Appendix 2B-3: Annual Permit Compliance Monitoring Report for Mercury in Downstream Receiving Waters of the Everglades Protection Area

Darren Rumbold and Larry Fink

KEY FINDINGS AND OVERALL ASSESSMENT

This report summarizes data from compliance monitoring of mercury influx and bioaccumulation in the downstream receiving waters of the Stormwater Treatment Areas (STAs) during the reporting year May 1, 2001 through April 30, 2002. Results from this monitoring program describe significant spatial distributions and, in some instances, between-year differences in mercury concentrations.

Key findings are as follows:

1. As observed previously, rainfall volumes and total mercury (THg) concentration increased in late summer/early fall; consequently, atmospheric wet deposition of THg also increased during these months (i.e., the third and fourth quarter). Volume-weighted average concentrations of THg in rainfall were higher in 2000 and 2001 compared to the preceding two years at all three stations. Preliminary data also suggest substantially greater deposition at the Everglades Nutrient Removal (ENR) Project and Andytown in 2001 compared to the preceding two years. Conversely, deposition at Everglades National Park (ENP or Park) in 2001 was less than in 2000.
2. Generally, concentrations (i.e., not volume-weighted) of THg were similar to or lower than levels observed during the previous year at non-Everglades Construction Project (non-ECP) water control structures. More importantly, concentrations of methylmercury (MeHg) were greatly reduced compared to the spikes observed in the third and fourth quarters of 2000. As was previously observed, seasonal average concentrations of both THg and MeHg were highest in 2001 during the third quarter at the height of the wet season. There were no violations of the Florida Class III numerical Water Quality Standard of 12 ng/L during the reporting year.
3. The 2001 basin-wide average concentration of Hg in mosquitofish was 94 ng/g, representing a 33-percent increase from the 2000 basin-wide average concentration. Mosquitofish at most sites exhibited a pattern of dramatic increase in 1999 following a drydown and reflooding, decreasing substantially in 2000 but rebounding (increasing) in 2001. This among-year

difference in mercury concentration in mosquitofish was statistically significant, with levels in 1999 different from those in other years.

4. The basin-wide median Hg concentration declined slightly in sunfish in 2001 compared to the previous three years. While THg levels declined in sunfish at most sites in 2001, THg concentrations increased in sunfish at L-67F1, approaching peak levels observed in 1999. Between-year percent change from 2000 to 2001 ranged from a 63-percent increase at L-67F1 to a 64-percent decrease in concentration in sunfish from Water Conservation Area 2A-U3 (WCA-2A-U3).
5. In 2001, average tissue-Hg concentration in largemouth bass was 549 ±464 ng/g; median concentration was 390 ng/g. Similar to sunfish, basin-wide median concentration of Hg in bass was lower in 2001 relative to medians reported in 2000, 1999 and 1998. As with sunfish, the highest tissue Hg concentrations in bass occurred at L-67F1. Also, within-site temporal patterns in tissue Hg levels in bass (i.e., EHg3) were often similar to patterns observed in sunfish.
6. Based on U.S. Fish and Wildlife Service (USFWS) and U.S. Environmental Protection Agency (USEPA) guidance values, Everglades populations of piscivorous avian and mammalian wildlife continue to be at risk from adverse effects due to mercury exposure.
7. THg concentrations ranged from 1.5 to 3.1 µg/g dry weight in feathers taken from six great egret nestlings (mean ±1SD was 2.08 ±0.54), and from 9.5 to 19.0 µg/g in plumes from three adult egrets. These feather Hg concentrations were less than levels observed in 1994 or in 2001. While THg concentrations have varied in egret eggs since 1999, appearing to increase slightly in 2001 and then decreasing again in 2002, among-year differences were not statistically significant at either of the two colonies monitored.

INTRODUCTION

This is the fifth annual permit compliance monitoring report for mercury in the downstream receiving waters of the Everglades Protection Area (EPA). This report summarizes the mercury-related reporting requirements of the U.S. Army Corps of Engineers (USACE) Section 404 Dredge and Fill Permit (Permit No.199404532), the Florida Department of Environmental Protection (FDEP or Department) NPDES Permit (FL0177962-001), and the FDEP Everglades Forever Act (EFA) Permits (EFA Chapter 373.4592, F.S.). The latter includes permits for non-Everglades Construction Project discharge structures, Stormwater Treatment Area 6 (STA-6), STA-5, STA-1W and STA-2 (No. 06,502590709, 262918309, 0131842, FL0177962-001, 0126704). This report summarizes the results of monitoring in the reporting year ending April 30, 2002. This year, results of mercury monitoring within the STAs will be reported separately in the *2003 Everglades Consolidated Report* (2003 ECR) in **Appendix 4A-4** and **Appendix 4A-7**.

This chapter consists of key findings, an overall assessment, an introduction, a background, a summary of the Mercury Monitoring and Reporting Program, and monitoring results. The background section briefly summarizes the operation of the STAs and discusses their possible impact on South Florida's mercury problem. The next section summarizes sampling and reporting requirements of the Mercury Monitoring Program. Monitoring results are then summarized and discussed. Recent results from the Mercury Monitoring and Reporting Program describe significant spatial distributions and, in some instances, among-year differences in mercury concentrations.

BACKGROUND

The STAs are treatment marshes designed to remove nutrients from stormwater runoff originating from upstream agricultural areas. The STAs are being built as part of the Everglades Construction Project (ECP). When completed, the ECP will include six STAs that will comprise about 43,000 acres of constructed wetlands. The downstream receiving waters to be restored and protected by the ECP include the South Florida Water Management District's (SFWMD's or District's) water management canals of the Central and Southern Florida (C&SF) Project and the interior marshes of the Everglades Protection Area (EPA) encompassing WCAs 1, 2 and 3 and Everglades National Park (ENP or Park).

Concerns were raised that in reducing downstream eutrophication, this restoration effort might inadvertently worsen the Everglades mercury problem (FGMFWTF, 1991). Widespread elevated concentrations of mercury were first discovered in freshwater fish from the Florida Everglades in 1989 (Ware et al., 1990). Mercury is a persistent, bioaccumulative, toxic pollutant that can build up in the food chain to levels harmful to human and ecosystem health. Based on mercury levels observed in 1989, state fish consumption advisories were issued for select species and locations (Florida Department of Health and Rehabilitative Services and Florida Game and Fresh Water Fish Commission, March 6, 1989). Subsequently, elevated concentrations of mercury have also been found in predators, such as raccoons, alligators, Florida panthers and wading birds (Fink et al., 1999).

To provide assurance that the ECP is not exacerbating the mercury problem, the District monitors concentrations of total mercury (THg) and methylmercury (MeHg) in various abiotic (e.g., water and sediment) and biotic (e.g., fish and bird tissues) media within the STAs and downstream. Monitoring mercury concentrations in aquatic animals provides several advantages. First, MeHg occurs at a much greater concentration in biota relative to the surrounding water, making chemical analysis more accurate and precise. Although detection levels of parts per trillion (ppt, or ng/L) have been achieved for THg and MeHg in water, uncertainty boundaries can become large when ambient concentrations are very low, as is often the case in the Everglades. Second, organisms integrate exposure to MeHg over space and time. While surface water concentrations fluctuate daily, per event, and seasonally, mosquitofish are a short-lived species and can therefore be used to monitor short-term changes in environmental concentrations of mercury through time. Sunfish and largemouth bass, on the other hand, are long-lived species and represent average conditions that have occurred over previous years. Finally, the mercury concentration in aquatic biota is a true measure of MeHg bioavailability and is a better indication of possible exposure to fish-eating wildlife than the concentration of MeHg in water.

SUMMARY OF THE MERCURY MONITORING AND REPORTING PROGRAM

The monitoring and reporting program summarized below is described in detail in the Mercury Monitoring and Reporting Plan for the Everglades Construction Project, the Central and Southern Florida Project, and the Everglades Protection Area, which the District submitted to the FDEP, the USEPA and the USACE in compliance with the requirements of the aforementioned permits. The details of the procedures to be used in ensuring the quality of and accountability for the data generated in this monitoring program are set forth in the District's Quality Assurance

Project Plan (QAPP) for the Mercury Monitoring and Reporting Program, which was approved on issuance of the permit by the FDEP. The FDEP approved QAPP revisions on June 7, 1999.

PRE-OPERATIONAL MONITORING AND REPORTING REQUIREMENTS

Levels of THg and MeHg in various compartments (i.e., media) of the downstream receiving waters collected prior to the operation of the first STA define the baseline condition from which to evaluate the mercury-related changes, if any, brought about by STA operation. The pre-ECP mercury baseline conditions are defined in the Everglades Mercury Background Report, which summarized all the relevant mercury studies conducted in the Everglades through July 1997, during the construction of but prior to the operation of the first STA. Originally prepared for submittal in February 1998, it has now been revised to include the most recent data released by the USEPA and the U.S. Geological Survey (USGS) and was submitted in February 1999 (FTN Associates, 1999).

OPERATIONAL MONITORING AND REPORTING REQUIREMENTS

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 brought about by the Everglades Construction Project (for site locations, see **Figures 1**, **2** and **3**).

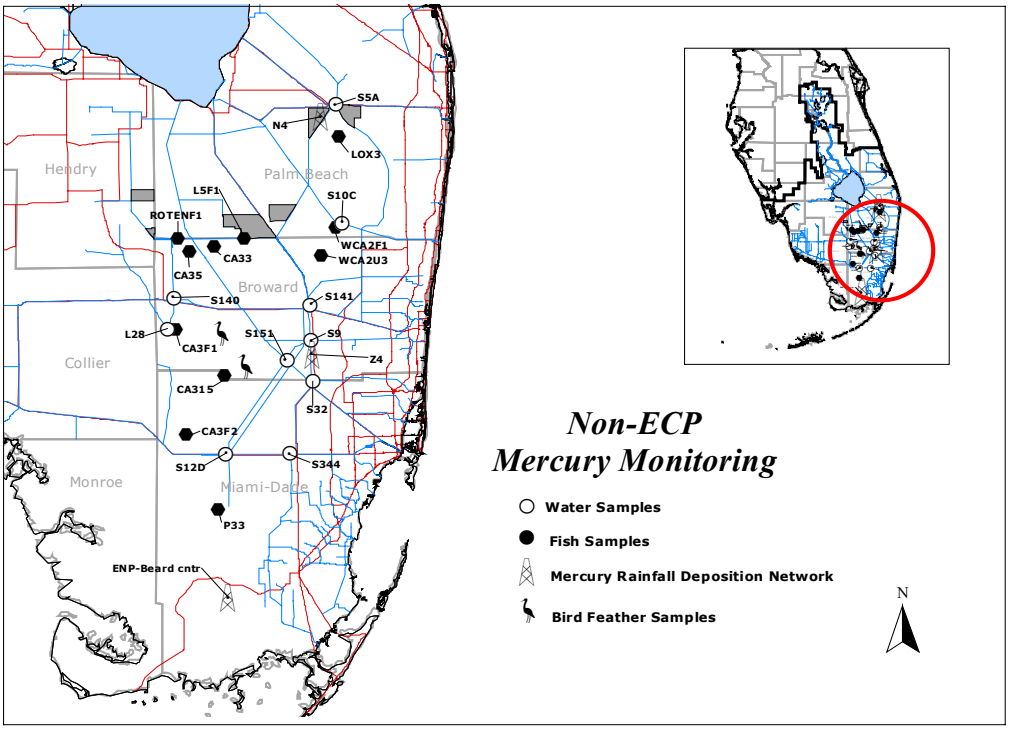

Figure 1. Map showing all non-ECP mercury monitoring test sites. Errata: N4 and Z4 are fish collection locations in WCA-2, MDN sites are ENR and Andytown, respectively

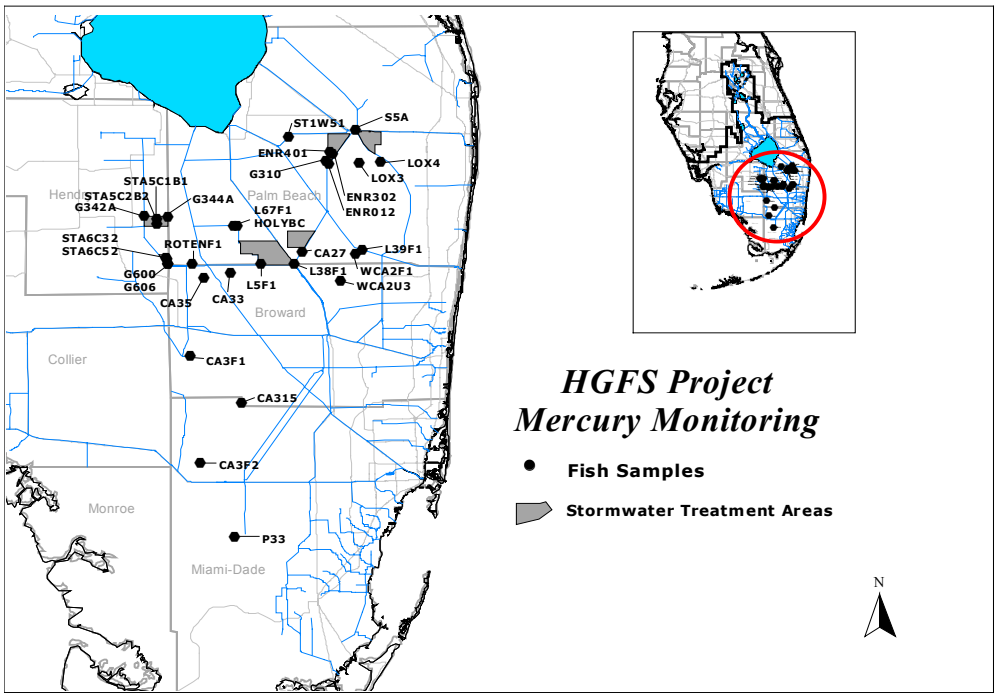

Figure 2. Map showing collection sites for monitoring mercury levels in mosquitofish, sunfish and largemouth bass

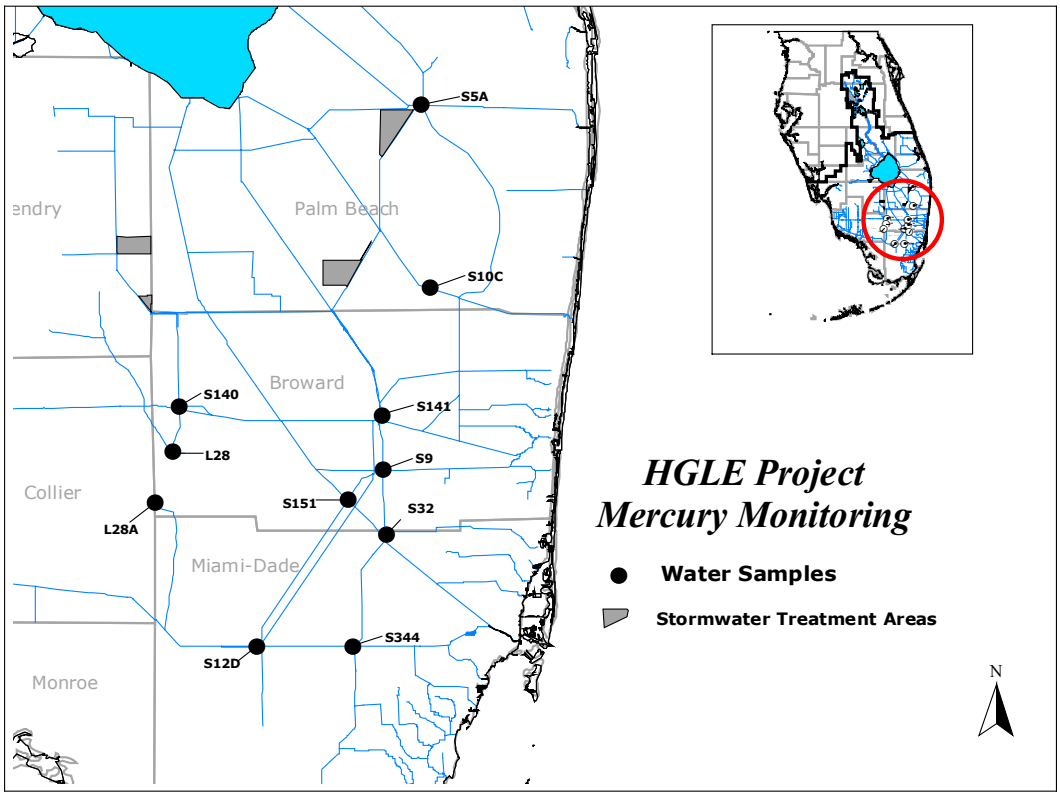

Figure 3. Map showing non-ECP structures where unfiltered surface water is collected quarterly to monitor concentration of total and methylmercury

Rainwater

From 1992 to 1996, the District, the FDEP, the USEPA and a consortium of southeastern United States power companies sponsored the Florida Atmospheric Mercury Study (FAMS). FAMS results, in comparison with monitoring of surface water inputs to the Everglades, showed that greater than 95 percent of the annual mercury budget came from rain. As such, it was clear that the major source of mercury to the Everglades was from the air. Accordingly, the District continues to monitor atmospheric wet deposition of THg to the Everglades by participating in the National Atmospheric Deposition Program's Mercury Deposition Network (MDN). Following MDN protocols, bulk rainfall was collected weekly at the top of 48-foot towers located at the Everglades Nutrient Removal (ENR) Project at the Andytown substation of Florida Power and Light (I-75/U.S. 27) and Everglades National Park. The samples were then analyzed for THg.

