

Appendix 5-4: Annual Permit Compliance Monitoring Report for Mercury in the STAs

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KEY FINDINGS AND OVERALL ASSESSMENT

This report summarizes data from compliance monitoring of mercury (Hg) storage, release, and biomagnification in Stormwater Treatment Areas (STAs). Fish data in this report are summarized for calendar year 2007 (CY2007) while surface water data are summarized for Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008).

Key findings are as follows:

1. **All STAs:** There were no violations of the Florida Class III numerical water quality standard of 12 nanograms (ng) of total mercury per liter (THg/L) during the reporting year at any of the STAs. In addition, there were no exceedances of each criterion listed in the *Protocol for Monitoring Mercury and Other Toxicants* (SWFMD, 2006). As such, the project has met the requirements of Section 6.i of the mercury monitoring program of the referenced permits.
2. **STA-1W:** Stormwater Treatment Area 1 West (STA-1W) subsumed the Everglades Nutrient Removal (ENR) project in April 1999. The ENR project served as the prototype STA and had been in operation since 1994. After more than 10 years of operation, this STA maintains low concentrations of both total mercury (THg) and methylmercury (MeHg) in surface water and consistently exhibits a negative percent change in both THg and MeHg, evidence that mercury concentrations in the outflows were consistently lower than in the inflow. Outflow loads of THg and MeHg continue to be considerably lower than inflow. For WY2008, this STA also showed the largest difference between inflow and outflow loading for both THg and MeHg. Furthermore, MeHg biomagnification in resident large-bodied fishes (e.g., sunfish

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[*Lepomis* spp.] and largemouth bass [*Micropterus salmoides*]) has remained relatively constant over the monitoring period at levels almost an order of magnitude lower than observed in fishes from the downstream Everglades. Mercury levels in fish do not appear to pose a threat to fish-eating wildlife based on the U.S. Fish and Wildlife Service (USFWS) and the U.S. Environmental Protection Agency (USEPA) predator protection criteria.

3. **STA-1E:** During WY2008, THg remained at relatively low concentrations in the outflow, as compared to the multiple inflows; however, MeHg demonstrated higher levels in the outflow. This STA continues to show some of the highest surface water THg levels in comparison to all other STAs and downstream monitoring locations, which may be due to start-up related factors. For WY2008, THg and MeHg loading at the outflow was less than inflow, however only marginally. Mercury levels in mosquitofish (*Gambusia holbrooki*) from the interior marshes were the second highest out of all STAs and did not change appreciably from the first to the fourth quarter of 2007. Mercury levels were also elevated in STA-1E sunfish and largemouth bass. Regarding risks to fish-eating wildlife, mosquitofish (falling under trophic level [TL] 2 or 3) did not exceed the 77 nanograms per gram (ng/g) criterion. Nearly all resident sunfish with STA-1E were well below the USFWS criterion of 100 ng/g and the USEPA predator protection criterion of 77 ng/g for trophic level 3 (TL 3) fish.
4. **STA-2:** For WY2008, both THg and MeHg remained at low concentrations in the outflow relative to previous years; however, inflow concentrations have increased two-fold since WY2006. In addition, outflow loads of both THg and MeHg are higher than inflow. Average levels of mercury in mosquitofish have increased since 2007 (tissue-Hg; measured as nanograms of mercury per gram of fish weight [ng Hg/g]), but remain relatively low compared to all other STAs and downstream marshes. Sunfish from interior cells show no major change since 2006 and THg concentration more than doubled at the interior and downstream locations. Regarding risk to fish-eating wildlife, all resident fish at STA-2 contained mercury levels greater than both the USFWS and USEPA predator protection criteria for TL 3 species (100 ng/g and 77 ng/g, respectively).
5. **STA-3/4:** Water-column THg concentrations were low and uniform during WY2008. However, concentrations of THg were highly variable among structures in the fourth quarter. Outflow loads of MeHg and THg were much lower than inflow. Similar to 2006, resident sunfish from the interior marshes of STA-3/4 contained slightly elevated mercury levels compared to fish from all other STAs, but were lower in comparison to downstream sites. Also similar to 2006, tissue-Hg levels in mosquitofish from this STA were moderate compared to mosquitofish from other STAs. Mosquitofish contained mercury at concentrations lower than the criteria set by the USFWS (100 ng/g) and the USEPA (77 ng/g). Five percent of all sunfish from the inflow, 8 percent from the interior, and 18 percent from the downstream location exceeded the USFWS criteria. THg concentration in largemouth bass from interior sites averaged 184 ng/g ($\pm$ 129 ng/g), which is a 36 percent reduction from 2006. Nearly all largemouth bass from inflow, interior marshes, and outflow (with mean results of 85, 128, and 266 ng/g, respectively) were less than the USEPA predator protection criteria based on TL 4 fish (346 ng/g). Only one to two samples from each location exceeded the TL 4 criterion.
6. **STA-5:** With the exception of minor spikes in THg in the inflows and outflows during the fourth quarter, water-column concentrations of both THg and MeHg remained low at STA-5 during WY2008. Inflow and outflow loads of both THg and MeHg continue to decrease and outflow loads are lower than inflow. Mosquitofish and sunfish collected in 2007 contained similar mercury levels compared to fish previously collected at this STA and these levels were low compared to downstream marshes. From 2006 to 2007 there was an increase (30 percent) in average sunfish mercury concentration within the interior marsh. The lack of fish

collection and ability age-standardize down through the years has made long-term evaluation of largemouth bass in this STA difficult. From 2006 to 2007, largemouth bass within the interior marsh showed a slight increase (10 percent). Fish-eating wildlife foraging preferentially from the interior marsh of STA-5 appears to be at low to moderate risk from mercury exposure and a slight elevated risk if feeding near site RA1.

7. **STA-6:** THg and MeHg concentrations at the inflows and outflows were nearly the same throughout WY2008, and remained relatively low compared to previous spikes. Cells 3 and 5 dried down twice during WY2008 for approximately three months, yet neither THg nor MeHg spiked. While it is possible that the methylation rate did not spike, past STA performance following the rewetting of the marsh indicates the likelihood that quarterly surface water sampling missed a transient spike. For WY2008, inflow and outflow loads of THg and MeHg were lowest compared to all other STAs and outflow loads were less than inflow. There was an 83 percent increase in mosquitofish THg concentration from 2006 to 2007. Sunfish from the interior marshes for 2007 exhibited higher levels than all other STAs. Average level also increased by more than 50 percent since 2006. Based on USFWS and USEPA predator protection criteria, fish-eating wildlife foraging preferentially at STA-6 appears to have a moderate to elevated risk for mercury exposure, particularly if feeding on sunfish from the interiors and downstream locations. Unlike the increase for sunfish, largemouth bass THg concentrations stayed nearly the same level since 2006 for both the interior marsh and the downstream monitoring stations. Overall, this STA demonstrates some of the highest THg levels in all fish species. Despite lacking the observation of transitory spikes or constant elevated surface water MeHg concentrations (relative to other STAs), it is likely that the natural dryout and re-flood within this STA is playing a major role in the elevated THg levels in fish.

INTRODUCTION

This is the annual permit compliance monitoring report for mercury (Hg) in Stormwater Treatment Areas (STAs) by the South Florida Water Management District (SFWMD or District). The report summarizes the mercury-related reporting requirements of the Florida Department of Environmental Protection (FDEP) Everglades Forever Act (EFA) permits (Chapter 373.4592, Florida Statutes [F.S.]), including permits for STA-1W, STA-1E, STA-2, STA-3/4, STA-5, and STA-6. This report summarizes the results of monitoring in the Calendar Year 2007 (CY2007) for fish and Water Year 2008 (WY2008) (May 1, 2007–April 30, 2008) for surface water. The results of mercury monitoring at far-field sites downstream of the STAs in accordance with these permits, as well as non-Everglades Construction Project (non-ECP) discharge structures (Permit No. 06.502590709), is reported separately in Appendix 3B-1 of this volume.

This report consists of key findings and overall assessment, an introduction and background, a summary of the Mercury Monitoring and Reporting Program, and monitoring results. The background section briefly summarizes previously identified and published concerns regarding possible impact of STA operations on South Florida's mercury problem. The subsequent section summarizes sampling and reporting requirements of the Mercury Monitoring and Assessment Program within the STAs. The summary and discussion is divided into two sections: monitoring results during the reporting year and optimizing the Mercury Monitoring Network.

BACKGROUND

STAs are constructed wetlands designed to remove phosphorus from stormwater runoff originating from upstream agricultural areas and other areas, including Lake Okeechobee releases. The original six STAs totaling about 50,000 acres were built as part of the Everglades Construction Project (ECP) authorized under the Everglades Forever Act (EFA), Chapter 373.4592, Florida Statutes (F.S.).

Even prior to passage of the EFA, concerns were being raised that, in attempting to reduce downstream eutrophication, the restoration effort could inadvertently aggravate the mercury problem known to be present in the Everglades (Ware et al., 1990; Mercury Technical Committee, 1991). These concerns stemmed from studies in other areas that showed flooded soils in new impoundments to be a source of inorganic mercury (Cox et al., 1979). Of greater concern, studies also showed wetlands to be a significant site of mercury methylation.

Methylmercury (MeHg) is more bioaccumulative and toxic than the inorganic or elemental form of mercury (St. Louis et al., 1994; Rudd, 1995). Decomposition of flooded terrestrial vegetation and soil carbon in new reservoirs was reported to stimulate the sulfate-reducing bacteria that methylate inorganic mercury (Kelly et al., 1997; Paterson et al., 1998). Environments that favor methylation also drive bioaccumulation. For example, Paterson et al. (1998) found that annual fluxes of MeHg increased 10 to 100 times through a zooplankton community after impoundment.

Newly created reservoirs were also found to contain fish with elevated mercury burdens (Abernathy and Cumbie, 1977; Bodaly et al., 1984; Bodaly and Fudge, 1999). This so-called reservoir effect can occasionally persist for several decades after initial soil flooding (Bodaly et al., 1984; Verdon et al., 1991; Fink et al., 1999). For instance, Verdon et al. (1991) reported that mercury levels in northern pike (*Esox lucius*) increased from 0.61 to 2.99 parts per million and

continued to increase nine years after the initial soil flooding. Given these observations, Kelly et al. (1997) recently recommended that in siting a new reservoir total land area flooded should be minimized, and flooding the wetlands, which contain more organic carbon than the uplands, should be avoided.

However, applying these observations directly to the Everglades is problematic because most of these observations were made in deepwater lakes or reservoirs in temperate regions. In a report to the SFWMD on the potential impact of nutrient removal on the Everglades nutrient problem (Watras, 1993), the author stated that “the boreal and temperate watersheds, wetlands and reservoirs studied to date are very different geologically, hydrologically, meteorologically and ecologically from the subtropical systems in the Everglades.” Watras recommended monitoring and integrating mass balance and process-oriented studies to understand how this subtropical system would behave. Such studies were initiated in 1994 with the start-up of the prototype STA, the Everglades Nutrient Removal (ENR) Project. Baseline collections at the ENR Project (funded by the SFWMD and others) found no evidence of MeHg spikes in either surface water (PTI, 1994 attributed to KBN, 1994a; Watras, 1993 and 1994) or resident fishes (mosquitofish and largemouth bass; PTI, 1994 attributed to KBN, 1994b).

During the first two years of operation, median concentrations of total mercury (THg) and MeHg in unfiltered surface water were reported to be 0.81 and 0.074 nanograms per liter (ng/L), respectively (Miles and Fink, 1998). These low levels persisted in later years: from January 1998 through April 1999, median water-column concentrations in the interior marsh (i.e., excluding inflows and outflows) were 0.81 ng THg/L and 0.04 ng MeHg/L (Rumbold and Fink, 2002b).

Resident fishes also continued to have only low mercury levels: 8–75 nanograms per gram (ng/g) in mosquitofish, and 100–172 ng/g in three-year-old bass (Miles and Fink, 1998; SFWMD, 1999a; Lange et al., 1999). Finally, a mass balance assessment found the ENR Project to be a net sink for both THg and MeHg, removing approximately 70 percent of the inflow mass (Miles and Fink, 1998). Nonetheless, to provide continuing assurance that the ECP does not exacerbate the mercury problem, the FDEP construction and operating permits issued for the STAs require the SFWMD to monitor levels of THg and MeHg in various abiotic (e.g., water and sediment) and biotic (e.g., fish and bird tissues) media, both within STAs and the downstream receiving waters.

Results from monitoring programs at STAs constructed and operated since 1999 (after the ENR Project) have revealed transitory spikes in MeHg production (see previous reports published by the SFWMD, including Rumbold and Fink, 2002b). Combined with the results of a 1999 field study on the effect that drought and muck fires had on mercury cycling in the Everglades (Krabbenhof and Fink, 2001), these monitoring results demonstrated that spikes can sometimes occur following dryout and rewetting. Accumulating evidence suggests that oxidation of sulfide pools in the sediments (e.g., organic sulfide, disulfides, and acid volatile sulfides) during the dryout can lead to increased methylation upon rewetting of the marsh either by providing free sulfate, which stimulates the sulfate-reducing bacteria or, in highly sulfidic areas, by reducing porewater sulfide, which can inhibit methylation (Benoit et al., 1999a and b).

SUMMARY OF THE MERCURY MONITORING AND ASSESSMENT PROGRAM

The following section provides information on current monitoring and reporting activities used for the District's Mercury Monitoring and Assessment Program. The Mercury Monitoring Program was a plan developed for the Everglades Construction Project, the Central and Southern Florida Project, and the Everglades Protection Area. The SFWMD submitted this plan to the FDEP, the U.S. Environmental Protection Agency (USEPA), and the U.S. Army Corps of Engineers (USACE) in compliance with the requirements of the aforementioned permits (SFWMD, 1999b).

Details on the procedures for ensuring the quality of and accountability for data generated in this monitoring program are set fourth in the SFWMD's Quality Assurance Project Plan (QAPP) for the Mercury Monitoring and Assessment Program (SFWMD, 1999c), which was approved on issuance of the permit by the FDEP. QAPP revisions were approved by the FDEP on June 7, 1999.

On February 13, 2006, a revised sampling protocol was approved by both the FDEP and the District entitled *A Protocol for Monitoring Mercury and Other Toxicants* (SFWMD, 2006), hereafter referred to as the Protocol. Adapted from the District Guidance in the Design of a Project-Level Monitoring and Assessment Plan for Mercury and Other Toxicants (Rumbold and Pfeuffer, 2005), this new plan was developed to replace the Mercury Monitoring Program.

The primary drivers of the Protocol are to (1) stream-line sampling procedures; (2) eliminate the need for extended, open-ended sampling activities; and (3) phase-out surface water sampling. The same QAPP is used. As of May 16, 2008, all mercury monitoring within each STA follows the Protocol.

MERCURY MONITORING PROGRAM

Everglades Mercury Baseline Monitoring and Reporting Requirements

Levels of THg and MeHg in the pre-operational soils of each of the STAs and various abiotic and biotic media of the downstream receiving waters define the baseline condition from which to evaluate mercury-related changes, if any, brought about by STA operations. The Everglades Mercury Background Report, prepared prior to the operation of the first STA, defines pre-ECP mercury baseline conditions (FTN Associates, 1999).

Pre-Operational Monitoring and Reporting Requirements

Prior to the completion of construction and flooding of the soils for each STA, the District is required to collect 10-centimeter (cm) core samples of soil at six representative interior sites for THg and MeHg analyses. Prior to the initiation of discharge, the District is also required to collect biweekly samples of supply canal and interior unfiltered water for THg and MeHg analyses. If concentrations at the interior sites are not significantly greater than that of the supply canal, this information is reported to the permit-issuing authority, and then the biweekly sampling can be discontinued.

Discharge begins after all the start-up criteria are met. Results from pre-operational monitoring of STAs 1W, 1E, 2, 3/4, 5, and 6 were reported previously (SFWMD, 1998c and 1999d; Rumbold and Rawlik, 2000; Rumbold and Fink, 2002a and 2003a; Rumbold, 2004 and 2005a; Rumbold et al., 2001 and 2006). **Figure 7** in this appendix summarizes the results of pre-operational sediment collection.

Operational Monitoring

Following approval for initiation of routine operation of an STA and thereafter, the ECP permits require that the following samples be collected at the specified frequencies and analyzed for specified analytes:

Water

On a quarterly basis, 500-milliliter unfiltered grab samples of water are collected in pre-cleaned bottles using the ultraclean technique at the supply canals and outflows of each STA. They are analyzed for MeHg and THg (this includes the sum of all mercury species in a sample, including Hg^0 , Hg^{1+} , and Hg^{2+} , as well as organic mercury). THg results are analyzed for compliance with the Florida Class III water quality standard of 12 ng/L. Outflow concentrations of both THg and MeHg are compared to concentrations at the supply canal.

Sediment

Triennially, sediment cores are collected at depth from 0 to 10 cm at six representative interior sites. Each depth-homogenized core is then analyzed for THg and MeHg.

Prey Fish

Semiannually, grab samples in the range of 100 and 250 mosquitofish (*Gambusia* sp.) are collected using a dip net at the supply canal sites, interior sites, and outflow sites of each STA. Individual fish are composited from each size, the homogenate is subsampled in quintuplicate, and each subsample is then analyzed for THg. On March 5, 2002, the FDEP approved a reduction in the number of replicate analyses of the homogenate from five to three (correspondence from F. Nearhoof, FDEP). In 2007, reduction was approved for reducing the homogenate from three to one.

Top Predator Fish

Annually, 20 largemouth bass (*Micropterus salmoides*) are collected primarily through electroshocking methods at representative supply and discharge canal sites and representative interior sites in each STA. Fish muscle (fillet) samples are analyzed for THg as an indicator of potential human exposure to mercury.

In 2000, the District began routine collection of sunfish (*Lepomis* spp.) at the same frequency, intensity (i.e., $n = 20$), and locations as for largemouth bass collection. This permit revision fulfilled a USFWS recommendation (USFWS recommendation 9b in USACE Permit No. 199404532; correspondence to Bob Barron, USACE, July 13, 2000). Sunfish, which are analyzed as whole fish, also serve as a surrogate for attempts to monitor mercury in wading birds that do not nest in the STAs. (For details on the monitoring program tracking mercury in wading birds in

downstream areas; see Appendix 3B-1 of this volume.) The addition of sunfish to the compliance monitoring program was approved by the FDEP on March 5, 2002, (correspondence from F. Nearhoof, FDEP).

Tissue concentrations in each of the three monitored fishes reflect ambient MeHg levels, indicating their exposure as a function of factors including body size, age, rate of population turnover, and trophic position. Mosquitofish usually respond rapidly to changing ambient MeHg concentrations due to their small size, lower trophic status, short life span, and rapid population turnover. Mosquitofish become sexually mature in approximately three weeks and have an average lifespan of only four to five months; the lifespan of males is shorter than females (Haake and Dean, 1983; Haynes and Cashner, 1995; Cabral and Marques, 1999).

Conversely, the longer lifespan of sunfish (thought to have an average lifespan of four to seven years in the wild) and bass means they ordinarily take longer to respond, in terms of tissue concentrations, to changes in ambient MeHg availability. Most importantly, sunfish and bass represent exposure at higher trophic levels (TL) with a requisite time lag for trophic exchange. While this focus on a three-year old bass is appropriate to evaluate exposure to fishermen, it complicates the data results by only interpreting tissue concentration over a three-year period. The key is to use these species-related differences to better assess MeHg availability within the system overall.

It is important to also recognize that virtually all of the mercury in fish muscle tissues (more than 85 percent) is in the methylated form (Grieb et al., 1990; Bloom, 1992). Therefore, the analysis of fish tissue for THg, which is a more straightforward and less costly procedure than for MeHg, can be interpreted as being equivalent to the analysis of MeHg. Further details regarding rationales for sampling scheme, procedures, and data reporting requirements are set fourth in the Everglades Mercury Monitoring Plan revised in March 1999 (SWFMD, 1999).

PROTOCOL FOR MONITORING MERCURY AND OTHER TOXICANTS

Phase 1: Baseline Collection and Assessment

Phase 1 baseline collection and assessment is meant to provide information regarding the likelihood that a constructed facility under an ECP project may exacerbate or create a mercury (or other toxicant) problem. Identifying problematic areas will allow managers to avoid sites or areas that may present risk.

Phase 1 is operated under three tier levels: Tier 1 (Compilation and Review of Available Data), Tier 2 (Field Sampling), and Tier 3 (Bioaccumulation Tests and Dynamic Modeling).

Under Tier 1, the Environmental Site Assessment (ESA) is evaluated to determine (1) if any corrective actions were taken during the ESA, (2) there was potential for contamination, and/or (3) the time interval between the ESA and project construction. If information data gaps exist or where preponderance of the baseline data demonstrates a potential problem, then Phase 1, Tier 2, or Tier 3 is initiated.

Under Phase 1 Tier 2, five representative soil/sediment cores are collected and analyzed for several constituents (e.g., TFe, TS) that help evaluate MeHg production and mercury bioaccumulation. **Figure 7** summarizes sediment collection under Phase 1. Along with sediment,

mosquitofish and large-bodied fish (sunfish, largemouth bass) are collected and analyzed for THg within the same operating unit (OU). The methods used for fish and sediment collection are described in the sections below.

Phase 1 Tier 3 is initiated if at least one of the following occurs: (1) absolute concentrations of MeHg or average percent MeHg in sediments/soils from an OU exceeds the 90 percent upper confidence level of the basin average or, if not available, the 75th percentile concentration (percent MeHg) for all basins; or (2) ambient fish collected with the project boundary demonstrate excessive bioaccumulation that exceeds the 90 percent upper confidence level of the basin-wide average or, if that value is not available, the 75th percentile concentration for all basins. Phase 1, Tier 3 is used to evaluate extending uncertainties surrounding mercury bioaccumulation. This is accomplished through the use of bioaccumulation testing and modeling.

Phase 2: Monitoring During Three-Year Stabilization Period

If Phase 1 monitoring is not necessary, then Tier 2 monitoring can occur following OU flow-through. Under Phase 2, Tier 1, one surface water sample is collected and analyzed for THg and MeHg on a quarterly basis at inflow and outflow structures (SFWMD, 2006). Additionally, at least 100 mosquitofish are collected from multiple locations within each OU on a quarterly basis, to be composited and analyzed for THg. Sunfish and largemouth bass ($n \geq$ five) are collected and analyzed for THg on an annual basis.

Six criteria (SFWMD, 2006) are used to evaluate the performance of an OU in terms of mercury bioaccumulation and enhancement. These criteria are related to long-term trends in fish tissue concentrations, surface water THg/MeHg loading, and water quality standards.

If any of the action criteria is exceeded, then Phase 2, Tier 2 is triggered. Tier 2 sequentially involves (1) notifying the permitting authority; (2) resampling the media that triggered Tier 2 Monitoring; (3) evaluating the spatial and temporal extent of the mercury bioaccumulation/enhancement accompanied with bioaccumulation modeling; and (4) developing an adaptive management plan.

Phase 3: Operational Monitoring

If after the first three years of monitoring, neither downstream loading nor residue levels in fishes have exceeded action levels in the two years prior, then the Project can move into Phase 3, Tier 1. Under Phase 3, Tier 1, (1) surface water sampling is discontinued; (2) the frequency of mosquitofish collection is reduced to semiannually; and (3) the frequency of large-bodied fish collection is reduced to one collection event every three years. If the conditions are not met within the first three years, then criteria can be reevaluated annually based on the preceding two-year period.

Phase 3, Tier 2, is triggered if (1) the annual average THg levels in mosquitofish progressively increase over time; (2) any semiannual mosquitofish composite exceeds the 90 percent upper confidence level of the basin-wide annual average (or, if basin-specific data are lacking, it exceeds the 75th percentile concentration for the period of record for all basins); or (3) if triennial monitoring of large-bodied fish (i.e., in years six to nine) reveal tissue Hg levels have statistically increased over time (i.e., over two or more years) or have become elevated to the point of exceeding the 90 percent upper confidence level of the basin-wide annual average (or if basin-specific data are lacking, exceeds the 75th percentile for the period of record for all basins).

If fishes under Phase 3 operational monitoring have not exceeded action levels by the ninth year, project-specific mercury monitoring can be moved into Phase 3, Tier 3. Under Phase 3, Tier 3, all of the project's mercury-related monitoring is discontinued. Future assessments would be based on regional monitoring under RECOVER. However, project managers are cautioned that action levels may be revised in the future.

