Appendix 3B-1: Annual Permit Compliance Monitoring Report for Mercury in Downstream Receiving Waters of the Everglades Protection Area

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SUMMARY

This appendix summarizes data from compliance monitoring of mercury (Hg) influx and bioaccumulation in the downstream receiving waters of the Everglades Protection Area (EPA). The EPA comprises the Arthur R. Marshall Loxahatchee National Wildlife Refuge, which contains Water Conservation Area 1 (WCA-1); Water Conservation Areas 2A and 2B (WCA-2A and WCA-2B); Water Conservation Areas 3A and 3B (WCA-3A and WCA-3B); and Everglades National Park (ENP or Park). Results in this appendix are based on calendar year 2009 (CY2009) (January 1, 2009–December 31, 2009), except for bird feather collections, which are based on CY2010.

The key findings presented in this appendix are as follows:

1. Total annual deposition for the ENP in CY2009 was 167 kilograms of mercury per year (kg Hg/yr), a 14 percent decrease from CY2008. This figure represents the average of stations FL11 (the ENP), FL34 (Stormwater Treatment Area 1 West), and FL97 (Western Broward County). In CY2009, annual volume-weighted maximum total mercury (THg) concentrations differed slightly between the FL97 and FL11 stations; however, concentrations at both stations were significantly greater (approximately 16 percent) than at station FL34. Stations FL34 and FL97 showed the largest difference in annual deposition since CY2008, with a decrease of 13 and 30 percent, respectively. Typically, missed samples occur as a result of difficulties associated with sampling handling, low collection volumes, and mechanical failures. Consequently, estimates for both the volume-weighted (wet) concentration and annual wet deposition are to be viewed with caution.

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2. Mosquitofish (*Gambusia holbrooki*) collected from downstream marsh sites had THg levels ranging from 10 nanograms per gram (ng/g) at site WCA2F1 to 128 ng/g at site CA35ALT. The average basinwide concentration in 2009 was 65.7 ng/g, representing a 13 percent increase from the basinwide mean concentration in 2008. The grandmean for the period of record (POR) (1998–2008) over all basins is 64.3 ng/g (± 4.6). Since 2005, samples from sites WCA2U3, CA33ALT, CA315ALT, and ROTENC have shown increases in THg levels; however, only sites CA33 (Pearson $r = 0.99$, $p < 0.001$) and ROTENC (Pearson $r = 0.98$, $p = 0.002$) have shown statistically significant increases.
3. Sunfish (*Lepomis* spp.) collected from downstream sites had THg levels ranging from a minimum of 38 ng/g at site CA2NF to a maximum of 952 ng/g at site WCA2U3. The basinwide average concentration for sunfish in 2009 was 254 ng/g, representing a 20 percent increase since 2008. When the dataset was censored to only consider bluegill (*L. macrochirus*) and length-standardized mercury levels, sites CA35ALT, CA33ALT, CA315, ROTENC, and L67F1 had statistically higher THg levels than all the other sites. Sampling sites HOLYBC, WCA2U3, and CA33ALT had statistically significant temporal increases. The grandmean for the POR (1998–2009) over all basins is 183 ng/g (± 6.6). Based on arithmetic means, sunfish have shown an overall increase in THg concentration since 2008.
4. Fillets from individual largemouth bass (*Micropterus salmoides*) collected from downstream sites had tissue THg concentrations ranging from a minimum of 100 ng/g at site CA3F2 to a maximum of 2,270 ng/g at site WCA2U3. Site-specific, age-standardized concentrations (estimated for a 3-year-old bass symbolized as EHg3) ranged from 342 ng/g at site CA2NF to 1,070 ng/g at site WCA2U3. Standardized total mercury levels (EHg3) increased 39.7 percent from 2008 to 2009; however, this increase should be viewed with caution as this is an average of only five available EHg3 values.
5. Great egret (*Ardea alba*) feathers were collected from four locations within WCA-3 in CY2010. The range in feather THg concentrations was 1.0 to 12 micrograms per gram (μg/g). Overall, levels in 2010 were similar to levels in 2009; however, these levels were significantly reduced compared to average concentrations observed in chicks between 1994 and 1995 (14 μg/g to 21 μg/g).
6. Overall, THg concentrations in fish species increased from 11 to 40 percent in CY2009. Certain areas continue to be MeHg hot spots across South Florida wetlands or are showing reversing THg trends in recent years, such as the increases at sites HOLYBC in the Holeyland Water Management Area and WCA2U3 in WCA-2. Conversely, site L67F1 in the ENP, which has shown the highest fish THg levels since the beginning of the POR, has shifted toward lower concentrations, particularly for large-bodied fish. Site WCA2U3 is beginning to demonstrate some of the highest levels for all fish species. From these datasets, it appears the commonly observed north-to-south spatial trend in fish THg is changing, with concentrations becoming more uniform across the lower to middle portion of the EPA. The exception remains for stations within the northern section of WCA-2A and WCA-1. These areas remain relatively low in fish mercury levels. Based on guidance from the U.S. Fish and Wildlife Service and the U.S. Environmental Protection Agency on mercury concentrations in fish, localized populations of fish-eating birds and mammals continue to be at risk from adverse effects due to mercury exposure depending on their respective foraging areas. As such, most of South Florida remains under fish consumption advisories for the protection of human health.

INTRODUCTION

This appendix is the annual permit compliance report for calendar year 2009 (CY2009) (January 1, 2009–December 31, 2009) for fish and atmospheric deposition, summarizing the results of mercury (Hg) monitoring in the downstream receiving waters of the Everglades Protection Area (EPA). Additionally, this appendix summarizes data from great egret (*Ardea alba*) feather collections in CY2010. This report, in tandem with Appendix 5-5 of this volume, satisfies the mercury-related reporting requirements of the Florida Department of Environmental Protection (FDEP) Everglades Forever Act (EFA) permits [Chapter 373.4592, Florida Statutes (F.S.)], including permits for Everglades Stormwater Treatment Areas (STAs) 1 East, 1 West, 2, 3/4, 5, and 6 (STA-1E, STA-1W, STA-2, STA-3/4, STA-5, and STA-6). Fish data for STA-1W are reported in Appendix 5-5. In 2000, STA-1W subsumed the Everglades Nutrient Removal Project (Cells 1 through 4), which had been in operation since 1994.

BACKGROUND

In 1994, the Florida legislature enacted the EFA (Chapter 373.4592, F.S.) that established long-term water quality goals for the restoration and protection of the Everglades. To achieve these goals, the South Florida Water Management District (SFWMD or District) implemented the Everglades Construction Plan. A crucial element of EFA implementation was the construction of six wetlands, called Everglades STAs, to reduce phosphorus loading in runoff from the Everglades Agricultural Area (EAA). The original STAs were built mainly on formerly cultivated lands within the EAA and total over 26,000 hectares (approximately 65,000 acres, equating to approximately 45,000 acres of effective treatment area). The downstream receiving waters to be restored and protected by the EFA are part of the Everglades Protection Area (EPA). The EPA comprises the following defined regions: the Arthur R. Marshall Loxahatchee National Wildlife Refuge, which contains Water Conservation Area 1 (WCA-1); Water Conservation Areas 2A and 2B (WCA-2A and WCA-2B); Water Conservation Areas 3A and 3B (WCA-3A and WCA-3B); and Everglades National Park (ENP or Park).

Despite legislation and related goals, concerns were expressed that the restoration effort might inadvertently worsen the Everglades mercury problem while reducing downstream eutrophication (Mercury Technical Committee, 1991). Mercury is a persistent, bioaccumulative, toxic pollutant that can build up in the food chain to levels harmful to human and ecosystem health. Widespread elevated concentrations of mercury were first discovered in freshwater fish from the Everglades in 1989 (Ware et al., 1990). Based on the mercury levels observed in 1989, state fish consumption advisories were issued for select species and locations [Florida Department of Health and Rehabilitative Services (known as FDOH) and Florida Game and Fresh Water Fish Commission (currently the Florida Fish and Wildlife Conservation Commission or FWC), March 6, 1989]. Subsequently, elevated concentrations of mercury have also been found in predators, such as raccoons (*Procyon lotor*), alligators (*Alligator mississippiensis*), Florida panthers (*Felis concolor*), and wading birds (Fink et al., 1999).

A key to understanding the Everglades mercury problem is recognizing that it is primarily a methylmercury (MeHg) problem, not an inorganic or elemental mercury problem. MeHg is more toxic and bioaccumulative than the inorganic or elemental form. Elsewhere in the world, industrial discharge or mine runoff (e.g., chlor-alkali plant in Lavaca Bay in Texas, New Idria Mine in California, and Idrija Mercury Mine in Slovenia) can contain total mercury (THg) concentrations much greater (in some areas three-hundredfold higher) than that found in the Everglades, but at the same time have lower MeHg concentrations. In the Everglades, atmospheric loading has been found to be the dominant, proximate source of inorganic mercury, with the ultimate source likely being coal-fired utility boilers (far field) and municipal and medical waste incinerators (Atkeson and Parks, 2002). After deposition, a portion of this inorganic mercury is then converted to MeHg by sulfate-reducing bacteria (SRB) in the sediments of aquatic systems (Gilmour et al., 1992; Gilmour et al., 1998; Jeremiason et al., 2006). This methylation process is extraordinarily effective in the Everglades due to the availability of sulfate, the large pool of labile dissolved organic matter, and significant mercury source input from atmospheric deposition (Gilmour and Krabbenhoft, 2001; Renner, 2001; Bates et al., 2002).

To provide assurance that EFA implementation was not exacerbating the mercury problem, construction and operation permits for the STAs, issued by the FDEP, required that the District monitor the levels of THg and MeHg in various abiotic (e.g., water and sediment) and biotic (e.g., fish and bird tissues) media, within both the downstream receiving waters of the EPA and in the STAs (see Appendix 5-5). The downstream system is monitored to track changes in mercury concentrations over space and time in response to the changes in hydrology and water quality associated with the EFA.

SUMMARY OF THE MERCURY MONITORING AND REPORTING PROGRAM

RAINFALL

From 1992 through 1996, the District, the FDEP, the U.S. Environmental Protection Agency (USEPA), and a consortium of southeastern U.S. power companies sponsored the Florida Atmospheric Mercury Study (FAMS). The FAMS results, in comparison with monitoring of surface water inputs to the Everglades, showed that more than 95 percent of the annual mercury came from rainfall. As such, it was clear that the major source of mercury to the Everglades was from the atmosphere. Accordingly, the District continues to monitor atmospheric wet deposition of THg to the Everglades by collecting information from the National Atmospheric Deposition Program's (NADP) Mercury Deposition Network (MDN). Under MDN protocols, bulk rainfall samples are collected weekly at STA-1W (station FL34), Western Broward County (referred to as Broward County station FL97), and the ENP (station FL11) to measure wet deposition (i.e., dry deposition is not measured; for locations see **Figure 1**). Surface measurements at the Broward County station began at the end of November 2006, replacing former monitoring site Andytown station.

