Analyses for persistent organic pollutants (POPs) and polycyclic aromatic compounds (PACs) in white shrimp (*Penaeus setiferus*) sampled over a seven month period following Hurricane Katrina

Margaret M. Krahn, Gina M. Ylitalo, Donald W. Brown and Tracy K. Collier
Environmental Conservation Division
Northwest Fisheries Science Center
NOAA Fisheries Service

Summary
Analyses have been completed on white shrimp (*Penaeus setiferus*) sampled from nearshore areas of the northern Gulf of Mexico over a period of seven months following Hurricane Katrina. Levels of persistent organic pollutants (POPs; e.g., PCBs and DDTs) and polycyclic aromatic compounds (PACs; e.g., naphthalene, phenanthrene, benzo[*a*]pyrene) in all samples were consistently below levels associated with substantive human health concerns. Although distinct increases in low molecular weight PACs (LMWACs) were found during the first six weeks following Katrina, by April 2006 these increased levels had diminished to approximately the same low levels seen immediately following the hurricane. Overall, the results suggest that there was short-term exposure of white shrimp to low levels of oil or other petroleum-derived products in the area affected by Hurricane Katrina, but that over the winter of 2005-6 this exposure ceased.

Introduction
One of the major concerns following Hurricane Katrina was the risk to human health through consumption of contaminated seafood. During a number of cruises in coastal waters of the Gulf of Mexico, white shrimp (*Penaeus setiferus*) were sampled in order to measure chemical contaminant levels (POPs and PACs) and determine their suitability for consumption. 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) through trophic transfer. POPs enter the marine environment via several sources (e.g., atmospheric transport, terrestrial runoff) and are found in environmental samples world-wide (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; Meador *et al.*, 2002; O'Hara and O'Shea, 2001). Many of these POPs are toxic to wildlife and humans, thus 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).

PBDEs are a class of "emerging" POPs that are quickly 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 are known to enter the environment through urban runoff and sewage outfalls and have been shown to bioaccumulate in marine animals (de Wit, 2002). A number of studies have shown that some PBDE congeners may induce toxicological effects in laboratory

animals, including immune dysfunction, liver toxicity and thyroid disruption (de Wit, 2002).

PACs (e.g., phenanthrene, benzo[*a*]pyrene) are a class of chemical contaminants primarily derived from oil products or combustion of oil products. These compounds are frequently found in urban embayments and can alter physiological functions in marine biota (Johnson *et al.*, 2002). Concerns have been raised over 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 in areas that support populations of marine fish and invertebrates. Marine animals can be exposed to PACs via various routes (e.g., consumption of contaminated prey, uptake via gills, direct contact with sediments) and rapidly take up PACs present in the environment. Vertebrates efficiently metabolize PACs, and thus rarely contain substantial amounts of PACs in their edible muscle (Varanasi *et al.*, 1989). In contrast, invertebrate species have limited ability to metabolize PACs, so these compounds, if present in the environment, are comparatively more likely to accumulate in edible tissues of invertebrate species.

Methods

Station names and identification numbers for locations where white shrimp were captured during *F/V Patricia Jean* cruises (17 November -18 December 2005) and the *F/V Miss Peggy* cruise (11-15 April 2006) are shown in Figure 1. The study area was divided into three regions—Mobile Bay, Mississippi Sound and Lake Borgne—and these regions are indicated in Figure 1.

Prior to analysis, the shrimp heads and shells were removed and the remaining edible portion (tail muscle) of individual shrimp were composited. The shrimp composite samples were extracted and analyzed for POPs and PACs using the method of Sloan *et al.* (2005). This method involves: (1) extraction of tissue using methylene chloride in an accelerated solvent extraction procedure, (2) clean-up of the methylene chloride extract on a single stacked silica gel/alumina column, (3) separation of POPs and PACs 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 sets of up to ten multi-level calibration standards of known concentrations. Following this procedure, a total of 40 PCB and 10 PBDE congeners and 24 chlorinated pesticides were determined in these samples. Total lipid in the shrimp samples was measured by a thin-layer chromatography flame ionization method (Ylitalo *et al.*, 2005).

All contaminant concentrations in this document are reported in ng/g (parts per billion), wet weight. 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) is the sum of *alpha-*, *beta-*, and *gamma*-HCH isomers, and sum PBDEs is the sum of congeners 28, 47, 49, 66, 85, 99, 100, 153, 154, 183. 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.

As part of performance-based laboratory quality assurance (Sloan *et al.*, in press), quality control samples [a method blank, replicate and Standard Reference Materials (SRMs, e.g., NIST 1974a and 1946)] were analyzed with each sample set (Krahn *et al.*, 1988). Results for SRMs and other quality control samples met established laboratory criteria.

Results and Discussion

Persistent organic pollutants

Concentrations of POPs in white shrimp sampled during the *F/V Patricia Jean* (17 November-18 December 2005) and *F/V Miss Peggy* (11-15 April 2006) cruises are summarized in Tables 1 and 2, respectively. Data for each of the samples and individual analytes, as well as Quality Assurance results, are available in Appendix 1. In all the shrimp composites, summed concentrations of POPs (i.e., the sums of PCBs, DDTs, chlordanes, HCHs and PBDEs) were below 3 ng/g (Tables 1 and 2). The highest concentrations for sum PCBs (2.8 ng/g) and sum DDTs (0.84 ng/g) were found in the shrimp composite (12/14/2005) from station number 104 in Mississippi Sound. Sum chlordanes was highest in the shrimp composite (12/15/2005) from station number 111 in Mississippi Sound (2.6 ng/g); sum HCHs and sum PBDEs were below LOQ in all samples, except for one from Lake Borgne (station 120; 12/16/2005; 0.65 ng/g).

The concentrations of POPs found in shrimp from the study area were similar to those reported for seafood from nonurban areas of the world, e.g., for pollock from remote areas of Alaska (Heintz *et al.*, 2004) and invertebrates (i.e., lobster tail muscle, blue mussel) from Johns Bay, Maine (Ylitalo *et al.*, 1999). PDBE flame retardants—thought to be associated with urban runoff—were below LOD in all but one of the samples, suggesting that the POPs detected in the shrimp samples were not likely a result of contamination released as a result of Hurricane Katrina.

To look at temporal trends in POPs among samples collected during the five time periods from mid-September 2005 to mid-April 2006, the mean concentrations of summed PCBs and DDTs in shrimp samples from three regions (Mobile Bay, Mississippi Sound and Lake Borgne) were graphed (Figures 2-4). Although sum PCBs in shrimp from Mississippi Sound had shown a statistically significant temporal increase from mid September to late October (Krahn *et al.*, 2006), the trend had reversed by the November/December sampling and low levels—similar to those found immediately after

the hurricane—were evident by April (Figure 3A). No other significant increasing temporal trends were found for POPs in the three regions (Figures 2-4), even initially (Krahn *et al.*, 2006). Although temporal increases in PCB concentrations in Mississippi Sound might suggest that contamination had been released in that area following Hurricane Katrina, the highest concentrations were still very low (less than 5 ng/g).

