8.0 MERCURY

8.1 Introduction

Since the initial detection of elevated levels of Hg in freshwater fish in 1989 (Ware et al. 1990), it has become increasingly apparent that South Florida has an extensive Hg contamination problem. The state of Florida has issued human health fish consumption advisories due to Hg contamination that either ban or restrict the consumption of largemouth bass and other freshwater species from over 7,600 km^2 (2 million acres) encompassing the Everglades and BCNP. The maximum concentrations found in largemouth bass (4.4 mg/kg) and bowfin (over 7 mg/kg) collected from the Everglades are the highest concentrations found in Florida to date. Hg contamination has also been found at levels of concern in largemouth bass throughout Florida's surface waters (Lange et al. 1993). Hg accumulation through the food web may reduce the breeding success of wading birds (Frederick and Spalding 1994) and the survival of the endangered Florida panther (Roelke et al. 1991).

Prior to the initiation of this and other studies (e.g., USGS, EPA ORD, FDEP, SFWMD, EPRI) in the mid-1990s, the sources, distribution, magnitude, transport, transformations, and pathways of Hg through the Everglades ecosystem were poorly known. Among the possible Hg sources in South Florida are natural mineral and peat deposits (Rood et al. 1995) and atmospheric deposition from global, regional and local sources (e.g., fossil-fuel fired electrical generating plants, municipal waste incinerators, medical waste incinerators, paint operations, and agricultural operations). Although there are multiple interactions among these sources and several possible pathways for Hg transport and bioaccumulation through the Everglades ecosystem, none of these individual sources appear to adequately explain the vast area apparently contaminated by Hg.

The issues of Hg contamination of Everglades biota are extremely complex. Various hypotheses have been put forward to account for the apparent susceptibility of the Everglades to Hg impacts (SFMSP 1996), including (1) high historical accumulations of readily methylatable Hg in the downstream sediment attributable to the historical oxidation of peat in the EAA; (2) a high mobilization rate of readily methylatable Hg from the sediment associated with the dry-wet cycles in the EAA and some locations in the WCAs; (3) a high atmospheric deposition flux of

methylatable Hg from local, regional, and global sources; (4) a high rate of net methylation of Hg associated with high concentrations of conducive factors in water and sediment pore water; (5) change in flow path from overland flow to infiltration and subsurface flow following drainage; (6) a high bioavailable fraction of MeHg; (7) the absence of a freeze-thaw cycle and high average annual temperatures that accelerate aquatic metabolic processes; (8) high bioaccumulation and biomagnification factors resulting from the complex aquatic and terrestrial food webs; or (9) combinations of the above (EPA 1993). The importance of wetlands as sites of abiotic and biotic Hg methylation was recognized in the review by Zillioux et al. (1993). The large surface to volume ratio of wetlands makes them sensitive to atmospheric inputs and sentinel indicator ecosystems for this global contamination problem.

For fish Hg contamination to reach concentrations that have ecological or human health consequences, five conditions must exist: (1) presence of Hg in locations, forms, and concentrations available to aquatic bacteria; (2) combination of environmental factors favorable to a high rate of net MeHg production and bioavailability; (3) bioaccumulation and biomagnification through the food chain; (4) significant rate of exposure by consumption of contaminated food; and (5) one or more species of wildlife sensitive to consuming Hg contaminated food at rates that result in the accumulation of MeHg to toxic levels. This chapter discusses: (1) the external loadings or sources of Hg to the South Florida Everglades ecosystem; (2) the spatial patterns, water quality gradients, and constituent interactions in the canal and marsh ecosystems; and (3) the general attributes and response of the biological indicator, the Eastern mosquitofish (*Gambusia holbrooki*).

8.2 Initial Conceptual Mercury Cycling Model

A conceptual model of Hg cycling in the Everglades was initially developed in 1992. Several testable hypotheses were developed from this initial model (Table 8.1). This section presents the initial conceptual model that formed the basis of data collection activities in the Everglades from 1993 through 1996.

Table 8.1 Initial Hg hypotheses developed in the Interagency Scope of Study (Stober et al. 1992).

- Hg contamination is significantly increased by anthropogenic (global, regional and local) releases to the air and subsequent wet/dry deposition to the Everglades ecosystem.
- Water discharged from the EAA is loading the downstream WCA and ENP with Hg and/or MeHg.
- Eutrophication of the Everglades is resulting in conditions conductive for the methylation of Hg of geologic origin in peat soils. Specific hypotheses include:
  - Phosphorus loading to the Everglades ecosystem is stimulating primary production leading to increased organic matter, which leads to increased oxygen demand and development of anaerobic conditions that favor the methylation of Hg.
  - The addition of nutrients to wetland soils results in proliferation of excess biomass and microbial consumption of organic matter leading to reducing conditions and Hg methylation.
  - The sedimentation of autochthonous and allochthonous organic matter in canals and waterways results in the development of anaerobic conditions near the sediment-water interface, which contributes to an increase in the rate of methylation and solubilization of naturally occurring Hg. Because these canals are often the source of (or directly associated with) Hg contaminated fish, anaerobic sediments are a likely contributor of MeHg for bioaccumulation by fish.
  - Agricultural practices lead to increased soil oxidation and compaction and cause Hg concentration increases (mg/kg) in cultivated fields. Subsequently increases in bulk density of these soils allows less oxygen to diffuse into the soil matrix. Thus, intermittent repeated flooding occurring naturally or used in nematode control, causes an increase in the rate of methylation and solubilization of naturally occurring Hg followed by transport from the fields into the Everglades.
  - For Hg to be methylated, a specific set of conditions must occur — anaerobiosis, specific range of Eh, presence of sulfate and organic matter — which have limited geographic distribution in South Florida, but are not foreign to the Everglades.
  - The distribution of THg and MeHg concentrations in soils, sediments, surface waters and selected biota is the same throughout the Everglades study area.
  - There is no relationship between MeHg concentrations in soils and indicators of eutrophic effects (e.g., TP) in soils and surface waters of the Everglades ecosystem.
  - Irrigation and drainage water from the EAA is loading the downstream Everglades ecosystem with Hg.

Significant quantities of Hg cycle through air, water, and solid phases of the global environment. Hg cycling through the atmosphere is estimated at 6 billion grams/year (Fitzgerald 1986, 1989; Porcella et al. 1992), and additional research indicates that this amount has increased at about 1.5% per year over the North Atlantic Ocean since 1970 (Slemr and Langer 1992). Deposition of atmospheric Hg has increased since 1850 in lake sediments taken in midcontinental North America (Swain et al. 1992). The rate closely parallels that documented for greenhouse gases. Within this global background, regional areas exist that may exhibit higher atmospheric background concentrations due to the proximity of urban or industrial activity. The entire southeast coast of Florida is an urban area inhabited by about 5 million people. The operation of solid waste incinerators and fossil fuel power plants has increased significantly since 1940 (Newman 1992), presenting the prospect that regional atmospheric Hg might have increased similarly over this time period (Figure 8.1). The predominant wind directions are from the east to southeast, which causes an air mass to be transported from above the Atlantic Ocean, westward over the urban area and across the Everglades. There are a variety of Hg emission sources in the urban areas along the east coast. Hg is emitted into the atmosphere as a mixture of gases and particulates. As the Hg from individual sources mixes together, the mass of air containing the Hg is transported over the Everglades where it is then potentially deposited through a variety of mechanisms. The most likely mechanism is through wet deposition, with the Hg being washed out by rainfall. The other mechanism is dry deposition with particulates dropping into the Everglades and gaseous Hg coming into contact with the water. The fate and transport of point source atmospheric discharges and speciation of atmospheric Hg from regional incinerators and power plants must be evaluated to determine the depositional contributions to the Everglades ecosystem. Regional (far-field) atmospheric Hg flux was monitored by the Florida Atmospheric Mercury Study (FAMS). Local (near-field) source apportionment and fate and transport studies of Hg are being investigated by EPA and the University of Michigan.

Two common factors in Hg contamination in temperate regions are low pH of receiving waters and acid rain (Winfrey and Rudd 1990). Both lead to conditions that contribute directly to the enhanced solubilization of inorganic Hg. Once inorganic Hg enters the water, it becomes more available to the methylation processes. Although acid rain and acidic conditions in other

ecosystems could be responsible for Hg contamination, it is unlikely that these factors contribute significantly in the subtropical Everglades because the Everglades are generally circumneutral or alkaline in pH and underlying limestone strata provide a high buffering capacity.

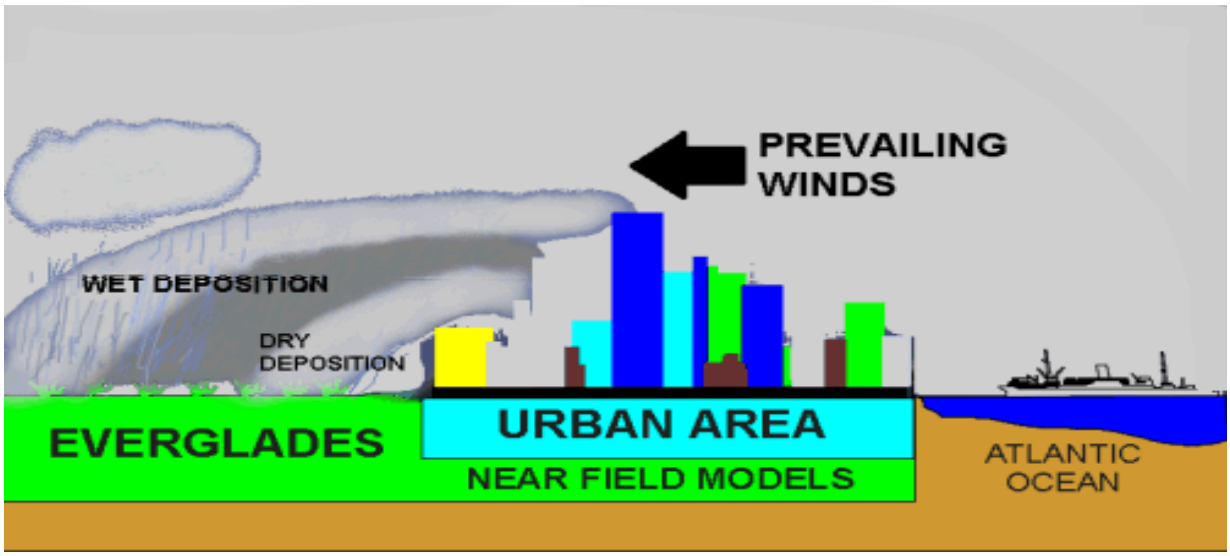

Figure 8.1. Schematic figure depicting atmospheric deposition of Hg.

Organic soils and sediments, such as those found throughout Everglades wetlands, would be expected under appropriate conditions to contain and retain Hg. The natural processes by which this occurs, however, have been altered by water management and other anthropogenic activities in South Florida and, perhaps, by large-scale global Hg inputs (Slemr and Langer 1992). To understand the biogeochemical cycling of Hg in the Everglades ecosystem, it is necessary to understand the processes and factors influencing the flux of Hg through this system. An important step in this process is identifying the sources of Hg and quantifying the relative contribution of these sources to the Everglades ecosystem (Figure 8.2).

The soils and sediments (Figure 8.2) of the Everglades ecosystem represent the largest deposits of circumneutral peat in the world. However, the abundant organic matter in wetlands sequesters Hg (Lodenius et al. 1987, Schuster 1991), and Everglades soils and sediments can contain a substantial Hg pool even without continuing atmospheric deposition. When this study was initiated in 1992, the Hg pool was not yet quantified. Preliminary results of Hg sediment and

soil accumulation rates in the Everglades suggested that the rate may have increased at some locations since 1980 (Delfino 1992). Therefore, these soils and sediments were a candidate source of the Hg that may ultimately contaminate the tissues of fishes found in associated waters (Stober et al. 1992).

A unique feature of these organic soils is that peat and muck are subject to subsidence and lose surface elevation when drained because of (1) shrinkage due to desiccation; (2) consolidation by loss of the buoyant force of groundwater; (3) compaction by tillage; (4) wind erosion; (5) burning; and (6) biochemical oxidation (Stephens 1984). The subsidence of the organic soils in the EAA in recent decades may have resulted in the concentration of Hg in the remaining soil, thereby facilitating the methylation and/or transport of Hg downstream via forced drainage. Considering the surface area under cultivation and drainage and the fact that over 70% of the EAA peat volume has been lost to subsidence since farming began at the turn of the century (Stephens 1984), a significant mass of Hg may have been transported downstream to the Everglades by drainage canals over the years.

Inorganic Hg is converted to MeHg primarily through the actions of microorganisms. Sulfate-reducing bacteria, which are obligate anaerobes, have been implicated in Hg methylation (Gilmour et al. 1992). The methylation process vastly increases the toxicity and likelihood for Hg to bioaccumulate (Gilmour et al. 1992). Methylation of Hg not only increases the bioavailability of this metal, it also increases the mobility of Hg in the environment by decreasing the formation of relatively insoluble salts and oxides (Grieb et al. 1990). The interactions of the sulfur cycle and sulfate-reducing bacteria with the chemistry of Hg present numerous questions for understanding the processes affecting Hg contamination in the Everglades. Zillioux et al. (1993) in a review of Hg cycling and effects in freshwater wetland ecosystems state that both abiotic and biotic methylation processes are likely to occur in wetlands.

One of the most noticeable changes in the Everglades ecosystem in recent years is eutrophication (Figure 8.2). Pristine Everglades wetland soils are not highly reduced (anaerobic), even when flooded (Bachoon and Jones 1992). Primary production and microbial respiration in the Everglades are apparently limited by TP, with average TN to TP ratios (TN:TP) as high as 170:1 reported in Everglades waters (Scheidt et al. 1989, SFWMD 1992). Typically, TP limits primary production when TN:TP ratios exceed 20:1 to 30:1 (Redfield 1958). However, TN

includes organic N contributions and the bioavailability of organic N to microbial assemblages in the Everglades is not well known. Effective N:P ratios, therefore, might be lower than 170, based on TN:TP. Phosphate enrichments in Everglades soils and sediments have accelerated production of organic matter, resulting in a change from oligotrophic to eutrophic ecosystems in some areas, an increased water column and sediment oxygen demand, and the establishment of anaerobic conditions. Under anoxic conditions, inorganic Hg is converted to MeHg by sulfur bacteria and bioaccumulated in the food chain. Methylation of inorganic Hg in Everglades soil samples has been shown in laboratory tests to increase with increased nutrient concentrations (Barkay 1992). However, highly eutrophic soils showed a decline in methylation or an increase in demethylation (Barkay 1992). The methylation/ demethylation (M/D) ratios in soil, sediment, and water and the influence of nutrients (TN and TP) on these processes can result in both increased methylation and demethylation of Hg (Figure 8.2). This relationship has yet to be elucidated in the Everglades. Surface flow of water (Figure 8.2) may be an important transport mechanism that moves sediment, TP, inorganic Hg, and organic Hg off the EAA via canals to the downstream WCAs and ENP. An average of 204 metric tons (225 tons) of TP flow from the 3,000 km^2 (700,000 acres) of the EAA into downstream habitats from 1980 to 1996 (SFWMD 1997c) resulting in changes in wetland plant communities (Nearhoof 1992).

Evasion or soil degassing of Hg is an important component of the biogeochemical model describing the Hg cycle (Figure 8.2). Evasion from seepage lakes has been measured on northern temperate lakes (Fitzgerald et al. in press), but wetlands in the Everglades have higher ambient temperatures than temperate seepage lakes, so evasion rates are likely different. Evasion estimates also are likely to be confounded because of highly managed hydroperiods. Evasion estimates from wetland habitats, other land uses, and open waters are important components of the model that must be defined.

A definition of the aquatic and terrestrial bioaccumulation pathways (Figure 8.2) also must be determined. Critical path analyses should be made for the top terrestrial predators (e.g., fish, birds, reptiles, and mammals) in several habitat types in the Everglades ecosystem with particular attention to endangered or threatened species.

Development and operation of the C&SF canal system for flood control has greatly modified the hydrology of the Everglades over the last 40 years. The result is that parts of the

study area presently have shorter hydroperiods while other areas have longer hydroperiods than occurred historically. The process of flooding soils by itself, however, does not appear to lead to anaerobic conditions and the methylation of Hg in the pristine Everglades system. It is the development of reducing conditions that leads to methylation. In addition, reducing conditions can occur in microhabitats within the peat. Anaerobic zones can be contiguous to oxic zones in these microhabitats. However, the interaction of hydroperiod (duration of inundation) with the methylation process may result in generation of MeHg under some conditions (e.g., alligator holes are naturally nutrient enriched, maintain reducing conditions, and contain some fish). Thus, despite the presence of flooded soils, Hg methylation may be expected to be limited in the absence of eutrophic conditions. Recycling from the soil and water surfaces, however, might be an important loss from the system under water management conditions.

An ecological risk assessment must evaluate the impacts of Hg on the entire ecosystem, as well as selected rare and endangered species. The identification of these components will determine the factors and processes to be incorporated into mathematical models of the biogeochemical cycling of Hg in the Everglades ecosystem. An *a priori* Hg model for the South Florida Everglades ecosystem was developed to help guide the study.

8.3 Results

8.3.1 Mercury Loading

Hg loading to the Everglades was estimated from bi-weekly monitoring of water samples that were collected at S-5A, S-6, S-7, and S-8 during 1994, 1995, and 1996. Sampling at these four structures was used to estimate the mass transport of Hg through the canal system from the EAA to the downstream Everglades. Total discharge was measured at each of these structures by SFWMD. The total biweekly discharge was multiplied times the biweekly Hg concentration to obtain the Hg mass for the biweekly period. These masses were summed to obtain seasonal and annual estimates. The loading of THg in the water flowing south through the structures was estimated at 0.5 to 0.6 kg during the dry season and 1.3 to 2.7 kg during the wet season. Annual estimates of THg loadings from the EAA ranged from 1.8 to 3.3 kg/yr. Estimates of the loading of MeHg flowing through the structures was 0.1 to 0.2 kg during the dry season and 0.2 to 0.4 kg during the wet season. Annual estimates of MeHg loading from the EAA ranged from 0.3 to

0.6 kg/yr. Atmospheric loading of THg from wet deposition to the system was estimated at between 40 and 50 kg/yr, clearly indicating that most of the Hg entering the system comes from atmospheric deposition.

8.3.2 Water Quality Patterns

The methylation of inorganic Hg to its bioaccumulated form (i.e., MeHg) occurs under a favorable set of environmental conditions. These conditions include anoxia (Matilianen 1995), moderate TSO_4 concentrations (Gilmour et al. 1992), moderate TOC concentrations (Driscoll et al. 1994), low pH and/or alkalinity concentrations (Rudd 1995). In general, oligotrophic, rather than eutrophic, aquatic ecosystems have Hg contamination problems. Wetlands are particularly conducive to Hg methylation (Zillioux et al. 1993). In general, southern and southeastern aquatic ecosystems under fish consumption advisories have these water quality characteristics (Southern States Mercury Task Force 1997). Based on these patterns observed in other wetland systems, and the conceptual model developed for the Everglades ecosystem, analyses were performed to evaluate these observations and associations in the South Florida ecosystems.

The following sections present the spatial patterns, gradients, and associations among water quality constituents in South Florida canal and marsh ecosystems.

8.3.2.1 Canal Water Quality by Subarea

Exploratory analyses (i.e., cluster, factor, and principal components analyses) were used to investigate possible relationships among THgF, MeHg concentrations in water, and the water quality constituents discussed above. Principal components analyses indicated TOC, TSO_4, and TP grouped as one principal component and MeHg as a second component in describing variance in THgF. Analyses subsequently focused on the spatial patterns and gradients in these five constituents.

Distinct gradients by subarea in canal water quality occurred with each of these parameters. TOC showed a strong gradient from the EAA canals through the WCA canals declining to significantly lower concentrations in the ENP canals (Figure 8.3). If the 95% confidence intervals around the median (the notch) in the box and whisker plots are nonoverlapping, the medians are significantly different at the 5% level ($P<0.05$). Seasonally the

gradient was most pronounced during the wet season with significant declines from the north to the south (Figure 8.3). TOC concentrations in BCNP were similar to ENP. TOC concentrations during the dry season remained higher in the EAA and WCA with a significant decline in ENP and BCNP (Figure 8.3). TSO_4 demonstrated a similarly strong north to south gradient (Figures 8.4 and 8.5) with higher concentrations occurring during the wet season (Figure 8.5). Significant declines in TSO_4 occurred between the EAA and WCA canals during both wet and dry (Figure 8.5) seasons; TSO_4 concentration in the WCA and ENP canals were not significantly different ($P<0.05$) during either season. A well defined north to south gradient also occurred with TP significantly declining along this latitudinal gradient. A significant gradient in TP persisted in the subarea canals through both wet and dry seasons, but TP concentrations were higher in the EAA during the wet season (Figure 8.6 and 8.7).

The source of the highest concentrations for each of these variables was the EAA. The high TOC concentrations in water were most likely enhanced by the runoff of agricultural stormwater, which increased during the wet season. The TSO_4 emanating from the EAA may result from both fertilizer applications and the entrainment of connate seawater in groundwater during pumping in the wet season (Miller 1988). High TP concentrations in the EAA result from fertilizer application, soil subsidence, and water management (Izuno et al. 1991, Coale et al. 1994, Stone and Legg 1992).

The THg concentrations in water among the subarea canals for all cycles combined did not show a significant north to south gradient as observed in the other constituents (Figures 8.8 and 8.9). However, a comparison of the wet and dry (Figures 8.8 and 8.9) season samples by subarea indicated higher THg concentrations in water occurred during the wet season when a significant decline was evident from north to south. THg concentrations in canal water could be dominated by the runoff of atmospheric wet deposition and particulate loading from the EAA during the wet season. A comparison of the canal data for all cycles combined indicates MeHg concentrations were similar in the EAA and WCA subareas and decline significantly ($P<0.05$) downstream in ENP and BCNP (Figure 8.10). A significant MeHg gradient declining from the EAA through the WCA to ENP occurred during the wet season (Figure 8.10). However, during the dry season (Figure 8.10), MeHg concentration in the WCA showed significantly higher concentrations than

in the EAA or ENP. The MeHg concentrations in the ENP were significantly lower statistically than in the EAA and WCA during both seasons.

Overall, the wholebody mosquitofish THgF concentrations were found to be lowest in the EAA while significantly higher concentrations were found in mosquitofish from the WCA, ENP, and BCNP regardless of season (Figures 8.11 and 8.12). The highest concentrations occurred in mosquitofish from the WCA canals, but these concentrations were not statistically different from the THgF concentrations in mosquitofish from the ENP and BCNP canals. When THg concentrations in water and THgF concentrations in mosquitofish are evaluated, THg concentrations in water do not provide a good indication of THgF concentrations in mosquitofish; however, water concentrations might provide information on atmospheric deposition and source.

8.3.2.2 Canal Water Quality by Latitude

Scatter plots of combined canal data for all four cycles are presented by latitude in Figure 8.13. These plots show the gradients from north to south in TOC, TSO_4, and TP, a gradient for MeHg in water was less apparent. The THgF concentrations indicated a cluster of high values between Alligator Alley and Tamiami Trail bounding the southern two-thirds of WCA3. This indicated that Alligator Alley and Tamiami Trail were reasonable latitudinal demarcation points on which to parse the data for this analysis.

An ANOVA was conducted on constituent concentrations north of Alligator Alley, between Alligator Alley and Tamiami Trail, and south of Tamiami Trail (Table 8.2). These latitudinal subregions showed significant ($P<0.05$) differences in the geometric mean concentrations between subregions in TP and TOC. TSO_4 showed a significant ($P<0.05$) concentration decline from north of Alligator Alley to between Alligator Alley and Tamiami Trail with no significant difference in TSO_4 concentrations between Alligator Alley and Tamiami Trail and the area south of Tamiami Trail. MeHg concentrations in the areas north and south of Alligator Alley were equal, but a significant ($P<0.05$) decline occurred in ENP. In contrast, THgF in mosquitofish was significantly ($P<0.05$) higher between Alligator Alley and Tamiami Trail than in either the north or the south sectors.

Table 8.2 Comparison of canal constituent geometric means concentrations in water by latitude. Sample size in parenthesis. (> or < is statistically significant, P<0.05)

Constituent[a]	Latitude		
	North of Alligator Alley	Alligator Alley - Tamiami Trail	South of Tamiami Trail
TP (μg/L)	79 (114)	> 24 (64)	> 14 (21)
TOC (mg/L)	26 (114)	> 18 (64)	> 11 (21)
TSO_4 (mg/L)	27 (114)	> 7 (64)	= 8 (21)
MeHg (ng/L)	0.2 (114)	= 0.2 (64)	> 0.1 (21)
THg Fish (μg/kg)	33 (114)	< 83 (64)	> 37 (21)
THg (ng/L)	1.6 (114)	= 1.2 (64)	> 0.8 (21)

An ANOVA on a seasonal comparison of the canal data of the two wet and two dry seasons combined (Table 8.3) showed a more pronounced gradient in TP concentrations from north to south during the wet season when compared to the dry season, which had a concentration gradient (P<0.05) through all three subareas. A significant (P<0.05) gradient in TOC occurred during the wet season. During the dry season, the decline in the canal water TOC concentration was significant only south of Tamiami Trail in ENP. The north to south gradient in TSO_4 only occurred between the northern two subregions and was twice as high during the wet season when compared to the dry season. The lower concentrations of TSO_4 south of Alligator Alley may not be significant because the MDLs vary from 5 to 2 mg/L for these analyses. MeHg in water showed a significant (P<0.05) gradient during the wet season. The gradient was less pronounced during the dry season and only occurred south of Tamiami Trail.

THgF in mosquitofish was significantly higher (P<0.05) during both wet and dry seasons between Alligator Alley and Tamiami Trail with the highest THgF concentrations in the dry season.

Table 8.3 Comparison of canal constituent geometric mean concentration, by latitude and by season. Sample size in parenthesis. (> or < is significant, P<0.05)

Constituent	Latitude		
	North of Alligator Alley	Alligator Alley - Tamiami Trail	South of Tamiami Trail
TP (μg/L)			
Wet	101 (56)	> 18 (35)	= 10 (8)
Dry	62 (58)	> 36 (27)	> 19 (10)
TOC (mg/L)			
Wet	31 (56)	> 16 (35)	> 10 (8)
Dry	22 (58)	= 21 (27)	> 11 (10)
TSO_4 (mg/L)			
Wet	40 (56)	> 7 (35)	= 10 (8)
Dry	19 (58)	> 6 (29)	= 6 (13)
MeHg (ng/L)			
Wet	0.4 (56)	> 0.2(35)	> 0.1 (8)
Dry	0.2 (58)	= 0.2 (29)	> 0.1 (13)
THgF (μg/kg)			
Wet	30 (50)	< 69 (34)	> 27 (8)
Dry	36 (58)	< 103 (29)	> 45 (13)
THg (ng/L)			
Wet	2.3 (56)	> 1.3 (35)	= 0.8 (13)
Dry	1.1 (58)	= 1.2 (29)	= 0.9 (13)

8.3.3 Transect Gradients

8.3.3.1 Water

Four transects were selected that had been previously studied by others (Doren et al. 1996) to investigate the differential effects of TP on the eutrophication of the marsh. Because this historical information was available and the differences in nutrient impacts on each transect were known, the interrelationships of TP and other constituents along the same transects were investigated. The transects were oriented 90° to a canal and extended various distances into the marshes (Figure 8.14). The transect in LNWR was oriented perpendicular to the flow. The WCA3 transect was oriented upstream or opposite the flow, while the transects in WCA2 and ENP were oriented downstream or with the flow.

TP concentrations in water on each transect are shown in Figure 8.15. A sharp decline in TP was apparent within the first 1,000 m (3,281 feet) in LNWR indicating the influence of agricultural stormwater runoff in the canals surrounding LNWR. Stormwater does not penetrate the center of LNWR because the interior is a rain driven marsh system. The transect in WCA2 showed the highest TP concentrations in water, which had a sharp decline from about 90 μg/L near the canal to about 40 μg/L 2,000 m (6,562 feet) from the canal, declining further to about 10 μg/L 8,000 m (26,246 feet) into the marsh. The lowest transect TP concentration (~10μg/L) was measured along the WCA3 transect. TP delivery through S12C into ENP tended to increase water concentrations to about 15 μg/L across most of this transect. TOC in water declined from 25 to 20 mg/L about 2,000 m (6,562 feet) from the canal along the LNWR transect. TOC concentrations also decreased from 32 to 24 mg/L about 2,000 m (6,562 feet) from the canal along the WCA2 transect, but then increased again to about 32 mg/L and remained relatively constant about 8,000 m (26,246 feet) from the canal on into the marsh. TOC also decreased after about 2,000 m (6,562 feet) along the WCA3 and ENP transects (Figure 8.16). There were few differences among the transects or apparent gradients in TOC concentrations in water. TSO_4 concentrations in water declined from about 15 to 5 mg/L within 3,000 m (9,842 feet) of the canal in LNWR and remained at those concentrations along the remainder of the transect (Figure 8.17). TSO_4 concentrations were highest in WCA2 ranging from 25 to 50 mg/L with no apparent trend along the length of the transect. TSO_4 in WCA3 was consistently at the MDL of 2 mg/L; however, ENP showed a decline in TSO_4 from 23 mg/L near the canal to baseline concentrations of 2 mg/L 5,000 m (16,404 feet) along the transect. Higher TSO_4 concentrations near the canal along the ENP transect indicate that stormwater is transported through the canal system from upstream and discharged into ENP.

