ASSESSING LAND-BASED SOURCES OF POLLUTANTS TO COASTAL WATERS OF SOUTHERN BELIZE

FINAL REPORT, PROJECT NA07NOS4630029

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SUMMARY

Water samples were collected from coastal waters of southern Belize along eight transects starting from rivers in the region during 2008. Rivers were North Stann Creek (NSC), Sittee (SR), South Stann Creek (SSC), Mango Creek (MBC/MC), Monkey (MR), Golden Stream (GS), Rio Grande (RG), and Sarstoon (SAR). Five samples were collected at each transect from each river mouth out to waters overlying coral reefs where possible. Sampling sites were spaced approximately 2-3 miles apart. Samples for pesticide analysis were collected during four periods encompassing the dry and rainy seasons: February-March, May-June, August, December. During the May-June and August sampling periods, separate samples were collected for measurement of glyphosate and paraquat and for analysis of lead and mercury.

All samples were analyzed for a suite of current-use pesticides: trifluralin, chlorothalonil, dacthal, malathion, chlorpyrifos, cadusafos, ethoprophos, acetochlor, fenamiphos, carbofuran, dimethoate, metribuzin, pendimethalin, glyphosate, paraquat, parathion, carbaryl, atrazine and chlorpyrifos methyl. Analyses were done using capillary gas chromatography - mass spectrometry (GC-MS) in the electron capture negative ion (ECNI) mode and a DB-5 column for some pesticides and the electron impact (EI) mode and a RTX-5MS column for others. Glyphosate and paraquat were measured by a commercial laboratory via HPLC, using a photodiode array detector with an absorbance wavelength of 257 nm for paraquat and derivatization followed by fluorescence detection for glyphosate. A commercial laboratory also analysed samples for lead and mercury following EPA Method SW-846 and suitable procedures therein.

Glyphosate and paraquat were below detection in all samples. Lead and mercury were present in virtually all samples tested for these metals. Mercury was present at around detection limits while lead concentrations varied considerably between transects. Some current-use pesticides were detected in most of the sampling stations and during all sampling periods. These include trifluralin, dacthal, chlorothalonil, and chlorpyrifos. Some were detected less frequently, including dimethoate, malathion, atrazine, acetochlor, parathion, oxamyl, cadusafos and chlorpyrifos methyl. In general, pesticide levels were higher in August and May/June and lower in February/March and December. Temporal differences are likely due to rainy versus dry seasons and application patterns. Results suggest that pesticides discharged via rivers undergo mixing due to coastal circulation patterns. They also indicate that some pesticides are transported far enough offshore to waters overlying coral reefs.

There has never been to our knowledge a systematic study to document levels of pesticides in coastal waters of Belize. In southern Belize only one limited study has looked at pesticides in organisms in coastal waters in southern Belize (M. McField, unpublished).

1. INTRODUCTION AND OBJECTIVES

Previous studies have shown that coastal waters are susceptible to contamination from land-bases sources (Saison et al., 2008; Hapeman et al., 2002; Alegria et al., 2000; Leonard, 1990; Wauchope, 1978). Pollutants in coastal waters may originate from agricultural areas (pesticides, excessive nutrients, pathogens), urban areas (pesticides, polycyclic aromatic hydrocarbons, metals, polychlorinated biphenyls, flame retardants, hydrocarbons, etc.), industrial parks (organic solvents, flame retardants, fuel, polycyclic aromatic hydrocarbons, metals, etc.), vehicles (hydrocarbons, oils, etc.) and a myriad other sources (Jeong et al., 2008; Hou et al., 2006: Southwick et al., 2002; Dietrich and Gallagher, 2002).

Coastal areas are also known for their tremendous value, both ecologically and economically (Cooper et al., 2009; Burke et al, 2008). They are important areas for spawning of many valuable species of fish and also serve an important function for recreation and tourism (Cooper et al., 2009: Burke et al., 2008). As a result, protection of coastal areas is at the top of the environmental agenda of all countries with coastlines. In fact, the United Nations, through its United Nations Environmental Programme (UNEP), has made coastal protection one of its key initiatives. In the Wider Caribbean countries it has set up a programme to fund research on Land-Based Sources of Pollutants to Coastal Waters.