QUALITY ASSURANCE MEASURES

For quality assurance/quality control (QA/QC) assessment of the District's Mercury Monitoring Program during 2007, see Appendix 3B-1 of this volume.

STATISTICAL METHODS

The proper interpretation of residue levels in tissues can sometimes prove problematic due to the confounding influences of age or species of collected animals. For comparison, special procedures are used to normalize the data (Wren and MacCrimmon, 1986; Hakanson, 1980). To be consistent with the reporting protocol used by the Florida Fish and Wildlife Conservation Commission (Lange et al., 1998 and 1999), mercury concentrations in largemouth bass are standardized to an expected mean concentration in three-year-old fish at a given site by regressing mercury against age (hereafter symbolized as EHg3). Sunfish are not aged. Instead, arithmetic means are reported. Additionally, the distribution of the different species of sunfish (warmouth [*L. gulosus*], spotted sunfish [*L. punctatus*], bluegill [*L. macrochirus*], and redear sunfish [*L. microlophus*]) that are collected during electroshocking is also qualitatively considered as a potential confounding influence on mercury concentrations prior to each comparison.

Where appropriate, analysis of covariance (ANCOVA) using the SAS General Linear Model procedure, is used to evaluate spatial and temporal differences in mercury concentrations, with age (largemouth bass) or weight (sunfish) as a covariate. However, use of ANCOVA is predicated on several critical assumptions (Zar, 1996). These assumptions are that (1) regressions are simple linear functions, (2) regressions are statistically significant (i.e., nonzero slopes), (3) a covariate is a random, fixed variable, (4) both the dependent variable and residuals are independent and normally distributed, and (5) slopes of regressions are homogeneous (parallel, i.e., no interactions). Regressions also require that collected samples exhibit a relatively wide range of covariate; that is, that fish from a given site are not all the same age or weight. Where these assumptions were not met, ANCOVA is inappropriate. Instead, standard analysis of variance (ANOVA [$n > \text{two groups}$]) or Student's t-tests ($n \leq \text{two groups}$) is used.

Possible covariates are considered separately and often qualitatively. The assumptions of normality and equal variance are tested by the Kolmogorov-Smirnov and Levene Median tests, respectively. Datasets that either lacked homogeneity of variance or departed from normal distribution are natural-log transformed and reanalyzed. If transformed data met the assumptions, then they are used in ANOVA. If multi-group null hypotheses are rejected under ANOVA, then the group is compared using either Tukey HSD (Honestly Significant Difference; for equal sized data sets) test, the Tukey-Kramer (for unequal sized data sets), or the Holm-Sidak test.

If the group did not meet any of these assumptions, then raw datasets are evaluated using nonparametric tests such as the Kruskal-Wallis ANOVA on ranks ($n > \text{two groups}$) or the Mann-Whitney Rank sum test ($n \leq \text{two groups}$). If the multi-group null hypothesis is rejected, then the groups are compared using either the Nemenyi test (for equal sized data sets) or Dunn's Method (for unequal sized datasets). The Pearson Product moment (or the non-parametric

equivalent Spearman Rank Order) is used to evaluate the relationship between two parameters. Linear regression is used to develop a line of best fit (linear model) between parameters.

SITE DESCRIPTIONS

Site descriptions and operational plans for STAs 1W, 2, 3/4, 5, and 6 are published elsewhere (SFWMD, 1997; 1998a; 1998b; 1999d; 2004); similar information on STA-1E was not available as of the date of this report. For maps of monitoring locations, see **Figures 1** through **6** below.

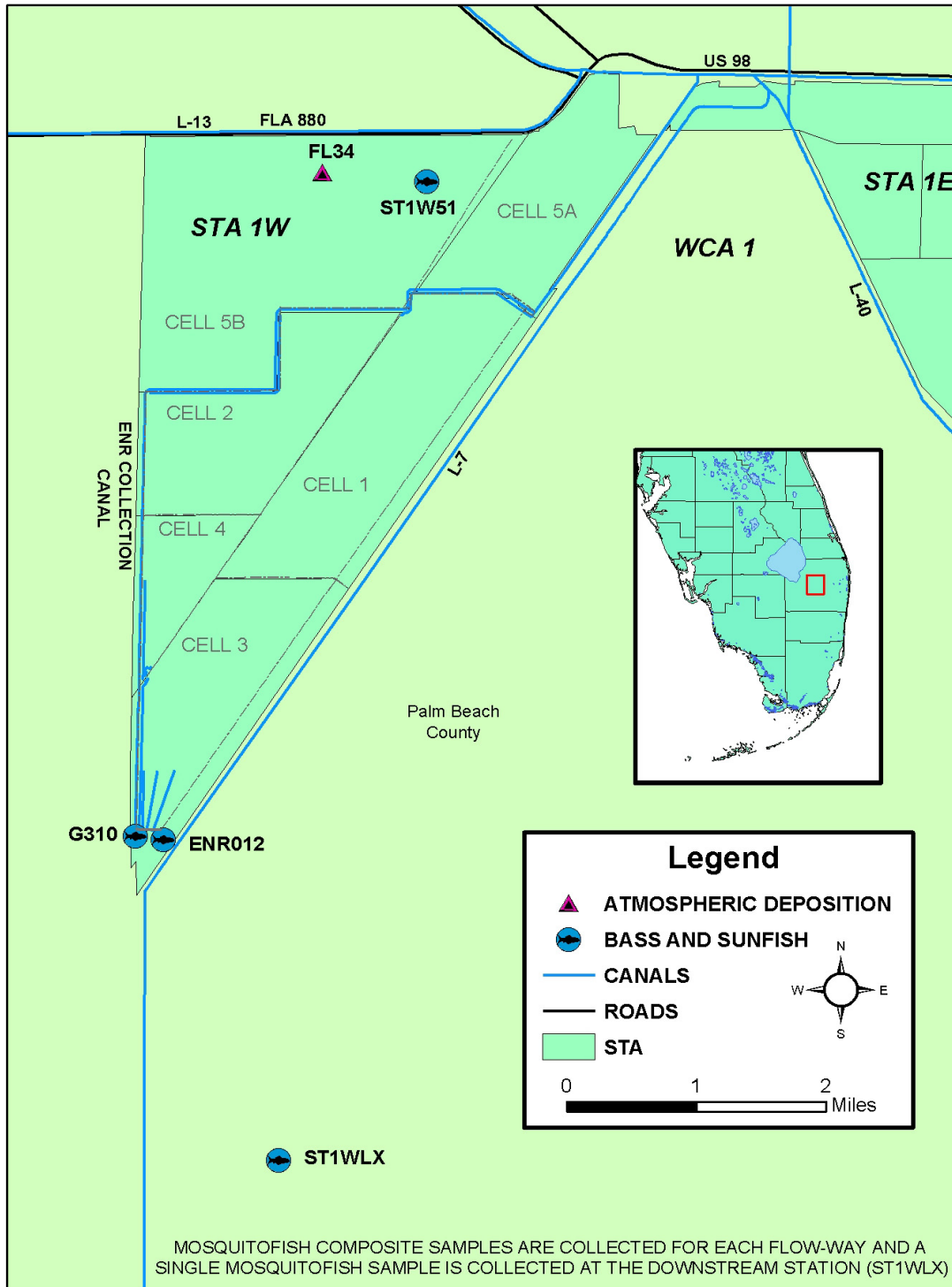


Figure 1. Stormwater Treatment Area 1 West (STA-1W) showing current mercury monitoring sites.

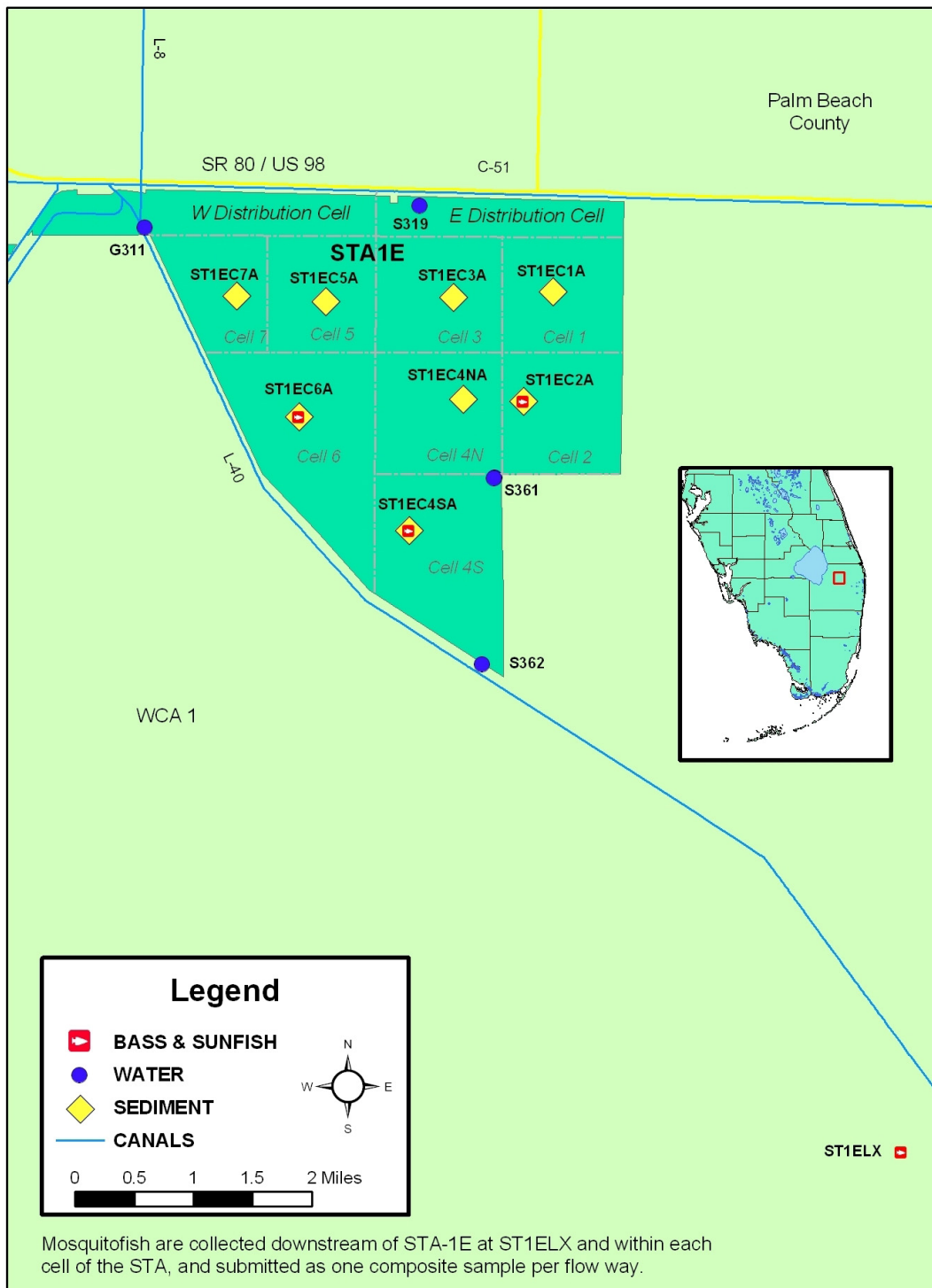


Figure 2. Map of Stormwater Treatment Area 1 East (STA-1E) showing current mercury monitoring sites.

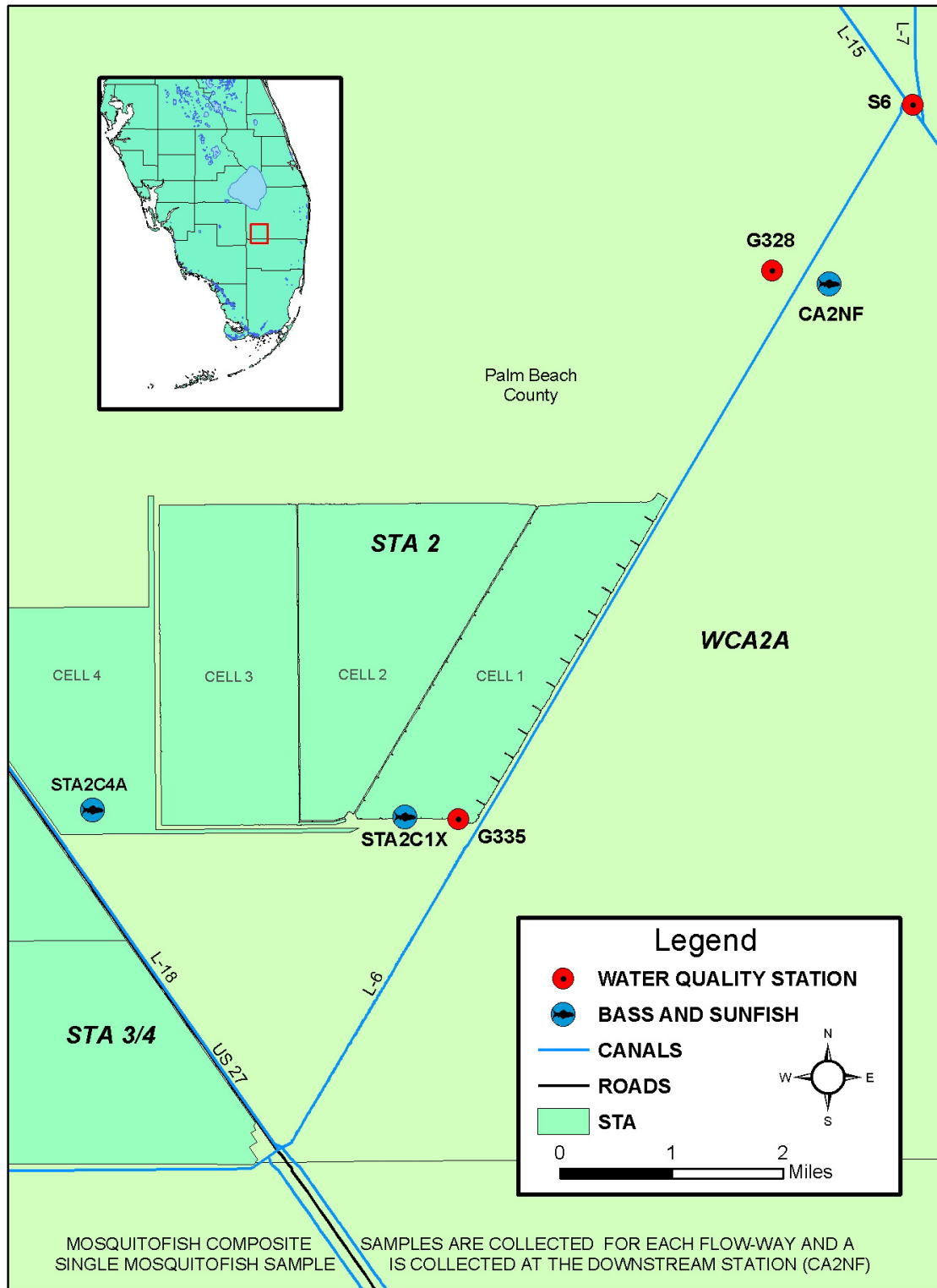


Figure 3. Map of Stormwater Treatment Area 2 (STA-2) showing current mercury monitoring sites.

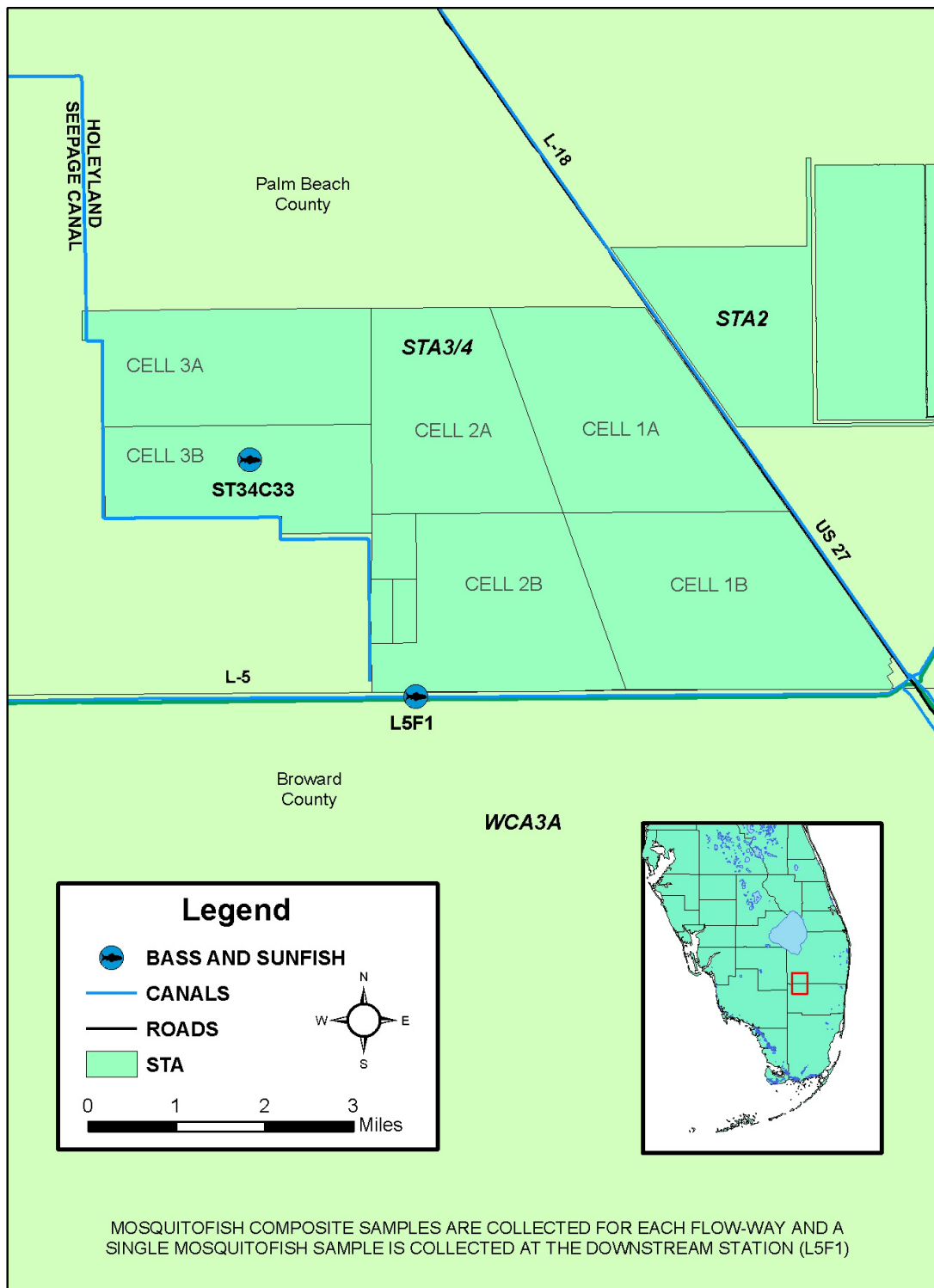


Figure 4. Map of Stormwater Treatment Area 3/4 (STA-3/4) showing current mercury monitoring sites.

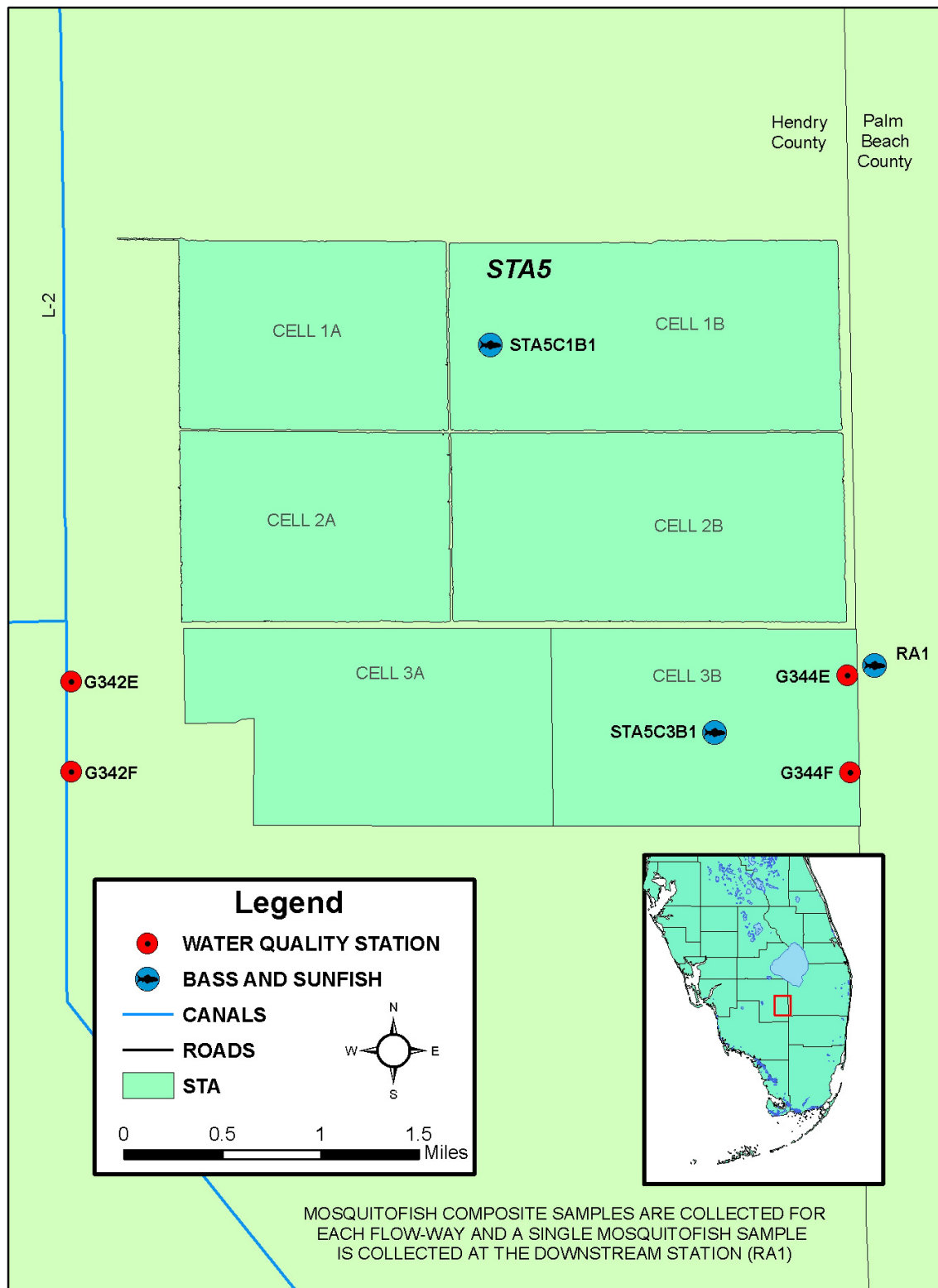


Figure 5. Map of Stormwater Treatment Area 5 (STA-5) showing current mercury monitoring sites.