District Structures Surface Water

Unfiltered grab samples of water were collected quarterly using an ultra-clean technique upstream of structures S-5A, S-10C, S-140, S-9, S-32, S-151, S-141, S-190/L-28 interceptor, S-334 and S-12D. The samples were then analyzed for THg and MeHg. These sites bracket the WCAs or are major points of inflow or outflow. Monitoring of these sites is intended to capture the effect of seasonal changes in the relative contributions of rainfall and stormwater runoff contributing to water quality entering the EPA.

Preyfish

A grab sample of between 100 and 250 mosquitofish (*Gambusia* sp.) was collected annually using a dipnet at 12 downstream interior marsh sites. The fish were then homogenized, the homogenate was subsampled in quintuplicate, and each subsample was analyzed for THg. This species was selected as a representative indicator of short-term, localized changes in water quality because of its small range, short lifespan and wide occurrence in the Everglades.

Secondary Predator Fish

Twenty fish in the genus *Lepomis* (sunfish species) are to be collected annually at 12 downstream interior marsh sites and each whole fish is to be analyzed for THg. Because of their widespread occurrence, and because they are a preferred prey for a number of fish-eating Everglades species, sunfish (*Lepomis* spp.) were selected as an indicator of mercury exposure to wading birds and other fish-eating wildlife.

Top-predator Fish

Twenty largemouth bass (*Micropterus salmoides*) were collected annually (primarily via electroshocking) at 12 downstream interior marsh sites and their muscle was analyzed for THg. Largemouth bass were selected both as an indicator of potential human exposure to mercury and because this species has been monitored at several Everglades sites since 1989.

It is important to note that virtually all (> 85 percent) the mercury in fish tissues is in the methylated form (Grieb et al., 1990; Bloom, 1992; SFWMD, unpublished data). Therefore, the analysis of fish tissue for THg, which is a more straightforward and less-costly procedure than for MeHg, can be interpreted as being equivalent to the analysis of MeHg.

Feathers

Feathers will be collected annually from 20 great egret nestlings from two different nesting colonies within WCA-3A and will be analyzed for THg under appropriate state and federal permits (WX99076, MB007948-1). Because MeHg bioaccumulates in top-predator fish, the fish-eating birds, including wading birds, are the most highly exposed organisms in the Everglades. Note that this is a modification from the sampling scheme initially proposed, which would have involved collecting molted feathers from post-breeding adults at or 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 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 can be found in the Everglades Mercury Monitoring Plan revised in March 1999 (Appendix 1 of QAPP, June 7, 1999).

Quality Assurance and Quality Control Measures

The following section is an assessment of the District's Mercury Monitoring Program during the reporting year May 1, 2001 through April 30, 2002. Where appropriate, this section evaluates data quality in terms of accuracy, precision and completeness. This assessment is based on data quality objectives contained in the District's Quality Assurance Project Plan for the Mercury Monitoring and Reporting Program, which was approved on issuance of the permit by the FDEP (FDEP, revisions approved June 7, 1999).

Quality assurance (QA) and quality control (QC) are integral parts of all monitoring programs. A stringent QA/QC program is especially critical when dealing with ultra-trace concentrations of analytes in natural and man-modified environments. Quality assurance includes design, planning, and management activities conducted prior to implementation of a project to ensure that the appropriate kinds and quantities of data will be collected. QA is intended to ensure that the following four goals are met: (1) standard collection, processing, and analysis techniques will be applied consistently and correctly; (2) the number of lost, damaged and uncollected samples will be minimized; (3) the integrity of the data will be maintained and documented from the point of sample collection to the time the data is entered into the data record; and (4) data are useable based on project objectives. When using multiple laboratories, it is also important to establish and maintain comparability of performance and results among participating laboratories.

QC measures are incorporated to evaluate data quality during sample collection and laboratory analysis. QC measures give an indication of measurement error and bias (or accuracy and precision). Aside from using these results as an indication of data quality, an effective QA program must utilize QC results to determine areas of improvement and implement corrective measures. QC measures include both internal and external checks. Typical internal QC checks include replicate measurements, internal test samples, method validation, blanks and use of standard reference materials. Typical external QC checks include split and blind studies, independent performance audits and periodic proficiency examinations. Because mercury-related degradation of water quality is being defined in this project relative to baseline data generated by one or more laboratories, data comparability is a primary concern. Comparability of reporting

units and calculations, database management processes, and interpretative procedures must be ensured if the project's overall goals are to be realized.

Laboratory Quality Control

Comparability of laboratory performance was ensured through compliance with the requirements in USEPA Methods 1631 Rev. B ("Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry, 821/R-96-001), Draft Method 1630 (Methylmercury in Water and Tissues by Distillation, Extraction, Aqueous Phase Ethylation, Purge and Trap, Isothermal GC Separation, Cold Vapor Atomic Fluorescence Spectrometry 01A0007846 CD-98-1600 08/01/1998), Method 245.5 (Mercury in Sediment by Cold Vapor AAS; 600/4-79-020), Method 245.6 (Mercury in tissues by Cold Vapor AAS, 600/4-91-010) and Method 245.7 (Mercury-CVA Fluorescence spectrometry; CD-98-Stan 02/01/1999), which identify performance-based standards and the appropriate levels of QA/QC. The District utilizes laboratories certified by the Florida Department of Health under the National Laboratory Accreditation Program (NELAP).

Both laboratories under contract to the District in the past year had some level of deviation from the original reference method, EPA1631. As discussed in last year's Everglades Consolidated Report (ECR), the primary laboratory (Florida Department of Environmental Protection Central Laboratory) had applied to the USEPA for an alternate test procedure (ATP) from Method 1631 for ultra-trace THg determination. This request resulted from a necessity to modify digestion protocol to allow in-bottle digestion and subsequent re-use of Teflon bottles. However, in May 2001 the monitoring program switched from Teflon to single-use glass bottles. Consequently, the ATP was no longer necessary, and accordingly the laboratory's revised digestion protocol was fully compliant with Method 1631. It was determined that the secondary laboratory's deviations from the reference method did not affect the quality of data generated for the District. The reference method is under revision by the USEPA, taking differences in laboratory technology into account.

Field Quality Control Samples

A total of 364 field QC (FQC) samples (e.g., trip blanks, equipment blanks, field blanks, field duplicates, replicate samples and split samples) were collected with unfiltered surface water samples at STA-1W, STA-2, STA-5, STA-6 and non-ECP structures during the reporting year (**Tables 1** and **2**). This represents 42 percent of the 858 samples collected. These FQC check samples demonstrated that two persistent problems that had been noted in last year's 2002 ECR (blank contamination and variable field precision) were addressed and corrected during the 2002 reporting year. As is evident from **Table 1**, the frequency of occurrence of target analytes in blanks was reduced from previous years. This reduction in blank contamination likely resulted from corrective actions taken by both laboratories that included additional internal monitoring of de-ionized distilled water (DDW) systems, which generate the analyte-free water used in preparing FQC blanks systems, and the use of disposable glass bottles. Switching from re-use Teflon bottles to single-use glass bottles (as of May 10, 2001) eliminated an apparent bottle memory problem that significantly improved field precision (note: glass bottles for MeHg collection are pre-cleaned and heated to eliminate reported trace MeHg contamination). As is shown in **Table 2**, mean relative percent differences (RPDs) and relative standard deviation (RSD) between field duplicates (FDs) and among replicate samples (RS), which are sent to the laboratory as blind duplicates, ranged from 4 percent to 17 percent.

Table 1. Frequency of occurrence and mean concentration (ng/L) of target analyte in field quality control (FQC) blanks collected with unfiltered surface water samples from STA-1W, STA-2, STA-5, STA-6 and non-ECP structures. Note, method detection limits (MDLs) are 0.1 ng THg/L and 0.022 ng MeHg/L

FQC*	THG						MeHg					
	n**	Collection frequency	n>MDL	ng/L	V‡ flagged	% flagged	n**	Collection frequency	n>MDL	ng/L	V‡ flagged	% flagged
TB	24	6%	0	-	0	0%	23	5%	7	0.05	2	9%
LABQC	8	2%	0	-	0	0%	2	0%	0	-	0	0%
EB1	23	5%	2	0.03	1	4%	23	5%	7	0.05	3	13%
EB2	21	5%	0	-	0	0%	22	5%	6	0.04	0	0%
EB (unlabled)	19	4%	1	0.35	1	5%	17	4%	1	0.04	0	0%
FB	24	6%	1	0.32	0	0%	24	6%	11	0.05	3	13%

*TB - trip blank, LABQC -bottle & DI water check, EB - equipment blank, EB1 - equipment blank collected at start of sampling, EB2 - equipment blank collected at the end of sampling, FB - field blank.

** Total number (n) of unfiltered surface water samples collected under these 5 projects during the water-year was 428 THg and 430 MeHg.

‡ Indicates that the analyte was detected in the method blank.

Table 2. Relative percent difference (RPD) between field duplicates and relative standard deviation (RSD) among replicate samples, as reported by the primary laboratory

Analyte	RPD				RSD			
	N	Mean	Median	Max.	n	Mean	Median	Max.
THg	22	4%	3%	18%	6	11%	10%	21%
MeHg	22	17%	13%	75%	7	12%	9%	40%

Interlaboratory Comparability

To ensure further comparability (i.e., reproducibility) between this and other ongoing mercury sampling initiatives, split samples were submitted to the secondary laboratory (Frontier Geoscience, Inc.) for independent analysis of THg and MeHg. It should be noted that this laboratory also generated all the pre-ECP soil and water data for the STAs and the non-ECP structures, respectively. However, the primary laboratory generated all the baseline fish data.

Water

Results from independent analyses of split water samples collected at non-ECP structures (n = 18 samples, or 2 percent of water samples collected) are summarized in **Figure 4**. RPD between paired ultra-trace THg data ranged from 6.6 percent to 66.7 percent, with no statistically significant (consistent) bias (paired t-test; df = 8, t = 0.686, p = 0.512).

Alternatively, ultra-trace MeHg concentrations in surface water splits exhibited variance from the expected 1-to-1 line (**Figure 4**), with RPD between splits averaging 71 percent (range: 14 percent to 99 percent). The difference between laboratories was statistically significant (paired t-test, df = 8, t = 5.22, $p < 0.001$).

Fish

Split samples of 107 of the 998 large-bodied fishes (i.e., 11 percent of whole sunfish homogenates and fillets of largemouth bass) collected during the reporting year were sent to the secondary laboratory (FGS, Inc.) for independent analysis. As shown in **Figure 5**, the primary laboratory reported slightly higher concentrations for fishes with mid-level THg, but lower concentrations for fishes with low-level THg relative to the secondary laboratory. Interestingly, this is the reverse of the pattern observed the previous year (Rumbold and Fink, 2002). Splits were highly correlated (Pearson Product Moment correlation, df = 107, r = 0.97, $p < 0.001$), with an average RPD of 26 percent (maximum RPD was 110 percent). This difference between laboratories was statistically significant (paired t-test, df = 106, t = − 2.23, p = 0.03); however, concentrations differed by only 40 ng/g on average (ranged up to 149 ng/g).

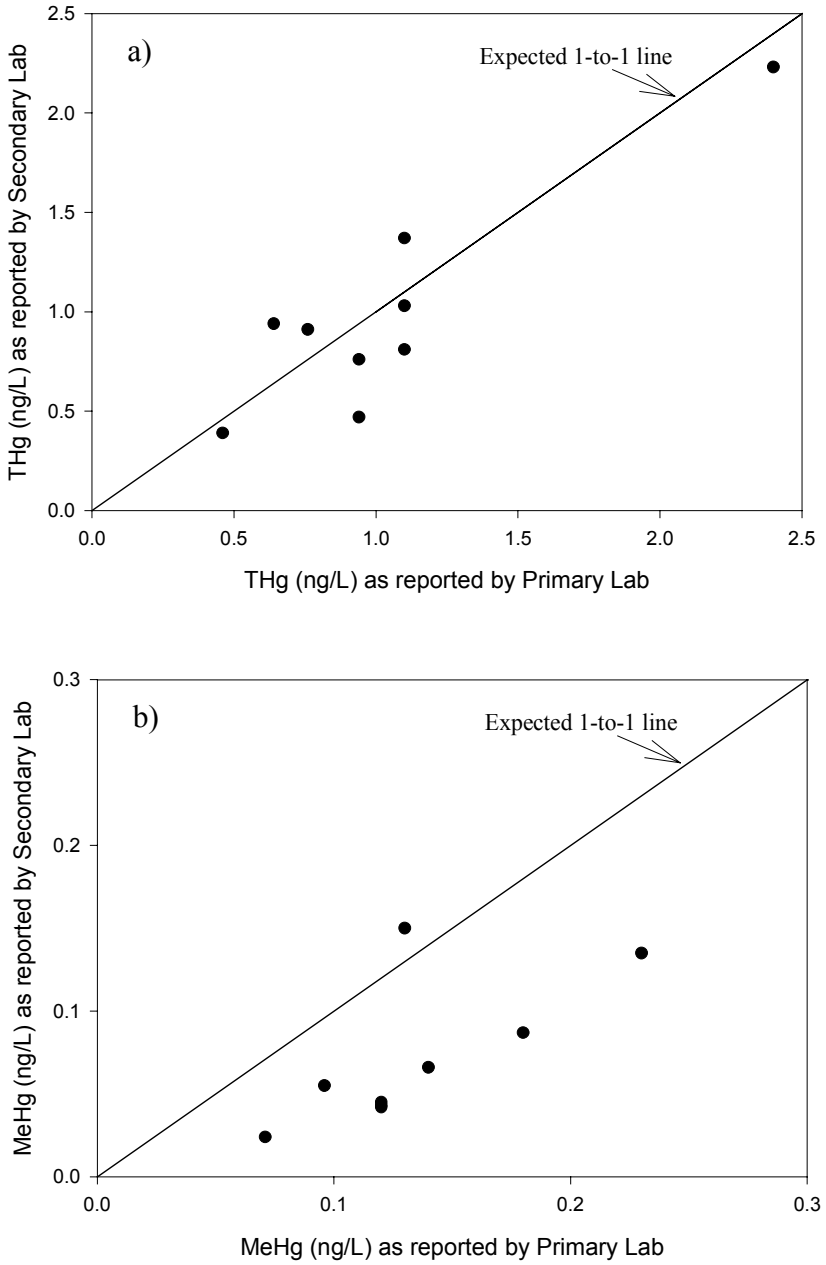

Figure 4. Interlaboratory comparison for THg (a) and MeHg (b) determined in surface water splits from non-ECP structures, i.e., HGLE Project