The FDA has published regulatory guidelines for seafood safety as follows (wet weight): PCBs, 2,000 ng/g; DDTs, 5,000 ng/g; chlordanes, 300 ng/g (National Academy of Sciences, 1991). There are no FDA guidelines available for HCHs or PBDEs. All the shrimp analyzed during all time periods had concentrations of POPs (less than 5 ng/g) that were well below the FDA regulatory guidelines.

Polycyclic aromatic compounds

Concentrations of PACs in white shrimp sampled during the *F/V Patricia Jean* (17 November-18 December 2005) and *F/V Miss Peggy* (11-15 April 2006) cruises, based on collection site and region, are summarized in Tables 4 and 5, respectively. Data for each of the samples and individual analytes, as well as Quality Assurance results, are available in Appendix 2. Sum LMWACs (petroleum-related PACs) were found in all shrimp composite samples, but at levels less than 20 ng/g (Tables 4 and 5). Shrimp from site 104 (Mississippi Sound/Gulf of Mexico) had the highest sum LMWACs (17 ng/g, 12/14/2005; Table 4). In contrast, many shrimp composites contained concentrations of sum HMWACs (urban run-off related PACs) that were below LOQ and the highest concentration was 0.98 ng/g, also at site 104 (Table 4). Comparisons of sum PAC levels in white shrimp by collection region showed that the three regions (Mississippi Sound/Gulf of Mexico, Lake Borgne and Mobile Bay) had mean sum PACs that were 12 ng/g or less during November/December (Table 4), decreasing to 7ng/g or less in April (Table 5).

Sum PACs in individual white shrimp composites were low (Tables 4 and 5) compared to levels measured in other marine seafood species (e.g., blue crab, blue mussels, American lobster) collected near urban or semi-urban areas of the U.S. (Mercaldo-Allen *et al.*, 1994; Mothershead *et al.*, 1991). For example, the highest sum PAC levels in white shrimp was 18 ng/g (from station number 104; Table 4) and this value was much lower than the range (7,200 – 10,900 ng/g, wet wt.) reported in grass shrimp from Bayou Trepagnier near Lake Pontchartrain, Louisiana (Oberdorster *et al.*, 1999). In addition, the highest PAC sum was about two orders of magnitude lower than the mean values in muscle of live-caught and moribund lobsters captured in oiled areas following the 1996 *North Cape* oil spill (1,200 ng/g and 9,500 ng/g, respectively) (Krahn *et al.*, 2005) and was similar to concentrations measured in tail muscle of lobster captured from unoiled areas (12 ng/g) (Krahn *et al.*, 2005).

To investigate temporal trends in concentrations of LMWACs and HMWACs in shrimp composites collected from the three regions (Mobile Bay, Mississippi Sound and Lake Borgne; Table 4) from mid-September 2005 to mid-April 2006, the data from this report, as well as from the previous study (Krahn *et al.*, 2006), were graphed (Figures 5-7). Although shrimp from both Lake Borgne and Mississippi Sound had initially shown

statistically significant increases in sum LMWACs from early September to late October (Krahn *et al.*, 2006), this increasing trend had moderated by November/ December and had decreased by April (Figures 6A and 7A). In addition, no significant temporal trends were found for sum HMWAC for any of the three regions (Figures 5B-7B). Because LMWACs, but not HMWACs, showed increases, these results suggest an initial increase in exposure to petroleum products (e.g., fuel or crude oils) following Hurricane Katrina. Because concentrations of organic contaminants can be influenced by seasonal changes in lipid levels (Elskus *et al.*, 2005), samples were also analyzed for lipid content. No evidence was found to indicate that the temporal trends noted here were influenced by changes in lipid content (data not shown).

All the individual shrimp composite samples analyzed thus far in our studies had concentrations of sum PACs that were low (less than 30 ng/g). However, the FDA provides no regulatory limits for PACs in seafood. For comparison, the PAC levels measured in shrimp from the Gulf of Mexico were similar to those measured in clams and mussels from nonurban areas [e.g., from remote areas of Alaska (Varanasi *et al.*, 1993)]. Additionally, the levels reported here are far lower than levels found in other crustacean species following oil spills.

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Table 1. Concentrations of persistent organic pollutants (POPs) measured in white shrimp collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina during the *F/V Patricia Jean* cruises 17 November-18 December 2005

Station number	Collection site[1]	Date sampled	ng/g wet weight				
			Sum PCBs[2]	Sum DDTs[2]	Sum CHLDs[2]	Sum HCHs[2]	Sum PBDEs[2]
Mobile Bay							
101	Little Point Clear	12/13/2005	0.73	0.65	< LOQ	< LOQ	< LOQ
102	Middle Ground, Mobile Bay	12/7/2005	0.90	0.75	< LOQ	< LOQ	< LOQ
103	Stump Beacon	12/14/2005	1.3	0.88	< LOQ	< LOQ	< LOQ
			0.98 ± 0.29	***0.76 ± 0.12***	***< LOQ***	***< LOQ***	***< LOQ***
Mississippi Sound/Gulf of Mexico							
104	North of Dauphin Island	12/14/2005	2.8	0.84	0.32	< LOQ	< LOQ
106	North of Petit Bois Island	12/14/2005	2.3	0.55	0.12	< LOQ	< LOQ
107	Pascagoula Ship Channel	11/17/2005	1.4	0.48	< LOQ	< LOQ	< LOQ
108	North of Horn Island	12/14/2005	1.3	0.84	< LOQ	< LOQ	< LOQ
109	Middle Ground, Horn Island	12/17/2005	0.42	< LOQ	< LOQ	< LOQ	< LOQ
110	South of Horn Island	12/18/2005	1.1	0.45	< LOQ	< LOQ	< LOQ
111	Cat Island	12/15/2005	1.0	0.28	2.6	< LOQ	< LOQ
112	Pass Marianne	12/16/2005	0.39	< LOQ	< LOQ	< LOQ	< LOQ
125	Cat Island Shoal	12/15/2005	0.38	< LOQ	0.33	< LOQ	< LOQ
126	North of Ship Island	12/17/2005	1.1	0.15	0.80	< LOQ	< LOQ
127	Biloxi Ship Channel	12/15/2005	1.3	0.19	0.33	< LOQ	< LOQ
			1.2 ± 0.8	***0.34 ± 0.31***	***0.41 ± 0.77***	***< LOQ***	***< LOQ***
Lake Borgne							
114	Malheureux Point	12/10/2005	0.59	< LOQ	< LOQ	< LOQ	< LOQ
115	Alligator Point	12/10/2005	0.79	< LOQ	< LOQ	< LOQ	< LOQ
119	St. Joe Pass	12/10/2005	0.39	< LOQ	< LOQ	< LOQ	< LOQ
120	Gamblers Bend	12/16/2005	1.0	0.15	< LOQ	< LOQ	0.65
			0.69 ± 0.26	***0.04 ± 0.08***	***< LOQ***	***< LOQ***	***0.13 ± 0.29***

[1] Collection stations are shown on the map in Figure 1.

[2] Individual compounds summed are given in the Methods section.

< LOQ for the sum indicates concentrations of all compounds included in the sum were below their individual limits of quantitation. For each < LOQ, a value of zero was used to calculate the mean and standard deviation of the mean.