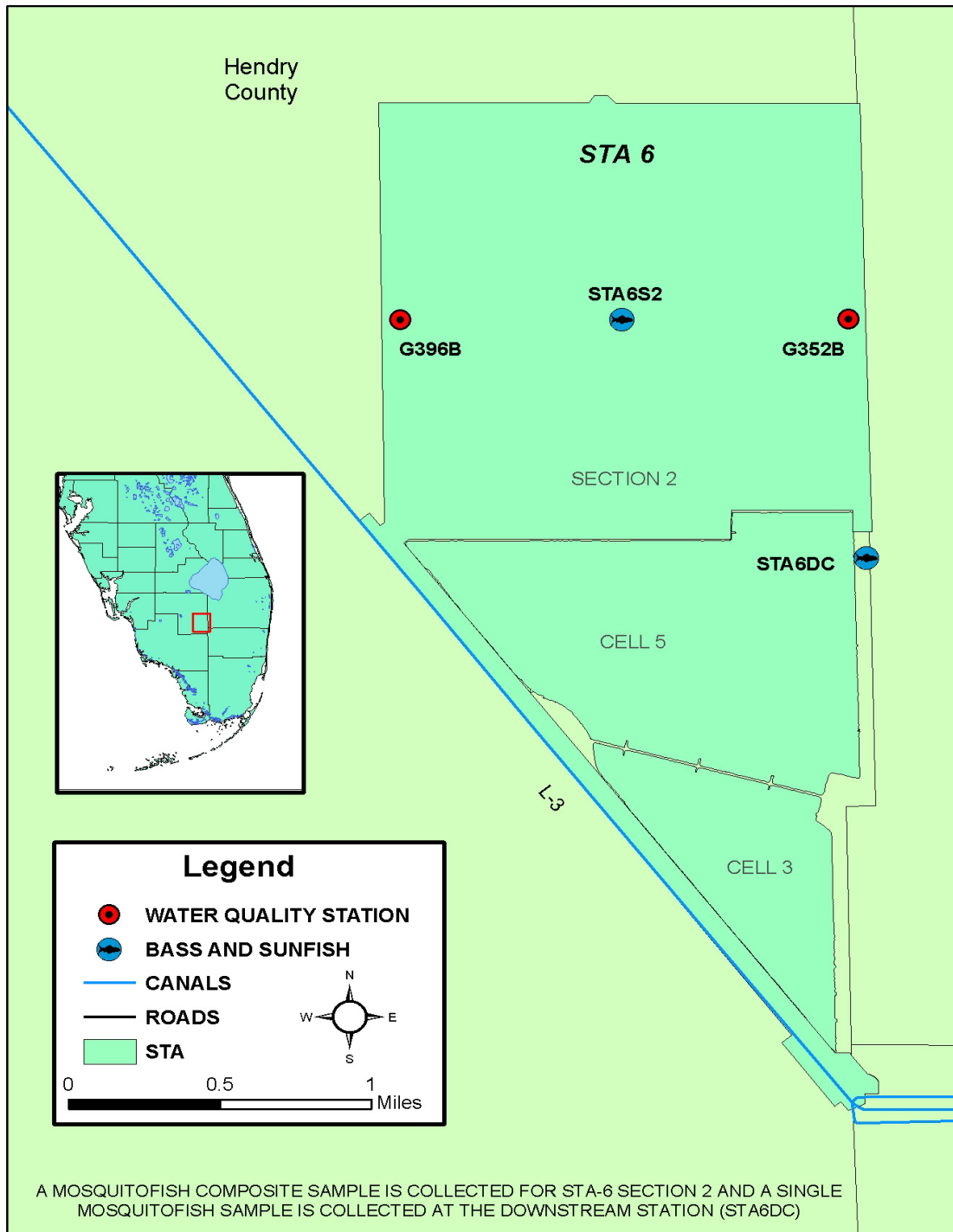


Figure 6. Map of Stormwater Treatment Area 6 (STA-6) showing current mercury monitoring sites.

MONITORING RESULTS

STA-1W

In 2000, STA-1W subsumed the ENR Project (Cells 1 through 4, **Figure 1**), which had been in operation since 1994. STA-1W surface water passed start-up criteria during the week of January 17, 2000; flow-through operations began in early February 2000. Formal monitoring of mercury levels in STA-1W surface water began on February 16, 2000 (for discussion of results observed prior to WY2008, see Rumbold and Rawlik, 2000; Rumbold et al., 2001, 2006; Rumbold and Fink, 2002a, 2003a; Rumbold, 2004, 2005a, Gabriel et al. 2007). In mid-2007, all mercury monitoring was moved into Phase 3-Operational Monitoring (see A Protocol for Monitoring Mercury and Other Toxicants [SFWMD, 2006]). Thus, surface water monitoring for THg and MeHg was terminated beyond this point.

Despite a steady increase in surface water THg and MeHg concentrations since the last quarter of WY2007, levels of both THg and MeHg in surface water at the outflows of STA-1W in WY2008 remained low compared to inflow and outflows of other STAs (**Figures 8, 10, and 11**). As discussed in Appendix 5-7 of the *2007 South Florida Environmental Report – Volume I*, after a period of inundation dating back to 1997 (Rumbold and Fink, 2002b), several of the cells were taken off-line during the CY2007 and were allowed to draw down for construction activities (**Figure 9**). The drawdowns appeared to have no marked effect on water-column concentrations at the outflows during this Calendar Year (**Figure 8**). For WY2008, there was no drawdown that occurred therefore the steady increase was likely not related to soil oxidation. Concurrently, outflow loads of MeHg and THg are considerably lower than inflow (**Figures 12 and 13**). During WY2008, no surface water samples exceeded the water quality standard (WQS) of 12 ng/L.

Concentrations of THg in mosquitofish are summarized in **Table 1** and graphically presented in **Figure 14**. Mosquitofish from STA-1W continue to have very low mercury levels particularly from the interior and outflow sampling sites, similar to levels when the area was operated as the ENR project (Rumbold and Fink, 2002b). Furthermore, mercury levels in STA-1W mosquitofish continue to be lower than levels currently observed in fish from other areas of the Everglades (see Appendix 3B-1 of this volume). Mosquitofish consistently exhibited a negative percent change in tissue-Hg levels across STA-1W (**Table 1**). This pattern was also observed in sunfish and largemouth bass. The average annual mosquitofish composite for 2007 including all individual mosquitofish composites within STA1W did not exceed the period of record (POR) 75th percentile for all Southern Everglades downstream receiving water sampling locations (see Appendix 3B-1) during 2007.

As shown in **Table 2** and **Figure 14**, STA-1W sunfish continued to have mercury levels much lower than those observed in sunfish at other STAs and locations within the Everglades (Appendix 3B-1 of this volume). Sunfish Hg levels can, however, vary depending upon several factors, namely, species type, size and age. After standardizing all sunfish for 2007 by the most predominant type (bluegill) and normalizing by length, statistical differences existed among all STAs (Kruskall-Wallis; $p < 0.001$; $df = 5$, $H = 67$). Bluegill from all STA-1W sites were significantly lower than all other STAs, except STA-2 (Dunn's Method of pair-wise comparisons). The average annual sunfish THg concentration for all locations within STA-1W did not exceed the POR 75th percentile for all Southern Everglades downstream receiving water sampling locations (see Appendix 3B-1) during 2007.

As with sunfish, largemouth bass from interior sites of STA-1W contained lower mercury levels than bass from most other STAs (**Table 3** and **Figure 14**). Moreover, STA-1W bass contained much lower mercury than fish from downstream sites in the WCAs (see Appendix 3B-1 of this volume). As with mosquitofish and sunfish, bass exhibited a negative percent change in mercury levels from the inflow to outflow (**Table 3**). Bass from the supply canal (upstream of S5A) contained substantially greater mercury levels than fish both from interior marshes and from the discharge canals (**Figure 14**). The average annual largemouth bass THg concentration did not exceed the POR 75th percentile for all Southern Everglades downstream receiving water sampling locations (see Appendix 3B-1) during 2007.

All fish species from the interior cells (ST1W51, ENR302, ENR401, ENR012) from STA-1W show no visible temporal increase in THg for $\geq$ three years to merit statistical investigation. Prior to performing the above temporal trend analyses for this STA and all other STAs, sunfish were first standardized to only include bluegill and then divided by length. All largemouth bass were standardized by age three.

Mercury levels in fish tissue can also be evaluated for risk to fish-eating wildlife. Contrary to other areas of the Everglades, fish-eating wildlife foraging preferentially at STA-1W do not appear to be at risk from mercury exposure. STA-1W mosquitofish, sunfish, and largemouth bass continue to have some of the lowest tissue-Hg levels in South Florida — well below both the USEPA and USFWS guidance level for predator protection (Eisler, 1987; USEPA, 1997).

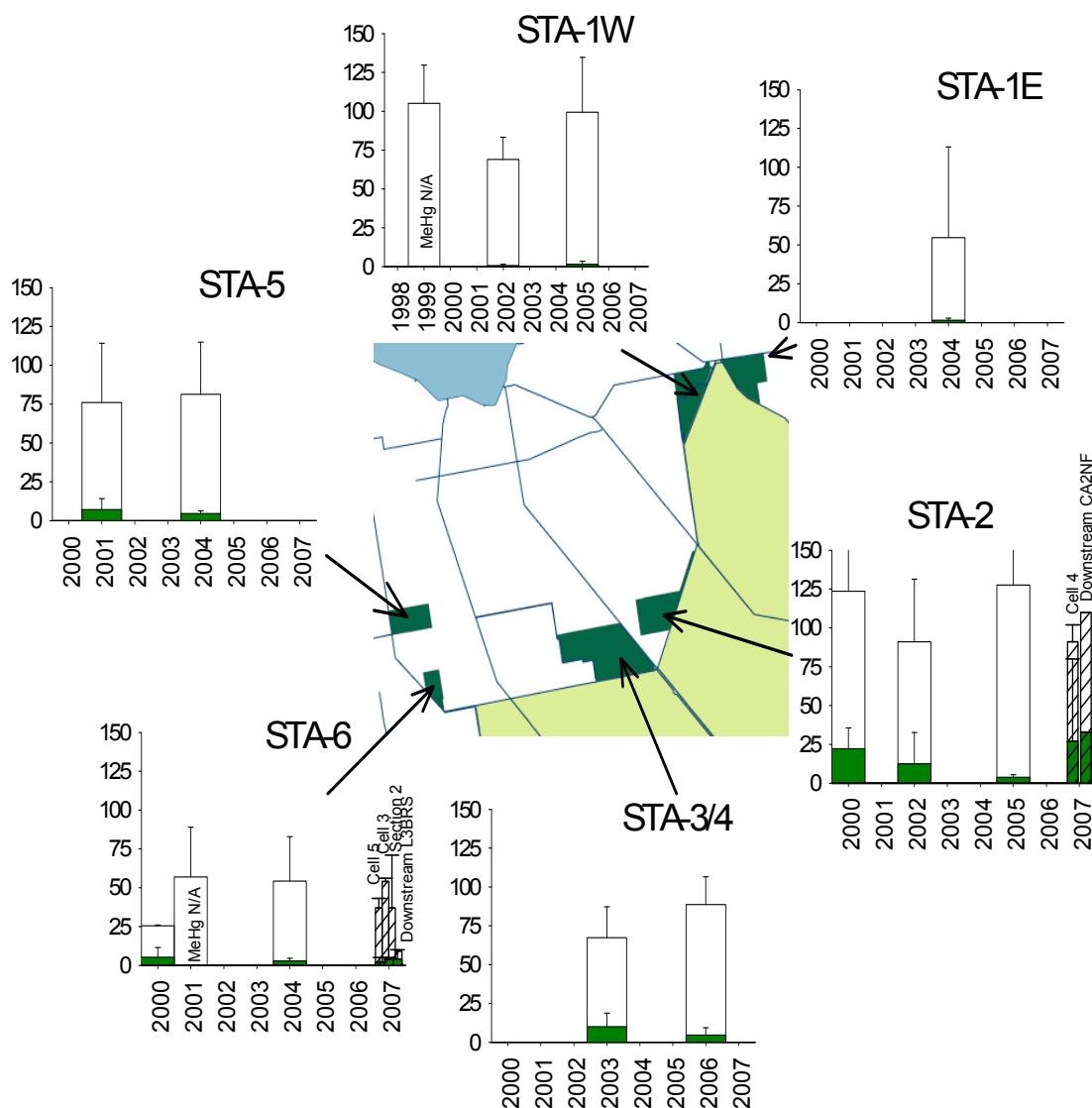


Figure 7. Mean concentration (+1 standard deviation [SD]; dry weight basis) of THg (ng/g) and MeHg (10X ng/g) in sediment cores (n = 5 per cell/section; 0-10 cm) collected from each STA prior to start-up. Crossed-hatched columns indicate collections following the new Hg monitoring program (SFWMD, 2006).

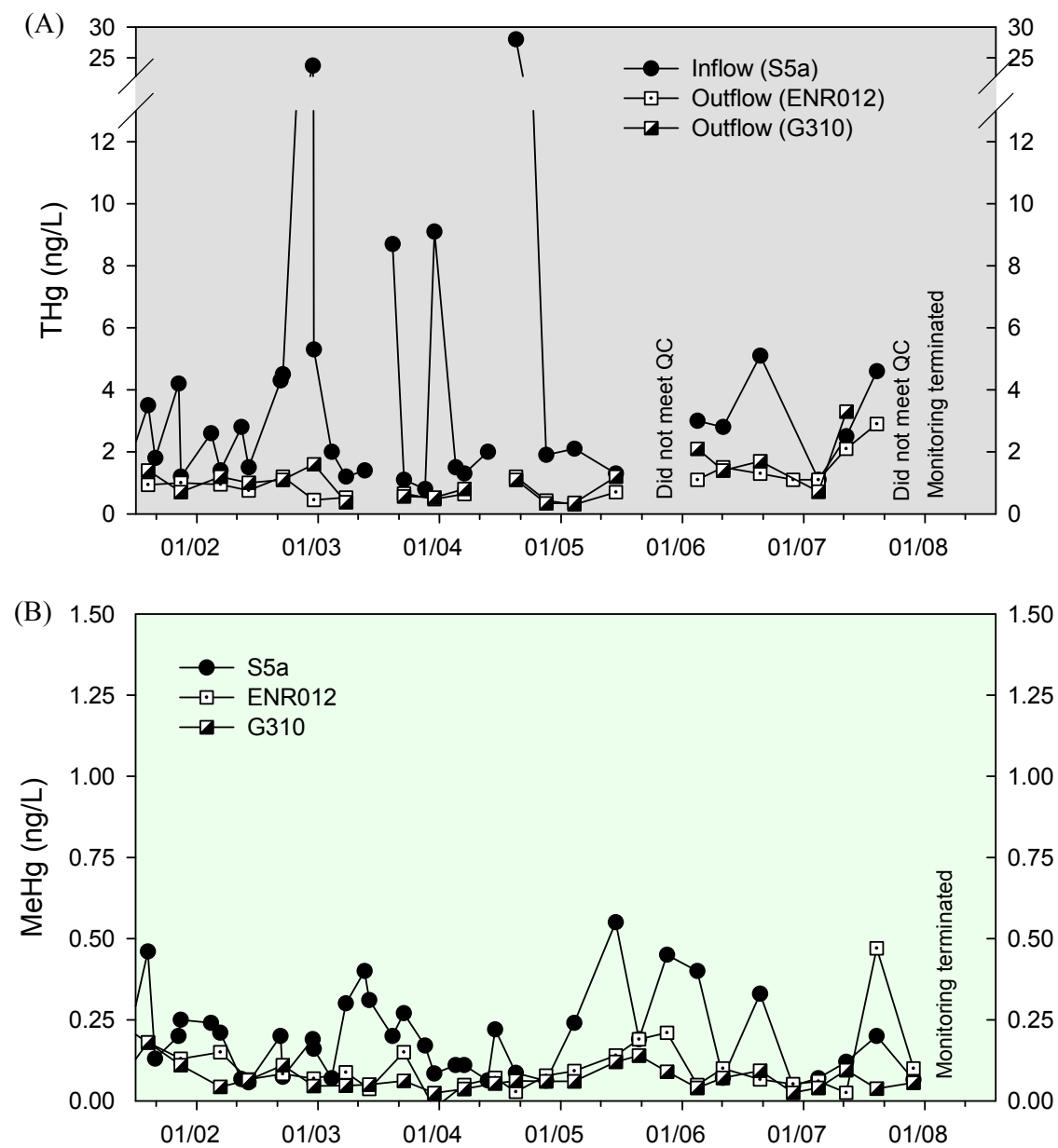


Figure 8. Concentrations of (panel A) THg and (panel B) MeHg (ng/L) in unfiltered surface water collected at STA-1W.

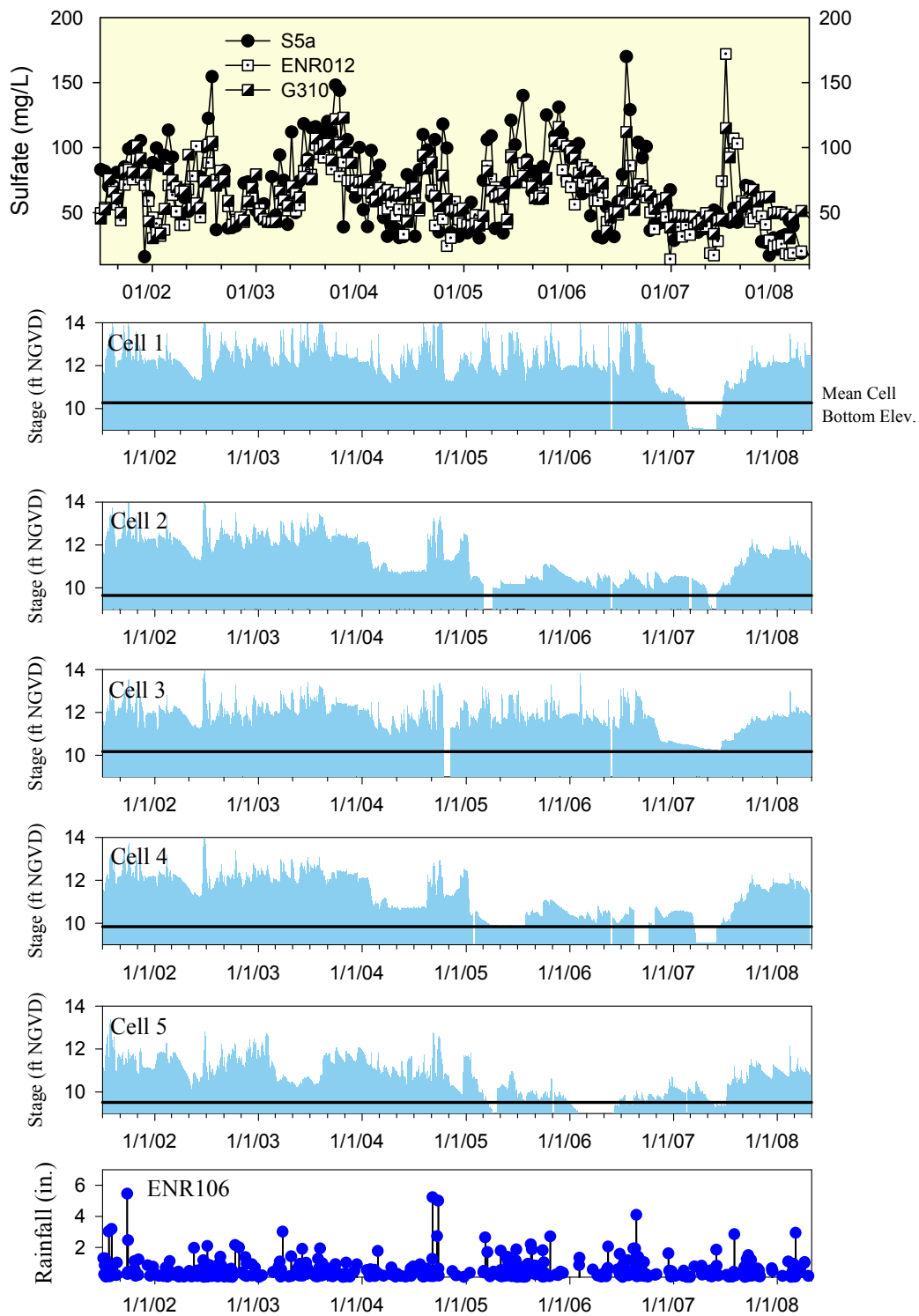


Figure 9. Water column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-1W.

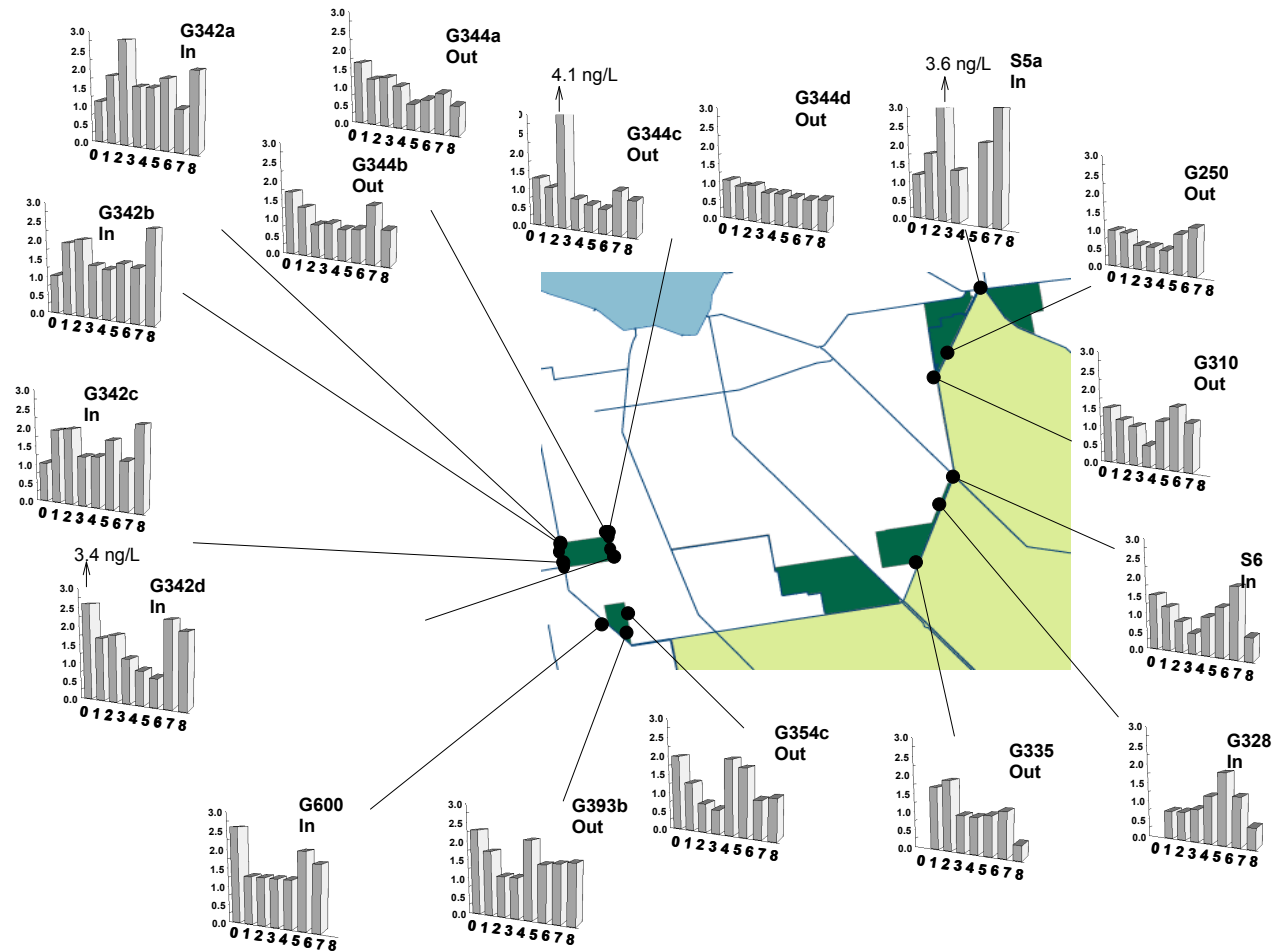


Figure 10. Annual median THg concentrations (ng/L) for period of record (POR) at inflows and outflows of STAs.