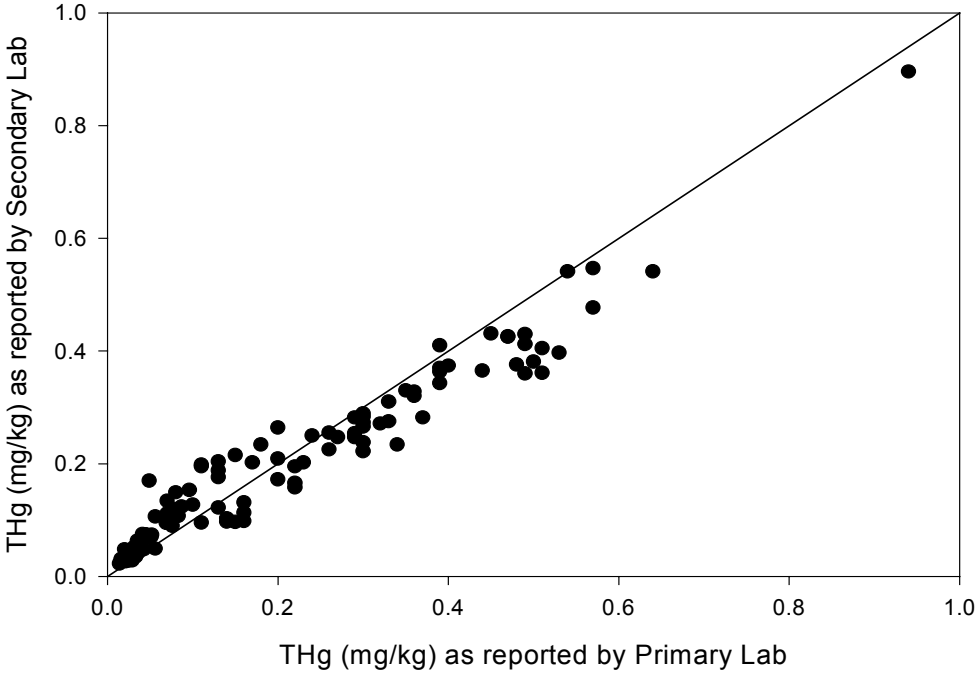

Figure 5. Interlaboratory comparison in THg determination in large-bodied fishes (e.g., sunfish and largemouth bass)

STATISTICAL METHODS

As stated above, monitoring Hg concentrations in aquatic animals provides several advantages; however, interpretability of residue levels in animals can sometimes prove problematic due to the confounding influences of the age or species of the collected animal. 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 Florida Fish and Wildlife Conservation Commission (FWC) (Lange et al., 1998; 1999), mercury concentrations in largemouth bass were standardized to an expected mean concentration in three-year-old fish at a given site by regressing mercury against age (for details, see Lange et al., 1999 and references therein). Note that to adjust for month of collection, otolith ages were first converted to decimal ages using protocols developed by Lange et al. (1999). Sunfish were not aged; consequently, 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 lepomis (*L. gulosus* warmouth; *L. punctatus*, spotted sunfish; *L. macrochirus*, bluegill; *L. microlophus*, redear sunfish) 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; also see Sepulveda et al., 1999), THg concentrations in nestling feathers were similarly standardized for each site and were expressed as LSM for chicks with a 7.1-cm bill.

Where appropriate, analysis of covariance (ANCOVA; SAS GLM procedure) was used to evaluate spatial and temporal differences in mercury concentrations, with age (largemouth bass), weight (sunfish), or bill size (egret nestlings) as a covariate. However, use of ANCOVA is predicated on several critical assumptions (for review, see 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 ANOVAs or student's t-tests (SigmaStat, Jandel Corporation, San Rafael, California) were used; possible covariates were considered separately. The assumptions of normality and equal variance were tested by the Kolmorogov-Smirnov and Levene Median tests, respectively. Data sets that either lacked homogeneity of variance or departed from normal distribution were natural-log transformed and were re-analyzed. If transformed data met the assumptions, they were used in ANOVA. If not, then raw data sets were evaluated using non-parametric Mann-Whitney Rank sum tests. If the multigroup null hypothesis was rejected, groups were compared using either Tukey HSD or Dunn's method.

MONITORING RESULTS

RAINFALL: NATIONAL ATMOSPHERIC DEPOSITION PROGRAM, MERCURY DEPOSITION NETWORK

Samples of bulk rainfall were collected weekly under the protocols of the National Atmospheric Deposition Program's Mercury Deposition Network (MDN) at the ENR Project, the Andytown substation, and the Baird Research Center in Everglades National Park (**Figure 2**). For more information on MDN, and to retrieve raw data, see http://nadp.sws.uiuc.edu/mdn.

As is evident from **Table 3,** atmospheric deposition of THg to South Florida was highly variable both spatially and temporally. In general, results observed in 2001 were consistent with seasonal trends observed during the Florida Atmospheric Mercury Study (FAMS, Guentzel, 1997). As is shown in **Figure 6**, THg concentrations in precipitation were substantially higher during the summer months, possibly due to seasonal, tall, convective thunderstorms that can scavenge particulate Hg and water soluble reactive gaseous Hg (RGM) from the middle and upper troposphere. This is consistent with observations of Guentzel (1997) during the FAMS study. Because both THg concentration and rainfall volumes generally increase during the summer, the latter by a factor of 2 to 3, THg wet deposition typically increases five-to-eight fold during the wet season (**Figure 6)**.

As is evident from **Table 3**, the volume-weighted average concentrations were higher in 2000 and 2001 compared to the preceding two years at all three stations. Furthermore, preliminary data suggest substantially greater deposition in 2001 at the ENR Project and at Andytown in 2001.

Collectively, the results reported here for wet deposition of THg in comparison with monitoring of surface water at non-ECP structures (following section) continued to show that the major source of mercury to the Everglades is from the air. This is consistent with previous

assessments by both the FDEP (Atkeson, at http://www.dep.state.fl.us/labs/hg/ flmercury.htm) and the USEPA (USEPA, 1998). Dry deposition, which may exceed wet deposition by a factor of 2 (Keeler and Lindberg, 2001), likely adds significantly to the overall atmospheric input.

Table 3. Biweekly mean bulk rainfall THg concentration data (ng/L) from the compliance sites of the Mercury Deposition Network in the reporting year ending April 30, 2002

Week ending	ENR (FL34)	Andytown (FL04)	ENP (FL11)
4/10/01	0.0	10.8	12.1
4/24/01	0.0	0.0	11.2
5/8/01	14.6	8.6	4.8
5/22/01	0.0	2.9	0.0
6/5/01	33.5	12.0	16.2
6/19/01	21.5	16.6	34.5
7/3/01	16.6	21.3	14.4
7/17/01	9.4	7.8	12.6
7/31/01	14.3	19.7	22.0
8/14/01	7.9	13.6	25.3
8/28/01	33.7	32.8	23.1
9/11/01	20.9	21.5	17.9
9/25/01	15.6	12.2	25.6
10/9/01	10.5	2.7	5.3
10/23/01	17.3	6.3	2.5
11/6/01	13.6	10.0	4.1
11/20/01	10.4	0.0	4.4
12/4/01	3.9	4.0	7.8
12/18/01	4.0	5.9	5.3
1/2/02	8.6	6.3	10.9
1/15/02	13.1	12.4	3.3
1/29/02	20.2	0.0	13.7
2/12/02	6.6	12.8	9.2
2/26/02	8.6	6.9	8.6
3/12/02	6.6	13.1	11.3
3/26/02	0.0	0.0	8.2
	Volume-wt. concentration (ng/L)		
1997*	NA	NA	14.7
1998*	11.4	13.8	12.7
1999*	10.8	12.3	11.6
2000*	13.7	15.8	13.6
2001[1]	13.4	12.8	13.8
	Deposition Annual ($\mu g/m^2$)		
1997*	NA	NA	27.2
1998*	18.4	20.1	20.3
1999*	12.1	17.5	17.7
2000*	14.3	18.1	20.0
2001[1]	20.5	20.9	17.8

* Adapted from NADP / MDN Program Office Report by C. Sweet,

[1] Preliminary data; final data set may use seasonal averages to estimate annual concentration and depostion where Qualtiy Rating of a given value is C.

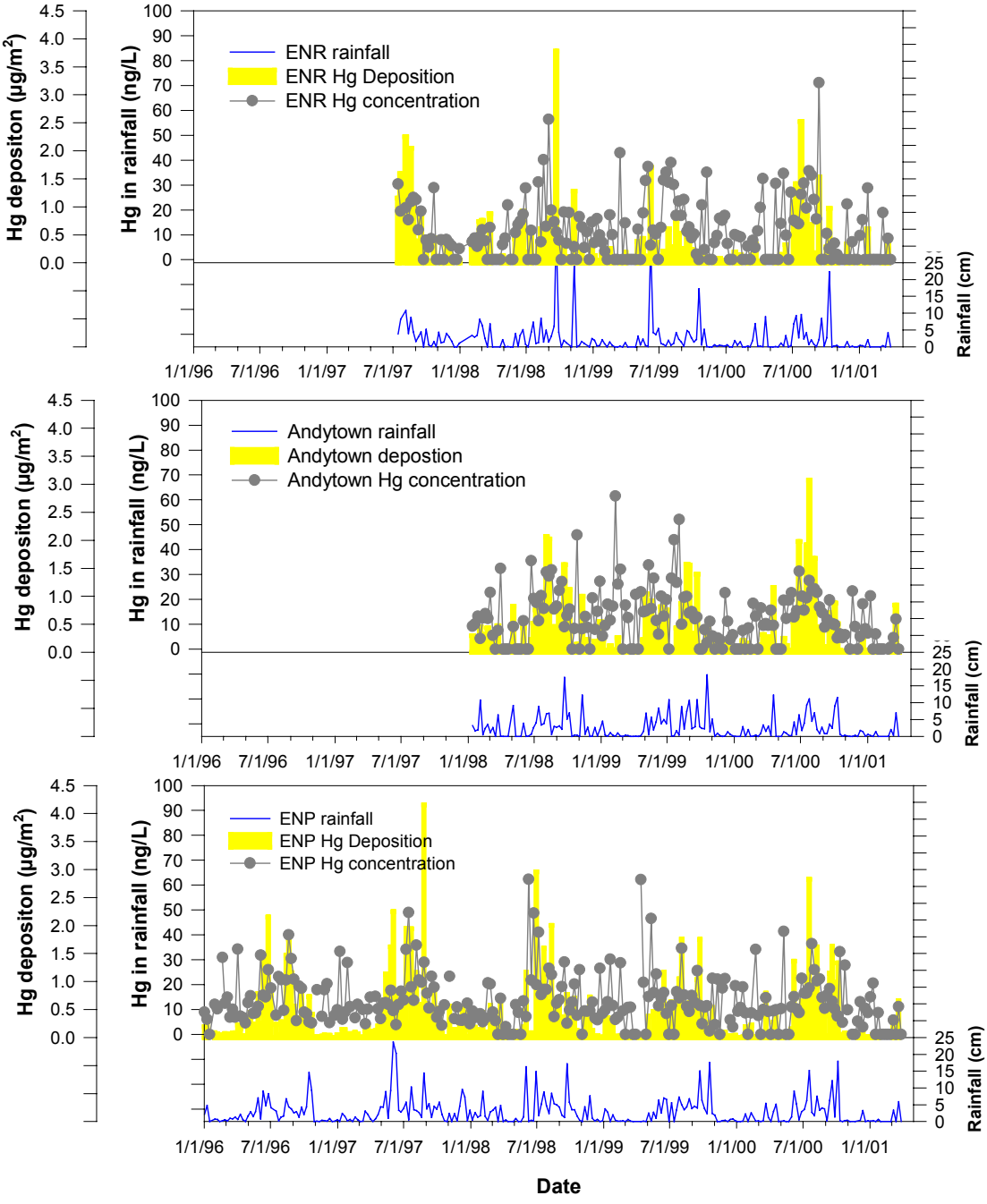

Figure 6. Time series of rainfall, rainfall Hg concentrations, and Hg rainfall deposition at MDN sites located at the ENR Project, Andytown, and ENP Baird Research Center. Note: All 2001 data and 1998 through 2000 data for ENP should be considered preliminary

SURFACE WATER AT NON-ECP STRUCTURES

Table 4 and **Figure 7** summarize monitoring results of unfiltered THg and MeHg in surface water samples collected quarterly at non-ECP structures (**Figure 3**). There are no baseline water concentration data generated by comparable analytical methods for any District structures prior to 1997. As in previous years, there were no exceedances of the Florida Class III Water Quality Standard for THg (12 ng THg/L) at any of the structures monitored. The maximum THg concentration observed during the reporting year was 4.2 ng/L and occurred at S-5A during the fourth quarter of 2001 (**Figure 7**). The maximum MeHg concentration observed during the reporting year at a non-ECP structure was 0.48 ng/L and occurred at S-32 during the third quarter of 2001. Currently, Florida has no Water Quality Standard (WQS) for MeHg. Generally, concentrations (i.e., not volume-weighted) of THg were similar to or lower than levels observed during the previous year (**Figure 7**). More importantly, concentrations of MeHg were much reduced compared to the spikes observed in the third and fourth quarters of 2000. As was previously observed, seasonal average concentrations of both THg and MeHg were highest in 2001 during the third quarter at the height of the wet season (**Table 4**).

Table 4. Concentrations of total mercury (THg) and methylmercury (MeHg) in non-ECP structure surface waters (units, ng/L) in 2001 through 2002

Structure	Quarter	THg			MeHg		% MeHg
		ng/L	remark **	WQS*	ng/L	remark **	
L28	2nd Quarter	1.70		<WQS	0.100		6%
	3rd Quarter	1.50		<WQS	0.160		11%
	4th Quarter	2.00		<WQS	0.022	U	
	1st Quarter	0.90		<WQS	0.095		11%
	Average[1] last 4 qt.	1.53			0.094		9%
	cumulative avg[1].	1.39			0.232		13%
S10C	2nd Quarter	2.40		<WQS	0.230	Q	
	3rd Quarter	1.70		<WQS	0.340		20%
	4th Quarter	0.79		<WQS	0.110		14%
	1st Quarter	0.95		<WQS	0.066	I	7%
	Average last 4 qt.	1.46			0.172		14%
	cumulative avg.	1.26			0.222		18%
S12D	2nd Quarter	1.10		<WQS	0.390		35%
	3rd Quarter	2.20	A	<WQS	0.180		8%
	4th Quarter	0.99	A	<WQS	0.180		18%
	1st Quarter	1.20		<WQS	0.092		8%
	Average last 4 qt.	1.37			0.211		17%
	cumulative avg.	1.08			0.23		23%
S140	2nd Quarter	1.10	A	<WQS	0.130	Q	
	3rd Quarter	2.00		<WQS	0.280		14%
	4th Quarter	1.50		<WQS	0.039	I	3%
	1st Quarter	0.91		<WQS	0.074	I	8%
	Average last 4 qt.	1.38			0.131		8%
	cumulative avg.	1.21			0.17		12%
S141	2nd Quarter	1.00		<WQS	0.220		22%
	3rd Quarter	1.40	A	<WQS	0.290		21%
	4th Quarter	1.30		<WQS	0.250		19%
	1st Quarter	0.61		<WQS	0.084	I	14%
	Average last 4 qt.	1.08			0.211		19%
	cumulative avg.	1.29			0.193		14%
S151	2nd Quarter	1.00		<WQS	0.330		33%
	3rd Quarter	2.00		<WQS	0.160		8%
	4th Quarter	0.72		<WQS	0.050	I	7%
	1st Quarter	0.54		<WQS	0.072	I	13%
	Average last 4 qt.	1.07			0.153		15%
	cumulative avg.	1.13			0.21		14%
S32	2nd Quarter	1.00		<WQS	0.250		25%
	3rd Quarter	2.60		<WQS	0.480		18%
	4th Quarter	1.40		<WQS	0.180		13%
	1st Quarter	0.85		<WQS	0.032	I	4%
	Average last 4 qt.	1.46			0.236		15%
	cumulative avg.	1.14			0.169		15%

Table 4. (Cont'd.)