Table 2. Concentrations of persistent organic pollutants (POPs) measured in white shrimp collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina during the *F/V Miss Peggy* cruise 11-15 April 2006.

Station number	Collection site[1]	Date sampled	ng/g wet weight				
			Sum PCBs[2]	Sum DDTs[2]	Sum CHLDs[2]	Sum HCHs[2]	Sum PBDEs[2]
Mobile Bay							
101	Little Point Clear	4/11/2006	0.54	0.59	< LOQ	< LOQ	< LOQ
103	Stump Beacon	4/12/2006	0.33	0.41	< LOQ	< LOQ	< LOQ
			0.44 ± 0.15	***0.50 ± 0.13***	***< LOQ***	***< LOQ***	***< LOQ***
Mississippi Sound/Gulf of Mexico							
108	North of Horn Island	4/12/2006	1.3	0.32	0.33	< LOQ	< LOQ
109	Middle Ground, Horn Island	4/12/2006	0.65	0.30	0.21	< LOQ	< LOQ
111	Cat Island	4/13/2006	0.11	< LOQ	< LOQ	< LOQ	< LOQ
112	Pass Marianne	4/13/2006	0.11	< LOQ	< LOQ	< LOQ	< LOQ
113	Grand Island Channel	4/15/2006	< LOQ	< LOQ	< LOQ	< LOQ	< LOQ
126	North of Ship Island	4/13/2006	0.72	0.17	0.15	< LOQ	< LOQ
127	Biloxi Ship Channel	4/15/2006	0.74	0.40	1.10	< LOQ	< LOQ
			0.52 ± 0.47	***0.17 ± 0.17***	***0.26 ± 0.39***	***< LOQ***	***< LOQ***
Lake Borgne							
114	Malheureux Point	4/14/2006	0.05	< LOQ	< LOQ	< LOQ	< LOQ
115	Alligator Point	4/14/2006	0.28	< LOQ	< LOQ	< LOQ	< LOQ
116	Proctor Point	4/14/2006	0.49	< LOQ	< LOQ	< LOQ	< LOQ
117	Blind Bayou	4/14/2006	< LOQ	< LOQ	< LOQ	< LOQ	< LOQ
118	Pointe aux Marchettes	4/14/2006	0.29	< LOQ	< LOQ	< LOQ	< LOQ
119	St. Joe Pass	4/14/2006	< LOQ	< LOQ	< LOQ	< LOQ	< LOQ
120	Gamblers Bend	4/15/2006	0.64	< LOQ	< LOQ	< LOQ	< LOQ
			0.25 ± 0.25	***< LOQ***	***< LOQ***	***< LOQ***	***< LOQ***

[1] Collection stations are shown on the map in Figure 1.

[2] Individual compounds summed are given in the Methods section.

< LOQ for the sum indicates concentrations of all compounds included in the sum were below their individual limits of quantitation. For each < LOQ, a value of zero was used to calculate the mean and standard deviation of the mean.

Table 3. Comparisons of concentrations of persistent organic pollutants (POPs) measured in white shrimp collected from mid-September 2005 to mid-April 2006 in coastal waters of the Gulf of Mexico affected by Hurricane Katrina.

F/V Patricia Jean cruise date	number of sites averaged	ng/g wet weight				
		Sum PCBs[1]	Sum DDTs[1]	Sum CHLDs[1]	Sum HCHs[1]	Sum PBDEs[1]
Mobile Bay						
13-19 September 2005	3	1.9 ± 2.3	1.1 ± 0.64	0.14 ± 0.13	< LOQ	< LOQ
2-6 October 2005	3	0.55 ± 0.52	0.53 ± 0.15	< LOQ	< LOQ	< LOQ
27-31 October 2005	3	0.74 ± 0.40	0.86 ± 0.31	< LOQ	< LOQ	< LOQ
8 November-18 December 2005	3	0.98 ± 0.29	0.76 ± 0.12	< LOQ	< LOQ	< LOQ
11-15 April 2006	2	0.44 ± 0.15	0.50 ± 0.13	< LOQ	< LOQ	< LOQ
Mississippi Sound/Gulf of Mexico						
13-19 September 2005	13	1.3 ± 1.1	0.31 ± 0.38	0.14 ± 0.31	< LOQ	< LOQ
2-6 October 2005	9	0.90 ± 0.99	0.17 ± 0.33	0.08 ± 0.16	0.03 ± 0.08	< LOQ
27-31 October 2005	12	3.4 ± 1.2	0.50 ± 0.60	0.07 ± 0.13	< LOQ	< LOQ
8 November-18 December 2005	11	1.2 ± 0.8	0.34 ± 0.31	0.41 ± 0.77	< LOQ	< LOQ
11-15 April 2006	7	0.52 ± 0.47	0.17 ± 0.17	0.26 ± 0.39	< LOQ	< LOQ
Lake Borgne						
13-19 September 2005	10	0.72 ± 0.46	0.02 ± 0.07	< LOQ	< LOQ	< LOQ
2-6 October 2005	7	2.0 ± 0.89	0.16 ± 0.33	0.09 ± 0.09	< LOQ	0.05 ± 0.13
27-31 October 2005 + 8 November 2005[2]	8	0.59 ± 0.53	0.03 ± 0.08	0.09 ± 0.12	< LOQ	< LOQ
17 November-18 December 2005	4	0.69 ± 0.26	0.04 ± 0.08	< LOQ	< LOQ	0.13 ± 0.29
11-15 April 2006	7	0.25 ± 0.25	< LOQ	< LOQ	< LOQ	< LOQ
Pre-Katrina[2]						
	3	0.50 ± 0.36	0.22 ± 0.38	< LOQ	< LOQ	< LOQ

[1] Individual compounds summed are given in the Methods section.

[2] Includes one sample from Pointe aux Marchettes collected on 11/8/2005 not reported previously. Sum PCBs = 1.3 ng/g; sum DDTs = 0.22 ng/g and sum CHLDs = 0.20 ng/g; sum HCHs and sum PBDEs were both <LOQ.

[3] "Reference" shrimp that were collected and frozen prior to hurricane

< LOQ for the sum indicates concentrations of all compounds included in the sum were below their individual limits of quantitation. For each < LOQ, a value of zero was used to calculate the mean and standard deviation of the mean.

Table 4. Concentrations of sum polycyclic aromatic compounds (PACs) measured in white shrimp collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina during the *F/V Patricia Jean* cruises 17 November - 18 December 2005.