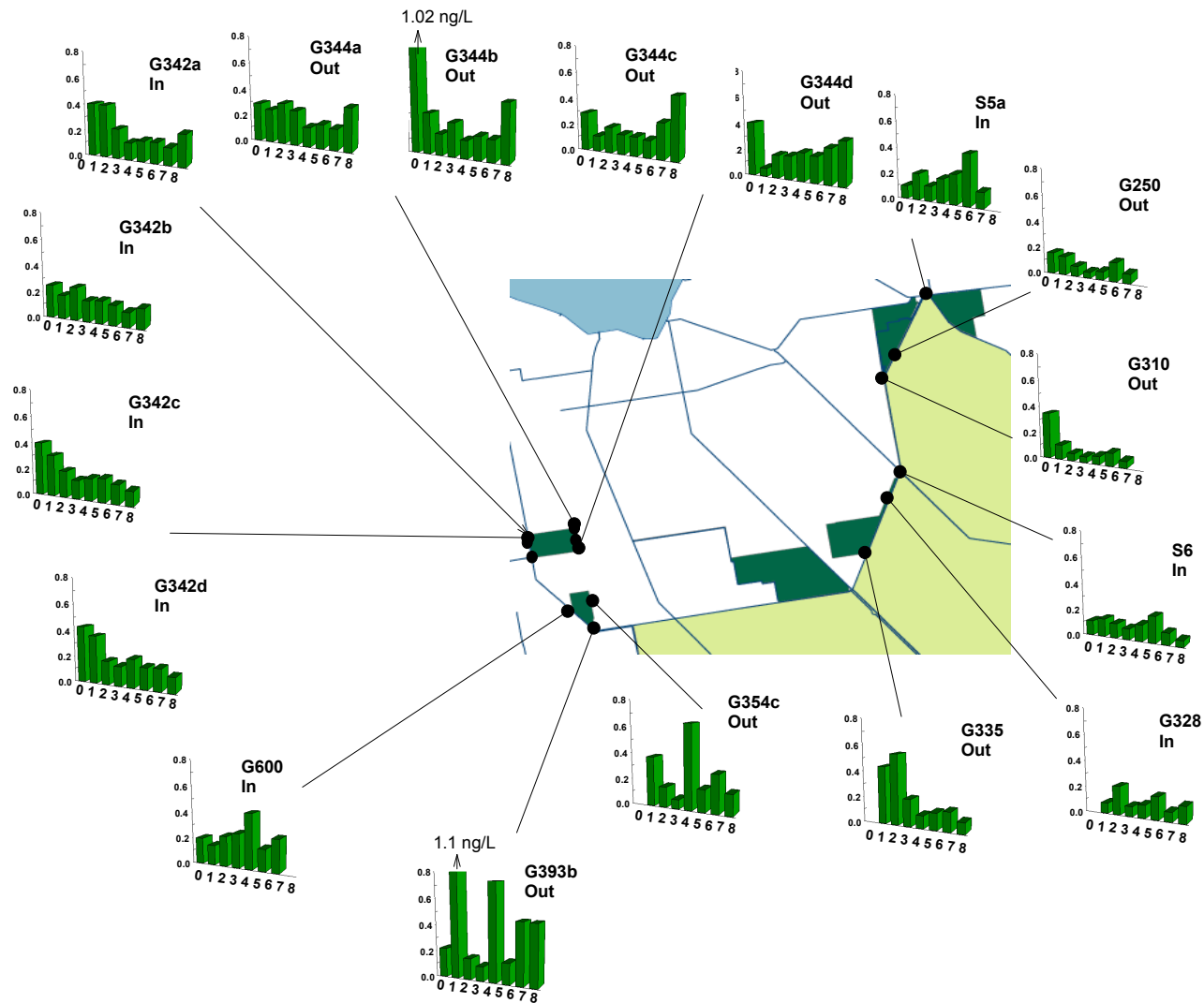


Figure 11. Annual median MeHg concentrations (ng/L) for POR at inflows and outflows of STAs.

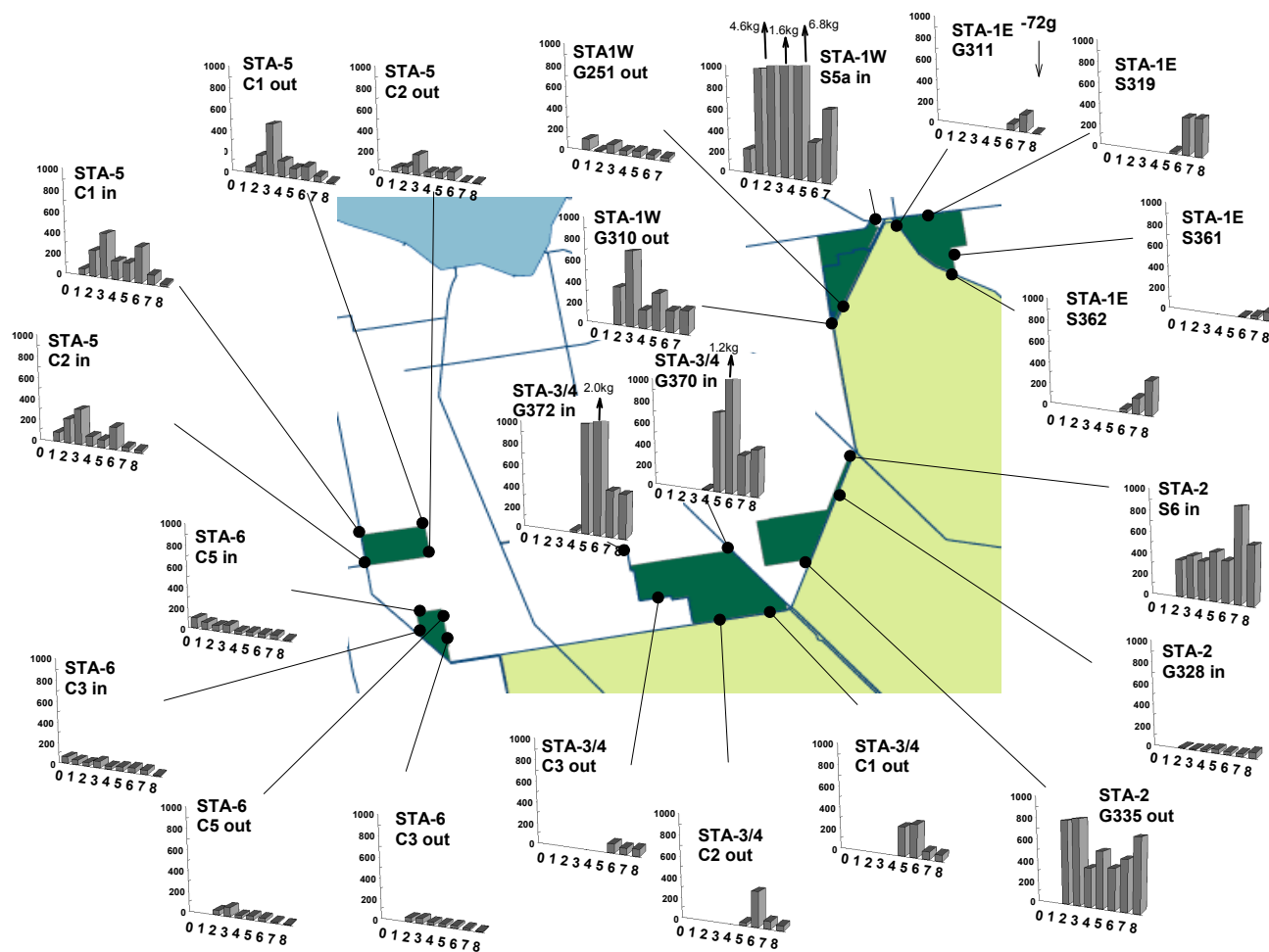


Figure 12. Estimated annual THg loads (scale = 1000 grams) at inflows and outflows of STAs for period of record (2000 to 2008). The loading estimates for WY2008 are more complex than in years past due to a combination of flow irregularities (associated with the drought), QA issues, changes in the monitoring program and incomplete data to allow interpolation through WY2008.

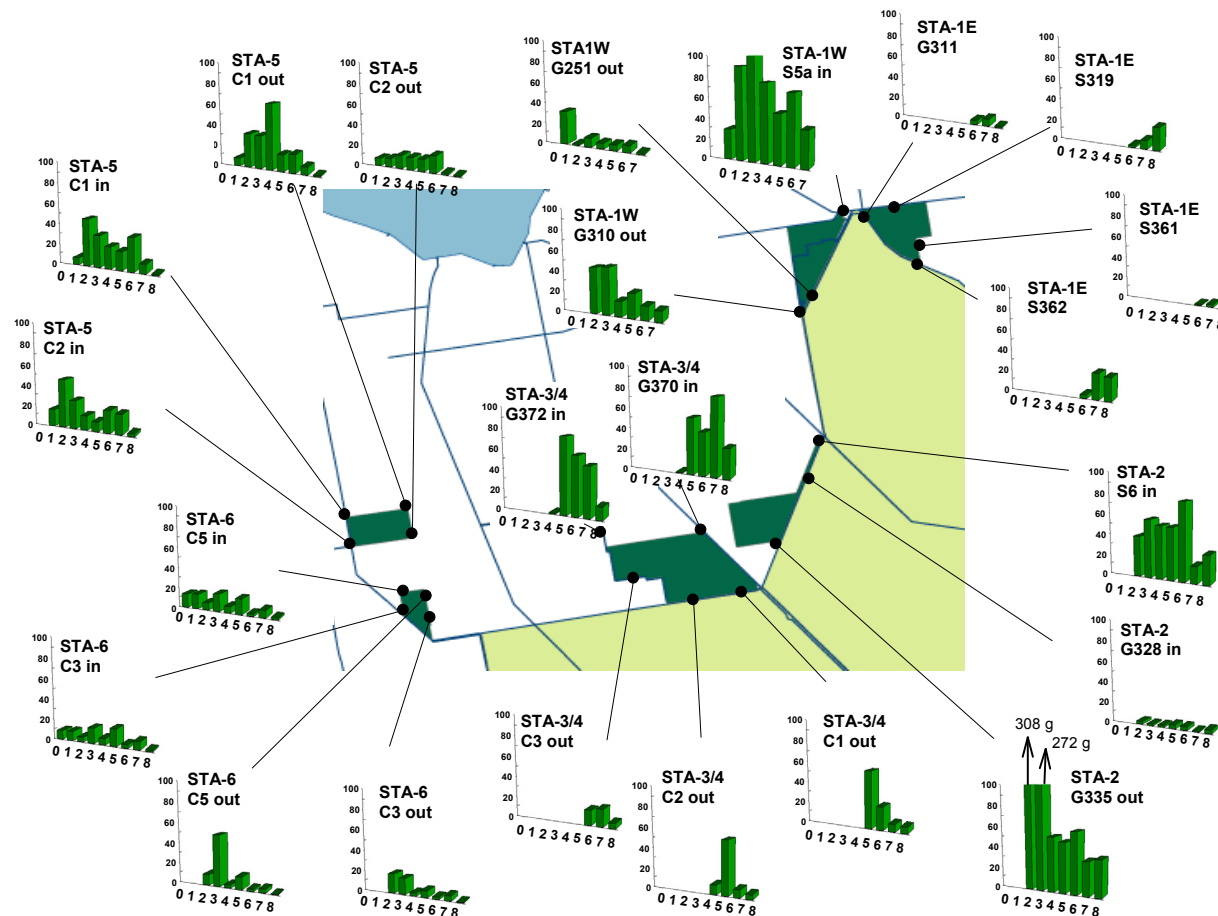


Figure 13. Estimated annual THg loads (scale = 1000 grams) at inflows and outflows of STAs for POR 2000 to 2008. The loading estimates for WY2008 are more complex than in years past due to a combination of flow irregularities (associated with the drought), quality assurance issues, changes in the monitoring program, and incomplete data to allow interpolation through WY2008.

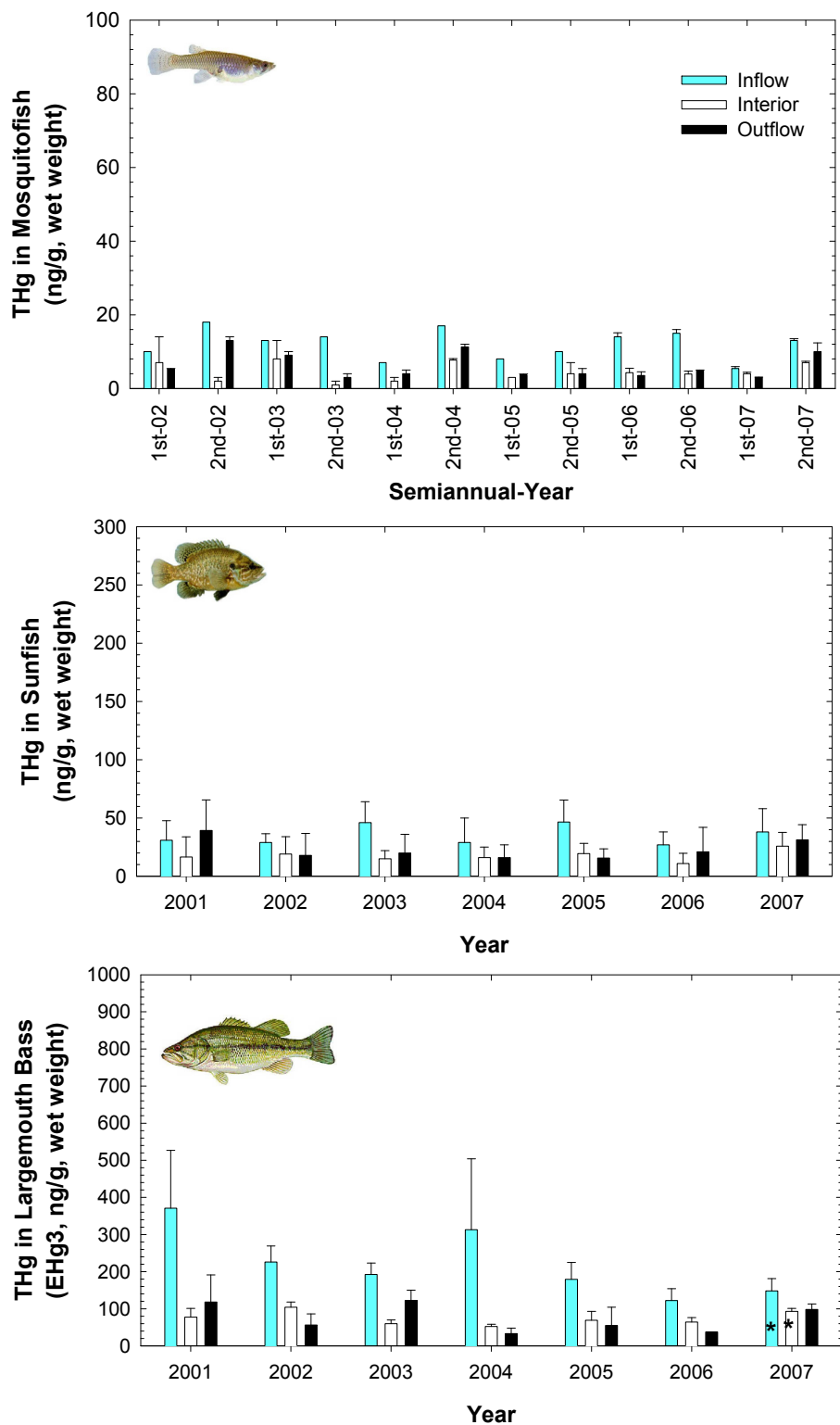


Figure 14. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites (+range), (*middle*) whole sunfish ($\pm$ SD), and (*bottom*) fillets of largemouth bass ($\pm$ 95 percent C.I. or, if arithmetic, SD) collected at STA-1W. Arithmetic means are noted by an asterisk.

Table 1. Concentration of THg (ng/g, wet weight) in mosquitofish composites from Stormwater Treatment Areas (STAs).

STA	HALF-YEAR/ QUARTERLY	INFLOW FISH	INTERIOR FISH	OUTFLOW/ DOWNSTREAM FISH	PERCENT CHANGE(%) ^A
STA-1W*	2007-1	5.4	4.0	3.1	-42.0
	2007-2	13.0	8.0	10	-23.0
	Annual mean	9.2	6.0	6.5	-29.0
	Cumulative mean	27	20	13	-52.0
STA-1E ^b	2007-1	Not Applicable	11.5	33	Not Applicable
	2007-2	Not Applicable	28	No fish*	Not Applicable
	2007-3	Not Applicable	25	71	Not Applicable
	2007-4	Not Applicable	12.6	61	Not Applicable
	Annual mean	Not Applicable	19.2	55	Not Applicable
	Cumulative mean	Not Applicable	23.8	64	Not Applicable
STA-2 ^c	2007-1	7.9	8.5	12.3	55.0
	2007-2	Not Applicable	15.6	14.0	Not Applicable
	Annual mean	7.9	12.0	13	62
	Cumulative mean	14	72	77	450
STA-3/4*	2007-1	No fish	10.6	23.3	
	2007-2	16	11.4	23.8	48.0
	Annual mean	13	11.0	23.5	80.0
	Cumulative mean	13.6	15.4	29.1	110
STA-5 ^c	2007-1	6.2	7.2	5.0	-19
	2007-2	Not Applicable	12.5	28.8	Not Applicable
	Annual mean	6.2	9.8	16.9	172
	Cumulative mean	29	25	30	3.4
STA-6 ^c	2007-1	11.3	No fish	14.6	30
	2007-2	Not Applicable	31.2	Failed QA/QC	Not Applicable
	Annual mean	11.3	31.2	14.6	29
	Cumulative mean	26	13	23	-11

* Followed old monitoring plan for CY2007 (see *Mercury Monitoring Program* section)

a Percent change = (outflow-inflow/inflow)*100

b Follows new monitoring plan (see *Protocol for Monitoring Mercury and Other Toxicants* section)

c Overlap between new and old monitoring plans

No fish–Not sampled due to dry conditions

Table 2. Concentration of THg (ng/g, wet weight) in sunfish (*Lepomis* spp.) collected from STAs in 2007 (sample size in parentheses).

STA	INFLOW FISH	INTERIOR FISH	OUTFLOW/DOWNSTREAM FISH	PERCENT CHANGE ^A
STA-1W ^b	38 ± 20 (20)	25 ± 12 (60 ^d)	31 ± 13 (40)	-18%
Cumulative mean	40	19	23	-45%
STA-1E ^c	Not applicable	50 ± 28 (15 ^e)	105 ± 24 (4 ^f)	--
Cumulative mean		82	119	--
STA-2 ^c	Not applicable	46 ± 32 (10 ^e)	104 ± 112(4 ^f)	--
Cumulative mean		99	104	--
STA-3/4 ^b	45 ± 25 (20)	61 ± 31 (60 ^d)	72 ± 56 (39 ^d)	60%
Cumulative mean	41	76	70	70%
STA-5 ^c	Not applicable	55 ± 25 (5)	130 ± 40 (5)	--
Cumulative mean		102	94	--
STA-6 ^c	Not applicable	94 ± 31 (10 ^e)	108 ± 28(5)	--
Cumulative mean		54	93	--

a Percent change = (outflow–inflow/inflow)*100

b Followed old monitoring plan (see the *Mercury Monitoring Program* section of this appendix)

c Followed new monitoring plan (*Protocol for Monitoring Mercury and Other Toxicants* section)

d Where n > 20, multiple sites were sampled and pooled, i.e., multiple interior or outflows (*Mercury Monitoring Program* section)

e Where n > five, multiple sites were sampled and pooled, i.e., multiple interior or outflows (*Protocol for Monitoring Mercury and Other Toxicants* section)

f Where n < five, not enough sunfish in sample area

Table 3. Standardized, EHg3 $\pm$ 95%, and arithmetic mean concentration (mean $\pm$ 1 SD, n; in parentheses) of THg (ng/g, wet weight) in fillets from largemouth bass collected at STAs in 2007.

STA	INFLOW FISH	INTERIOR FISH	OUTFLOW/ DOWNSTREAM FISH	PERCENT CHANGE ^a
STA-1W ^b	148 $\pm$ 33 (190 $\pm$ 88, 16 ^g)	93 $\pm$ 8 (75 $\pm$ 30, 22 ^d)	NC (1) (92 $\pm$ 25, 33 ^d)	--
Cumulative mean	249	62	71	-72%
STA-1E ^c	Not applicable	NC (3) (161 $\pm$ 59, 15 ^e)	NC (1,3) (169, 1 ^f)	--
Cumulative mean ^c		161	453	--
STA-2 ^c	Not applicable	NC (3) (227 $\pm$ 86, 8 ^e)	NC (1,3) (363 $\pm$ 156, 9 ^e)	--
Cumulative mean	237	248	539	--
STA-3/4 ^b	214 $\pm$ 30 (123 $\pm$ 115, 40 ^d)	256 $\pm$ 26 (184 $\pm$ 129, 54 ^d)	NC (1) (384 $\pm$ 117, 20)	--
Cumulative mean	182	315	431	136%
STA-5 ^c	Not applicable	NC(3) (110 $\pm$ 57, 5)	Not Available Not Available	--
Cumulative mean		251	370	--
STA-6 ^c	Not applicable	NC(3) (141 $\pm$ 38, 5)	NC(3) (541 $\pm$ 16, 5)	--
Cumulative mean		199	472	--

a Percent change = outflow-inflow/inflow based on EHg3 where available.

b Followed old Hg monitoring plan during 2007 (see the *Mercury Monitoring Program* section of this appendix)

c Followed new Hg monitoring plan during 2007 (*Protocol for Monitoring Mercury and Other Toxicants*)

d Where n > 20; multiple sites were sampled and pooled, i.e., multiple interior or outflows (*Mercury Monitoring Program* section)

e Where n > five; multiple sites were sampled and pooled, i.e., multiple interior or outflows (*Protocol for Monitoring Mercury and Other Toxicants* section)

f Where n < five, not enough sunfish in sample area

g Where n < 20, not enough sunfish in sample area

NC—Not calculated, where: (1) regression slope was not significantly different from 0, (2) poor age distribution of collected fish, or (3) permit modification (bass are approximately age 3)

NA—Not available; no bass in sample area

STA-1E

Monitoring water-column collections for THg and MeHg began in January, 2005, at STA-1E. Both the central flow-way (Cells 3, 4N, and 4S) and the westernmost flow-way (Cells 5–7) met the start-up criteria, as specified in EFA Permit No. 0195030-001-GL, in August, 2005, (correspondence from R. Bearzotti, SFWMD, dated September 9, 2005). The USACE constructed a Periphyton-Based Stormwater Treatment Area (PSTA) Demonstration Project in the easternmost flow-way (Cells 1 and 2) of STA-1E. The most recent eastern flow-way passed startup in 2007.

In WY2008, MeHg remained at relatively low concentrations in the outflow following the operation of the central, western, and eastern flow-ways and outflow concentrations were typically lower than inflow (**Figure 15**). Inflow concentrations were fairly high compared to most other STAs. STA-1E displays some of the highest THg concentrations in comparison to all other STAs, including downstream monitoring locations. A concentration of 9.4 ng/L (collected on February, 14, 2008) was the highest recorded level since sampling began in 2005. Despite overall high THg levels from this STA, all samples are below the WQS of 12 ng/L. The high THg levels may be related to several factors including (1) construction issues during start-up operations, (2) high pre-existing soil mercury concentrations, (3) high mercury levels within source water discharging into this STA, and (4) “first-flush” effects. The elevated Hg levels are not related to impacts from dryout and rewetting as each cell has been inundated since early 2006 (**Figure 16**). Similar to performance-related concentrations, both THg and MeHg loads at the outflow were marginally below inflow (342g THg [inflow], 26g MeHg [inflow]; 308g THg [outflow], 22g MeHg [outflow]).

Quarterly collection of mosquitofish from STA-1E sites at interior marshes and the single downstream site (ST1ELX), began during the third quarter of 2005. As shown in **Table 1**, mercury levels in mosquitofish from the interior marsh were higher than all other STAs in 2007, except STA-6. The high levels in mosquitofish may be attributed to high THg in surface water (**Figure 15**) or previous constructed related activities. As with many STAs, levels were higher in downstream or outflow locations than the interior sites (**Figure 15**). Average annual mosquitofish composites for the interior and the downstream site (ST1ELX) of STA-1E including all mosquitofish composites did not exceed the POR 75th percentile for all Southern Everglades downstream receiving water sampling locations (see Appendix 3B-1) during 2007.

Annual collection of sunfish occurred in October 2007. As evident from **Table 2**, mercury levels were elevated in STA-1E fish compared to the other STAs. Levels in fish from the near-field downstream site (ST1ELX) were similar to levels recently observed at one of the far-field downstream sites, LOX4 (Appendix 3B-1). The standardized concentration in bluegill from ST1ELX was 1.11 ng/g/mm, whereas bluegill from nearby LOX4 averaged 1.4 ng/g/mm (**Figure 17**; cf. Figure 13 in Appendix 3B-1).

In past years there was a fairly large contrast between LOXF4 and ST1ELX. THg concentration in sunfish has decreased for both stations since 2006. The largest change was for the interior marsh, where average sunfish and largemouth bass concentrations decreased by approximately 50 percent. The average annual sunfish THg concentration for interior and downstream locations did not exceed the POR 75th percentile for all Southern Everglades sampling locations during 2007 (see Appendix 3B-1).