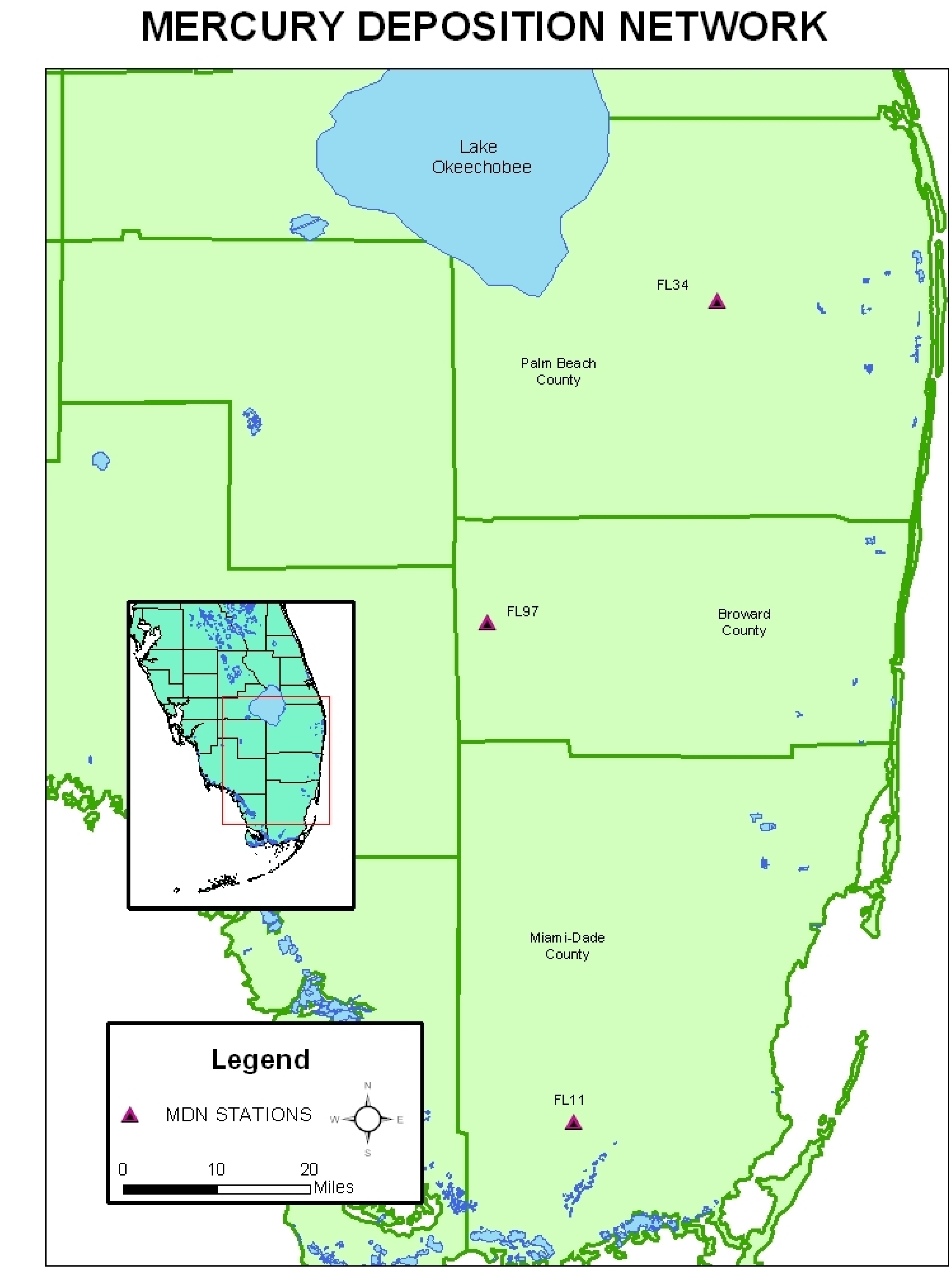

Figure 1. Mercury (Hg) deposition monitoring sites.

PREYFISH

Using a dip net, a grab sample of between 100 and 250 mosquitofish (*Gambusia* spp.) is collected during single sampling events at 12 downstream interior marsh sites **(Figure 2)**. Mosquitofish are selected as a representative indicator of short-term, localized changes in water quality because of their small range, short life span, and widespread occurrence in the Everglades. Mosquitofish become sexually mature at approximately three weeks of age and have an average life span of only four to five months (though some individual females may live up to 1.5 years); the life span of males is shorter than females (Haake and Dean, 1983; Haynes and Cashner, 1995; Cabral and Marques, 1999). After collection, the mosquitofish are homogenized, the homogenate is sub-sampled (aliquot), and each sub-sample is analyzed for THg. On March 5, 2002, the FDEP approved a reduction in the number of aliquots of the homogenate from five to three (correspondence from F. Nearhoof, FDEP). In March 2007, the District revised its use of three aliquots to one aliquot. In October 2007, the District took responsibility of analyzing all fish types (mosquitofish and large-bodied fish) for THg that do not require pesticide analysis. Samples needing both mercury and pesticide analysis are analyzed by the FDEP.

SECONDARY PREDATOR FISH

Up to 20 sunfish (*Lepomis* spp.) are also collected at the same 12 downstream interior marsh sites using electroshocking techniques **(Figure 2)**. Sunfish are thought to have an average life span of four to seven years in the wild. Each whole fish is analyzed for THg. Sunfish are prevalent in the Everglades and are the preferred prey for a number of fish-eating species; therefore, this species was selected as an indicator of mercury exposure for wading birds and other fish-eating wildlife.

TOP-PREDATOR FISH

Using electroshocking techniques, up to 20 largemouth bass (*Micropterus salmoides*) (LMB) are also collected at the 12 downstream interior marsh sites **(Figure 3)**; the fillets are analyzed for THg. Largemouth bass are long-lived (oldest bass collected as part of this effort was nine years old) and have been monitored at several Everglades sites since 1989. Therefore, LMB were selected as an indicator of potential human exposure to mercury.

Tissue concentrations in each of these three monitored fish species reflect ambient MeHg levels; i.e., their exposure is a function of a combination of factors, including body size, age, rate of population turnover, and trophic position. Mosquitofish should respond rapidly to changing ambient MeHg concentrations due to their small size, lower trophic status, short life span, and rapid population turnover. Conversely, sunfish and LMB should take a greater amount of time to respond, in terms of tissue concentrations, to changes in ambient MeHg availability. Most importantly, sunfish and LMB represent exposure at higher trophic levels (TLs) with a requisite time lag for trophic exchange. While focusing on 3-year-old bass is appropriate to evaluate exposure to fishermen, it complicates the data results by only interpreting tissue concentration integrated over a three-year period. The key is to use these species-related differences to better assess MeHg availability within the system.

More than 85 percent of the mercury found in the muscle tissue of fish is in the methylated form (Grieb et al., 1990; Bloom, 1992). Therefore, the analysis of fish tissue for THg, which is a more straightforward and less costly procedure than the analysis for MeHg, can be interpreted as being equivalent to the analysis of MeHg.

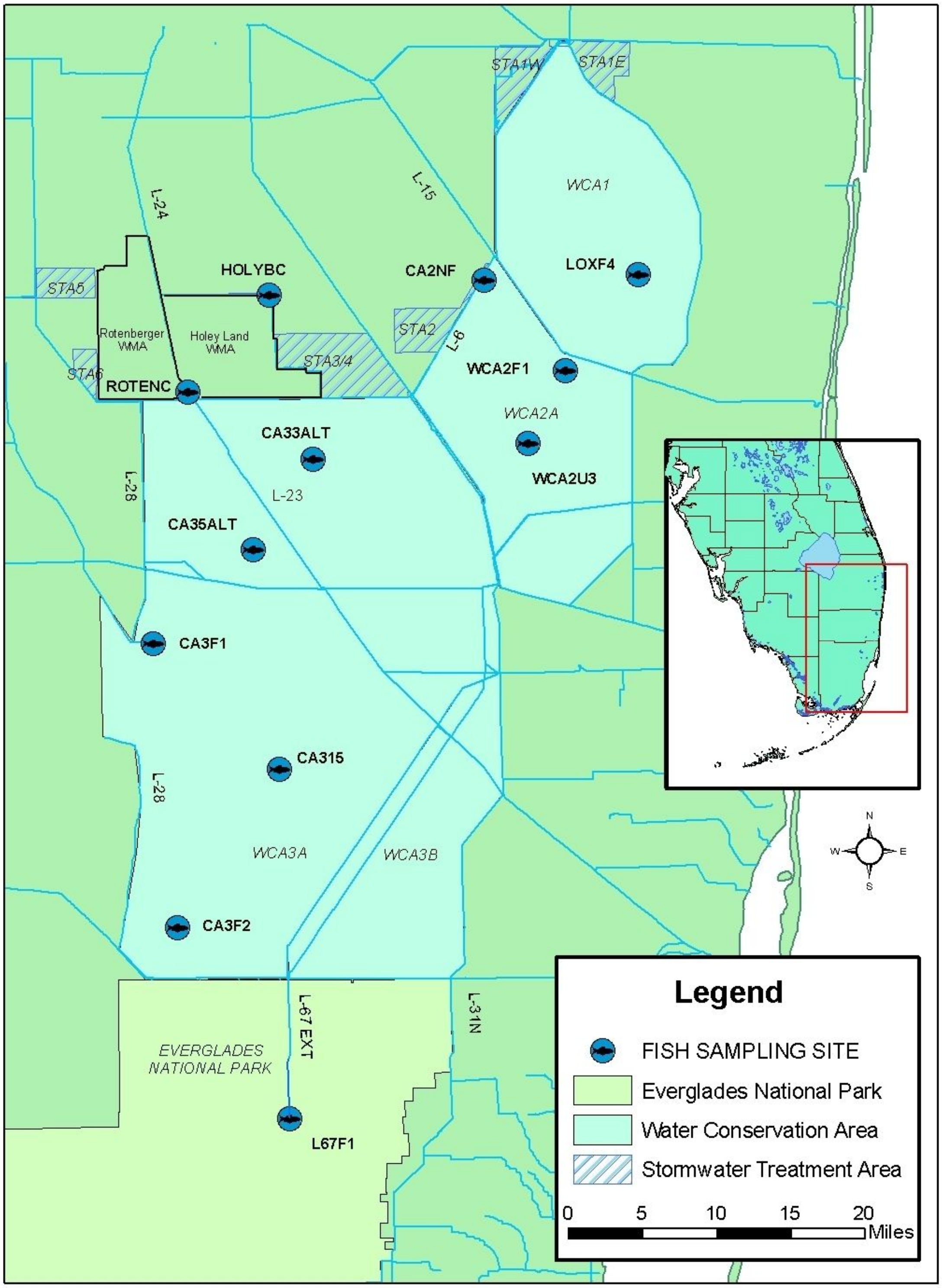

Figure 2. Collection sites for monitoring total mercury (THg) levels in mosquitofish (*Gambusia* spp.), sunfish (*Lepomis* spp.), and largemouth bass (*Micropterus salmoides*). [Note: site CA33ALT is an alternate site for CA33.]

