Analysis of edible tissue and bile from fish collected in coastal waters of the Gulf of Mexico potentially affected by Hurricane Katrina to determine exposure to persistent organic pollutants (POPs) and polycyclic aromatic compounds (PACs)

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Summary
Analyses have been completed for edible tissue and bile samples of fish from all the sites sampled during the *R/V Nancy Foster* cruises of 12-16 September 2005 and 28 September-2 October 2005. The results indicated that the samples of Atlantic croaker and bigeye tuna collected after Hurricane Katrina contained concentrations of persistent organic pollutants (POPs; e.g., PCBs and DDTs) that were well below the Food and Drug Administration (FDA) regulatory limits for seafood, but did fall within levels subject to fish consumption advice from the U.S. Environmental Protection Agency (EPA). Unfortunately, there are no "pre-Katrina" measurements available for POPs in fish muscle for these species from the study area. However, the levels of POPs found in fish from the study area were similar to those reported for nonurban areas of the world. Because the brominated flame retardants thought to be associated with urban runoff were detected only at very low levels (≤ 1 ng/g), the results indicated that the concentrations of POPs in the fish tissues were not likely a result of contamination released due to Hurricane Katrina.

Because PACs are rapidly metabolized by vertebrates and the metabolites are transferred to bile for elimination, fish were expected to have low levels of unmetabolized polycyclic aromatic compounds (PACs) in muscle. To demonstrate that this supposition was correct, a few Atlantic croaker muscle samples were analyzed for PACs and mean concentrations were found to be low (< 70 ng/g). Furthermore, the results of measuring PAC metabolites in bile demonstrated that Atlantic croaker, bigeye tuna, hardhead catfish and spot collected after Hurricane Katrina showed no greater exposure to PACs indicative of petroleum than had been found for croaker and hardhead catfish collected in 1989-91 under NOAA's National Benthic Surveillance Project (NBSP). Although the PAC metabolite levels of Atlantic croaker collected four weeks after the hurricane were comparable to or somewhat higher (but not significantly higher) than the levels measured in croaker collected two weeks earlier, it is difficult to determine if this finding is due to variability of biliary PAC metabolites in these fish or to an increased PAC input into the region over this time period. Continued sampling efforts in this region are needed to help determine if there is a trend showing an increase in PAC metabolites bile.

Introduction
Following Hurricane Katrina, major concerns included risks to human health through consumption of contaminated seafood, as well as effects of contaminants on the health of living marine resources. During the cruises of the *R/V Nancy Foster* (12-16 September 2005 and 28 September-2 October 2005), seafood species (e.g., fish, crustaceans) were

sampled to determine their suitability for consumption by measuring chemical contaminant levels. Analyses of fish captured from coastal waters of the Gulf of Mexico for POPs and PACs in edible tissue, as well as for PAC metabolites in bile, have now been completed.

POPs include several classes of pesticides and industrial chemicals (e.g., PCBs, chlordanes, DDTs) that can bioaccumulate to relatively high concentrations in top-level predators (e.g., fish and marine mammals) of the marine food web through trophic transfer. POPs enter the marine environment via several sources (e.g., atmospheric transport, terrestrial runoff) and are found in environmental samples from all over the world (de Wit *et al.*, 2004). A large body of evidence links POP exposure to a wide range of deleterious biological effects (e.g., immunosuppression, endocrine disruption) in marine animals (de Wit *et al.*, 2004; O'Hara and O'Shea, 2001). Because so many of these POPs are toxic to wildlife and humans, a number of these compounds have been banned in the U.S. (e.g., DDTs 1972; PCBs for new uses 1970; lindane 1983; chlordanes 1988) (AMAP, 1998).

Polybrominated diphenyl ethers (PBDEs) are an “emerging” class of POPs that are rapidly gaining the attention of regulatory agencies (de Wit, 2002). These compounds are added to plastics, textiles, clothing, electronic circuit boards and other materials as flame retardants. PBDEs often enter the environment through urban runoff and sewage outfalls and have been shown to bioaccumulate in marine animals (de Wit, 2002). Various studies have shown that some PBDE congeners may induce various toxicological effects in laboratory animals, including immune dysfunction, liver toxicity and thyroid disruption (de Wit, 2002).