THg concentrations in water along the transect in (Figure 8.18) LNWR initially increased from the canal toward the center. THg concentrations along the WCA2 transect showed a sharp increase about 500 m (1,640 feet) from the canal with declining concentrations from the canal along the remainder of the transect until the end when THg concentrations increased again. WCA3 shows a consistent background THg concentration of about 1 ng/L. MeHg concentrations in water on transects in LNWR and ENP show increased concentrations beyond about 3,000 m

(9,842 feet) from the canal, while MeHg concentration along the WCA2 transect decline rapidly near the canal with an increase between 8,000 to 9,000 m down the transect (Figure 8.19). No trend was seen along the WCA3 transect.

The ratio of MeHg to THg is plotted in Figure 8.20. Increasing trends down the WCA2 and ENP transects are apparently reaching a maximum of 45% on each. A MeHg response reaching 60% in LNWR near the interface of marsh and stormwater was also evident. No trend in the percent MeHg in water was apparent on the transect in WCA3.

THg in wholebody mosquitofish in LNWR showed increased concentrations down the transect (Figure 8.21). A similar pattern also was apparent along the ENP transect. An increase of THg in fish begins beyond 8,000 m (26,246 feet) along the WCA2 transect. The THg concentrations in fish along the WCA3 transect are highest near the canal and declined into the marsh.

8.3.3.2 Soil Parameters

Sulfide in soil expressed as bulk density (i.e., mg/cc) indicated a maximum concentration of 0.03 mg/cc within 1,500 m (4,921 feet) of the canal, which declined toward the center of LNWR (Figure 8.22). A similar relationship occurred on the ENP transect. The concentrations remained somewhat higher in WCA2 throughout the length of the transect. The lowest soil sulfide concentrations were found along the entire length of the transect in WCA3.

TP expressed as μg/cc indicated an exponential decline within the initial 4,000 m (13,123 feet) of the LNWR transect (Figure 8.23). A linear decline occurred in WCA2, which remained generally higher throughout the transect length. The transect in the ENP showed an initial rapid decline near the canal; however, TP concentrations then increased and paralleled the linear decline in TP observed along the WCA2 transect. The concentrations in WCA3 were nearly constant at 0.06 μg/cc except for immediately adjacent the canal.

THg in soil expressed by bulk density indicated a relatively consistent pattern on all transects (Figure 8.24). MeHg concentrations were found to be higher on transects in LNWR, WCA2, and WCA3 and lowest in ENP (Figure 8.25). Highest concentrations tended to occur either near the canal (WCA3) or within about 4,000 m (13,123 feet) of the canal, LNWR and

WCA2, but MeHg concentrations were highly variable. In general, BAFs in mosquitofish were highest near the canal and decreased toward the marsh interior (Figure 8.26). BAFs in the ENP initially declined away from the canal and then slowly increased toward the interior.

8.3.4 Marsh Characteristics

8.3.4.1 Marsh Water Quality by Subarea

Box plots were used to analyze the water variables identified by principal components analysis as influencing the distribution and speciation of Hg. These variables were initially analyzed by geographic subarea to identify the existing water quality relationships and possible gradients in the system. The combined marsh data (all four sampling cycles) showed a significant north to south gradient in median TOC concentrations from WCA2 to ENP (Figure 8.27). The median concentration in LNWR was 22.6 mg/L. TOC concentrations usually increase during the dry season; however, because the April 1995 dry season was exceptionally wet, only the May 1996 dry sample was significantly higher ($P<0.05$) than either wet season sample. Significantly higher TSO_4 concentrations ($P<0.05$) occurred in WCA2 with a median concentration of 34 mg/L (Figures 8.28 and 29). The median TSO_4 concentrations in WCA3 and ENP were 3.3 mg/L and 2.0 mg/L, respectively. With only a small peripheral area of the LNWR marsh affected by stormwater runoff, the central marsh in LNWR was near the minimum TSO_4 detection limit of 2.0 mg/L.

The concentrations of TP in the marsh system were much lower than those found in the canal system indicating the canals load the marsh at numerous overflow points. A clear gradient decreasing downstream occurred with TP concentrations in the canal system; the TP concentration gradient in the marsh was much less, ranging from a median TP concentration of 17.8 μg/L in WCA2 to 14.8 μg/L in WCA3 and 10 μg/L in ENP. Dry season concentrations were approximately twice the wet season concentrations. The high TP concentrations indicated in Figures 8.30 and 8.31 occurred in random samples near overflowing canals where canal water high in TP directly influenced the marsh.

TN was sampled in the marsh water only during the wet and dry seasons in 1996. A TN gradient was apparent from WCA2 through ENP (Figure 8.32). A similar gradient was present in both seasons; however, concentrations were higher during the dry season.

There were no apparent trends by marsh subarea for THg concentrations in water (Figures 8.33 and 8.34). LNWR exhibited the highest median THg concentration of 3.4 ng/L. The wet season concentrations were somewhat higher than the dry season, which may be due to increased wet deposition. When distribution of MeHg in marsh water by subarea was examined, MeHg in marsh water was slightly higher in LNWR than the other subareas (Figures 8.35 and 8.36). There was no significant difference ($P<0.05$) in MeHg in water concentrations downstream through WCA3. A significant ($P<0.05$) decline in MeHg concentrations occurred in the ENP and BCNP. The variance in MeHg concentrations was greater in the dry season than in the wet season.

THgF concentrations in wholebody mosquitofish were significantly higher in WCA3 with a median of 185 μg/kg and ENP with a median of 176 μg/kg than the subareas to the north (Figure 8.37), which all had medians less than 115 μg/kg. This was apparent during both wet and dry seasons. The bioaccumulation factor (BAF) was consistently low in LNWR, WCA2, and ROT-EAA at less than 180,000 (Figure 8.38). The median BAF increased to 354,000 in WCA3 and continued to increase in ENP to 729,000, which was similar to the BAF in BCNP. The increased BAF downstream in WCA3, ENP, and BCNP was significantly higher ($P<0.05$) than LNWR, WCA2, and ROT-EAA.

Box plots of the combined THg in floating periphyton by subarea indicate that the highest concentrations occurred in LNWR, WCA2, and WCA3, with significant declines in ENP and BCNP (Figures 8.39 and 8.40). Seasonally the wet season periphyton samples showed consistently higher concentrations across all subareas with an apparent decline from northern to southern subareas. MeHg in floating periphyton was highest in LNWR with a linear decline downstream through all areas (Figure 8.41). The consistency in this MeHg gradient in periphyton indicates methylation occurs throughout the system, with higher concentrations occurring in the north. The incidence of floating periphyton was most consistent in WCA3 and ENP.

THg in soil periphyton did not show a consistent pattern in the data (Figure 8.42). MeHg in soil periphyton indicated the highest concentrations occurred in LNWR declining to ENP (Figure 8.43); however, the incidence of soil periphyton, which formed a distinct layer on the surface of the soil which could be excised from the top of the soil core, was most prevalent in WCA3 and ENP. The high concentrations of MeHg in periphyton in LNWR indicate that methylation is also very active in this subarea.

The median soil THg expressed by bulk density was significantly lower in LNWR than found over the remainder of the study area (Figure 8.44) with increasing concentrations from WCA2 to WCA3 and ENP. The soil MeHg expressed by bulk density was significantly higher ($P<0.05$) in LNWR than in WCA2, a pattern opposite that for soil THg (Figure 8.45). Soil MeHg concentrations also were higher in WCA3, ENP, and BCNP during both the wet and dry seasons.

8.3.4.2 Marsh Water Quality by Latitude

Scatter plots of combined marsh data for all four cycles are presented by latitude in Figure 8.46. These plots show the gradients in TOC and TSO_4 declining from north to south. Although there is a smaller TP gradient in the marsh than canals there are high values in the northern part of the system, which occurred in overflow areas near canals that carried water high in TP. There was also an apparent decline in TP concentrations about midway through ENP, which may indicate the southern extent of canal water influence on the marsh. MeHg concentrations in water were high in LNWR and WCA3 and low in ENP. THg concentrations in mosquitofish were highest in WCA3 extending into northern ENP. Latitudinal analysis of these data using Alligator Alley and Tamiami Trail as demarcation points was made to achieve a comparison with the canal data.

An ANOVA was conducted on three latitudinal subsets of the data (north of Alligator Alley, between Alligator Alley and Tamiami Trail, and south of Tamiami Trail) with all cycles combined (Table 8.4). Analysis of the data in these latitudinal subregions showed significant differences ($P<0.05$) in the geometric means for TOC, which declined from north to south through the system. A significant difference in the data was found for TSO_4 between the northern two sectors. Data from the southern sites were typically near the MDLs of 2 and 0.5 mg/L. TP in

water showed a significant decline from north of Alligator Alley to the area between Alligator Alley and Tamiami Trail. MeHg in water declined significantly from north to south. The concentration of THgF in wholebody mosquitofish was significantly lower ($P<0.05$) north of Alligator Alley and increased to comparable concentrations in the two southern subareas.

Table 8.4 Comparison of geometric means of marsh constituents by latitude. Sample size is in parenthesis. (< or > is statistically significant, $P < 0.05$)

Constituent	Latitude		
	North of Alligator Alley	Alligator Alley - Tamiami Trail	South of Tamiami Trail
TOC (mg/L)	27 (146)	> 19 (157)	> 16 (138)
TSO_4 (mg/L)	7 (146)	> 3 (157)	= 2 (138)
TP (μg/L)	18 (146)	> 12 (157)	= 10 (138)
MeHg (ng/L)	0.5 (145)	> 0.4 (156)	> 0.2 (138)
THgF (μg/kg)	88 (129)	< 1550 (145)	= 151 (120)
THg (ng/L)	2.3 (146)	> 1.8 (157)	= 1.8 (137)

An ANOVA also was conducted on the three latitudinal subareas by season (Table 8.5). There were significant declining gradients of TOC during the wet and dry seasons from north of Alligator Alley to between Alligator Alley and Tamiami Trail. The TSO_4 gradient was the same for both seasons with a significant decline from north of Alligator Alley to between Alligator Alley and Tamiami Trail with higher dry season concentrations. A complete assessment of this parameter was limited by high detection levels. TP concentrations in water showed a gradient from north of Alligator Alley to south of Tamiami Trail for the wet and dry seasons, respectively. The TP concentrations were nearly twice as high during the dry season. MeHg in water showed a significant decline downstream in all three areas during the wet season and a significant decline between the southern two areas (i.e., Alligator Alley - Tamiami Trail to south of Tamiami Trail) in the dry season. The concentrations in the dry season were approximately twice as high as those of the wet season. The THgF concentrations in wholebody mosquitofish were consistently lower north of Alligator Alley during both seasons. The THgF concentrations in mosquitofish were higher in the dry season south of Alligator Alley.

Table 8.5 Comparison of marsh geometric mean constituents by latitude and season. Sample size in parenthesis. (> or < is statistically significant, P<0.05)

Constituent	Latitude		
	North of Alligator Alley	Alligator Alley - Tamiami Trail	South of Tamiami Trail
TOC (mg/L)			
Wet	7 (84)	> 3 (81)	= 2 (77)
Dry	8 (62)	> 3 (76)	= 2 (61)
TSO_4 (mg/L)			
Wet	15 (84)	> 8 (81)	= 8 (77)
Dry	25 (62)	> 20 (76)	= 16 (61)
TP (μg/L)			
Wet	24 (84)	> 15 (81)	> 12 (77)
Dry	32 (62)	> 25 (76)	> 23 (61)
MeHg (ng/L)			
Wet	0.4 (84)	> 0.2 (81)	> 0.1 (77)
Dry	0.7 (61)	= 0.6 (75)	> 0.4 (61)
THgF (μg/kg)			
Wet	94* (76)	< 124 (77)	= 130 (73)
Dry	81* (53)	< 199 (68)	= 195 (47)
THg (ng/L)			
Wet	2.6* (84)	> 2.0 (81)	= 1.7 (77)
Dry	2.0 (62)	= 1.7 (76)	= 1 .9 (60)

8.3.4.3 Marsh Spatial Analysis

A spatial analysis of the TOC data by cycle is shown in Figure 8.47. The maps of the wet season show high TOC water concentrations primarily occur in WCA2 and northern WCA3 and flow across the marsh in a downstream direction. The highest water conditions and flow rates occurred during the September 1995 sample event, which showed a clear gradient in TOC flowing across the marsh system. Water concentrations of TOC decrease downstream across the system. The April 1995 and May 1996 dry seasons and the September 1996 wet season indicate

areas of higher TOC concentrations in ENP Shark Slough flowway, which may result from water brought in via the canal system. The dry season in May 1996 was the driest sample period in the study, and it is evident that with the reduced water volume and decreased flow across the marsh the TOC concentrations generally increased throughout the system.

Maps of water TSO_4 concentrations in the system (Figure 8.48) show gradients similar to those observed with TOC. The concentrations are consistently highest in WCA2 due to the overflow of canal water, which generally spreads downstream across northeastern WCA3. The reduction of TSO_4 appears to occur rapidly across the system. There is also an indication of transport of water with higher TSO_4 concentrations to the northern ENP via L67 extension. Future monitoring by USGS should further resolve the TSO_4 gradient with an MDL below 0.5 mg/L.

Spatial maps of TP (Figure 8.49) in marsh system water are leveraged by the relatively few high concentrations which were found in random samples taken near canals where high TP water was flowing into the marsh. The transport of high TP concentrations downstream via the canal system to ENP is also evident. TP concentrations in excess of 50 μg/L affect an area of less than 5% of the marsh that occurs, primarily near canals. A very well defined gradient in TP can be seen in the wet season September 1996 sample showing most of the marsh at less than 10 μg/L with concentrations between 10 and 50 μg/L limited to the extreme northern WCA3, WCA2, and the perimeter of LNWR. During the dry season in May 1996, higher TP concentrations appear to occur in the zone between the dry and wet areas where the shallowest water occurs.

Spatial analysis of MeHg in water (Figure 8.50) shows an area in excess of 0.5 ng/L in northern WCA3 during the high flow wet season in September 1995. A similar area was found below Alligator Alley in WCA3 during the dry season in April 1995. Similar concentrations were apparent below Alligator Alley in 1996. High MeHg concentrations occurred in LNWR and WCA2; but there was no consistent pattern.

A spatial map of the combined MeHg concentrations in floating periphyton for all four cycles (Figure 8.51) shows high concentrations in WCA3 south of Alligator Alley. Floating periphyton, however, were not consistently found across the entire marsh system as indicated by the sample points where it occurred. The most consistent distribution of floating periphyton was

south of Alligator Alley extending into the area of Shark Slough. While soil periphyton had even a more discontinuous coverage; the combined data indicates a periphyton Hg hot spot in WCA3 south of Alligator Alley (Figure 8.52). MeHg in soil, however, (Figure 8.53) did not show a distribution similar to the periphyton. Soil MeHg concentrations were higher across the northern extreme of WCA3 and in LNWR. A homogenate of the top 10 cm of soil did not indicate a hot spot in soil MeHg south of Alligator Alley.

Spatial maps of the THgF concentrations in wholebody mosquitofish (Figure 8.54) showed a consistent hot spot in WCA3 south of Alligator Alley during each synoptic sample. This THgF in mosquitofish hot spot tended to continue to the south into ENP reaching approximately halfway down Shark River Slough. Areas with THgF concentrations in mosquitofish greater than 200 μg/kg were rare north of Alligator Alley. Due to the consistency of the areas of high THgF in mosquitofish between cycles all the data were combined (Figure 8.55) along with the rookery locations with Hg concentrations from Great Egret chick feathers (Frederick et al. 1997). The highest concentrations in feathers occurred in the THgF hot spot for mosquitofish with lower Hg concentrations in chick feathers at successive rookery locations to the south and east of the hot spot. The similar spatial distribution of MeHg in water, periphyton, and fish, indicates a consistency in the location of enhanced bioaccumulation in the food chain south of Alligator Alley.

8.3.5 Eastern Mosquitofish

A predator protection criteria of 0.1 mg/kg THg for prey species has been proposed by the USFWS (Eisner et al. 1987). The eastern mosquitofish, *Gambusia holbrooki*, wholebody THgF concentrations were presented in the proceeding section. About 15% of the canal miles and almost 70% of the marsh area have mosquitofish with THgF concentrations exceeding the predator protection criteria of 0.1 mg/kg. Because the mosquitofish is a prey species for piscivorous fish and birds and is an excellent indicator of Hg bioaccumulation, additional analyses were conducted on the mosquitofish populations in the canals and marsh. The purpose of these analyses were to determine if differences in population attributes or feeding habits among subareas

or among latitudes might contribute to Hg bioaccumulation. The results are presented in Appendix D.

8.4 Synthesis

Hg loading to the South Florida Everglades ecosystem was dominated by atmospheric deposition, rather than loading from the EAA. Deposition was relatively uniform spatially over South Florida, but there were definite seasonal patterns with the greatest Hg loading occurring during the wet seasons. Even though the spatial deposition of Hg was relatively uniform, there were distinct north to south gradients in Hg in water, periphyton, and mosquitofish and other water quality constituents in both the canal and marsh systems. In contrast to Hurley et al. 1998, the highest MeHg concentrations in water were measured in the north while the highest Hg concentrations in mosquitofish occurred in the central area of the marsh and canal, between Alligator Alley and Tamiami Trail. The hot spot in mosquitofish Hg concentrations also coincided with peak Hg concentrations in periphyton and Great Egret chick feathers. There were complex relationships among water depth and TOC, sulfate and TP concentrations and MeHg concentrations in periphyton, and Hg in mosquitofish. The canals appeared to play a major role in the transport of TP from the canal to the marsh, while the marsh was the primary site for the methylation of Hg and might contribute to the higher fish Hg concentrations in the canals. Numerous preliminary studies related to the processes of mercury cycling in the Everglades ecosystem (Hurley et al. 1998, Krabbenhoft et al. 1998, and Cleckner et al. 1998) have been reported by the USGS ACME effort. Additional process oriented reports are under development from this group, however, a revised conceptual model for the marsh ecosystem is discussed in greater detail in Chapter 10.0, Synthesis and Integration.

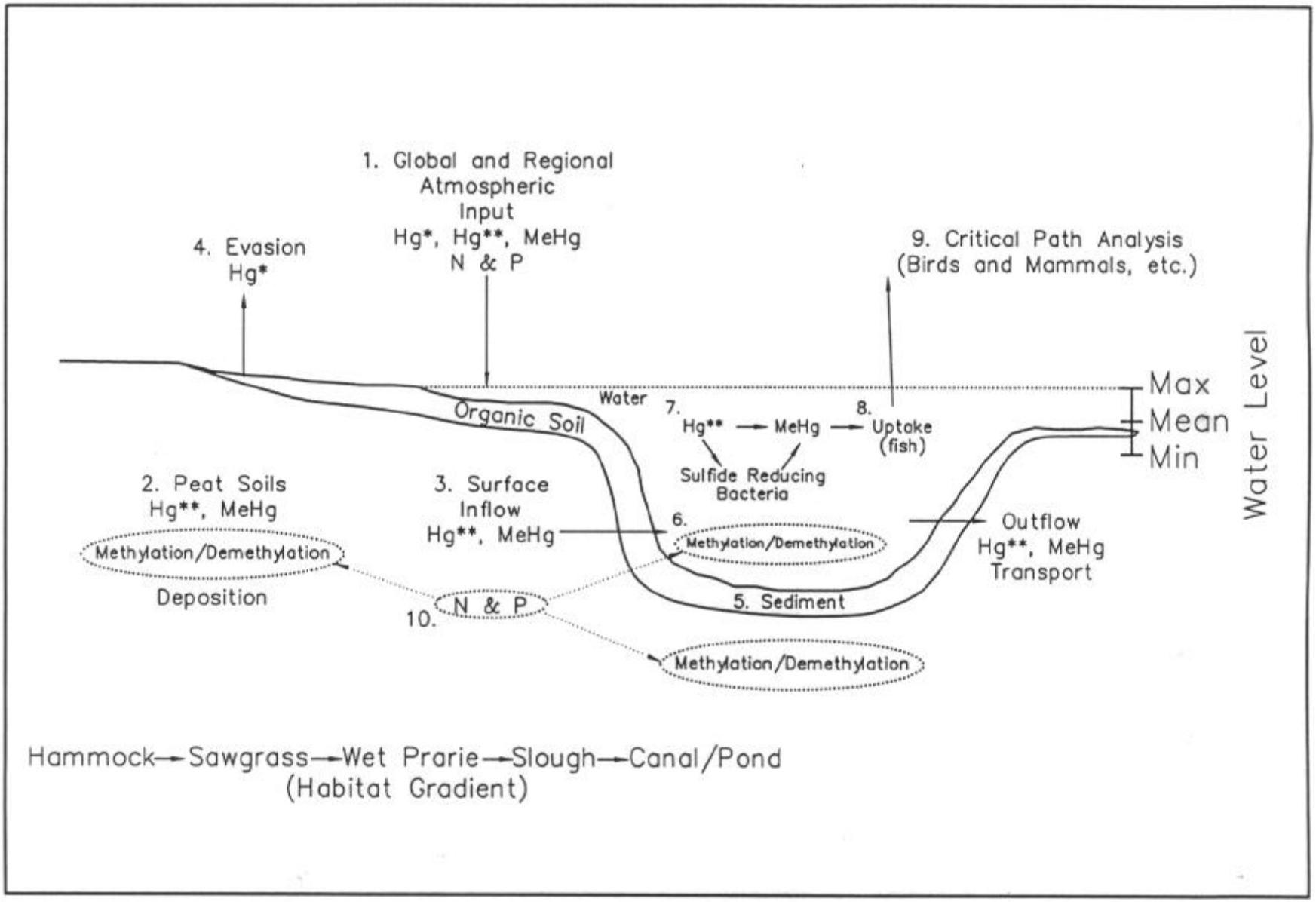

Figure 8.2 Biogeochemical cycling of Hg in the Everglades ecosystem.

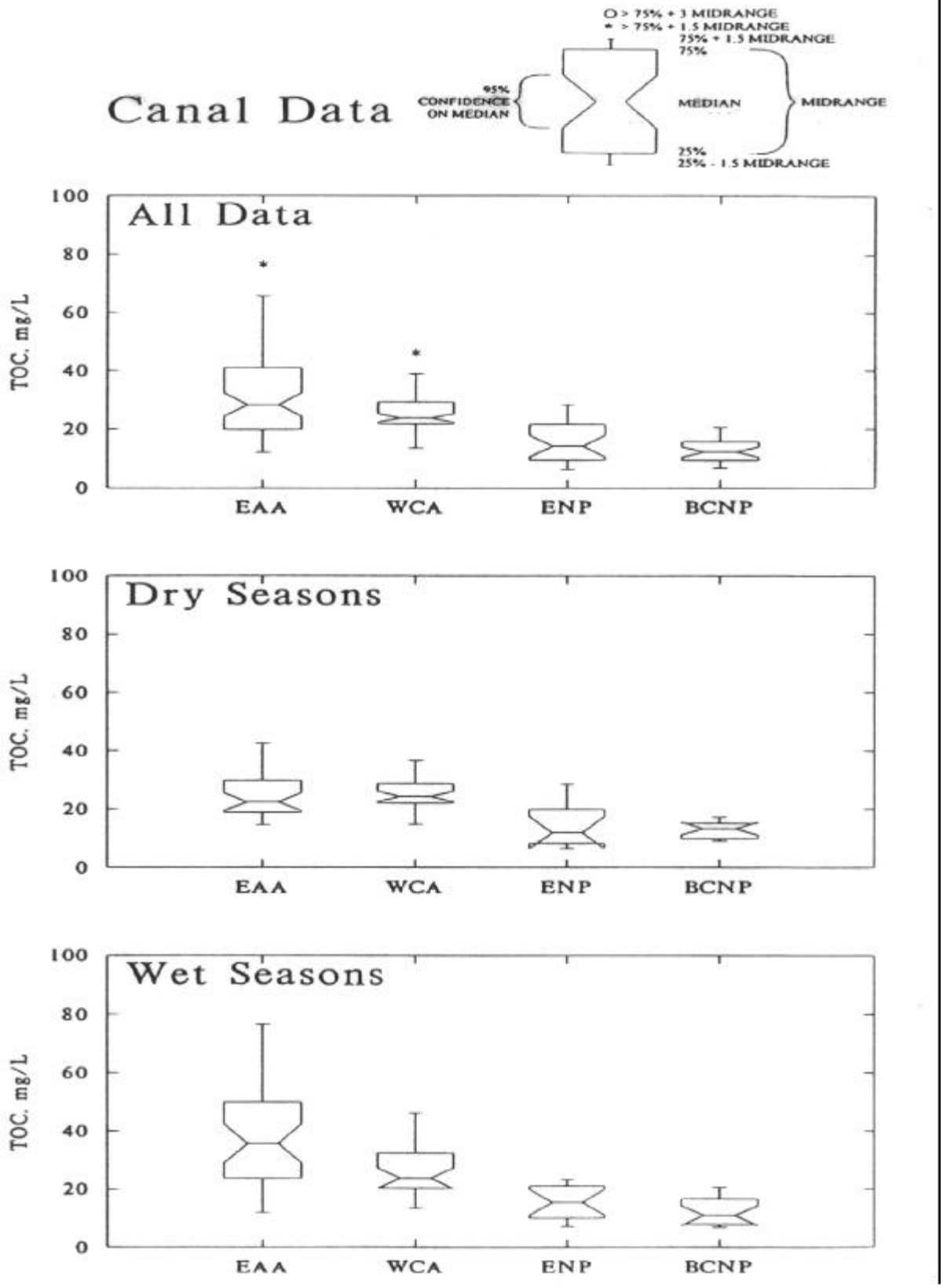

Figure 8.3 Notched box and whisker plots comparing canal TOC in subareas during dry and wet seasons.

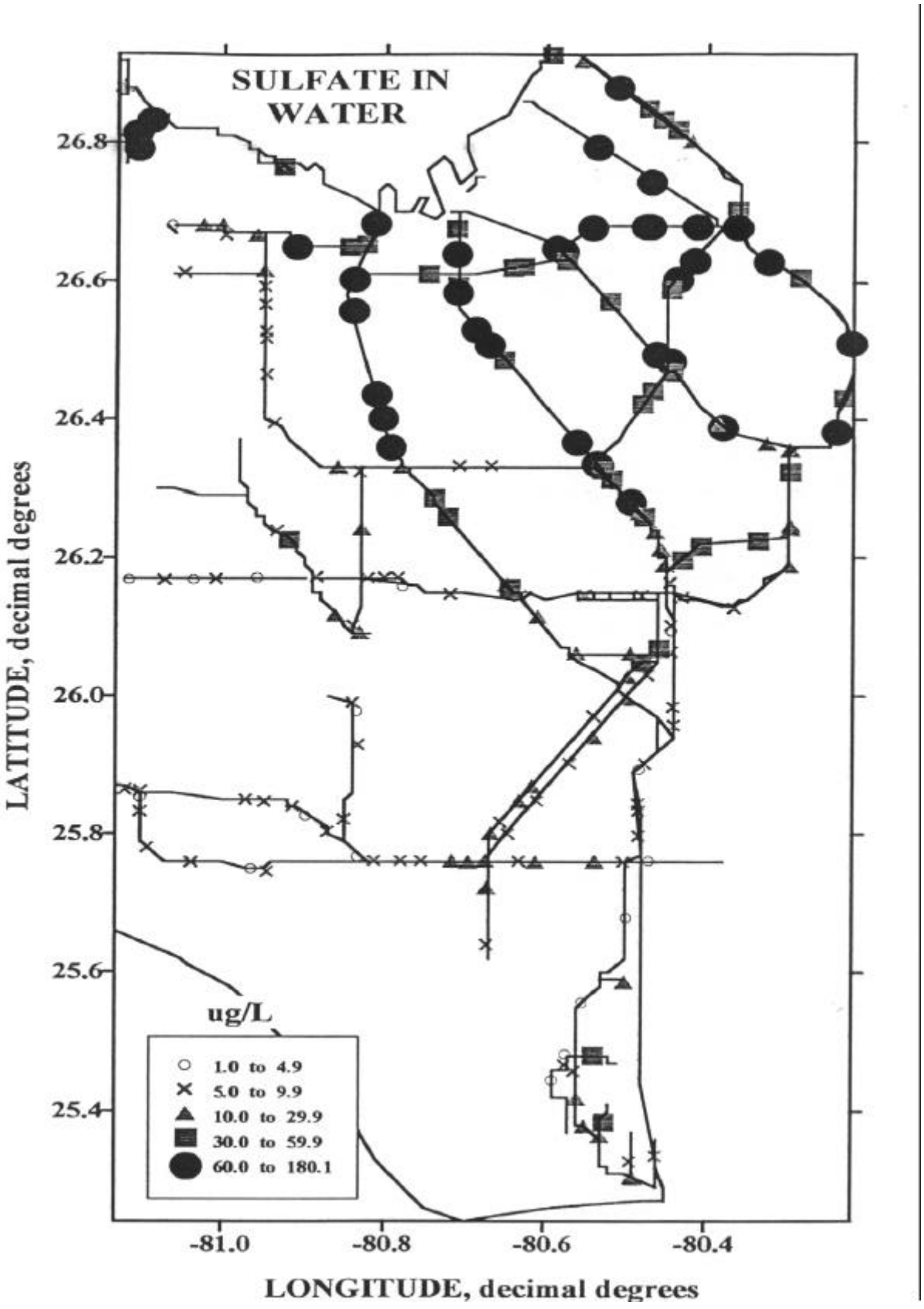

Figure 8.4 TSO_4 concentrations in canals during the study period.