FEATHERS

To monitor temporal trends in mercury bioaccumulation of fish-eating wildlife, the District collects feathers from great egret nestlings. The District's monitoring program has focused on two egret colonies, designated as JW1 and L67, which are located in WCA-3A (**Figure 3**). These two colonies consistently showed the highest THg concentrations during background studies (Frederick et al., 1997; FTN Associates, 1999; Sepulveda et al., 1999). However, nesting at the JW1 colony has been erratic in recent years and, consequently, samples have been collected from another nearby colony designated Cypress City (**Figure 3**). Under appropriate state and federal permits, feathers are collected (for THg analysis) from the oldest nestling in 10 nests in each of the two different nesting colonies. This is a modification from the sampling scheme initially proposed, which would have involved collecting molted feathers from post-breeding adults, either in the immediate vicinity of nests or from feathers found at STAs. This modified sampling design is more consistent with protocols used in the collection of background data (Frederick et al., 1997). In early 2009, the District contracted the University of Florida (UF) to conduct the annual juvenile egret feathers collections. This was set in place to streamline District costs and employ expert knowledge on great egret feather collection techniques. The UF researchers collected or attempted collection of feathers from the traditional District sites (Alley North, L67F1, Cypress City, and JW1) with additional collections from other areas within the WCAs (**Figure 3**). All sampling locations can be used to for the purpose of evaluating spatial and temporal THg trends in juvenile great egrets.

In addition to the monitoring program described above, in accordance with Condition 4.iv of the Mercury Monitoring Program, the District is required to "report changes in wading bird habitat and foraging patterns using data collected in ongoing studies conducted by the permittee and other agencies." Further details regarding rationales for sampling scheme, procedures, and data reporting requirements are in the District's Everglades Mercury Monitoring Plan revised in March 1999 (Appendix 1 of the Quality Assurance Protection Plan, June 7, 1999). Information about wading bird nesting activity is provided in Chapter 6 of this volume.

QUALITY ASSESSMENT FOR THE MERCURY MONITORING PROGRAM

See Appendix 5-5 (Annual Permit Compliance Monitoring Report for Mercury in the STAs) of this volume for details on all quality assurance and quality control measurements for data collected under the EFA permits.

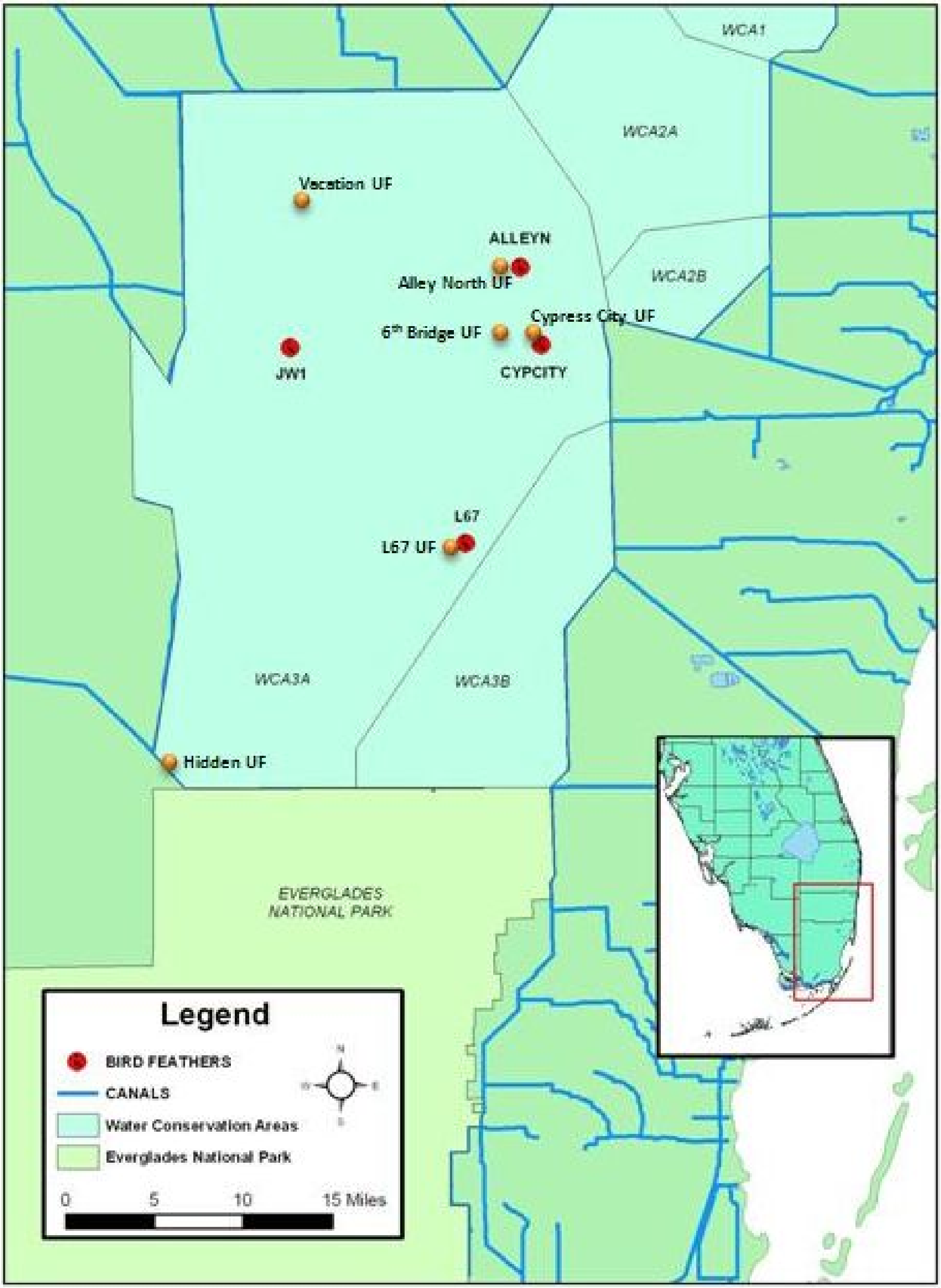

Figure 3. Collection sites for great egret (*Ardea alba*) nestling feathers. Although efforts to collect repeatedly from the same colony are made, colonies are sometimes inactive or abandoned, thus requiring collection at an alternate colony.

STATISTICAL METHODS

Temporal trends in atmospheric THg deposition were evaluated using the Seasonal Kendall test (SAS; for macro see USEPA, 1993), which is a generalization of the Mann-Kendall trend test for trend detection (Gilbert, 1987). The test is applied to datasets exhibiting seasonality, and may be used even though there are missing, tied, or non-detect values. The validity of the test does not depend on the data being normally distributed. However, use of this analysis presupposes the presence of large multiyear, multiseason datasets. Five years is the minimum dataset for proper use of both the test and standard statistical tables. Consequently, the application of this test on quarterly obtained data, some of which were unusable due to fatal qualifiers, should be approached cautiously, and results should be viewed as approximations only.

Monitoring mercury concentrations in aquatic animals provides several advantages. However, interpretability of residue levels in animals can be problematic due to the confounding influences of age or species. For comparative purposes, special procedures are used to normalize the data. Standardization to size, age, or lipid content is a common practice (Wren and MacCrimmon, 1986; Hakanson, 1980). To be consistent with the reporting protocol used by the FWC (Lange et al., 1998, 1999), Hg concentrations in LMB were standardized to an expected mean concentration in 3-year-old fish (EHg3) at a given site by regressing Hg on age (Lange et al., 1999). Because sunfish were not aged, age normalization was not available. Instead, arithmetic means were reported. However, efforts were made to estimate a least square mean (LSM) THg concentration based on the weight of the fish. Additionally, the distribution of the different species of sunfish, including warmouth (*L. gulosus*), spotted (*L. punctatus*), bluegill (*L. macrochirus*), and redear (*L. microlophus*), collected during electroshocking was also considered to be a potential confounding influence on THg concentrations prior to each comparison. To be consistent with the reporting protocol of Frederick et al. (1997; see also Sepulveda et al., 1999), THg concentrations in egret nestling feathers were similarly standardized for each site and were expressed as LSM for chicks with a 7.1 centimeter (cm) bill.

Where appropriate, an analysis of covariance (ANCOVA; SAS GLM procedure) was used to evaluate spatial and temporal differences in Hg concentrations with age (LMB), weight (sunfish), or bill size (egret nestlings) as a covariate. However, the use of ANCOVA is predicated on several critical assumptions (Zar, 1996), including that regressions are simple linear functions and are statistically significant (i.e., non-zero slopes); that the covariate is a random, fixed variable; that both the dependent variable and residuals are independent and normally distributed; and that slopes of regressions are homogeneous (parallel). Where these assumptions were not met, standard analysis of variance (ANOVA) or Student's t-test was used; possible covariates were considered separately. If multigroup null hypotheses were rejected under ANOVA, then the groups were compared using either Tukey HSD (Honestly Significant Difference; for equal-sized datasets) test or the Tukey-Kramer (for unequal-sized datasets). The assumptions of normality and equal variance were tested by the Kolmorogov-Smirnov and Levene Median tests, respectively. Datasets that either lacked homogeneity of variance or departed from normal distribution were natural-log transformed and reanalyzed. If transformed data met the assumptions, then they were used in ANOVA. If the assumptions were not met, then the raw datasets were evaluated using non-parametric Mann-Whitney or Kruskal-Wallis Rank sum tests. If the multigroup null hypothesis was rejected, then groups were compared using either Nemenyi test (for equal-sized datasets) or Dunn's Method (for unequal-sized datasets). Pearson Product moment (or the non-parametric equivalent Spearman Rank Order) was used to evaluate the relationship between two parameters. Linear regression was used to develop a line of best fit (linear model) between two parameters.