PACs, chemical contaminants that are ubiquitous in urban embayments, are derived from petroleum or their combustion products. PACs can alter normal physiological function in marine biota (Johnson *et al.*, 2002; Stein *et al.*, 1992; Varanasi *et al.*, 1989). Therefore, concerns have been raised about the effects of exposure to PACs, alone or in combination with other toxic contaminants, on marine organisms because of the worldwide use of fossil fuels (Geraci and Aubin, 1990) and the occurrence of oil spills. Marine fish can be exposed to PACs by various routes (e.g., consumption of contaminated prey, direct contact via gills). Fish and other vertebrates rapidly take up PACs present in their food and the environment and metabolize these compounds to more polar compounds (Varanasi *et al.*, 1989). The polar PAC metabolites are then secreted into the bile for elimination. As a result, fish exposed to high levels of PACs contain relatively low levels of these compounds in their muscle (Hom *et al.*, 1996; Hom *et al.*, 1999). Therefore, it is necessary to analyze bile for PAC metabolites to provide information on recent exposure of fish to PACs.

Methods

The station identification numbers for fish captured during the *R/V Nancy Foster* cruises are shown in Figure 1.

Fish muscle analyses for POPs and PACs

Muscle samples from two croaker were usually composited to have sufficient tissue for analysis. Then, the samples of Atlantic croaker and juvenile bigeye tuna were extracted and analyzed for POPs and PACs using the method of Sloan *et al.* (2005).

This method involves: (1) extraction of tissue using an accelerated solvent extraction procedure, (2) clean-up of the entire methylene chloride extract on a single stacked silica gel/alumina column, (3) separation of POPs from the bulk lipid and other biogenic material by high-performance size exclusion liquid chromatography, and (4) analysis on a low resolution quadrupole GC/MS system equipped with a 60-meter DB-5 GC capillary column. The instrument was calibrated using a set of ten multi-level calibration standards of known concentrations. Total lipid in the fish muscle samples were measured by a TLC/FID method (Ylitalo *et al.*, 2005).

In this report, sum PCBs is the sum of congeners 17, 18, 28, 31, 33, 44, 49, 52, 66, 70, 74, 82, 87, 95, 99, 101/90, 105, 110, 118, 128, 138/163/164, 149, 151, 153/132, 156, 158, 170, 171, 177, 180, 183, 187/159/182, 191, 194, 195, 199, 205, 206, 208, 209; sum DDTs is the sum of o,p'-DDD, p,p'-DDD, o,p'-DDE, p,p'-DDE, o,p'-DDT and p,p'-DDT; sum chlordanes is the sum of oxychlordane, *gamma*-chlordane, nona-III-chlordane, *alpha*-chlordane, *trans*-nonachlor, and *cis*-nonachlor; sum hexachlorocyclohexanes (HCHs) includes the sum of *alpha*-, *beta*-, and *gamma*-HCH isomers, and finally, sum PBDEs is the sum of congeners 28, 47, 49, 66, 85, 99, 100, 153, 154, 183. In addition, sum "low molecular weight PACs" (LMWACs) includes naphthalene, C1- through C4-naphthalenes, biphenyl, acenaphthylene, acenaphthene, fluorene, C1- through C3-fluorenes, phenanthrene, C1- through C4-phenanthrenes, dibenzothiophene, C1- through C3-dibenzothiophenes and anthracene. Sum "high molecular weight PACs" (HMWACs) includes fluoranthene, pyrene, C1-fluoranthenes/pyrenes, benz[a]anthracene, chrysene/ triphenylene, C1- through C4-chrysenes/ benz[*a*]anthracenes, benzo[*b*]fluoranthene, benzo[*j*]fluoranthenes/ benzo[*k*]fluoranthene, benzo[*e*]pyrene, benzo[*a*]pyrene, perylene, idenopyrene, dibenz[*a,h*+*a,c*]anthracene, benzo[*ghi*]perylene. Total PACs is the sum of LMWACs and HMWACs.