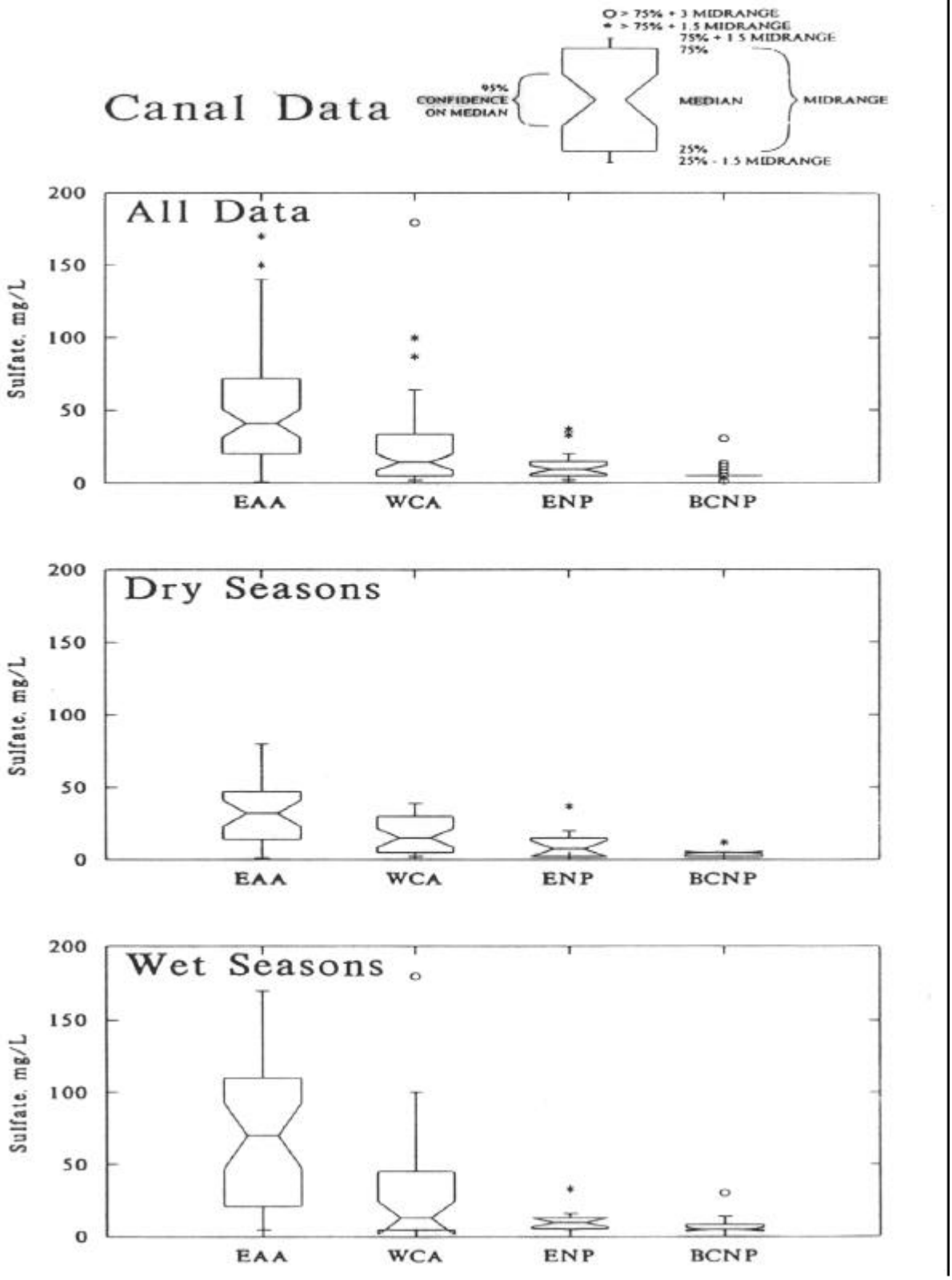

Figure 8.5 Notched box and whisker plots comparing canal TSO_4 in subareas during dry and wet seasons.

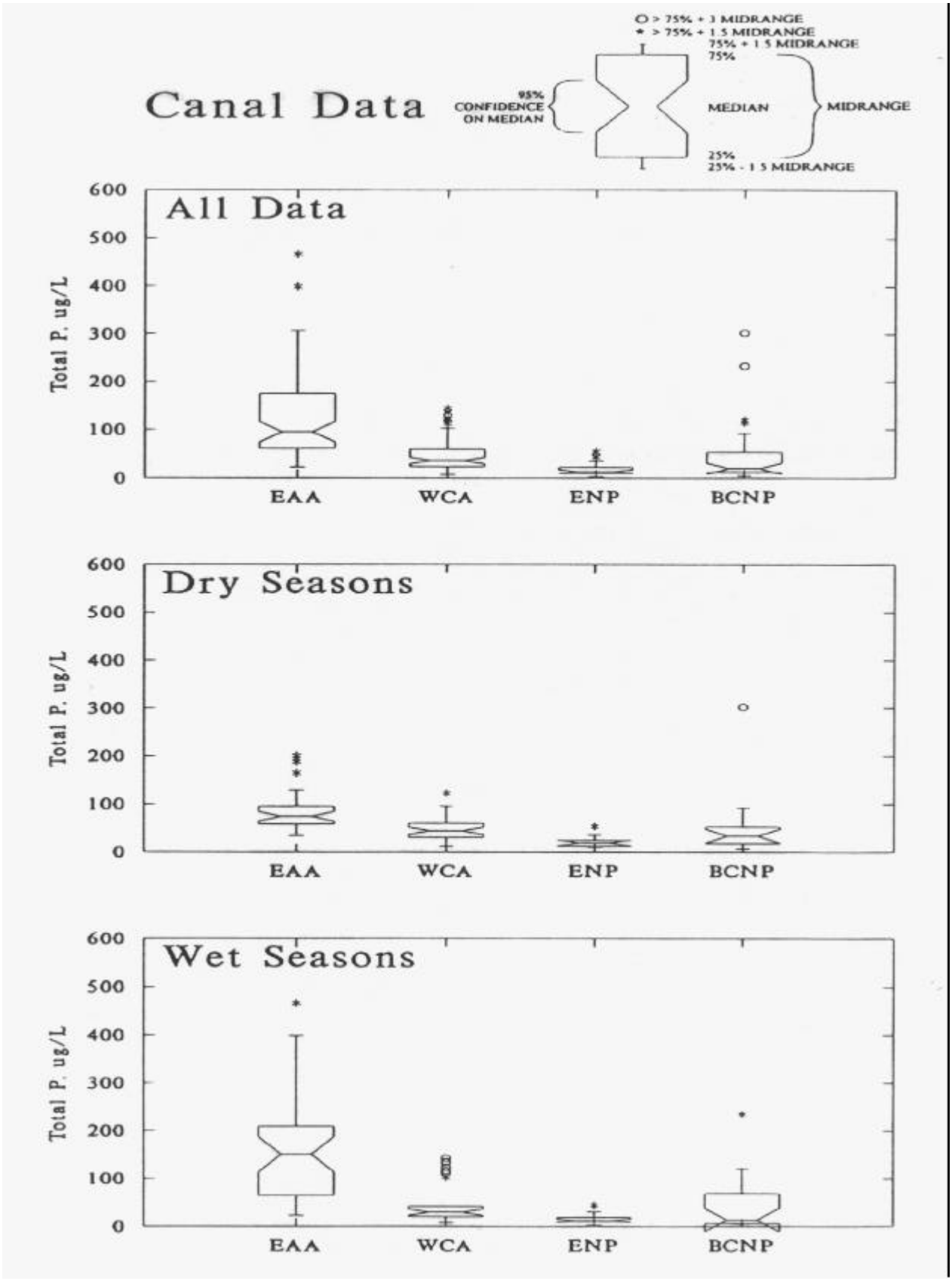

Figure 8.6 Notched box and whisker plots of canal TP in subareas during dry and wet seasons.

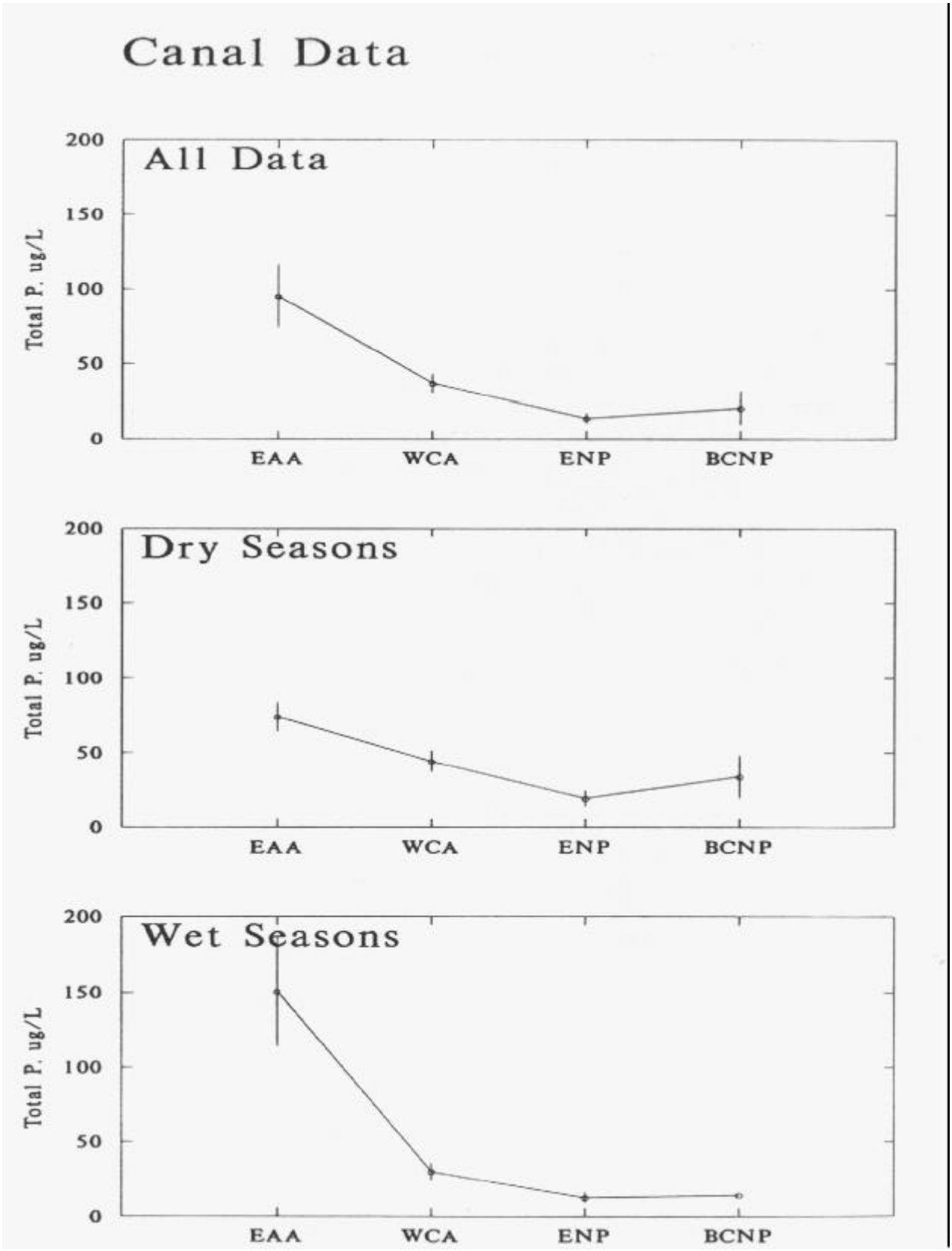

Figure 8.7 Plots of median canal TP for subareas with vertical lines indicating 95% confidence interval of each median.

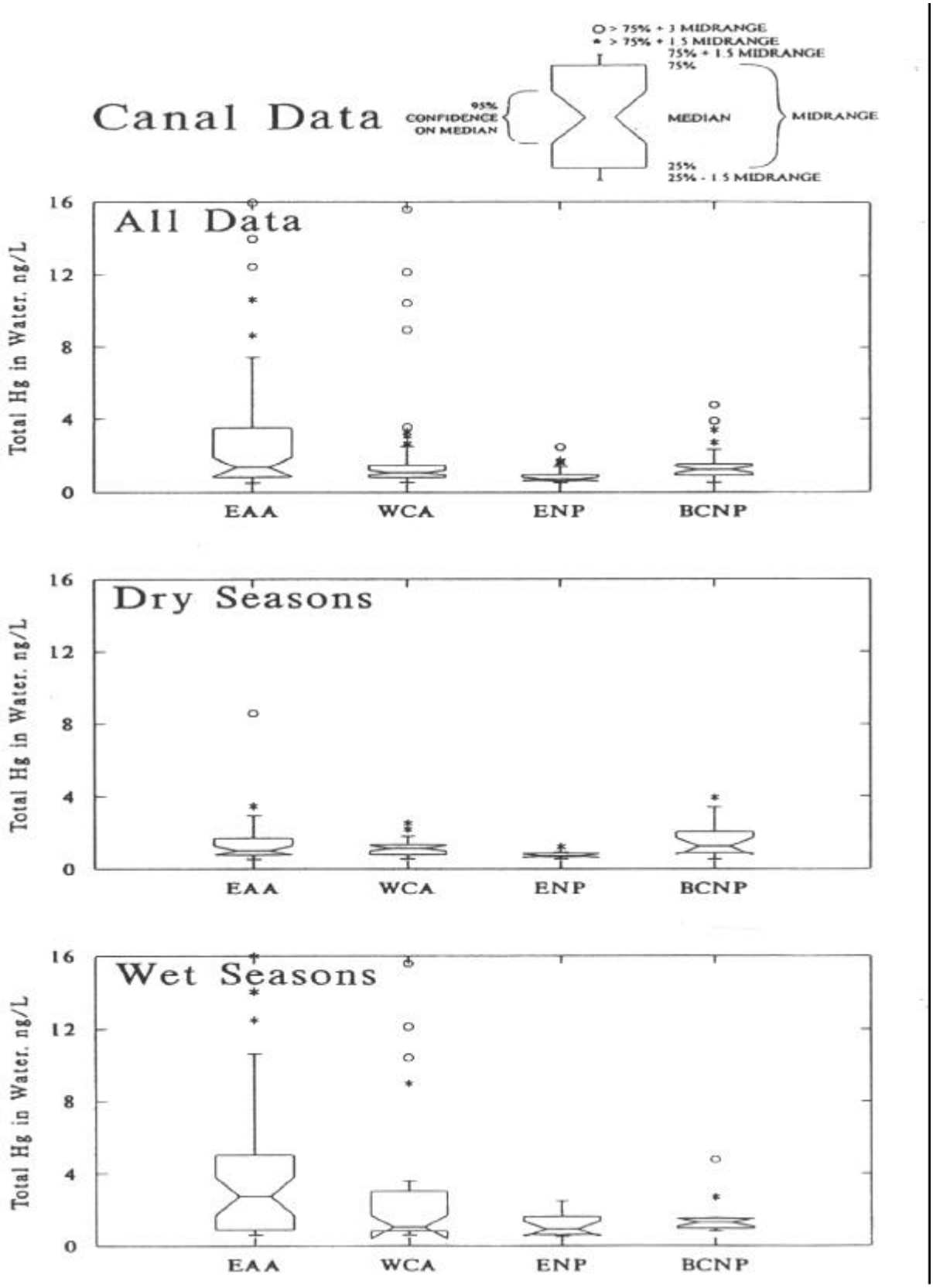

Figure 8.8 Notched box and whisker plots comparing canal THg in water by subareas during dry and wet seasons.

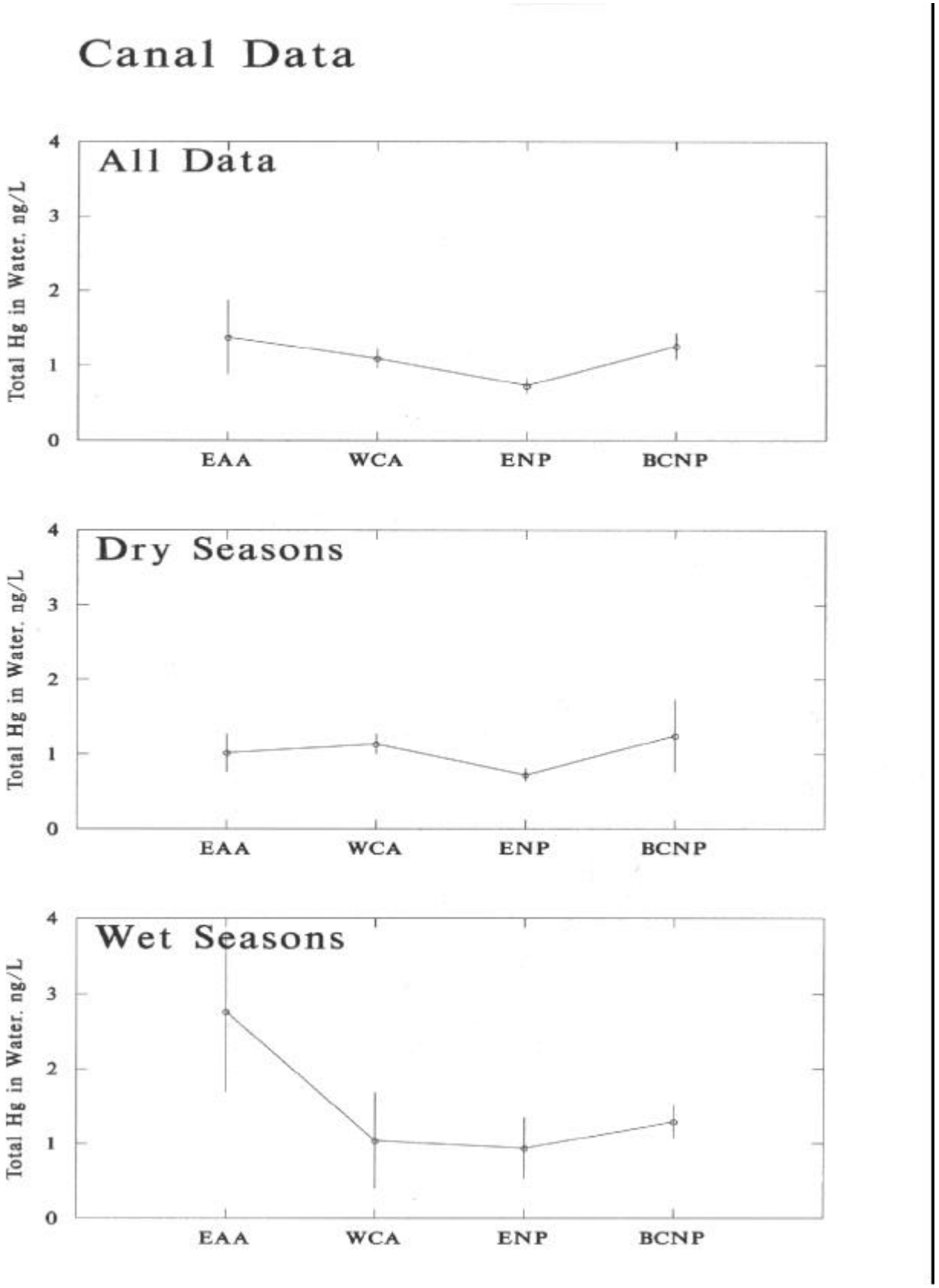

Figure 8.9 Plots of median canal THg in water for subareas with vertical lines indicating the 95% confidence interval for each median.

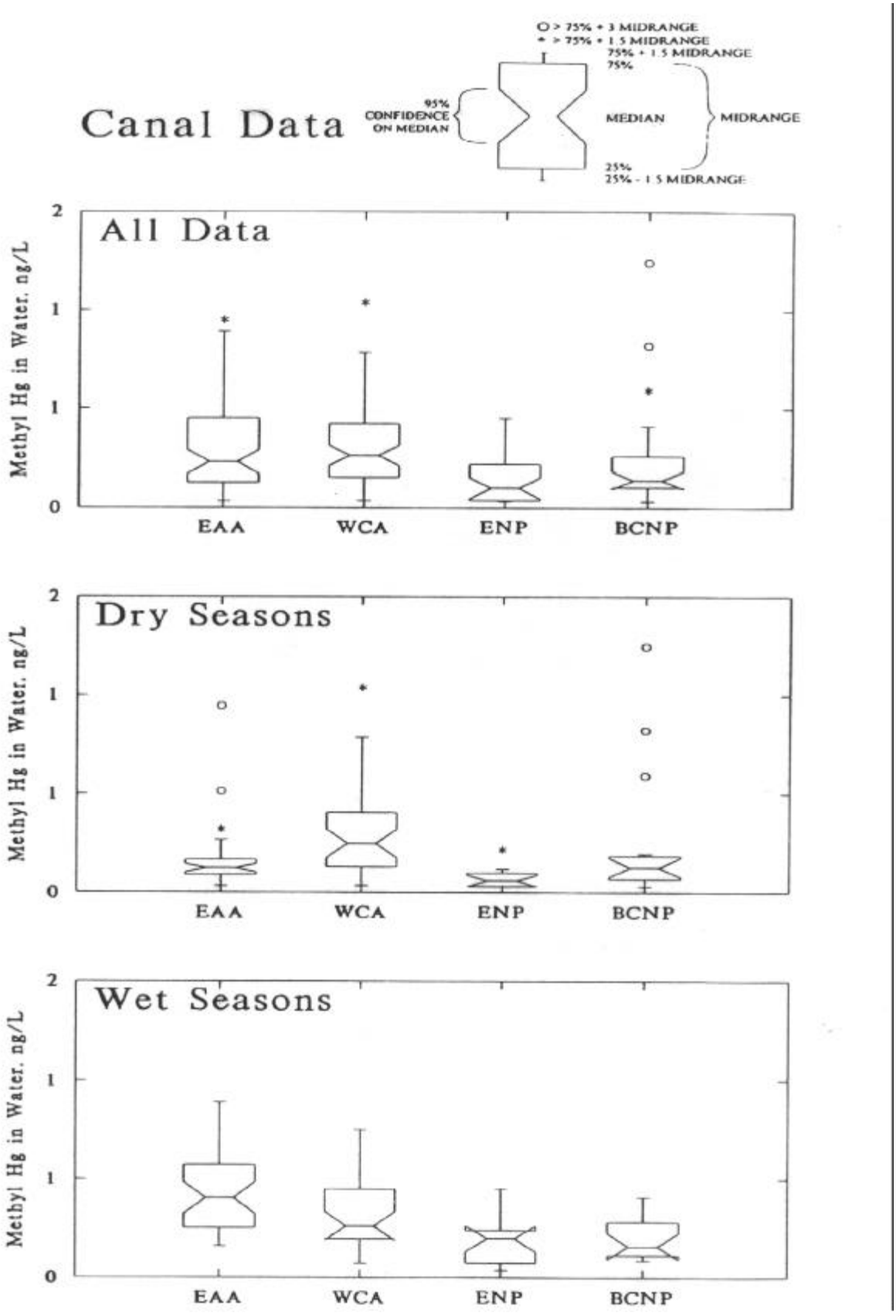

Figure 8.10 Notched box and whisker plots comparing canal MeHg in water for subareas during dry and wet seasons.

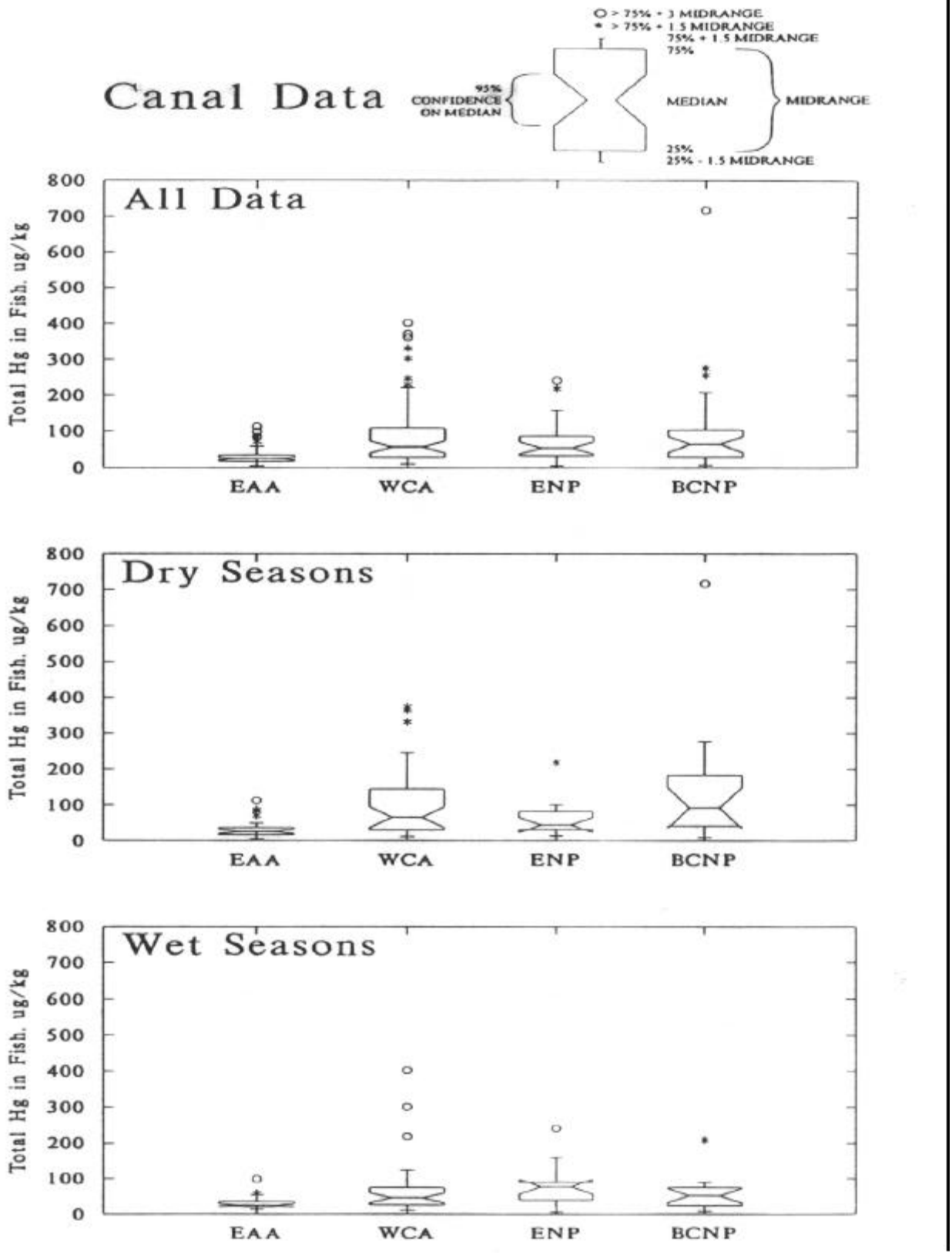

Figure 8.11 Box and whisker plots comparing canal THg in mosquitofish by subareas during dry and wet seasons.

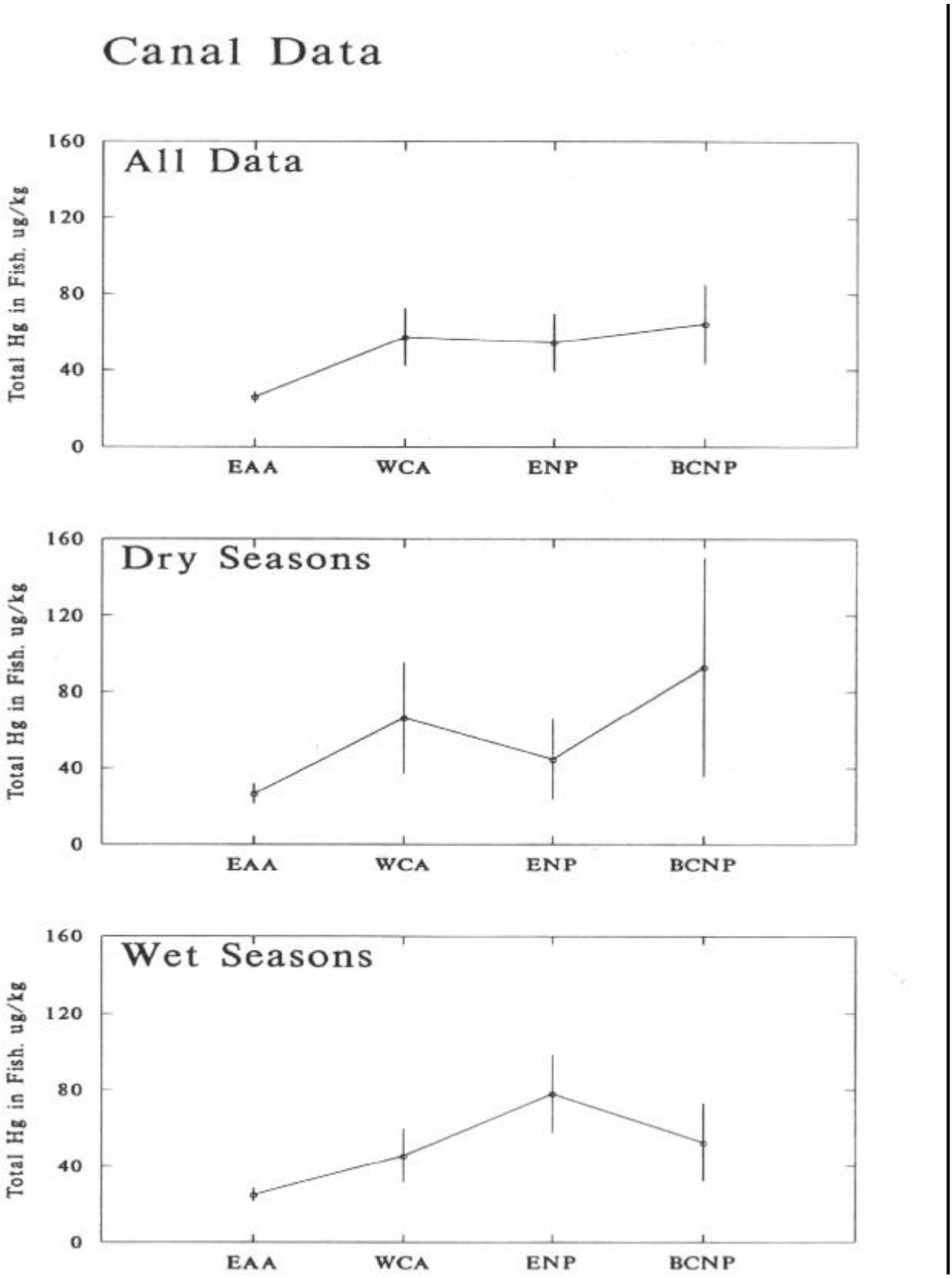

Figure 8.12 Medians of THg in mosquitofish in canals for subareas with vertical lines indicating the 95% confidence interval for each median.