Structure	Quarter	THg ng/L	remark**	WQS*	MeHg ng/L	remark**	% MeHg
S334	2nd Quarter	0.76	A	<WQS	0.170		22%
	3rd Quarter	2.20		<WQS	0.340		15%
	4th Quarter	0.68		<WQS	0.060	I	9%
	1st Quarter	0.87		<WQS	0.130		15%
	Average last 4 qt.	1.13			0.175		15%
	cumulative avg.	1.03			0.168		16%
S5A	2nd Quarter	1.10		<WQS	0.120		11%
	3rd Quarter	1.80		<WQS	0.130		7%
	4th Quarter	4.20		<WQS	0.200		5%
	1st Quarter	2.60		<WQS	0.240	I	9%
	Average last 4 qt.	2.43			0.173		8%
	Cumulative avg.	2.24			0.200		9.9%
S9	2nd Quarter	0.90	A	<WQS	0.082	I	9%
	3rd Quarter	0.87		<WQS	0.440		51%
	4th Quarter	1.00		<WQS	0.034	I	3%
	1st Quarter	0.59		<WQS	0.033	I	6%
	Average last 4 qt.	0.84			0.147		17%
	Cumulative avg.	1.01			0.078		11%
	Ann. avg[1]. 01-2	1.21	±0.5(10)[¶]		0.22	±0.1 (7)	23%
	Ann. avg. 01-3	1.83	±0.5 (10)		0.28	±0.1 (10)	17%
	Ann. avg. 01-4	1.46	±1.0 (10)		0.11	±0.1 (10)	9%
	Ann. avg. 02-1	1.00	±0.6 (10)		0.09	±0.1 (10)	9%
	Cum. avg[1]. 1st Q	0.99	±0.5 (49)		0.10	±0.2 (37)	11%
	Cum. avg. 2nd Q	0.92	±0.4 (35)		0.15	±0.1 (36)	18%
	Cum. avg. 3rd Q	1.62	±0.6 (30)		0.31	±0.3 (35)	16%
	Cum. avg. 4th Q	1.59	±1.3 (48)		0.20	±0.3 (49)	16%

*Class III Water Quality Standard of 12 ng THg/L

**For qualifier definitions, see FDEP rule 62-160: "A" - averaged value; "U" - undetected, value is the MDL; "I" - below PQL; "J" - estimated value, the reported value failed to meet established QC criteria; "J3" -estimated value, poor precision, "V" - analyte detected in both the sample and the associated method blank. Flagged values were not used in calculating averages.

1 Averages were not volume-weighted.

[¶] Value in parenthesis, i.e., (n), is number of unqualified values used to calculate mean ±1SD.

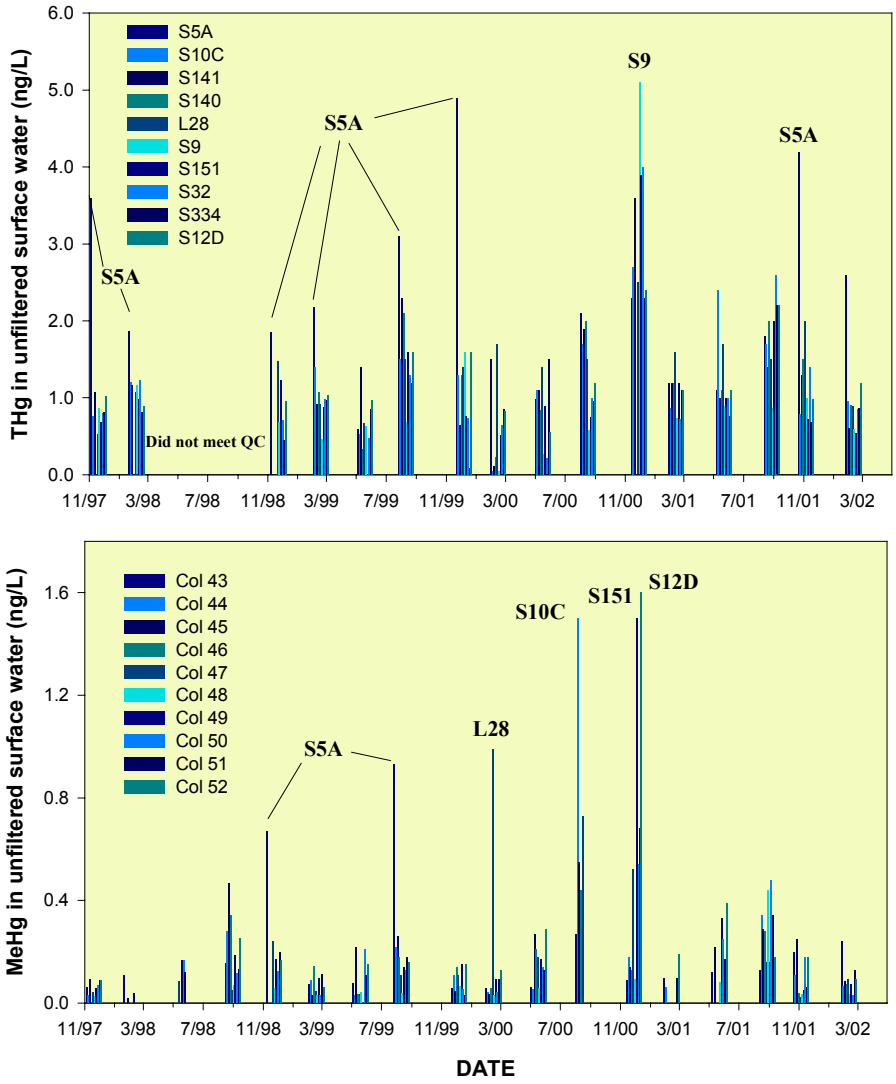

Figure 7. Concentrations of THg (top panel) and MeHg (bottom panel) in unfiltered surface waters at 10 non-ECP structures

FISH FROM ECP AND NON-ECP INTERIOR MARSHES

Results from monitoring downstream interior marsh mosquitofish, sunfish and largemouth bass are summarized in **Tables 5** through **7** (values for individual large-bodied fish are provided in **Table 1** at the end of this document). Fish are collected from a total of 12 downstream interior marsh sites (**Figure 1**). Where fish could not be collected after a good-faith effort, collection sites defaulted to nearby canals where fish were more plentiful and the same source water was being sampled. Mercury levels in largemouth bass at three of these sites, LOX4 (WCA-1 GFC4), CA2U3 (WCA-2A U3), and CA3-15 (WCA-3A 15), were monitored by the FWC prior to initiation of the ECP (period of record extends back to 1993).

As is discussed below, fishes collected in 2001 showed both spatial and temporal patterns in tissue mercury concentrations. In keeping with the primary objective of this monitoring program, the focus will be on temporal changes in mercury concentration in fish tissues to assess possible adverse effects from the construction of the ECP and the operation of the STAs. Nevertheless, spatial patterns of tissue mercury concentrations are important, particularly where there has been a variation from background conditions (i.e., pre-ECP conditions established by the FWC). Therefore, spatial patterns will be reviewed in detail only where there has been change over time (i.e., interaction between treatment effects).

Mosquitofish

THg concentrations in mosquitofish collected from marsh sites in 2001 ranged from 5 ng/g at CA2F1 to 212 ng/g at P33 (**Table 5**). It is noteworthy that the maximum concentration in 2000 was also at P33. The 2001 basin-wide average concentration was 94 ng/g (**Table 5**; for locations, see **Figure 2**), which represents a 33-percent increase from the 2000 basin-wide average concentration. Mosquitofish at most sites exhibited a dramatic increase in 1999 following a drydown and reflooding, decreasing substantially in 2000 but rebounding (increasing) in 2001 (**Table 5**, **Figure 8**; exceptions were mosquitofish at the Rotenberger tract and at CA3F1). This among-year difference in mercury concentration in mosquitofish was statistically significant (ANOVA; $df = 3,46$; $F = 14.1$; $p < 0.001$), with levels in 1999 different from those of other years (Tukey Test, $p < 0.05$). Comparisons between other years were not significant ($p > 0.05$).

Table 5. Concentration of total mercury (THg) in mosquitofish composites (units ng/g wet weight) collected in 2001 from downstream sites. Value represents a mean of 3 to 5 analyses

Location	THg (ng/g)	Between-yr. change (%)	Cum. average
LOX4	63	3%	89
CA2 F1	5		28
CA27 Alt (Z4)	83		83
CA27 Alt (N4)	186		186
Holey Land (North canal)	48	58%	54
Rotenberger Alt. (RotenF1)	52	-145%	141
CA2U3	128	40%	135
CA33 Alt (L5F1)	39	87%	89
CA35	138		104
Non-ECP North (CA3F1; end of L-28)	57	-15%	80
CA315	160	61%	154
Non ECP South (CA3F2)	47	32%	71
P33	212	28%	173
annual mean	94	33%	108

NA = data not available due to the absence of fish at the site.
Grandmean of site means for POR (1998-01) ±95%CI: n=50, 108±22

Table 6. Mean concentration (± 1SD; ng/ g wet weight) of total mercury (THg) in sunfish (*Lepomis* spp.) collected in 2001 from marshes within the EPA downstream of the STAs

Target location	Sampling Location	Mean THg ng/g (±1SD, n)	Between-yr. change (%)	Mean for fish collected 1998-2001
WCA1-LOX3	LOX4	128 (±38, 21)	-12%	143
WCA-2A F1	L39F1	62 (±54, 20)	-11%	79
WCA-2A 2-7	Z4	106 (±29,29)		106
Holey Land	Holey Land	108 (±50, 19)	35%	66
Rotenberger†		NA		
WCA-2A U3	CA2U3	94 (±44, 20)	-64%	154
WCA-3A 3	L5F1	45 (±36, 20)	-48%	72
WCA-3A 5		216 (±143, 20)	-1%	216
Non-ECP North	CA3F1	88 (± 73, 20)	-1%	120
WCA-3A 15	CA315	223 (±84, 19)	-29%	321
Non-ECP South	CA3F2	95 (±44, 17)	-14%	172
ENP P33 Marsh	L67F1	644 (±394, 20)	63%	532
ENP P33 Marsh	P33 Marsh	NA		562
Average		165	-2%	182 (n=808)

† Unable to collect 20 fish from each site.
NA = data not available due to the absence of fish at the site.
Grandmean of site means for POR (1998-01) ±95%CI: n=45, 195±48

Table 7. Standardized (EHg3) and arithmetic mean concentrations of total mercury (THg) in largemouth bass fillets (ng/g wet weight) collected in 2001 from ECP and non-ECP interior marsh sites

Target Location	Sampling Location	EHg3 ± 95th CI (mean ±1SD, n) ng/g wet	Consumption advisory exceeded*	Cum. mean‡
CA1-LOX3	LOX4	NC (2) (350±122, 5)	No	387
CA2-F1	L39F1	267±31 (248±85, 20)	No	263
CA2-7	Z4	NC (2) (370±28, 2)		370
Holeyland	HOLYBC	458±54 (500±233, 20)	No	440
Rotenberger†		NC (2) (NA, 0)		
CA2-U3	CA2U3	518±127 (379±105, 20)	Yes	538
CA3-3	L5F1	NC (1) (356±128, 20)	No	426
CA3-5	CA3-5	NC (2) (NA, 0)		990
Non-ECP North	CA3F1	405±52 (394±164, 20)	No	504
CA3-15	CA3-15	NC (2) (528±226, 5)	Likely	817
Non-ECP South	CA3F2	NC (2) (270±NA, 1)		822
ENP-P33	ENP-P33	NC (2) (NA , 0)		1,250
ENP-P33	L67F1	1,354±220 (1,501±451, 20)	Yes	1,215

* Florida limited fish consumption advisory threshold is 500 ng/g in 3-yr-old bass.
† Unable to collect fish from site.
‡ Arithmetic mean of all fish collected from a given site, 1998-2001
NC - not calculated for: (1) insignificant slope or (2) if poor age distribution. NA - not available.
Grandmean of site arithmetic means for POR +95%CI: n=41, 609±102

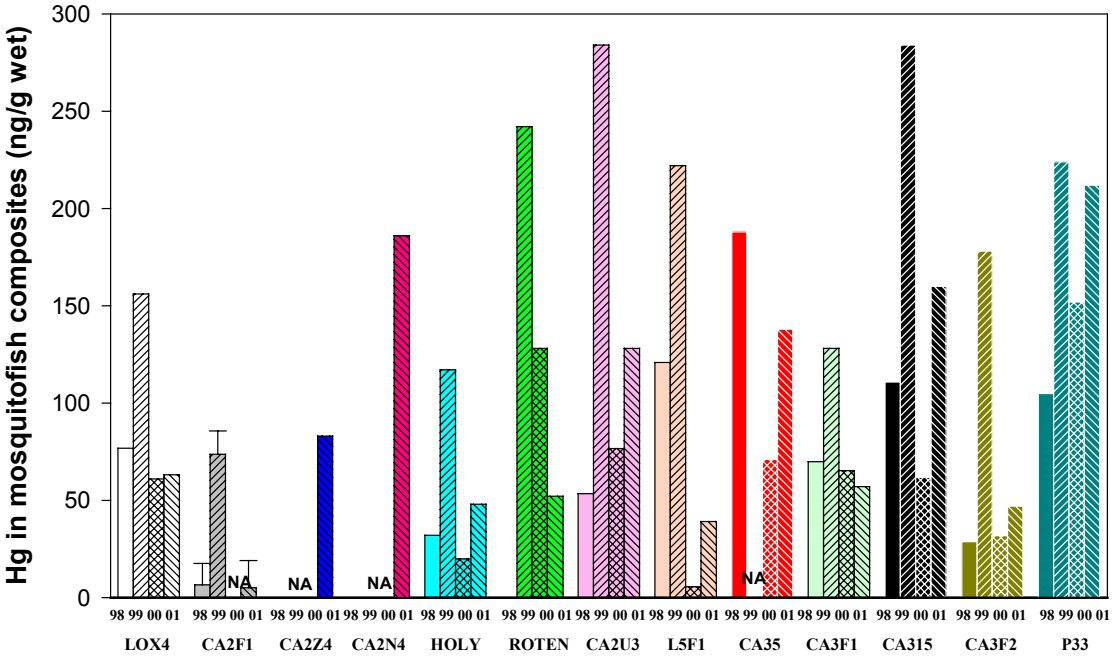

Figure 8. Mercury concentrations in mosquitofish (*Gambusia* sp.) collected at ECP and non-ECP sites in 1998, 1999, 2000 and 2001. Not all sites sampled in all years (for details, see **Table 5**)

Sunfish

THg concentration in sunfish collected from marsh sites in 2001 (n = 213) averaged 165 ng/g (median was 110 ng/g), but ranged as high as 1500 ng/g in a bluegill from L67F1 (**Table 6**). The basin-wide median concentration declined slightly in 2001 relative to the last three years (median was 126 ng/g in 1998, 120 ng/g in 1999 and 2000). While THg levels declined in sunfish at most sites in 2001, THg increased in concentration in sunfish at L67F1. As is evident from **Figure 9**, the average concentration of THg in sunfish collected in 2001 from L67F1 approached peak levels observed in 1999. Between-year percent change from 2000 to 2001 ranged from a 63-percent increase at L67F1 to a 64-percent decrease in concentration in sunfish from WCA-2A U3 (**Table 6**, **Figure 9**).