Bile analyses for PAC metabolites

Because each Atlantic croaker and spot contained a small volume of bile (< 25 µL), bile samples from 2 to 11 fish were composited in the field to provide adequate bile volume for HPLC/fluorescence analysis. Bile of Atlantic croaker, bigeye tuna, hardhead catfish and spot were analyzed for metabolites of PACs using a high-performance liquid chromatography/ fluorescence detection (HPLC/fluorescence) method described by Krahn *et al.* (1984).

Bile was injected directly onto a C-18 reverse-phase column (Phenomenex Synergi Hydro) and eluted with a linear gradient from 100% water (containing a trace amount of acetic acid) to 100% methanol at a flow of 1.0 mL/min. Chromatograms were recorded at the following wavelength pairs: 1) 293/335 nm where many 2-3 benzene ring aromatic compounds (e.g., naphthalene) fluoresce, 2) 260/380 nm where several 3-4 ring compounds (e.g., phenanthrene) fluoresce and 3) 380/430 nm where 4-5 ring compounds (e.g., benzo[a]pyrene) fluoresce. Peaks eluting after 5 minutes were integrated and the areas of these peaks were summed. The concentrations of fluorescent PACs in the bile samples of fish were determined using naphthalene (NPH), phenanthrene (PHN) or benzo[a]pyrene (BaP) as external standards and converting the fluorescence response of bile to phenanthrene (ng PHN equivalents/g bile), naphthalene (ng NPH equivalents/g bile) or benzo(a)pyrene (ng BaP equivalents/g bile) equivalents.

Statistical methods

All multivariate and univariate statistical analyses were conducted using JMP Statistical Discovery Software (Macintosh profession edition, version 5.01). Univariate comparisons between 2 group means were significance tested ($\alpha = 0.05$) using a 2-sample Student's *t*-test. All values that were less than the limit of quantitation were set to zero.

Quality assurance

Quality control samples [i.e., method blank; replicate; and a standard reference material (SRM) or a Control Material (for bile)] were analyzed with each set of field samples as part of a performance-based quality assurance Program (Krahn *et al.*, 1988). Results obtained for SRMs 1974b and 1947 were in excellent agreement with certified and reference values published for these materials by the National Institute of Standards and Technology. In addition, the other quality control samples met established laboratory criteria.

Results and Discussion

Persistent organic pollutants in fish muscle

A summary of the results obtained from analyses for POPs in Atlantic croaker and bigeye tuna from the two *R/V Nancy Foster* cruises are presented in Table 1; results for each of the samples and individual analytes, as well as Quality Assurance tables, are available in Appendix 1. From Table 1, it is apparent that most POP groups (i.e., the sums of PCBs, DDTs, chlordanes, HCHs and PBDEs) in the Atlantic croaker and bigeye tuna had mean concentrations that ranged in the low parts-per-billion (ng/g). The highest mean concentrations for sum PCBs (60 ng/g) and sum DDTs (15 ng/g) were found for Atlantic croaker from station number 3 (Head of Passes, in the Mississippi River Delta region). Sum chlordanes were highest in Atlantic croaker from station number 49 (about 3 ng/g), whereas sum HCHs and sum PBDEs were 1 ng/g or less in all samples.

Samples of fish were collected at two time periods about two weeks apart, but only Atlantic croaker from Southwest Pass (designated as station 3 on the first cruise and 32/37 on the second) were sampled on both cruises. Comparing the results from the two time periods for Southwest Pass croaker (Table 2), the concentrations of all summed POPs were higher in the samples collected during the first cruise, but the only statistically significant differences found ($p<0.05$) were for sum PCBs and sum chlordanes. Although the decrease in concentrations may just reflect a natural variability in POP levels in fish from the area, the results indicate that the expected increase in POPs levels resulting from Hurricane Katrina has not yet been demonstrated. Unfortunately, no pre-Katrina fish muscle samples were available for comparison.