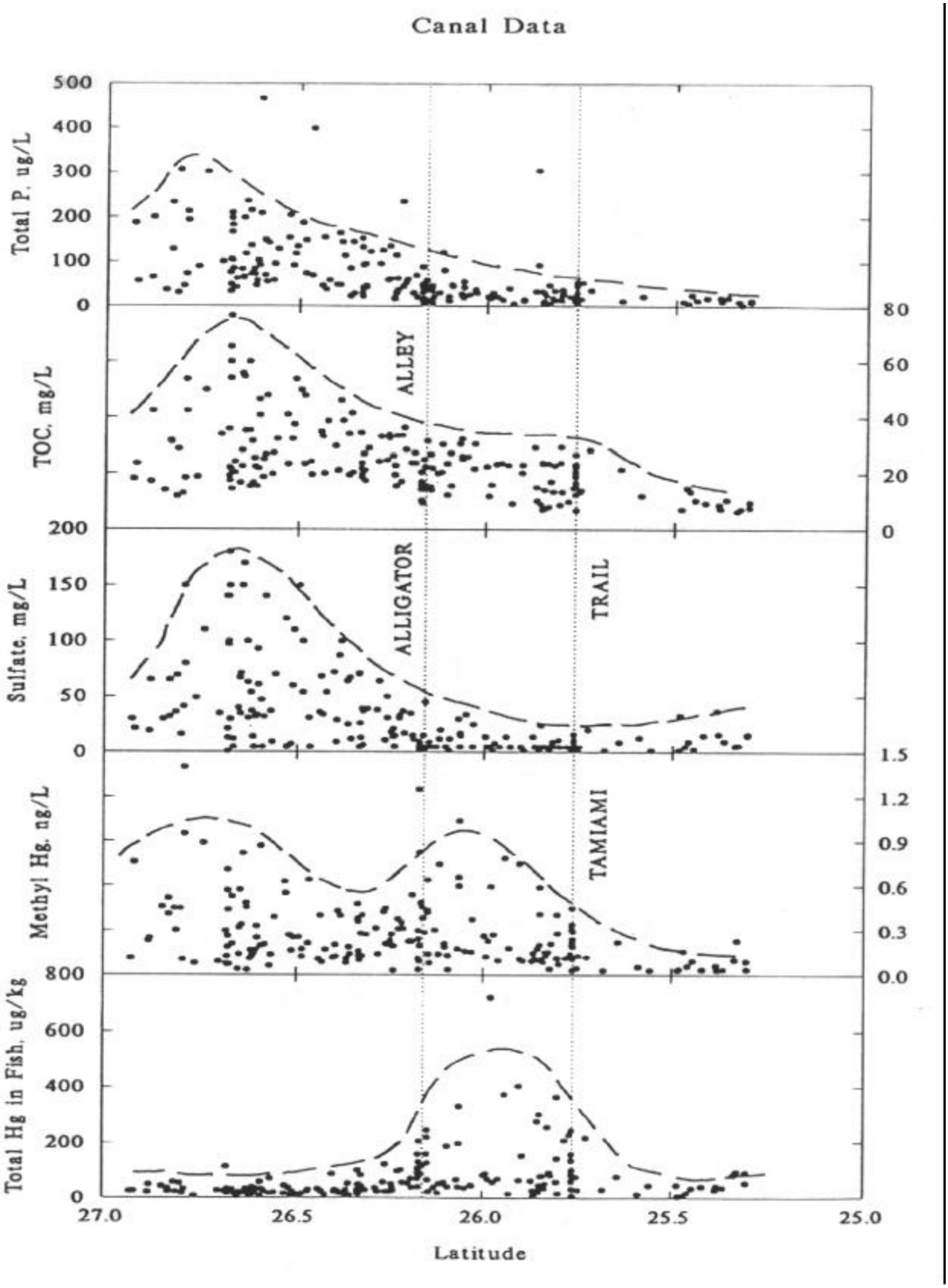

Figure 8.13 Plot of selected constituents showing latitudinal gradients in canals.

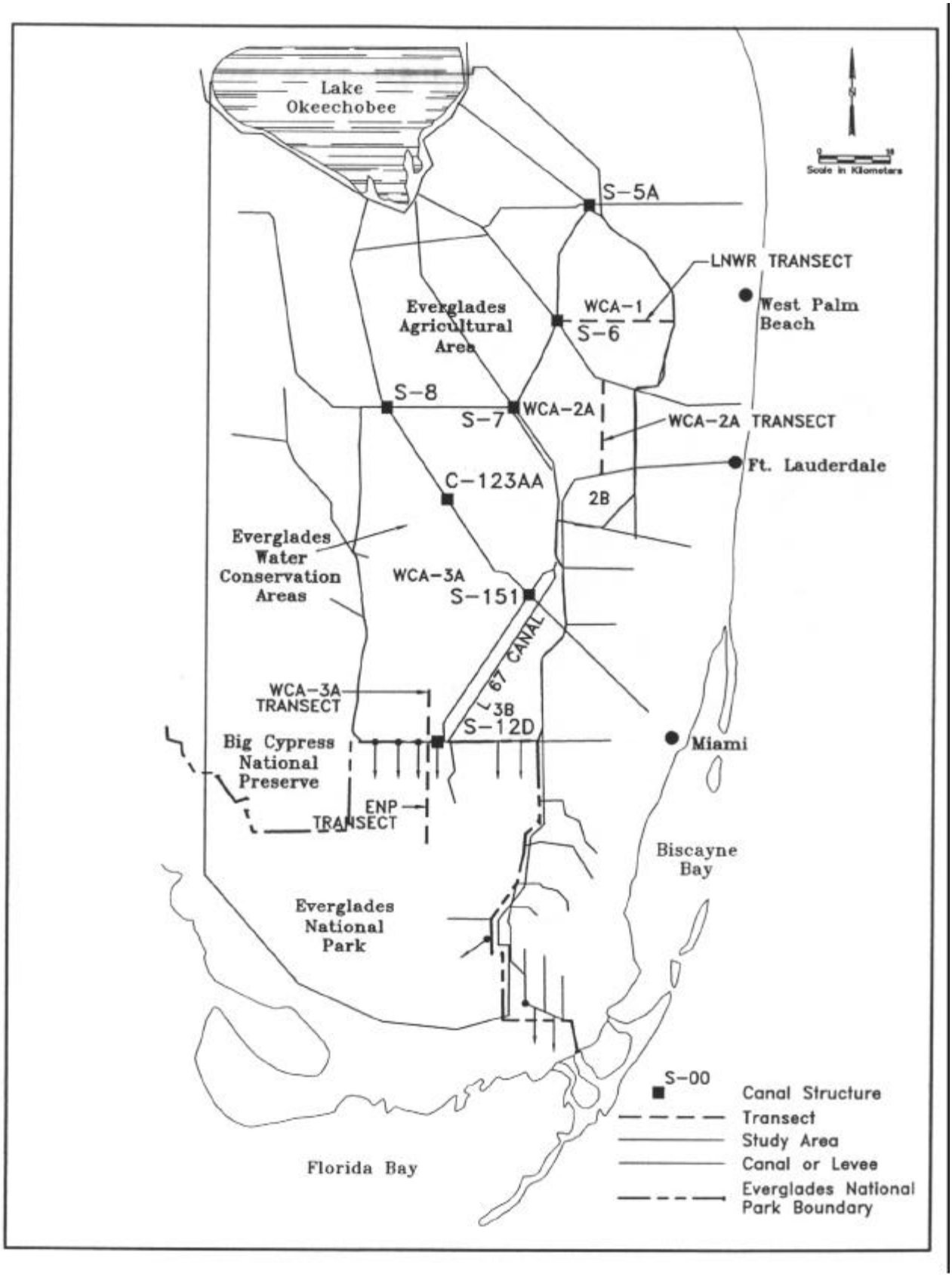

Figure 8.14 Location of four marsh transects sampled in April 1994 and canal water control structures sampled on a biweekly basis from February 1994 through February 1997.

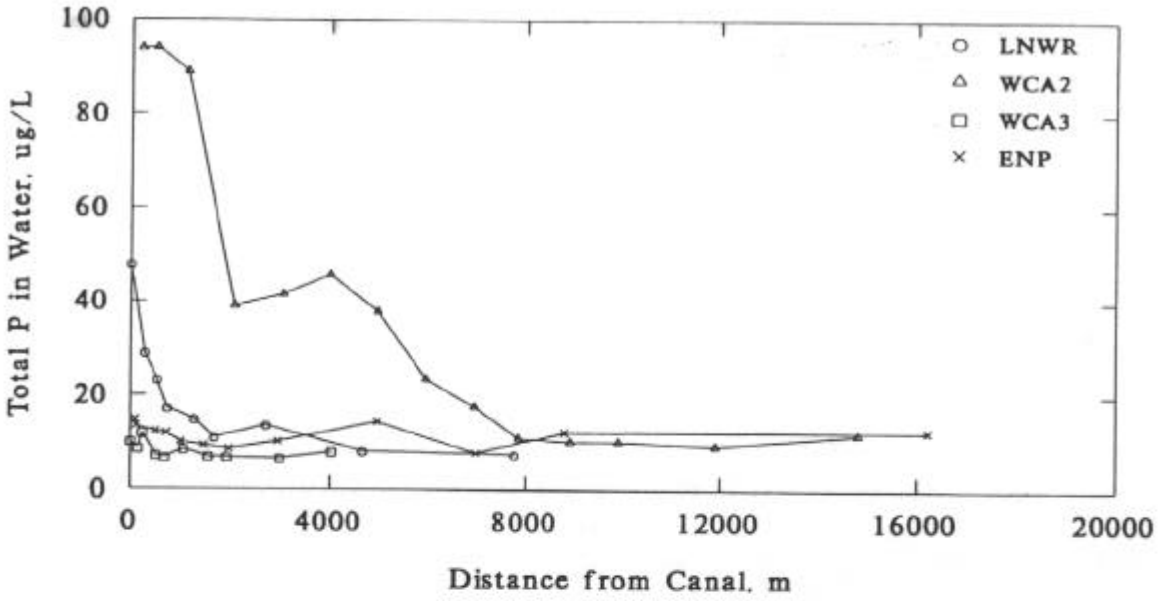

Figure 8.15 Measurements of TP in water along marsh transects.

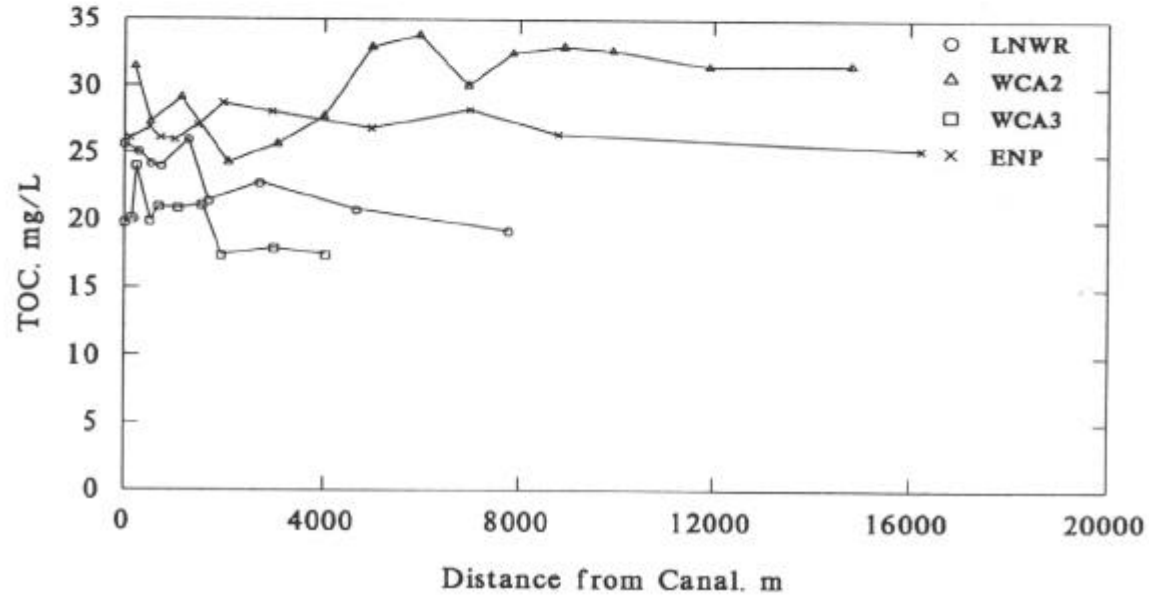

Figure 8.16 TOC concentrations along marsh transects.

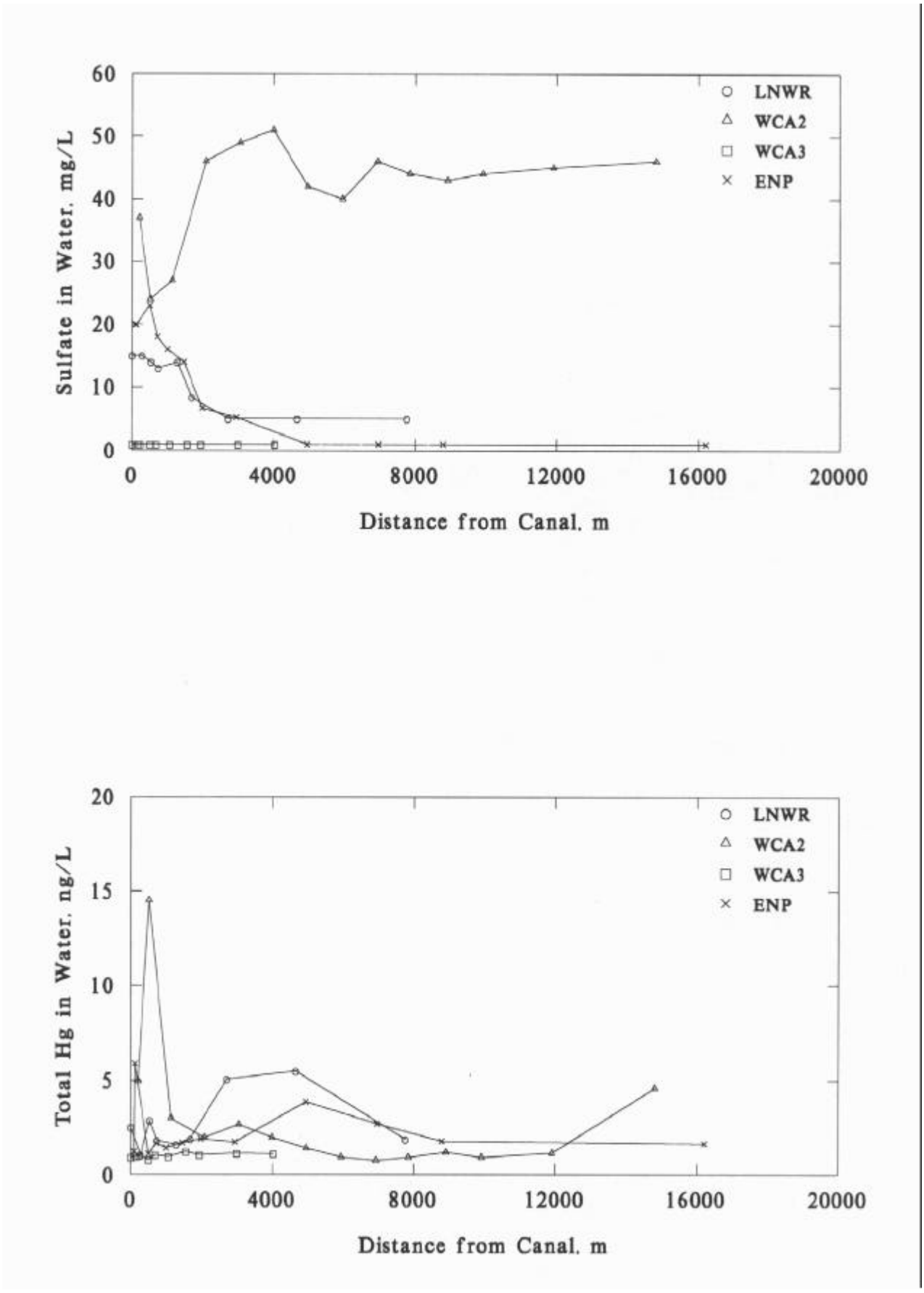

Figure 8.18 Measurements of THg in water along marsh transects.

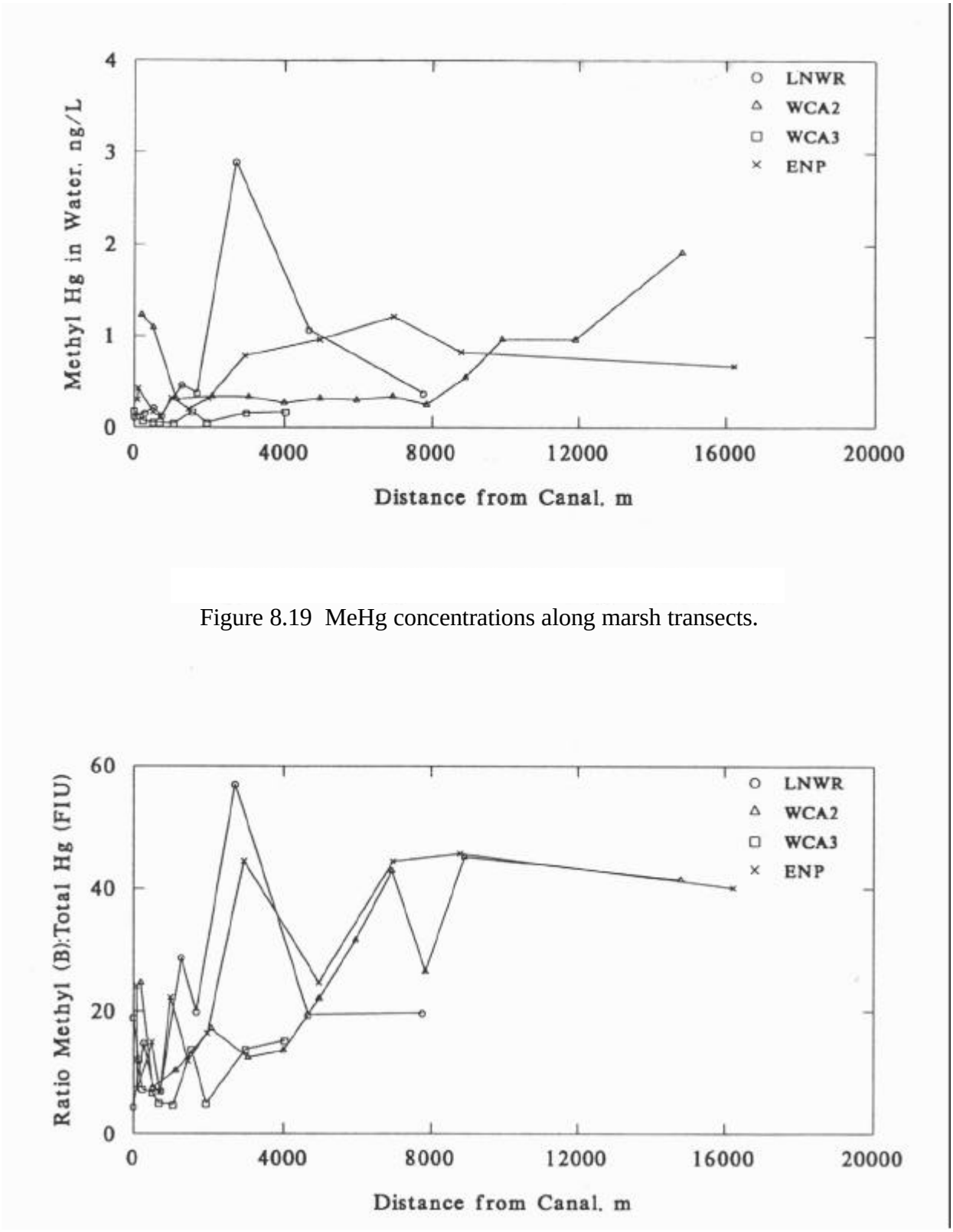

Figure 8.19 MeHg concentrations along marsh transects.

Figure 8.20 Ratio of MeHg to THg in water along marsh transects.

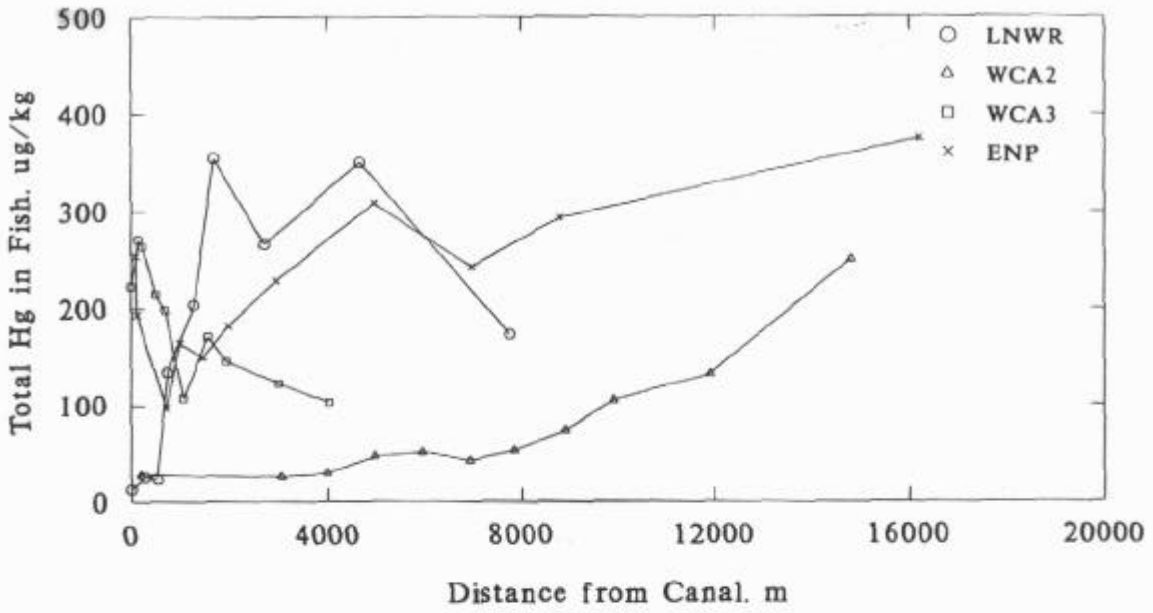

Figure 8.21 THg in mosquitofish collected along marsh transects.

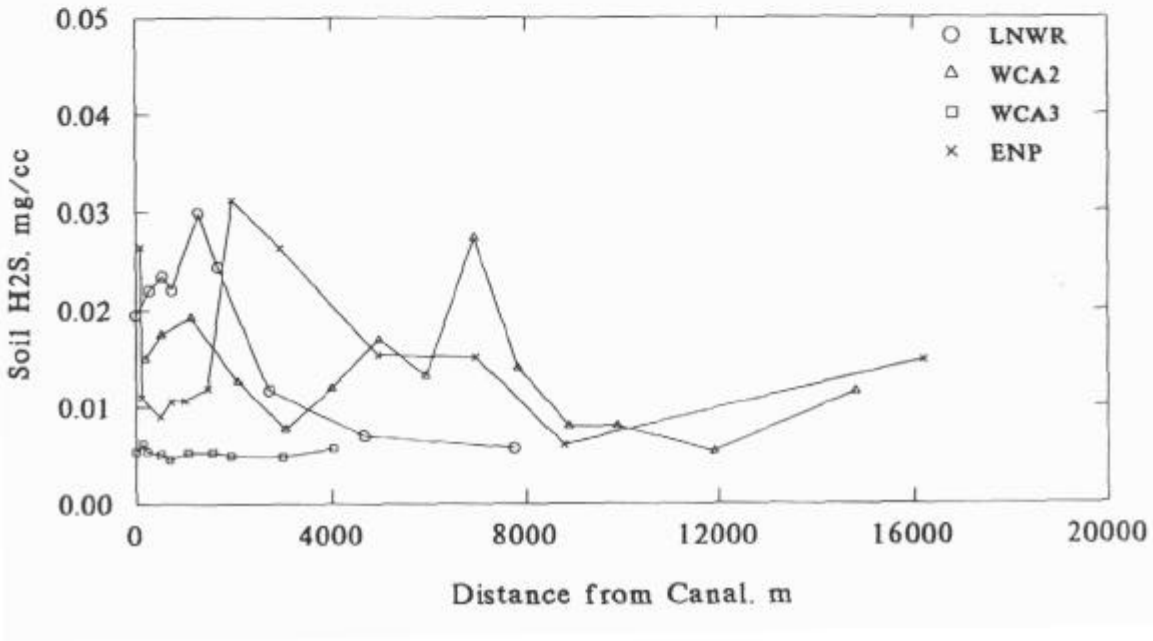

Figure 8.22 Sulfide in soils along marsh transects.

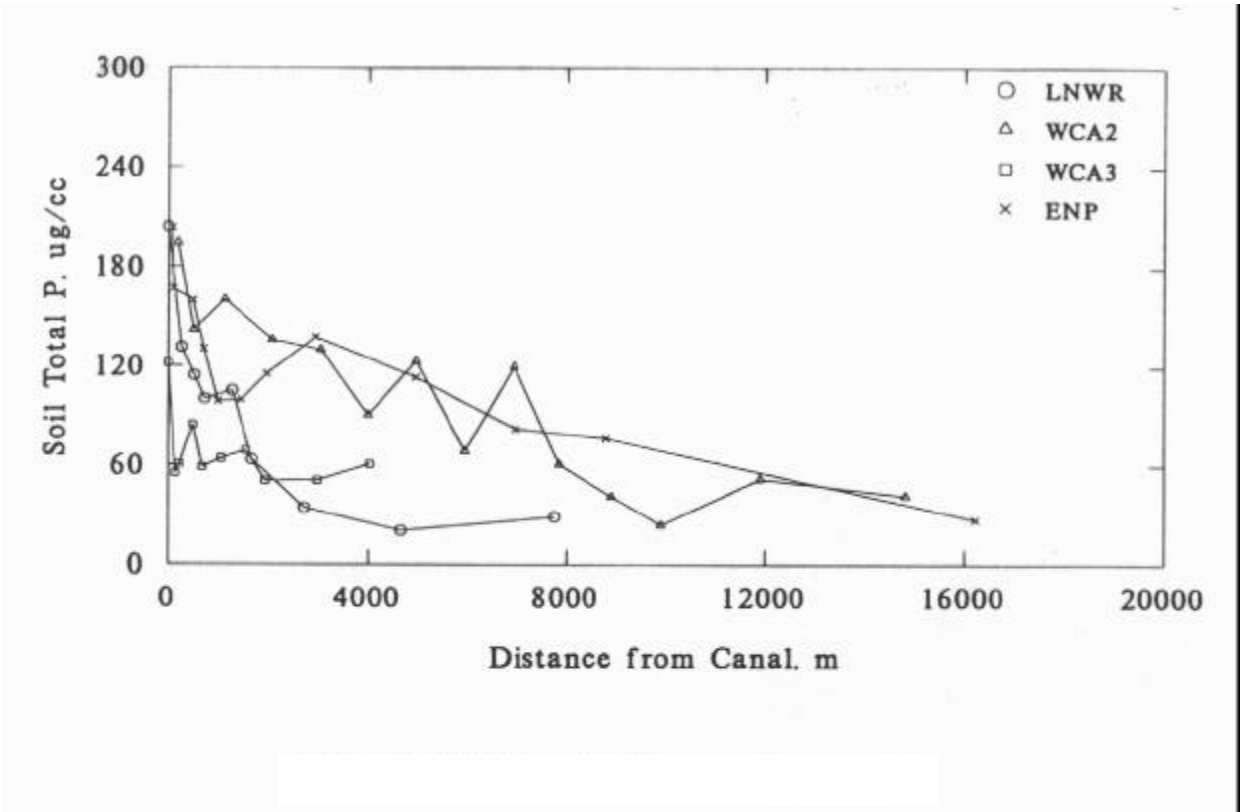

Figure 8.23 TP in soils along marsh transects.