Station number	Collection site[1]	Date sampled	ng/g wet weight		
			Sum LMWACs[2]	Sum HMWACs[3]	Sum PACs[4]
Mobile Bay					
101	Little Point Clear	12/13/2005	8.6	0.43	9.0
102	Middle Ground, Mobile Bay	12/7/2005	12	0.54	13
103	Stump Beacon	12/14/2005	8.8	0.47	9.3
			9.8 ± 1.9	***0.48 ± 0.06***	***10 ± 2.0***
Mississippi Sound/Gulf of Mexico					
104	North of Dauphin Island	12/14/2005	17	0.98	18
106	North of Petit Bois Island	12/14/2005	11	0.50	12
107	Pascagoula Ship Channel	11/17/2005	11	0.48	11
108	North of Horn Island	12/14/2005	14	0.79	15
109	Middle Ground, Horn Island	12/17/2005	13	0.48	13
110	South of Horn Island	12/18/2005	6.7	< LOQ	6.7
111	Cat Island	12/15/2005	8.4	< LOQ	8.4
112	Pass Marianne	12/21/2005	15	0.77	16
125	Cat Island Shoal	12/15/2005	8.6	0.23	8.8
126	North of Ship Island	12/17/2005	8.9	0.45	9.4
127	Biloxi Ship Channel	12/15/2005	11	0.72	12
			11 ± 3.2	***0.49 ± 0.32***	***12 ± 3.4***
Lake Borgne					
114	Malheureux Point	12/10/2005	9.4	0.43	9.8
115	Alligator Point	12/10/2005	8.1	0.23	8.3
119	St. Joe Pass	12/10/2005	8.9	0.23	9.1
120	Gamblers Bend	12/16/2005	11	0.62	12
			9.4 ± 1.2	***0.38 ± 0.19***	***9.7 ± 1.4***

[1] Collection stations are shown on the map in Figure 1.

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

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

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

< LOQ for the sum indicates concentrations of all compounds included in the sum were below their individual limits of quantitation. For each <LOQ, a value of zero was used to calculate the mean and standard deviation of the mean.

Table 5. Concentrations of sum polycyclic aromatic compounds (PACs) measured in white shrimp collected in coastal waters of the Gulf of Mexico affected by Hurricane Katrina during the F/V Miss Peggy cruise 11-15 April 2006.

Station number	Collection site[1]	Date sampled	ng/g wet weight		
			Sum LMWACs[2]	Sum HMWACs[3]	Sum PACs[4]
Mobile Bay					
101	Little Point Clear	4/11/2006	5.9	0.28	6.2
103	Stump Beacon	4/12/2006	5.5	< LOQ	5.5
			5.7 ± 0.30	***0.14 ± 0.20***	***5.8 ± 0.48***
Mississippi Sound/Gulf of Mexico					
108	North of Horn Island	4/12/2006	6.5	0.21	6.7
109	Middle Ground, Horn Island	4/12/2006	7.6	0.22	7.8
111	Cat Island	4/13/2006	7.6	0.18	7.8
112	Pass Marianne	4/13/2006	6.3	< LOQ	6.3
113	Grand Island Channel	4/15/2006	2.7	< LOQ	2.7
126	North of Ship Island	4/13/2006	7.5	0.50	8.0
127	Biloxi Ship Channel	4/15/2006	6.1	< LOQ	6.1
			6.3 ± 1.7	***0.16 ± 0.18***	***6.5 ± 1.8***
Lake Borgne					
114	Malheureux Point	4/14/2006	5.9	< LOQ	5.9
115	Alligator Point	4/14/2006	6.7	< LOQ	6.7
116	Proctor Point	4/14/2006	6.9	< LOQ	6.9
117	Blind Bayou	4/14/2006	7.9	< LOQ	7.9
118	Pointe aux Marchettes	4/14/2006	5.8	< LOQ	5.8
119	St. Joe Pass	4/14/2006	3.8	< LOQ	3.8
120	Gamblers Bend	4/15/2006	6.9	0.20	7.1
			6.3 ± 1.3	***0.03 ± 0.08***	***6.3 ± 1.3***

[1] Collection stations are shown on the map in Figure 1.

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

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

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

< LOQ for the sum indicates concentrations of all compounds included in the sum were below their individual limits of quantitation. For each <LOQ, a value of zero was used to calculate the mean and standard deviation of the mean.

Table 6. Comparisons of concentrations of sum polycyclic aromatic compounds (Sum PACs) measured in white shrimp collected from mid-September 2005 to mid April 2006 in coastal waters of the Gulf of Mexico affected by Hurricane Katrina.

F/V Patricia Jean cruise date	number of sites averaged	ng/g wet weight		
		Sum LMWACs[1]	Sum HMWACs[2]	Sum PACs[3]
Mobile Bay				
13-19 September 2005	3	7.0 ± 1.8	0.19 ± 0.20	7.2 ± 1.6
2-6 October 2005	3	11 ± 0.60	0.13 ± 0.23	11 ± 0.6
27-31 October 2005	3	10 ± 1.2	< LOQ	10 ± 1.2
17 November-18 December 2005	3	9.8 ± 1.9	0.48 ± 0.06	10 ± 2.0
11-15 April 2006	2	5.7 ± 0.30	0.14 ± 0.20	5.8 ± 0.48
Mississippi Sound/Gulf of Mexico				
13-19 September 2005	13	6.8 ± 3.1	0.28 ± 0.31	7.2 ± 3.4
2-6 October 2005	9	11 ± 3.8	0.17 ± 0.21	11 ± 4.0
27-31 October 2005	12	15 ± 1.7	0.35 ± 0.58	15 ± 2.1
17 November-18 December 2005	11	11 ± 3.2	0.49 ± 0.32	12 ± 3.4
11-15 April 2006	7	6.3 ± 1.7	0.16 ± 0.18	6.5 ± 1.8
Lake Borgne				
13-19 September 2005	10	5.9 ± 1.7	0.17 ± 0.23	6.1 ± 1.9
2-6 October 2005	7	6.9 ± 0.80	0.28 ± 0.36	7.2 ± 1.0
27-31 October 2005 + 8 November 2005[4]	8	13 ± 4.6	0.21 ± 0.60	13 ± 5.3
17 November-18 December 2005	4	9.4 ± 1.2	0.38 ± 0.19	9.7 ± 1.4
11-15 April 2006	7	6.3 ± 1.3	0.03 ± 0.08	6.3 ± 1.3
Pre-Katrina[5]				
	3	9.9 ±0.2	0.05 ±0.08	9.9 ±0.2

[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.

[4] Includes one sample from Pointe aux Marchettes collected on 11/8/2005 not reported previously. Sum LMWACs = 24 ng/g; sum HMWACs = 1.7 ng/g and sum PACs = 25.7 ng/g.

[5] "Reference" shrimp that were collected and frozen prior to hurricane

< LOQ for the sum indicates concentrations of all compounds included in the sum were below their individual limits of quantitation. For each < LOQ, a value of zero was used to calculate the mean and standard deviation of the mean.