Interannual differences in tissue mercury concentration were significant at six sites, but the direction of change was variable among locations. Results must be interpreted with caution due to differences in sizes and species of fish. While there are statistical methods to address confounding factors, such as age or weight, addressing species differences is more problematic, particularly when it is one of two possible confounding factors (i.e., weight, species or both). Statistical analyses of the sunfish data sets were also hampered or prevented because THg concentration, weights, or both often failed assumptions of normality and equal variance.

As was discussed in previous Everglades Consolidated Reports, attempts to use analysis of covariance (ANCOVA) to evaluate patterns of mercury concentrations in sunfish (*Lepomis* spp.) using weight as a covariate were often inappropriate because weight/concentration relationships were inconsistent (i.e., slopes were either not significant or were not parallel each year). The lack of a strong concentration/size relationship likely resulted from interspecies differences (i.e., among the different *Lepomis* species) in growth and bioaccumulation factors. Further, as reported previously (Rumbold et al., 2001), species was a significant factor in tissue mercury concentration in sunfishes caught in 2001 (Kruskal-Wallis ANOVA on Ranks, $df = 3$, $H = 52.2$, $p < 0.001$); THg less concentrated in *L. microlophus* (redear, mean 76 ±68 ng/g) than each of the other three species, e.g., *L. punctatus* (spotted sunfish, mean = 243 ±92 ng/g), *L. macrochirus* (bluegill, mean = 210 ±255 ng/g), *L. gulosus* (warmouth, mean = 118 ±28 ng/g). While other paired comparisons were not significant, it is noteworthy that THg in warmouth appears to continue to decline, with average concentration in warmouth less than bluegill.

Consequently, as in past years, among-year differences in tissue Hg and fish weights were assessed at each location using a one-way ANOVA (i.e., parametric tests on raw or transformed data or non-parametric tests, if assumptions were violated; **Figure 9**), with qualitative consideration of possible influences from among-year differences in collected species. As is mentioned above, using this approach, six sites were identified as having among-year differences (**Figure 9**). One of the six sites, L67F1, exhibited among-year difference ($df = 3$, $H = 8.27$, $p = 0.04$), but due to excessive intra-year variability, paired comparisons between years were not significant. Another site, the Holey Land, exhibited among-year variability ($df = 3$, $H = 34.9$, $p < 0.001$), with greater concentrations in 2001 compared to 1998, 1999 and 2000. While the size of fish also increased during this same period, the among-year differences were not statistically significant. Alternatively the other four sites all showed recent declines in THg. Sunfish at WCA-3A-15 differed in THg among years ($df = 3$, $H = 10.2$, $p = 0.02$) and in particular declined between 2001 and 1999 (Dunn's Method). As is evident from **Figure 9**, this difference was not associated with a change in fish size. Having previously been identified as a mercury "hot spot" in the Everglades, a decline in Hg at CA315 would be ecologically important. THg declined monotonically in sunfish at CA32F, with levels in 2001 statistically similar to 2000, but with both significantly lower than concentration in 1998 and 1999 (Dunn's Method).

However, fish in 2001 were significantly smaller in 2001 (Dunn's method). THg also varied among years at L5F1, with 2001 levels different than 1999 and 2000. While size of fish also varied, 2001 fish were larger than fish caught earlier. Sunfish at WCA-2A-U3 also varied among years, with 2000 fish having greater THg concentration than most other years; however, 2000 fish were also larger than fish caught in most other years. Alternatively, sunfish caught at U3 in 2001 also differed and were lower compared to 1999 fish in terms of THg levels, but not size. This decrease may reflect actual changes in exposure.

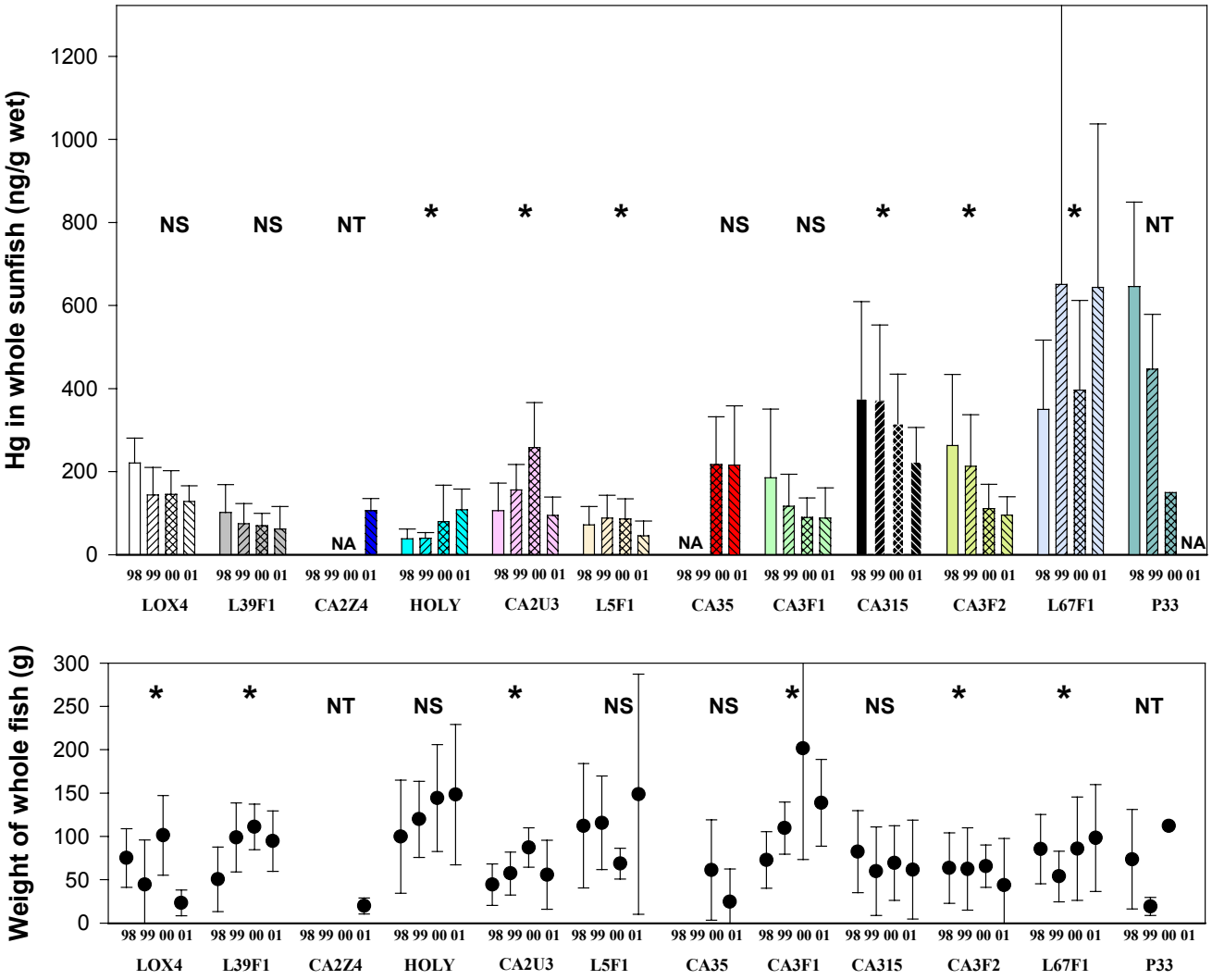

Figure 9. THg concentration (a) and weights (b) of whole sunfish (*Lepomis spp.*) collected at ECP and non-ECP sites in 1998, 1999, 2000 and 2001. Significant within-site, among-year differences are designated by *

Largemouth Bass

A total of 133 largemouth bass were collected at 10 of the 12 sites in 2001. The average tissue-Hg concentration in these bass was 549 ± 464 ng/g; the median concentration was 390 ng/g. Similar to sunfish, the basin-wide median concentration of Hg in bass was lower in 2001 relative to medians reported in 2000 (415 ng/g), 1999 (485 ng/g) and in 1998 (543 ng/g). Note that the median age varied only slightly among years (2.9 yrs old in 1998, 2.8 yrs old in 1999, 2.8 yrs old in 2000 and 2.8 yrs old in 2001). Ignoring among-year differences in age distributions, the difference in basin-wide Hg levels between 2001 and 1998 would be statistically significant ($df = 3$, $H = 11.3$, $p = 0.011$; Dunn's post-hoc test, $p < 0.05$). Other between-year differences were not significant.

Largemouth bass exhibited spatial patterns in tissue Hg concentrations similar to those observed in sunfish, with higher levels generally being found at the southern sites (**Table 7, Figure 10**). For instance, the highest tissue Hg concentrations in both sunfish and bass occurred at L67F1. Furthermore, within-site temporal patterns in tissue Hg levels in bass (i.e., EHg3, **Figure 10**) were also often similar to patterns observed in sunfish (**Figure 9**). This consistency between trophic levels was best exemplified at the Holey Land Water Management Area (WMA) and CA2U3 sites. The concentration of Hg increased in both bass and sunfish in 2001 at the Holey Land site; ANCOVA revealed that levels in bass in 2001 differed from fish caught in the other three years at the Holey Land WMA ($df = 3,74$; $F = 8.87$, $p < 0.001$; Tukey HSD, $p < 0.001$). At CA2U3, levels of THg increased from 1998 through 2000 but declined suddenly in bass and sunfish in 2001 (ANCOVA; $df = 3, 74$; $F = 14.82$, $p < 0.001$), with the estimated least square means (LSMs) for 2001 differing from 1998 and 2000, but not 1999 (Tukey HSD, $p < 0.00$).

It is also noteworthy that tissue Hg concentration increased slightly in the past year in bass at L67F1; however, similar to sunfish, among-year differences were not statistically significant (ANCOVA on 1998, 2000 and 2001; $df = 2, 54$; $F = 0.96$; $p = 0.39$). This was probably a result of the extensive, within-year variance among individuals (see confidence intervals in **Figure 10**). LSMs of tissue Hg in bass at L39F1 did not differ between 1999 and 2001 (ANCOVA; $df = 1, 30$; $F = 2.05$; $p = 0.16$). The CA3F1 data set did not meet the criteria for ANCOVA, i.e., interaction between age/year was significant ($df = 2, 54$; $F = 9.8$; $p = 0.0002$). Finally, regrettably only five bass were caught at CA315, of which four were first-year fish, preventing both estimation of EHg3 and confirmation of the declining trend observed in sunfish at this well-known methylmercury "hot spot."

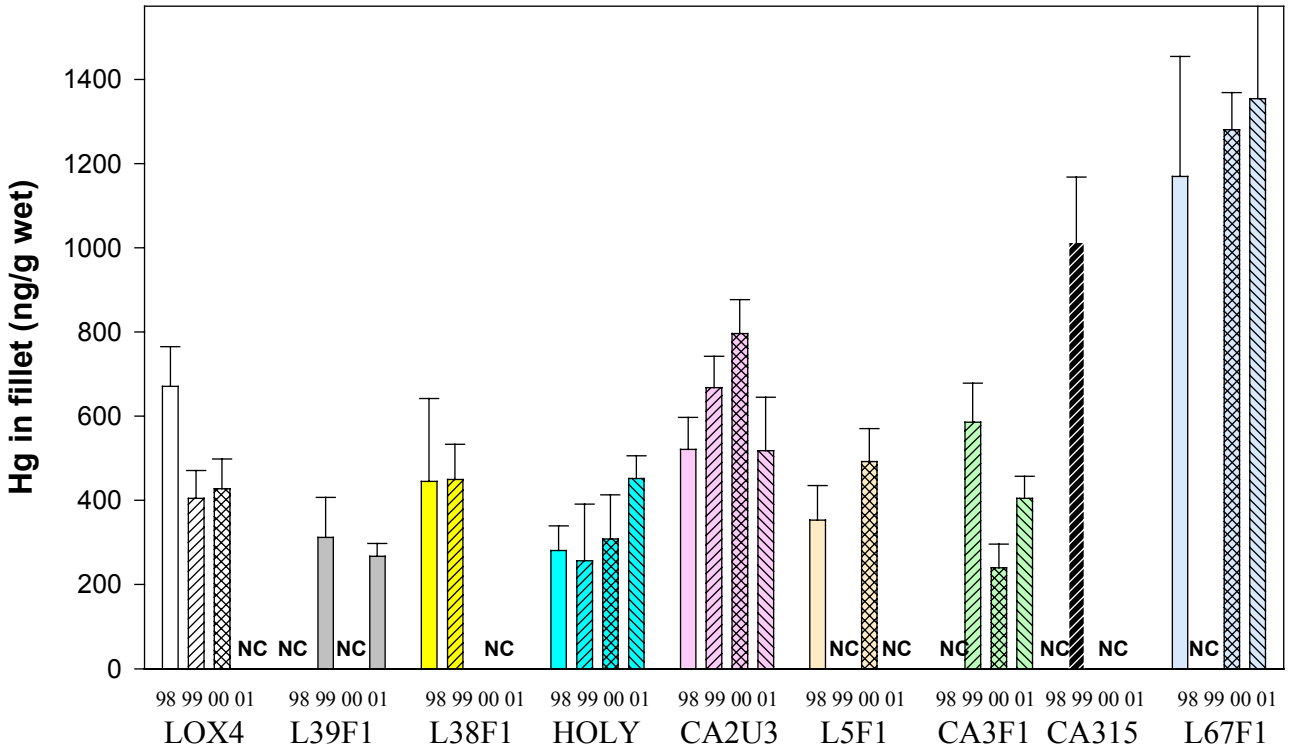

Figure 10. Standardized age(3) expected mercury concentration (EHg3) in largemouth bass (*Micropterus salmoides*) collected at ECP and non-ECP sites in 1998, 1999, 2000 and 2001. EHg3 was not calculated (NC) where regressions were not significant or if age distribution was narrow

Predator Protection Criteria

Levels of mercury in fish tissues can also be put into perspective and evaluated with respect to mercury risk to wildlife. The USFWS has proposed a predator protection criterion of 100 ng/g THg in prey species (Eisler, 1987). More recently, in its *Mercury Study Report to Congress*, the USEPA proposed 77 ng/g and 346 ng/g for trophic level (TL) 3 and 4 fish, respectively, for the protection of piscivorous avian and mammalian wildlife (USEPA, 1997).

In 2001, mosquitofish (considered to be at TL 2 to 3, depending on age; Loftus et al., 1998) at seven of the downstream sites had THg concentrations exceeding either the USFWS or USEPA criterion (i.e., 50 percent of the monitored sites; **Table 5**). Based on mean concentrations, sunfish, which are at TL 3 (*L. gulosus* at TL 4; Loftus et al., 1998), at eight of 11 sites contained THg concentrations exceeding one or both of the predator protection criteria in 2001 (**Table 6**). This represents a decline from 92 percent of the sites in 2000 to 73 percent in 2001. This finding is significant because, as is noted above, sunfishes represent the preferred prey item of many fish-eating species in the Everglades. Consequently, sunfish represent the best measure of potential upper trophic-level exposure to THg. After adjusting arithmetic mean THg concentrations in largemouth bass fillets (**Table 7**) to whole-body concentrations (whole-body

THg concentration = 0.69 x fillet THg; Lange et al., 1998), bass at three of the 10 sites (30 percent) also exceeded the guidance value for TL 4 fish. However, caution must be exercised in the latter assessment because largemouth bass are considered to be at TL 5 (Loftus et al., 1998). Based on these guidance values it appears that Everglades populations of piscivorous avian and mammalian wildlife continue to be at risk of adverse effects from mercury exposure.

WADING BIRD FEATHERS FROM ECP INTERIOR MARSHES

To evaluate temporal trends, results from the District's program to monitor mercury bioaccumulation in wading birds are compared to results from similar collections made by Frederick et al. (1997; later published by Sepulveda et al., 1999) in 1994 and 1995. In accordance with USACE permit 199404532 Condition 8b.2, these results were found to be representative of background mercury concentrations in Everglades wading birds (FTN Associates, 1999). The study by Frederick et al. (1997) involved monitoring THg in feathers of great egret (*Ardea albus*) nestlings at various Everglades colonies. The District's monitoring program focuses on two egret colonies designated JW1 and L67 that are located in WCA-3A. These two colonies consistently showed the highest THg concentrations during background studies (Frederick et al., 1997; FTN Associates, 1999; Sepulveda et al., 1999).