The FDA has published regulatory guidelines for seafood safety as follows (wet weight): PCBs, 2,000 ng/g; DDTs, 5,000; chlordanes, 300 ng/g (National Academy of Sciences, 1991). There are no FDA guidelines available for HCHs or PBDEs. All the fish tissues analyzed in the current study had concentrations well below the FDA regulatory guidelines. However, the EPA also issues risk-based guidance for consuming fish containing PCBs, and some of the samples had levels of PCBs that would fall within the EPA guidance (EPA, 1999; EPA, 2005). The EPA and FDA are discussing how to coordinate scientific assessments for risks posed by PCBs in fish.

Metabolites of polycyclic aromatic compounds in fish bile

Levels of PAC metabolites measured in bile of Atlantic croaker, bigeye tuna, hardhead catfish and spot collected near coastal regions impacted by Hurricane Katrina are reported in Table 3; results for each bile sample, as well as Quality Assurance tables, are available in Appendix 2. Both NPH and PHN equivalents were highest in bile of Atlantic croaker from Southwest Pass and BaP equivalents were highest in samples from EPA-K14. However, similar concentrations of NPH and BaP equivalents were measured in Atlantic croaker collected in Louisiana and Alabama in 1989-91 for NOAA's NBSP (Table 4) (Ylitalo, pers. commun.). Similarly, the PAC equivalents determined in bile of hardhead catfish captured in 2005 were in the same range as those determined for hardhead catfish captured in 1990-91 as part of the NBSP (Table 4). In general, the concentrations of NPH and BaP metabolites measured in bile of hardhead catfish were somewhat lower than those measured in bile of Atlantic croaker and spot. Overall, the levels of NPH and BaP equivalents measured in bile of Atlantic croaker, hardhead catfish and spot collected in 2005, as well as croaker and hardhead catfish captured in 1989-91 were similar to those measured in bile of fish collected in urbanized and semi-urbanized waterways of the U.S. (Myers *et al.*, 1994; Stehr *et al.*, 2000).

To look at temporal trends, PAC metabolite levels measured in bile of Atlantic croaker captured two and four weeks post-hurricane from Southwest Pass were compared (Table 5). At this site, PHN and BaP equivalents in the bile of croaker collected four weeks after the hurricane were comparable to or somewhat higher, but not significantly higher, than the levels measured in croaker collected two weeks earlier, whereas NPH equivalents were comparable between the two time points. Although these findings may reflect the variability of biliary PAC metabolite levels in croaker from the area, they may also be a result of increased PAC input into the region over this time period. Additional sampling efforts in the near future will help determine whether this trend continues.

Polycyclic aromatic compounds in fish muscle

Because PACs are rapidly metabolized by vertebrates (Varanasi *et al.*, 1989), the fish collected for this study were expected to have low levels of unmetabolized PACs in muscle. To demonstrate that this supposition is correct, several Atlantic croaker muscle composites were analyzed for PACs and were found to be below 70 ng/g (Table 6; results for the muscle samples, as well as Quality Assurance tables, are provided in Appendix 3). Furthermore, PAC concentrations in muscle of the fish from Southwest Pass collected on the second cruise of the *RV Nancy Foster* were significantly lower ($p<0.05$) than those from the first cruise (Table 6). Thus, there is little indication of increasing exposure of fish to PACs released due to Hurricane Katrina. Because the FDA provides no regulatory limits for PACs in seafood, no comparisons could be made.

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Table 1. Concentrations of persistent organic pollutants (POPs) measured in edible tissue (muscle) of Atlantic croaker and bigeye tuna collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina (*R/V Nancy Foster* #1 cruise 12-16 September 2005 and *R/V Nancy Foster* #2 cruise 28 September-1 October 2005).

