Relative Motility of Fishes in a Southeastern Reservoir Based on Tissue PCB Residues

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Abstract

Our objective was to investigate the potential utility of polychlorinated biphenyl (PCB) residues in fish tissue as an indicator of relative motility of fish species in Lake Logan Martin, a 6,179 ha reservoir located in east-central Alabama. Choccolocco Creek, a mid-lake tributary, was the site of deposition of PCBs and this embayment had the highest concentrations of PCBs. The relationship between PCB concentrations in fish muscle tissue and distance of the fish, at capture, from the Choccolocco Creek embayment was used to infer relative motility of 12 species of warmwater sport and commercial fishes. Regression analyses of PCB concentration versus distance suggested that species ranged from low motility (highly significant regression and relatively high R^2) to highly motile (insignificant regression or relatively low R^2). Centrarchids were relatively immotile, moronids were relatively motile and flathead catfish Pylodictis olivaris, exhibited greatest motility. Our results reflect long term (perhaps lifetime) movements of fishes in one reservoir and provide motility information on spotted bass Micropterus punctulatus, blue catfish Ictalurus furcatus, freshwater drum Aplodinotus grunniens, and white bass Morone chrysops, for which little has been reported. Where PCBs occur in relatively discrete areas of aquatic ecosystems, this method can provide a long-term perspective on movements of numerous fish species under similar environmental conditions.

Fish move in response to many stimuli and some species are known to be more motile than others (Bond 1996). Modern fishery research and management frequently require knowledge of fish motility and movement behavior. Mark and recapture techniques provide information on stock identification, migrations, behavior, age, mortality rates, abundance and stocking success (Guy et al. 1996). Underwater biotelemetry using either ultrasonic or radio transmitters can provide more data on fish movement than mark and recapture without influencing fish behavior or disturbing habitat (Winter 1983). In addition, with appropriate electronic sensors, environmental (e.g. water temperature) and physiological (e.g. heart rate) data can be transmitted along with the radio signals (Winter 1996).

Studies of warmwater fish movements usually involve only one or a few species in streams (Moody 1960; Hubley 1963; Welker 1967; Hudson and Hester 1975; Hurley et al. 1987; Pellett et al. 1998; Smithson and Johnston 1999) and lakes (Dequine and Hall 1949; Fisher 1950; Hart and Summerfelt 1973; Warden and Lorio 1975; Ager 1976; Winter 1977; Summers 1979; Germann 1982; Guy et al. 1992; Guy et al. 1993; Chilton and Poarch 1997; Wilkerson and Fisher 1997). Comparative studies of warmwater fish movements involving five or more species are rare (Eschmeyer 1942; McVey 1955; Funk 1955). Simultaneous multispecies studies of fish movements in one water body offer the advantage that all organisms experience similar environmental conditions thereby allowing direct comparisons of fish motility.

We investigated the possibility of using polychlorinated biphenyl (PCB) accumulation in fish tissue to infer relative motility of the dominant sport and commercial species of a large river impoundment. PCBs bioaccumulate in the food web and diet appears to be the primary source of PCBs to fishes (Jackson and Schindler 1996; Maruya and Lee 1998). PCBs often enter an aquatic system at one discrete location and therefore exhibit a spacial concentration gradient within the system (Dycus and Lowery 1986; Connolly and Parkerton 1993; Stow 1995; Bremle and Larsson 1998). PCB residues in fishes often reflect this gradient with body burden depending upon where the fish is captured (Connolly and Parkerton 1993). In aquatic systems where PCBs occur in a relatively discrete location, the relationship of PCB concentration in the fish with distance of the fish at capture from the source of PCBs may be a reliable indicator of fish motility. Less motile species would reside in a limited area of the lake and reflect PCB concentrations for only that location resulting in a relatively strong relationship between PCB concentration and distance from the PCB source. Madenjian et al. (1998) reported that male walleye Stizostedion vitreum exhibited higher concentrations of PCBs because they spent more time in the heavily contaminated Saginaw River system than females, which spent more time in Saginaw Bay and Lake Huron. Zlokovitz and Secor (1999) found that male striped bass Morone saxatilis had higher PCB concentrations than females because males spent more time in the heavily contaminated Hudson River, whereas the females spent more time in the New York Bight. Our objectives were to determine if fish PCB residues were related to location-at-capture for a number of warmwater fishes and compare the inferred relative motility of each species derived from this relationship with existing information from previous studies of fish movement.