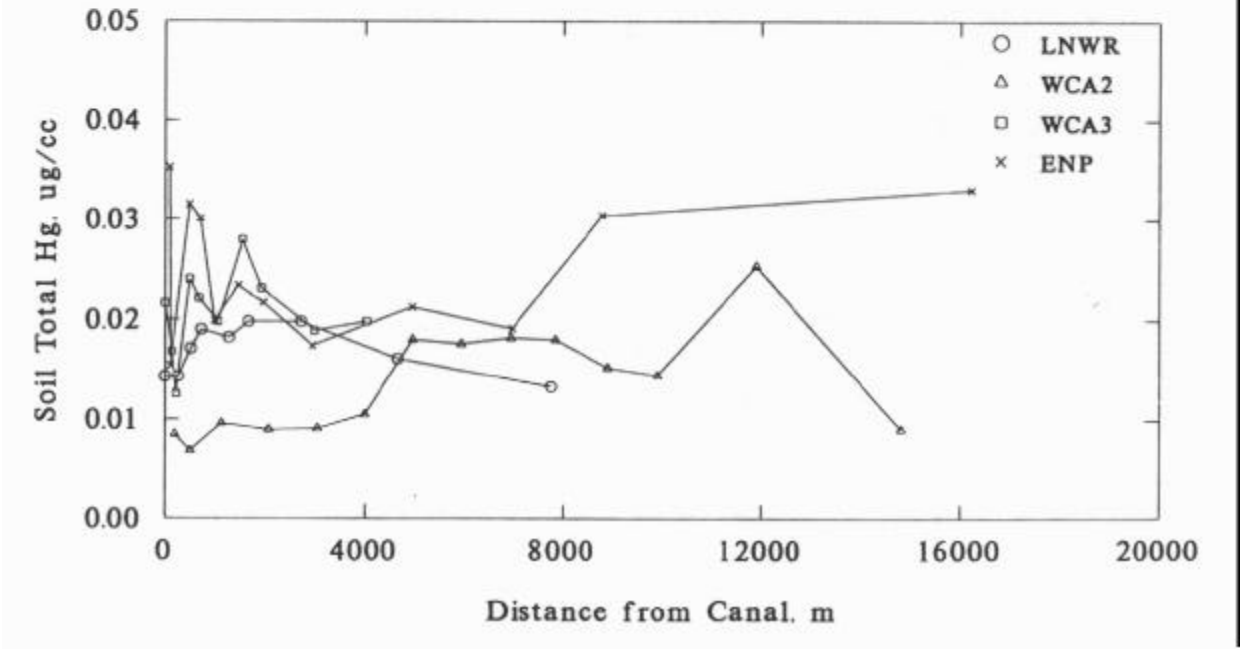

Figure 8.24 THg in soils along marsh transects.

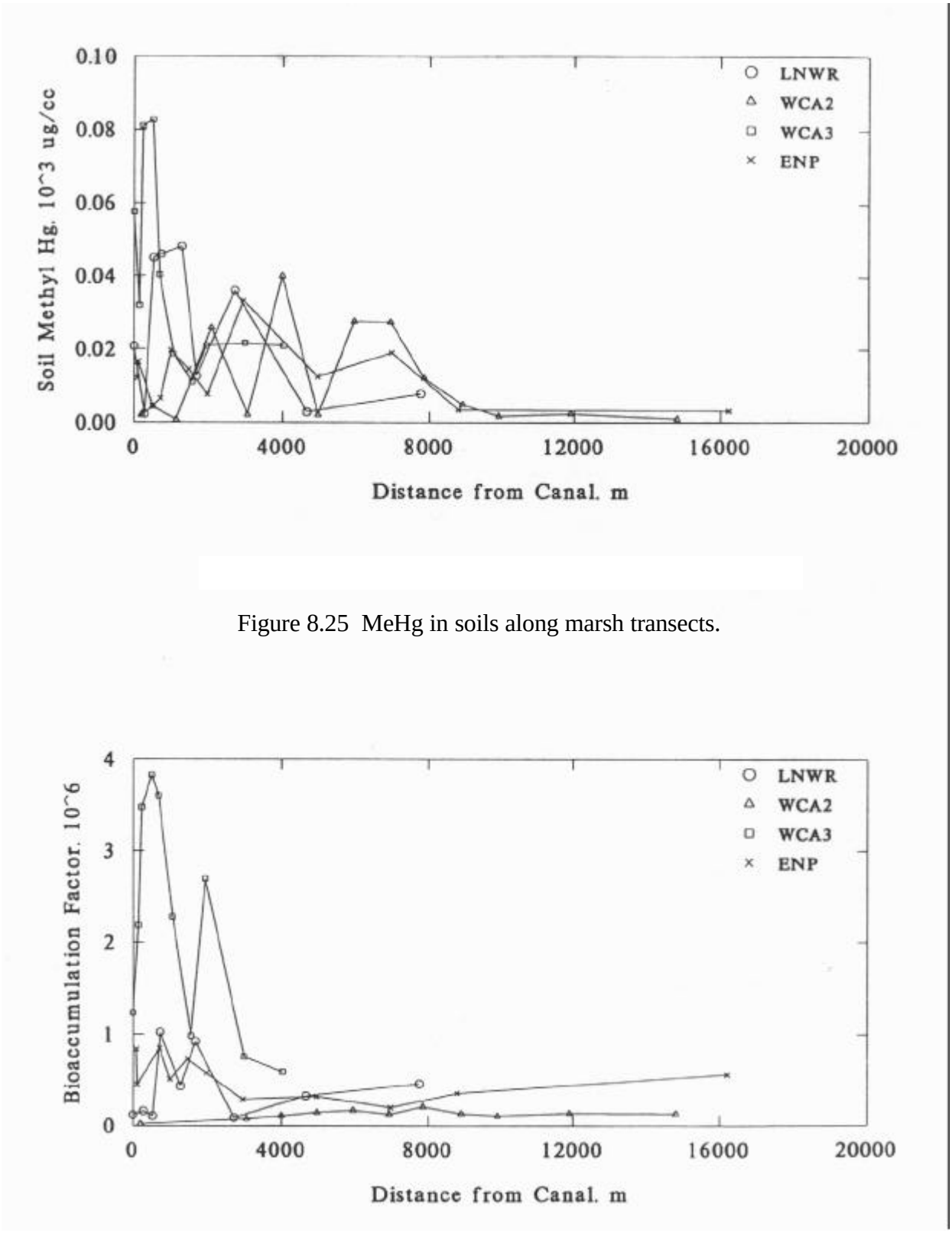

Figure 8.25 MeHg in soils along marsh transects.

Figure 8.26 Bioaccumulation along marsh transects.

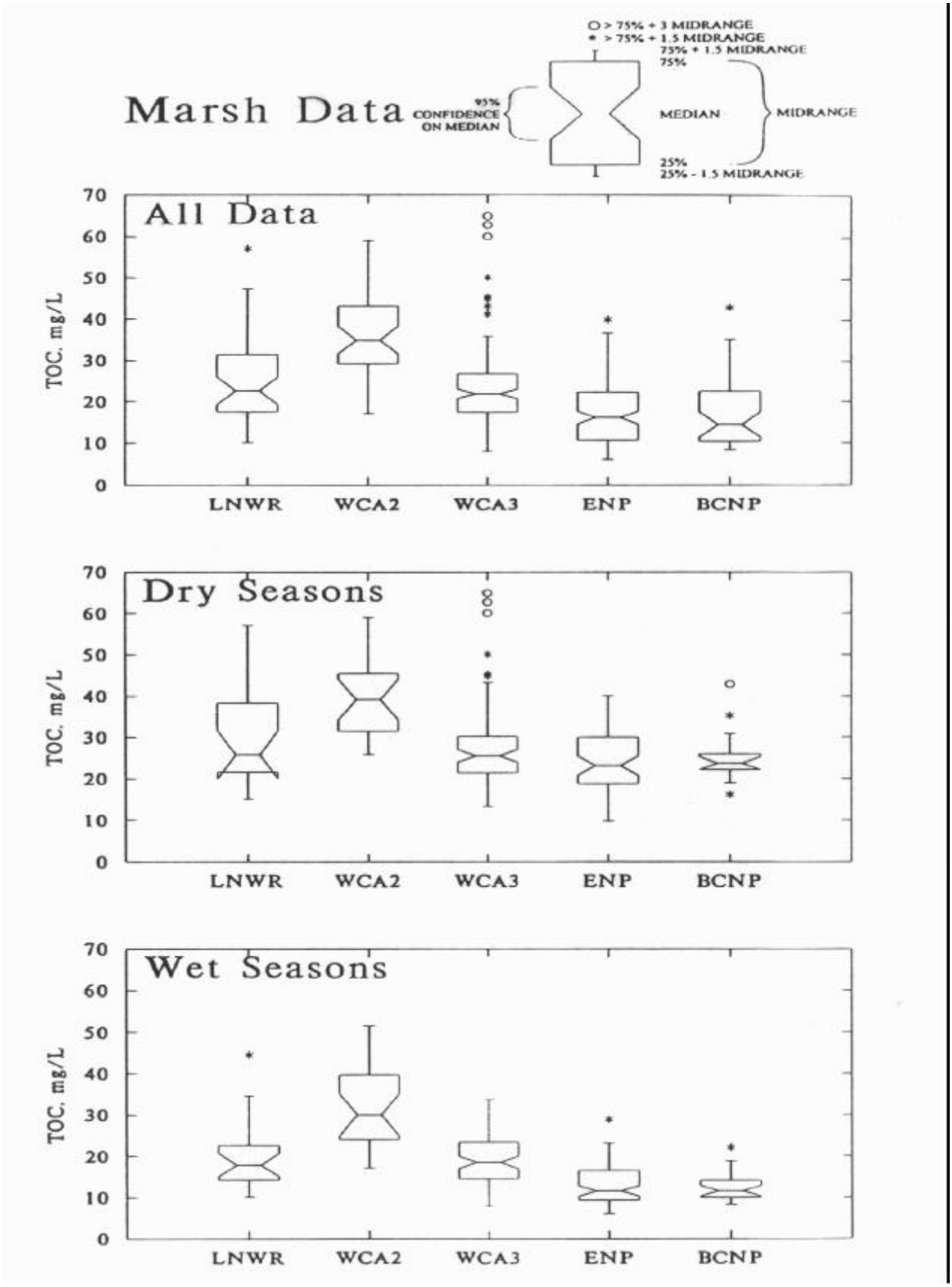

Figure 8.27 Notched box and whisker plots comparing marsh TOC in subareas during dry and wet seasons.

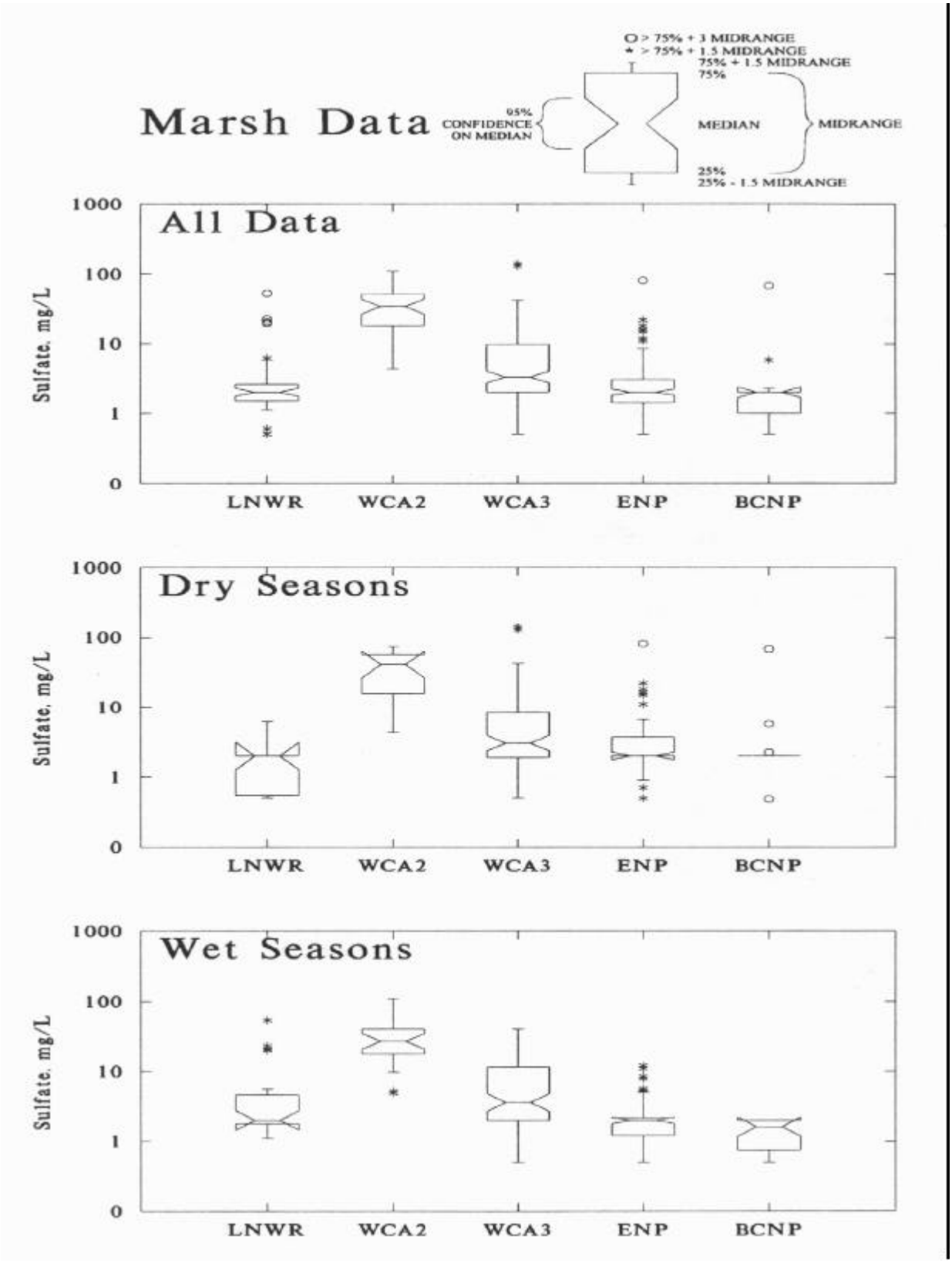

Figure 8.28 Notched box and whisker plots comparing marsh TSO_4 in subareas during dry and wet seasons.

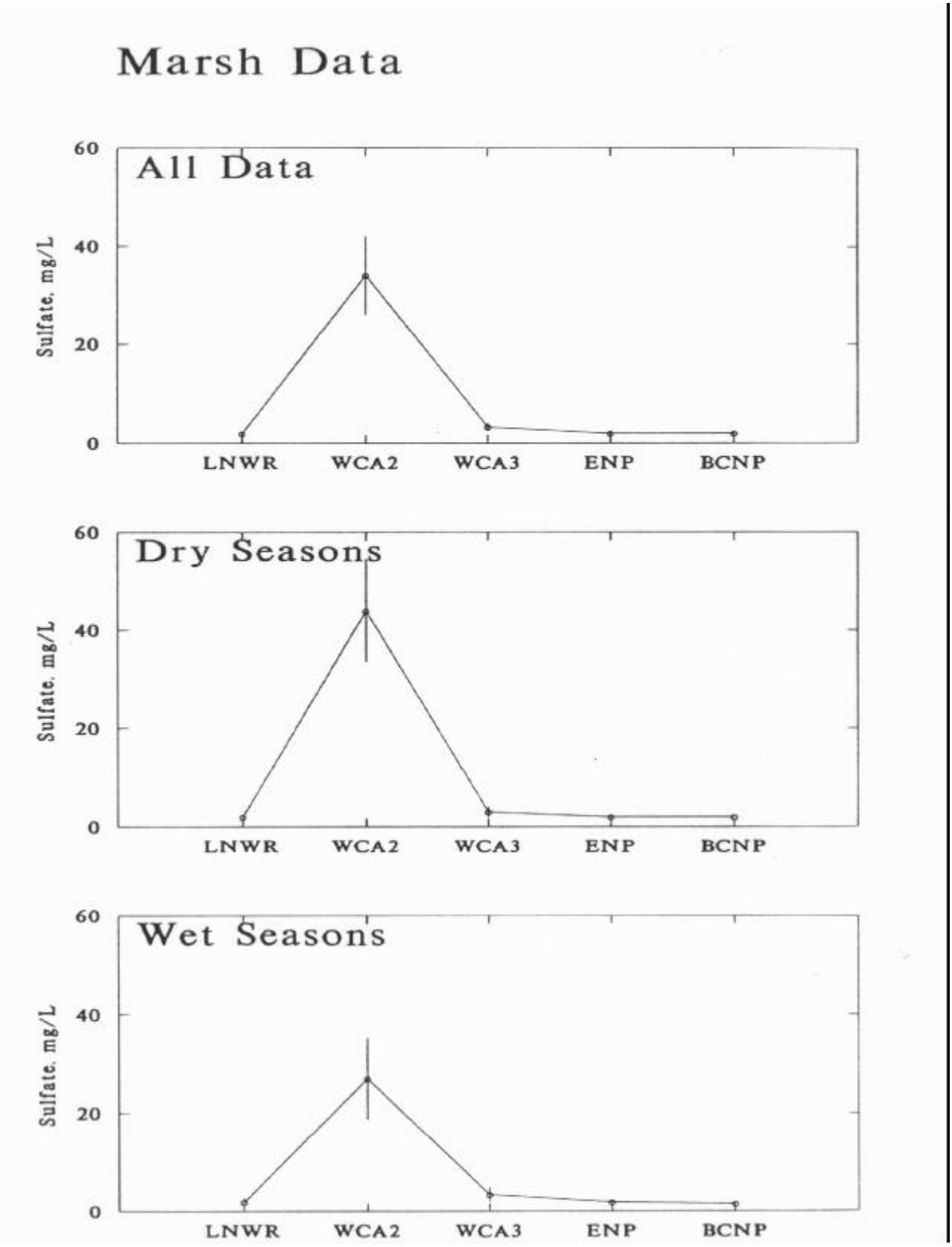

Figure 8.29 Median marsh TSO_4 values for subareas with a vertical line indicating the 95% confidence interval for each median.

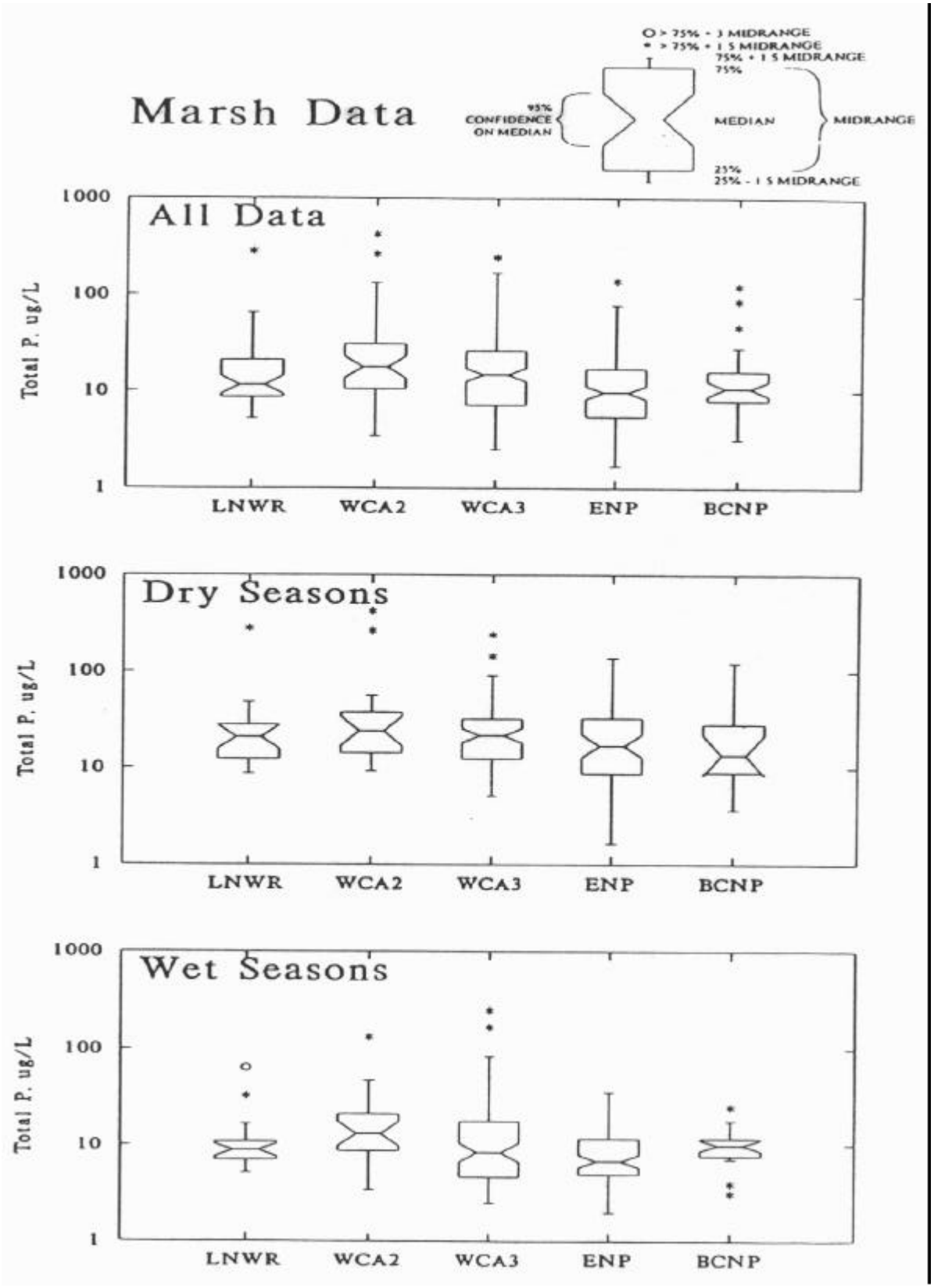

Figure 8.30 Notched box and whisker plots comparing marsh TP in subareas during dry and wet seasons.

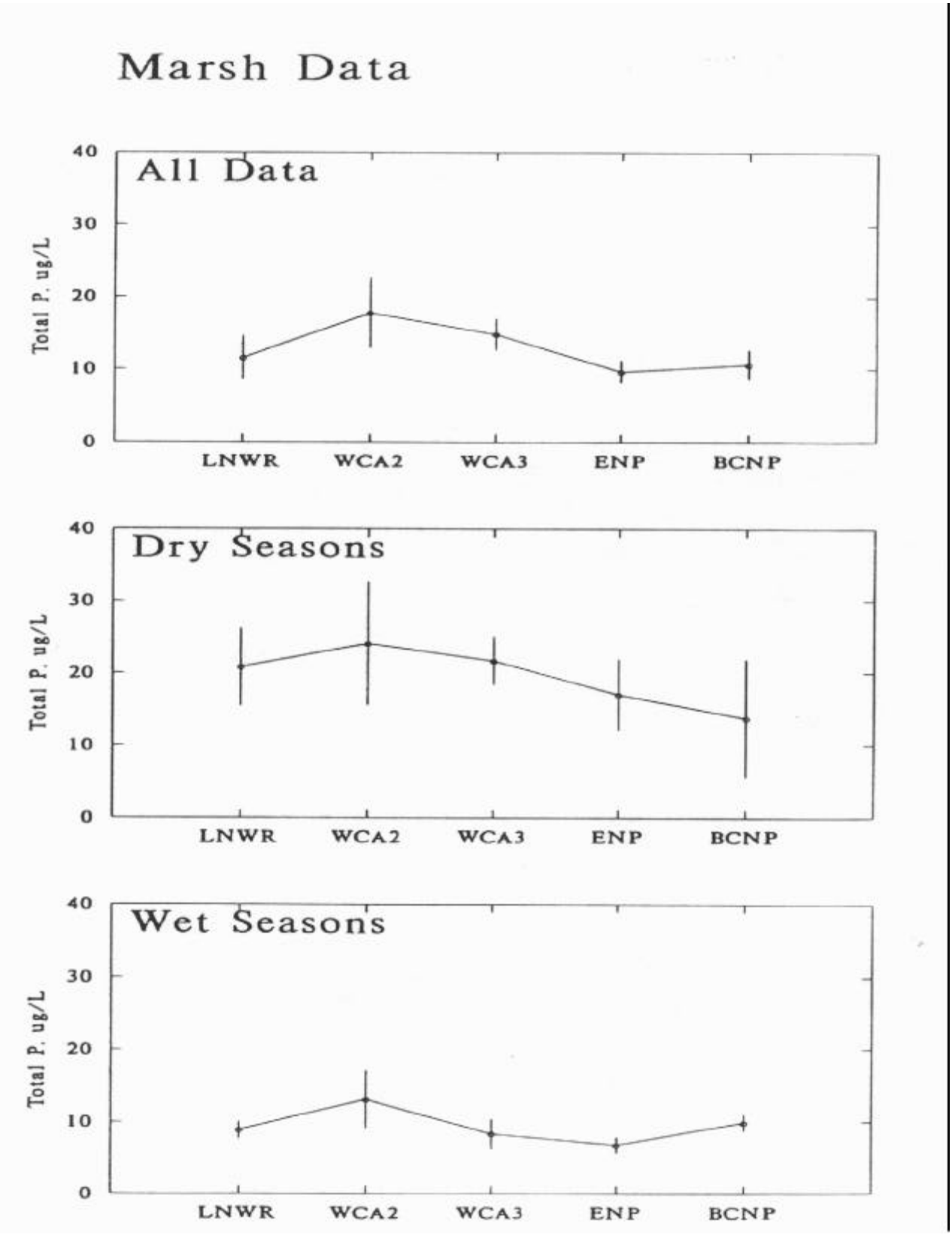

Figure 8.31 Median marsh TP values for subareas with vertical line indicating 95% confidence interval for each median.

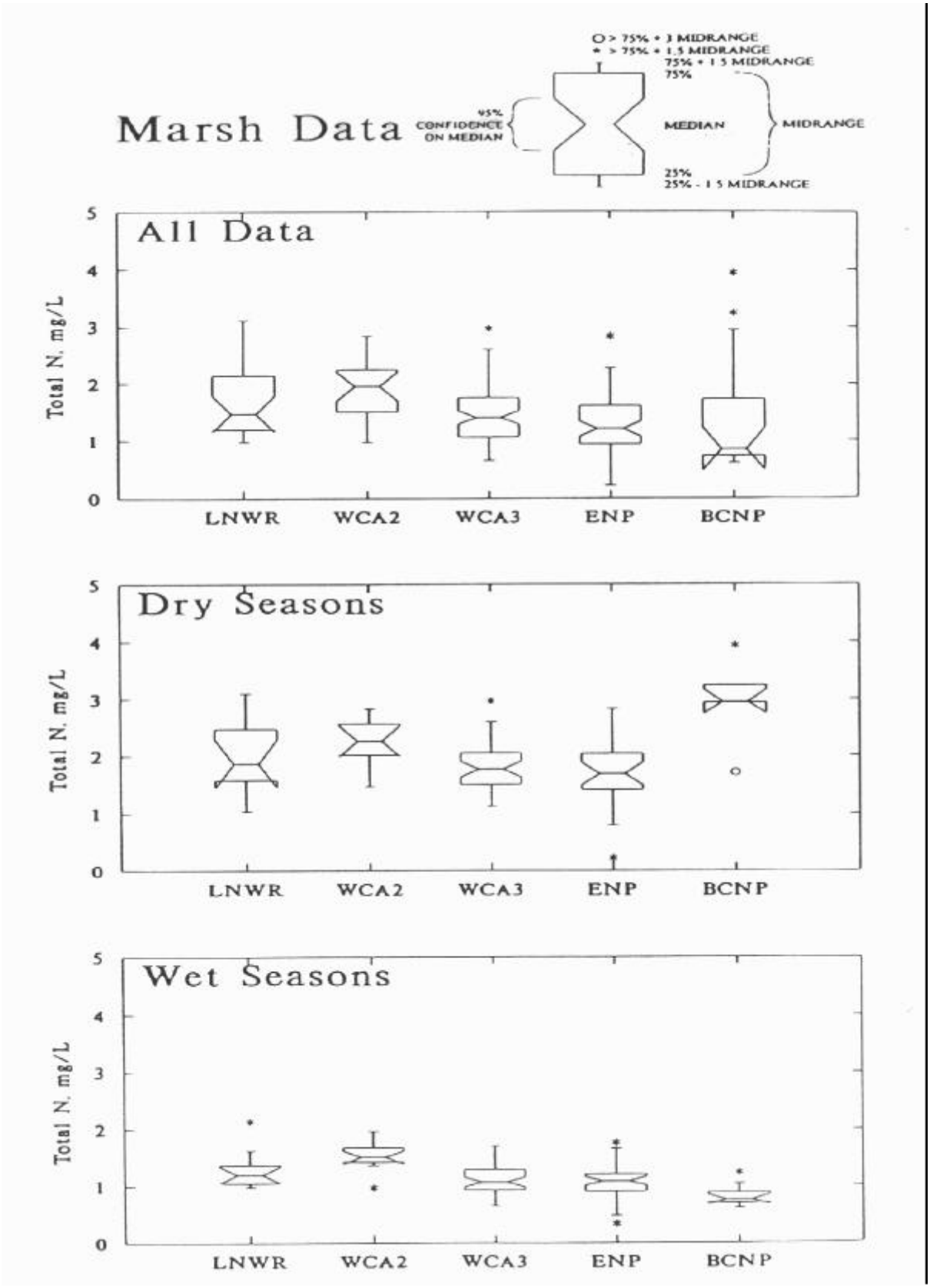

Figure 8.32 Notched box and whisker plots of marsh comparing TN in water during dry and wet seasons.