While conditions in 2002 appeared to be optimal for wading bird nesting in central and southern WCA-3A, great egrets experienced problems at both the JW1 and L67 colonies. The colonies were first visited on February 22, 2002 and were found to be active. Ten eggs (i.e., one egg each from 10 nests) were collected at each colony for THg determination (see discussion below). Chicks were also present in several nests at JW1 during the first sampling event; however, heavy egg predation was noted (empty eggshells remaining in 20 percent of the nests, with loss of the entire clutch). When colonies were revisited for feather collection on April 1, JW1 had been abandoned (no adults were present and nests were empty). It is noteworthy that egrets failed to even attempt to nest a year earlier at JW1. While the L67 colony was active on April 1 (more than 250 adult egrets were present), on active nests with eggs, no chicks could be located despite the fact that the eggs should have hatched by this time. Alternatively, anhinga nests contained large young. Interestingly, this was the first year that vulture chicks were observed on the ground at the colony. The L67 colony was revisited on April 18, but still no egret chicks were found. On May 8, the L67 was again visited and nestlings were found in the nest. Feathers were successfully collected from six nestlings. In addition, molted plumes from three adults were salvaged from three different locations (presumably representing three different individuals). Interestingly, subsequent visits by other researchers to this colony in 2002 found a significant number of active nests with young.

In 2002, feather THg concentrations ranged from 1.5 to 3.1 μg/g dry weight (dw) in the six nestlings (mean ±1SD was 2.08 ±0.54), and from 9.5 to 19.0 μg/g in the three adults' plumes. However, caution must be used when interpreting these results because THg concentration in nestling feathers is often dependent on the duration of exposure and, thus, the age of the bird. Efforts were unsuccessful to regress and standardize feather Hg concentration in 2002 for a nestling with a given bill length (i.e., age surrogate) due to the small sample size and narrow range of the ages of sampled nestlings. Previous attempts to standardize feather THg for the L67 colony failed in 1999 through 2001 (**Table 8**); however, this was because regressions were not statistically significant. This lack of significant regressions (i.e., concentration does not show a statistically significant increase with age) has been interpreted as an indication that exposure at L67 had been reduced to a level such that growth dilution overwhelmed daily intake.

Table 8. Standardized least square mean for a chick with a 7.1-cm bill (arithmetic mean concentration ±1SD, n) of THg (µg/g dw) in growing scapular feathers collected annually from great egret nestlings (two to three weeks old) at the JW1 and L67 colonies

Colony	1994 *[1]	1995 *	1999	2000	2001	2002
JW1	21.12 ± 6.1 (25.0 ±7.9, 9)	14.51±3.31 (NA, 8)	7.18 ±1.14 (4.0 ±2.2, 13)	6.9 ±1.3 (3.4 ±1.9, 10)	Failed to initiate nesting	Colony abandoned
L67	16.29 ± 4.53 (NA, 27)	15.51 ±6.16 (15.9 ±6.16, 14)	NC (3.6 ±1.5, 20)	NC (3.2 ±1.4, 10)	NC (7.0 ±2.9, 13)	NC (2.1 ±0.5, 6)

* Data from Frederick et al. (1997).
[1] Concentrations standardized to a bill length of 5.6 cm.
NC – not calculated where slope of regression was not significant ($p > 0.05$).
Estimated mean age of sampled nestling, 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 and 13 days in 2002.

Nevertheless, trends can be assessed temporally. On average, nestlings sampled in 2002 were only three days younger than chicks sampled in 1994, and only two days younger than chicks sampled in 2001 (estimated based on bill size and relationship developed by P. Frederick). Therefore, while the possibility cannot be ruled out that feather THg would have been greater had older chicks been sampled in 2002, there is no indication that concentrations would have approached the levels observed in 1994 or even 2001. An interpretation that mercury exposure to egrets was reduced compared to 1994 and even 2001 was strengthened by the results of egret egg collections.

In addition to collecting feather samples for compliance with the aforementioned federal and state permits, District staff have also collected egret eggs to support an ecological risk assessment of MeHg (Rumbold, 2000) and to better assess spatial and temporal trends in wading bird exposure (for details, refer to Rumbold et al., 2001). As mentioned above, in 2002 the District continued to collect egret eggs.

Median THg concentration was 0.32 µg/g (fresh weight) in eggs at L67, and 0.44 in eggs at JW1 (**Figure 11**). This between-colony difference was not significant (Mann-Whitney Rank Sum test, $T = 87$, $n = 10$, $p = 0.19$). While egg THg concentration has varied since 1999 (appearing to increase slightly in 2001), among-year differences were not statistically significant at either colony (L67: $df = 3, 36$; $F = 1.79$; $p = 0.17$; JW1: $df = 2, 20$; $F = 0.52$; $p = 0.6$).

Egg concentration is thought to be the best predictor of MeHg risk to avian reproduction (Wolfe et al., 1998); however, embryonic sensitivity differs among species. To date, a critical egg concentration has not yet been determined for wading birds. Thompson (1996) has proposed generic benchmarks based on a literature review, with heavy emphasis on studies of mallards. He concluded that adverse effects were unlikely to occur in birds at egg THg concentrations of less

than 0.5 µg/g, but toxic effects were probable at concentrations greater than 2.0 µg/g. In between was a gray area characterized by great uncertainty in terms of the probability of adverse effects. Note that the median THg concentration in egret eggs collected in 2002 was below Thompson's estimated NOAEL for *in ova* exposure.

However, results of a recent study may suggest that Thompson's benchmark underestimates the risk to the egret eggs. As a special request from the FDEP (2/26/01, letter from Tom Atkeson, FDEP mercury coordinator), in 2001 the District assisted the USGS in a study to reduce uncertainty and establish a critical egg concentration for various wading bird species. To assist the USGS, the District collected 168 eggs from five species (47 great egret eggs, 29 anhinga eggs, 58 white ibis eggs, 21 tricolor heron eggs, and 13 snowy egret eggs) and shipped them live to USGS-Patuxent in Laurel, Md., where they were incubated after being injected with MeHg. Preliminary results from that study suggest that the embryos of some species of fish-eating birds may be more sensitive to MeHg than the eggs of mallards, and that estimates of harmful levels of mercury may have to be re-evaluated (Heniz et al., 2001). In 2002 the District again made an effort to assist the USGS with this important study. Regrettably, because of difficulties in obtaining the necessary scientific collecting permits from the FWC, no eggs were collected and this opportunity was lost.

Establishing a benchmark for critical feather THg concentration has also been difficult because of observed or suspected interspecies differences in mercury sensitivity, particularly between piscivores and non-piscivores and between freshwater birds and seabirds. This is further complicated because, unlike MeHg in eggs, MeHg bonded to keratin and sequestered in feathers no longer represents a risk to the bird. Feather THg concentration is used only as an indicator of MeHg level and possible risk in targeted organs. However, Bouton et al. (1999) and Spalding et al. (2000) recently reported results of a controlled dosing study that combined feather analysis with toxicological observations of great egrets. They dosed great egret juveniles with MeHg-containing gelatin capsules at 0.5 mg Hg/kg food (n = 5) and found subtle behavioral changes and statistically significant differences in blood chemistry, liver biochemistry, and weight index (Bouton et al., 1999; Frederick et al., 1979; 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 (Spalding et al., 2000). For the reasons stated above, it is unlikely that levels of THg in egret nestling feathers in 2002 would have exceeded the lowest observed adverse effect benchmark established by Spalding et al. (2000).

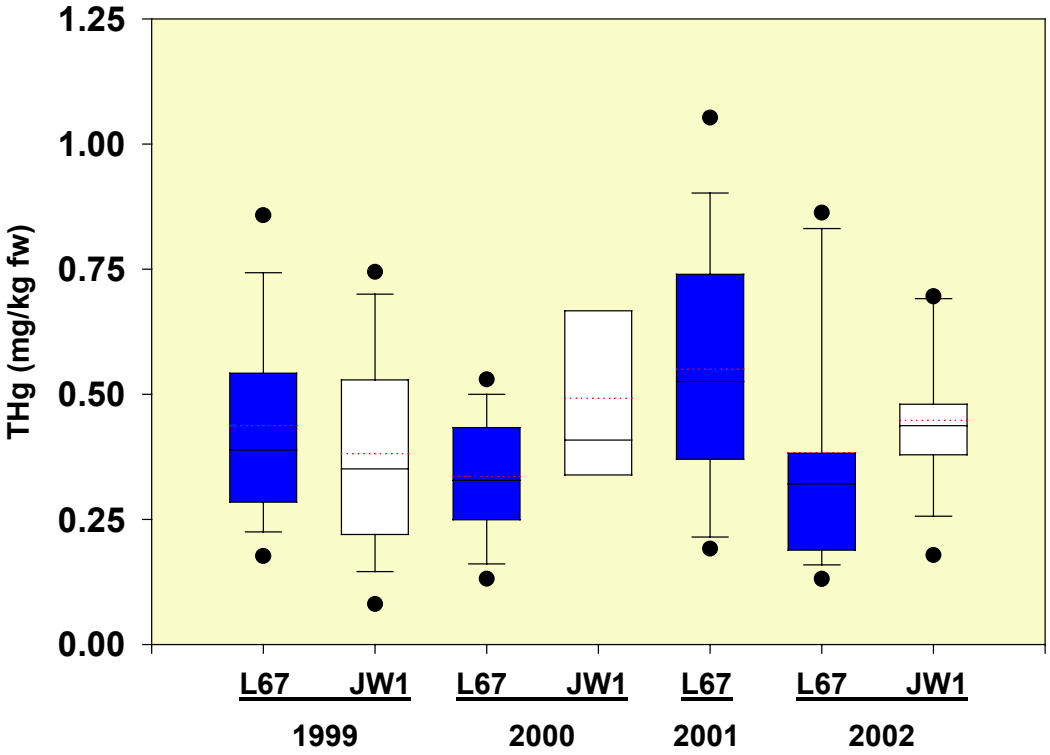

Figure 11. Boxplots of THg concentration in great egret eggs collected from colonies within WCA-3A. Outliers that lie outside the 10th and 90th percentile are shown as filled circles

WADING BIRD HABITAT AND FORAGING PATTERNS

Various combinations of environmental characteristics determine the suitability of an area for foraging and nesting wading birds. Among others, these characteristics include water depth, vegetation density, and densities and size distribution of the preferred prey populations. These factors have been reviewed in previous Everglades Consolidated Reports (Rumbold and Rawlik, 2000). In accordance with Condition (4).iv of the Mercury Monitoring Program, the District conducted a literature search for published and unpublished studies or monitoring programs that may show possible changes in wading bird habitat and foraging patterns within the Everglades basin during the reporting year. Studies and monitoring programs identified during this search are discussed below.

From February through June 2002, researchers for the USACE carried out systematic reconnaissance flights for wading bird activity in the Water Conservation Areas and Big Cypress National Preserve (D.A. Nelson, pers. comm). The Holey Land WMA and the portion of STA-1W that was the Everglades Nutrient Removal (ENR) Project were also surveyed. Wading birds were enumerated along parallel transects with 2-km spacing. The SRF survey methodology estimates total numbers of birds on the marsh surface, which is composed of breeding birds out feeding, nonbreeding birds, and juvenile birds. In addition, water conditions were recorded during the survey as wet, wet transitional, dry transitional, or dry.

Results from SRFs found that mean monthly estimated abundance was lower in 2002 than in 2001 for all species in the WCAs, except for white ibis and small dark herons. Numbers of birds peaked in February in the WCAs (92,848 birds, of which 61,900 were white ibis and 26,607 were great egret)), Big Cypress Preserve (31,513 birds), and the Holeyland WMA (2,613 birds). Numbers of birds in the WCAs dropped by half in March, increased to 79,113 in May, and then fell to 9,479 in June. Regarding the ENR Project, numbers of birds were generally low each month, ranging from 4 to 21 birds per month (monthly mean was 10 birds).

In 2002, various individuals or agencies also made systematic aerial and ground surveys of nesting wading birds in South Florida. (For a more detailed summary, see Gawlik, in prep.) Preliminary results suggest that 2002 was an excellent year for nesting. White ibises nested in extremely large numbers and may have exceeded 1,941 nesting estimates; it is estimated that over 20,000 ibis nests, representing 59 percent of all nests for this species, were found at the Alley North colony (D. Gawlik, pers. comm). Snowy egrets also nested in large numbers at the Alley North colony. Interestingly, the timing of nest starts was later this year.

In summary, during this reporting year the District is unaware of any evidence that would support a conclusion that wading bird foraging or nesting patterns were significantly altered or impacted by construction or operation of the STAs, or that such changes in foraging patterns would have led to an increased exposure to MeHg via consumption of MeHg-contaminated fish.

Table 1a. THg concentration (mg/Kg) and metadata for individual large-bodied fish collected in 2001

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
CA315	20-Sep-01	901087	SPSU		141	74	0.19
CA315	20-Sep-01	901061	LMB	0	181	94	0.39
CA315	20-Sep-01	901062	LMB	0	188	95	0.45
CA315	20-Sep-01	901081	RESU		205	200	0.18
CA315	20-Sep-01	901082	RESU		199	176	0.1
CA315	20-Sep-01	901085	BLUE		87	11	0.18
CA315	20-Sep-01	901086	BLUE		66	5	0.24
CA315	20-Sep-01	901084	BLUE		99	20	0.24
CA315	20-Sep-01	901083	RESU		125	38	0.075
CA315	17-Oct-01	901097	BLUE		97	19	0.26
CA315	17-Oct-01	901096	BLUE		109	28	0.31
CA315	17-Oct-01	901095	BLUE		127	46	0.22
CA315	17-Oct-01	901094	RESU		80	10	0.15
CA315	17-Oct-01	901093	RESU		132	52	0.17
CA315	17-Oct-01	901091	SPSU		126	53	0.45
CA315	17-Oct-01	901098	BLUE		85	13	0.21
CA315	17-Oct-01	901088	SPSU		150	97	0.25
CA315	17-Oct-01	901092	RESU		173	119	0.16
CA315	17-Oct-01	901068	LMB	0	177	73	0.75
CA315	17-Oct-01	901067	LMB	0	167	93	0.78
CA315	17-Oct-01	901066	LMB	1	265	290	0.27
CA315	17-Oct-01	901089	SPSU		154	105	0.27
CA315	17-Oct-01	901090	SPSU		146	92	0.28
CA315	17-Oct-01	901099	BLUE		86	13	0.3
CA35	17-Oct-01	1001439	BLUE		88	13	0.13
CA35	17-Oct-01	1001448	BLUE		61	5	0.11
CA35	17-Oct-01	1001447	BLUE		73	9	0.23
CA35	17-Oct-01	1001446	BLUE		73	9	0.17
CA35	17-Oct-01	1001445	BLUE		87	13	0.32
CA35	17-Oct-01	1001444	BLUE		79	10	0.14
CA35	17-Oct-01	1001443	BLUE		79	10	0.14
CA35	17-Oct-01	1001442	BLUE		81	11	0.11
CA35	17-Oct-01	1001449	RESU		71	8	0.085
CA35	17-Oct-01	1001440	BLUE		96	17	0.15
CA35	17-Oct-01	1001433	BLUE		106	22	0.16
CA35	17-Oct-01	1001438	BLUE		72	8	0.14
CA35	17-Oct-01	1001437	BLUE		99	17	0.28
CA35	17-Oct-01	1001436	BLUE		84	12	0.17
CA35	17-Oct-01	1001435	BLUE		87	15	0.13
CA35	17-Oct-01	1001434	BLUE		95	17	0.17
CA35	17-Oct-01	1001430	BLUE		165	81	0.37
CA35	17-Oct-01	1001431	BLUE		196	137	0.7
CA35	17-Oct-01	1001432	BLUE		147	67	0.39
CA35	17-Oct-01	1001441	BLUE		81	11	0.22
CA3F1	17-Sep-01	901217	RESU		225	208	0.024
CA3F1	17-Sep-01	901211	BLUE		164	95	0.033
CA3F1	17-Sep-01	901205	BLUE		198	130	0.16