Study Site

Lake Logan Martin is a 6,179 ha multipurpose impoundment of the Coosa River located near Anniston in east-central Alabama (Figure 1). The reservoir was constructed by Alabama Power Company for hydroelectric power generation and began operation in 1964 (ADEM 1984). At full pool the mean depth was 5.5 m, volume was 33,736 ha-m and the mean hydraulic retention time was 11 days. The water is normally lowered 1.52 m during winter and spring for flood control. The reservoir is eutrophic and seldom thermally stratifies, but dissolved oxygen in deeper areas declines at times to levels that are considered threatening to aquatic life (ADEM 1996; Bayne et al. 1998).

A chemical manufacturer produced PCBs at an Anniston facility from 1935 to 1971 and PCBs have been detected in sediment of Snow and Choccolocco Creeks flowing from Anniston to Lake Logan Martin (ADEM 1994). In the early 1990s, snagging and dredging operations in the upstream reaches of Choccolocco Creek exposed PCBs previously buried in the sediment, which caused an increase in PCBs in resident fishes (Bayne 1997) especially those in the Choccolocco Creek embayment (station 5, Figure 1).

Methods

Adult sport and commercial fishes were collected at nine stations throughout Lake Logan Martin by gill netting and boat electrofishing (Figure 1). This sampling was conducted during the 1996 growing season, 22 May through 12 November. Captured fish were individually wrapped in aluminum foil, placed in a sealed plastic bag on ice in coolers for transport to an Auburn University laboratory. Each fish was identified to species, weighed (g) and measured (mm). All fish were skinned, filleted, packaged and frozen. In October and November of 1999 four common forage fish species were collected by boat electrofishing at stations 3, 5, 6 and 9 (Figure 1). Whole fish composite samples of threadfin shad Dorosoma petenense, gizzard shad D. cepedianum, bluegill Lepomis macrochirus and blacktail shiner Cyprinella venusta were prepared and frozen. The frozen samples were then shipped to Savannah Laboratories in Savannah, Georgia for analysis. A U. S. Environmental Protection Agency approved protocol

(ADEM 1991) was used for fish sampling and tissue preparation. Skinned fillets of individual fish collected in 1996 and whole fish composite samples of the four forage species collected in 1999 were homogenized prior to analysis. Following tissue extraction, PCBs were analyzed by Savannah Laboratories using gas chromotography and reported as total PCBs.

For each fish collected, a distance (km) from the Choccolocco Creek embayment (station 5, Figure 1) to the site of capture was assigned. We modeled the relationship between the dependent variable, fillet PCB residues and the independent variable, distance at capture of each fish from station 5 as a power function $y = aX^b$ (Littell et al. 1993). Regression models were evaluated based on level of significance (P value) and magnitude of R^2. Regression analyses were conducted by fish species for fish collected throughout the entire lake (stations 1-9, Figure 1).

Results and Discussion

In 1996, we collected 1,085 fish, representing 8 families and 26 species. Twelve species representing most of the important sport and commercial fishes were chosen for this study (Table 1). All fish were adults ranging in total length from 150 mm to 851 mm. The total number of fish examined per species ranged from 25 flathead catfish Pylodictis olivaris to 121 largemouth bass Micropterus salmoides (Table 1). PCB tissue residues ranged from 0.14 mg/kg (detection limit) to 57.6 mg/kg (Table 1).