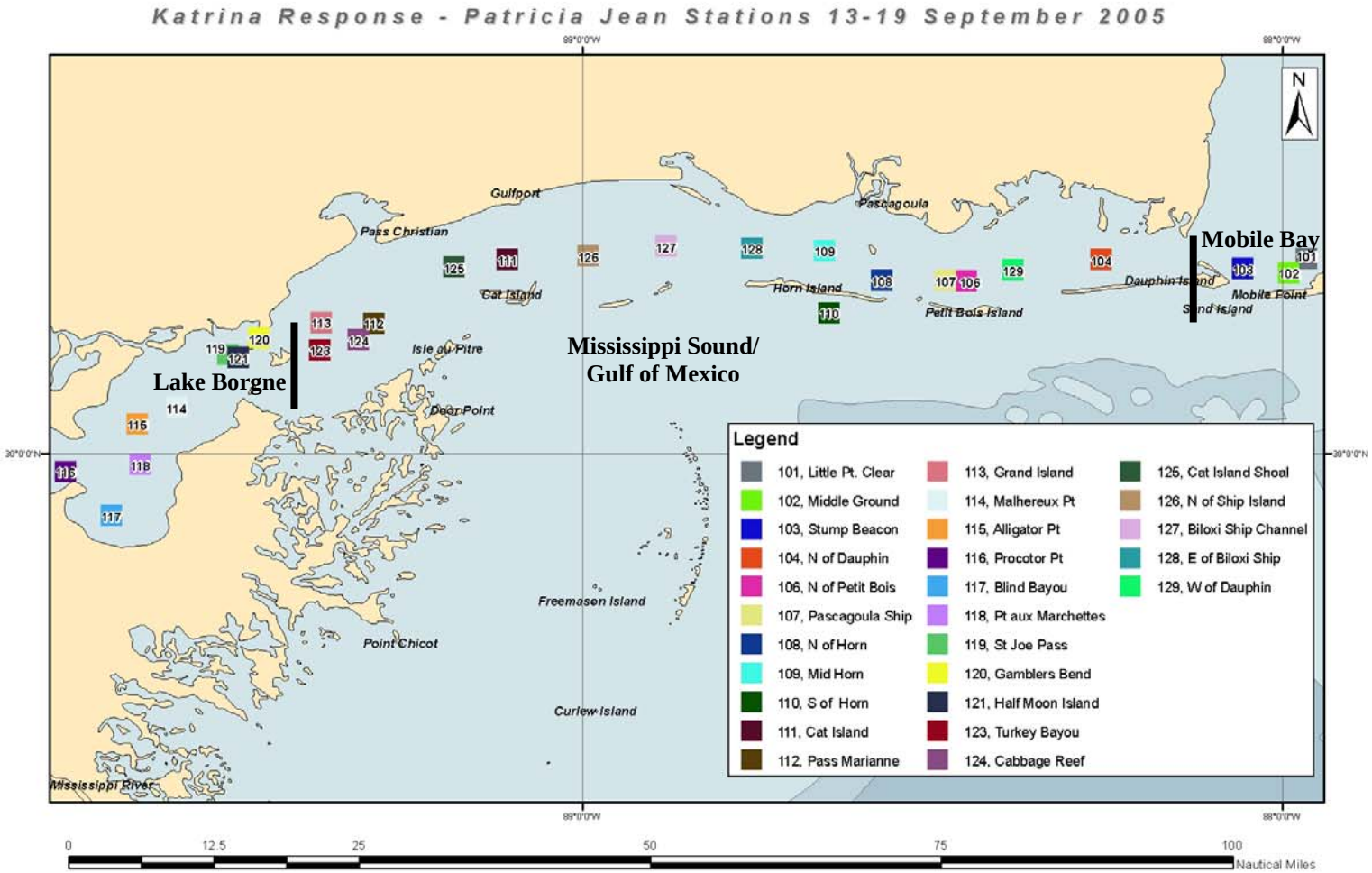

Figure 1. Stations (numbers 101-129) sampled during the *F/V Patricia Jean* cruise of 13-19 September 2005; many of these stations were re-sampled on the *F/V Patricia Jean* cruises of 2-6 October 2005 and 27-31 October 2005 and the F/V Miss Peggy cruise of 11-15 April 2006. Vertical bars divide the sites into three regions: Lake Borgne, Mississippi Sound/Gulf of Mexico and Mobile Bay.

Mobile Bay

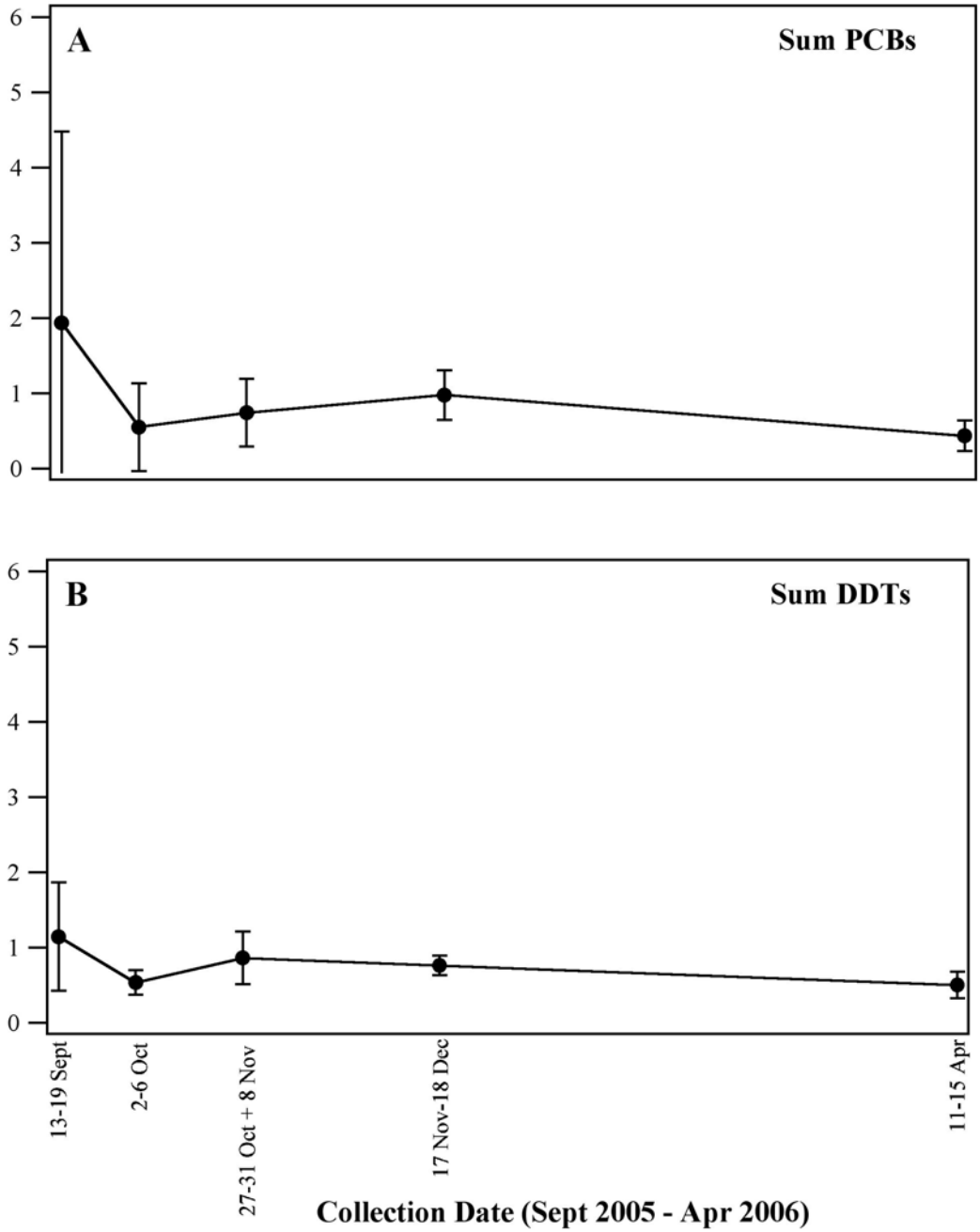

Figure 2. Concentrations ± 95% confidence interval (ng/g wet weight) of sum PCBs (A) and sum DDTs (B) measured in white shrimp collected in Mobile Bay region during various sampling cruises from 13 September 2005 to 15 April 2006.