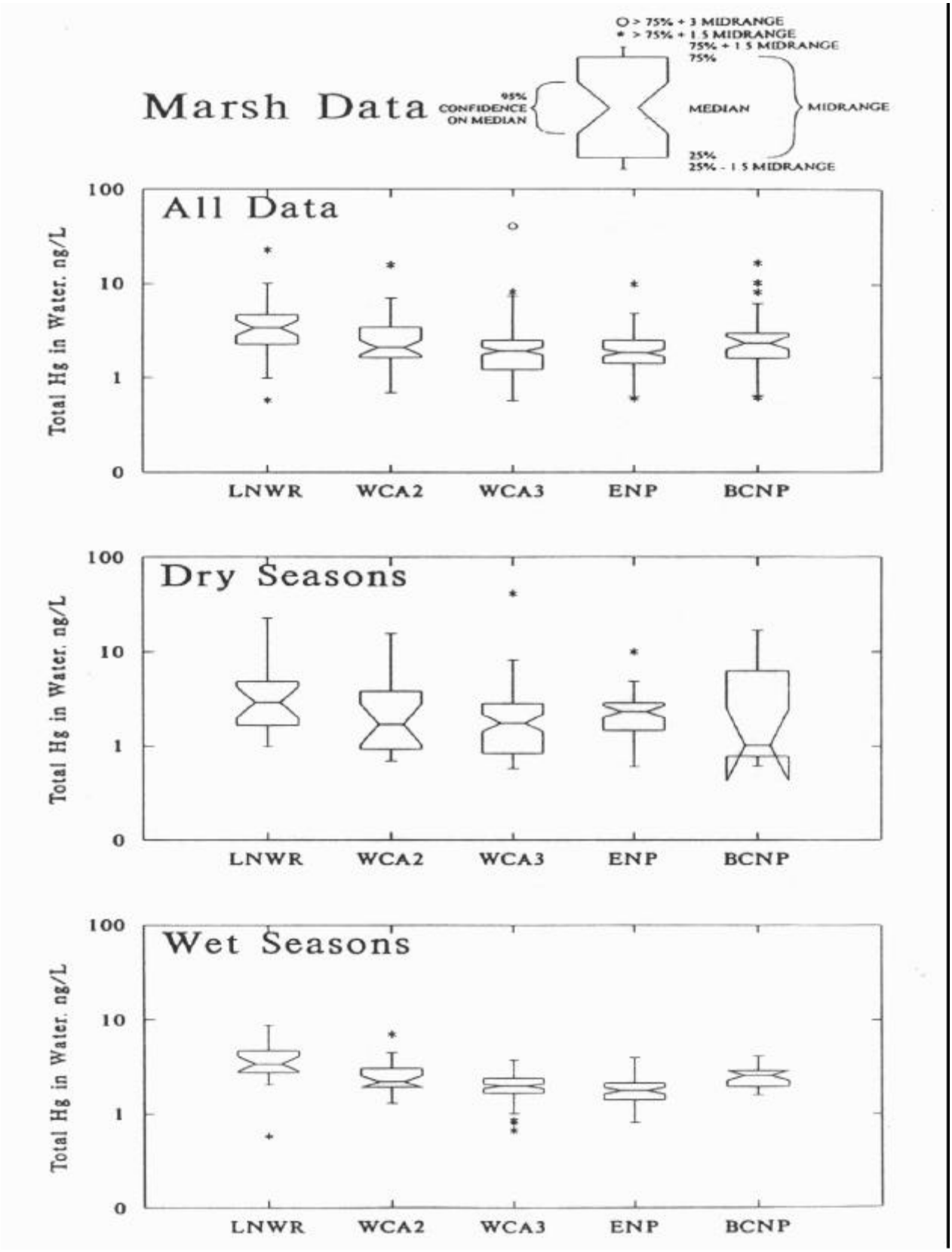

Figure 8.33 Notched box and whisker plots comparing marsh THg in subareas during dry and wet seasons.

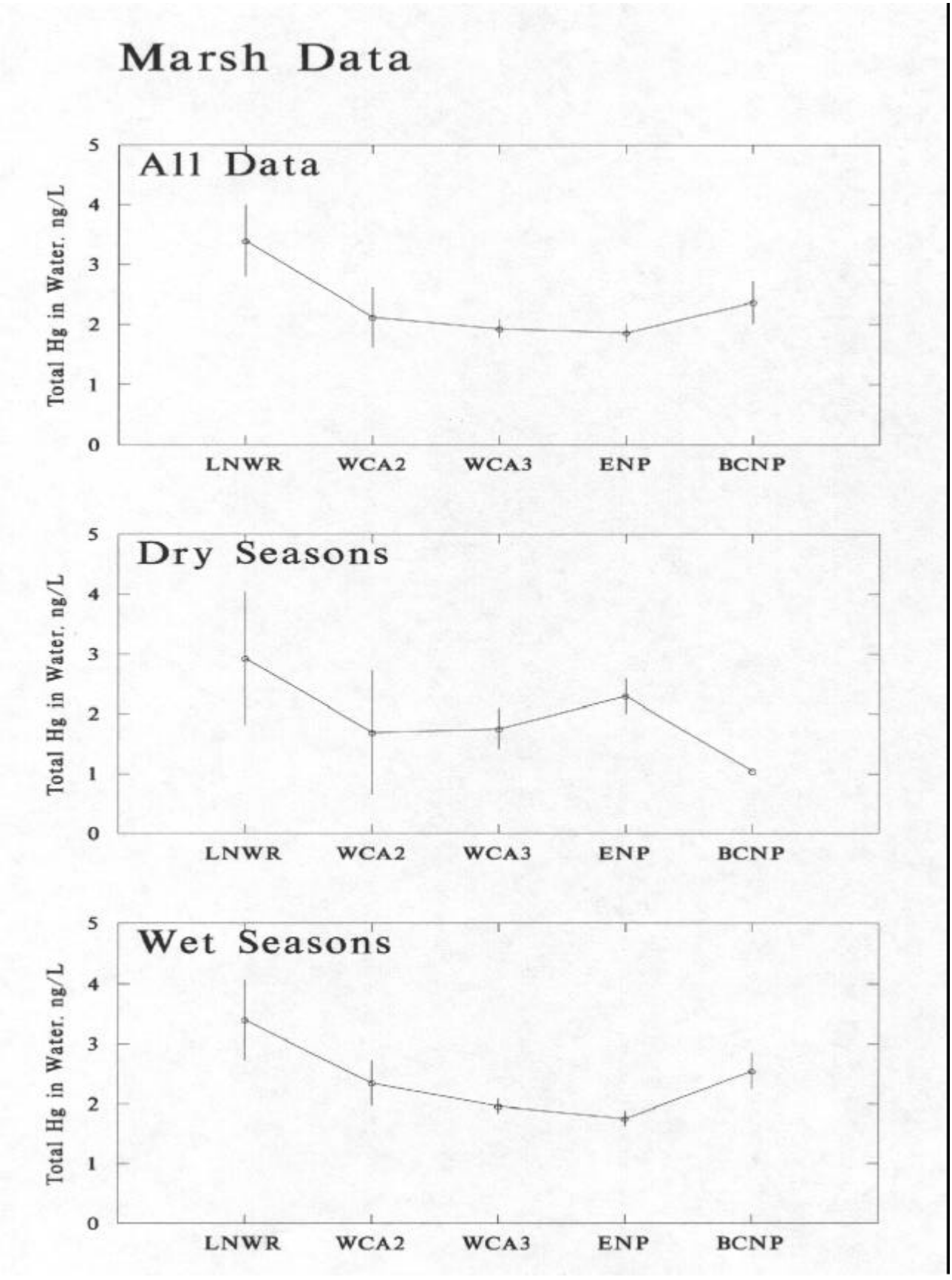

Figure 8.34 Median values of marsh THg for subareas with a vertical line indicating the 95% confidence interval for each median.

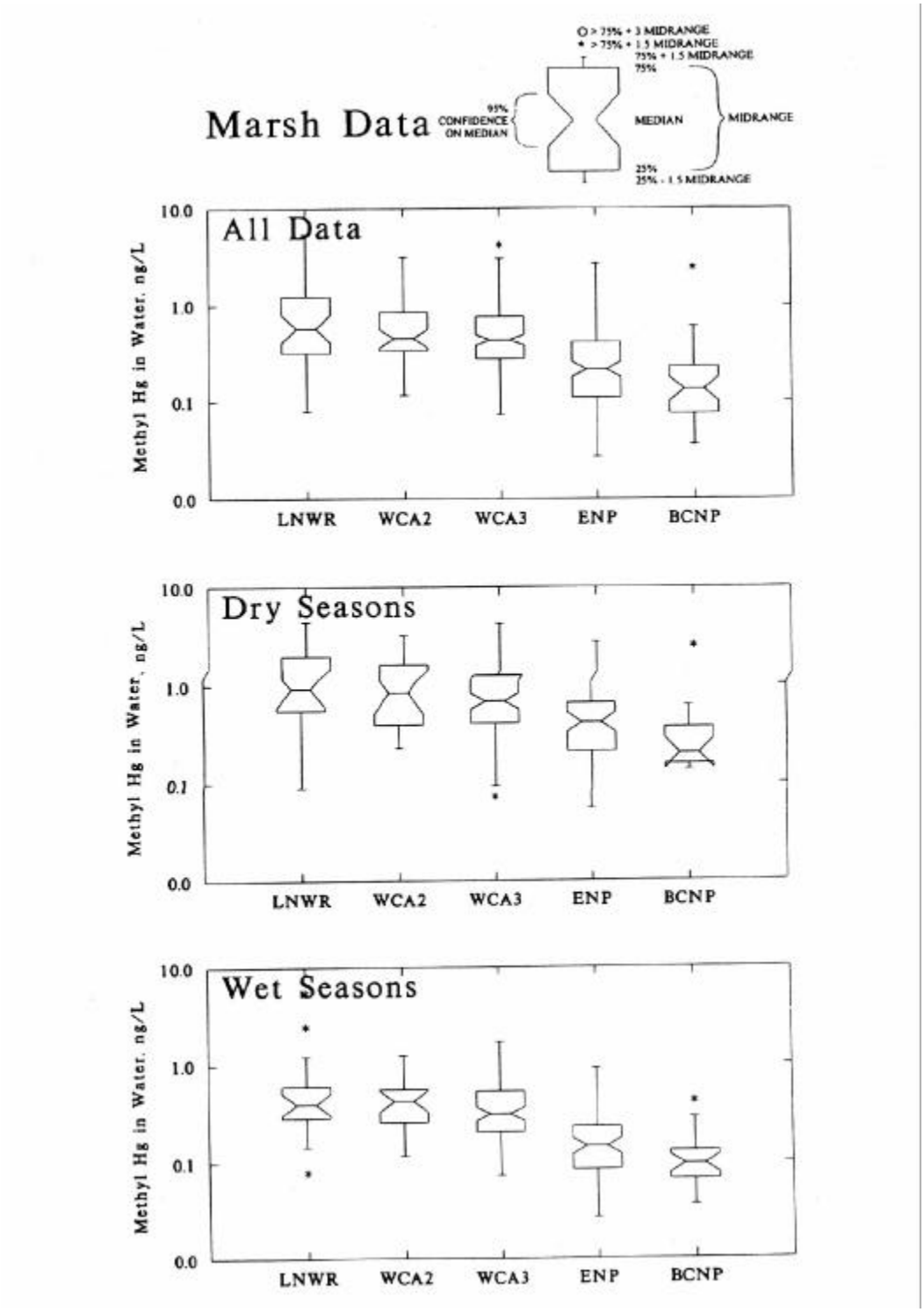

Figure 8.35 Notched box and whisker plots comparing marsh MeHg in subareas during dry and wet seasons.

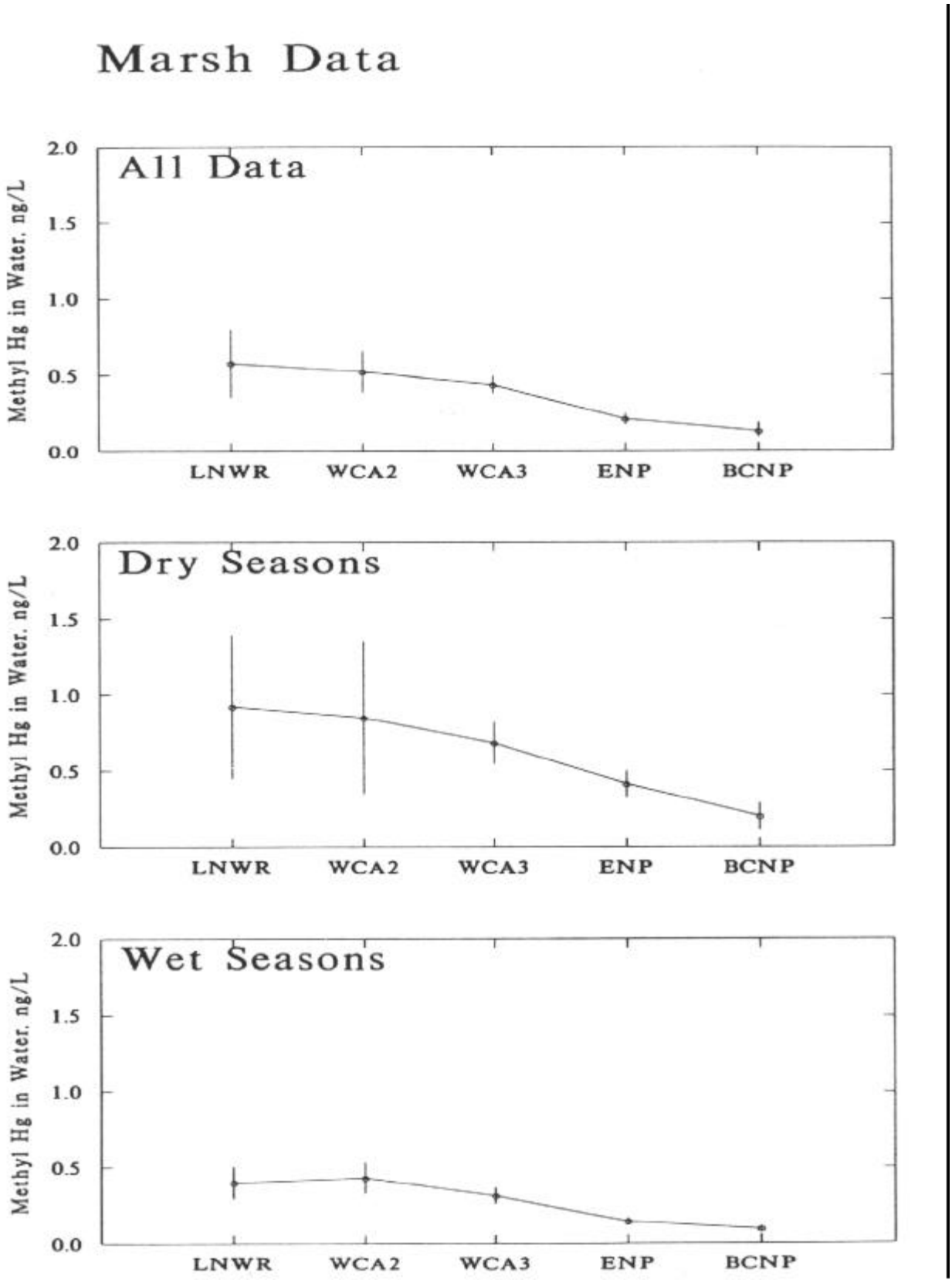

Figure 8.36 Median values of marsh MeHg for subareas with vertical lines indicating the 95% confidence interval for each median.

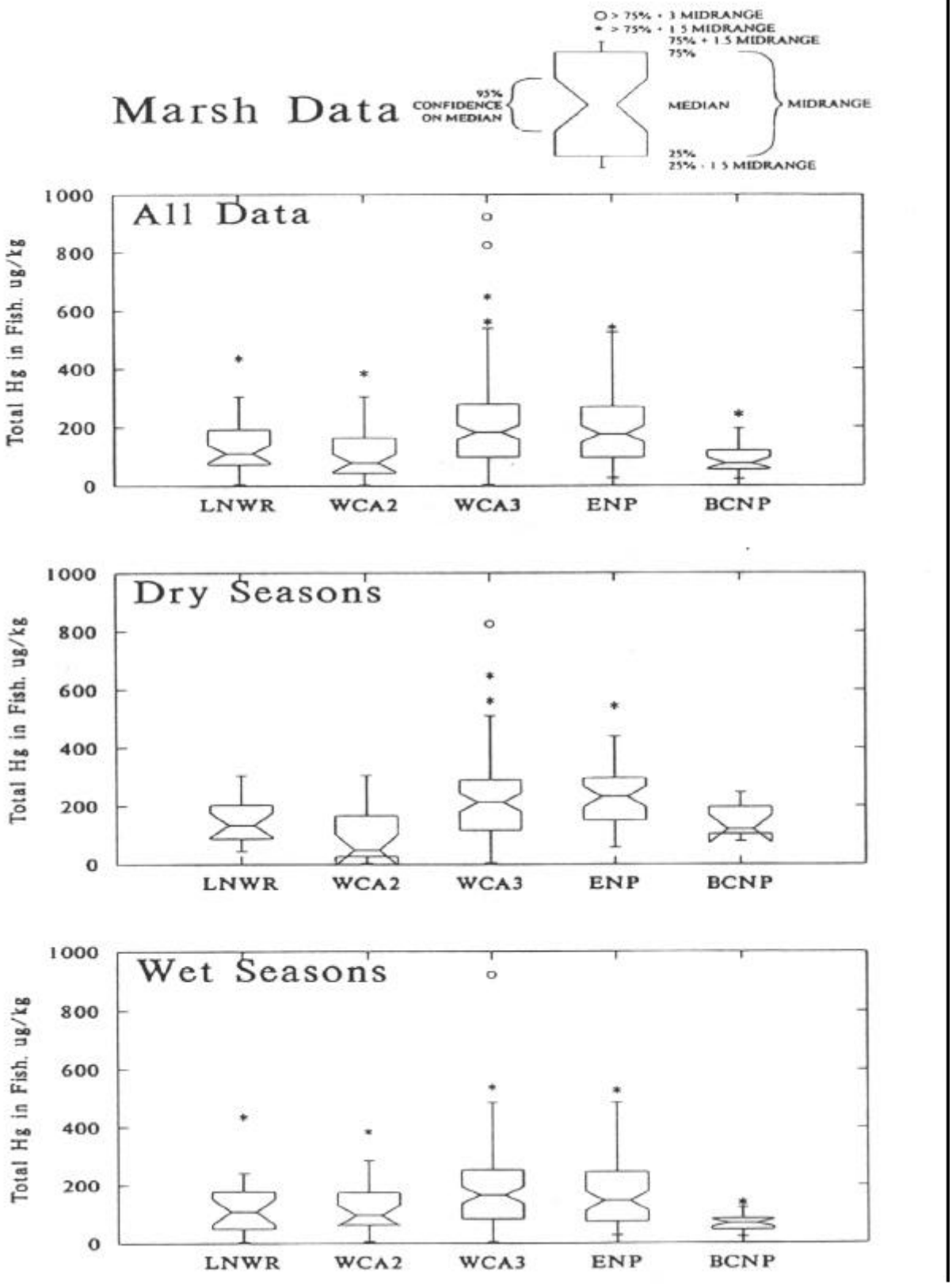

Figure 8.37 Notched box and whisker plots comparing THg in fish in marsh in subareas during dry and wet seasons.

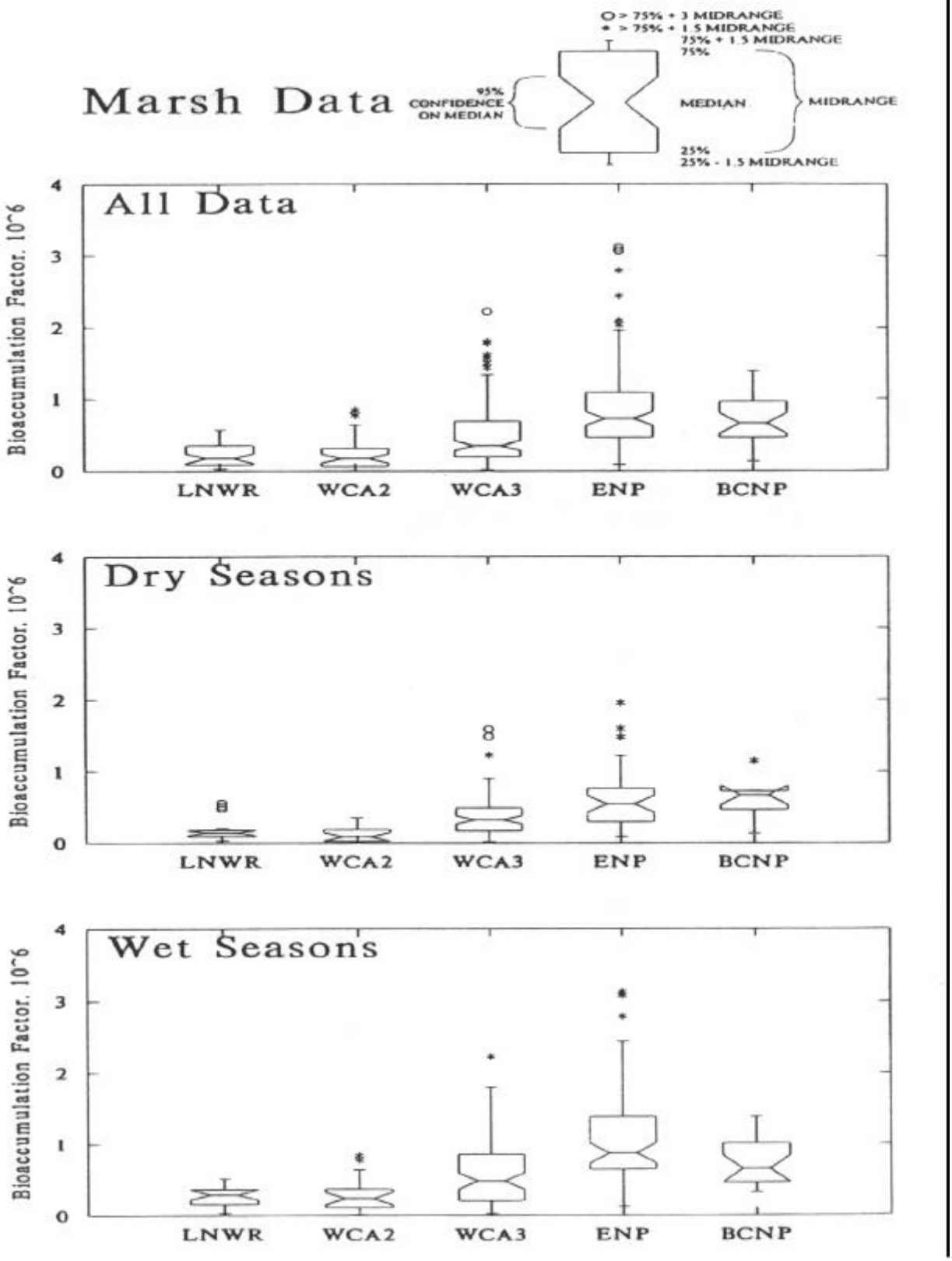

Figure 8.38 Notched box and whisker plots comparing marsh BAF factor in subareas during dry and wet seasons.

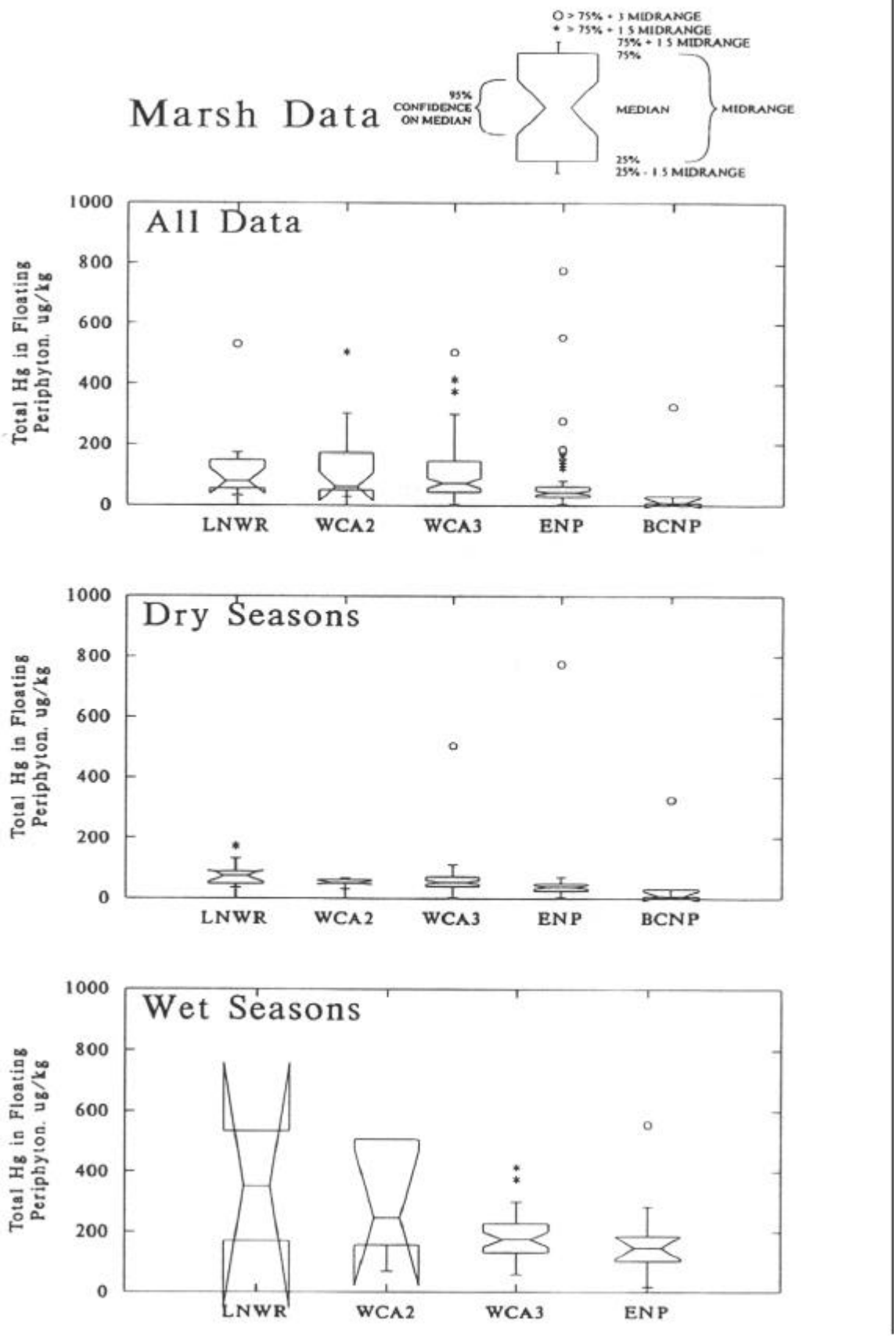

Figure 8.39 Notched box and whisker plots comparing THg in floating periphyton in subareas during dry and wet seasons.

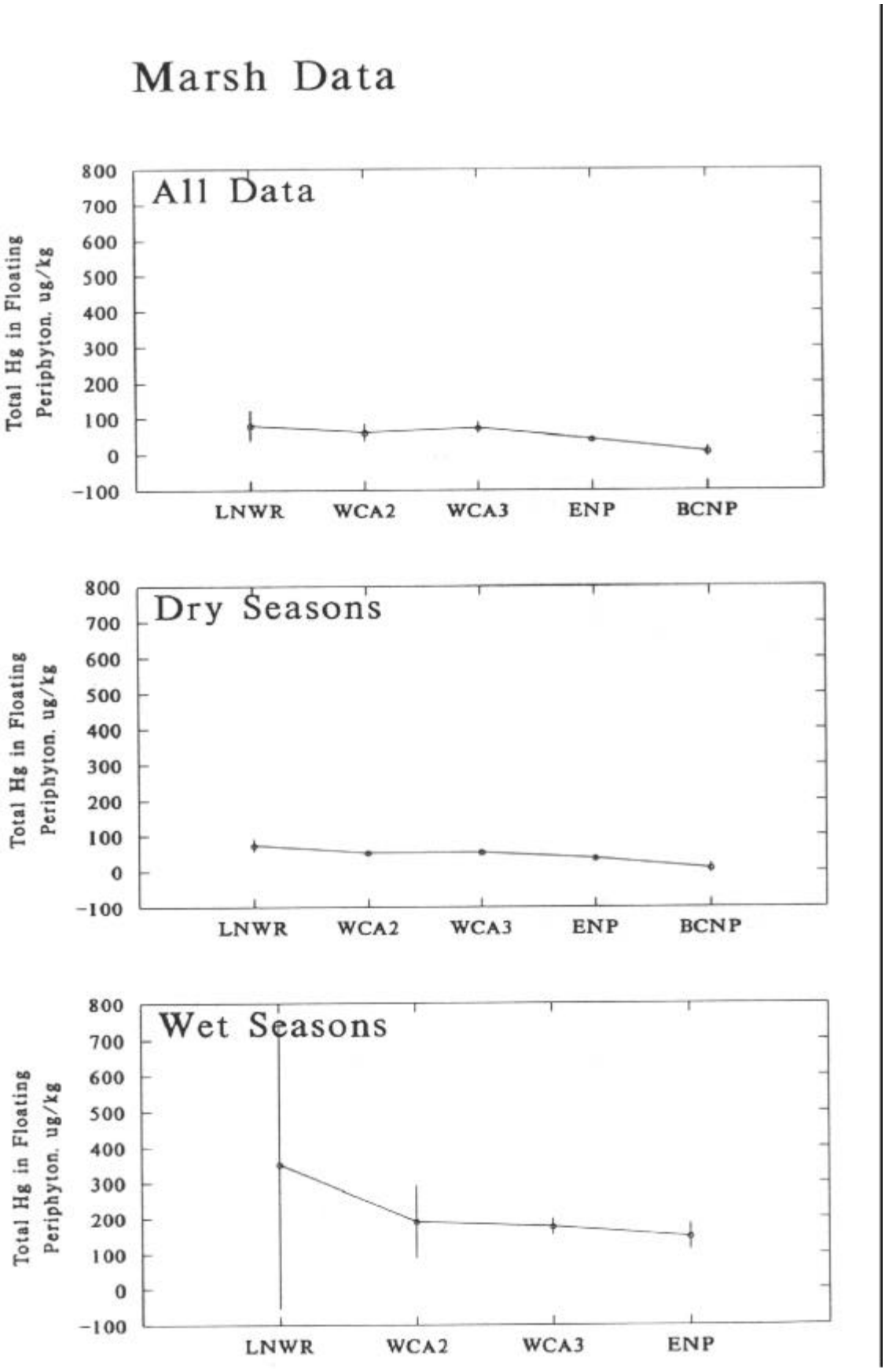

Figure 8.40 Median values of THg in floating periphyton for subareas with a vertical line indicating the 95% confidence interval for each median.