In countries such as those in the wider Caribbean, there is special concern about the presence of pollutants from land-based sources because many of these countries have coral reefs in their coastal waters. The health of coral reefs has been in decline for several years, and although coral bleaching due to warming waters has been implicated as the main culprit, there exists the distinct possibility that pollutants from land-based sources may at the very least be contributing to coral reef decline.

Unfortunately, in most countries of the Caribbean very few studies have been carried out to document the extent of pollution in coastal areas. This is due in part to scarce resources for scientific research and a lack of analytical facilities and trained personnel to carry out such studies. Such is the case in Belize.

The vast majority of the Mesoamerican Barrier Reef System (MBRS), the second longest reef system in the world, runs parallel to the coast of Belize. Coastal waters of southern Belize are home to abundant and diverse marine species, including commercially-valuable species (e.g. shrimp, spiny lobster, conch). The productivity of these waters is partly due to the nutrients that rivers transport to coastal waters, partly due to nutrients from open ocean upwellings, and partly to the proximity of mangroves, seagrass beds and coral reefs.

The southern Belizean districts of Stann Creek and Toledo are home to large-scale agricultural enterprises (bananas and citrus) and several aquaculture farms. Consequently, there is the real possibility that runoff from farms are contaminating the coastal areas of these districts with agrochemicals and excessive nutrients. In addition, several open dump sites have been identified beside streams that drain into coastal waters in these districts, with the potential to contaminate them with metals.

Previous monitoring work (extremely limited in scope) carried out by TIDE, an environmental group in Belize, has focused on the Port Honduras Marine Reserve in southern Belize. TIDE concluded that land-based runoff was one of the greatest threats to the coral reefs in the region (J. Villafranco, personal communication). TIDE and DoE have identified potential sources of pollutants to coastal waters and the coral reefs, including agriculture, aquaculture, industries in neighboring Guatemala and Honduras, and major garbage disposal (open dump) sites.

The predominant direction of currents in the region varies with seasons. There is a persistent counter-clockwise long-shore flow over the shelf off the coast of Belize, which is most pronounced during the summer months when it combines with wind-driven currents. During winter, there is coastal upwelling off Honduras with an associated westward long-shore flow. The end result of the currents is that pollutants ending up in coastal waters at a given location are transported along the coasts over long distances.

The only study to actually measure levels of pollutants in the region was a limited study carried out by the World Wildlife Fund in the nearby Gulf of Honduras, which indicated the presence of agrochemicals (J. Villafranco, pers. Comm.). There has never been, however, a comprehensive study to document levels of pollutants in coastal waters of southern Belize and their potential effects on the MBRS. Therefore, there is a critical need to carry out such a comprehensive study if the proper regulatory and protection strategies can be developed by the appropriate agencies in conjunction with concerned stakeholders. Indeed, based on the preliminary work carried out by TIDE, local stakeholders in southern Belize recognized the need for further research and the development of a management plan for the wider area.

The aim of this project is to determine the extent of contamination of coastal waters of southern Belize from agricultural and urban sources in order to determine potential impacts on coral reefs and develop mitigation strategies. This will be accomplished by (i) identifying and quantifying agrochemicals and heavy metals in coastal waters of southern Belize, including those areas in which coral reefs are present; (ii) identifying major sources of any pollutants quantified; (iii) advising DoE and TIDE on strategies for reducing pollutant input by coordinating with stakeholders to engage in best management practices in given industries.

Specific objectives of this project were:

- To identify the major types of pollutants and their levels in coastal waters of southern Belize, including those areas in which coral reefs are present.
- To identify the major sources of pollutants to coastal waters of southern Belize and the MBRS.
- To develop a box model for the study area.
- To advise DoE/TIDE on strategies for reducing pollutant input by coordinating with stakeholders (e.g. shrimp farm owners, farmers, municipal governments, etc.).