Mississippi Sound/Gulf of Mexico

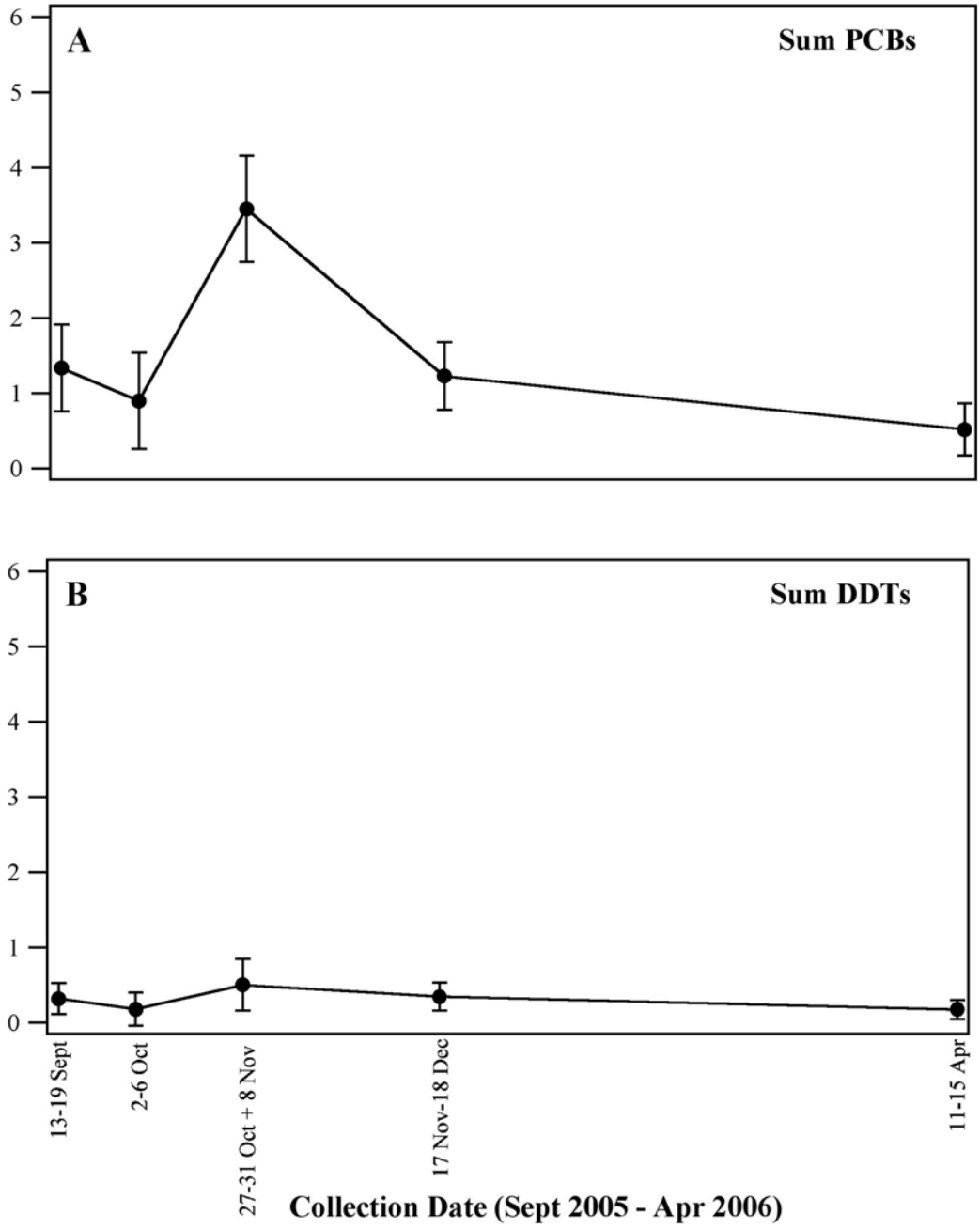

Figure 3. Concentrations ± 95% confidence interval (ng/g wet weight) of sum PCBs (A) and sum DDTs (B) measured in white shrimp collected in Mississippi Sound / Gulf of Mexico region during various sampling cruises from 13 September 2005 to 15 April 2006.

