample information for samples analyzed in duplicate for aromatic hydrocarbons as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	Sample Wt. (g)	Dry Wt. (%)	DNPH Recovery (%)	DACE Recovery (%)	DBAP Recovery (%)
Point Judith Pond Station 9 Jar 1 Of 3						
NC386	115-54	10.05	28.47	90	98	117
NC388	115-78	10.08	31.40	89	97	106
	Average	10.07	29.94	89.55	97.32	111.47
	Standard Deviation	0.02	1.46	0.85	0.60	5.38
	Relative Standard Deviation	0.1%	4.9%	0.9%	0.6%	4.8%

DNPH = naphthalene-d8; DACE = acenaphthene-d10; DBAP = benzo[a]pyrene-d12.

Table 1H-p1: QA: Concentrations (ng/g, dry weight) of low molecular weight aromatic hydrocarbons in sediment samples analyzed in duplicate as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	NPH	C1NPH	C2NPH	C3NPH	C4NPH	ACY	ACE	FLU	C1FLU	C2FLU	C3FLU	DBT	C1DBT	C2DBT	C3DBT	C4DBT
Point Judith Pond Station 9 Jar 1 Of 3																	
NC386	115-54	27	100	610	1700	1400	3.4	13	56	370	1000	540	30	240	810	760	250
NC388	115-78	27	100	640	1800	1000	< 2.3	11	48	360	700	430	29	230	720	670	170
	Average*	26.84	102.20	623.32	1744.79	1202.92	1.72	11.89	52.01	364.42	854.81	486.02	29.52	234.36	766.98	716.23	207.69
	Standard Deviation	0.16	2.51	13.92	29.08	158.61	1.72	0.80	3.87	6.98	154.30	53.14	0.69	7.70	42.75	44.57	40.47
Relative	Standard Deviation	0.6%	2.5%	2.2%	1.7%	13.2%	100.0%	0.1%	7.4%	1.9%	18.1%	10.9%	2.3%	3.3%	5.6%	6.2%	19.5%

NPH = naphthalene; C1NPH = C1-naphthalenes; C2NPH = C2-naphthalenes; C3NPH = C3-naphthalenes; C4NPH = C4-naphthalenes; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; C1FLU = C1-fluorenes; C2FLU = C2-fluorenes; C3FLU = C3-fluorenes; DBT = dibenzothiophene; C1DBT = C1-dibenzothiophenes; C2DBT = C2-dibenzothiophenes; C3DBT = C3-dibenzothiophenes; C4DBT = C4-dibenzothiophenes.

* When an analyte was detected in some, but not all of the samples, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the samples, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1l-p1: QA: Concentrations (ng/g, dry weight) of low and high molecular weight aromatic hydrocarbons in sediment samples analyzed in duplicate as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	PHN	C1PHN	C2PHN	C3PHN	C4PHN	FLA	PYR	C1PYR	C2PYR	BAA	CHR†	BBF	BKF†	BAP	IDP	DBA	BZP
Point Judith Pond Station 9 Jar 1 Of 3																		
NC386	115-54	240	1200	2300	1500	82	230	300	380	240	67	150	89	88	75	62	4.7	57
NC388	115-78	240	1100	2100	1200	23	240	290	340	230	80	140	110	97	91	68	12	71
	Average*	244.55	1151.54	2213.71	1369.96	52.11	237.05	294.80	360.05	234.73	73.81	142.89	100.08	92.53	82.83	64.63	8.18	64.29
	Standard Deviation	0.05	44.42	107.94	149.19	29.58	7.08	3.66	15.51	6.11	6.37	3.26	11.09	4.40	8.04	2.96	3.50	6.97
Relative	Standard Deviation	0.0%	3.9%	4.9%	10.9%	56.8%	3.0%	1.2%	4.3%	2.6%	8.6%	2.3%	11.1%	4.8%	9.7%	4.6%	42.8%	10.8%

PHN = phenanthrene; C1PHN = C1-phenanthrenes/anthracenes; C2PHN = C2-phenanthrenes/anthracenes; C3PHN = C3-phenanthrenes/anthracenes; C4PHN = C4-phenanthrenes/anthracenes; FLA = fluoranthene; PYR = pyrene; C1PYR = C1-fluoranthenes/pyrenes; C2PYR = C2-fluoranthenes/pyrenes; BAA = benz[a]anthracene; CHR = chrysene + triphenylene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene + benzo[j]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

† Chrysene (CHR) and triphenylene, as well as benzo[k]fluoranthene (BKF) and benzo[j]fluoranthene, are not resolved by our gas chromatographic procedure, whereas these compounds are resolved by the NIST procedure. In addition, the two pairs of compounds have very similar mass spectra, and we report each pair's combined concentrations as "CHR" and "BKF" respectively.