Scatter plots of PCB residues versus distance of the fish at capture from the Choccolocco Creek embayment showed different patterns of PCB accumulation for different fish species (Figures 2 and 3). Some species (e.g. bluegill, Figure 2) had relatively high PCB body burden near the source with declining concentrations at greater distances. Other species (e.g. flathead catfish Figure 3) had relatively high PCB concentrations throughout their range within the reservoir.

Differences among species is apparently related to differences in motility of these fishes but could also occur because of high motility of fish prey. If prey of a particular fish species were highly motile, the prey could accumulate PCBs in the Choccolocco Creek embayment and transport the chemical to distant predators giving the appearance that the predators were highly motile. Since forage fish are more motile than invertebrate prey, this would be more likely to occur with piscivorous fishes. However, the evidence does not support this alternative explanation. Similar to other less motile fishes, forage species sampled in 1999 had wholebody PCB concentrations an order of magnitude or more higher at locations near the Choccolocco Creek embayment (Table 2). Piscivores feeding near the dam (Station 9) would be less likely to accumulate PCBs from dietary sources than those feeding nearer to the Choccolocco Creek embayment. Also adult largemouth bass and striped bass both rely heavily upon shad Dorosoma spp as prey in southern reservoirs (Combs 1978; Timmons and Pawaputanon 1980; Moore et al. 1985) and yet they differed greatly in relative motility (Figures 2 and 3).

We found the five members of the family Centrarchidae to be relatively immotile (Figure 2). Eschmeyer (1942) examined fish migrations in Norris Reservoir using mark and recapture and reported that over 50% of the largemouth bass (121 recaptures) had moved less than 4.8 km while several were recaptured over 32.2 km away also two of five recaptured black crappie Pomoxis nigromaculatus were found in excess of 12.9 km from the point of release. A tagging study of Florida largemouth bass M. s. floridanus in natural lakes revealed that 40% of the fish were recaptured within 2.6 km of the release area and 84% were caught within 8.0 km of the release site (Dequine and Hall 1949). In California's Millerton Lake, a 2,024 ha impoundment of the San Joaquin River, tagged largemouth bass and bluegill moved an average of only 1.9 km and 2.3 km prior to recapture, respectively (Fisher 1950). McVey (1955) examined home ranges of five centrarchid species in Lake of the Ozarks, Missouri and reported that along straight shorelines 55% of recaptured bluegills were within 30.5 m of the tagging point while in coves 71% were retaken in the same cove. Based on biotelemetry studies of black and white crappie Pomoxis annularis in two South Dakota glacial lakes, monthly and diel movements were similar for the two species and white crappie home ranges varied from 0.1 to 85.0 ha with a median of 15.8 ha (Guy et al. 1992; Guy et al. 1993). Strong homing tendencies have been reported for largemouth bass living in a 240 ha Mississippi impoundment (Warden and Lorio 1975), however, Stang et al. (1996) reported limited dispersal of largemouth bass following release from weigh-in sites after tournaments held at two New York lakes. Radiotelemetry revealed that only 8 of 42 fish returned to their capture site during the 22 weeks of surveillance.

We found three moronid species (including the hybrid palmetto bass Morone chrysops x saxitilis) in Lake Logan Martin were similar to each other and relatively motile compared to other fishes (Figure 3). Mettee et al. (1996) reported that white bass Morone chrysops and striped bass live in rivers and reservoirs during most of the year but move into smaller cool flowing streams during summer. In Missouri lakes, Pflieger (1975) described white bass as an active, pelagic fish moving frequently in pursuit of forage fish. The variable results of stocking the anadromous striped bass into large southeastern reservoirs as an additional sportfish led to numerous studies to determine the source of this variability (Combs and Peltz 1982; Coutant 1985; Braschler et al. 1989; Farquhar and Gutreuter 1989; Zale et al. 1990; Wilkerson and Fisher

1997) and revealed that striped bass moved extensively during cooler months but were confined during warmer months to lake areas having relatively cool (<25.0C) water with sufficient dissolved oxygen and prey to support the population. The palmetto bass has been reported to be extremely motile (Jones and Rogers 1998) with a requirement for thermal refuge similar to that of the striped bass (Douglas and Jahn 1987, Muncy et al. 1990).