MONITORING RESULTS

RAINFALL: NATIONAL ATMOSPHERIC DEPOSITION PROGRAM, MERCURY DEPOSITION NETWORK

Samples of rainfall were collected weekly under the protocols of the National Atmospheric Deposition Program (NADP) Mercury Deposition Network (MDN) at STA-1W (FL34), the Baird Research Center in the Park (FL11), and the Western Broward County station (FL97) (**Figure 1**). For more information on MDN and to retrieve raw data, refer to the NADP's website, nadp.sws.uiuc.edu/mdn. In 2004, difficulties were encountered due to the landfall of four hurricanes (Rumbold et al., 2006). In 2005, the pattern and difficulties continued with the landfall or near misses of Hurricanes Katrina (fourth week of August), Rita (third week of September), and Wilma (fourth week of October). In 2004, the northernmost station, STA-1W, was most affected. In 2005, the southern station, ENP, was most significantly affected by the first two storms. During these events, the collectors recorded significant precipitation with little THg. All three collectors were non-functioning during Hurricane Wilma (2005). Therefore, among-year differences in both volume-weighted concentration and deposition must be viewed with caution. In 2009, missing samples at each station were due to a combination of no precipitation and mechanical failure.

Notwithstanding the uncertainties caused by tropical rainfall events and periodic mechanical failures, atmospheric deposition of THg to South Florida continues to be highly variable both spatially and temporally (**Table 1, Figure 4,** and **Figure 5**). As observed in the past, THg concentrations in precipitation were substantially higher during the summer months (**Figure 4**), likely due to seasonal and tall, convective thunderclouds that can scavenge particulate mercury and water-soluble reactive gaseous mercury from the middle and upper troposphere. This is commonly understood, as observed with several studies, e.g., Guentzel (1997); Lai et al. (2007); Selin and Jacob (2008). Because both THg concentrations and rainfall volumes generally increase during the summer, THg wet deposition typically peaks in mid-summer (**Figure 4**).

Table 1. THg concentration data [nanograms per liter (ng/L); wet only] from the compliance sites of the Mercury Deposition Network (MDN) in calendar year 2009 (CY2009).

Week Ending	STA-1W (FL34)	Broward (FL97)	ENP (FL11)
1/6/2009	NA	19.8	NA
1/13/2009	14.8	12.0	15.2
1/20/2009	7.67	NA	6.02
1/27/2009	NA	NA	NA
2/3/2009	3.00	5.85	6.61
2/10/2009	NA	NA	NA
2/17/2009	NA	NA	NA
2/24/2009	NA	NA	NA
3/3/2009	NA	NA	NA
3/10/2009	NA	NA	NA
3/17/2009	NA	NA	NA
3/24/2009	5.60	7.61	10.0
3/31/2009	6.20	NA	NA
4/7/2009	8.00	16.0	NA
4/14/2009	NA	NA	NA
4/21/2009	11.8	5.70	NA
4/28/2009	NA	NA	6.70
5/5/2009	NA	2.8	NA
5/12/2009	NA	11.5	NA
5/19/2009	16.9	12.6	9.65
5/26/2009	11.0	8.87	12.7
6/2/2009	10.5	9.60	9.52
6/9/2009	15.2	12.0	20.4
6/16/2009	17.4	13.1	20.2
6/23/2009	11.3	21.3	18.6
6/30/2009	12.3	13.1	17.4
7/7/2009	12.3	18.49	25.7
7/14/2009	18.0	24.2	36.8
7/21/2009	25.7	23.2	29.2
7/28/2009	21.2	28.1	16.4
8/4/2009	17.2	13.9	22.9
8/11/2009	32.5	36.1	16.8
8/18/2009	12.7	195	13.1
8/25/2009	12.6	17.4	21.1
9/8/2009	18.4	23.8	14.6
9/15/2009	11.4	14.1	14.5
9/22/2009	10.7	19.6	15.8
9/29/2009	14.8	NA	14.2
10/6/2009	11.9	3.70	10.8
10/13/2009	7.90	12.4	12.9
10/20/2009	NA	22.3	16.8
10/27/2009	NA	5.50	13.0
11/3/2009	7.60	6.60	3.70
11/10/2009	NA	NA	NA
11/17/2009	3.50	NA	14.1
11/24/2009	4.90	2.80	2.00
12/1/2009	35.5	NA	NA

Table 1. Continued.

Week Ending	STA-1W (FL34)	Broward (FL97)	ENP (FL11)
12/8/2009	6.60	4.80	7.70
12/15/2009	11.6	9.70	11.9
12/22/2009	3.60	2.50	6.20
12/29/2009	6.70	6.50	24.9
Volume-Weight Concentration (ng/L)			
1997*	18.70	NA	14.70
1998*	11.40	13.80[b]	12.70
1999*	10.80	12.30[b]	11.60
2000*	13.70	15.80[b]	13.60
2001*	13.90	13.20[b]	13.10
2002*	12.30	14.20[b]	12.10
2003*	16.10	16.40[b]	16.40
2004*	13.70[a]	14.70[b]	14.70
2005*	11.70	13.70[b]	10.60
2006*	12.60	14.90[c]	12.40
2007	11.80	11.30	14.50
2008	10.80	13.50	13.70
2009	12.60	14.96	14.80
Deposition Annual (µg/m^2)			
1997*	32.40	NA	27.20
1998*	26.10	20.10[b]	20.30
1999*	12.10	17.50[b]	17.70
2000*	14.30	18.10[b]	20.00
2001*	21.00	21.10[b]	18.00
2002*	10.30[a]	18.70[b]	18.20
2003*	17.80	28.50[b]	26.80
2004*	a	18.30[b]	18.70
2005*	11.50	14.50[b]	17.50
2006*	14.40	NA[a,c]	15.40
2007	13.50	22.30	16.80
2008	17.80	24.70	21.90
2009	15.65	17.55	22.81

*Adapted from 2008 South Florida Environmental Report – Volume I
[a] Rain gauge malfunction in 2004; several trips missed because of highly active tropical season (four hurricanes)
NA – Not available due to mechanical problems with collector, failure to meet quality control criteria, or no precipitation
NA[a] – No calculation due to (1) discontinuation of station FL04 and (2) not enough data existed for station FL97 to calculate annual deposition
[b] Data just from the Andytown station (FL04)
[c] Combination of data from the Andytown (FL04) and the Broward County stations (FL97)

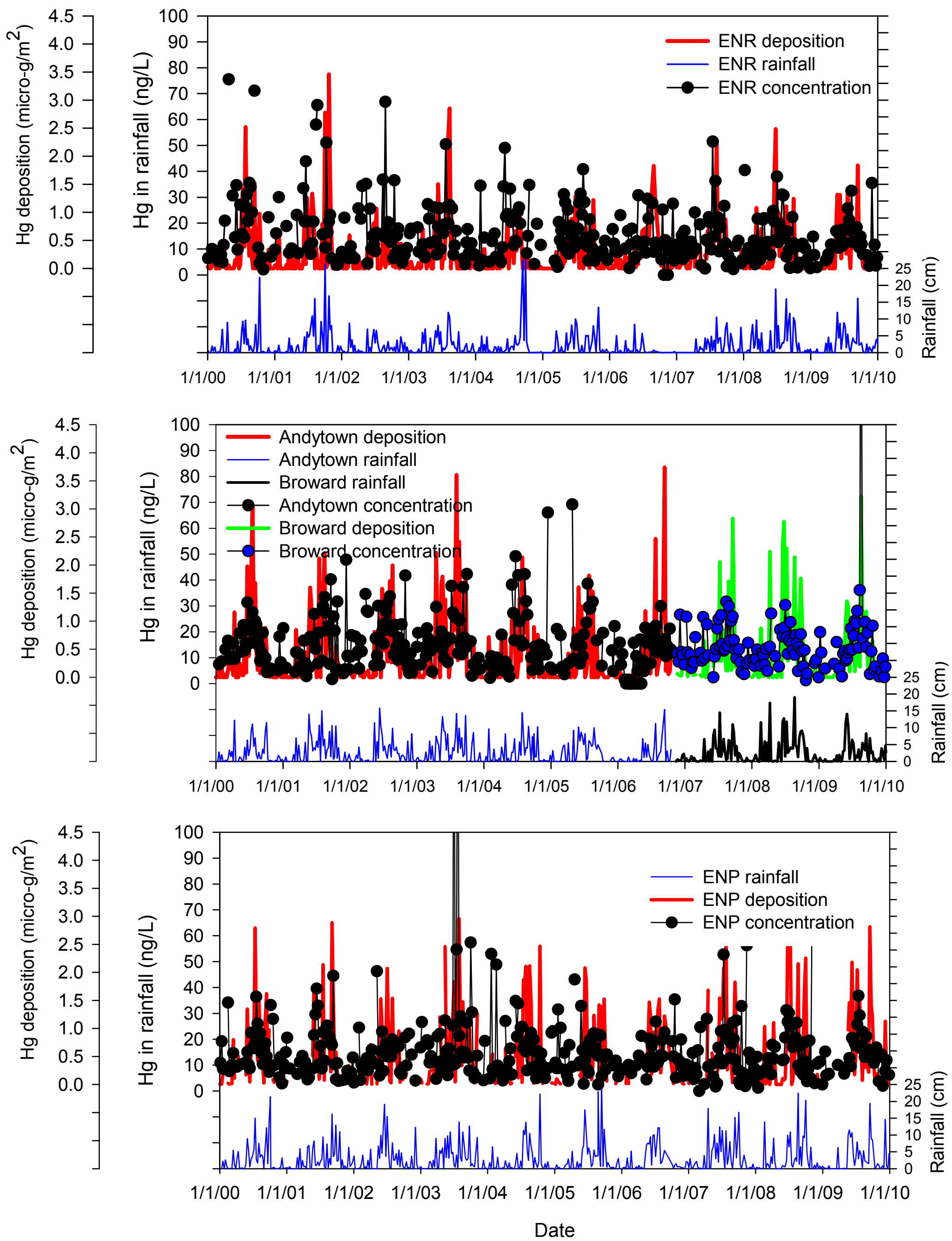

Figure 4. Time series of rainfall, rainfall Hg concentrations, and wet Hg deposition at STA-1W (FL34), Andytown (FL04), Everglades National Park (ENP) Bair Research Center (FL11), and Broward County (FL97), as reported by the Mercury Deposition Network (MDN). STA-1W (FL34) is the same site as ENR.