* When an analyte was detected in some, but not all of the samples, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the samples, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1J-p1: QA: Continuing calibration verification data (based on % recoveries) for aromatic hydrocarbons in standards run before, during and after the samples analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Sample Name	NPH	ACY	ACE	FLU	DBT	PHN	FLA	PYR	BAA	CHR	BBF	BKF	BAP	IDP	DBA	BZP
NCRR																
NCRRAH4K1A	99	101	100	100	98	99	99	100	99	98	102	100	102	106	103	102
NCRRAH4K1B	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NCRRAH4K1C	103	101	102	102	100	101	102	102	97	101	94	101	99	88	91	94
Average	101	101	101	101	99	100	100	101	99	100	99	100	100	98	98	99
Standard Deviation	1.89	0.46	0.76	0.93	0.88	0.91	1.05	1.21	1.24	0.94	3.55	0.62	1.21	7.32	5.14	3.22
RSD	1.9%	0.5%	0.8%	0.9%	0.9%	0.9%	1.1%	1.2%	1.3%	0.9%	3.6%	0.6%	1.2%	7.5%	5.3%	3.3%
NC386																
NC386AH4K1A	105	103	104	102	99	99	97	98	95	98	97	96	98	92	93	95
NC386AH4K1B	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NC386AH4K1C	100	100	100	99	99	98	99	99	101	102	101	105	103	101	98	104
Average	101	101	101	100	99	99	99	99	99	100	99	100	101	98	97	100
Standard Deviation	2.27	1.44	1.59	0.96	0.47	0.75	1.09	0.94	2.83	1.74	1.48	3.72	2.01	3.91	2.90	3.65
RSD	2.2%	1.4%	1.6%	1.0%	0.5%	0.8%	1.1%	1.0%	2.9%	1.7%	1.5%	3.7%	2.0%	4.0%	3.0%	3.7%
NC387																
NC387AH4K1A	100	100	99	100	97	99	96	98	94	99	96	96	98	90	96	98
NC387AH4K1B	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NC387AH4K1C	97	98	100	98	97	98	98	99	97	98	96	101	98	96	97	100
Average	99	99	100	99	98	99	98	99	97	99	97	99	98	95	97	99
Standard Deviation	1.37	0.69	0.31	0.74	1.32	0.63	1.66	0.95	2.39	0.77	1.93	1.96	1.09	4.14	1.83	0.71
RSD	1.4%	0.7%	0.3%	0.7%	1.3%	0.6%	1.7%	1.0%	2.5%	0.8%	2.0%	2.0%	1.1%	4.3%	1.9%	0.7%
NC388																
NC388AH4K1A	105	103	104	101	100	102	101	100	101	99	101	99	100	101	100	98
NC388AH4K1B	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NC388AH4K1C	101	96	99	98	100	100	101	100	101	102	100	101	102	99	103	102
Average	102	100	101	100	100	101	100	100	101	101	101	100	101	100	101	100
Standard Deviation	2.14	2.82	2.19	1.24	0.19	0.76	0.35	0.27	0.52	1.31	0.56	1.14	0.70	0.82	1.11	1.67
RSD	2.1%	2.8%	2.2%	1.2%	0.2%	0.8%	0.3%	0.3%	0.5%	1.3%	0.6%	1.1%	0.7%	0.8%	1.1%	1.7%

NPH = naphthalene; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; DBT = dibenzothiophene; PHN = phenanthrene; FLA = fluoranthene; PYR = pyrene; BAA = benz[a]anthracene; CHR = chrysene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

Continuing calibration data for each set are reported as percent recovery versus calibration run B.

Table 1K: Standard curve correlation (r) from the linear regression of the concentrations of the analyte to the area response for the multilevel standards.

Analyte	Set NC386 r	Set NC387 r	Set NC388 r
naphthalene	1.000	0.999	1.000
acenaphthylene	1.000	1.000	0.999
acenaphthene	1.000	1.000	0.999
fluorene	1.000	1.000	1.000
phenanthrene	1.000	0.999	1.000
fluoranthene	0.999	0.999	1.000
pyrene	0.999	0.998	1.000
benz[a]anthracene	0.998	0.996	1.000
chrysene	0.999	0.999	1.000
benzo[a]pyrene	1.000	0.999	0.999
indeno[1,2,3-cd]pyrene	0.997	0.994	0.998
dibenz[a,h]anthracene	0.998	0.996	1.000
benzo[ghi]perylene	0.997	0.997	1.000
d8-naphthalene	0.999	0.998	1.000
d10-acenaphthene	0.999	0.998	1.000
d12-benzo[a]pyrene	0.999	0.998	1.000
d12-perylene	0.999	0.999	1.000
d10-phenanthrene	0.999	0.998	1.000
d10-biphenyl	0.999	0.998	1.000
d8-fluorene	0.999	0.998	1.000

Based on six concentration levels of standards.

Table 1L-p1: Concentrations of analytes in 7 replicates of spiked clean matrix and calculated method detection limits (MDL, ng/g, dry weight) for aromatic hydrocarbons calculated by the method in appendix B of 40CFR part 136.

Sample	NPH	MN2	ACY	ACE	FLU	PHN	ANT	FLA	PYR	BAA	CHR	BBF	BKF	BAP
110-43	14.2	13.3	13.6	14.4	15.6	16.1	11.6	20.0	20.8	16.1	19.4	22.4	18.6	18.0
110-44	15.5	12.6	15.0	12.6	17.7	17.7	13.5	22.1	21.7	15.6	18.8	20.0	18.6	17.6
110-45	16.6	10.2	15.0	14.1	13.7	16.2	12.4	19.5	19.6	17.3	19.0	19.7	18.2	18.5
110-46	13.9	8.4	13.9	11.5	13.0	16.1	13.0	19.3	19.3	15.4	18.8	19.5	17.5	18.2
110-47	14.2	11.2	13.3	11.7	16.0	16.6	13.0	20.4	19.0	17.2	18.6	20.3	17.7	18.3
110-48	16.2	10.4	13.1	15.3	14.9	17.2	13.7	19.4	20.8	16.9	18.9	20.1	18.8	17.2
110-49	15.0	12.0	12.7	14.0	13.5	17.9	12.5	19.7	18.2	16.6	19.6	19.9	17.6	17.6
Average	15.1	11.2	13.9	13.4	14.9	16.8	12.8	20.0	19.9	16.5	19.0	20.3	18.2	17.9
Std Dev	1.05	1.66	1.04	1.44	1.66	0.77	0.73	0.96	1.22	0.77	0.39	0.96	0.53	0.48
MDL	3.29	5.22	3.25	4.51	5.20	2.43	2.29	3.01	3.85	2.41	1.21	3.01	1.68	1.50