We found three species of ictalurids were the most divergent group in terms of motility with flathead catfish the most motile of the 12 species examined while the channel catfish Ictalurus punctatus and blue catfish Ictalurus furcatus were among the least motile fishes (Figures 2 and 3). Homing behavior has been reported for both flathead catfish (Hart and Summerfelt 1973; Duncan and Myers 1978) and channel catfish (Houser 1960; Duncan and Myers 1978). In a mark and recapture study conducted in Beaver Reservoir, Arkansas, 76% of the channel catfish and 50% of the flathead catfish were found within 8.0 km of the tagging site while 9% of the channel catfish and 25% of the flathead catfish were recaptured in excess of 16 km of the tagging site (Duncan and Myers 1978). Duncan and Myers (1978) suggested that while these species have strong homing tendencies, periodic migrations cause temporary departure from the home range. Pflieger (1975) stated that the blue catfish is believed to be somewhat migratory, moving seasonally in response to temperature changes. Little is known about the movements of the bottom dwelling freshwater drum Aplodinotus grunniens outside of our study.

Conclusions and Management Implications

Our estimates of relative motility of warmwater fishes in Lake Logan Martin seem to be congruent with previous published work for the same species. We believe this demonstrates that in cases in which PCBs are confined to a relatively discrete area of an aquatic ecosystem, relative motility of fish species can be determined by examining the relationship of PCB residues in fish tissue versus distance of the fish at capture from the area of highest concentration. Our results provide estimates of relative motility for four species (spotted bass Micropterus punctulatus, white bass, blue catfish and freshwater drum) for which little is known.

The release of PCBs into aquatic ecosystems as chemical markers to examine fish movements is not desirable, but PCBs have reached surface waters in many locations worldwide (Laws 1993) and PCB residue data may already exist at some locations where PCB concentrations in fish tissue have been examined. If data exist, the cost of estimating fish motility would be minimal. Current cost of measuring total PCBs in fish tissue is about US $100.00 per fish (A. Stewart, Savannah Laboratories, Savannah, Georgia, personal communication). The time and expense of conducting fish movement studies using mark-recapture or radiotelemetry can be compared to the PCBs determination method in waters where PCBs occur. The PCBs determination method offers the following advantages: provides long-term perspective on fish movements; virtually all fish are marked (exposed to PCBs) reducing the time and effort to capture target fishes; and allows simultaneous comparisons of relative fish movement for numerous species under similar environmental conditions. Other chemicals that bioaccumulate in the food web (e.g. Hg and DDT) could also be used as markers.

Management decisions on fish consumption advisories are frequently made on toxic residue concentrations in one or a few fish species with little regard to the relative motility of the species. Our study revealed that highly motile species like striped bass and flathead catfish had much higher concentrations of PCBs at greater distances from Choccolocco Creek than did largemouth bass and channel catfish, the two species normally sampled for toxic residue analysis in many areas of the southern U.S.A. (ADEM 1991). After examining fish tissue residue data reported in our study, the Alabama Department of Public Health issued a no consumption advisory for all species of catfish and bass over a much larger area (67 river km) of Lake Logan Martin than had been involved previously. Highly motile fish species should be included in fish consumption advisories because they have the potential to accumulate and transport the chemical of concern greater distances from the primary source.

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Table 1. Scientific and common names of fishes, number of fish sampled, means for total PCBs, distance at capture from the Choccolocco Creek embayment, fish length, and fish weight for 12 species collected in Lake Logan Martin in 1996. Mean values are subtended by the range in parenthesis.