For 2007, largemouth bass were collected from the STA-1E interior site and the downstream site, however only one bass was caught from the downstream site. Largemouth bass THg levels were similar in spatial pattern to sunfish, where concentrations were on the moderate to high end compared to all other STAs. The average annual largemouth THg concentration for interior and downstream locations did not exceed the POR 75th percentile for all Southern Everglades downstream receiving water sampling locations during 2007 (see Appendix 3B-1).

All fish species from the interior cells (ST1EWFC, ST1EEFC, ST1MFC) of STA-1E show no visible temporal increase in THg levels for $\geq$ three years to merit statistical investigation.

Regarding risks to fish-eating wildlife, mosquitofish (falling under TL 2 or 3) did not exceed the USEPA's 77 ng/g criterion. Nearly all resident sunfish with STA-1E were well below the USFWS criterion of 100 ng/g and the USEPA predator protection criterion of 77 ng/g for trophic level 3 (TL3) fish. Most of the exceedance for sunfish was due to the elevated concentrations from the downstream location (105 ± 60 ng/g). After standardizing by whole fish length concentration (fillet concentration $\times 0.695$ [Lange et al., 1998]), there was no exceedance of the USEPA criterion of 346 ng/g for TL4 fish species for largemouth bass.

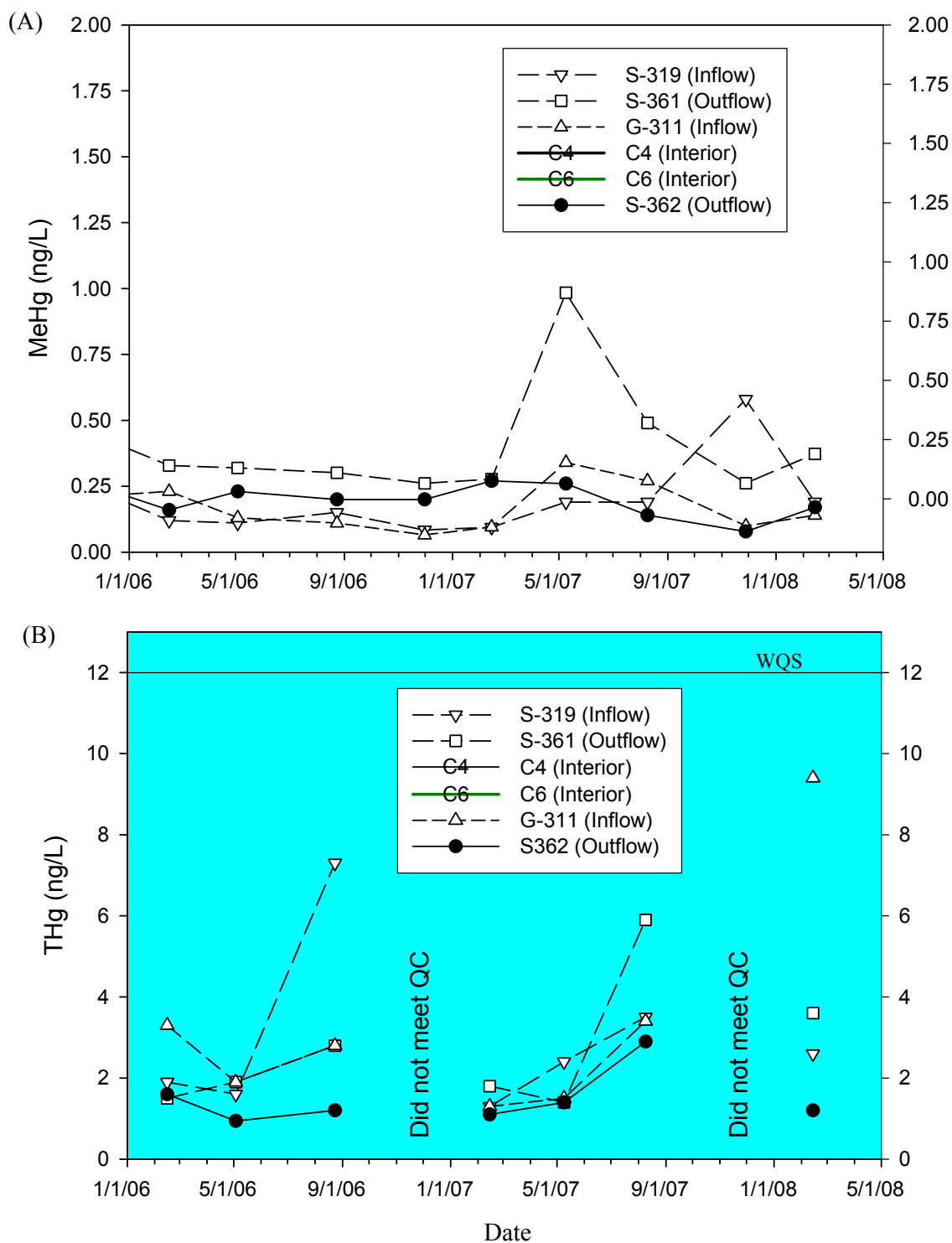


Figure 15. Concentrations of (panel A) MeHg and (panel B) THg (ng/L) in unfiltered surface water collected at STA-1E.

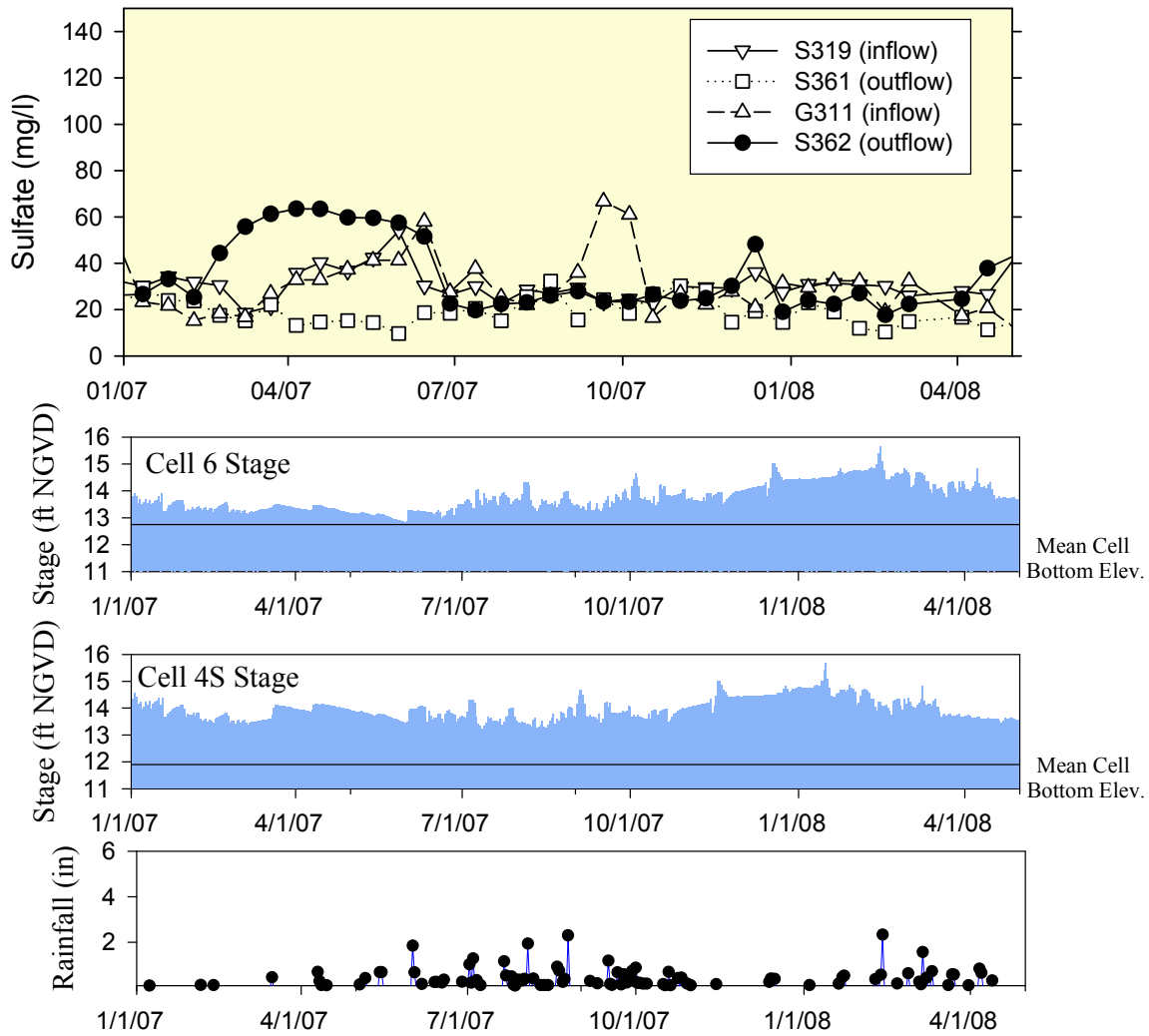


Figure 16. Water-column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-1E.

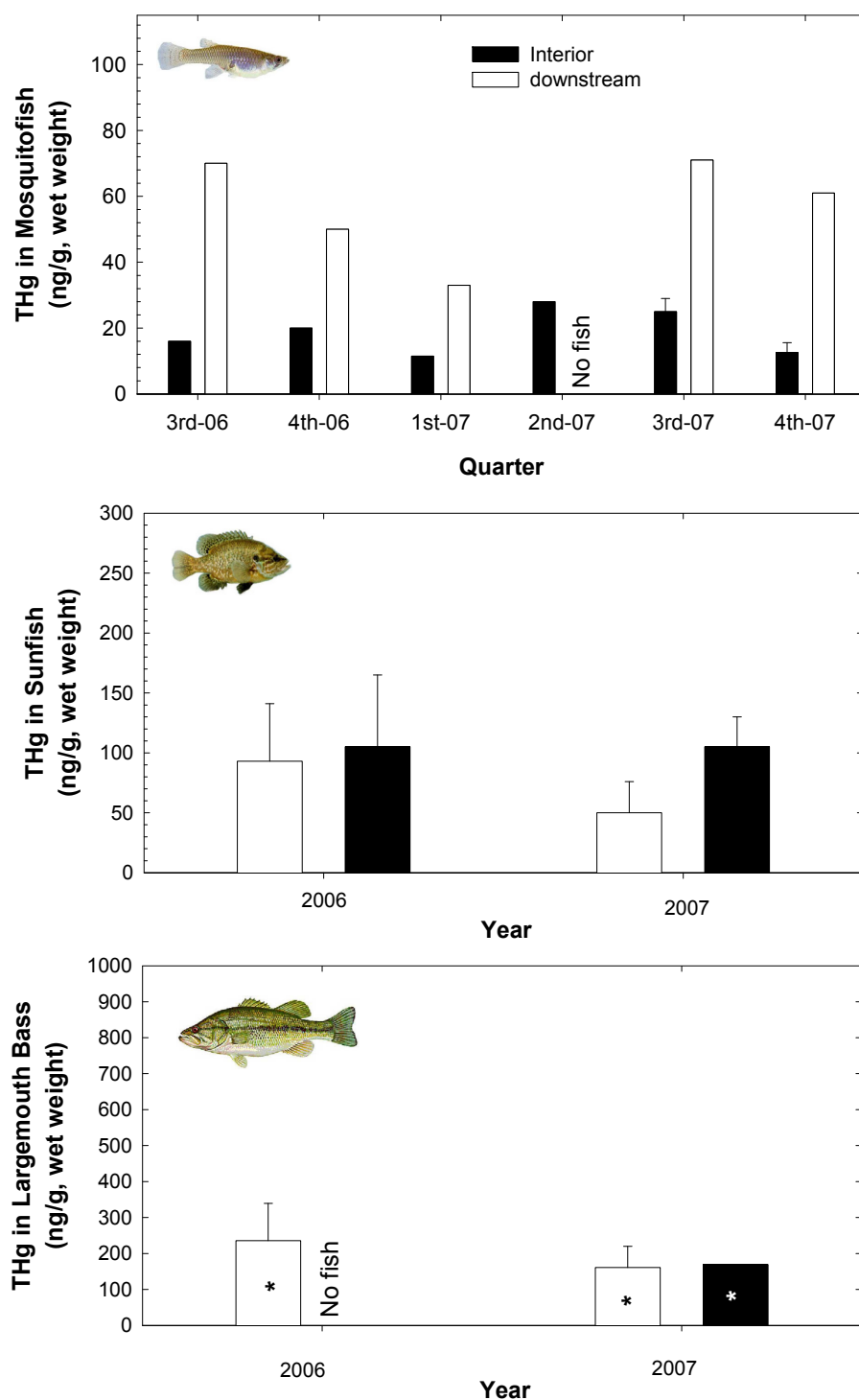


Figure 17. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites ($\pm$ range), (*middle*) whole sunfish ($\pm$ SD), and (*bottom*) fillets of largemouth bass ($\pm$ 95 percent C.I. or, if arithmetic, SD) collected at STA-1E. Arithmetic means are noted by an asterisk.

STA-2

STA-2 Cells 2 and 3 met mercury start-up criteria in September 2000 and November 2000, respectively. In August 2001, flow-through operation of Cell 1 was approved under a permit modification. Cell 1 met start-up criteria in November 26, 2002. Operational monitoring of mercury at STA-2 began during the third quarter of 2001 after completion of the S-6 connection (for discussion of results observed prior to 2005, see Rumbold and Fink, 2002b, 2003b; Rumbold 2004, 2005a; Rumbold et al., 2006). The most recently developed Cell 4 passed mercury start-up criteria and flow-through began in 2007.

Results from monitoring mercury concentrations in surface water at STA-2 (**Figure 18**) show THg concentration in outflow and inflow did not exceed the Class III numerical water quality standard of 12 ng/L during WY2008. More importantly, both MeHg, which has no numerical WQS, and THg remained at low concentrations in outflow despite a steady increase since 2005. However, outflow loads of both THg and MeHg are well above inflow (**Figures 12 and 13**). During June 2007 water level stage fell below mean cell bottom elevation for approximately one month in Cell 1, two weeks in Cell 2, and one week in Cell 3. This drop in water level had no visible impact on sulfate levels (**Figure 19**); however, the drawdown may be linked to the observed surge in water column THg (**Figure 18**) from sediment resuspension following inundation.

Table 1 and **Figure 20** summarize results from operational monitoring of mercury concentrations in STA-2 mosquitofish for 2007. **Figure 20** graphs results from different interior sites separately for this STA because of the degree of spatial variability previously observed. The figure indicates that mercury levels in mosquitofish from Cell 1 and the discharge canal have declined dramatically since 2001 and 2002 (in some cases, by an order of magnitude). Moreover, among-cell differences in mercury levels in mosquitofish decreased greatly in the second quarter of 2005. However, concentrations have risen slightly since 2005. In 2007, the average mosquitofish composite and each individual mosquitofish composite for all STA-2 locations did not exceed the POR 75th percentile for all Southern Everglades sampling locations (see Appendix 3B-1).

Sunfish from STA-2 interior cells show no major change since 2006 (**Table 2** and **Figure 20**). The newly established downstream site CA2NF shows considerably higher levels than the previously sampled outflow stations. Standardizing by species (bluegill) and length reveals the same general trend in concentration distribution between interior and downstream locations. Following standardization, average concentration was 0.20 nanograms per gram per millimeter of length (ng/g/mm) at interior locations and 0.86 ng/g/mm for the downstream location. In 2007, the average annual sunfish concentration for all STA-2 locations did not exceed the POR 75th percentile for all Southern Everglades sampling locations (see Appendix 3B-1).

Concentrations of THg in fillets of resident largemouth bass from STA-2 (**Table 3** and **Figure 20**) reflect an overall average of 227 ± 86 ng/g collected across the three cells, which is the highest of all interior STA sites and more than twice the average EHg3 of 2006. This estimate for 2007 can be compared to the average 2006 EHg3 level because all fish collected in 2007 were roughly all age three (see Appendix 3B-1). All fish species from the interior locations (STA2C1X, STA2C2A, STA2C3A) of STA2 showed no visible temporal increase for $\geq$ three years. Regarding risk to fish-eating wildlife, all resident fish at STA-2 contained mercury levels greater than both the USFWS (100 ng/g) and USEPA predator protection criteria for TL3 species (77 ng/g). In 2007, the average annual largemouth bass concentration for all STA-2 locations did not exceed the POR 75th percentile for all Southern Everglades downstream receiving water sampling locations (see Appendix 3B-1).

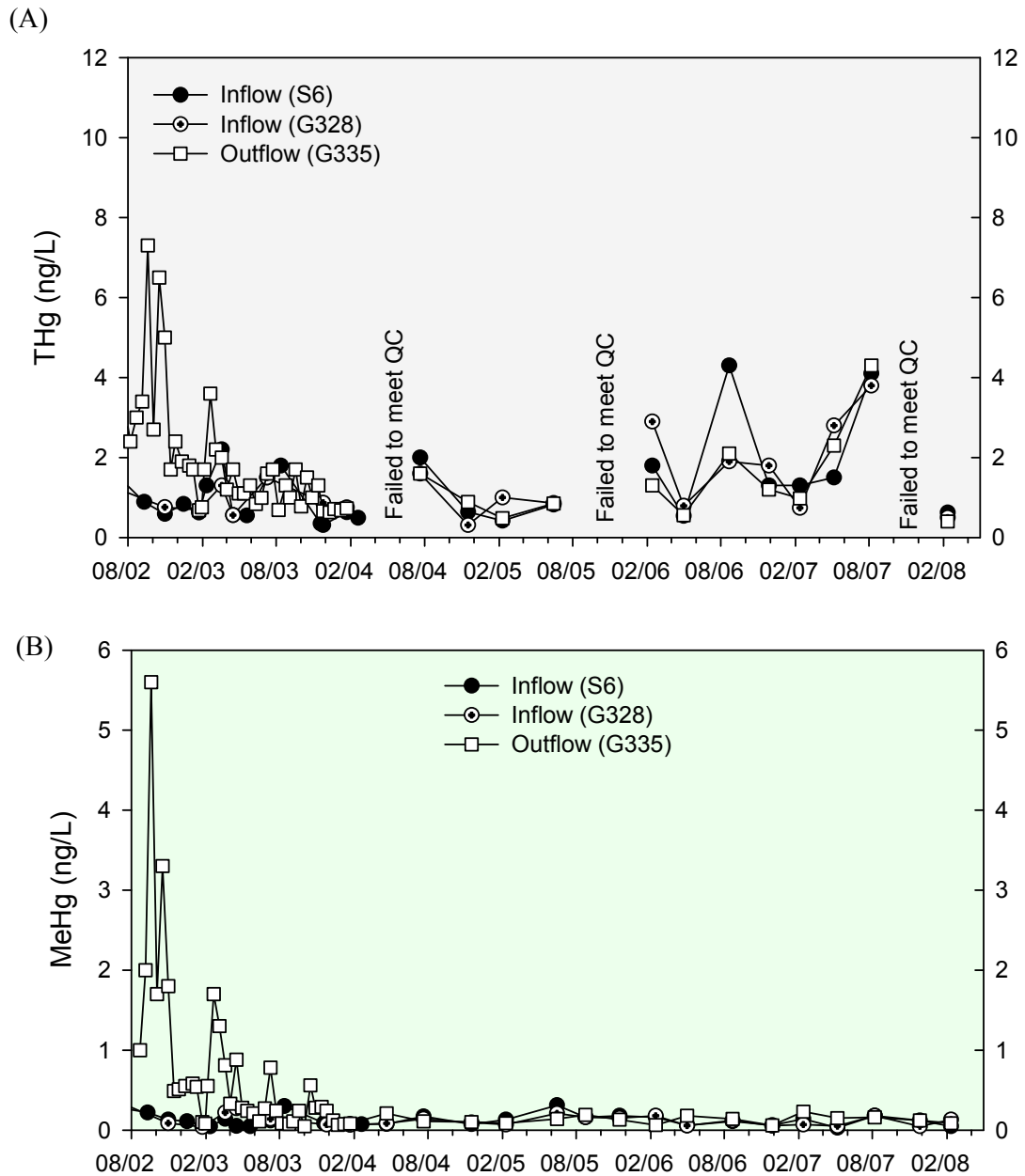


Figure 18. Concentrations of (panel A) THg and (panel B) MeHg (ng/L) in unfiltered surface water collected at STA-2.

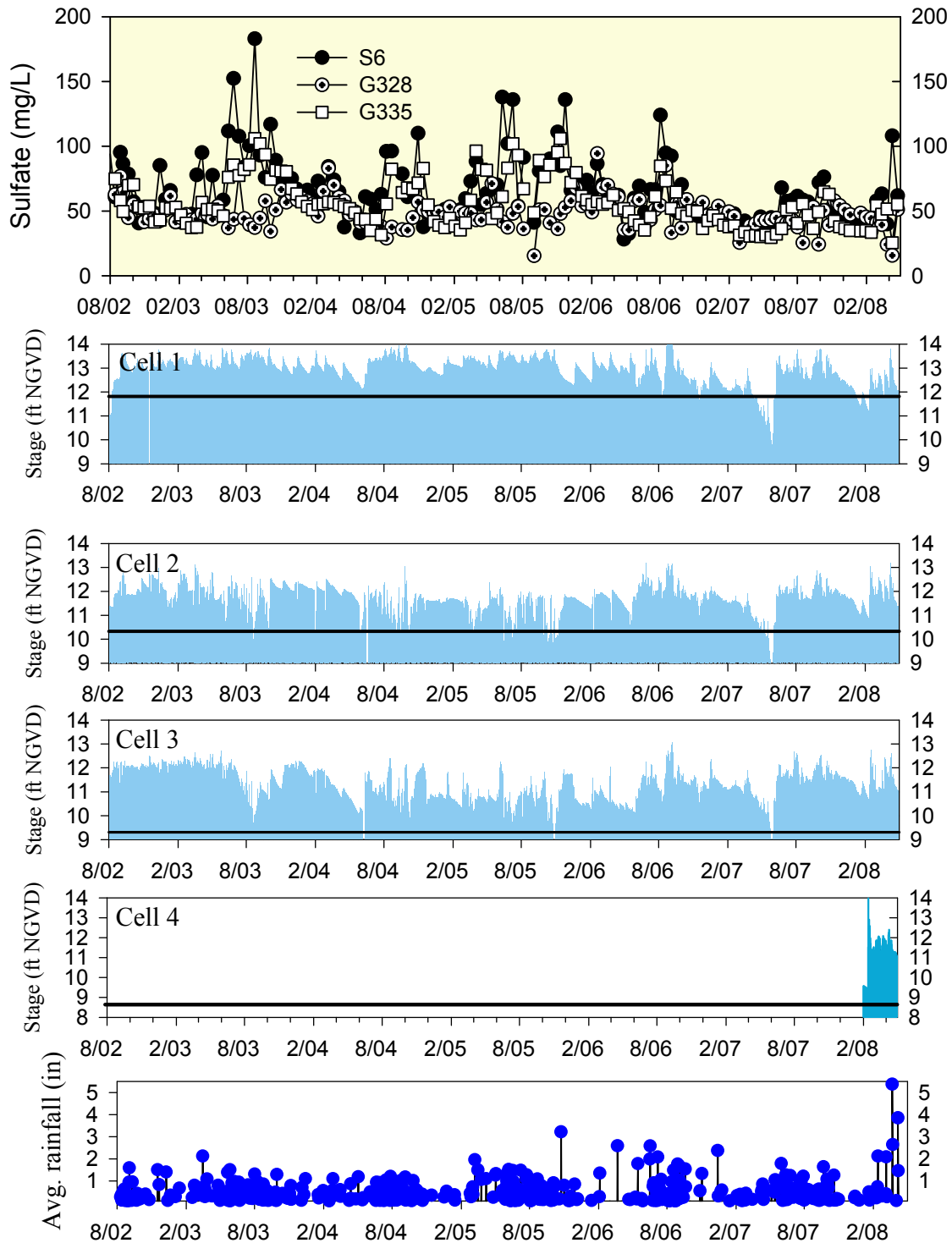


Figure 19. Water-column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall totals at STA-2.