Lake Borgne

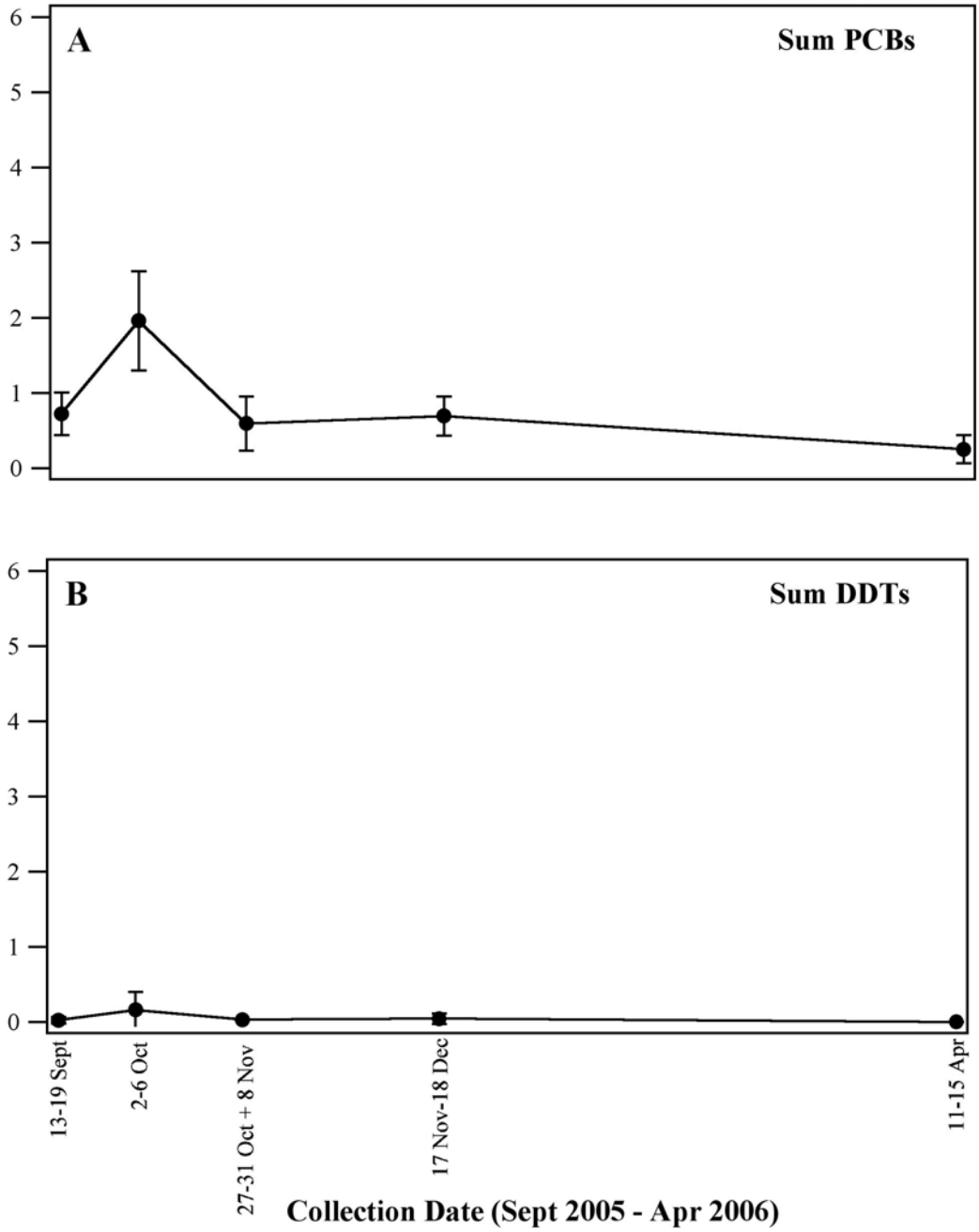

Figure 4. Concentrations ± 95% confidence interval (ng/g wet weight) of sum PCBs (A) and sum DDTs (B) measured in white shrimp collected in Lake Borgne region during various sampling cruises from 13 September 2005 to 15 April 2006.

Mobile Bay

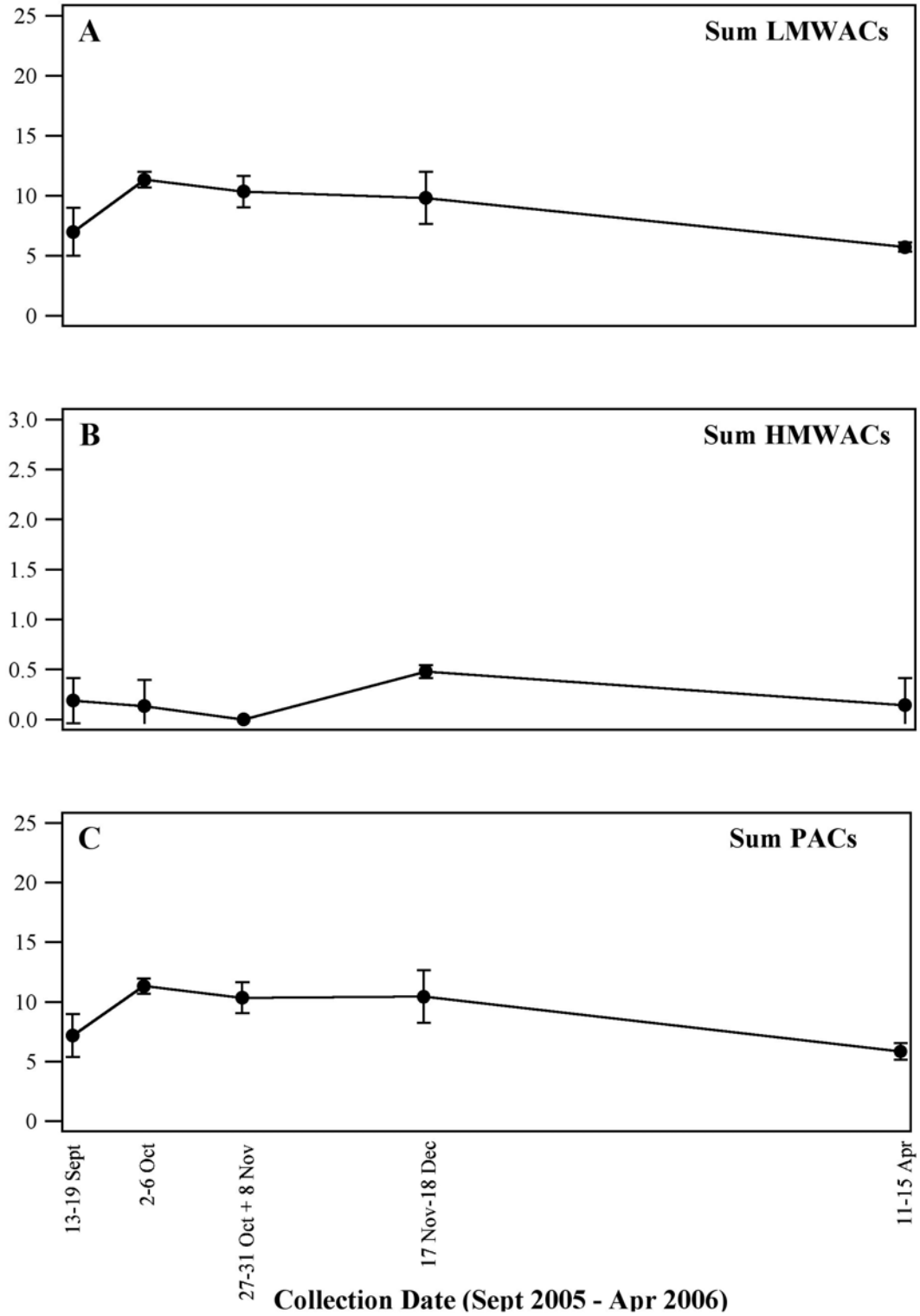

Figure 5. Concentrations ± 95% confidence interval (ng/g wet weight) of (A) sum LMWACs, (B) sum HMWACs and (C) sum PACs measured in white shrimp collected in Mobile Bay region during various sampling cruises from 13 September 2005 to 15 April 2006.