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
CA3F1	17-Sep-01	901206	BLUE		205	164	0.07
CA3F1	17-Sep-01	901207	BLUE		185	138	0.15
CA3F1	17-Sep-01	901200	LMB	1	260	210	0.22
CA3F1	17-Sep-01	901208	BLUE		200	172	0.056
CA3F1	17-Sep-01	901219	RESU		178	106	0.037
CA3F1	17-Sep-01	901210	BLUE		211	174	0.16
CA3F1	17-Sep-01	901220	RESU		141	47	0.029
CA3F1	17-Sep-01	901212	BLUE		173	99	0.3
CA3F1	17-Sep-01	901213	BLUE		183	144	0.13
CA3F1	17-Sep-01	901214	BLUE		195	155	0.037
CA3F1	17-Sep-01	901215	BLUE		174	122	0.033
CA3F1	17-Sep-01	901216	BLUE		110	22	0.024
CA3F1	17-Sep-01	901218	RESU		212	163	0.035
CA3F1	17-Sep-01	901209	BLUE		200	132	0.043
CA3F1	17-Sep-01	901189	LMB	1	304	409	0.36
CA3F1	17-Sep-01	901202	BLUE		195	180	0.14
CA3F1	17-Sep-01	901204	BLUE		225	230	0.11
CA3F1	17-Sep-01	901181	LMB	3	386	308	0.4
CA3F1	17-Sep-01	901182	LMB	2	348	612	0.29
CA3F1	17-Sep-01	901183	LMB	5	400	929	0.94
CA3F1	17-Sep-01	901184	LMB	3	380	825	0.54
CA3F1	17-Sep-01	901185	LMB	3	378	841	0.24
CA3F1	17-Sep-01	901186	LMB	3	400	888	0.47
CA3F1	17-Sep-01	901188	LMB	2	330	474	0.23
CA3F1	17-Sep-01	901190	LMB	1	292	370	0.36
CA3F1	17-Sep-01	901191	LMB	2	303	367	0.39
CA3F1	17-Sep-01	901199	LMB	1	256	195	0.2
CA3F1	17-Sep-01	901203	BLUE		206	178	0.16
CA3F1	17-Sep-01	901187	LMB	4	314	433	0.53
CA3F1	17-Sep-01	901201	BLUE		175	116	0.028
CA3F1	17-Sep-01	901192	LMB	3	306	390	0.47
CA3F1	17-Sep-01	901198	LMB	1	267	224	0.35
CA3F1	17-Sep-01	901197	LMB	1	281	256	0.39
CA3F1	17-Sep-01	901196	LMB	1	261	262	0.32
CA3F1	17-Sep-01	901195	LMB	1	262	267	0.29
CA3F1	17-Sep-01	901194	LMB	1	248	219	0.39
CA3F1	17-Sep-01	901193	LMB	3	295	286	0.5
CA3F2	16-Oct-01	1001229	BLUE		65	5	0.049
CA3F2	16-Oct-01	1001237	BLUE		77	9	0.1
CA3F2	16-Oct-01	1001223	BLUE		141	55	0.17
CA3F2	16-Oct-01	1001221	BLUE		190	179	0.18
CA3F2	16-Oct-01	1001224	BLUE		13	22	0.15
CA3F2	16-Oct-01	1001225	BLUE		85	10	0.094
CA3F2	16-Oct-01	1001226	BLUE		80	10	0.13
CA3F2	16-Oct-01	1001227	BLUE		70	7	0.065
CA3F2	16-Oct-01	1001228	BLUE		79	8	0.083
CA3F2	16-Oct-01	1001222	BLUE		165	96	0.13
CA3F2	16-Oct-01	1001231	RESU		190	157	0.094
CA3F2	16-Oct-01	1001232	RESU		133	46	0.065

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
CA3F2	16-Oct-01	1001233	RESU		142	73	0.054
CA3F2	16-Oct-01	1001234	RESU		110	25	0.049
CA3F2	16-Oct-01	1001236	RESU		66	6	0.054
CA3F2	16-Oct-01	1001201	LMB	0	222	152	0.27
CA3F2	16-Oct-01	1001230	WAR		84	12	0.11
CA3F2	16-Oct-01	1001235	RESU		110	26	0.037
HOLYBC	19-Sep-01	901261	LMB	2	315	455	0.49
HOLYBC	19-Sep-01	901270	LMB	5	376	834	0.55
HOLYBC	19-Sep-01	901269	LMB	2	307	411	0.48
HOLYBC	19-Sep-01	901268	LMB	1	260	232	0.23
HOLYBC	19-Sep-01	901267	LMB	2	266	279	0.52
HOLYBC	19-Sep-01	901266	LMB	2	334	551	0.4
HOLYBC	19-Sep-01	901265	LMB	1	265	275	0.25
HOLYBC	19-Sep-01	901264	LMB	2	344	576	0.4
HOLYBC	19-Sep-01	901262	LMB	3	314	436	0.43
HOLYBC	19-Sep-01	901271	LMB	4	354	608	0.47
HOLYBC	19-Sep-01	901290	WAR		150	84	0.12
HOLYBC	19-Sep-01	901263	LMB	5	311	376	0.69
HOLYBC	19-Sep-01	901295	RESU		169	88	0.081
HOLYBC	19-Sep-01	901288	BLUE		200	203	0.069
HOLYBC	19-Sep-01	901272	LMB	1	259	257	0.26
HOLYBC	19-Sep-01	901299	RESU		125	43	0.078
HOLYBC	19-Sep-01	901298	RESU		142	55	0.06
HOLYBC	19-Sep-01	901296	RESU		164	90	0.077
HOLYBC	19-Sep-01	901294	RESU		175	111	0.059
HOLYBC	19-Sep-01	901293	RESU		151	73	0.11
HOLYBC	19-Sep-01	901292	RESU		230	219	0.13
HOLYBC	19-Sep-01	901291	RESU		238	305	0.16
HOLYBC	19-Sep-01	901289	BLUE		201	203	0.2
HOLYBC	19-Sep-01	901287	BLUE		220	246	0.23
HOLYBC	19-Sep-01	901286	BLUE		153	82	0.087
HOLYBC	19-Sep-01	901280	LMB	1	224	152	0.4
HOLYBC	19-Sep-01	901275	LMB	1	278	315	0.32
HOLYBC	19-Sep-01	901276	LMB	1	248	198	0.34
HOLYBC	19-Sep-01	901273	LMB	4	343	548	0.85
HOLYBC	19-Sep-01	901297	RESU		190	139	0.073
HOLYBC	19-Sep-01	901285	BLUE		220	214	0.081
HOLYBC	19-Sep-01	901279	LMB	1	251	229	0.47
HOLYBC	19-Sep-01	901277	LMB	8	485	1726	1.2
HOLYBC	19-Sep-01	901281	BLUE		199	183	0.14
HOLYBC	19-Sep-01	901274	LMB	5	343	580	0.8
HOLYBC	19-Sep-01	901282	BLUE		140	57	0.05
HOLYBC	19-Sep-01	901283	BLUE		223	279	0.084
HOLYBC	19-Sep-01	901284	BLUE		190	141	0.16
HOLYBC	19-Sep-01	901278	LMB	1	235	172	0.46
L39F1	15-Oct-01	901487	BLUE		162	83	0.046
L39F1	15-Oct-01	901488	BLUE		181	127	0.035
L39F1	15-Oct-01	901486	BLUE		159	78	0.025
L39F1	15-Oct-01	901489	BLUE		213	155	0.1

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
L39F1	15-Oct-01	901484	BLUE		134	39	0.029
L39F1	15-Oct-01	901497	RESU		155	78	0.016
L39F1	15-Oct-01	901483	BLUE		203	161	0.043
L39F1	15-Oct-01	901482	BLUE		168	88	0.092
L39F1	15-Oct-01	901485	BLUE		179	111	0.055
L39F1	15-Oct-01	901490	BLUE		182	131	0.1
L39F1	15-Oct-01	901491	SPSU		134	67	0.25
L39F1	15-Oct-01	901492	RESU		151	65	0.02
L39F1	15-Oct-01	901493	RESU		167	93	0.024
L39F1	15-Oct-01	901494	RESU		181	105	0.064
L39F1	15-Oct-01	901496	RESU		148	62	0.022
L39F1	15-Oct-01	901498	RESU		174	98	0.12
L39F1	15-Oct-01	901481	BLUE		201	150	0.063
L39F1	15-Oct-01	901472	LMB	2	316	411	0.29
L39F1	15-Oct-01	901499	RESU		138	47	0.037
L39F1	15-Oct-01	901500	RESU		160	77	0.077
L39F1	15-Oct-01	901495	RESU		157	77	0.027
L39F1	15-Oct-01	901463	LMB	1	269	245	0.17
L39F1	15-Oct-01	901474	LMB	3	320	460	0.21
L39F1	15-Oct-01	901462	LMB	2	324	478	0.32
L39F1	15-Oct-01	901480	LMB	1	248	215	0.091
L39F1	15-Oct-01	901464	LMB	2	313	423	0.21
L39F1	15-Oct-01	901465	LMB	1	268	242	0.19
L39F1	15-Oct-01	901466	LMB	3	448	1323	0.46
L39F1	15-Oct-01	901467	LMB	2	310	404	0.28
L39F1	15-Oct-01	901468	LMB	4	346	563	0.34
L39F1	15-Oct-01	901478	LMB	1	259	230	0.21
L39F1	15-Oct-01	901461	LMB	3	350	590	0.27
L39F1	15-Oct-01	901469	LMB	1	296	367	0.21
L39F1	15-Oct-01	901479	LMB	2	321	525	0.3
L39F1	15-Oct-01	901477	LMB	2	355	612	0.31
L39F1	15-Oct-01	901476	LMB	1	268	263	0.12
L39F1	15-Oct-01	901475	LMB	1	260	222	0.21
L39F1	15-Oct-01	901473	LMB	3	344	558	0.28
L39F1	15-Oct-01	901471	LMB	1	286	304	0.17
L39F1	15-Oct-01	901470	LMB	2	395	781	0.31
L5F1	19-Sep-01	901112	LMB	3	268	253	0.3
L5F1	19-Sep-01	901107	LMB	3	274	273	0.26
L5F1	19-Sep-01	901110	LMB	2	266	256	0.44
L5F1	19-Sep-01	901109	LMB	2	266	238	0.37
L5F1	19-Sep-01	901108	LMB	1	215	142	0.48
L5F1	19-Sep-01	901111	LMB	1	266	255	0.29
L5F1	19-Sep-01	901106	LMB	1	240	181	0.22
L5F1	19-Sep-01	901105	LMB	2	255	202	0.22
L5F1	19-Sep-01	901104	LMB	2	260	214	0.26
L5F1	19-Sep-01	901103	LMB	2	276	284	0.64
L5F1	19-Sep-01	901101	LMB	3	432	1190	0.18
L5F1	19-Sep-01	901133	RESU		175	101	0.026
L5F1	19-Sep-01	901102	LMB	3	350	587	0.3

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
L5F1	19-Sep-01	901138	RESU		270	415	0.027
L5F1	19-Sep-01	901113	LMB	2	257	225	0.33
L5F1	19-Sep-01	901139	RESU		250	370	0.045
L5F1	19-Sep-01	901137	RESU		280	475	0.056
L5F1	19-Sep-01	901136	RESU		175	118	0.052
L5F1	19-Sep-01	901135	RESU		125	37	0.018
L5F1	19-Sep-01	901134	RESU		215	208	0.049
L5F1	19-Sep-01	901131	RESU		187	123	0.021
L5F1	19-Sep-01	901132	RESU		180	112	0.021
L5F1	19-Sep-01	901130	RESU		101	19	0.014
L5F1	19-Sep-01	901129	RESU		117	28	0.016
L5F1	19-Sep-01	901128	BLUE		117	26	0.035
L5F1	19-Sep-01	901127	BLUE		98	16	0.021
L5F1	19-Sep-01	901118	LMB	2	245	173	0.34
L5F1	19-Sep-01	901140	RESU		233	318	0.021
L5F1	19-Sep-01	901114	LMB	3	325	426	0.49
L5F1	19-Sep-01	901126	BLUE		115	25	0.02
L5F1	19-Sep-01	901117	LMB	2	254	209	0.51
L5F1	19-Sep-01	901115	LMB	1	218	145	0.2
L5F1	19-Sep-01	901119	LMB	2	254	217	0.51
L5F1	19-Sep-01	901120	LMB	0	150	43	0.3
L5F1	19-Sep-01	901121	BLUE		182	98	0.14
L5F1	19-Sep-01	901122	BLUE		166	81	0.07
L5F1	19-Sep-01	901123	BLUE		196	170	0.08
L5F1	19-Sep-01	901124	BLUE		195	115	0.13
L5F1	19-Sep-01	901125	BLUE		185	120	0.041
L5F1	19-Sep-01	901116	LMB	1	253	199	0.49
L67F1	16-Oct-01	1001417	BLUE		114	25	0.22
L67F1	16-Oct-01	1001416	BLUE		163	90	0.78
L67F1	16-Oct-01	1001415	BLUE		193	140	1.4
L67F1	16-Oct-01	1001414	BLUE		183	123	0.95
L67F1	16-Oct-01	1001413	BLUE		188	141	0.45
L67F1	16-Oct-01	1001412	BLUE		205	184	0.4
L67F1	16-Oct-01	1001411	RESU		193	193	0.42
L67F1	16-Oct-01	1001418	BLUE		108	22	0.42
L67F1	16-Oct-01	1001409	LMB	3	280	304	1
L67F1	16-Oct-01	1001427	BLUE		153	71	0.47
L67F1	16-Oct-01	1001410	RESU		239	270	0.29
L67F1	16-Oct-01	1001419	BLUE		129	41	0.41
L67F1	16-Oct-01	1001420	BLUE		153	65	1.5
L67F1	16-Oct-01	1001421	BLUE		146	61	0.38
L67F1	16-Oct-01	1001422	BLUE		174	98	1.4
L67F1	16-Oct-01	1001423	BLUE		160	77	0.84
L67F1	16-Oct-01	1001424	BLUE		159	81	0.42
L67F1	16-Oct-01	1001426	BLUE		147	61	0.86
L67F1	16-Oct-01	1001428	BLUE		163	82	0.54
L67F1	16-Oct-01	1001429	BLUE		159	81	0.39
L67F1	16-Oct-01	1001408	LMB	2	333	528	1
L67F1	16-Oct-01	1001399	LMB	4	413	1011	1.6