Fish Species	Number	Total PCBs (mg/kg)	Distance (km)	Fish Length (mm)	Fish Weight (g)
Ictalurus furcatus blue catfish	81	2.20 (0.14-57.6)	14.9 (0-45.6)	373 (240-759)	517 (101-6,000)
Ictalurus punctatus channel catfish	90	2.37 (0.14-14.6)	16.7 (0-45.6)	320 (215-492)	272 (68-1,159)
Pylodictis olivaris flathead catfish	25	4.03 (0.14-18.50)	16.2 (0-27.3)	445 (205-851)	1,680 (76-7,200)
Morone chrysops white bass	41	2.80 (0.14-20.10)	20.6 (0-45.6)	316 (231-390)	402 (145-833)
Morone saxatilis striped bass	36	5.09 (0.14-35.20)	14.3 (0-45.6)	457 (286-793)	1,228 (275-4,546)
Morone chrysops x saxatilis palmetto bass	42	2.53 (0.14-12.20)	12.6 (0-45.6)	343 (245-509)	549 (178-1,688)
Lepomis macrochirus bluegill	45	0.91 (0.14-6.90)	16.8 (0-45.6)	180 (150-207)	110 (69-169)
Lepomis microlophus redear sunfish	37	0.35 (0.14-2.26)	18.9 (0-45.6)	195 (166-238)	123 (73-233)
Micropterus punctulatus spotted bass	99	2.77 (0.14-16.10)	17.2 (0-45.6)	386 (243-512)	848 (203-2,059)
Micropterus salmoides largemouth bass	121	1.66 (0.14-17.2)	17.2 (0-45.6)	385 (223-585)	919 (145-3,228)
Pomoxis nigromaculatus black crappie	82	1.17 (0.14-10.06)	17.2 (0-45.6)	272 (215-376)	321 (135-927)
Aplodinotus grunniens freshwater drum	77	1.41 (0.14-28.50)	16.7 (0-45.6)	346 (230-502)	559 (121-1,979)

Table 2. PCB concentrations (mg/kg) and number of fish in composite samples (in parenthesis) for four common forage fishes collected fall 1999 in Lake Logan Martin at varying distances from the Choccolocco Creek embayment (station 5).

	Stations			
	5	6	3	9
	Distance (km)			
Species	0.0	5.0	16.0	27.0
Dorosoma cepedianum				
Gizzard shad	2.3	0.6	0.6	0.2
	(6)	(6)	(6)	(4)
Dorosoma petenense				
Threadfin shad	4.2	2.3	0.0	0.0
	(54)	(31)	(34)	(23)
Cyprinella venusta				
Blacktail shiner	6.7	1.1	-	0.3
	(8)	(13)		(12)
Lepomis macrochirus				
Bluegill	3.5	1.4	0.1	0.1
	(6)	(6)	(6)	(6)