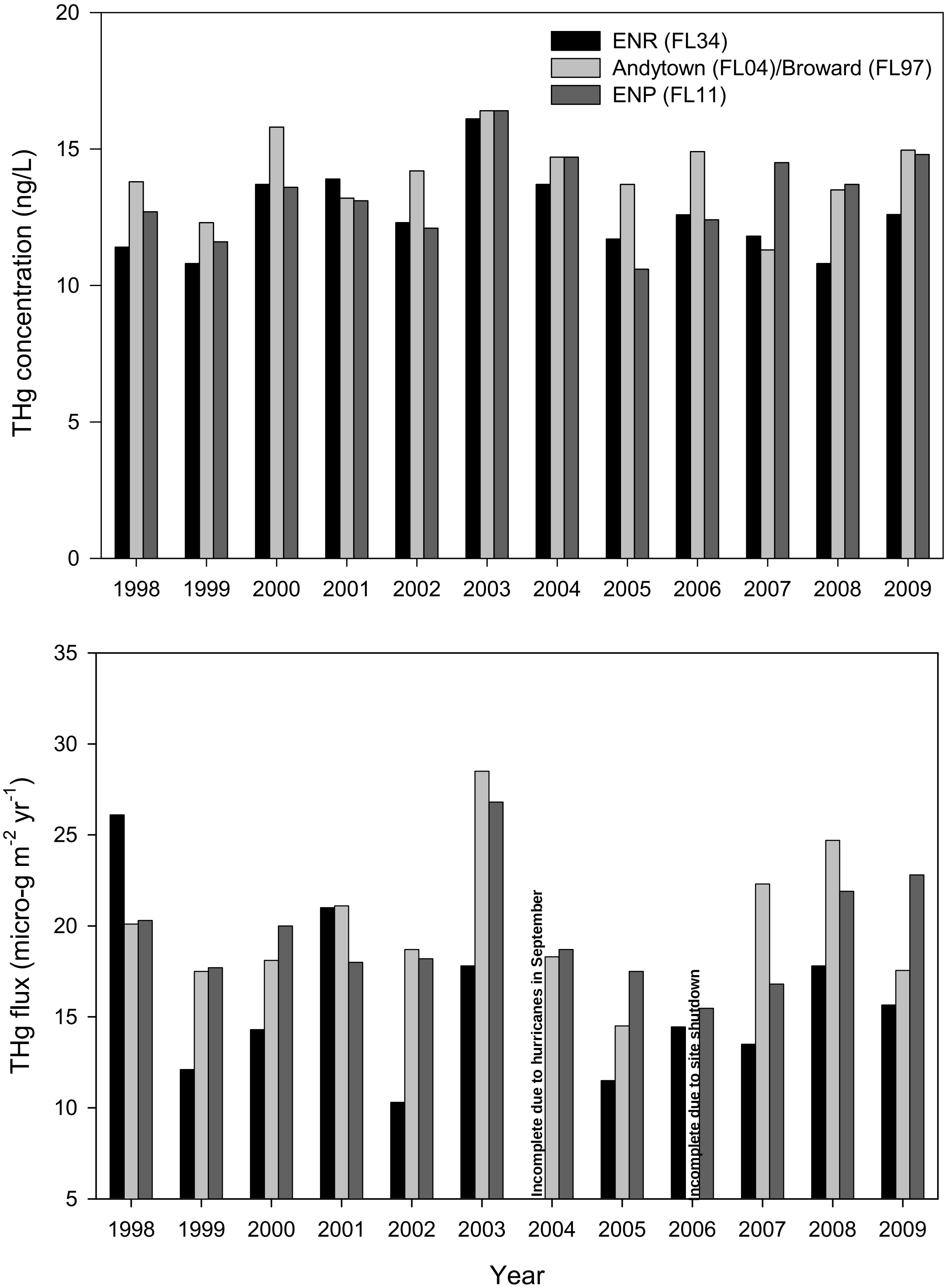

Figure 5. Time series of annual volume-weighted concentration (top) and annual THg flux (bottom) at three MDN stations. The Andytown site closed down in mid-2006 and was replaced with Broward County site FL97. STA-1W (FL34) is the same site as ENR.

In CY2009, annual volume-weighted THg concentrations differed slightly between the FL97 and FL11 stations; however, concentrations at each of these stations were significantly greater than concentrations at FL34 station (**Table 1** and **Figure 5**), which is similar to the scenario in CY2008. In general, as in past years, THg deposition tracks annual precipitation depth: 128 cm of rain versus 17.5 micrograms per square meter per year ($\mu g/m^2/yr$) (FL97), 126 cm versus 15.65 $\mu g/m^2/y$ (FL34), and 155 cm versus 22.8 $\mu g/m^2/yr$ (FL11). Sites FL34 and FL97 dropped significantly in deposition from CY2008–CY2009; however, the volume-weighted concentrations at these sites showed an overall slight increase. More specifically, site FL34 dropped in annual Hg deposition from 2008 to 2009 by 20 percent, site FL97 dropped by 30 percent, and site FL11 rose by 5 percent. An anomalously high THg concentration was observed during the week of 8/18/2009 at station FL97. From 2005–2009, all sites showed no apparent decreasing or increasing trend in atmospheric Hg deposition. Temporal trends are discussed further in the following section.

Seasonal Kendall analyses (of ranks) revealed a significant decreasing trend in monthly median THg concentrations at FL34 (1997–2009; n = 145 months; Tau = -0.154; p = 0.01); however, there was no trend for sites FL11 (1996–2009; n = 163 months; Tau = -0.012; p = 0.84) or FL97 (2007–2009; n = 36 months; Tau = -0.05; p = 0.88; (S. Hill, SFWMD, personal communication, July 1, 2010). The finding of no trends is consistent with a report by Nilles (2004) and previous District MDN investigations, which found no trends in volume-weight monthly averages from the three sites in South Florida. Seasonal Kendall analysis did not show any long-term trend in the monthly deposition at FL34 (n = 145 months; Tau = -0.035; p = 0.58), FL11 (n = 163, Tau = -0.003, p = 0.96) or FL97 (n = 36, Tau = 0.11, p = 0.65) (S. Hill, SFWMD, personal communication, July 12, 2010) for the 1997–2009 period of record (POR). There was a decrease in rainfall (Tau = -0.15, p = 0.01) at FL34 for the POR.

Based on the average deposition rates measured at the three sites, wet-only atmospheric loading of THg to the EPA (9.01×10^9 m^2) was estimated at 167 kilograms of mercury per year (kg Hg/yr) (**Table 3**). While the focus is only on wet deposition, dry deposition likely adds significantly (30 to 60 percent of wet deposition) to the overall atmospheric load (FDEP, 2003; Marsik et al., 2007). The estimate of 167 kg Hg/yr should be viewed with caution as mechanical failure and/or collection efficiency issues are associated with a number of samples collected. The overall decrease in atmospheric deposition from 2008 to 2009 is a result of drop in precipitation at stations FL34 and FL97.

Table 2. Atmospheric THg loading to the Everglades Protection Area (EPA).

Calendar Year	Atmospheric Deposition (kg Hg/yr)
1994[a]	238
1995[a]	206
2003	161-258[b]
2004	172[d]
2005	131[e]
2006	134[f]
2007	157[g]
2008	193[g]
2009	167[g]

[a] USEPA (2001, as cited by FDEP, 2003) annual deposition derived from Florida Atmospheric Mercury Study (FAMS), 1993–1996; surface water loading derived from biweekly monitoring of into structures discharging from the Everglades Agricultural Area into the Everglades Protection Area
[b] Rumbold (2005)
[d] Rumbold et al. (2006)
[e] Value highly uncertain due to passage or near misses of Hurricanes Katrina (fourth week of August), Rita (third week of September), and Wilma (fourth week of October) in 2005
[f] Based on average annual loading from FL34 and FL11
[g] Based on an average annual loading from FL34, FL11, and FL97

FISH FROM EFA AND NON-EFA INTERIOR MARSHES

Results from monitoring downstream interior marsh mosquitofish, sunfish, and LMB are summarized in **Tables 4** through **6**, respectively. Raw data for individual fish can be found on the District's website at www.sfwmd.gov/dbhydro. In 2009, 12 downstream marsh sites in the interior of the WCAs and the ENP (**Figure 2**) were targeted for fish collections. Three of these sites (LOXF4, WCA2U3, and CA315) have been monitored by the FWC since 1993. If fish could not be collected from a targeted marsh site due to inaccessibility, poor habitat, or both, collections defaulted to nearby marshes or, in some cases, canals where fish were more plentiful if source water was similar (approval for these alternate sites was received from the FDEP on March 5, 2002; correspondence from F. Nearhoof, FDEP).

Table 4. Concentrations [nanograms per gram (ng/g) wet weight] of THg in mosquitofish composites collected in CY2009 from downstream sites. Value presents the concentration of one aliquot.

Site	THg (ng/g)	Between-Year Change (%) (2008–2009)*	Cumulative Average (ng/g)
LOXF4	38.0	-21.1	56.0
WCA2F1	10.0	35.2	14.1
CA2NF	16.0	-60.8	83.5
HOLYBC	29.0	-49.3	39.1
ROTENC	100	18.5	56.1
WCA2U3	179	60.3	110
CA33ALT	105	30.7	49.1
CA35ALT	128	49.7	93.9
CA3F1	22.0	-119	48.2
CA315	88.0	98.3	83.3
CA3F2	24.0	0	41.8
L67F1	50.0	-48.4	100
Annual mean	**65.7**	**-0.49**	†**64.6**

*[(2009–2008)/Average]*100
NA – Data not available due to low water or no fish available
Note: Grandmean for period of record (POR) (1998–2009; aliquots pooled across time and space) ± 95% C.I. of mean: n = 445; 64.3 ± 4.6 ng/g; 50th, 75th, and 90th percentiles for POR were 53.0, 80.0, and 130 ng/g, respectively
† Mean includes dropped stations no longer under permit

Table 5. Mean concentrations (± 1 SD; ng/g wet weight) of THg in sunfish collected in CY2009 from marshes downstream of the Everglades Stormwater treatment Areas (STAs).