Species / Cruise	Station number[1]	Collection site	Composites per Station[2]	Collection date	ng/g, wet weight ± SD				
					Sum PCBs[3]	Sum DDTs[3]	Sum Chlordanes[3]	Sum HCHs[3]	Sum PBDEs[3]
Atlantic croaker									
***Nancy Foster* #1**									
	3	Head of Passes, LA	3	9/13/2005	60 ± 53	15 ± 13	2.0 ± 2.0	0.13 ± 0.22	0.74 ± 0.75
	4	Southwest Pass, LA	11	9/13/2005	41 ± 22	11 ± 6.5	2.0 ± 1.6	0.17 ± 0.18	0.89 ± 1.0
	9	SE of Chandeleur Islands, LA	3	9/14/2005	25 ± 29	6.7 ± 8.1	1.3 ± 2.1	0.09 ± 0.16	1.0 ± 1.4
	10	North of Horn Island, AL	7	9/15/2005	2.5 ± 1.2	0.8 ± 0.4	1.1 ± 0.5	< LOQ	< LOQ
	11	South of Horn Island, AL	10	9/15/2005	4.9 ± 2.1	2.4 ± 1.3	0.2 ± 0.3	< LOQ	< LOQ
			Mean (34 composites) ± SD		23 ± 28	6.2 ± 7.2	1.2 ± 1.4	0.08 ± 0.14	0.44 ± 0.81
***Nancy Foster* #2**									
	32/37	Southwest Pass, LA	4	9/30/2005	13 ± 5.0	3.4 ± 1.3	0.1 ± 0.1	< LOQ	< LOQ
	42	Fish Site #3	5	10/1/2005	13 ± 5.2	3.5 ± 1.2	0.2 ± 0.3	< LOQ	< LOQ
	43	Fish Site #4	4	10/1/2005	5.3 ± 2.5	1.5 ± 0.63	< LOQ	< LOQ	< LOQ
	49	EPA K14	5	10/2/2005	5.8 ± 1.9	2.6 ± 1.2	2.9 ± 1.0	0.04 ± 0.08	0.26 ± 0.24
			Mean (18 composites) ± SD		9.5 ± 5.4	2.8 ± 1.3	0.88 ± 1.4	0.01 ± 0.04	0.07 ± 0.16
Bigeye tuna									
***Nancy Foster* #1**									
	8	SE of Chandeleur Islands, LA	4	9/14/2005	15 ± 8.8	2.2 ± 1.6	0.09 ± 0.10	< LOQ	0.69 ± 0.57

[1]Stations are shown on the map in Figure 1.

[2]Each composite contained muscle tissue from two fish; the composites from each station were averaged for this table.

[3]Individual compounds summed are given in the Methods section. When calculating averages, if a concentration for a composite was "less than the limit of quantitation" (<LOQ), it was set = 0.

Table 2. Concentrations of persistent organic pollutants (POPs) measured at two time points in edible tissue (muscle) of Atlantic croaker collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina.

Cruise	Station number[1]	Collection site	Composites per Station[2]	Collection date	ng/g, wet weight ± SD				
					Sum PCBs[3]	Sum DDTs[3]	Sum Chlordanes[3]	Sum HCHs[3]	Sum PBDEs[3]
Nancy Foster #1	4	Southwest Pass, LA	11	9/13/2005	41 ± 22*	11 ± 6.5	2.0 ± 1.6*	0.17 ± 0.18	0.89 ± 1.0
Nancy Foster #2	32/37	Southwest Pass, LA	4	9/30/2005	13 ± 5.0	3.4 ± 1.3	0.1 ± 0.1	< LOQ	< LOQ

[1]Stations are shown on the map in Figure 1.

[2]Each composite contained muscle tissue from one or two fish; the composites from each station were averaged for this table.

[3]Individual compounds summed are given in the Methods section. When calculating averages, if a concentration for a composite was "less than the limit of quantitation" (<LOQ), it was set = 0.

*Statistical analysis found significantly different (higher; $p<0.05$) levels for the 9/13/2005 samples than for samples from the later time period.

Table 3. Concentrations of metabolites of polycyclic aromatic compounds (PACs) measured in bile of Atlantic croaker, hardhead catfish, bigeye tuna and spot collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina.