Sample	IDP	DBA	BZP
110-43	12.6	7.3	14.1
11044	13.1	7.4	12.9
110-45	12.9	8.5	13.1
110-46	11.0	6.6	11.2
110-47	13.7	9.6	14.1
110-48	12.1	5.2	12.0
11049	10.3	6.3	12.1
Average	12.2	7.3	12.8
Std Dev	1.21	1.48	1.11
MDL	3.80	4.64	3.50

NPH = naphthalene; 2MN = 2-methylnaphthalene; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; PHN = phenanthrene; ANT = anthracene; FLA = fluoranthene; PYR = pyrene; BAA = benz[a]anthracene; CHR = chrysene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

CASE NARRATIVE

Sediment Analyses for the North Cape Oil Spill Damage Assessment

Semivolatile Organics—Sampling #2—7/96

Calibrations

The calibration data used to quantitate the analytes (Tables 1J and 1K) met the initial and continuing calibration criteria detailed in the "Commencement Bay Quality Assurance Plan, 12/95" (QAP).

Method Blank Analysis

The criteria in the QAP for method blanks (Tables 1E & 1F) were met (no more than 4 analytes to exceed 3 X MDL; Table 1L).

Surrogate Recoveries

Surrogate recoveries for samples analyzed by GC/MS for ACs (Table 1A) were within the guidelines detailed in the QA Plan (50-125% recovery).

SRM Analyses

An aliquot of NIST tissue SRM 1941a was analyzed with each of the sample sets, and the results (Tables 1E & 1F) met the criteria in the QA plan (>70% of concentrations for the certified analytes that were present in NIST SRM 1941a in concentrations greater than 10 times the MDL were within 35% of either end of the NIST certified value ± 95% confidence interval. Noncertified values for the other analytes in the SRM are also shown in the tables.

Sample Duplicates/Replicates

One sample was analyzed in duplicate (Tables 1H& 1I) and the criteria in the QAP were met. In several instances, the concentrations of analytes were so low that they were not detected in one sample but were detected in the duplicate--in these cases the RSD may be >50%, but is meaningless.

Reanalyses

There is no plan to reanalyze any samples.

Barge North Cape Oil Spill Study

Analyses for Aromatic Contaminants
Table 1 Notes

The "less than" symbol (<) indicates that the analyte was not detected in concentrations above the stated value.

Results were determined by gas chromatography/mass spectrometry (GC/MS) using scan mode.

The concentrations of the analytes from naphthalene through C4-naphthalene were calculated using naphthalene-d8 as the surrogate standard; analytes from acenaphthylene through fluoranthene/C2-pyrene were calculated using acenaphthene-d10 as the surrogate standard; and analytes from benz[a]anthracene through benzo[ghi]perylene were calculated using benzo[a]pyrene-d12 as the surrogate standard.

Response factors for the parent (non-alkyls substituted compounds) are also used as the response factors for the corresponding alkyl substituted homologs.

Concentrations of ACs are rounded to two significant figures.

LACs, or low molecular weight ACs, are determined by summing the calculated (nonrounded) concentrations of 2 and 3-ring ACs, from naphthalene through the C4-phenanthrenes, and are then rounded to two significant figures. HACs, or high molecular weight ACs, are determined by summing the calculated (nonrounded) concentrations of 4 through 6-ring ACs, from fluoranthene through benzo[ghi]perylene, and are then rounded to two significant figures. ACs below the detection limit are counted as zero when summing concentrations.

The percent recoveries of the surrogate standards were calculated using phenanthrene-d10 to correct for the fraction of the total extract used for the HPLC clean-up step.

Set # and Sample # designations are intended for internal lab use and identification only. Site name, station, and jar number represent official sample identification designations, as given by those groups providing the samples.

The sample weight used to calculate concentrations for the method blank is the mean sample weight calculated for the field samples in the same set.

Table 1A-p1: Sample information for sediments analyzed for aromatic hydrocarbons as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample#	Station	Jar #	Date Collected	Dry Wt. (%)	Sample Wt. (g)	DNPH Recovery (%)	DACE Recovery (%)	DBAP Recovery (%)
Point Judith Pond									
NC406	115-83	1	JAR 1 OF 3	7/26/96	44.00	10.04	91	92	100
NC406	115-84	2	JAR 1 OF 3	7/26/96	41.90	10.06	91	92	100
NC406	115-85	3	JAR 1 OF 3	7/26/96	50.50	10.26	95	96	103
NC406	115-86	4	JAR 1 OF 3	7/26/96	60.50	10.03	96	95	101
NC406	115-87	5	JAR 1 OF 3	7/26/96	34.70	10.16	89	90	98
NC406	115-88	6	JAR 1 OF 3	7/26/96	31.40	10.08	92	93	95
NC406	115-89	7	JAR 1 OF 3	7/26/96	33.40	10.03	91	89	95
NC406	115-90	8	JAR 1 OF 3	7/26/96	31.50	10.13	93	94	94
NC406	115-91	9	JAR 1 OF 3	7/26/96	29.20	10.14	96	94	88
NC406	115-92	4	JAR 1 OF 3	7/26/96	59.60	10.11	95	97	94
NC384	115-97	10	JAR 1 OF 3	7/30/96	72.14	10.60	99	94	102
NC384	115-98	11	JAR 1 OF 3	7/26/96	81.85	10.09	100	94	99
NC384	115-99	12	JAR 1 OF 3	7/26/96	80.15	10.34	98	97	97
Ninigret Pond									
NC384	115-100	1	JAR 1 OF 3	7/25/96	25.49	10.23	93	95	98
NC384	115-101	2	JAR 1 OF 3	7/25/96	33.20	10.23	91	95	102
NC384	115-102	3	JAR 1 OF 3	7/25/96	47.69	10.35	91	93	100
NC384	115-103	4	JAR 1 OF 3	7/25/96	35.24	10.03	88	93	97

DNPH = naphthalene-d8; DACE = acenaphthene-d10; DBAP = benzo[a]pyrene-d12.