Site	Mean THg ng/g (± 1 SD, n)	Between-Year Change (%) (2008-2009)$	Grandmean (1998-2009) (ng/g)
LOXF4	135 (± 41.8, 20)	12.5	122
WCA2F1	NA	NA	65.1
CA2NF	137 (± 96.2, 20)	-22.0	125
HOLYBC	221 (± 113, 20)	-6.14	163
ROTENC	294 (± 89.9, 20)	20.2	189
WCA2U3	286 (± 41.8, 20)	-12.4	195
CA33ALT	403 (± 250, 20)	30.6	205
CA35ALT	566 (± 156, 3*)	60.5	214
CA3F1	135 (± 85.2, 20)	17.7	122
CA315	332 (± 111, 20)	63.5	273
CA3F2	148 (± 103, 2*)	28.5	119
L67F1	135 (± 184, 20)	-50.8	400
Annual Mean	254	12.9	183†

*Unable to collect 20 fish
$ [(2009–2008)/mean]*100
NA – Data not available due to low water or no fish available
Note: Grandmean of sites (pooled across space and time) for period of record (POR) (1998 to 2009) ± 95% C.I. of mean: n = 2,559, 183 ± 6.66 ng/g; 50th, 75th, and 90th percentiles for POR were 136, 240, and 373 ng/g, respectively
† Mean includes dropped stations no longer under permit

Table 6. Age-standardized (EHg3) and arithmetic mean concentrations of THg in largemouth bass fillets (ng/g wet weight) collected in CY2009 from non-Everglades Forever Act (non-EFA) marsh sites.

Site	EHg3 ± 95th C.I. (mean ± 1 SD, n) ng/g wet	Between-Year Change (%) (2008 to 2009)	Cumulative EHg3
LOXF4	NC (1) (221 ± 66, 20)	NA	439
WCA2F1	NA	NA	265
CA2NF	342 ± 78.8 (328 ± 158, 20)	-15.6	417
HOLYBC	562 ± 69.6 (537±179, 20)	9.89	565
ROTENC	NC (2) (456 ± 79, 13*)	NA	806
WCA2U3	1070 ± 34.6 (803 ± 379, 20)	32.1	773
CA33ALT	NC (2) (679 ± 214, 3*)	NA	1,311
CA3F1	433 ± 70.5 (323 ± 115, 20)	3.04	494
CA35ALT	NA	NA	NC(1)
CA315	NC (2) (507 ± 177, 20)	NA	812
CA3F2	NC (2) (267 ± 141, 7*)	NA	474
L67F1	1,060 ± 142 (1,000 ± 231, 20)	39.4	1,277

*Unable to collect 20 fish
NC – Not calculated for (1) insignificant slope or (2) poor age distribution
NA – Data not available due to low water or no fish available
Note: Grandmean for sites (pooled across space and time) for period of record (POR) (1998 to 2009) ± 95% C.I. of mean: n = 1,993, 545 ± 18 ng/g; 50th, 75th, and 90th percentiles for POR were 430, 674, and 1,000 ng/g, respectively

To preserve long-term datasets that are crucial for temporal trend assessment, reverting to the original target site will involve sampling at both the alternate and the original site for some period to assess spatial differences. Accordingly, sampling will revert to the original targeted site only after it has been established that long-term hydrologic and habitat restoration has occurred so that chances of finding fish year-to-year are high. Although this level of restoration may take a number of years at certain sites (e.g., sites WCA2F1, CA33ALT, and CA35ALT), waiting until fish are present consistently will prevent alternating collections between the two sites and the concomitant disruption of data continuity.

Fish collected in CY2009 showed both spatial and temporal patterns in tissue mercury concentrations. In keeping with the primary objective of the Mercury Monitoring Program, the focus will be on temporal changes in mercury concentration in fish tissues to assess possible adverse effects from the EFA construction components and the operation of the STAs. Nevertheless, spatial patterns of tissue mercury concentrations are important, particularly if there has been a variation from pre-EFA conditions established by the FWC. Therefore, spatial patterns will be reviewed in detail only where significant changes have occurred over time.

Mosquitofish

Mercury levels in mosquitofish collected from marsh sites in CY2009 ranged from 10 nanograms per gram (ng/g) at site WCA2F1 to 128 ng/g at site CA35ALT (**Table 4** and **Figure 6**). The average annual basinwide concentration in mosquitofish collected in CY2009 is 65.7 ng/g (**Table 4** and **Figure 2**), which represents a 13 percent increase from the basinwide mean concentration in 2008 (57.3 ng/g). The mean aliquot for tissue-mercury concentrations in mosquitofish for the POR (1998–2009; $n = 548$) was 64.6 ng/g. In CY2009, THg levels in mosquitofish declined at five of the 12 sites (**Table 4**). From CY2007–CY2009, concentrations increased at sites CA33ALT, CA35ALT, and CA3F1 and decreased at stations LOXF4, HOLYBC, ROTENC, CA3F2, and L67F1 (**Figure 6**). Since 2005, collections from sites WCA2U3, CA33, CA315ALT, and ROTENC have shown increases in THg levels; however, only sites CA33ALT (Pearson $r = 0.99$, $p < 0.001$) and ROTENC (Pearson $r = 0.98$, $p = 0.002$) have shown statistically significant increases. **Figure 7** shows that the spatial variability in mean mosquitofish THg levels is relatively high. A few stations reveal consistently low (e.g., L39F1, LOXF4) or high (L67F1) levels; however, there does not appear to be any definitive spatial trend or concentration gradient.

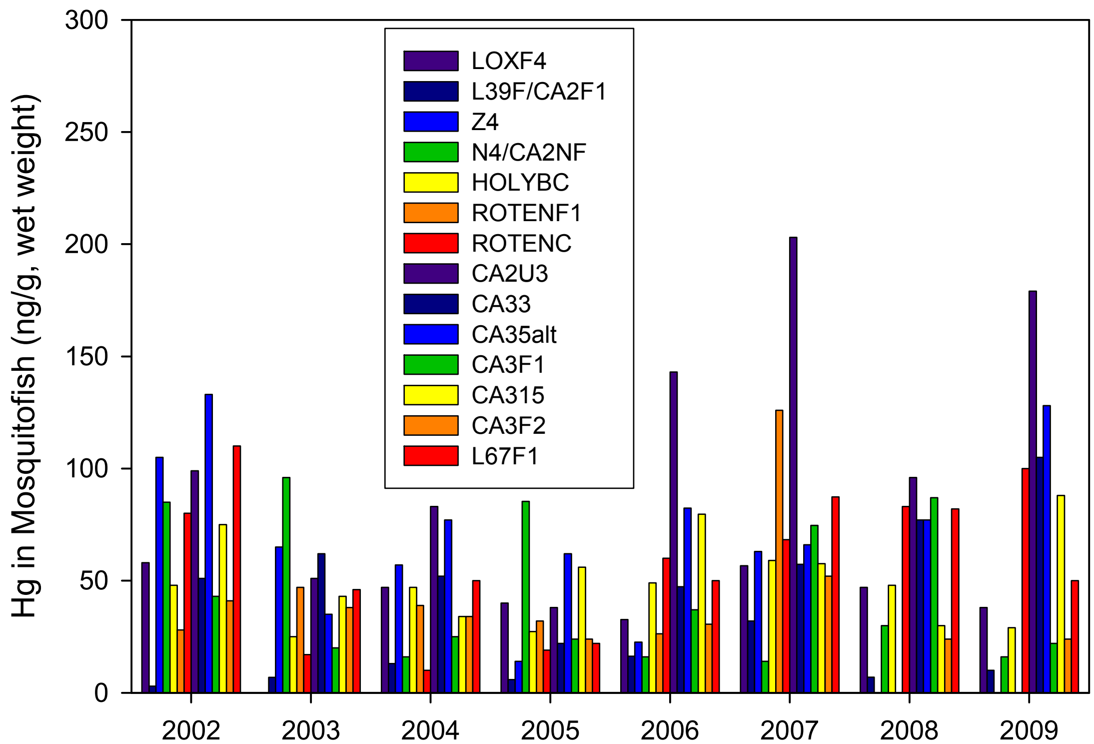

Figure 6. Hg concentrations in mosquitofish collected at non-EFA marsh sites. Not all sites were sampled in all years (see **Table 4**).

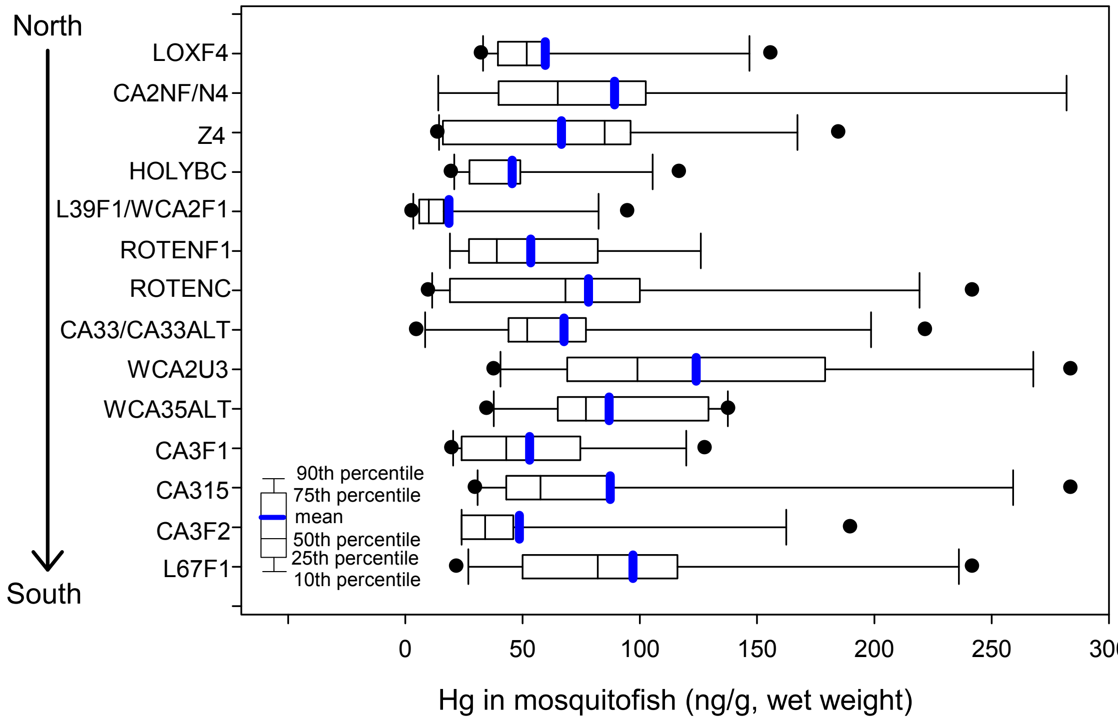

Figure 7. Hg concentration distributions in mosquitofish collected at non-EFA marsh sites for the POR (i.e., 1998–2009). Not all sites were sampled in all years (see **Table 4**).