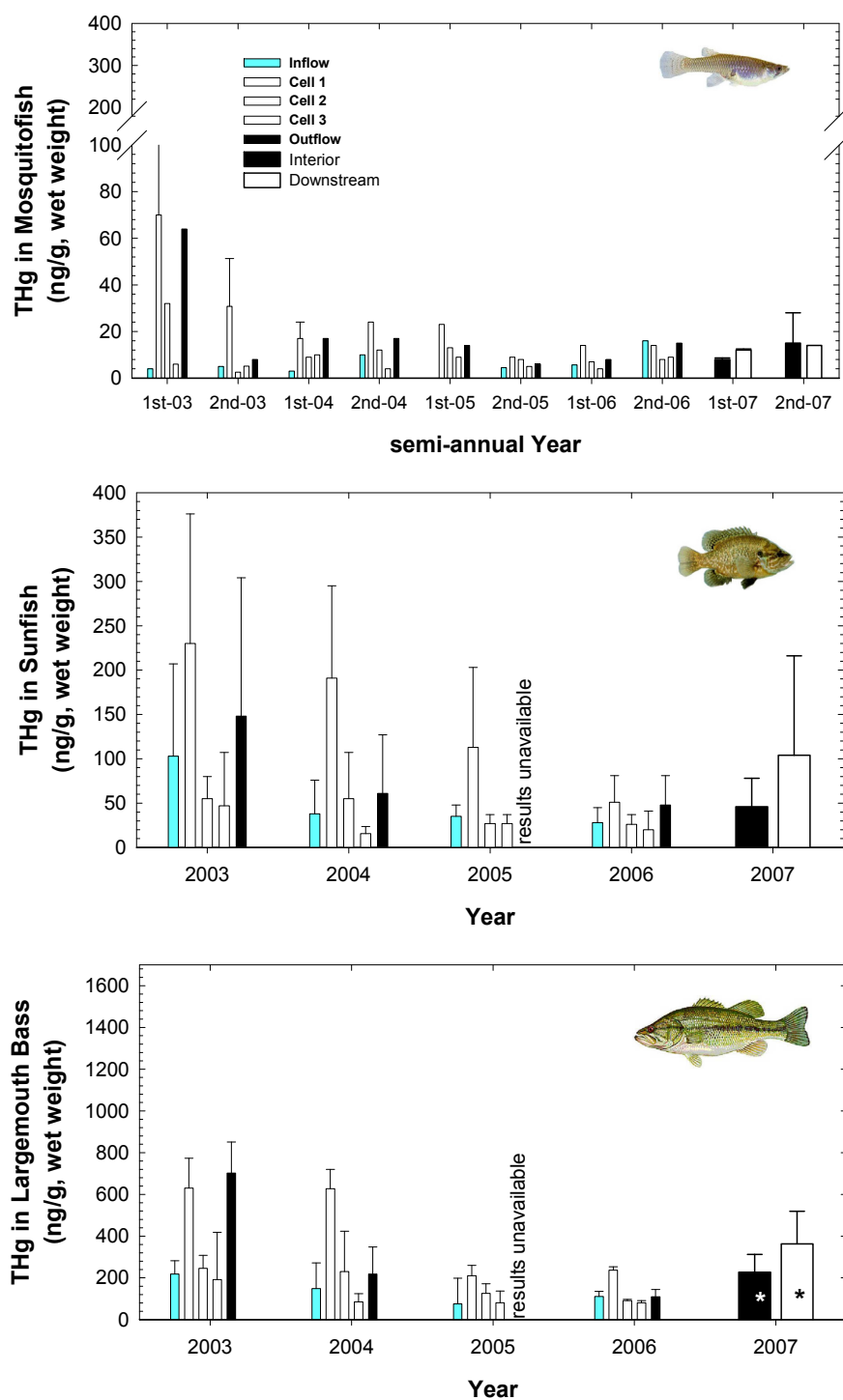


Figure 20. Mercury concentrations (ng/g, wet weight) in (top) mosquitofish composites (+range), (middle) whole sunfish ($\pm$ SD), and (bottom) fillets of largemouth bass ($\pm$ 95 percent C.I. or, if arithmetic, SD) collected at STA-2. Arithmetic means are noted by an asterisk.

STA-3/4

STA-3/4 Cell 1 satisfied start-up criteria for mercury in January 2004; the first discharges of treated water from this STA were in February 2004. Accordingly, routine operational monitoring of this flow-way began during the first quarter of 2004. STA-3/4 Cell 3 satisfied start-up criteria for mercury in June 2004 and Cell 2 passed in August 2004, with consensus from FDEP in September 2004, at which time discharges began (for discussion of results observed prior to 2005, see Rumbold et al., 2006).

Results from monitoring mercury concentrations in surface water at STA-3/4 (**Figure 21**) show THg concentrations were fairly low and uniform during WY2008. At no time during WY2008 did THg concentration at any of the STA-3/4 outflows exceed the Class III WQS of 12 ng/L. In addition, outflow loads of THg and MeHg were lower than inflow (**Figures 12 and 13**). THg concentrations show a gradual increase since 2006. Temporal variability of MeHg concentrations has decreased since 2006 and, overall, concentrations demonstrate a gradual decrease (**Figure 21**). Sulfate concentrations in the inflows and outflows were uniform through WY2008 (**Figure 22**). Since 2005, sulfate concentrations at all locations positively track water level stage of each cell.

Concentrations of THg in mosquitofish are summarized in **Table 1** and **Figure 23**. For 2007, mosquitofish from STA-3/4 have moderate levels compared to all other STAs, which is the typical scenario for past years. There was no major change in concentrations for all locations within STA-3/4 since 2006. This STA, along with STA-5, demonstrates the largest difference between inflow and outflow mosquitofish THg levels (48 percent difference; see **Table 1**). This suggests efficient MeHg bioaccumulation or food web exchange within the STA-3/4 marsh since MeHg levels at the outflow of this STA are not significantly higher than other STAs. The average annual composite for 2007 and each individual mosquitofish composite within STA-3/4 did not exceed the POR 75th percentile for POR for all receiving water sampling Everglades locations during 2007 (see Appendix 3B-1).

Similar to mosquitofish, resident sunfish from the interior marshes of STA-3/4 contained moderate mercury levels compared to fish from other STAs for 2007 (**Table 2** and **Figure 23**). The data also shows a large difference between inflow and outflow THg levels. In past years, considerable difference existed in sunfish THg levels between Cells. In 2007, these differences still exist. After filtering by bluegill and normalizing by length, a statistical difference existed among all Cells (Cells 1, 2 and 3) (ANOVA, $p = 0.001$, $F = 8.5$). The Holm-Sidak method of pairwise comparison demonstrated Cell 3 was greater than both Cells 1 and 2 ($p < 0.05$ in both cases). Cells 2 and 3 contained no statistical difference. The average annual sunfish concentration for all locations within STA-3/4 did not exceed the POR 75th percentile for all Southern Everglades sampling locations during 2007 (see Appendix 3B-1).

THg levels in largemouth bass from STA-3/4 were, as in 2006 and previous years, in the moderate range (**Table 3**). Age-standardized three-year-old bass comparisons between STA-3/4 and all other STAs could not be done because either regression slope was insignificant or there was poor age distribution (**Table 3**). Bass THg levels at outflow sites were higher than inflow and interior sites (**Figure 23**). Bass THg levels from interior sites ranged 287 ± 110 ng/g in 2006 and 184 ± 129 in 2007, showing a 36 percent reduction based on averages (regression for 2006 was insignificant). The average annual largemouth bass concentration for all locations within STA-3/4 did not exceed the POR 75th percentile for all Southern Everglades sampling locations during 2007 (see Appendix 3B-1). Annual average levels of each fish species within each interior location (STA34C1B1, STA34C2B4, and STA33) of STA-3/4 show no visible temporal increase for $\geq$ three years.

Regarding risk to fish-eating wildlife, mosquitofish from STA-3/4 contained mercury at concentrations lower than the USFWS (100 ng/g) and USEPA criterion (77 ng/g). Five percent of all sunfish from the inflow, eight percent from the interior, and 18 percent from the downstream location exceeded the USFWS criterion. After adjusting the arithmetic mean, mercury concentrations in fillets to whole-body concentrations (whole-body THg concentration = $0.69 \times$ fillet THg; Lange et al., 1998) nearly all largemouth bass from inflow, interior marshes, and outflow (mean THg levels of 85, 128, and 266 ng/g, respectively) were less than the USEPA predator protection criteria based on TL4 fish (346 ng/g). Only one to two samples from each location exceeded the TL4 criterion. These results are a large improvement over last year. Therefore, fish-eating wildlife foraging preferentially at STA-3/4 appear to have an overall low to moderate risk to mercury exposure.

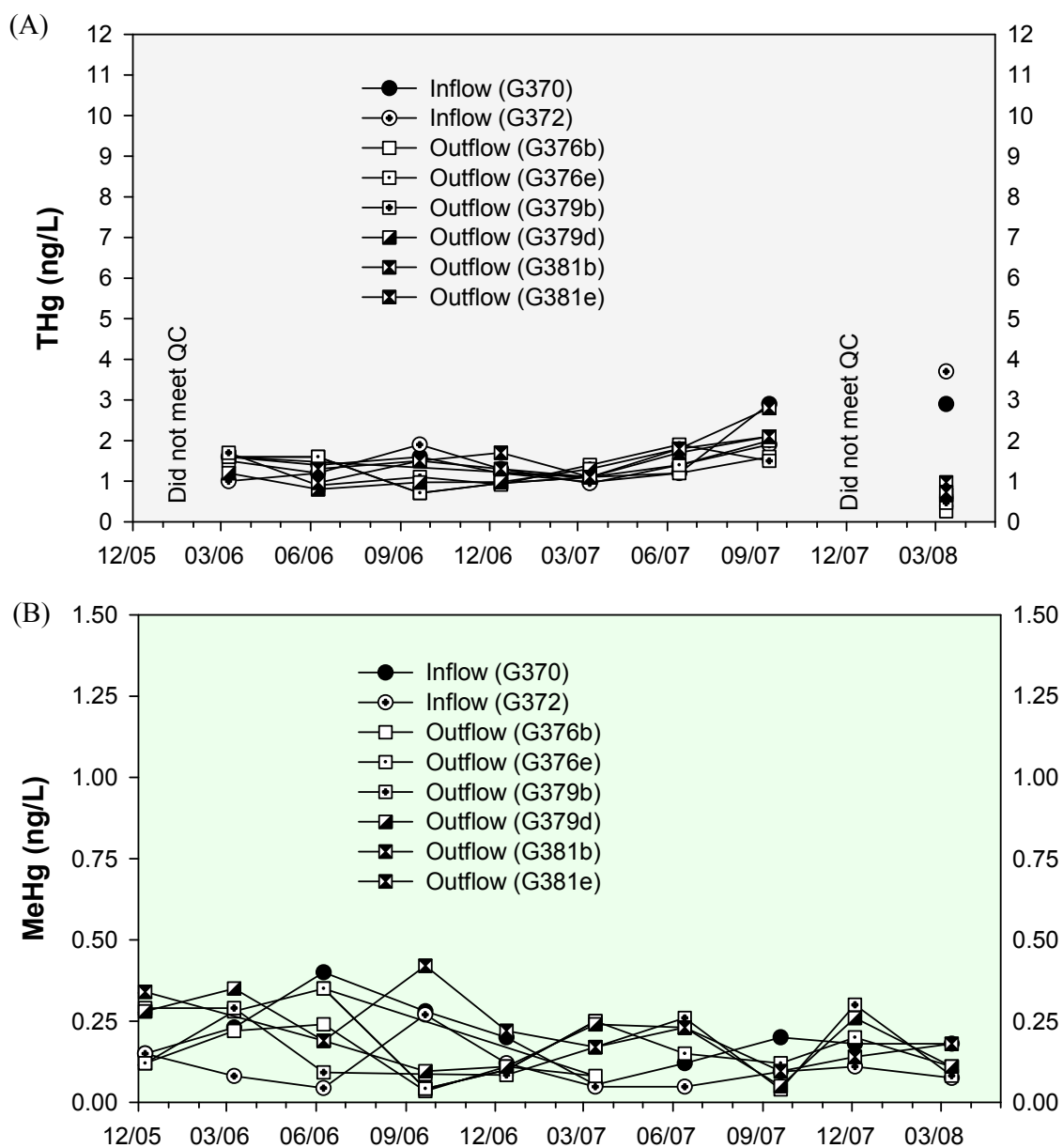


Figure 21. Concentrations of (A) THg and (B) MeHg (ng/L) in unfiltered surface water collected at STA-3/4.

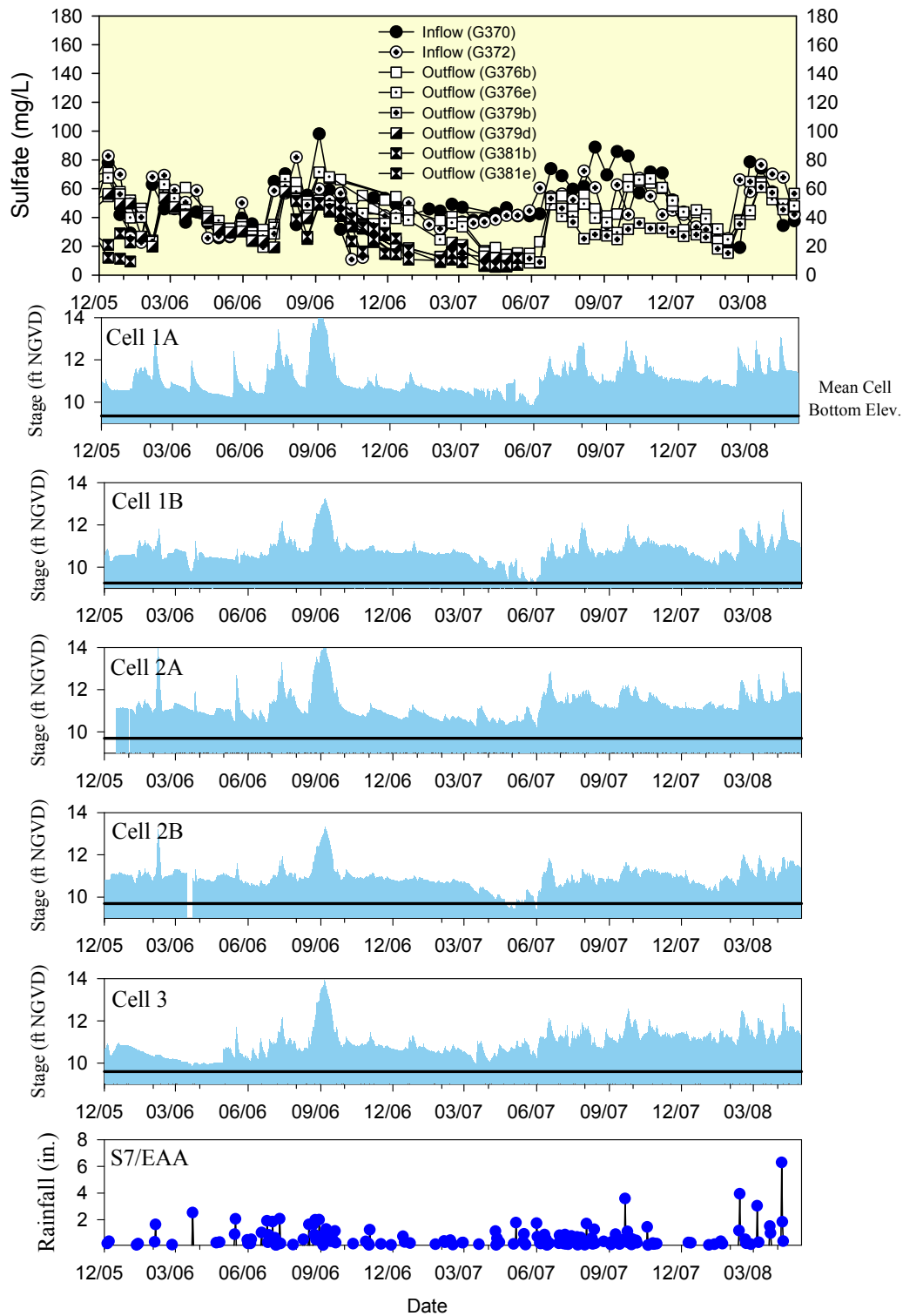


Figure 22. Water-column sulfate, stage (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-3/4.

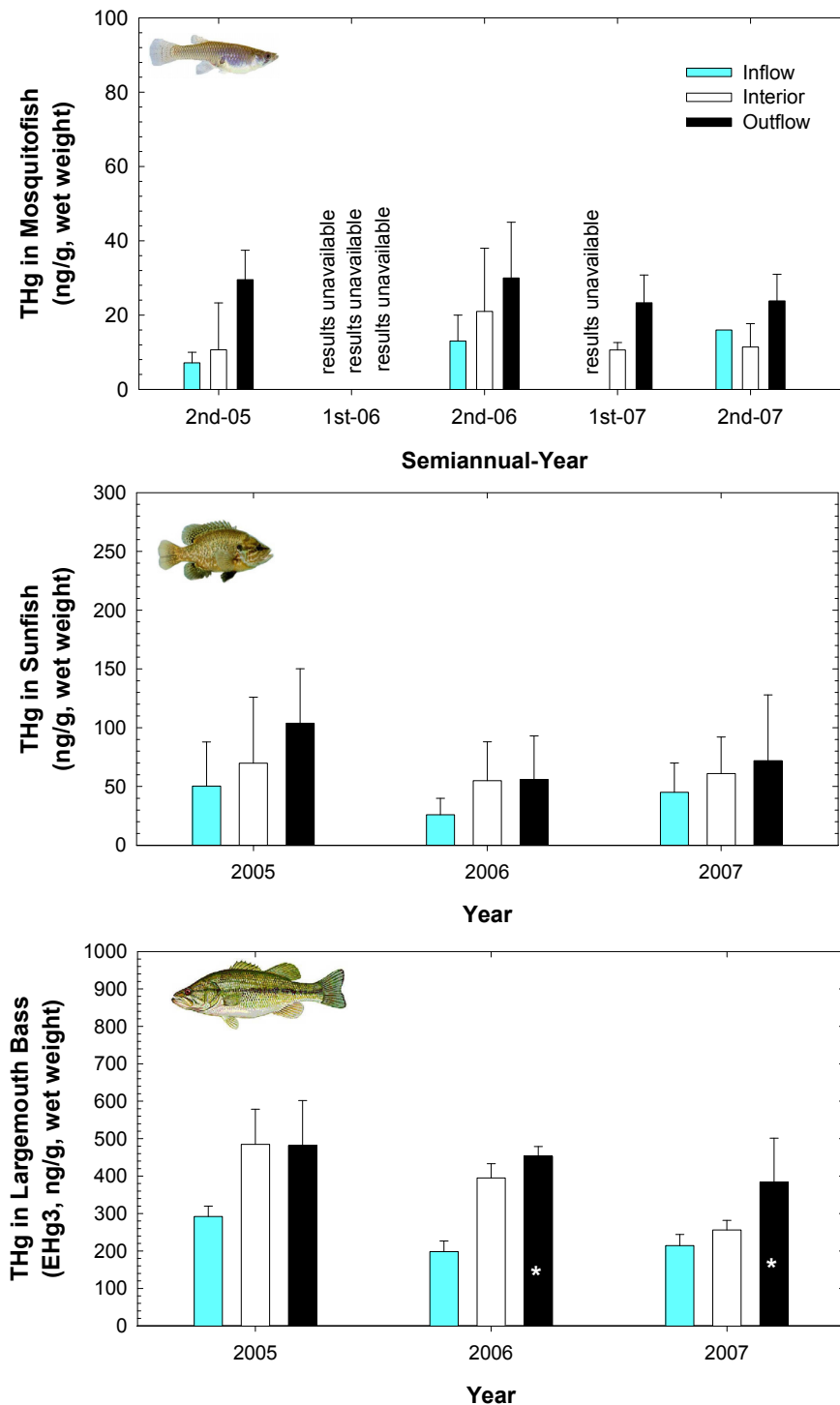


Figure 23. Mercury concentrations (ng/g, wet weight) in (*top*) mosquitofish composites ($\pm$ SD), (*middle*) whole sunfish ($\pm$ SD), and (*bottom*) fillets of largemouth bass ($\pm$ 95 percent C.I. or, if arithmetic, SD) collected at STA-3/4. Arithmetic means are noted by an asterisk.

STA-5

STA-5 met start-up criteria for mercury in September 1999. However, because of drought conditions and the detection of high phosphorus concentrations at the outflows, STA-5 did not begin flow-through operation until July 2000 (for discussion of results observed prior to 2005, see Rumbold and Rawlik, 2000; Rumbold et al., 2001, 2006; Rumbold and Fink, 2002a, 2003a; Rumbold, 2004 and 2005a). As of August 2008, the newest section, flow-way 3, has not passed start-up due to low water/drought conditions. As shown in **Figure 24**, water-column concentrations of both THg and MeHg in WY2008 remained low at STA-5, with the exception of a few spikes in THg at the inflows during the fourth quarter of 2007. At no time during the reporting year did THg concentrations exceed the Class III WQS of 12 ng/L at inflow and outflow locations. Overall, THg and MeHg loads have decreased appreciably since high levels were observed in 2001 and 2003. For WY2008, outflow loads for MeHg and THg were both lower than inflow.

Mosquitofish collected from STA-5 in 2006 contained moderate mercury levels (**Figure 26**), compared to all other STAs (**Table 1**). Average levels for 2007 in the interior marsh were slightly lower than the 2006 average (15 ng/g). Mosquitofish from downstream collection sites were, as with all other STAs, higher than the interior marsh. The average annual mosquitofish composite for 2007 and each individual mosquitofish composite for all locations within STA-5 did not exceed the POR 75th percentile for all Southern Everglades sampling locations (see Appendix 3B-1) during 2007.

Similar to mosquitofish, sunfish collected from the interior marsh contained moderate mercury levels compared to STAs (**Table 2**). For comparison purposes all sunfish were bluegill, therefore appropriate comparisons can be made to other STAs. All sunfish with STA-5 were collected from Cell 1 due to permit modifications (refer to the section *Mercury Monitoring Plan*) (**Figure 26**). From 2006 to 2007 there was an increase (30 percent) in average mercury levels in the interior marsh. The average annual sunfish for 2007 within STA-5 did not exceed the POR 75th percentile for all Southern Everglades sampling locations (see Appendix 3B-1) during 2007.

As in previous years, the Florida Fish and Wildlife Conservation Commission (FWC)—under contract to the District to electroshock and collect large-bodied fishes for mercury monitoring—encountered difficulties in filling sample quotas for STA-5. For 2007, no largemouth bass were collected from the downstream site RA1 (**Table 3**). The lack of fish collection and ability age-standardize has made long-term evaluation of largemouth bass in this STA difficult. However, despite these drawbacks in collection and data preparation in STA-5 (see 2007 SFER – Volume I, Appendix 5-7) there does appear to be a decline in mercury concentrations since sample collection began in 1999 (**Figure 26**). The average annual largemouth bass collected for 2007 in STA-5 did not exceed the POR 75th percentile for all Southern Everglades sampling locations (see Appendix 3B-1) during 2007. Annual average levels of each fish species within the marsh sites (STA5C1B1 and STA5C2B1) of STA-5 show no visible temporal increase for $\geq$ three years.

Regarding the risk to fish-eating wildlife, all resident sunfish with the marsh of STA-5 contain mercury levels below the USEPA criterion of 77 ng/g for TL 3 fish species. However, all fish from the new downstream site RA1 were above this criterion and nearly all were above the USFWS criterion of 100 ng/g. Largemouth bass from the interior marsh of STA-5 were all below the USEPA criterion of 346 ng/g for TL fish species (fillet concentration $\times$ 0.695 [Lange et al., 1998]). Therefore, fish-eating wildlife foraging preferentially from the interior marsh of STA-5 appears to be at moderate risk from mercury exposure and at a slight elevated risk if feeding near site RA1.