Table 1B-p1: Concentrations (ng/g, dry weight) of low molecular weight aromatic hydrocarbons in sediments analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Sample #	NPH	C1NPH	C2NPH	C3NPH	C4NPH	ACY	ACE	FLU	C1FLU	C2FLU	C3FLU	DBT	C1DBT	C2DBT	C3DBT	C4DBT
Point Judith Pond																
115-83	17	7.1	7.7	27	36	< 1.4	< 2.3	4.2	3.4	30	< 1.8	< 1.1	7.3	64	130	66
115-84	15	2.5	11	37	42	< 1.5	< 2.4	6.9	7.2	26	3.2	1.6	6.9	52	94	27
115-85	8.8	< 1.3	3.5	11	26	< 1.3	< 2.1	< 1.7	< 1.7	< 1.7	< 1.7	2.5	4.4	48	99	44
115-86	4.2	1.2	1	7.9	5.5	< .99	< 1.6	< 1.3	< 1.3	< 1.3	< 1.3	1.3	2.2	16	28	4.5
115-87	21	13	46	160	120	< 2	< 3.1	8	26	76	< 2.5	5.4	22	100	95	16
115-88	22	25	210	740	760	< 1.9	4.6	17	130	560	260	16	99	400	470	200
115-89	18	18	140	560	610	< 2	< 3.2	19	110	410	150	11	79	360	460	160
115-90	21	6.6	4.4	< 1.9	< 1.9	< 2	< 3.2	6.9	< 2.6	< 2.6	< 2.6	< 1.6	< 1.6	7.3	13	< 1.6
115-91	19	22	230	800	710	< 2.5	< 4	18	140	530	120	14	110	440	500	180
115-92	7.8	< 1.1	< 1.1	5.2	4.2	< 1.1	< 1.8	< 1.4	2.5	< 1.4	< 1.4	< 0.88	1.8	14	26	3.1
115-97	1.6	< 0.93	< 0.93	< 0.93	< 0.93	< 1	< 1.7	< 1.4	< 1.4	< 1.4	< 1.4	< 0.86	< 0.86	< 0.86	< 0.86	< 0.86
115-98	< 0.75	< 0.75	< 0.75	< 0.75	< 0.75	< 0.86	< 1.4	< 1.1	< 1.1	< 1.1	< 1.1	< 0.71	< 0.71	< 0.71	< 0.71	< 0.71
115-99	< 0.69	< 0.69	< 0.69	< 0.69	< 0.69	< 0.74	< 1.2	< .97	< .97	< .97	< .97	< 0.62	< 0.62	< 0.62	< 0.62	< 0.62
Ninigret Pond																
115-100	12	9.7	9.8	17	22	< 2.4	< 4	< 3.2	3.8	39	54	3.7	7.8	50	48	9.2
115-101	10	9	19	58	39	< 2.1	< 3.4	< 2.7	6.6	52	45	< 1.7	12	34	38	< 1.7
115-102	4.8	2.7	2.9	16	28	< 1.3	< 2.1	4.5	6.1	26	76	1.9	7.8	54	78	27
115-103	14	8.8	5.6	44	130	< 2.3	< 3.7	5	21	130	360	3.7	26	150	220	110

NPH = naphthalene; C1NPH = C1-naphthalenes; C2NPH = C2-naphthalenes; C3NPH = C3-naphthalenes; C4NPH = C4-naphthalenes; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; C1FLU = C1-fluorenes; C2FLU = C2-fluorenes; C3FLU = C3-fluorenes; DBT = dibenzothiophene; C1DBT = C1-dibenzothiophenes; C2DBT = C2-dibenzothiophenes; C3DBT = C3-dibenzothiophenes; C4DBT = C4-dibenzothiophenes.