Sunfish

Mercury levels in sunfish collected from downstream sites in CY2009 (n = 188) ranged from a low of 38 ng/g in a bluegill from site CA2NF to a high of 952 ng/g in a warmouth from site WCA2U3 (**Table 5**) in the northeastern portion of the EPA. The opposite occurred in 2007 and 2008, when the maximum concentration was observed toward the southern end of the EPA. However, low levels remain in or around L39F1 (WCA2F1). The grandmean of all sites in CY2009 was 254 ng/g compared to the grandmean of 208 ng/g in CY2008, indicating a 20 percent increase.

In CY2009, sunfish continued to show significant spatial variation in Hg levels (**Table 5**; **Figure 8**; df = 10; H = 90; $p < 0.001$). Fish from sites CA33ALT, CA35ALT, CA315, L67F1, and ROTENC contained the highest median concentrations (ranging from 286–482 ng/g) and sites CA35ALT and L67F1 were statistically greater than all other sites (Dunn's Method, $p < 0.05$). Because of differences in sizes and species of sunfish collected, the results must be interpreted with caution. Although there are statistical methods to address confounding factors, such as age or weight, addressing species differences is more problematic, particularly when convolved with size differences. As discussed in previous *South Florida Environmental Reports* (SFERs) (Rumbold et al., 2006; Gabriel et al., 2007), attempts to use ANCOVA to evaluate patterns of mercury concentrations in sunfish using weight as a covariate were often unavailable because concentration-weight relationship slopes were either not significant or not parallel for each year. For CY2009, ANCOVA could not be used once again because, among other requirements, datasets were non-normally distributed. Therefore, a robust alternative is to test the spatial variability using standardization. Overall, stations CA33ALT, L67F1, and CA315 exhibited the highest bluegill THg levels [1.84–3.11 nanograms per gram per millimeter (ng/g/mm)]; however, none of the pairwise comparisons were statistically different (Dunn's Method, $p > 0.05$).

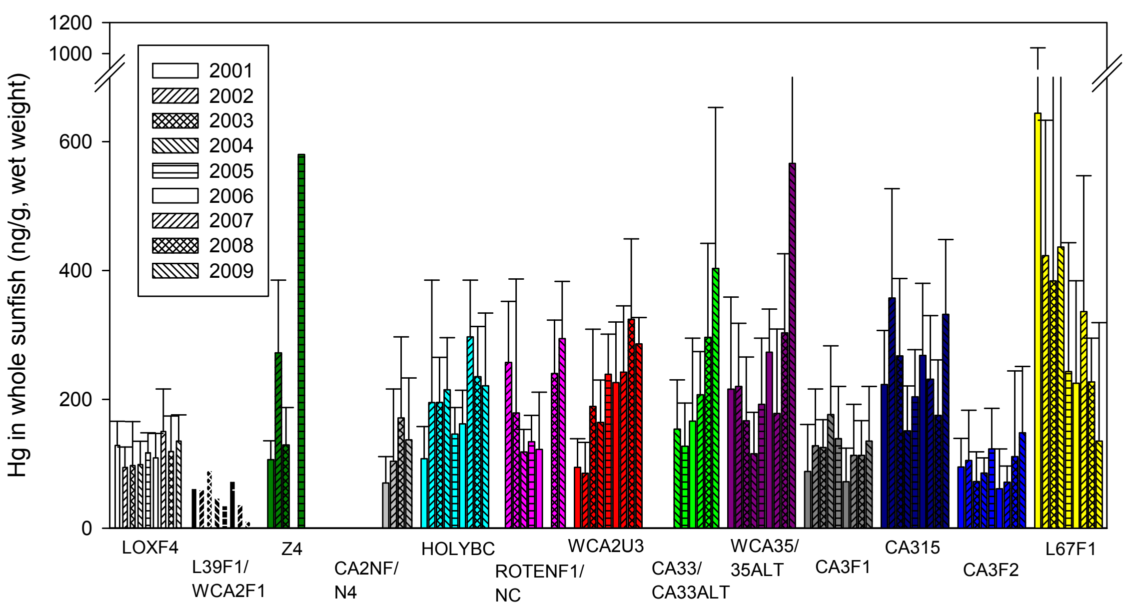

Figure 8. THg concentration of whole sunfish collected at Everglades Construction Project (ECP) and non-ECP sites from 2001–2009. Prior to 2006, collections were made at site Z4 (CA2NF/N4 after January 1, 2006).

As observed over the past several years, in CY2009 fish species were a significant factor in tissue mercury concentration when data were pooled across sites (Kruskal-Wallis ANOVA on Ranks; df = 3; H = 51.99; $p < 0.001$). In CY2009, mercury levels were statistically lower in bluegill (median length-standardized concentration = 0.99 ng/g/mm) and redear (median = 1.04 ng/g/mm) than in the other species, such as warmouth (median = 1.98 ng/g/mm) and spotted sunfish (median = 3.08 ng/g/mm) (Dunn's Method, $p < 0.05$). These species-specific medians are considerably higher than CY2008 results. The CY2009 concentrations, however, do not consider location as an independent variable; therefore, as a secondary check, a two-way ANOVA was run between location, species, and concentration, and statistical differences still existed for species type (F = 26.8, df = 3, $p < 0.001$). [Note: a two-way ANOVA (location|species) was disconnected due to the pattern of empty cells (invalidated data) and equal variance and normality tests failed, thus interactions were not investigated.] Differences existed between all species except between warmouth and bluegill (Tukey Method, $p < 0.05$). Overall, statistical differences in THg for each fish species indicate variation in diet, particularly between redear and spotted sunfish.

As depicted in **Figure 8**, sunfish appear to exhibit clear temporal variability in mercury burdens for most sites; however, these apparent trends may be again confounded by temporal differences in size or species of *Lepomid* collected. For example, the marked decline in mercury levels for CY2009 in sunfish from L39F1 (WCA2F1) may be an artifact of only collecting redear and bluegill (see above) compared with previous samples. Similarly, the increase in Hg levels in fish apparent at site CA33ALT may also be due to species type because the fish collected included many spotted sunfish. Spearman correlations were developed to evaluate whether concentrations increase progressively with time, specifically for stations that showed an increase since the start of the POR [LOXF4, HOLYBC, WCA2U3, and CA33ALT (**Figure 8**)]. Pearson correlation was used instead of ANCOVA to evaluate the effect of time, because the dependent variable (concentration) for each case was non-normally distributed (other ANCOVA rules apply; see Zar, 1996). To exclude this variability due to species and size, the sunfish dataset for 2009 was censored to assess only bluegill. To further reduce size-related effects, Hg levels were normalized by total fish length. Following standardization, three of the four sites showed progressive increases over time: HOLYBC ($p = 0.001$, $r = 0.796$), WCA2U3 ($p = 0.01$, $r = 0.68$), and CA33ALT ($p = 0.04$, $r = 0.832$).

Largemouth Bass

From October 2009 through November 2009, 163 largemouth bass (LMB) were collected at 10 downstream sites. Despite the FWC's best efforts, (the FWC was contracted to electrofish at these sites), LMB could not be collected from sites WCA2F1 and CA35ALT. LMB collected had tissue mercury concentrations ranging from a low of 100 ng/g in a 0.9-year-old LMB from site CA3F2 to 2,270 ng/g in a 6-year-old LMB from site WCA2U3. Site-specific, age-standardized concentrations (estimated for a 3-year-old bass symbolized as EHg3) ranged from 342 ng/g at site CA2NF to 1,070 ng/g at site WCA2U3 (**Table 6** and **Figure 9**). Calculation of EHg3 was not appropriate at sites LOXF4, ROTENC, CA3F2, CA33ALT, and CA315 either because the tissue mercury-age relationship was not significant or because of small sample size. Based on the sites where it was appropriate to calculate site-specific EHg3, the grandmean value was 693 ng/g in 2009, which represents a 39.7 percent increase over the grandmean estimated for 2008; however, this increase should be viewed with caution as this relies on only five regression calculations for 2009 and seven for 2008.

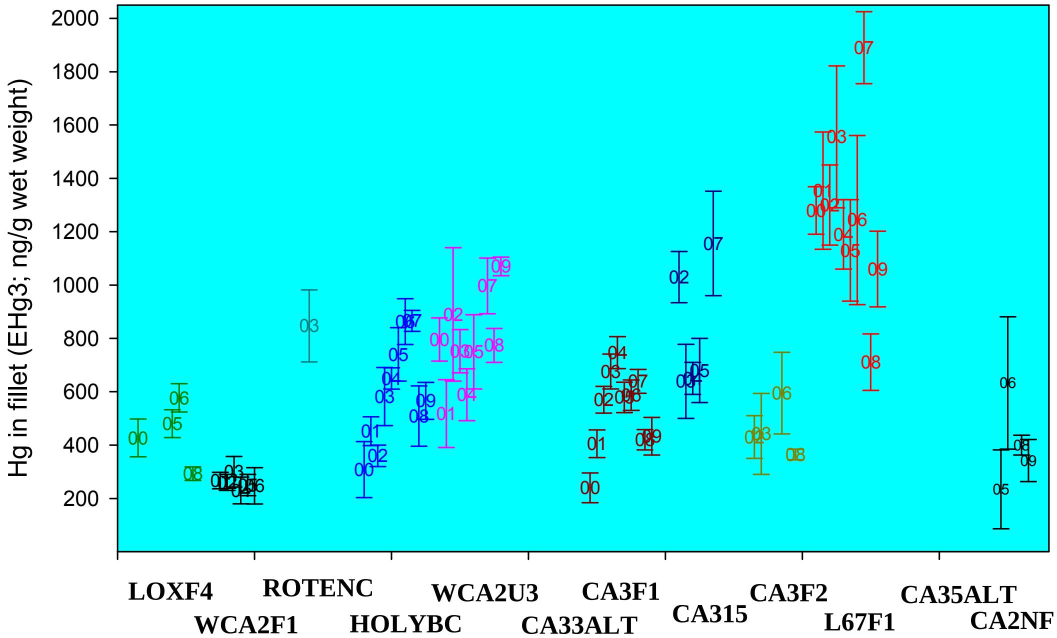

Figure 9. Age-standardized (estimated for a 3-year-old bass symbolized as EHg3) Hg concentrations in largemouth bass collected at downstream sites from 2000–2009. EHg3 was not calculated if regressions were not significant or if age distributions were narrow (see **Table 6**). Site WCA2F1 is the same as L39F1.