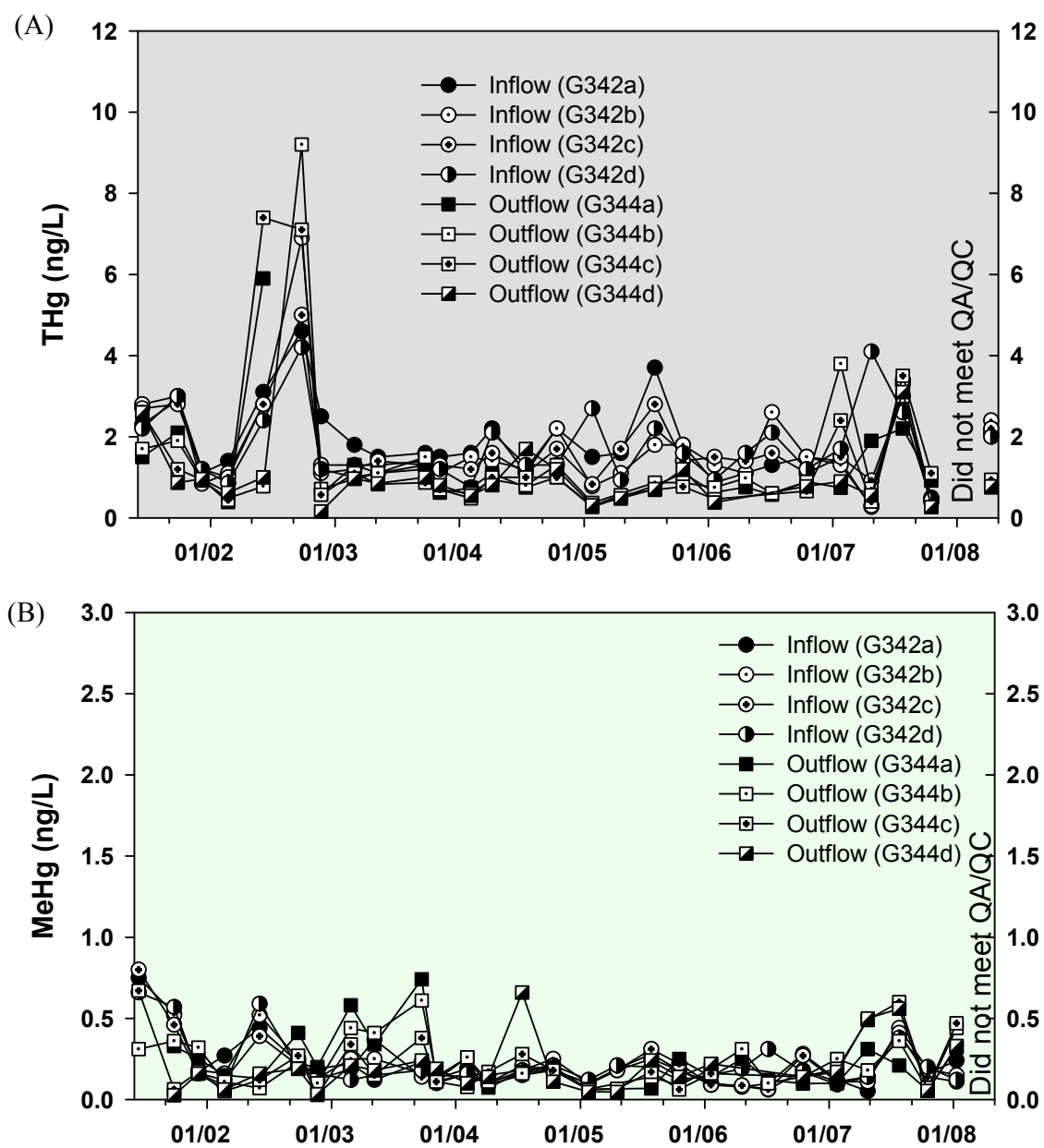


Figure 24. Concentrations of (panel A) THg and (panel B) MeHg (ng/L) in unfiltered surface water collected at STA-5.

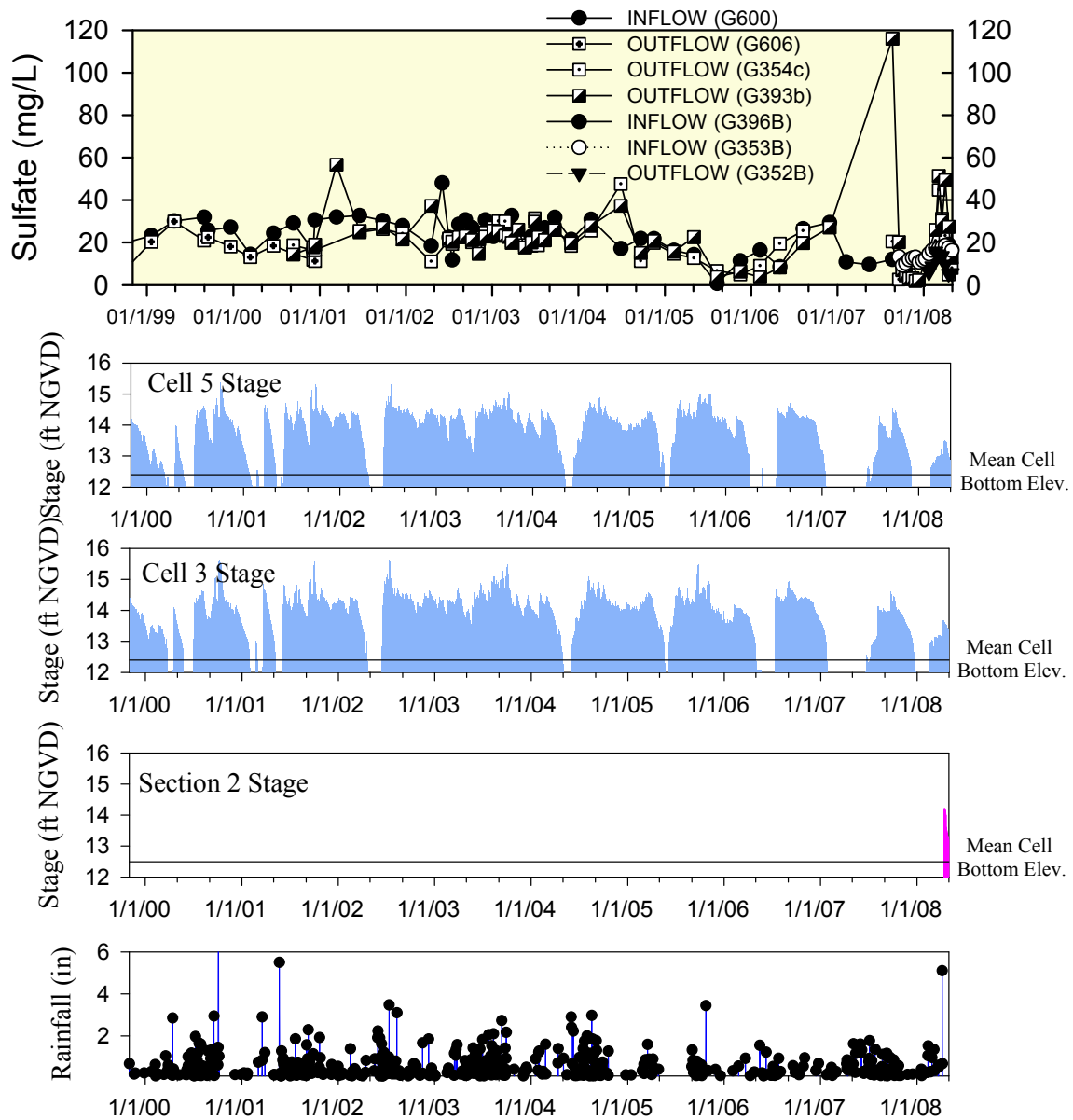


Figure 28. Concentrations of sulfate (*top*), stage in the two cells (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-6.

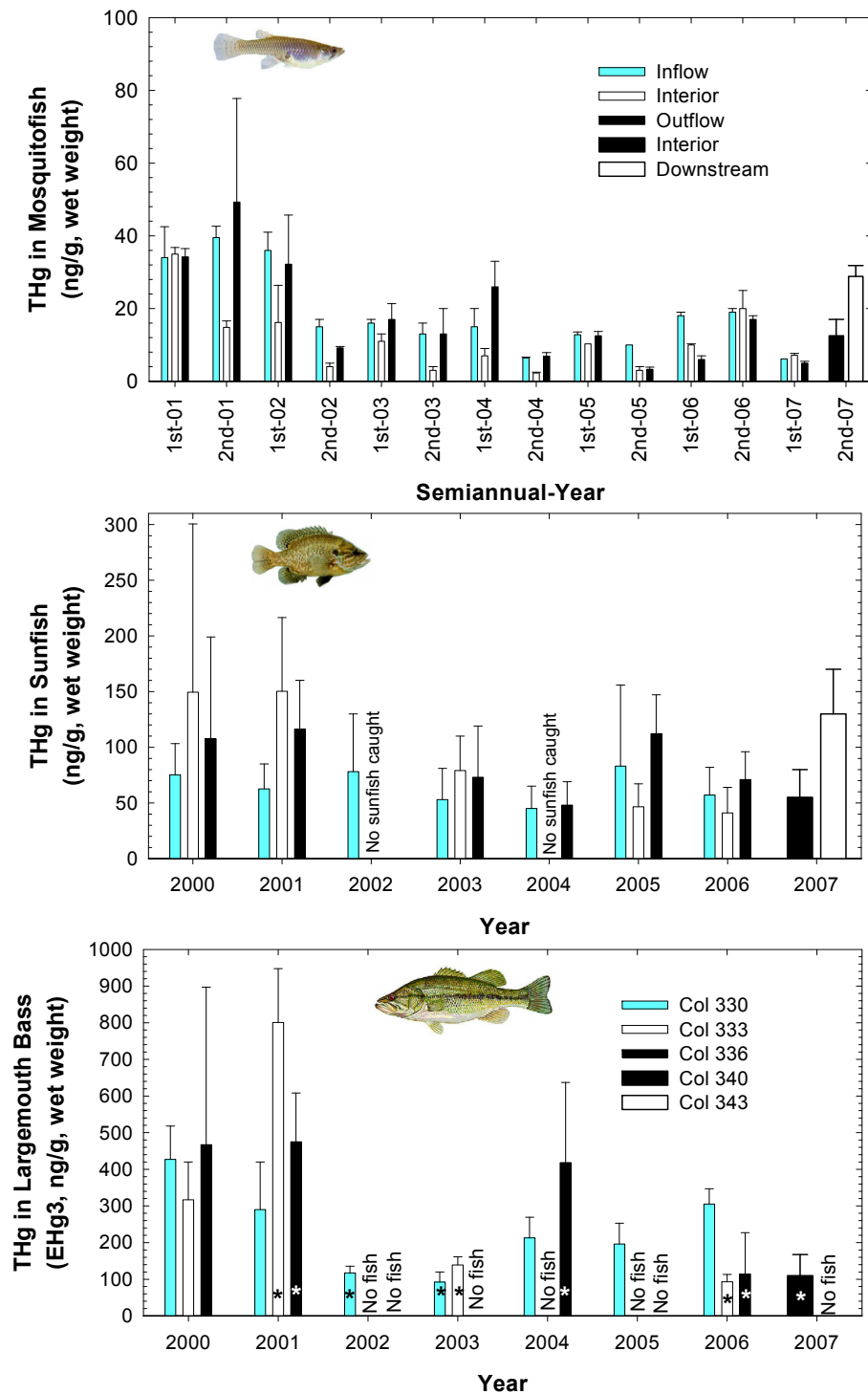


Figure 26. Mercury concentrations (ng/g, wet weight) in (top) mosquitofish composites (+range), (middle) whole sunfish ($\pm$ SD), and (bottom) fillets of largemouth bass ($\pm$ 95 percent C.I. or, if arithmetic, SD) collected at STA-5. Arithmetic means are noted by an asterisk.

STA-6

STA-6, Section 1 (Cells 3 and 5) met start-up criteria for mercury in November 1997, and began operation in December 1997. Routine monitoring of mercury at STA-6 was initiated in the first calendar quarter of 1998. Monitoring results prior to May 2004 have been reported (SFWMD, 1998c and 1999d; Rumbold and Rawlik, 2000; Rumbold et al., 2001; Rumbold and Fink, 2002a; Rumbold and Fink, 2003a; Rumbold, 2004 and 2005a; Rumbold et al., 2006). Start-up mercury monitoring occurred at the new section of STA-6, Section 2, on July 25, 2007.

THg concentrations at the inflows and outflows were consistent throughout WY2008 (**Figure 27**) and remained relatively low compared to previous spikes. MeHg remained at very low concentration throughout the year as well. However, as shown in **Figure 28**, both cells dried down during WY2008 for two periods lasting approximately 3 months each. Therefore, the relatively low concentrations of both THg and MeHg in the outflows appear incongruous with hypotheses previously offered regarding dryout and rewetting effects on sediment oxidation, sulfur biogeochemistry and stimulation of methylation by sulfate-reducing bacteria (Rumbold et al., 2006).

Nonetheless, if a spike in MeHg production did occur (as in the past) following dryout and rewetting, and if it was environmentally significant, it would likely be evident in the levels of MeHg bioaccumulated in downstream fish and newly immigrated fish. Nonetheless, as discussed below, it is reasonable to assume that the dryout and rewetting of this rain-driven STA has some part in higher tissue-Hg levels in large-bodied fish. Outflow loads of THg and MeHg were also lower than inflow.

Concentrations of THg in mosquitofish are summarized in **Table 1** and graphically presented in **Figure 29**. Levels of mercury in mosquitofish from the interior of STA-6 for 2007 were uncharacteristically high compared to past years. There was an 83 percent increase in average THg levels from 2006 to 2007. This large increase may be related to the extended dryout periods. An increase in fish THg without an observed similar increase in surface water MeHg may indicate changes in food chain dynamics that enhanced MeHg bioaccumulation. However, this does not consider potential changes in porewater MeHg. The average annual composite for 2007 and each individual mosquitofish composite for all locations within STA-6 did not exceed the POR 75th percentile for all Southern Everglades sampling locations during 2007 (see Appendix 3B-1).

As shown in **Table 2** and **Figure 29**, STA-6 sunfish from the interior marsh for 2007 have mercury levels greater than those observed in sunfish at all other STAs, with the exception of locations within the Everglades and EPA downstream monitoring locations (see Appendix 3B-1). To evaluate this large increase for 2007, fish from all STAs were normalized by bluegill and length. Following standardization, statistical difference existed between sites (ANOVA on ranks; $H = 31$; $df = 5$; $p < 0.001$). However, the only difference observed was between STA-6 and STA-1W, with STA-6 being higher (Dunn's method, $p < 0.05$). Since 2006 sunfish levels stayed nearly the same for the interior and the downstream/outflow locations. The average annual sunfish for 2007 for the interior marsh of STA-6 did not exceed the 75th percentile for POR for all receiving water sampling Southern Everglades locations during 2007 (see Appendix 3B-1).

Largemouth bass (all approximately three years old) at the interior site (STA6S2) had much lower concentrations compared to 2006 (50 percent decrease) (**Figure 29**); however, this decrease should be viewed with caution as the arithmetic mean was compared from last year due to the inability to standardize fish by age three. The downstream site (STA6DC) had much higher levels

than the interior (141 ng/g [interior] versus 541 ng/g [downstream]). Although highly variable, the interior concentrations still show a decreasing trend since the period of record. The average annual largemouth bass collected for 2007 in STA-6 did not exceed the POR 75th percentile all Southern Everglades sampling locations during 2007 (see Appendix 3B-1).

Annual average mercury levels in each fish species within the marsh sites (STA6S2, STA6C52, and STA6C32) of STA-6 show no visible temporal increase for $\geq$ three years.

Regarding risks to fish-eating wildlife, mosquitofish from interior, inflow and downstream locations did not exceed the 77 ng/g TL3 USEPA criterion. For sunfish, however, 70 percent of the catch from the interior marsh and 60 percent from the downstream site exceeded the USEPA TL3 criterion. Fifty percent of all sunfish from the downstream site exceeded the USFWS criterion. Nearly all largemouth bass (whole-body concentration estimated from fillet concentration) from the interior marsh of STA-6 were above the USFWS criterion, (100 ng/g) but none were above the USEPA criterion of TL4 species (346 ng/g). For the downstream location of STA-6, all largemouth bass exceeded the USFWS criterion and 60 percent exceeded the USEPA TL4 criterion. Therefore, the risk of mercury exposure to fish-eating wildlife foraging preferentially at interior and downstream locations within STA-6 appears to have a moderate to elevated risk of mercury exposure.

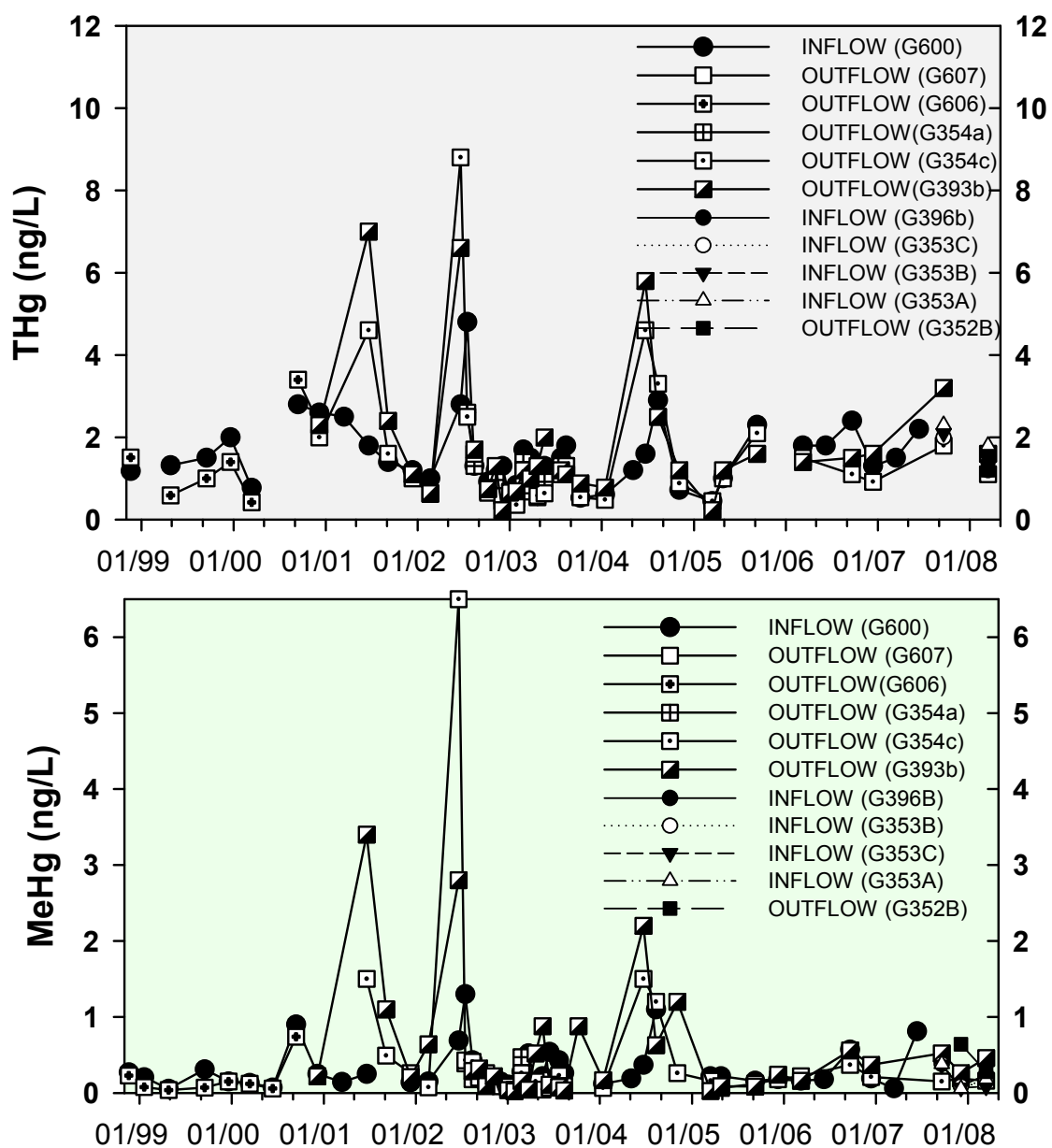


Figure 27. Concentrations of (panel A) THg and (panel B) MeHg (ng/L) in unfiltered surface water collected at STA-6.

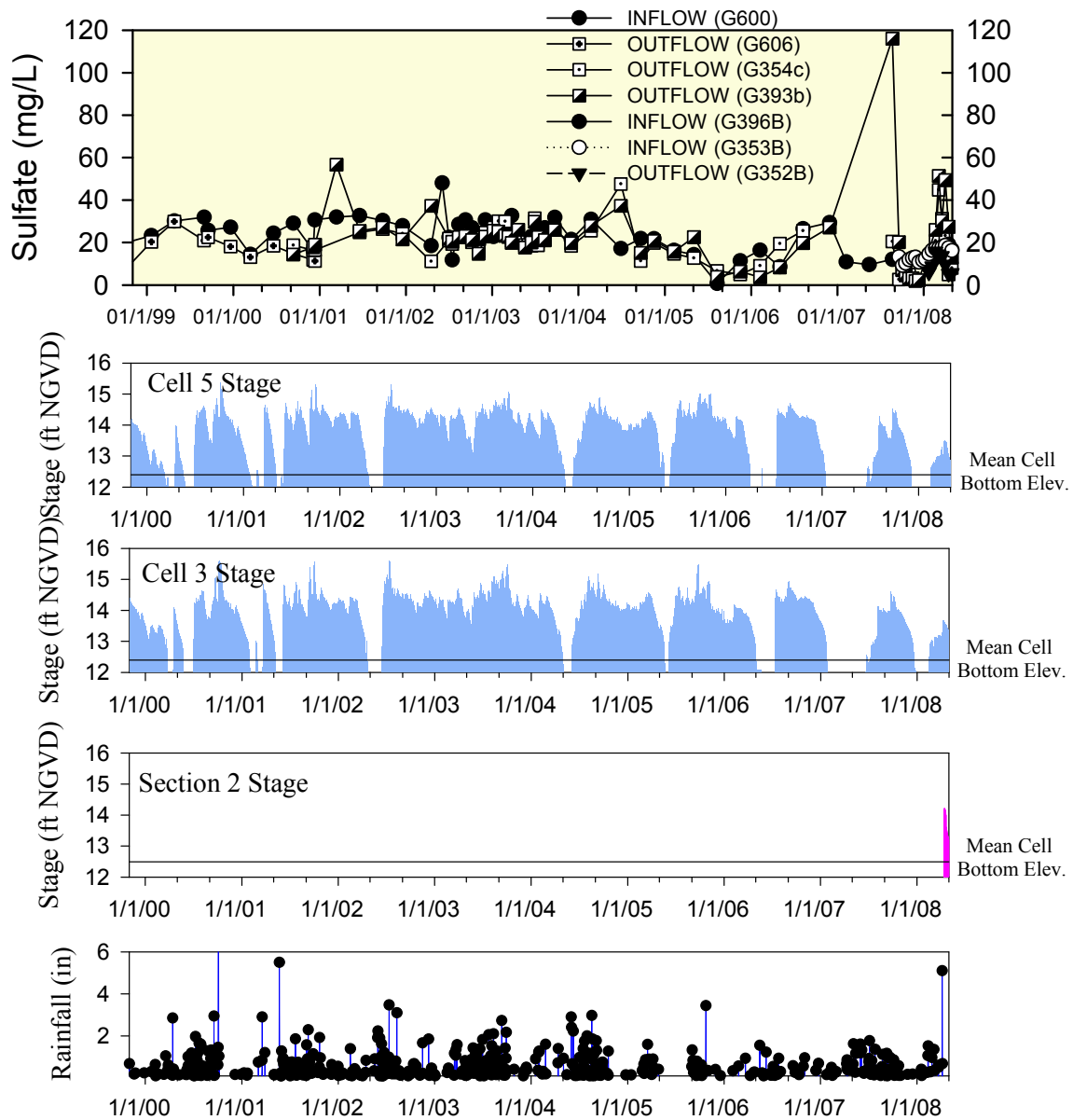


Figure 28. Concentrations of sulfate (*top*), stage in the two cells (recorded immediately upstream of outflow culvert of cell), and rainfall at STA-6.