Table 1C-p1: Concentrations (ng/g, dry weight) of low and high molecular weight aromatic hydrocarbons in sediments analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Sample #	PHN	C1PHN	C2PHN	C3PHN	C4PHN	LACs	FLA	PYR	C1PYR	C2PYR	BAA	CHR[1]	BBF	BKF[1]	BAP	IDP	DBA	BZP	HACs
Point Judith Pond																			
115-83	53	71	190	280	21	1000	120	130	120	73	43	72	79	65	63	56	7.5	60	890
115-84	49	63	170	220	12	850	150	130	100	50	44	67	75	57	58	48	7.5	49	840
115-85	73	42	140	230	12	740	140	120	77	40	37	58	47	49	44	33	4.7	35	690
115-86	21	20	60	70	< 0.77	240	45	40	28	8.7	15	24	21	21	16	12	0.58	14	250
115-87	83	150	330	250	3.8	1500	200	180	130	57	63	100	110	92	95	82	13	80	1200
115-88	150	430	1200	1000	110	6800	230	230	250	190	83	130	110	110	96	84	16	84	1600
115-89	120	350	1100	990	84	5700	210	220	250	150	72	120	110	82	88	70	9.5	69	1400
115-90	73	50	49	55	< 1.5	290	200	160	110	18	78	130	120	99	93	75	11	78	1200
115-91	160	490	1300	1000	65	6800	220	220	250	160	80	140	96	93	75	63	9.7	65	1500
115-92	22	24	59	59	< 0.85	230	72	70	39	6.7	31	55	37	43	40	30	4.6	30	460
115-97	< 0.81	< 0.81	< 0.81	< 0.81	< 0.81	1.6	4.2	3.6	< 0.65	< 0.65	< 0.55	1	1.7	< 0.38	0.79	< 0.33	< 0.31	< 0.3	11
115-98	< 0.67	< 0.67	< 0.67	< 0.67	< 0.67	0	< 0.54	< 0.51	< 0.54	< 0.54	< 0.47	< 0.44	< 0.36	< 0.32	< 0.35	< 0.28	< 0.27	< 0.25	0
115-99	< 0.58	< 0.58	< 0.58	< 0.58	< 0.58	0	2.2	1.1	< 0.46	< 0.46	< 0.43	0.47	0.45	0.35	< 0.32	< 0.26	< 0.25	< 0.23	4.6
Ninigret Pond																			
115-100	65	75	170	160	14	770	120	100	53	18	32	55	51	49	50	42	4.3	41	620
115-101	58	88	170	110	8	760	91	82	37	16	30	43	41	42	41	29	3.8	28	480
115-102	60	64	190	190	37	870	86	72	49	26	23	38	33	27	28	21	3	20	430
115-103	58	140	490	540	130	2600	78	88	90	66	23	47	36	30	28	25	2.9	27	540

PHN = phenanthrene; C1PHN = C1-phenanthrenes/anthracenes; C2PHN = C2-phenanthrenes/anthracenes; C3PHN = C3-phenanthrenes/anthracenes; C4PHN = C4-phenanthrenes/anthracenes; FLA = fluoranthene; PYR = pyrene; C1PYR = C1-fluoranthenes/pyrenes; C2PYR = C2-fluoranthenes/pyrenes; BAA = benz[a]anthracene; CHR = chrysene + triphenylene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene + benzo[j]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

LACs = NPH + C1NPH + C2NPH + C3NPH + C4NPH + ACY + ACE + FLU + C1FLU + C2FLU + C3FLU + DBT + C1DBT + C2DBT + C3DBT + C4DBT + PHN + C1PHN + C1PHN + C2PHN + C3PHN + C4PHN.
HACs = FLA + PYR + C1PYR + C2PYR + BAA + CHR + BBF + BKF + BAP + IDP + DBA + BZP.

[1] Chrysene (CHR) and triphenylene, as well as benzo[k]fluoranthene (BKF) and benzo[j]fluoranthene, are not resolved by our gas chromatographic procedure, whereas these compounds are resolved by the NIST procedure. In addition, the two pairs of compounds have very similar mass spectra, and we report each pair's combined concentrations as "CHR" and "BKF" respectively.

Table 1D-p1: QA: Sample information for method blanks and Standard Reference Material (SRM 1941a) analyzed for aromatic hydrocarbons as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	Sample Wt. (g)	Dry Wt. (%)	DNPH Recovery (%)	DACE Recovery (%)	DBAP Recovery (%)
Method Blank						
NC384	115-105	10.27	61.00	106	103	103
NC406	115-94	10.10	41.67	108	96	102
	Average†	10.19	51.34	107	99	103
	Standard Deviation†	0.08	9.67	1.03	3.50	0.77
	Relative Standard Deviation	0.8%	18.8%	1.0%	3.5%	0.7%
SRM 1941a						
NC384	115-104	2.09	51.20	89	90	110
NC406	115-93	1.98	50.92	96	92	95
	Average†	2.04	51.06	92	91	102
	Standard Deviation†	0.06	0.14	3.83	0.96	7.83
	Relative Standard Deviation	2.7%	0.3%	4.1%	1.1%	7.6%

DNPH = naphthalene-d8; DACE = acenaphthene-d10; DBAP = benzo[a]pyrene-d12.

Final

† In a previous report (dated 10/15/96), the averages and standard deviations for this table (1D) were incorrectly calculated. The correct values are displayed in this version (dated on or after 11/1/96).

Table 1E-p1: QA: Concentrations (ng/g, dry weight) of low molecular weight aromatic hydrocarbons in method blanks and Standard Reference Material (SRM 1941a) analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #		NPH	C1NPH	C2NPH	C3NPH	C4NPH	ACY	ACE	FLU	C1FLU	C2FLU	C3FLU	DBT	C1DBT	C2DBT	C3DBT	C4DBT
Method Blank																		
NC384	115-105		< 0.907	< 0.907	< 0.907	< 0.907	< 0.907	< .999	< 1.64	< 1.3	< 1.3	< 1.3	< 1.3	< 0.826	< 0.826	< 0.826	< 0.826	< 0.826
NC406	115-94		2.5	< 1.3	< 1.3	< 1.3	< 1.3	< 1.6	< 2.5	< 2	< 2	< 2	< 2	< 1.3	< 1.3	< 1.3	< 1.3	< 1.3
		Average*	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Standard	Deviation	1.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative	Standard	Deviation	100.0%	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
SRM 1941a																		
NC384	115-104		931	327	234	119	< 6.79	36.8	41.7	86.3	38.8	49.8	< 9.36	69.6	50.3	93.6	31.2	10.1
NC406	115-93		940	320	210	360	< 5.9	32	32	80	47	< 8.4	< 8.4	54	42	66	15	< 5.2
		Average*	937.87	324.51	221.78	237.54	0.00	34.54	37.01	83.42	43.11	24.88	0.00	61.70	46.05	79.74	22.88	5.04
	Standard	Deviation	7.05	2.82	11.90	118.24	0.00	2.26	4.65	2.92	4.33	24.88	0.00	7.87	4.25	13.90	8.36	5.04
Relative	Standard	Deviation	0.8%	0.9%	5.4%	49.8%	?	6.5%	0.1%	3.5%	10.0%	100.0%	?	12.8%	9.2%	17.4%	36.6%	100.0%