2. EXPERIMENTAL METHODS

2.1. Personnel involved in the study

Table 1 lists the persons involved in logistics, sample collection and analysis, their roles and responsibilities.

2.2. Site locations

Water samples were collected from coastal waters in southern Belize along eight transects (Figure 1). Coordinates of each sampling site are shown in Table 2. In order to obtain spatial resolution within the constraints of the project we decided to sample along transects parallel to the coastline starting from the mouths of all the rivers chosen for the study out to the areas containing coral reefs. Using a hand-held Global Positioning System unit, transects were laid out from each river mouth and sampling sites were chosen to make them as equi-distant as possible. Most worked out to 2.5 – 3 miles apart. Figure 1 indicates that it was not possible to always obtain nice transects parallel to the coast.or to run the transects all the way to the areas containing coral reefs. The most extreme case of this was with the Sarstoon River. Due to the distance of the coral reef areas from the coast it was not possible to run a transect all the way out there. Because of the maritime borders existing between Belize, Guatemala and Honduras it was necessary to run the transect so as not to violate any border. Rivers were chosen due to their characteristics.

- North Stann Creek River (NSC): Drains agricultural lands, serving as the main water source for citrus farms. NSC also flows through Dangriga, the major urban center in the Stann Creek District.
- Sittee River (SR): Drains agricultural lands, serving as a major source of water for citrus farms.
- South Stann Creek River (SSC): Drains some agricultural lands, though less extensive than NSC and SR; mainly citrus farms but including some banana farms.
- Mango Creek (MBC/MC): Drains agricultural lands, mainly banana farms.
- Monkey River (MR): Drains extensive agricultural lands, mainly banana farms. Over 60% of the banana plantations in southern Belize use as their only water source the Swasey and Bladden Rivers, which join to form Monkey River. These rivers are intensively used by the banana plantations for a variety of purposes including chemical preparation, irrigation and processing. There are also mango farms in this watershed.
- Golden Stream (GS): Drains protected areas. Its watershed has protected status as a biological corridor managed by Yax'che Conservation Group and TIDE. This river was chosen as representative of streams draining fairly pristine lands and thus to serve as a background site.

- Rio Grande (RG): Drains a mixture of mainly forest areas with some low impact agriculture such as small scale rice and citrus plantations and subsistence farming. A particular point of interest with this river is that it has a dump site only a couple miles from the river mouth. Punta Gorda Town (the main urban centre in the Toledo District) and neighboring communities dump all categories of waste in this site.

- Sarstoon River (SAR): Forms the boundary between Belize and Guatemala. On the Belize side there are mainly forests and some small-scale agriculture. On the Guatemala there is small-scale agriculture and cattle ranches.

2.3. Sampling methods

2.3.1. Sampling for pesticides

Water samples were collected in pre-cleaned stainless steel canisters from a small boat. Once a sampling site was identified by GPS the boat was positioned so as to face the direction of the current and the engine was turned off. A 5-gal stainless steel canister was then dipped into the water from the bow of the boat, ensuring that water was collected from the surface (to account for any surface-microlayer artifact) and from a depth of approximately 1 m. Once full, the canister was immediately pulled up, capped and stored in the shadiest portion of the boat. At each station a water probe was used to measure temperature, pH, and salinity.

Once on-shore, water for pesticide determination was filtered through glass fibre filters and XAD-2 resin as follows: Teflon-lined tubing from the stainless steel canister to the top of a stainless steel filter holder containing a 135-mm glass fibre filter; the same type of tubing was run from the bottom of the stainless steel filter holder to the top of a stainless steel tube containing XAD-2 resin; the same type of tubing was run to a peristaltic pump. The peristaltic pump pulled water through the assembly. The glass fibre filter is designed to trap particulate matter with any associated pesticides while the XAD-2 resin is designed to trap dissolved-phase pesticides. The filtration rate was set to 300 mL/min and was monitored frequently to adjust if needed to keep the rate as constant as possible, thus allowing the calculation of volume processed based on processing time. Samples collected from closer to shore often needed more than one glass fibre filter; in such cases all the filters used in a given site were combined.