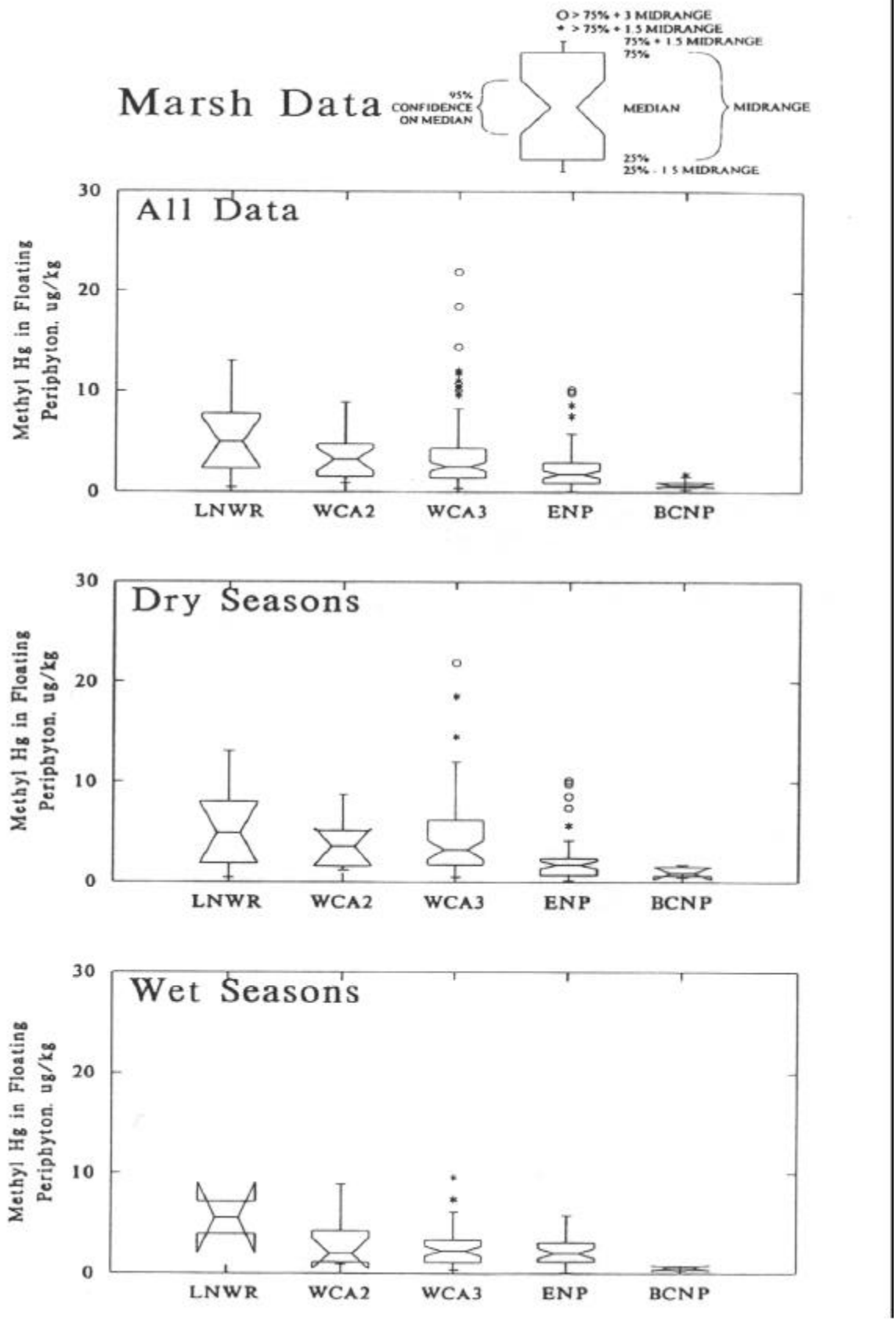

Figure 8.41 Notched box and whisker plots comparing MeHg in floating periphyton in subareas during dry and wet seasons.

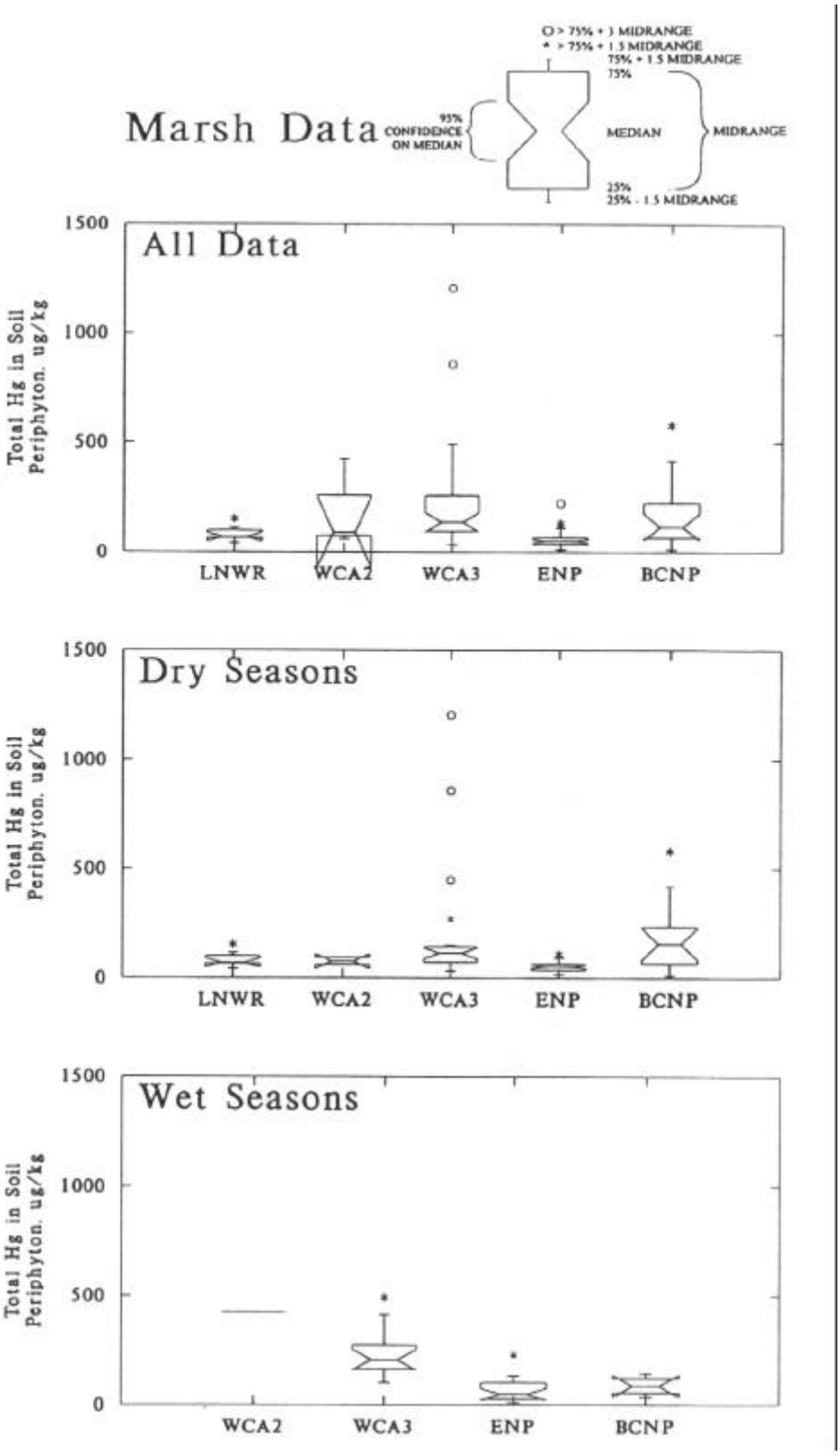

Figure 8.42 Notched box and whisker plots comparing THg in soil periphyton in subareas during dry and wet seasons.

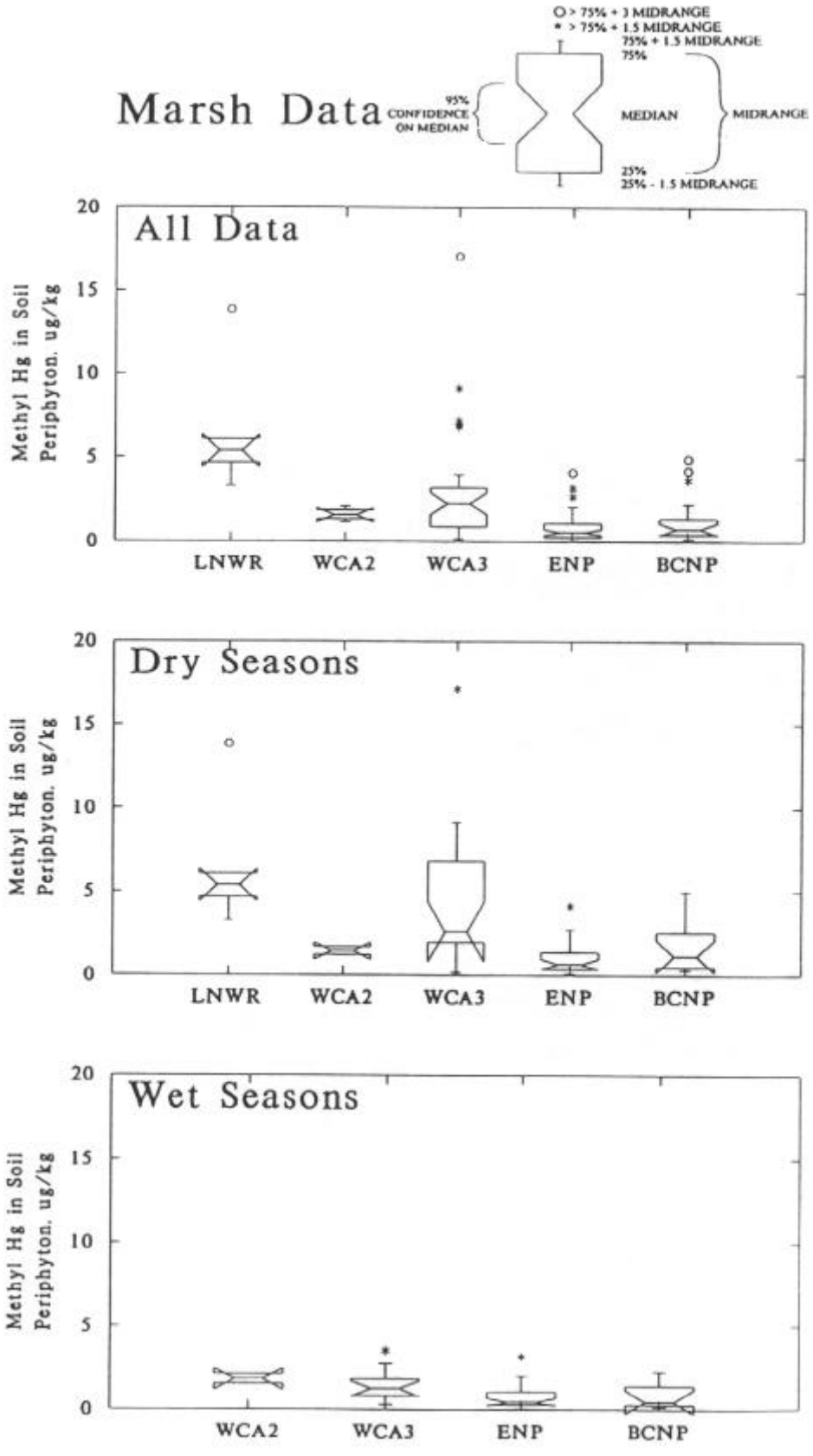

Figure 8.43 Notched box and whisker plots comparing MeHg in soil periphyton in subareas during dry and wet seasons.

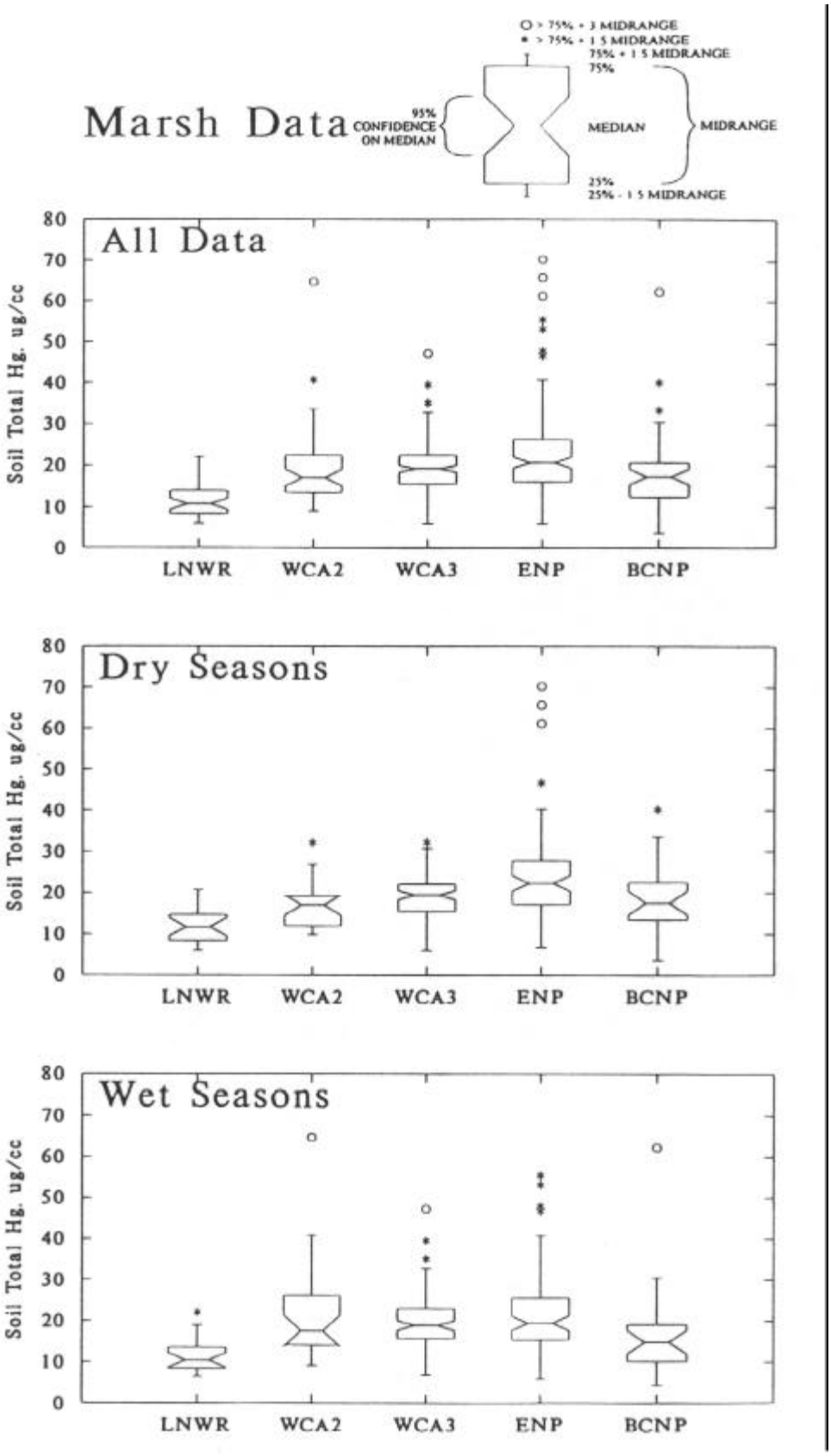

Figure 8.44 Notched box and whisker plots comparing marsh soil THg in subareas during dry and wet seasons.

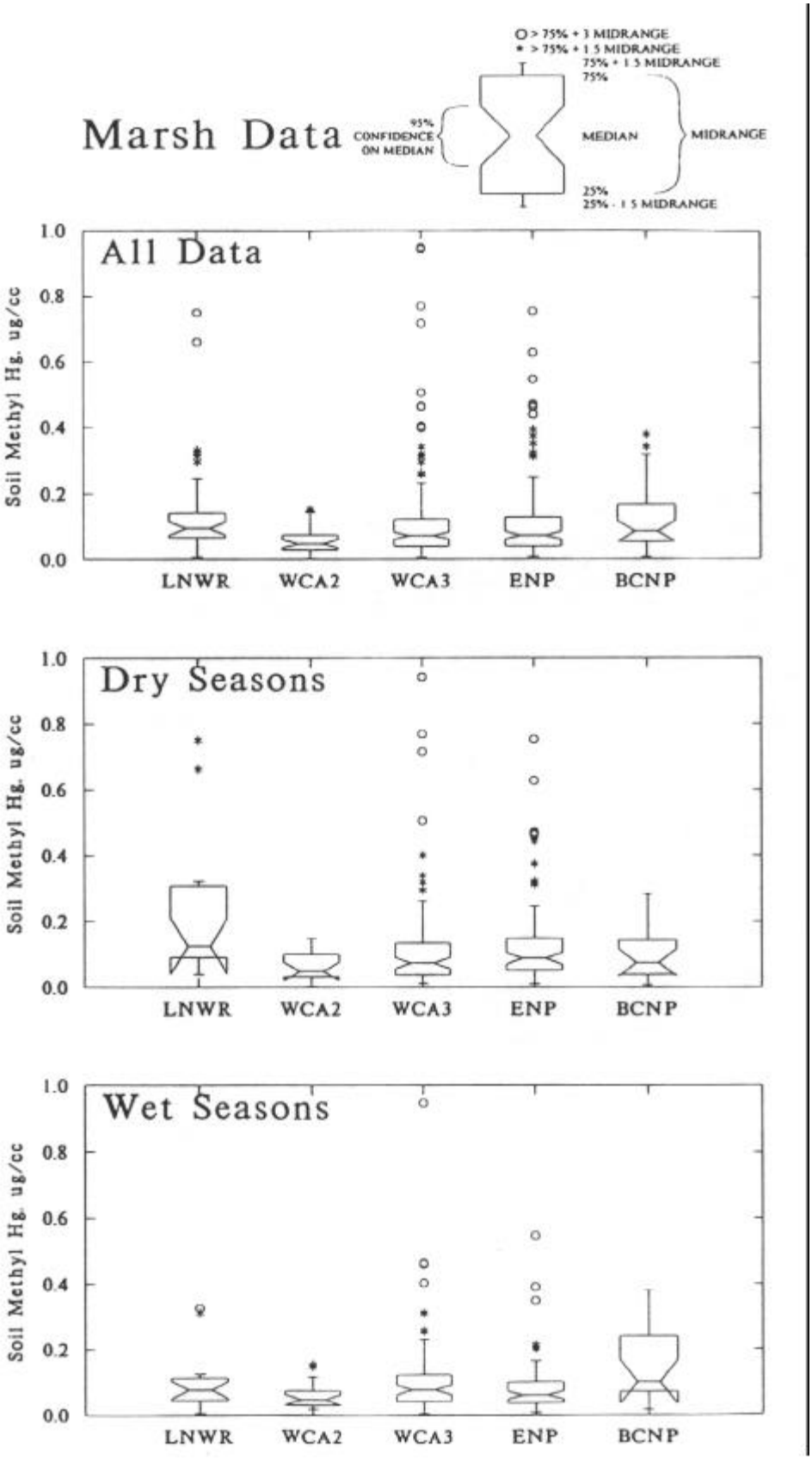

Figure 8.45 Notched box and whisker plots comparing marsh soil MeHg in subareas during dry and wet seasons.

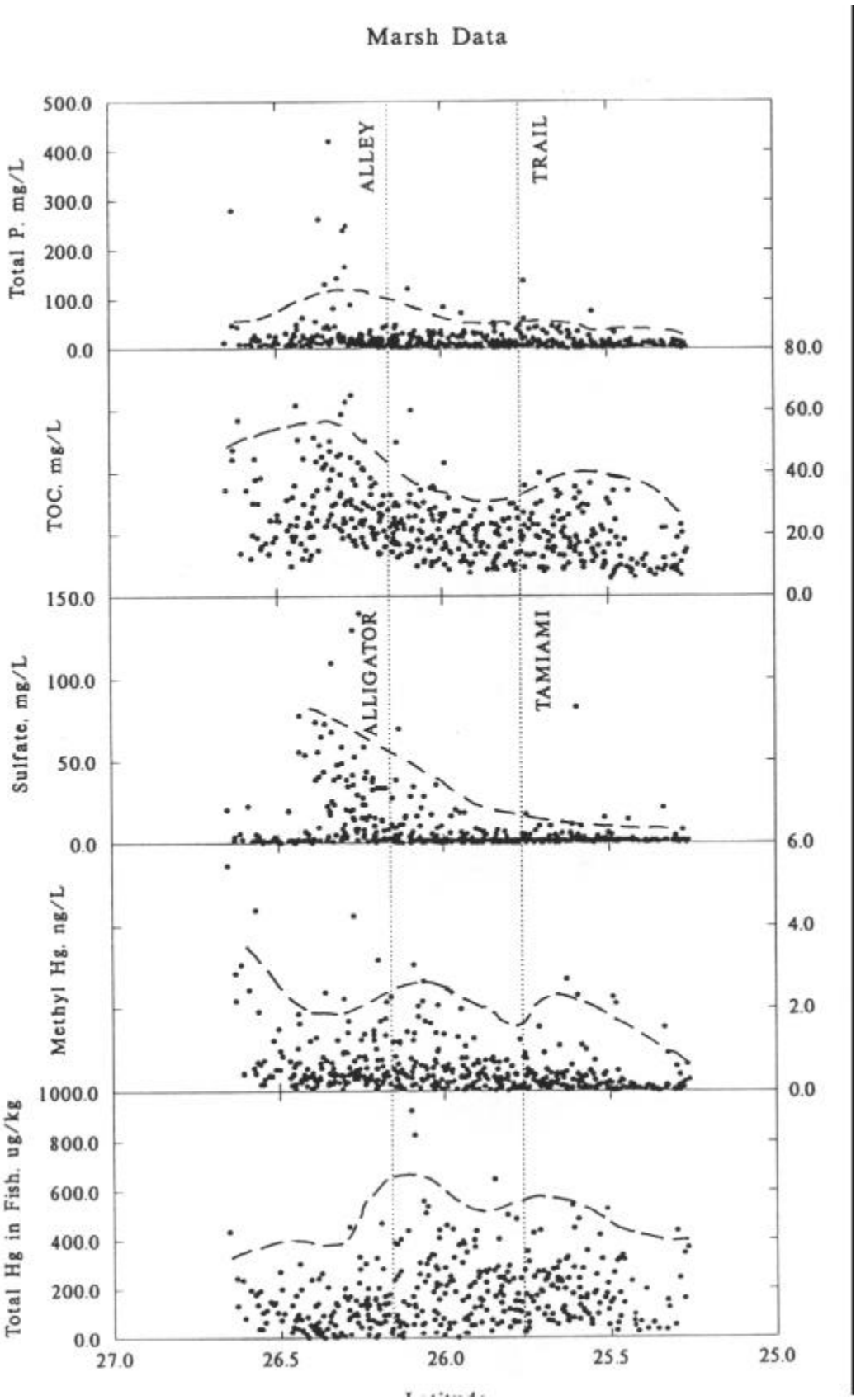

Figure 8.46 Selected marsh parameters shown by latitude.

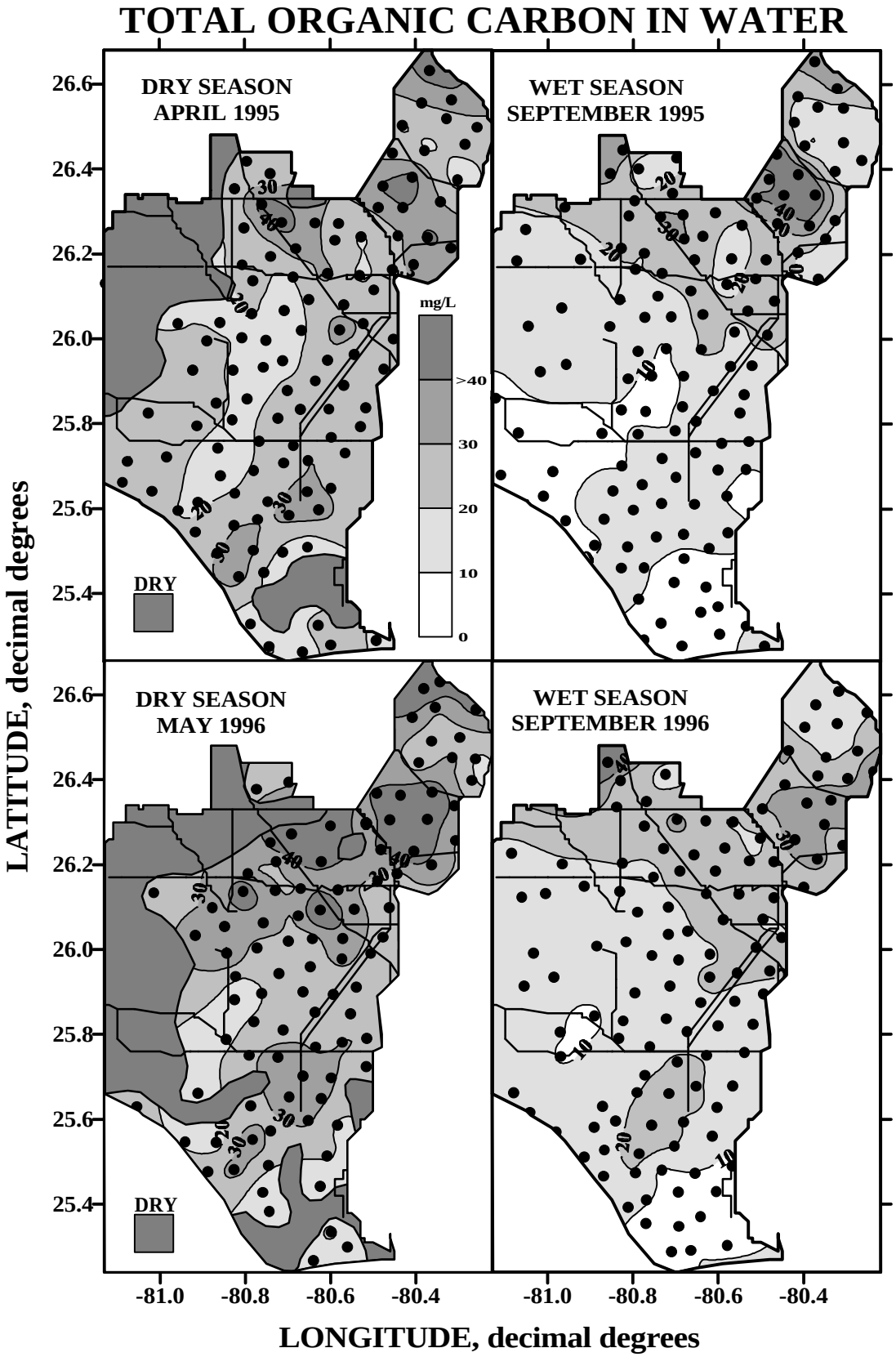

Figure 8.47 Kriged surfaces indicating marsh TOC concentrations during each sampling cycle.