SRM 1941a	CC	1010	---	---	---	---	37§	41§	97.3	---	---	---	70§	---	---	---	---
Certified Concentrations (ng/g, dry wt)	95% CI	140							8.6								
	UCL	1553							143								
	LCL	566							58								

CC is the certified concentration; 95% CI is the 95% confidence interval; UCL is the upper control limit ([CC + 95% CI] + 35%); LCL is the lower control limit ([CC - 95% CI] - 35%).

§ACY, ACE, and DBT concentrations are reported as noncertified values.

NPH = naphthalene; C1NPH = C1-naphthalenes; C2NPH = C2-naphthalenes; C3NPH = C3-naphthalenes; C4NPH = C4-naphthalenes; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; C1FLU = C1-fluorenes; C2FLU = C2-fluorenes; C3FLU = C3-fluorenes; DBT = dibenzothiophene; C1DBT = C1-dibenzothiophenes; C2DBT = C2-dibenzothiophenes; C3DBT = C3-dibenzothiophenes; C4DBT = C4-dibenzothiophenes.

* When an analyte was detected in some, but not all of the method blanks or SRMs, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the method blanks or SRMs, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1F-p1: QA: Concentrations (ng/g, dry weight) of low and high molecular weight aromatic hydrocarbons in method blanks and Standard Reference Material (SRM 1941a) analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #		PHN	C1PHN	C2PHN	C3PHN	C4PHN	FLA	PYR	C1PYR	C2PYR	BAA	CHR†	BBF	BKF†	BAP	IDP	DBA	BZP
Method Blank																			
NC384	115-105		< 0.776	< 0.776	< 0.776	< 0.776	< 0.776	< 0.623	< 0.596	< 0.623	< 0.623	< 0.571	< 0.536	< 0.44	< 0.393	< 0.426	< 0.339	< 0.325	< 0.308
NC406	115-94		< 1.2	< 1.2	< 1.2	< 1.2	< 1.2	< .97	< 0.91	< .97	< .97	< 0.82	< 0.76	< 0.6	< 0.55	< 0.58	< 0.46	< 0.44	< 0.43
		Average*	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
	Standard	Deviation	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Relative	Standard	Deviation	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?	?
SRM 1941a																			
NC384	115-104		574	465	397	177	< 5.57	1070	833	603	483	419	608	696	632	554	509	98.6	549
NC406	115-93		560	390	270	130	< 5	1000	830	530	250	450	620	770	620	540	500	97	520
		Average*	567.47	427.80	334.55	154.89	0.00	1049.99	829.78	567.94	364.21	435.19	616.07	731.35	626.34	545.48	503.24	97.88	531.85
	Standard	Deviation	6.23	37.17	62.83	21.65	0.00	16.65	3.58	34.92	118.74	16.43	8.41	35.31	5.75	8.29	5.73	0.75	16.76
Relative	Standard	Deviation	1.1%	8.7%	18.8%	14.0%	?	1.6%	0.4%	6.1%	32.6%	3.8%	1.4%	4.8%	0.9%	1.5%	1.1%	0.8%	3.2%

SRM 1941a	CC	489	---	---	---	---	981	811	---	---	427	380	740	361	628	501	73.9	525
Certified	95% CI	23					78	24			25	24	110	18	52	72	9.7	67
Concentrations	UCL	691					1430	1127			610	545	1148	512	918	774	113	799
(ng/g, dry wt)	LCL	303					587	512			261	231	410	223	374	279	42	298

CC is the certified concentration; 95% CI is the 95% confidence interval; UCL is the upper control limit ([CC + 95% CI] + 35%); LCL is the lower control limit ([CC - 95% CI] - 35%).

PHN = phenanthrene; C1PHN = C1-phenanthrenes/anthracenes; C2PHN = C2-phenanthrenes/anthracenes; C3PHN = C3-phenanthrenes/anthracenes; C4PHN = C4-phenanthrenes/anthracenes; FLA = fluoranthene; PYR = pyrene; C1PYR = C1 fluoranthenes/pyrenes; C2PYR = C2 fluoranthenes/pyrenes; BAA = benz[a]anthracene; CHR = chrysene + triphenylene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene + benzo[j]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

† Chrysene (CHR) and triphenylene, as well as benzo[k]fluoranthene (BKF) and benzo[j]fluoranthene, are not resolved by our gas chromatographic procedure, whereas these compounds are resolved by the NIST procedure. In addition, the two pairs of compounds have very similar mass spectra, and we report each pair's combined concentrations as "CHR" and "BKF" respectively. Thus, our reported values for CHR and BKF may exceed the NIST upper control limit.