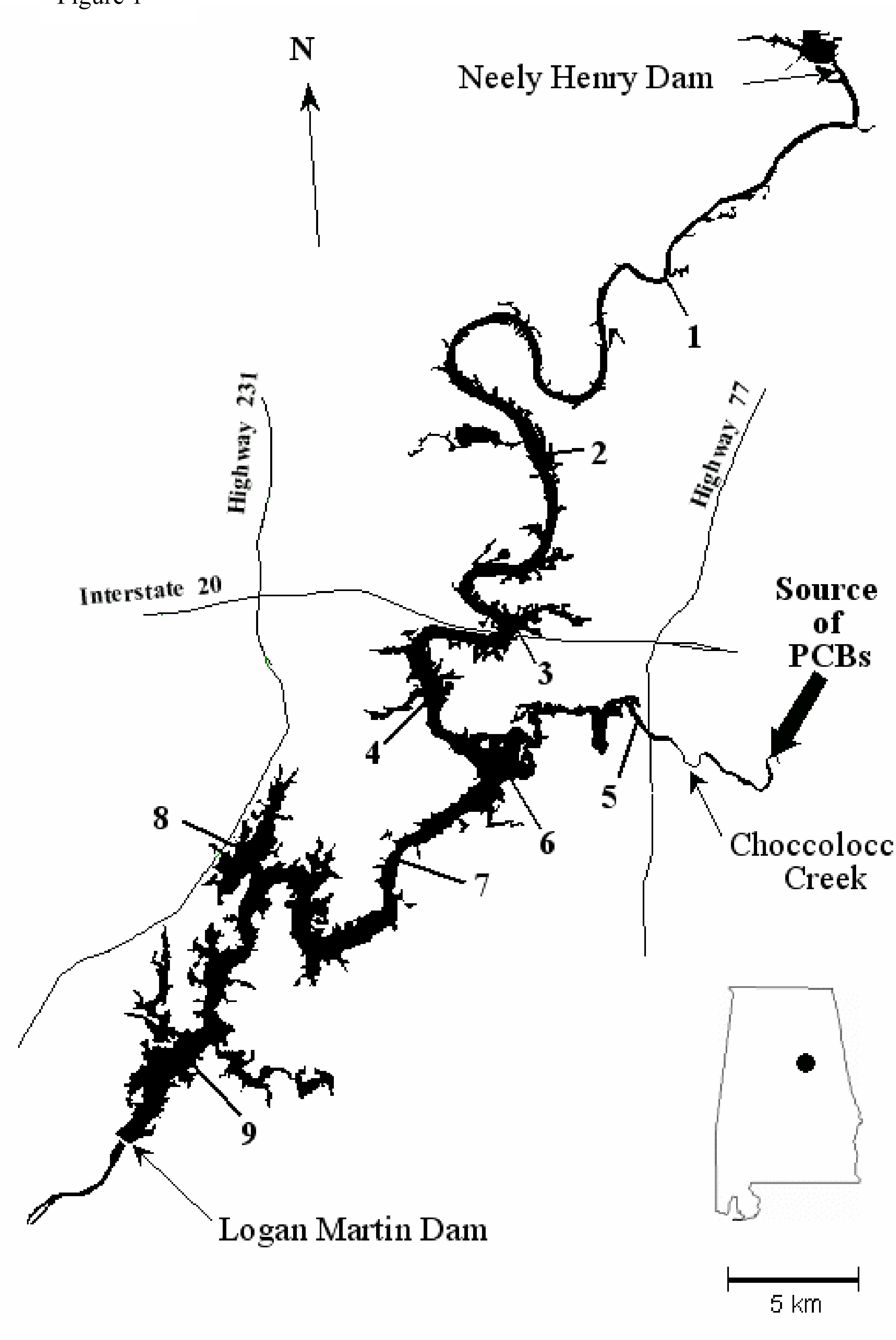
Figure legends

Figure 1. Map of Lake Logan Martin showing the nine sampling stations where fish were collected during the growing seasons of 1996 and 1999.

Figure 2. Plots of PCB concentrations in fish tissue versus distance, at capture, of the fish from Choccolocco Creek embayment (station 5). Regression lines and regression parameter values are presented for six of the 12 fish species examined in Lake Logan Martin.

Figure 3. Plots of PCB concentrations in fish tissue versus distance, at capture, of the fish from Choccolocco Creek embayment (station 5). Regression lines and regression parameter values are presented for six of the 12 fish species examined in Lake Logan Martin.

Figure 1


N
Neely Henry Dam
1
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Highway 231
Highway 77
Interstate 20
Source of PCBs
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7
8
Choccolocco Creek
9
Logan Martin Dam
5 km