Species / Cruise	Station number	Collection site	Composites or samples per station	Collection date	Equivalents of fluorescent aromatic compounds (ng/g bile, wet weight ± SD) NPH equivalents[1]	PHN equivalents[2]	BaP equivalents[3]
Atlantic croaker							
***Nancy Foster* #1**							
	3A	Head of Passes, LA	1	9/13/2005	170,000	51,000	770
	4	Southwest Pass, LA	3	9/13/2005	220,000 ± 50,000	75,000 ± 7,000	830 ± 110
	9	SE of Chandeleur Islands, LA	1	9/14/2005	140,000	21,000	620
	10	North of Horn Island, AL	1	9/15/2005	160,000	42,000	3,100
	11	South of Horn Island, AL	2	9/15/2005	63,000 ± 11,000	18,000 ± 6,400	1,500 ± 1,000
			Mean ± SD (n = 8 composites)		**160,000 ± 72,000**	**47,000 ± 27,000**	**1,200 ± 910**
***Nancy Foster* #2**							
	32/37	Southwest Pass, LA	5	9/30/2005	200,000 ± 59,000	84,000 ± 51,000	1,500 ± 840
	42	EPA Site #3	2	10/1/2005	170,000 ± 28,000	54,000 ± 28,000	650 ± 240
	43	North Pass, LA	1	10/1/2005	130,000	27,000	390
	49	EPA - K14	1	10/1/2005	170,000	22,000	9,300
			Mean ± SD (n = 9 composites)		**180,000 ± 49,000**	**64,000 ± 46,000**	**2,000 ± 2,800**
Bigeye tuna							
***Nancy Foster* #1**							
	8	Southeast of Chandeleur Islands, LA	1	9/14/2005	96,000	6,100	270
Hardhead catfish							
***Nancy Foster* #2**							
	49	EPA - K14	10	10/1/2005	100,000 ± 58,000	58,000 ± 41,000	1,000 ± 510
Spot							
***Nancy Foster* #2**							
	48	EPA - K06	3	10/1/2005	260,000 ± 60,000	86,000 ± 12,000	1,900 ± 200
	49	EPA - K14	3	10/1/2005	250,000 ± 44,000	61,000 ± 12,000	1,700 ± 320
			Mean ± SD (n = 6 composites)		**250,000 ± 47,000**	**74,000 ± 18,000**	**1,800 ± 270**

[1]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of naphthalene standard at 293/335 nm wavelengths

[2]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of phenanthrene standard at 260/380 nm wavelengths

[3]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of benzo[a]pyrene standard at 380/430 nm wavelengths

Table 4. Concentrations of metabolites of polycyclic aromatic compounds measured previously in bile of Atlantic croaker collected in the Gulf of Mexico region as part of NOAA's National Benthic Surveillance Project.

Species	Number of Samples	Station Number	Collection Site	Collection Year	Mean equivalents of fluorescent aromatic compounds (ng/g bile, wet weight): NPH equivalents[1]	PHN equivalents[2]	BaP equivalents[3]
Atlantic croaker	10	3A	Mississippi River Delta, Head of Passes, LA	1989	200,000 ± 26,000	not analyzed	1,000 ± 130
Atlantic croaker	10	12	Mississippi River Delta, Southeast Pass, LA	1990	200,000 ± 87,000	not analyzed	1,400 ± 710
Atlantic croaker	10	off map[4]	Calcasieu River, Prien Lake, LA	1990	730,000 ± 230,000	not analyzed	5,700 ± 2,400
Atlantic croaker	7	off map[4]	Calcasieu River, West Cove, LA	1990	510,000 ± 370,000	not analyzed	7,500 ± 8,200
Atlantic croaker	10	13	Mobile Bay, North Point, AL	1990	120,000 ± 64,000	not analyzed	1,400 ± 710
Hardhead catfish	10	12	Mississippi River Delta, Southeast Pass, LA	1990	84,000 ± 31,000	not analyzed	700 ± 430
Hardhead catfish	10	off map[4]	Calcasieu River, Prien Lake, LA	1900	240,000 ± 96,000	not analyzed	1,800 ± 670
Hardhead catfish	10	off map[4]	Calcasieu River, West Cove, LA	1990	42,000 ± 21,000	not analyzed	370 ± 140