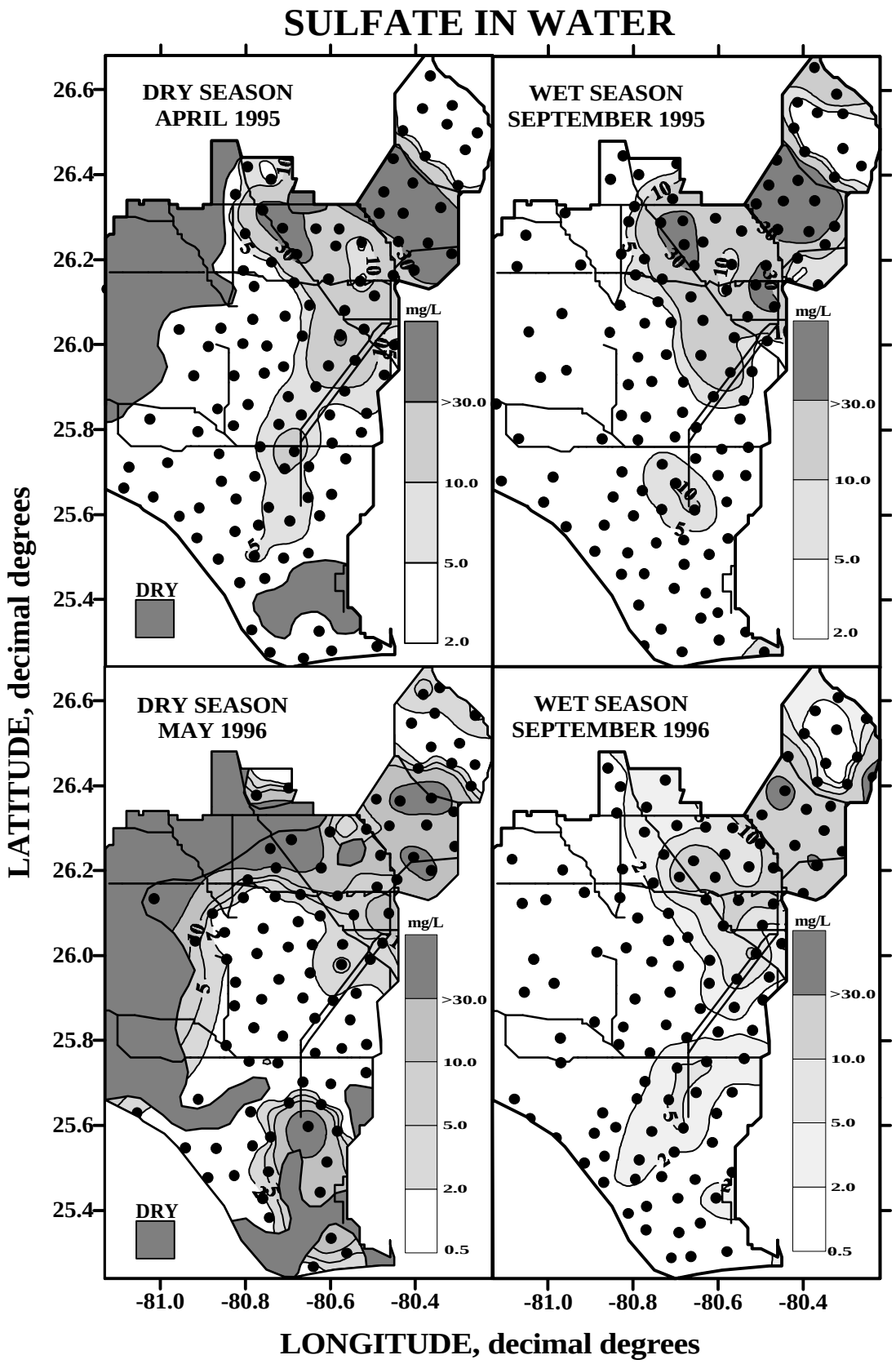

Figure 8.48 Kriged surfaces indicating marsh TSO_4 concentrations during each sampling cycle.

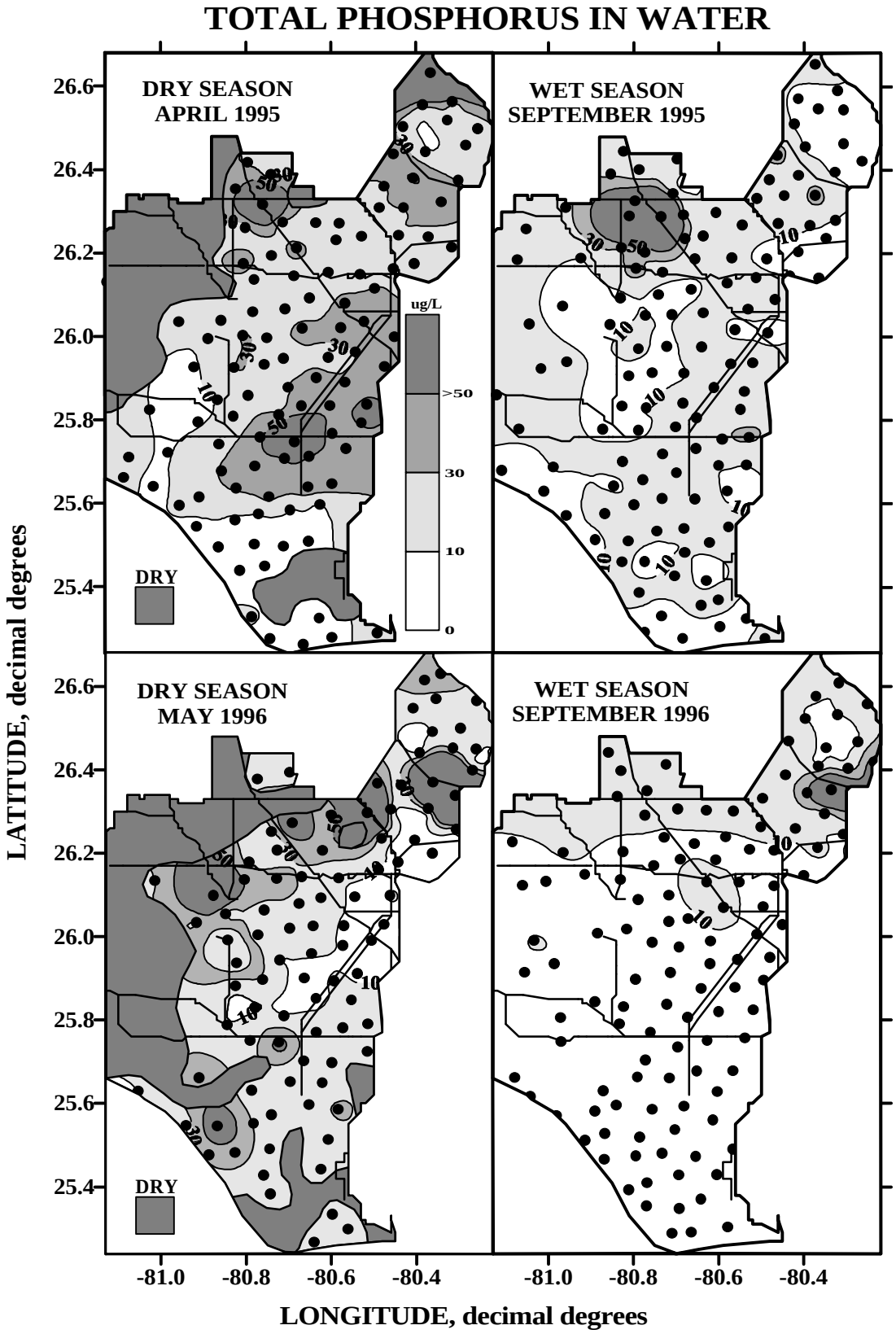

Figure 8.49 Kriged surfaces showing TP in the marsh for each sampling cycle based on sampling data.

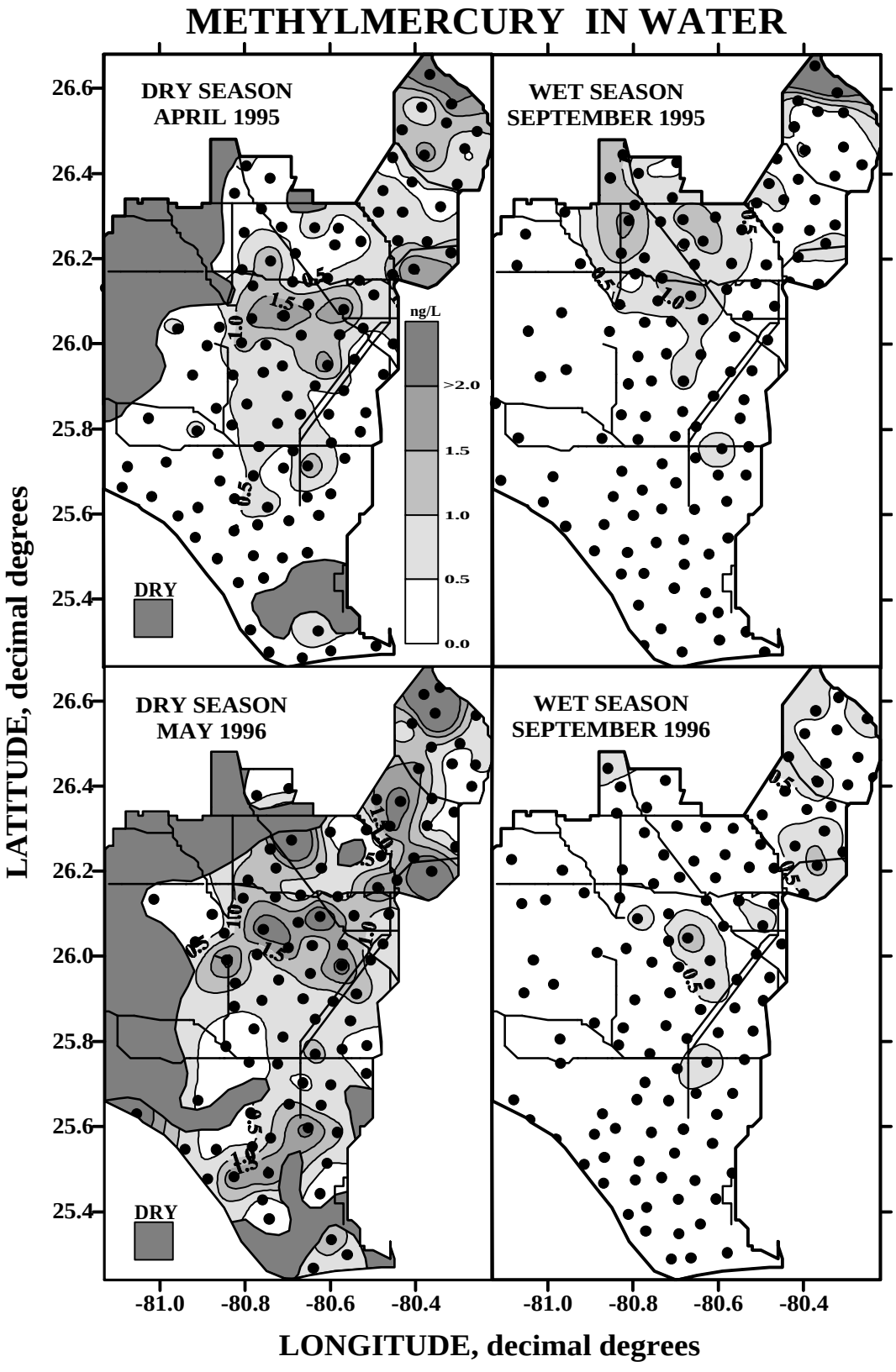

Figure 8.50 Kriged surfaces indicating marsh MeHg concentrations during each of the sampling cycles.

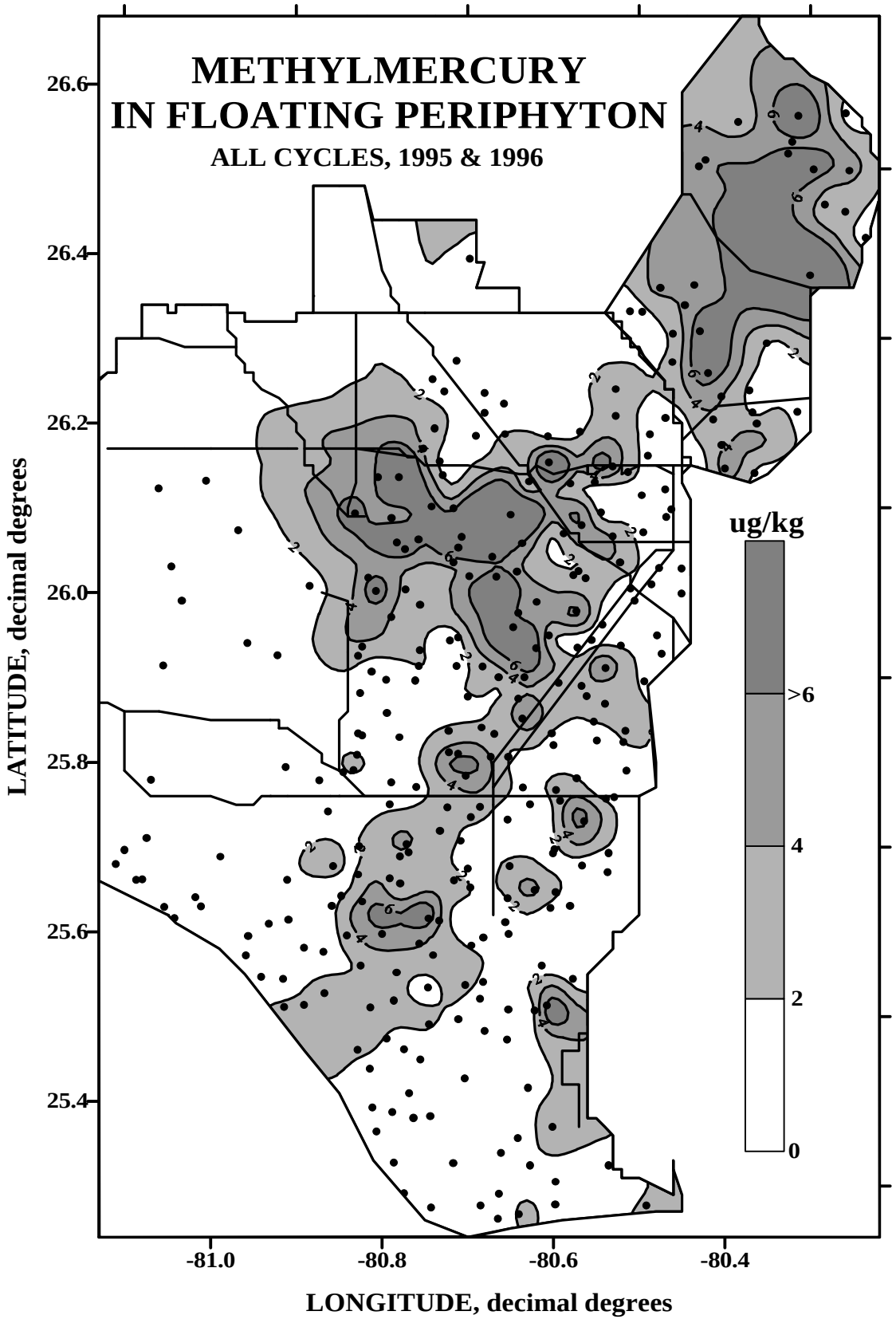

Figure 8.51 Locations of floating periphyton samples with kriged surfaces indicating concentrations of MeHg in floating periphyton.

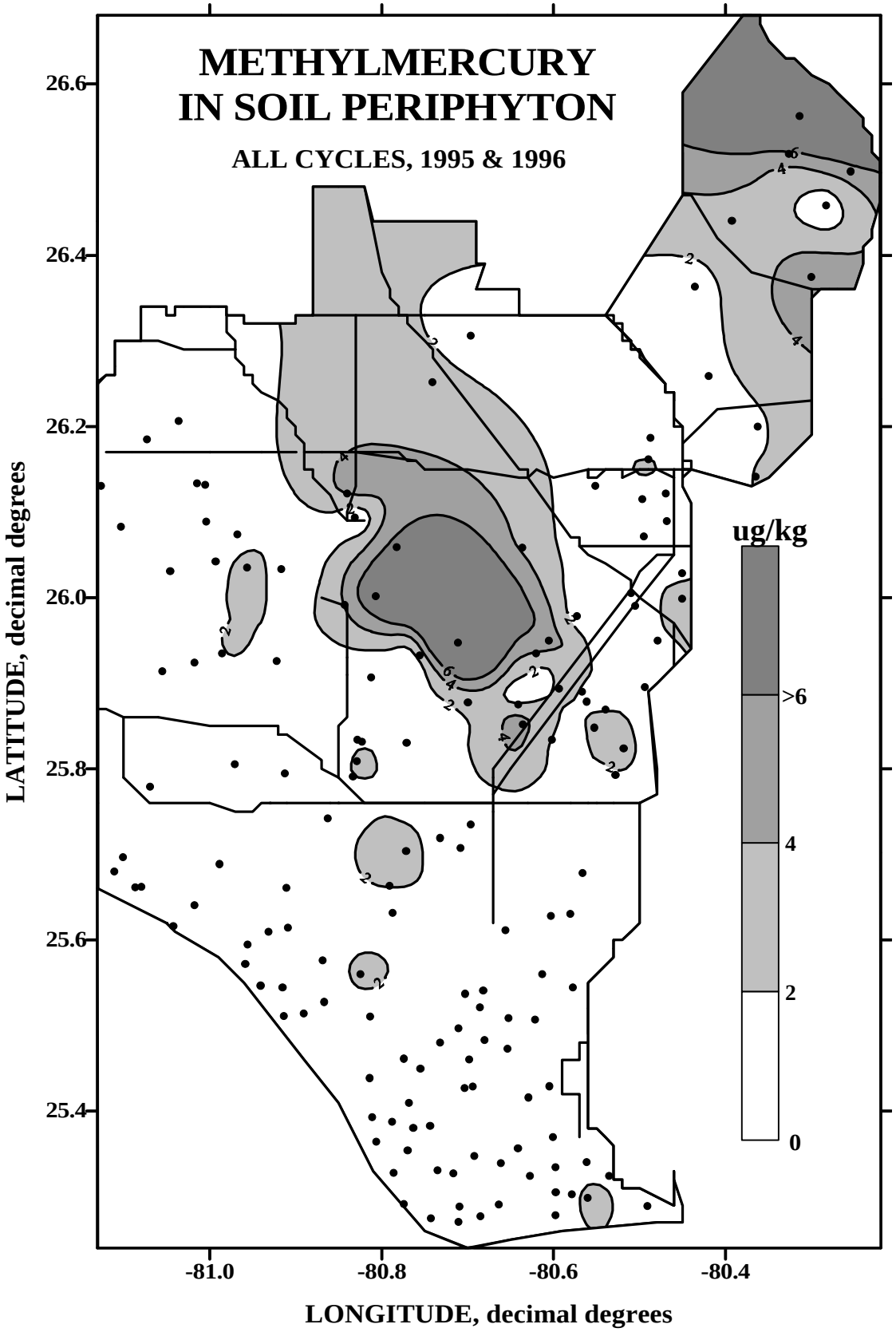

Figure 8.52 Locations of soil periphyton samples with kriged surface indicating concentrations of MeHg in soil periphyton.

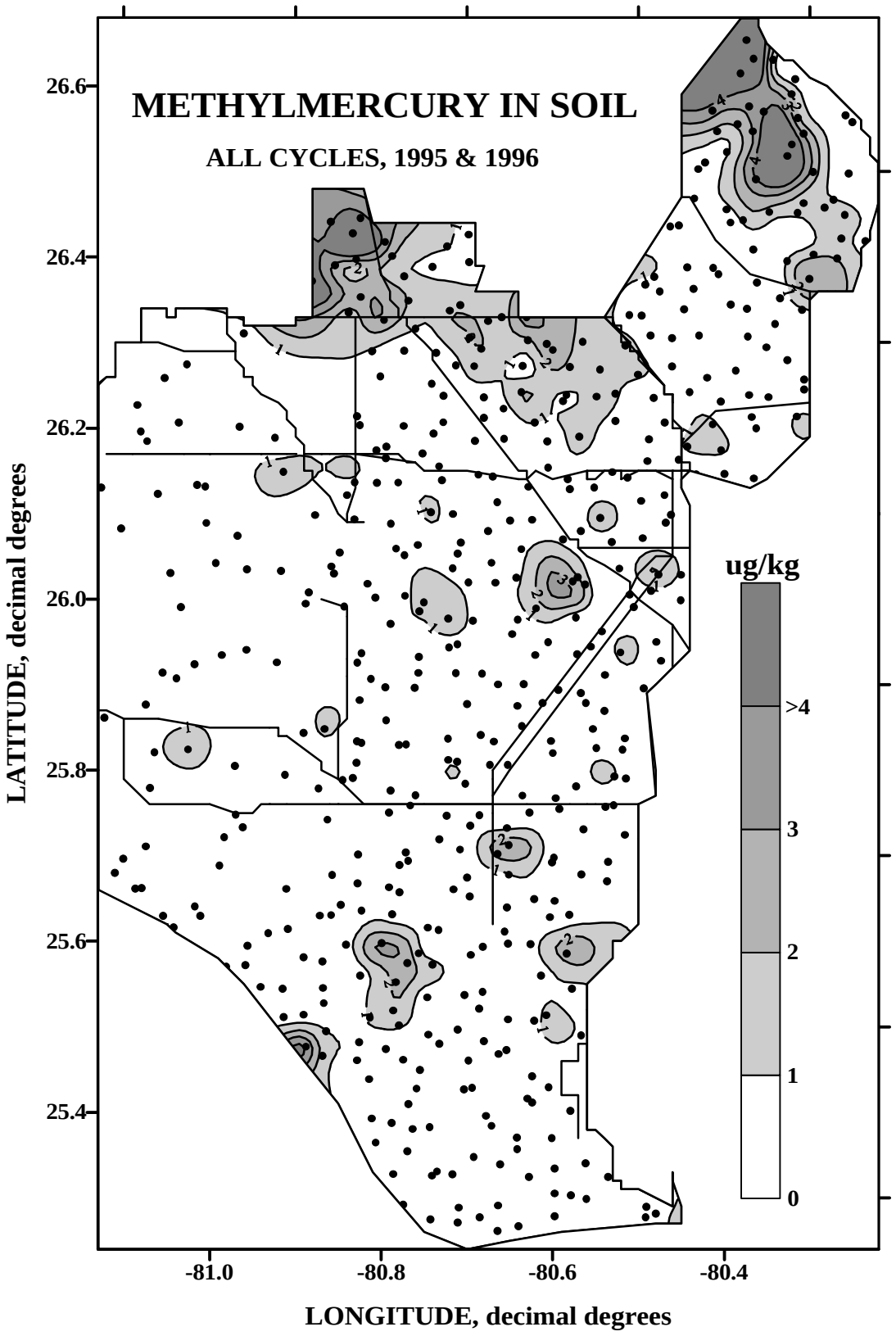

Figure 8.53 Kriged surfaces indicating concentrations of MeHg in marsh soils during study period.

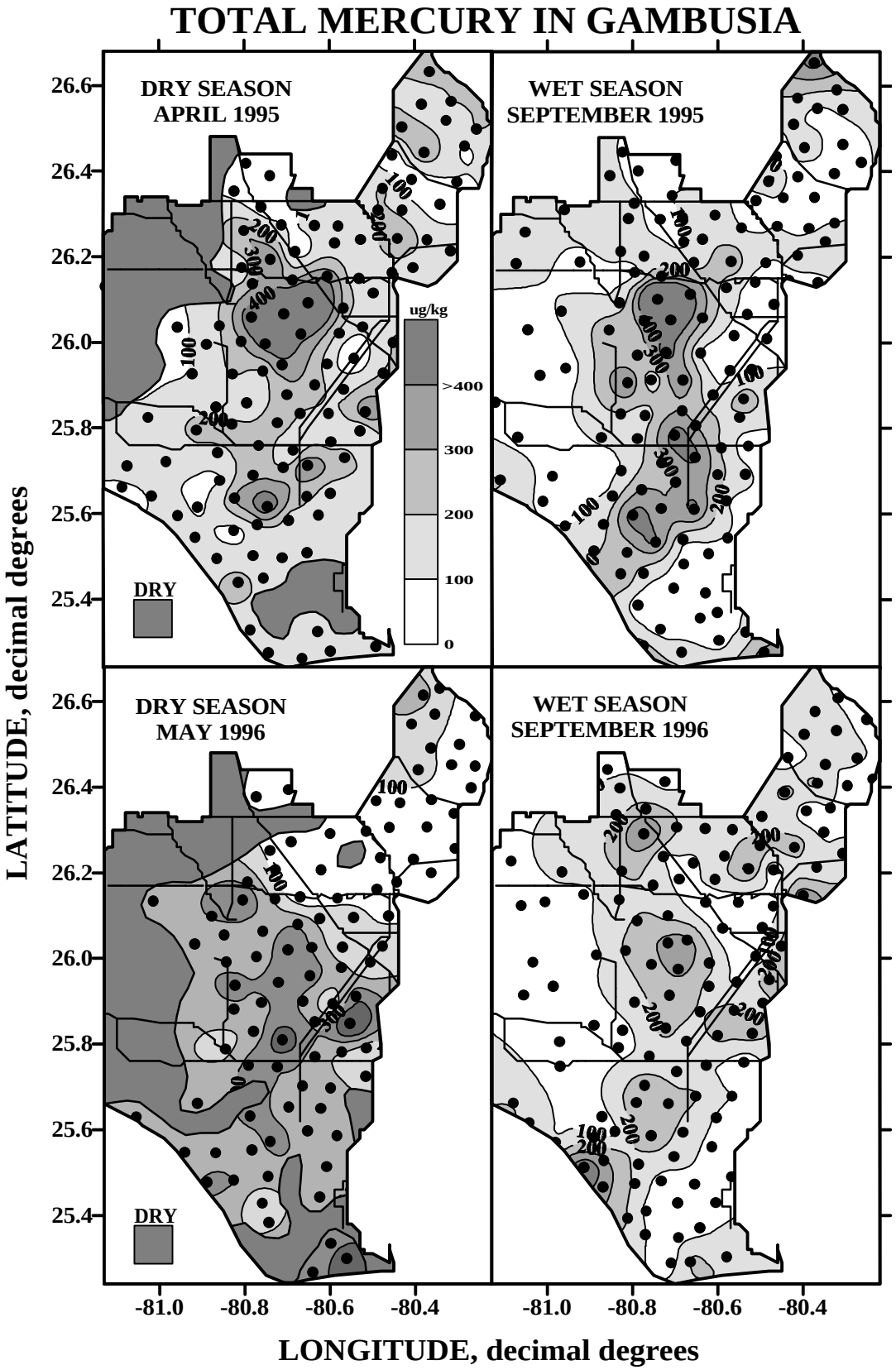

Figure 8.54 Kriged surfaces indicating concentrations of THg in mosquitofish collected in the marsh during each sampling cycle.

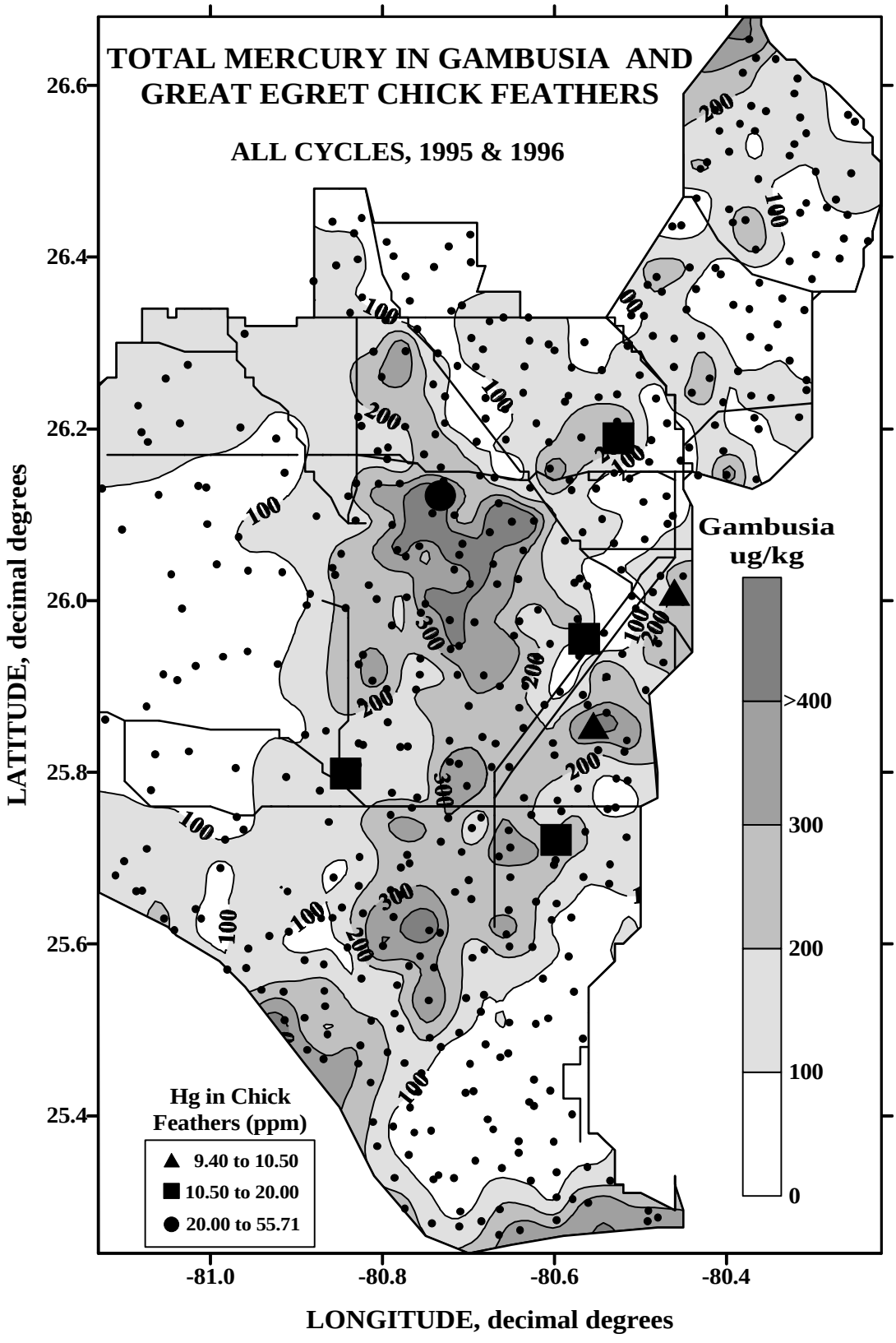

Figure 8.55 Hg concentrations in Great Egret chick feathers and mosquitofish indicate spatial distribution of Hg bioaccumulation.