Mississippi Sound/Gulf of Mexico

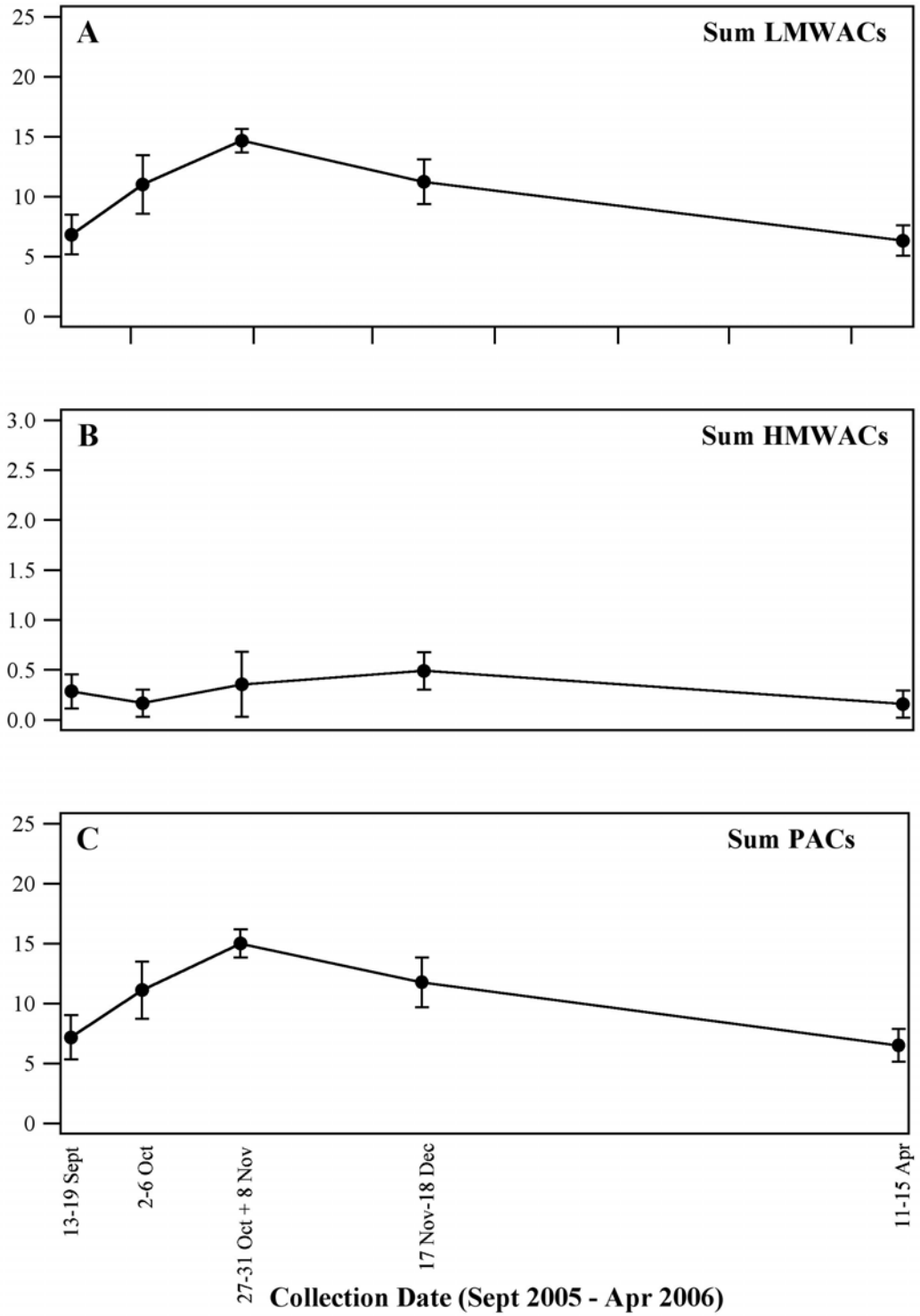

Figure 6. Concentrations ± 95% confidence interval (ng/g wet weight) of (A) sum LMWACs, (B) sum HMWACs and (C) sum PACs measured in white shrimp collected in Mississippi Sound/Gulf of Mexico region during various sampling cruises from 13 September 2005 to 15 April 2006.

Lake Borgne

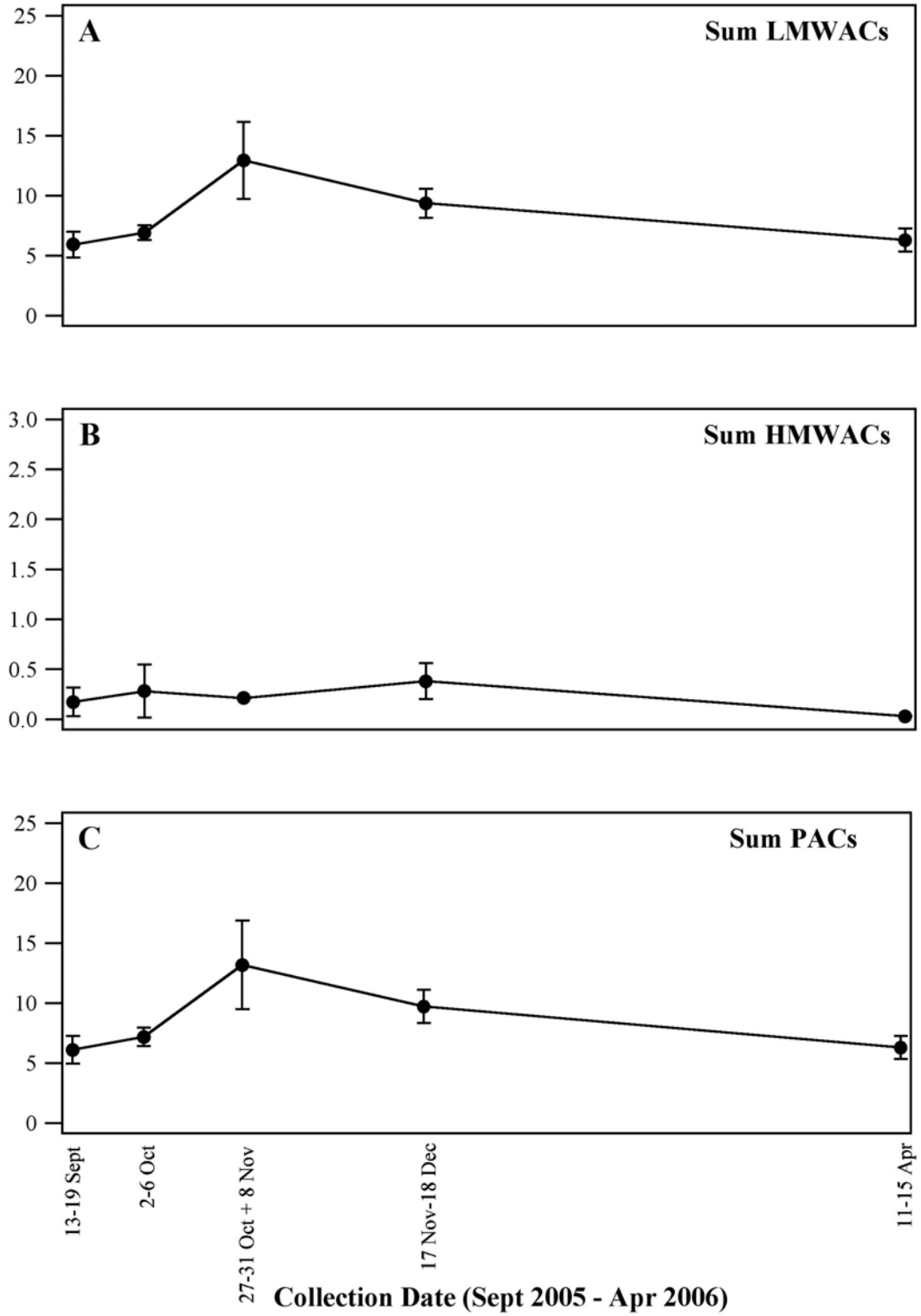

Figure 7. Concentrations ± 95% confidence interval (ng/g wet weight) of (A) sum LMWACs, (B) sum HMWACs and (C) sum PACs measured in white shrimp collected in Lake Borgne region during various sampling cruises from 13 September 2005 to 15 April 2006.