Figure 2

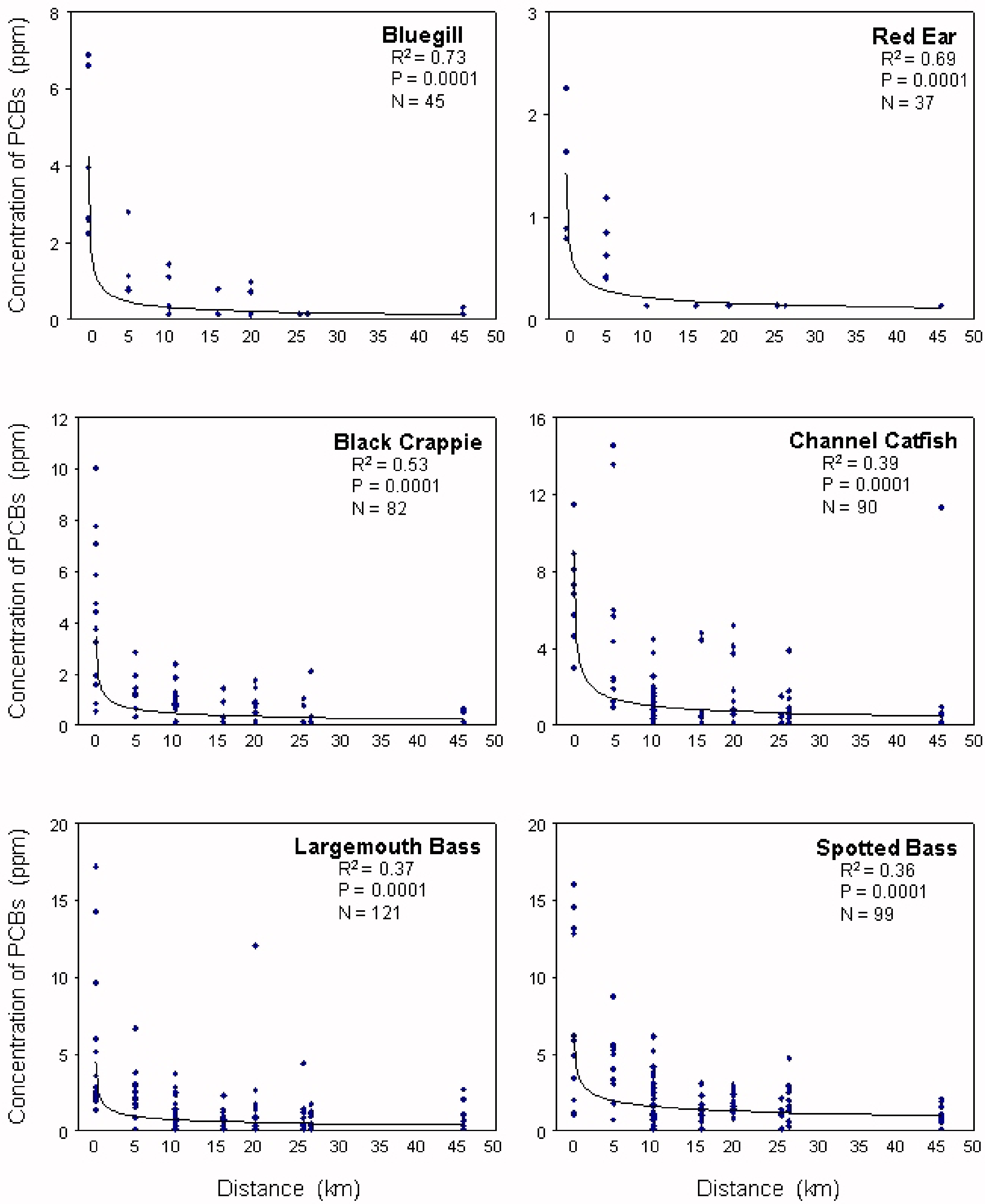
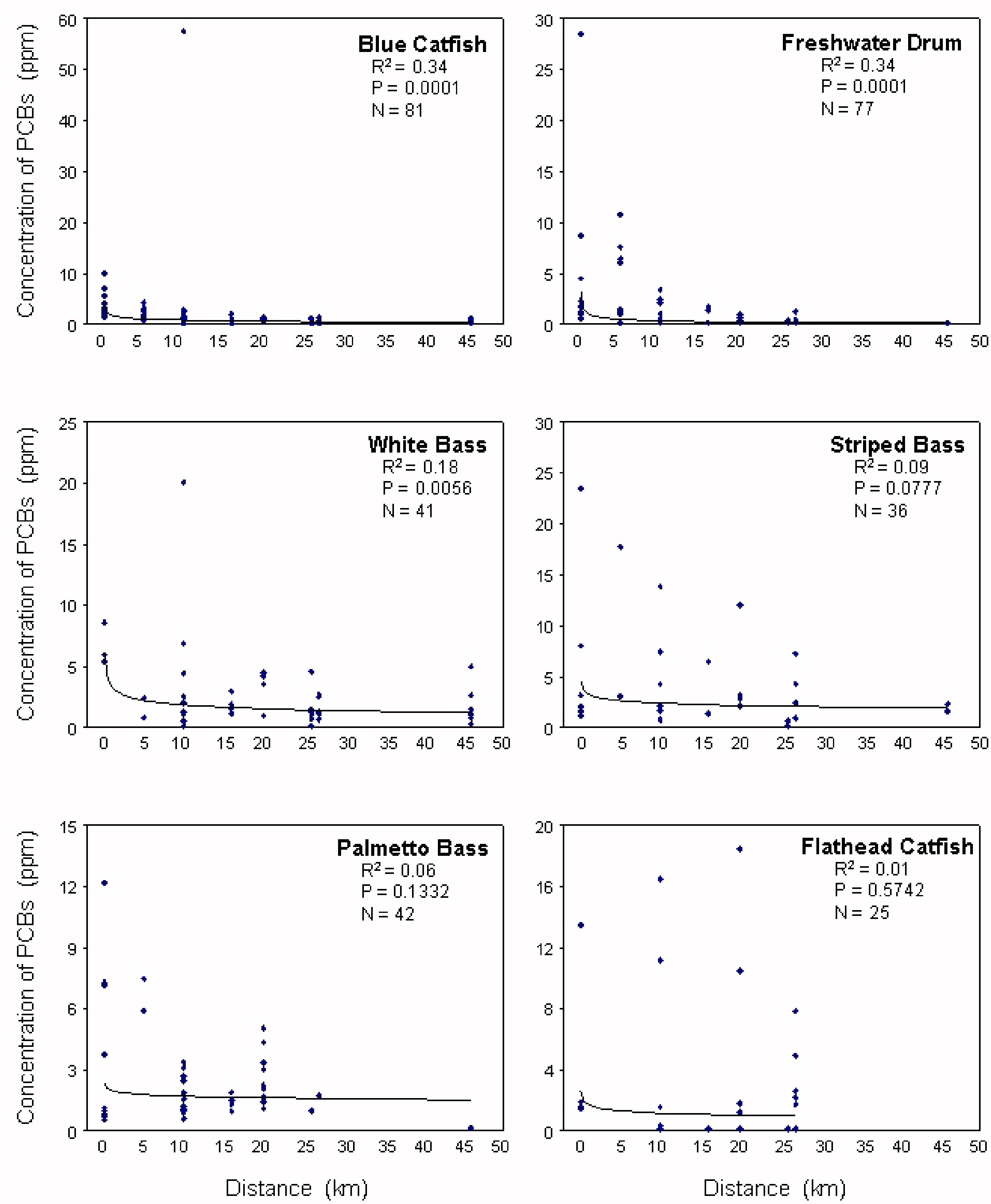

Bluegill
R² = 0.73
P = 0.0001
N = 45
Red Ear
R² = 0.69
P = 0.0001
N = 37
Black Crappie
R² = 0.53
P = 0.0001
N = 82
Channel Catfish
R² = 0.39
P = 0.0001
N = 90
Largemouth Bass
R² = 0.37
P = 0.0001
N = 121
Spotted Bass
R² = 0.36
P = 0.0001
N = 99
Concentration of PCBs (ppm)
Distance (km)

Figure 3



Blue Catfish
R² = 0.34
P = 0.0001
N = 81
Freshwater Drum
R² = 0.34
P = 0.0001
N = 77
White Bass
R² = 0.18
P = 0.0056
N = 41
Striped Bass
R² = 0.09
P = 0.0777
N = 36
Palmetto Bass
R² = 0.06
P = 0.1332
N = 42
Flathead Catfish
R² = 0.01
P = 0.5742
N = 25
Concentration of PCBs (ppm)
Distance (km)