* When an analyte was detected in some, but not all of the method blanks or SRMs, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the method blanks or SRMs, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1G-p1: QA: Sample information for samples analyzed in duplicate for aromatic hydrocarbons as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	Sample Wt. (g)	Dry Wt. (%)	DNPH Recovery (%)	DACE Recovery (%)	DBAP Recovery (%)
Point Judith Pond Station 4 Jar 1 Of 3						
NC406	115-86	10.03	60.50	96	95	101
NC406	115-92	10.11	59.60	95	97	94
	Average	10.07	60.05	95.82	95.65	97.42
	Standard Deviation	0.04	0.45	0.45	1.08	3.08
	Relative Standard Deviation	0.4%	0.7%	0.5%	1.1%	3.2%

DNPH = naphthalene-d8; DACE = acenaphthene-d10; DBAP = benzo[a]pyrene-d12.

Table 1H-p1: QA: Concentrations (ng/g, dry weight) of low molecular weight aromatic hydrocarbons in sediment samples analyzed in duplicate as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	NPH	C1NPH	C2NPH	C3NPH	C4NPH	ACY	ACE	FLU	C1FLU	C2FLU	C3FLU	DBT	C1DBT	C2DBT	C3DBT	C4DBT
Point Judith Pond Station 4 Jar 1 Of 3																	
NC406	115-86	4.2	1.2	1	7.9	5.5	< .99	< 1.6	< 1.3	< 1.3	< 1.3	< 1.3	1.3	2.2	16	28	4.5
NC406	115-92	7.8	< 1.1	< 1.1	5.2	4.2	< 1.1	< 1.8	< 1.4	2.5	< 1.4	< 1.4	< 0.88	1.8	14	26	3.1
	Average*	5.98	0.62	0.50	6.55	4.85	0.00	0.00	0.00	1.26	0.00	0.00	0.63	1.98	14.82	26.82	3.82
	Standard Deviation	1.78	0.62	0.50	1.36	0.69	0.00	0.00	0.00	1.26	0.00	0.00	0.63	0.19	0.95	0.80	0.71
Relative	Standard Deviation	29.7%	100.0%	100.0%	20.8%	14.2%	?	?	?	100.0%	?	?	100.0%	9.8%	6.4%	3.0%	18.5%

NPH = naphthalene; C1NPH = C1-naphthalenes; C2NPH = C2-naphthalenes; C3NPH = C3-naphthalenes; C4NPH = C4-naphthalenes; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; C1FLU = C1-fluorenes; C2FLU = C2-fluorenes; C3FLU = C3-fluorenes; DBT = dibenzothiophene; C1DBT = C1-dibenzothiophenes; C2DBT = C2-dibenzothiophenes; C3DBT = C3-dibenzothiophenes; C4DBT = C4-dibenzothiophenes.

* When an analyte was detected in some, but not all of the samples, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the samples, zero is reported for the average and the SD and a "?" is reported for the RSD.

Final

Table 1l-p1: QA: Concentrations (ng/g, dry weight) of low and high molecular weight aromatic hydrocarbons in sediment samples analyzed in duplicate as part of the Barge North Cape Oil Spill (BNCOS) Study.

Set #	Sample #	PHN	C1PHN	C2PHN	C3PHN	C4PHN	FLA	PYR	C1PYR	C2PYR	BAA	CHR†	BBF	BKF†	BAP	IDP	DBA	BZP
Point Judith Pond Station 4 Jar 1 Of 3																		
NC406	115-86	21	20	60	70	< 0.77	45	40	28	8.7	15	24	21	21	16	12	0.58	14
NC406	115-92	22	24	59	59	< 0.85	72	70	39	6.7	31	55	37	43	40	30	4.6	30
	Average*	21.68	21.85	59.43	64.66	0.00	58.21	54.95	33.81	7.69	23.38	39.48	29.34	32.45	27.86	21.27	2.59	21.71
	Standard Deviation	0.43	2.22	0.20	5.67	0.00	13.61	14.95	5.63	0.99	8.03	15.97	8.03	11.00	12.15	8.79	2.01	8.01
Relative	Standard Deviation	2.0%	10.1%	0.3%	8.8%	?	23.4%	27.2%	16.6%	12.9%	34.3%	40.5%	27.4%	33.9%	43.6%	41.3%	77.5%	36.9%

PHN = phenanthrene; C1PHN = C1-phenanthrenes/anthracenes; C2PHN = C2-phenanthrenes/anthracenes; C3PHN = C3-phenanthrenes/anthracenes; C4PHN = C4-phenanthrenes/anthracenes; FLA = fluoranthene; PYR = pyrene; C1PYR = C1-fluoranthenes/pyrenes; C2PYR = C2-fluoranthenes/pyrenes; BAA = benz[a]anthracene; CHR = chrysene + triphenylene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene + benzo[j]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

† Chrysene (CHR) and triphenylene, as well as benzo[k]fluoranthene (BKF) and benzo[j]fluoranthene, are not resolved by our gas chromatographic procedure, whereas these compounds are resolved by the NIST procedure. In addition, the two pairs of compounds have very similar mass spectra, and we report each pair's combined concentrations as "CHR" and "BKF" respectively.

* When an analyte was detected in some, but not all of the samples, the average concentration is based on the concentration when detected and zero when not detected. When an analyte was not detected in any of the samples, zero is reported for the average and the SD and a "?" is reported for the RSD.

Table 1J-p1: QA: Continuing calibration verification data (based on % recoveries) for aromatic hydrocarbons in standards run before, during and after the samples analyzed as part of the Barge North Cape Oil Spill (BNCOS) Study.