In 2009, LMB exhibited spatial patterns in tissue Hg concentrations similar to those observed in sunfish, with slightly higher concentrations occurring across the central sites (**Table 6** and **Figure 9**), which is similar to the trend found in 2007. The northernmost sites are still comparatively low. In previous years, a clear north-to-south trend was evident, with much higher concentrations in the southern sites. This shift in spatial trend in LMB mercury concentrations indicates a change in methylmercury production and/or bioaccumulation within the EPA. Because of a statistically significant interaction between location and age ($f = 27.0$; $df = 9$; $p < 0.001$), ANCOVA could not be used to assess differences in Hg levels among all sites. Therefore, a two-way ANOVA was used to test spatial differences. As in 2008, there were statistical differences with location ($df = 9$, $F = 53.47$, $p < 0.001$); however, a true location impact could not be evaluated because the interaction of location and age was not investigated [the two-way ANOVA was disconnected due to the pattern of empty cells (invalidated data) and equal variance and normality tests failed]. Results from the post-hoc test show that the concentration at site L67F1 was greater than at all other stations except CA33ALT (Tukey Method, $p < 0.05$).

As shown in **Figure 9,** the most apparent increasing temporal trends occur at site WCA2U3. For 2009, Pearson correlation was used to investigate these trends. After filtering all fish at these stations for 3-year-old LMB, this site demonstrated a statistically significant increase ($r = 0.40$, $p = 0.002$). Investigating the temporal trends using in-depth research at these stations may help to better understand factors causing mercury methylation fluctuations throughout the greater EPA.

PREDATOR PROTECTION CRITERIA

Mercury levels in fish tissues can also be evaluated and put into perspective regarding mercury risk to wildlife. The U.S. Fish and Wildlife Service (USFWS) has proposed a predator protection criterion of 100 ng/g of THg in prey species (Eisler, 1987). Likewise, the USEPA has proposed in a Mercury Study Report to the U.S. Congress a criteria of 77 ng/g and 346 ng/g for trophic level (TL) 3 and 4 fish, respectively, for the protection of fish-eating avian and mammalian wildlife (USEPA, 1997).

In CY2009, 36 percent of all mosquitofish collected (considered to be at TL 2 and TL 3, depending on age; Loftus et al., 1998) exceeded the USEPA criterion of 77 ng/g, and 30 percent exceeded the USFWS criterion of 100 ng/g. These exceedances were from the ROTENC, WCA2U3, CA35ALT, CA33ALT, and CA315 stations (**Table 4**). This is a slight increase over exceedances observed in CY2008. Sunfish also showed an increase since 2008. In 2009, 90 percent of all sunfish, which are TL 3, exceeded the USEPA criterion of 77 ng/g, 89 percent exceeded the USFWS 100 ng/g criterion, and 26 percent exceeded the EPA 346 ng/g criterion (**Table 5)**. In comparison, in 2008, 87 percent of all sunfish exceeded TL 3 criteria and 80 percent exceeded USFWS criteria of 100 ng/g. As discussed in previous reports, these findings are significant because sunfish and mosquitofish represent the preferred prey item of many fish-eating species in the Everglades.

There was also an increase for largemouth bass in 2009, however modest. In 2009, 39 percent of all LMB exceeded the guidance value for TL 4 fish [based on the following calculation: LMB (where whole body THg concentration) = 0.695 x fillet THg; (Lange et al., 1998)]. Thirty-five percent of all LMB exceeded the TL 4 criteria in 2008. Exceedances in 2009 were primarily at stations L67F1, WCA2U3, HOLYBC, CA33ALT, and CA35ALT. In 2009, four fish samples exceeded the USEPA human health criterion of 850 ng/g, which is a limited consumption criterion for women of child-bearing age and young children. These samples came from station WCA2U3 and L67F1. One fish sample exceeded the FDOH's human no consumption advisory of 1,500 ng/g, which was from station WCA2U3.

For more information on Florida fish consumption advisories see: www.doh.state.fl.us/floridafishadvice/. Based on 2009 findings, certain Everglades populations of fish-eating avian and mammalian wildlife continue to be at risk of adverse effects from mercury exposure depending on where they forage.

WADING BIRD FEATHERS FROM EVERGLADES CONSTRUCTION PROJECT INTERIOR MARSHES

In spring 2009 (March through June), the District contracted with UF to collect juvenile great egret feather samples from L67, Cypress City, and Alley North in addition to other UF selected sites within the WCAs (**Table 8**). The UF researchers collected samples at L67, Vacation, Alley North UF, Cypress City UF, Hidden, and 6Bridge (**Table 8**). Sample sizes ranged from two to 10 feather collections at each site. In total, 36 feather samples were collected and analyzed for THg. Despite the heterogeneity in sampling methods, locations, and sample quantities from year to year, there is an apparent decline in THg concentrations within great egret chicks for the POR (from 1994–2010), thus suggesting a decrease in mercury exposure (**Table 8**). A sharp drop occurred between 1994 and 1999. Site L67, which has the longest continuous record, showed that concentrations in 2010 are slightly above the levels found from 2006–2008.

Establishing a benchmark for critical feather THg concentration has been difficult because of observed or suspected interspecies differences in Hg sensitivity, particularly between piscivores and nonpiscivores and between freshwater birds and seabirds. However, Bouton et al. (1999) and Spalding et al. (2000) reported results of a controlled dosing study that combined feather analysis with toxicological observations of great egrets. Great egret juveniles were dosed with MeHg-containing gelatin capsules at 0.5 mg Hg/kg food (n = 5) and were found to have subtle behavioral changes and statistically significant differences in blood chemistry, liver biochemistry, and weight index (Bouton et al., 1999; Spalding et al., 2000). At five weeks, chicks in this dose group had 19 µg/g THg in feathers and showed a significant decline in packed cell volume (i.e., lowest observed effects level) (Spalding et al., 2000).

WADING BIRD HABITAT AND FORAGING PATTERNS

Critical environmental factors that determine the suitability of an area for foraging and nesting wading birds, e.g., water depth, vegetation density, and densities and size distribution of the preferred prey population, have been reviewed in previous consolidated reports (Rumbold and Rawlik, 2000). In accordance with Condition 4.iv of the Mercury Monitoring Program, the District conducts a literature search for published and unpublished studies or monitoring programs that may describe possible changes in wading bird habitat and foraging patterns within the Everglades and, as a consequence, their potential exposure to mercury. No new reports in 2010 were found; however, various individuals or agencies made systematic aerial and ground surveys of foraging and nesting wading birds in South Florida during the early 2010 breeding season. More details on wading birds are provided in Chapter 6 of this volume.

Table 8. Standardized least square mean of THg [micrograms per gram (µg/g)] for a chick with a 7.1 centimeter bill (arithmetic mean concentration ± 1 SD, n) in growing scapular feathers collected annually from great egret nestlings (2 to 3 weeks old) at colonies within Water Conservation Area 3A.

Year	JW1	L67/ L67UF	Cypress City/Cypress City UF	Alley North/Alley North UF	Vacation	Hidden	6Bridge
1994[1,2]	21 ± 6 (25 ± 8, 9)	16 ± 4 (NA)	NS	NS	NS	NS	NS
1995[2]	14 ± 3 (N/A ± 8)	16 ± 6 (16 ± 6, 14)	NS	NS	NS	NS	NS
1999	7 ± 1 (4 ± 2, 13)	NC (4 ± 2, 20)	NS	NS	NS	NS	NS
2000	7 ± 1 (3 ± 2, 10)	NC (3 ± 1, 10)	NS	NS	NS	NS	NS
2001	Failed to initiate nesting	NC (7 ± 3, 13)	NS	NS	NS	NS	NS
2002	Colony abandoned	NC (2 ± 0.5, 6)	NS	NS	NS	NS	NS
2003	Failed to initiate nesting	NC (5 ± 2, 3)	NC (6 ± 2, 15)	NS	NS	NS	NS
2004	Failed to initiate nesting	4 ± 2 (1 ± 1, 10)	5 ± 2 (2 ± 1, 10)	NS	NS	NS	NS
2005	NS	Failed to initiate nesting	NS	NC (4 ± 2, 3)	NS	NS	NS
2006	NS	NC (5 ± 2, 6)	NS	NC (3 ± 2, 8)	NS	NS	NS
2007	NS	NC (6.7 ± 3.7, 10)	NC (2.2 ± 1, 10)	NS	NS	NS	NS
2008[3]	NS	NA	NC (0.2, 2)	NA	NS	NS	NS
2009[3]	NS	NC (5 ± 1, 2)	NC (8 ± 3, 7)	NC (11 ± 4, 4)	NC (8 ± 3, 8)	NC (4 ± 2, 10)	NC (9 ± 3, 6)
2010[3]	NS	NC (7.7 ± 0.7, 2)	NC (7 ± 5, 10)	NC (9.7 ± 1.4, 10)	NS	NC (4 ± 1.7, 10)	NS

[1]Concentrations standardized to a bill length of 5.6 centimeters (cm)
[2]Data from P. Frederick et al. (1997)
[3]Data from P. Frederick, University of Florida
NA – Data not available
NC – Not calculated where slope of regression was not significant ($p > 0.05$)
NS – Not sampled
Estimated mean age of sampled nestlings based on bill length was 16 days in 1994; 24 days in 1995; 15 days in 1999; 16 days in 2000; 15 days in 2001; 13 days in 2002 and 2003; 12–14 days in 2004; 12 days in 2005; 28–29 days in 2006; 19 days in 2007; 28 days in 2008; 33 days in 2009; and 33 days in 2010

OPTIMIZING THE MONITORING NETWORK

The non-EFA mercury monitoring networks are routinely scrutinized to (1) streamline costs (2) improve scientific findings, and (3) adhere to compliance monitoring requirements. Specific changes to non-EFA monitoring during CY2009 (CY2010 for bird feathers) are summarized below. For updates on the permit compliance monitoring program for mercury in the STAs, refer to Appendix 5-5 of this volume.

DOWNSTREAM FISH MONITORING (PROGRAM HGFS):

- No changes or modifications in CY2009.

DOWNSTREAM GREAT EGRET FEATHER MONITORING (PROGRAM HGBM):

- No changes or modifications in CY2010.

MDN MONITORING:

- No changes or modifications in CY2009.

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