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
L67F1	16-Oct-01	1001425	BLUE		145	57	0.34
L67F1	16-Oct-01	1001398	LMB	3	384	831	1.3
L67F1	16-Oct-01	1001401	LMB	3	412	988	2.4
L67F1	16-Oct-01	1001407	LMB	3	332	504	1.6
L67F1	16-Oct-01	1001393	LMB	3	353	639	1.5
L67F1	16-Oct-01	1001394	LMB	2	382	746	1.3
L67F1	16-Oct-01	1001395	LMB	3	423	1101	2.1
L67F1	16-Oct-01	1001391	LMB	2	331	510	1.8
L67F1	16-Oct-01	1001397	LMB	4	358	640	1.5
L67F1	16-Oct-01	1001392	LMB	1	304	403	0.9
L67F1	16-Oct-01	1001400	LMB	3	393	991	2.2
L67F1	16-Oct-01	1001390	LMB	2	357	640	1
L67F1	16-Oct-01	1001402	LMB	2	362	712	1.1
L67F1	16-Oct-01	1001403	LMB	2	383	701	1.5
L67F1	16-Oct-01	1001404	LMB	3	327	512	1.4
L67F1	16-Oct-01	1001405	LMB	4	347	483	1.9
L67F1	16-Oct-01	1001406	LMB	2	287	318	0.92
L67F1	16-Oct-01	1001396	LMB	3	465	1441	2
LOX4	17-Sep-01	901341	LMB	1	285	394	0.56
LOX4	17-Sep-01	901342	LMB	0	184	96	0.25
LOX4	17-Sep-01	901343	LMB	0	180	82	0.29
LOX4	17-Sep-01	901362	BLUE		84	6	0.2
LOX4	17-Sep-01	901363	BLUE		82	5	0.12
LOX4	17-Sep-01	901361	WAR		90	15	0.12
LOX4	15-Oct-01	901381	BLUE		119	32	0.12
LOX4	15-Oct-01	901380	BLUE		127	40	0.22
LOX4	15-Oct-01	901379	BLUE		120	33	0.15
LOX4	15-Oct-01	901378	RESU		137	55	0.11
LOX4	15-Oct-01	901365	WAR		108	31	0.11
LOX4	15-Oct-01	901377	WAR		69	7	0.12
LOX4	15-Oct-01	901372	WAR		89	16	0.13
LOX4	15-Oct-01	901376	WAR		72	7	0.087
LOX4	15-Oct-01	901375	WAR		79	11	0.074
LOX4	15-Oct-01	901374	WAR		86	14	0.15
LOX4	15-Oct-01	901373	WAR		104	27	0.098
LOX4	15-Oct-01	901370	WAR		105	28	0.13
LOX4	15-Oct-01	901369	WAR		97	20	0.13
LOX4	15-Oct-01	901368	WAR		117	38	0.076
LOX4	15-Oct-01	901367	WAR		95	19	0.15
LOX4	15-Oct-01	901366	WAR		84	13	0.13
LOX4	15-Oct-01	901345	LMB	1	301	453	0.31
LOX4	15-Oct-01	901344	LMB	1	309	465	0.34
LOX4	15-Oct-01	901371	WAR		93	18	0.09
LOX4	15-Oct-01	901364	WAR		124	53	0.18
WCA2U3	19-Sep-01	901536	RESU		182	124	0.079
WCA2U3	19-Sep-01	901531	SPSU		119	34	0.13
WCA2U3	19-Sep-01	901532	RESU		158	69	0.051
WCA2U3	19-Sep-01	901533	RESU		160	84	0.045
WCA2U3	19-Sep-01	901534	RESU		182	129	0.096

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
WCA2U3	19-Sep-01	901539	RESU		135	44	0.083
WCA2U3	19-Sep-01	901530	SPSU		152	95	0.2
WCA2U3	19-Sep-01	901537	RESU		166	89	0.15
WCA2U3	19-Sep-01	901526	BLUE		88	11	0.076
WCA2U3	19-Sep-01	901538	RESU		117	31	0.031
WCA2U3	19-Sep-01	901529	SPSU		114	37	0.17
WCA2U3	19-Sep-01	901535	RESU		130	42	0.069
WCA2U3	19-Sep-01	901527	BLUE		92	14	0.13
WCA2U3	19-Sep-01	901525	BLUE		116	28	0.076
WCA2U3	19-Sep-01	901524	BLUE		173	107	0.11
WCA2U3	19-Sep-01	901522	BLUE		95	15	0.1
WCA2U3	19-Sep-01	901521	BLUE		124	36	0.11
WCA2U3	19-Sep-01	901501	LMB	2	271	301	0.57
WCA2U3	19-Sep-01	901523	BLUE		173	100	0.087
WCA2U3	19-Sep-01	901540	RESU		114	24	0.038
WCA2U3	19-Sep-01	901528	BLUE		61	3	0.06
WCA2U3	18-Oct-01	1001450	LMB	2	324	433	0.49
WCA2U3	18-Oct-01	1001466	LMB	0	167	55	0.26
WCA2U3	18-Oct-01	1001459	LMB	0	175	69	0.39
WCA2U3	18-Oct-01	1001451	LMB	1	288	303	0.57
WCA2U3	18-Oct-01	1001452	LMB	1	258	205	0.45
WCA2U3	18-Oct-01	1001453	LMB	1	260	190	0.27
WCA2U3	18-Oct-01	1001454	LMB	0	190	85	0.33
WCA2U3	18-Oct-01	1001455	LMB	0	176	66	0.24
WCA2U3	18-Oct-01	1001456	LMB	0	158	49	0.34
WCA2U3	18-Oct-01	1001468	LMB	0	160	49	0.37
WCA2U3	18-Oct-01	1001458	LMB	1	263	233	0.3
WCA2U3	18-Oct-01	1001467	LMB	0	166	60	0.44
WCA2U3	18-Oct-01	1001460	LMB	0	177	64	0.41
WCA2U3	18-Oct-01	1001461	LMB	0	171	62	0.18
WCA2U3	18-Oct-01	1001462	LMB	0	173	62	0.44
WCA2U3	18-Oct-01	1001463	LMB	0	166	64	0.35
WCA2U3	18-Oct-01	1001464	LMB	0	165	57	0.46
WCA2U3	18-Oct-01	1001465	LMB	0	170	61	0.43
WCA2U3	18-Oct-01	1001457	LMB	0	168	58	0.3
Z4	18-Oct-01	1001476	BLUE		118	37	0.12
Z4	18-Oct-01	1001481	BLUE		102	20	0.087
Z4	18-Oct-01	1001469	LMB	0	173	71	0.35
Z4	18-Oct-01	1001470	LMB	0	121	22	0.39
Z4	18-Oct-01	1001471	RESU		118	30	0.094
Z4	18-Oct-01	1001472	RESU		90	17	0.079
Z4	18-Oct-01	1001473	RESU		71	7	0.067
Z4	18-Oct-01	1001474	BLUE		118	32	0.11
Z4	18-Oct-01	1001475	BLUE		109	24	0.11
Z4	18-Oct-01	1001477	BLUE		108	27	0.18
Z4	18-Oct-01	1001478	BLUE		105	21	0.12
Z4	18-Oct-01	1001480	BLUE		85	11	0.087
Z4	18-Oct-01	1001490	BLUE		68	5	0.069
Z4	18-Oct-01	1001482	BLUE		92	14	0.098

Table 1a. (Cont'd.)

Location	Date	Sample ID	Species name	Age	Length (mm)	Weight (g)	THg (mg/Kg)
Z4	18-Oct-01	1001483	BLUE		100	24	0.12
Z4	18-Oct-01	1001484	BLUE		98	15	0.12
Z4	18-Oct-01	1001485	BLUE		101	21	0.097
Z4	18-Oct-01	1001486	BLUE		92	17	0.14
Z4	18-Oct-01	1001487	BLUE		92	15	0.099
Z4	18-Oct-01	1001488	BLUE		87	12	0.076
Z4	18-Oct-01	1001489	BLUE		74	7	0.097
Z4	18-Oct-01	1001479	BLUE		117	36	0.16

LITERATURE CITED

Bloom, N.S. 1992. On the chemical form of mercury in edible fish and marine invertebrates. *Can. J. Fish. Aquat. Sci.*, 49:1010-1017.

Bouton, S.N., P.C. Frederick, M.G. Spalding and H. McGill. 1999. Effects of chronic, low concentration of dietary methylmercury on the behavior of juvenile great egrets. *J. Environ. Toxicol. Chem*., 18(9):1934-1939.

Delfino, J.J., T.L. Crisman, J.F. Gottgens, B.R. Rood and C.D.A. Earle. 1993. *Spatial and temporal distribution of mercury in Everglades and Okefenokee wetland sediments*. Final Project Report (April 1, 1991 through June 30, 1993) to South Florida Water Management District (contract no. C91-2237), USGS (contract no. 14-08-0001-G-2012) and Florida DER (contract no. WM415).

FGMFWTF (Florida Governor's Mercury in Fish and Wildlife Task Force). 1991. *Mercury Technical Committee (MTC) Interim Report*.

Fink, L.E., D.G. Rumbold and P. Rawlik (1999). The Everglades mercury problem. Chapter 7 in *Everglades Interim Report*. South Florida Water Management District, West Palm Beach, FL.

Frederick, P.C., M.G. Spalding, M.S. Sepulveda, G.E. Williams, Jr., S.M. Lorazel and D.A. Samuelson. 1997. *Effects of elevated mercury on reproductive success of long-legged wading birds in the Everglades*. Final Report of the University of Florida to the Florida Department of Environmental Protection, Tallahassee, FL. August.

Frederick, P.C. and M. Spalding. 2000. *Temporal and geographical influences in mercury exposure in wading bird colonies across Florida*. Abstract from the Annual All-Investigators' Meeting: South Florida Mercury Science Program, May 9 through 11, 2000, Palm Harbor, FL.

Frederick, P.C., J. Heath, B. Hylton and M. Spalding. 2000. *Factors affecting breeding status of wading birds in the Everglades*. Report prepared for the U.S. Army Corps of Engineers. Jacksonville, FL.

FTN Associates. 1999. *Everglades mercury baseline report for the Everglades Construction Project under permit No. 199404532*. Prepared for the South Florida Water Management District, West Palm Beach, FL.

Gawlik, D.E. (ed.). 2000. *South Florida Wading Bird Report*. South Florida Water Management District, West Palm Beach, FL. Vol. 6, Issue 1. September 2000. Available online at: http://www.sfwmd.gov/org/erd/coastal/wading/rep00b.pdf.

Gilbert, R.O. 1987. *Statistical Methods for Environmental Pollution Monitoring*. Van Nostrand Reinhold, New York, NY.

Guentzel, J. 1997. The atmospheric sources, transport and deposition of mercury in Florida. Ph.D. thesis. Florida State University, Tallahassee.

Hakanson, L. 1980. The quantification impact of pH, bioproduction and Hg-contamination on the Hg content of fish (pike). *Environ. Pollut*., (Series B), 1:285-304.

Heinz, G.H., D.J. Hoffman, D.R. Murray and C.A Erwin. 2001. *Using egg injections to measure the toxicity of methylmercury to avian embryos*. Abstract submitted for November 2001 Annual Meeting of the Society of Environmental Toxicology and Chemistry, Philadelphia.

Hughes, K.D., P.J. Ewins and K.E. Clark. 1997. A comparison of mercury levels in feathers and eggs of osprey (Pandion halibuts) in North American Great Lakes. *Arch. Environ. Contam. Toxicol*., 33:441-452.

Hurley, J.P., D.P. Krabbenhoft, L.B. Cleckner, M.L. Olson, G.R. Aiken and P.S. Rawlik, Jr. 1998. System controls on the aqueous distribution of mercury in the northern Florida Everglades. *Biogeochem.*, 40:293-311.

Krabbenhoft, D.P. and L.E. Fink. 2001. The effect of drydown and natural fires on mercury methylation in the Florida Everglades. Appendix 7-8 in *2001 Everglades Consolidated Report*. South Florida Water Management District, West Palm Beach, FL.

Lange, T.R., D.A. Richard and H.E. Royals. 1998. *Trophic Relationships of Mercury Bioaccumulation in Fish from the Florida Everglades*. Annual Report, Florida Game and Fresh Water Fish Commission, Fisheries Research Laboratory, Eustis, FL. Prepared for the Florida Department of Environmental Protection, Tallahassee. August.

Lange, T.R., D.A. Richard and H.E. Royals. 1999. *Trophic relationships of mercury bioaccumulation in fish from the Florida Everglades*. Annual Report, Florida Game and Fresh Water Fish Commission, Fisheries Research Laboratory, Eustis, FL. Prepared for the Florida Department of Environmental Protection, Tallahassee. April.

Lange, T.R., D.A. Richard and H.E. Royals. 2000. *Long-term trends of mercury bioaccumulation in Florida's largemouth bass*. Abstract from the Annual All-Investigators Meeting: South Florida Mercury Science Program. May 9 through 11, 2000, Palm Harbor, FL.

Lange, T.R. and D.A. Richard. 2001. *Long-term trends of bioaccumulation of mercury in Florida largemouth bass*. Presented at the Annual All-Investigators Meeting: South Florida Mercury Science Program. May 7, 2001, West Palm Beach, FL.

Loftus, W.F., J.C. Trexler and R.D. Jones. 1998. *Mercury transfer through the Everglades aquatic food web*. Final report to the Florida Department of Environmental Protection, Tallahassee. December 1998.

Nelson D.A. and C.T. Theriot. 2000. *Distribution and abundance of wading birds in the Water Conservation Areas of the Florida Everglades, 2000*. U.S. Army Corps of Engineers, Waterways Experiment Station. December.

Pollman, C.D. and T.D. Atkeson. 2000. *Long-term trends in mercury atmospheric inputs and deposition in South Florida*. Abstract from the Annual All-Investigators Meeting: South Florida Mercury Science Program. May 9 through 11, 2000, Palm Harbor, FL.

Rumbold, D.G. 2000. Methylmercury risk to Everglades wading birds: a probabilistic ecological risk assessment. Appendix 7.3b in *2000 Everglades Consolidated Report*. South Florida Water Management District, West Palm Beach, FL.

Rumbold, D.G., L.E. Fink, K. Laine, F. Matson, S. Niemczyk and P. Rawlik. 2001. Annual permit compliance monitoring report for mercury in Stormwater Treatment Areas and downstream receiving waters of the Everglades Protection Area. Appendix 7-9 in *2001*

Everglades Consolidated Report. South Florida Water Management District, West Palm Beach, FL.

Rumbold, D.G. and P. Rawlik. 2000. Annual permit compliance monitoring report for mercury in Stormwater Treatment Areas and downstream receiving waters. Appendix 7-2 in *2000 Everglades Consolidated Report*. South Florida Water Management District, West Palm Beach, FL. January.

Rumbold, D.G., S.L. Niemczyk, L.E. Fink, T. Chandrasekhar, B. Harkanson and K.A. Laine. 2001. Mercury in eggs and feathers of great egrets (*Ardea albus*) from the Florida Everglades. *Arch. Environ. Contam. Tox*., 41:501-507.

Sepulveda, M., P.C. Frederick, M.S. Spalding and G.E. Williams, Jr. 1999. Mercury contamination in free-ranging great egret nestlings (*Ardea albus*) from southern Florida, U.S.A. *Environ. Tox. Chem*., 18:985-992.

Sweet, C.W. 2001. *Wet deposition of mercury in Florida, 1995 through 2000*. Abstract from the USEPA Workshop on the Fate, Transport, and Transformation of Mercury in Aquatic and Terrestrial Environments. May 8 through 10, 2001, West Palm Beach, FL.

Thompson, D.R. 1996. *Mercury in birds and terrestrial mammals*. Beyer W.N., G.H. Heinz and A.W. Redmon-Norwood (eds.). *Environmental contaminants in wildlife: interpreting tissue concentrations*. Lewis Publishers, Boca Raton, FL, p. 341.

USEPA. 1997. *Mercury study report to Congress. Vol. VI: An ecological assessment for anthropogenic mercury emissions in the United States*. EPA-452/R-97-008.

USEPA. 1998. *South Florida Ecosystem Assessment. Volume 1. Final Technical Report. Phase I. Monitoring for adaptive management: implications for ecosystem restoration*. Region 4 and Office of Research and Development. Athens, GA. EPA-904-R-98-002.

Ware, F.J., H. Royals and T. Lange. 1990. *Mercury contamination in Florida largemouth bass*, 44:5-12. Proc. at annual conference of the Southeast Assoc. of Fish Wildlife Agencies.

Watras, C. 1993. Potential impact of the Everglades Nutrient Removal Project on the Everglades mercury problem. (EV 930034). Unpublished report prepared for the South Florida Water Management District. University of Wisconsin, Madison. October.

Wren, C.D. and H.R. MacCrimmon. 1986. Comparative bioaccumulation of mercury in two adjacent freshwater ecosystems. *Water Research*, 20:763-769.

Zar, J.H. 1996. *Biostatistical analysis (third edition)*. Prentice-Hall, New Jersey.