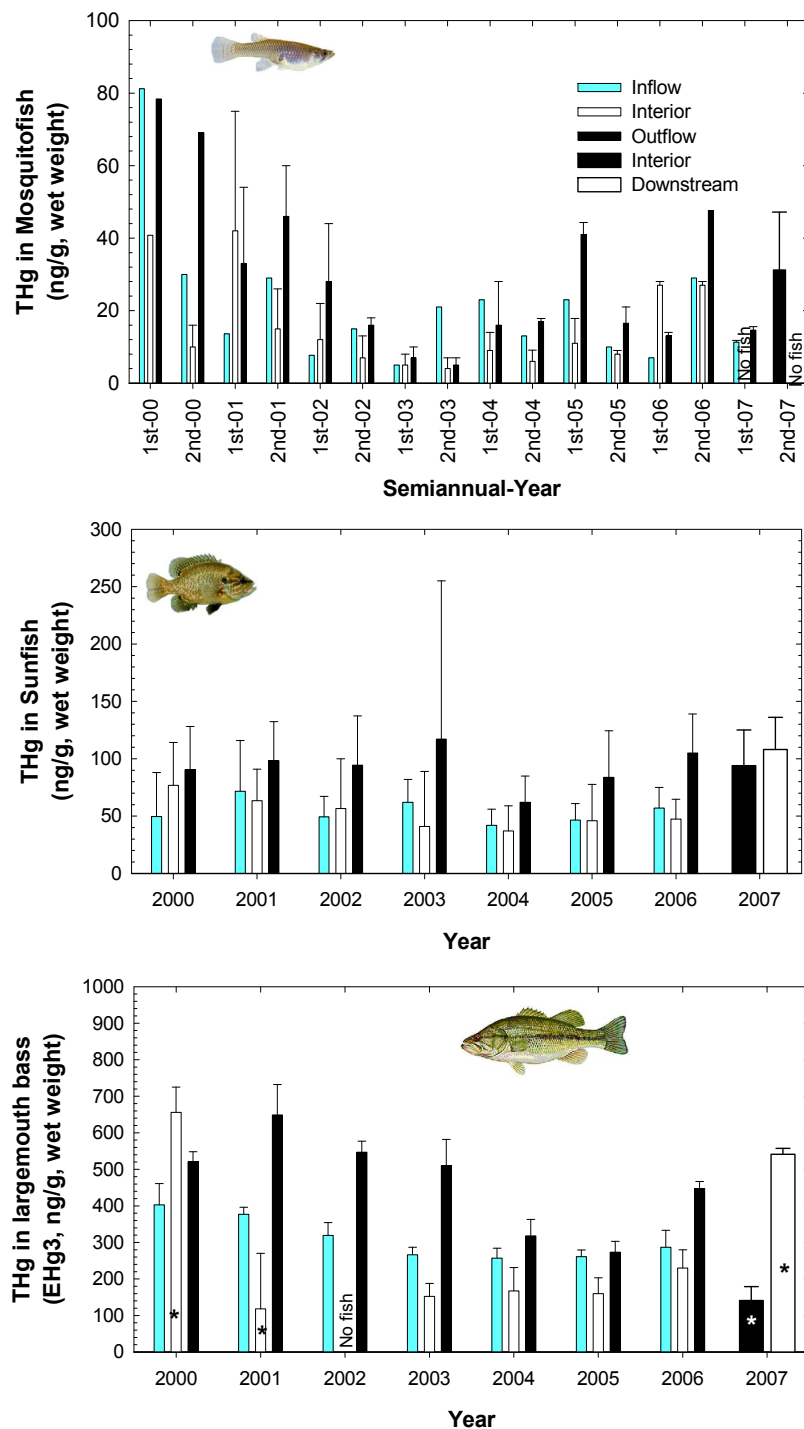


Figure 29. Mercury concentrations (ng/g, wet weight) in (top) mosquitofish composites (+range), (middle) whole sunfish ($\pm$ SD), and (bottom) fillets of largemouth bass ($\pm$ 95 percent C.I. or, if arithmetic, SD) collected at STA-6. Arithmetic means are noted by an asterisk.

OPTIMIZING THE MERCURY MONITORING NETWORK

A key component of any monitoring program is periodic reevaluation of objectives and methods to more sharply focus available finite resources. The monitoring plan should be revisited regularly to determine if improvements, such as using a different data collection method or a revised sampling regime, can be implemented without compromising the quality of the data stream while continuing to meet the program's objectives. In early 2005, a strategic plan was drafted to optimize the District's Mercury Monitoring Plan (Rumbold, 2005b). The summary below reflects the strategic plan and is based on guidance contained in SFWMD, 2006.

STA-1W/STA-1E

The new STA-1W/STA-1E EFA permit was issued on November 6, 2007. The mercury monitoring requirements contained under Section 4 of Downstream Receiving Water Monitoring for the EFA STA permit were omitted during the renewal process and instead codified in the non-ECP structures permit upon renewal. STA-1E is under Phase 2 Tier 1 and STA-1W is under Phase 3 Tier 1.

STA-1W mosquitofish are no longer collected semiannually at the inflow (S5A) nor the interior stations in Cells 3, 4, and 5 (ENR302, ENR401, and ST1W51, respectively). Instead, one composite sample per flow-way (ST1W13COM, ST1WC24COM, and ST1WC5COM) and a single sample from a new downstream station (ST1WLX) located in the Arthur R. Marshall Loxahatchee National Wildlife Refuge are collected semiannually. Mosquitofish at discharge stations G310 and ENR012 will be monitored in 2008 with the new downstream station, ST1WLX. If no spatial variability exists between the discharge stations and the new downstream station, monitoring will also be discontinued at G310 and ENR012.

Consistent with the Protocol (SFWMD, 2006), annual bass and sunfish monitoring frequency was reduced from annually to triennially and was reduced to one flow-way and one downstream station. The, $n = 20$ requirement was reduced to $n = \text{five}$ for bass and sunfish at each station and bass ageing is no longer required since a more specific size range is targeted. Bass and sunfish monitoring was discontinued at stations S5A, ENR302, and ENR401. Bass and sunfish will be collected from the flow-way with the highest observed concentrations at Cell 5 (ST1W51). In addition, bass and sunfish at discharge stations G310 and ENR012 will be monitored in 2008 with the new downstream station, ST1WLX. If no spatial variability exists between the discharge stations and the new downstream station, then monitoring will also be discontinued at G310 and ENR012.

In addition to fish sampling, surface water sampling for THg analysis was dropped at G310 and ENR012 (November 16, 2007); triennial sediment sampling for mercury analysis was dropped at STA-1W and STA-1E (SFWMD, 2006) due to EFA modifications.

STA-2

The new STA-2 EFA permit was issued on September 4, 2007. The mercury monitoring requirements contained under Section 4 of Downstream Receiving Water Monitoring for the EFA STA permit were omitted during the renewal process and instead codified in the non-ECP structures permit upon renewal. Mercury monitoring in STA-2 is currently under Tier 2 monitoring.

STA-2 mosquitofish are no longer collected semiannually at the inflow (G328B), discharge (G335) and from interior stations in Cells 2 (STA2C2A) and 3 (STA2C3A), but rather quarterly as one composite sample per flow-way (ST2C1COM, ST2C2COM, ST2C3COM, and ST2C4COM) and as a single sample from a downstream station (CA2NF). CA2NF has been monitored since 2005 for the non-ECP permit as an alternate to station N4. Three years of data are available to compare G335 and CA2NF for spatial variability. This analysis will be performed in the upcoming year. If results indicate no spatial variability exists, then monitoring at G335 will be terminated.

Annual bass and sunfish monitoring was reduced to one flow-way and one downstream station. In addition, consistent with the Protocol (SFWMD, 2006), $n = 20$ was reduced to $n =$ five for bass and sunfish at each station and bass ageing is no longer required since a more specific size range is targeted (102 to 178 for bluegill and 280 to 330 for largemouth bass). Bass and sunfish monitoring was discontinued at stations G328B, STA2C2A, STA2C3A, and G335. Bass and sunfish will continue to be collected from the flow-way with the highest observed concentrations, Cell 1 (STA2C1X) and from the downstream station CA2NF. CA2NF has been monitored since 2005 for the non-ECP permit as an alternate to station N4. Three years of data are available to compare G335 and CA2NF for spatial variability. This analysis will be done in the upcoming year. If no spatial variability exists, monitoring at G335 will be terminated.

STA-3/4

The new STA-3/4 permit modification was issued on September 4, 2007. The mercury monitoring requirements contained under Section 4 of Downstream Receiving Water Monitoring for the EFA STA permit were omitted during the renewal process and instead codified in the non-ECP structures permit upon renewal. All of STA-3/4 is currently under Phase 3, Tier 1, monitoring.

STA-3/4 mosquitofish are no longer collected semiannually at the inflows (G370 and G383), interior of Cells 1, 2, and 3 (ST34C1B1, ST34C2B4, and ST34C33), or discharges (G376B, G376E, G379B, G379D, G381B, and G381E), but rather quarterly as one composite sample per flow-way (ST34C1COM, ST34C2COM, and ST34C3COM) and along the discharge canal (L5F1).

Bass and sunfish monitoring frequency was reduced from annually to triennially and monitoring locations to one flow-way and one downstream station. Bass and sunfish monitoring was discontinued at inflow stations (G370 and G383), interior of Cells 1, 2, and 3 (STA34C1B1, and ST34C2B4). Bass and sunfish will continue to be collected from the flow-way with the highest observed concentrations, Cell 3 (ST34C33) and from the downstream station L5F1. Consistent with the Protocol, bass and sunfish collections were reduced from $n = 20$ to $n =$ five at each station and bass ageing was discontinued since a specific size range is targeted.

In addition to the fish sampling changes, surface water sampling for THg analysis was dropped at G370, G372, G376B, G376E, G379B, G379D, G381B, and G381E due to EFA modifications. Sediment collection for THg analysis was dropped from STA-3/4 on May 16, 2008.

STA-5

The new STA-5 EFA permit was issued September 4, 2007, and permit modification was issued May 16, 2008. The mercury monitoring requirements contained under Section 4 of Downstream Receiving Water Monitoring for the EFA STA permit were omitted during the renewal process and instead codified in the non-ECP structures permit upon renewal. Currently, no Hg monitoring occurs in flow-ways 1 and 2. The new section, flow-way 3, is under Phase 2 monitoring and flow-ways 1 and 2 are under Phase 3 monitoring.

STA-5 mosquitofish are no longer collected semiannually at the inflows (G342B and G342D), Flow-way 1 and 2 interior stations (STA5C1B1 and STA5C2B1) and discharge stations (G344B and G344D), but rather quarterly as one composite sample per flow-way (ST5C1COM, ST5C2COM, ST5C3COM, and as a single sample from a downstream station (RA1) in the Rotenberger Wildlife Management Area. Discharge stations G344B and G344D and downstream station RA1 were sampled in 2008. If no spatial variability exists between G344B–D, then RA1 monitoring will be terminated at G344-D.

Annual bass and sunfish monitoring was reduced to flow-ways 2 and 3 and one downstream station. Bass and sunfish monitoring was discontinued at the flow-way 1 and 2 inflow station (G342A), flow-way 2 interior station (STA5C2B1) and flow-way 1 and 2 discharge stations (G344B and D). Bass and sunfish will continue to be collected from the interior of the flow-way with the highest observed concentrations, Cell 1 (ST5C1B1) and from the downstream station RA1. Discharge stations G344B and G344D and downstream station RA1 were sampled in 2008. If no spatial variability exists between G344B and D and RA1 monitoring will be terminated at G344B and D. Consistent with the protocol, bass and sunfish collections were reduced from $n = 20$ to $n = \text{five}$ at each station and bass ageing was eliminated since a more specific size range is targeted.

In addition to fish sampling, on May 16, 2008, surface water sampling for THg analysis was dropped at G342A–D and G344A–D. Sediment collection for THg analysis was eliminated for STA-5 due to EFA modifications on September 4, 2007.

STA-6

The new STA-6 EFA permit was issued on September 4, 2007, and permit modification was issued on May 16, 2008. The mercury monitoring requirements contained under Section 4 of Downstream Receiving Water Monitoring for the EFA STA permit were omitted during the renewal process and instead codified in the non-ECP structures permit upon renewal. The new section, Section 2, is under Phase 2 monitoring and all mercury monitoring was limited to Section 1, consistent with Phase 3, Tier 3 monitoring.

Mosquitofish are no longer collected semiannually at (1) the inflow (G600), (2) Cell 3 interior (STA6C32) and discharge (G393B), and (3) Cell 5 interior (STA6C52) and discharge (G354C), but rather quarterly as one flow-way composite for Section 2 (STA6COM) and a STA-6 downstream station (STA6S2).

Annual bass and sunfish monitoring was eliminated at the inflow (G600), Cell 3 interior (STA6C32) and discharge (G393B), and Cell 5 interior (STA6C52) and discharge (G354C). Bass and sunfish monitoring are required only for the STA-6 Section 2 interior (STA6S2) and the STA-6 downstream station STA6S2. Consistent with the Protocol, bass and sunfish collections were reduced from $n = 20$ to $n = \text{five}$ at each station and bass ageing was eliminated since a more specific size range is targeted.

In addition to fish sampling on May 16, 2008, surface water sampling for THg analysis was dropped at G353A–C, G354C, and G393B. Sediment collection for THg analysis was eliminated for STA-6 due to EFA modifications on September 4, 2007.

LITERATURE CITED

- Abernathy, A.R. and P.M. Cumbie. 1977. Mercury Accumulation by Largemouth Bass (*Micropterus salmoides*) in Recently Impounded Reservoirs. *Bull. Environ. Contam. Toxicol.*, 17: 595-602.
- Benoit, J.M., C.C. Gilmour, R.P. Mason and A. Heyes. 1999a. Sulfide Controls on Mercury Speciation and Bioavailability to Methylating Bacteria in Sediment Pore Waters. *Env. Sci. Technol.*, 33(6): 951-957.
- Benoit, J.M., R.P. Mason and C.C. Gilmour. 1999b. Estimation of Mercury-Sulfide Speciation in Sediment Pore Waters Using Octanol-Water Partitioning and Its Implications for Availability to Methylating Bacteria. *J. Env. Toxicol. Chem.*, 8 (10): 2138-2141.
- Bloom, N.S. 1992. On the Chemical Form of Mercury in Edible Fish and Marine Invertebrates. *Can. J. Fish. Aquat. Sci.*, 49: 1010-1017.
- Bodaly, R.A. and R.J.P. Fudge. 1999. Uptake of Mercury by Fish in an Experimental Boreal Reservoir. *Arch. Environ. Contam. Toxicol.*, 37: 103-109.
- Bodaly, R.A., R.E. Hecky and R.J.P. Fudge. 1984. Increases in Fish Mercury Levels in Lakes Flooded by the Churchill River Diversion, Northern Manitoba. *Can. J. Fish. Aquat. Sci.*, 41: 682-691.
- Cabral, J.A. and J.C. Marques. 1999. Life History, Population Dynamics and Production of Eastern Mosquitofish, *Gambusia holbrooki* (Pisces, Poeciliidae), in Rice Fields of the Lower Mondego River Valley, Western Portugal. *Acta Oecologica*, 20: 607-620.
- Cox, J.A., J. Carnahan, J. Dinunzio, J. McCoy and J. Meister. 1979. Source of Mercury in New Impoundments. *Bull. Environ. Contam. Toxicol.*, 23: 779.
- Eisler, R. 1987. Mercury Hazards to Fish, Wildlife and Invertebrates: A Synoptic Review. *U.S. Fish Wildl. Serv. Biol. Rep.*, 85 (1.10). U.S. Department of the Interior, U.S. Fish and Wildlife Services. Laurel, MD.
- Fink, L., D.G. Rumbold and P. Rawlik. 1999. Chapter 7: The Everglades Mercury Problem. G. Redfield, ed. In: *1999 Everglades Interim Report*, South Florida Water Management District, West Palm Beach, 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.
- Gabriel, M., N., Howard, F. Matson, S. Atkins and D. Rumbold. 2006. Appendix 5-7: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas. In: *2008 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.
- Grieb, T.M., C.T. Driscoll, S.P. Gloss, C.L. Schofield, G.L. Bowie and D.B. Porcella. 1990. Factors Affecting Mercury Accumulation in Fish in the Upper Michigan Peninsula. *Environ. Toxicol. Chem.*, 9: 919-930.

- Haake, P.W. and J.M. Dean. 1983. Age and Growth of Four Everglades Fishes Using Otolith Techniques. Report to the National Park Service, Everglades National Park, Homestead, FL. May 1983.
- 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.
- Haynes, J. and C. Cashner. 1995. Life History and Population Dynamics of the Western Mosquitofish: A Comparison of Natural and Introduced Populations. *J. Fish Biol.*, 46: 1026-1041.
- KBN. 1994a. Report of Water Sampling in the Holey Land, Water Conservation Area 2A, and the Everglades Nutrient Removal Project. Prepared for the Sugar Cane Growers Cooperative, Inc., by KBN Engineering and Applied Science, Inc., Gainesville, FL.
- KBN. 1994b. Biological Sampling and Tissue Analysis of Fish Collected in Palm Beach County, Florida. Prepared for the Sugar Cane Growers Cooperative, Inc. by KBN Engineering and Applied Science, Inc., Gainesville, FL.
- Kelly, C.A., J.W.M. Rudd, R.A. Bodaly, N.P. Roulet, V.L. St. Louis, A. Heyes, T.R. Moore, S. Schiff, A. Aravena, K. J. Scott, B. Dyck, R. Harris, B. Warner and G. Edwards. 1997. Increases in Fluxes of Greenhouse Gases and Methyl Mercury Following Flooding of Experimental Reservoir. *Environmental Science and Technology*, 31: 1334-1344.
- Krabbenhoft, D.P. and L.E. Fink. 2001. Appendix 7-8: The Effect of Dry Down and Natural Fires on Mercury Methylation in the Florida Everglades. 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 Freshwater Fish Commission, Fisheries Research Laboratory, Eustis, FL. Prepared for the Florida Department of Environmental Protection, Tallahassee, FL.
- 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 Freshwater Fish Commission, Fisheries Research Laboratory, Eustis, FL. Prepared for the Florida Department of Environmental Protection, Tallahassee, FL.
- Mercury Technical Committee. 1991. Interim Report to the Florida Governor's Mercury in Fish and Wildlife Task Force and Florida Department of Environmental Regulation. Center for Biomedical and Toxicological Research, Florida State University, Tallahassee, FL. 60 pp.
- Miles, C.J. and L.E. Fink. 1998. Monitoring and Mass Budget for Mercury in the Everglades Nutrient Removal Project. *Archives of Environ. Contam. and Toxicol.*, 35(4): 549-557.
- Paterson, M.J., J.W.M. Rudd and V. St. Louis. 1998. Increases in Total and Methylmercury in Zooplankton Following Flooding of a Peatland Reservoir. *Environ. Sci. Technol.*, 32: 3868-3874.
- PTI. 1994. The Influence of Phosphorus on Mercury Cycling and Bioaccumulation in the Everglades. Prepared for the Sugar Cane Growers Cooperative, Inc. PTI Environmental Services Inc., Waltham, MA.

- Rudd, J.W.M. 1995. Sources of Methyl Mercury to Freshwater Aquatic Ecosystems: A Review. *Water, Air, and Soil Pollut.*, 80: 697-713.
- Rumbold, D.G. 2004. Appendix 4A-4: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas. G. Redfield, ed. In: *2004 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G. 2005a. Appendix 4-4: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas. G. Redfield, ed. In: *2005 South Florida Environmental Report – Volume I* South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G., 2005b. Optimization of the District's Mercury Monitoring Networks: A Proposed Strategy. South Florida Water Management District, West Palm Beach, FL. February 17, 2005.
- Rumbold, D.G. and P. Rawlik. 2000. Appendix 7-2: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas and Downstream Receiving Waters. G. Redfield, ed. In: *2000 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G., L. Fink, K. Laine, F. Matson, S. Niemczyk and P. Rawlik. 2001. Appendix 7-9: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas and Downstream Receiving Waters of the Everglades Protection Area. G. Redfield, ed. In: *2001 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G. and L. Fink. 2002a. Appendix 4A-8: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas. G. Redfield, ed. In: *2002 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G. and L. Fink. 2002b. Appendix 4A-6: Report on Expanded Mercury Monitoring at Stormwater Treatment Area 2. G. Redfield, ed. In: *2002 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G. and L. Fink. 2003a. Appendix 4A-4: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas. G. Redfield, ed. In: *2003 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G. and L. Fink. 2003b. Appendix 4A-7: Report on Expanded Mercury Monitoring at STA-2. G. Redfield, ed. In: *2003 Everglades Consolidated Report*, South Florida Water Management District, West Palm Beach, FL.
- Rumbold, D.G. and R. Pfeuffer. 2005. District Guidance in the Design of a Project-Level Monitoring and Assessment Plan for Mercury and Other Toxicants. Appendix A to CERP Guidance Memorandum 42.00. Online at http://www.evergladesplan.org/pm/program_docs/cerp-guidance-memo.cfm (August 4, 2006).
- Rumbold, D., N. Niemeyer, F. Matson, S. Atkins, J. Jean-Jacques, K. Nicholas, C. Owens, K. Strayer and B. Warner. 2006. Appendix 4-4: Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas. In: *2006 South Florida Environmental Report – Volume I*, South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1997. Operation Plan: Stormwater Treatment Area 6, Section 1. South Florida Water Management District, West Palm Beach, FL.

- SFWMD. 1998a. Operation Plan: Stormwater Treatment Area 5. Draft Report. South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1998b. Operation Plan: Stormwater Treatment Area 1 West. Draft Report. South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1998c. Annual Permit Compliance Monitoring Report for Mercury in Stormwater Treatment Areas and Downstream Receiving Waters. Prepared for the Florida Department of Environmental Protection, Tallahassee, FL, by the South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1999a. Everglades Nutrient Removal Project: 1998 Monitoring Report. Prepared for the Florida Department of Environmental Protection, Tallahassee, FL, by the South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1999b. Mercury Monitoring and Reporting Plan for the Everglades Construction Project, the Central and Southern Florida Project, and the Everglades Protection Area. South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1999c. Quality Assurance Project Plan (QAPP) for the Mercury Monitoring and Reporting Program. SFWMD. Operation Plan: Stormwater Treatment Area 2. Revision 1.0. South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 1999d. Stormwater Treatment Area 6, Section 1 Annual Monitoring Report. Prepared for the Florida Department of Environmental Protection, Tallahassee, FL, by the South Florida Water Management, West Palm Beach, FL.
- SFWMD. 2004. Operation Plan Stormwater Treatment Area 3/4. South Florida Water Management District, West Palm Beach, FL.
- SFWMD. 2006. A Protocol for Monitoring Mercury and Other Toxicants. Unpublished Report. South Florida Water Management District, West Palm Beach, FL.
- St. Louis, V.L., J.W.M. Rudd, C.A. Kelly, K.G. Beaty, N.S. Bloom and R.J. Flett. 1994. Importance of Wetlands as Sources of Methyl Mercury to Boreal Forest Ecosystems. *Can. J. Fish. Aquat. Sci.*, 51: 1065-1076.
- USEPA. 1997. Mercury Study Report to Congress. Volume VI: An Ecological Assessment for Anthropogenic Mercury Emissions in the United States. U.S. Environmental Protection Agency. EPA-452/R-97-008.
- Verdon, R., D. Brouard, C. Demers, R. Lalumiere, M. Laperle and R. Schetagne. 1991. Mercury Evolution (1978-1988) in Fishes of the La Grande Hydroelectric Complex, Quebec, Canada. *Water, Air, Soil Pollut.*, 56: 405-417.
- Ware, F.J., H. Royals and T. Lange. 1990. Mercury Contamination in Florida Largemouth Bass. *Proc. Ann. Conf. Southeast Assoc. Fish Wildlife Agencies*, 44: 5-12.
- Watras, C. 1993. Potential Impact of the Everglades Nutrient Removal Project on the Everglades Mercury Problem. (EV 930034). Unpublished Report Prepared by the University of Wisconsin, Madison, WI for the South Florida Management District, West Palm, Beach, FL.
- Watras, C. 1994. Mercury Field Training Exercise and Recommendations for Sampling Modification. Draft Letter Report dated February 19, 1994. Submitted to Larry Fink, South Florida Management District, West Palm Beach, FL.

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* (3rd edition). Prentice-Hall, Upper Saddle River, NJ.