Sample Name	NPH	ACY	ACE	FLU	DBT	PHN	FLA	PYR	BAA	CHR	BBF	BKF	BAP	IDP	DBA	BZP
NC384																
NC384AH4K1A	98	100	104	103	103	99	102	103	103	104	112	109	114	112	113	109
NC384AH4K1B	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NC384AH4K1C	100	103	105	104	103	101	99	102	101	102	102	101	103	101	101	102
Average	99	101	103	102	102	100	100	102	101	102	105	103	105	104	104	104
Standard Deviation	0.85	1.26	2.13	1.76	1.56	0.53	0.99	1.43	1.25	1.61	5.06	4.04	5.87	5.56	5.94	3.85
RSD	0.9%	1.2%	2.1%	1.7%	1.5%	0.5%	1.0%	1.4%	1.2%	1.6%	4.8%	3.9%	5.6%	5.3%	5.7%	3.7%
NC406																
NC406AH4K1A	96	100	100	102	101	100	102	101	102	100	102	100	102	101	103	103
NC406AH4K1B	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
NC406AH4K1C	102	102	101	102	102	101	104	102	97	105	100	101	100	99	99	100
Average	99	101	100	101	101	100	102	101	100	102	101	100	101	100	101	101
Standard Deviation	2.30	1.07	0.68	0.98	0.98	0.51	1.49	0.71	1.99	2.53	0.80	0.49	0.82	0.71	1.74	1.55
RSD	2.3%	1.1%	0.7%	1.0%	1.0%	0.5%	1.5%	0.7%	2.0%	2.5%	0.8%	0.5%	0.8%	0.7%	1.7%	1.5%

NPH = naphthalene; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; DBT = dibenzothiophene; PHN = phenanthrene; FLA = fluoranthene; PYR = pyrene; BAA = benz[a]anthracene; CHR = chrysene; BBF = benzo[b]fluoranthene; BKF = benzo[k]fluoranthene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.

Continuing calibration data for each set are reported as percent recovery versus calibration run B.

Table 1K: Standard curve correlation (r) from the linear regression of concentrations of the analyte to the area response for the multilevel standards.

Analyte	Set NC384 r	Set NC406 r
naphthalene	1.000	1.000
acenaphthylene	0.999	1.000
acenaphthene	0.999	1.000
fluorene	0.999	1.000
phenanthrene	0.999	1.000
fluoranthene	1.000	1.000
pyrene	0.999	1.000
benz[a]anthracene	0.999	1.000
chrysene	0.999	1.000
benzo[a]pyrene	1.000	0.999
indeno[1,2,3-cd]pyrene	0.999	1.000
dibenz[a,h]anthracene	0.999	1.000
benzo[ghi]perylene	0.999	1.000
d8-naphthalene	0.999	0.999
d10-acenaphthene	0.999	1.000
d12-benzo[a]pyrene	0.999	1.000
d12-perylene	0.999	1.000
d10-phenanthrene	0.999	1.000
d10-biphenyl	0.999	1.000
d8-fluorene	0.999	1.000

Based on six concentration levels of standards.

Table 1L-p1: Concentrations of analytes in 7 replicates of spiked clean matrix and calculated method detection limits (MDL, ng/g, dry weight) for aromatic hydrocarbons calculated by the method in appendix B of 40CFR part 136.

Sample	NPH	MN2	ACY	ACE	FLU	PHN	ANT	FLA	PYR	BAA	CHR	BBF	BKF	BAP
110-43	14.2	13.3	13.6	14.4	15.6	16.1	11.6	20.0	20.8	16.1	19.4	22.4	18.6	18.0
110-44	15.5	12.6	15.0	12.6	17.7	17.7	13.5	22.1	21.7	15.6	18.8	20.0	18.6	17.6
110-45	16.6	10.2	15.0	14.1	13.7	16.2	12.4	19.5	19.6	17.3	19.0	19.7	18.2	18.5
110-46	13.9	8.4	13.9	11.5	13.0	16.1	13.0	19.3	19.3	15.4	18.8	19.5	17.5	18.2
110-47	14.2	11.2	13.3	11.7	16.0	16.6	13.0	20.4	19.0	17.2	18.6	20.3	17.7	18.3
110-48	16.2	10.4	13.1	15.3	14.9	17.2	13.7	19.4	20.8	16.9	18.9	20.1	18.8	17.2
110-49	15.0	12.0	12.7	14.0	13.5	17.9	12.5	19.7	18.2	16.6	19.6	19.9	17.6	17.6
Average	15.1	11.2	13.9	13.4	14.9	16.8	12.8	20.0	19.9	16.5	19.0	20.3	18.2	17.9
Std Dev	1.05	1.66	1.04	1.44	1.66	0.77	0.73	0.96	1.22	0.77	0.39	0.96	0.53	0.48
MDL	3.29	5.22	3.25	4.51	5.20	2.43	2.29	3.01	3.85	2.41	1.21	3.01	1.68	1.50

Sample	IDP	DBA	BZP
110-43	12.6	7.3	14.1
11044	13.1	7.4	12.9
110-45	12.9	8.5	13.1
110-46	11.0	6.6	11.2
110-47	13.7	9.6	14.1
110-48	12.1	5.2	12.0
11049	10.3	6.3	12.1
Average	12.2	7.3	12.8
Std Dev	1.21	1.48	1.11
MDL	3.80	4.64	3.50

NPH = naphthalene; 2MN = 2-methylnaphthalene; ACY = acenaphthylene; ACE = acenaphthene; FLU = fluorene; PHN = phenanthrene; ANT = anthracene; FLA = fluoranthene; PYR = pyrene; BAA = benz[a]anthracene; CHR = chrysene; BAP = benzo[a]pyrene; IDP = indeno[1,2,3-cd]pyrene; DBA = dibenz[a,h]anthracene; BZP = benzo[ghi]perylene.