The steel column with XAD-2 resin was prepared as follows just before processing each sample: a plug of clean glass wool was added at the bottom of the tube; distilled water was added until it reached a height of approximately 20 cm; XAD-2 resin was added until the slurry reached approximately 25 cm; another plug of glass wool was added and the top cover of the column was secured.

Once processed, the glass fibre filters were wrapped in solvent-cleaned Al foil, placed in a Ziploc bag and stored in a freezer until transported for analysis. The XAD-2 resin slurry was poured in small amber bottles with Teflon-lined lids and refrigerated until transported for analysis. Both were transported to USFSP for analysis in an ice-cooler with ice-packs.

2.3.2. Sampling for Metals

During the May-June, August and December sampling campaigns samples were collected to measure concentrations of mercury and lead. At each station a pre-cleaned and pre-acidified 250-mL plastic bottle was dipped quickly from the bow of the boat from the side opposite the one where the stainless steel canister was dipped. Ultrapure concentrated nitric acid was added drop-wise to the water to take the pH to ~1. Each bottle was immediately placed in an ice cooler with ice.

2.3.3. Sampling for glyphosate and paraquat

These herbicides are too polar to be sampled using the methodology detailed above. To sample for these herbicides we employed method-specific solid-phase extraction (SPE) cartridges. For paraquat we employed Ultraquat cartridges and for glyphosate we employed SAX (strong anion exchange), quaternary amine ion-exchange cartridges (both purchased from Restek). We had the Ultraquat cartridges custom-made to hold 1g of adsorbent.

For paraquat, we collected 2L of water in pre-cleaned PVC bottles (following recommendations of EPA method 549.2). Bottles were stored in an ice-chest until further processing on-shore. Once on-shore, the Ultraquat SPE cartridges were conditioned by passing 4 mL ultrapure acetonitrile followed by 4 mL of deionized water. 1L of water was then filtered per cartridge so that 2 cartridges were used per sampling site. Filtration at a 25 mL/min was done using a six-position manifold attached to a vacuum pump. Cartridges were wrapped in pre-cleaned aluminum foil and refrigerated.

For glyphosate sampling, we collected 1L of water in pre-cleaned PVC bottles. Bottles were stored in an ice-chest during sampling. On-shore, the SAX cartridges were conditioned by passing through 12 mL of a pH 6 solution made by diluting ultrapure nitric acid with HPLC-grade water to the required pH. 1L of sample water was then filtered through the cartridge at 5 mL/min using a six-position manifold attached to a vacuum pump. Cartridges were wrapped in pre-cleaned aluminum foil and refrigerated.

Once each sampling campaign was completed, SPE cartridges were transported to our laboratories in a cooler with ice packs for analysis.

2.3.4. Cleanup of Sampling Equipment and Material

Prior to each sampling campaign all equipment and reagents were thoroughly cleaned to prevent sampling artifacts.

Stainless steel canisters were thoroughly washed with soap and warm water, followed by dilute acidic solution and finally several rinses with Ultrapure water. Each canister was sealed and triple-wrapped in plastic bags. The plastic bottles for metal determination were washed

thoroughly with soap and warm water, rinsed several times with deionized water, then washed with an acidic solution made by diluting ultrapure nitric acid with deionized water.

The stainless steel filter holder and the stainless steel columns for XAD-2 resin were thoroughly washed with soap and warm water, rinsed with Ultrapure water followed with pesticide-grade acetone. They were wrapped in solvent-cleaned Al foil and placed in a stainless steel case.

Glass fibre filters were baked at 500 ^{o}C in an oven overnight, wrapped in solvent-cleaned Al foil and stored in Ziploc bags. XAD-2 resin was cleaned by sequential Soxhlet extractions as follows: 24-h extractions in pesticide-grade methanol, followed by acetone, hexane, and dichloromethane. This is followed by sequential 4-h Soxhlet extractions with hexane, followed by acetone, and finally methanol. The methanol was displaced by several rinses with Ultrapure water. Finally, the resin was stored in an amber bottle under Ultrapure water.