[1]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of naphthalene standard at 293/335 nm wavelengths

[2]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of phenanthrene standard at 260/380 nm wavelengths

[3]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of benzo[a]pyrene standard at 380/430 nm wavelengths

[4]Station located in western Louisiana, near the border with Texas

Table 5. Concentrations of metabolites of polycyclic aromatic compounds (PACs) measured at two time points in bile of Atlantic croaker collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina.

Cruise	Station number[1]	Collection site	Composites per Station[2]	Collection date	Mean equivalents of fluorescent aromatic compounds (ng/g bile, wet weight ± SD)*: NPH equivalents[3]	PHN equivalents[4]	BaP equivalents[5]
Nancy Foster #1	4	Southwest Pass, LA	3	9/13/2005	220,000 ± 41,000	75,000 ± 5,700	830 ± 86
Nancy Foster #2	32/37	Southwest Pass, LA	5	9/30/2005	200,000 ± 59,000	84,000 ± 51,000	1,500 ± 840

[1]Stations are shown on the map in Figure 1.

[2]Each composite contained bile from two or more fish (see Table x); the composites from each station were averaged for this table.

[3]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of naphthalene standard at 293/335 nm wavelengths

[4]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of phenanthrene standard at 260/380 nm wavelengths

[5]Concentrations in part per billion (ng/g) based on total area compared to the fluorescence of benzo[a]pyrene standard at 380/430 nm wavelengths

*Results for the two time periods were not statistically different.

Table 6. Concentrations of polycyclic aromatic compounds (PACs) measured in edible tissue (muscle) of Atlantic croaker collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina.

Species / Cruise	Station number	Collection site	Composites per station	Collection date	Sum LMWACs[1] (ng/g, wet weight ± SD)	Sum HMWACs[2] (ng/g, wet weight ± SD)	Sum PACs[3] (ng/g, wet weight ± SD)
Atlantic croaker							
***Nancy Foster* #1**							
	4	Southwest Pass, LA	5	9/13/2005	60 ± 21*	1.6 ± 0.59*	62 ± 22*
	9	SE of Chandeleur Islands, LA	2	9/14/2005	41 ± 16	< LOQ	41 ± 16
	10	North of Horn Island, AL	3	9/15/2005	37 ± 6.7	0.60 ± 0.10	37 ± 6.8
	11	South of Horn Island, AL	3	9/15/2005	37 ± 13	0.49 ± 0.10	37 ± 13
			Mean (13 composites) ± SD		46 ± 18	0.88 ± 0.74	47 ± 19
***Nancy Foster* #2**							
	32/37	Southwest Pass, LA	4	9/30/2005	21 ± 3.4	0.84 ± 0.21	22 ± 3.5
	42	Fish Site #3	1	10/1/2005	35	0.85	36
	43	Fish Site #4	1	10/1/2005	20	< LOQ	20
	49	EPA K14	1	10/2/2005	41	0.66	42
			Mean (7 composites) ± SD		29 ± 10	0.59 ± 0.40	30 ± 11

[1] Sum concentrations of low molecular weight aromatic compounds that include 2 and 3-ring ACs, from naphthalene through C4-phenanthrenes.

[2] Sum concentrations of high molecular weight aromatic compounds that include 4 through 6-ring ACs, from fluoranthene through benzo[ghi]perylene.

[3] Sum PACs includes sum LWMACs and sum HMWACs.

*Statistical analysis found significantly different (higher; P<0.05) levels for the 9/13/2005 samples from Southwest Pass than for samples from the same site on 9/30/2005.