Amber bottles were washed with soap and warm water, rinsed with distilled water, soaked in an acid bath for 3 days, and finally baked in a furnace at 450 ^{o}C.

Glass wool was Soxhlet-extracted overnight with pesticide-grade dichloromethane followed by petroleum ether.

2.4. Analytical methods

2.4.1. Sources of chemicals

Solvents and reagents used were chromatographic or analytical quality. Solvents were pesticide-grade, Florisil (60-100 mesh), and granular anhydrous sodium sulfate were obtained from Fisher Scientific® (Pittsburgh, PA, U.S.A). Florisil (60-100 mesh, Fisher Scientific, Pittsburgh, PA, U.S.A.) Labeled surrogate chemicals and internal standard were atrazine (ethylamine-d5), [$^{13}C_6$]carbofuran, diazinon (diethyl-d10), malathion-d10 and [$^{13}C_{12}$]-PCB105 (internal standard), obtained from Cambridge Isotope Laboratories (Andover, MA, U.S.A.). Unlabeled standards were from AccuStandard (New Haven, CT, U.S.A.).

2.4.2. Extraction and cleanup of samples

XAD-2 resin and glass fibre filters were Soxhlet-extracted overnight (16-18 h) using 200 mL of 25% DCM/hexane. Resin and filters for each sample were extracted together since our objective in this project was to obtain overall concentrations of pesticides and not to determine partitioning between the dissolved and particulate phases. Extracts were concentrated using a rotary evaporator followed by a gentle stream of ultrapure nitrogen to a final volume of approximately 1 mL after solvent-exchanging into pure hexane.

The concentrated extract was subjected to column chromatography using Florisil. A column was prepared by placing a plug of pre-cleaned glass wool at the bottom of the column, adding 8 g of Florisil (pre-baked at 450 ^{o}C) deactivated with 200 µL distilled water and overlaying with 1 cm

pre-cleaned anhydrous sodium sulfate. The column was pre-eluted with 100 mL DCM followed by 100 mL hexane. The sample was placed on the top of the column and then eluted with 100 mL hexane followed by 100 mL 25% hexane/DCM and finally 100 mL DCM.

All fractions were concentrated and solvent-exchanged into isooctane using a rotary evaporator followed by a gentle stream of nitrogen. Final volumes were 1 mL.

Due to a lack of instrumentation available we had to contract out the samples for mercury and lead analysis. Samples were stored in a freezer until they were shipped in a cooler to a commercial laboratory for analysis.

For paraquat, an acidic solution for elution was prepared by diluting 1 mL of 85% phosphoric acid to 1L with deionized HPLC-grade water. 2 mL of this solution was added to each cartridge and allowed to soak into the adsorbent bed for ~ 1 min. Then 4 mL of the solution was passed through the cartridge slowly (dropwise) into glass test-tubes. All test-tubes were previously deactivated with dichlorodimethylsilane as per instructions on the reagent. The pH of the eluent was checked and if it was acidic it was neutralized with drops of concentrated ammonium hydroxide; then deionized HPLC-grade water was added to adjust the final volume to 5 mL. The extracts from the two cartridges per site were combined into one final extract. Extracts were shipped in a cooler to a commercial laboratory for analysis.

For glyphosate, a pH 5 solution was prepared using ultrapure nitric acid and deionized HPLC-grade water. 2 mL of the pH 5 solution was added to each cartridge and allowed to soak into the adsorbent bed for ~ 1min. Then 13 mL of the pH 5 solution was added and slowly (dropwise) passed through the cartridge and collected in silica-deactivated glass test-tubes. Extracts were shipped in a cooler to a commercial laboratory for analysis.