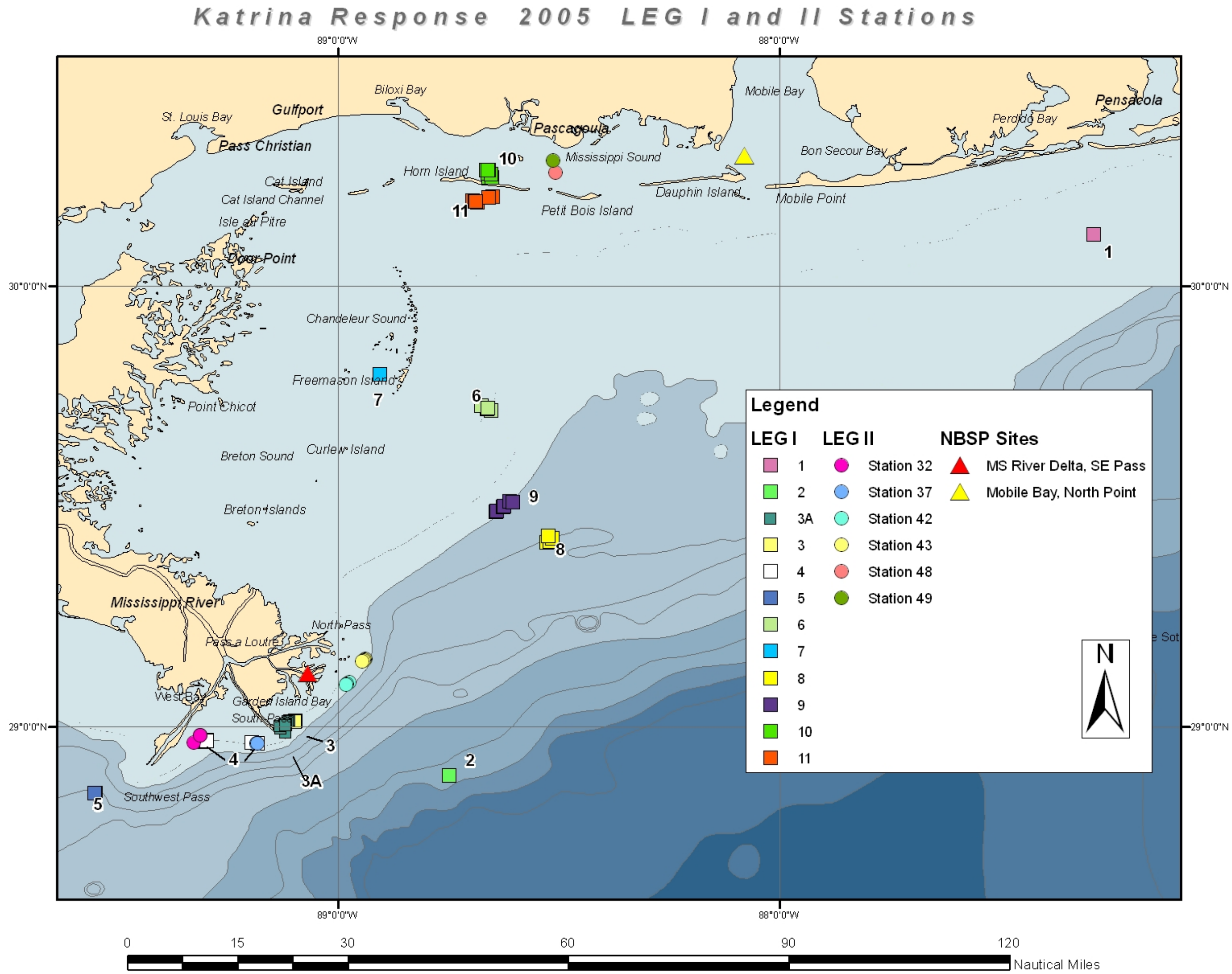

Figure 1. Stations (numbers 1-11) sampled during the R/V Nancy Foster cruise of 12-16 September 2005 (Leg I in Legend) and those sampled during the Nancy Foster cruise of 28 September-2 October 2005 (Leg II).