2.4.3. Quantitative analysis

Pesticides were analyzed in two groups. The first group consisted of acetochlor, cadusafos, atrazine, carbofuran, azoxystrobin, ethoprophos, fenamiphos, bitertanol, chlorpyrifos methyl, parathion and oxamyl. The second group consisted of dacthal, chlorpyrifos, diazinon, chlorothalonil, pendimethalin, azinphosmethyl, trifluralin, carbaryl, metribuzin, terbufos, dimethoate, phorate, simazine, alachlor, disulfuton, and malathion. The reason for carrying out the analysis in two groups was because a method was already in place for the second set of target pesticides from work done for another project. Thus, we decided to run the samples through that method first and then reanalyze them for the first set of target pesticides.

Analytical details for the first group are as follows: Instrument – Shimadzu; detector type – mass spectrometer, quadrapole type operated in electron impact mode; transfer line temperature – 290 ^{o}C; injection temperature – 250^{o}C; carrier gas – helium; injector type – split/splitless set at splitless mode; injection volume – 3uL; column – RTX-5MS from Restek – 15 meters long, 0.25um ID; detector settings – analyzing for ions 35 to 550; oven program - initially at 90 ^{o}C for 2.0 minutes, ramp 15 ^{o}C/minute to 250 ^{o}C, hold for 3.0 minutes; instrument was run in selective ion monitoring (SIM) mode to enhance sensitivity.

Analytical details for the second group are as follows: Instrument – Agilent 6890 GC – 5973; detector type – mass spectrometer, quadrapole type operated in electron capture negative ion mass spectrometry (GC-ECNI-MS); transfer line temperature – 250 ^{o}C; injection temperature – 250^{o}C; reagent gas – methane; injector type – split/splitless set at splitless mode; injection volume – 2uL; column – DB5 – 30 meters long, 0.25um ID; oven program -initially at 90 ^{o}C for 1.0 minute, ramp 20 ^{o}C/minute to 160 ^{o}C, ramp 2 ^{o}C/minute to 200 ^{o}C, ramp 20 ^{o}C/min and hold for 15 minutes; instrument was run in selective ion monitoring (SIM) mode to enhance sensitivity.

Injection standards for pesticides were prepared from stock standards of individual compounds, also from AccuStandard. Calibration plots were made from 5-7 dilutions. Samples were quantified vs. a [$^{13}C_{12}$]-PCB-105 internal standard for the first set of pesticides and vs. mirex as internal standard for the second set of pesticides using the linear regression algorithm provided by MSD Chemstation software in the former instance and by using average response factors derived from the standards in the latter instance.

We initially planned to carry out the analysis for paraquat and glyphosate ourselves but our instrument is not equipped with the appropriate detector, so we had to have those samples analyzed by a commercial laboratory. Both herbicides were measured by HPLC, using a photodiode array detector with an absorbance wavelength of 257 nm for paraquat and derivatization followed by fluorescence detection for glyphosate.

Due to a lack of instrumentation available we had to contract out the samples for mercury and lead analysis. Mercury and lead were measured in the water samples following EPA Method SW-846 and suitable procedures therein.

2.5. Data processing and statistical analysis

Chromatographic data for the first set of target pesticides were integrated manually. The raw chromatographic data were stored on the hard drive of the instrument and backed up on flashdrives. The integrated data was transferred to a spreadsheet with the best-fit equation obtained for the calibration curve for each target in order to obtain a quantity.

Chromatographic data for the second set of pesticides were integrated directly on the GC-MS using HP Chemstation software. The raw chromatographic data were stored on the hard drive of the instrument and backed up on flashdrives. Chemstation yielded pg amounts of the analytes in the sample extract, and these were transferred to analytical spreadsheets for further processing before the summary spreadsheets were prepared.

The spreadsheets are maintained on the laboratory computer hard drives and backed up on flashdrives. Each spreadsheet is dated so that updates can be tracked. The analytical spreadsheets contain:

- sample designation (number)

- ion ratio check status (within 20-30% of standards for quantitative analysis)
- uncorrected sample pg/ng amounts
- blank pg amounts and LOD calculation
- corrected pg/ng amounts (after blank adjustment, for samples exceeding LOD)
- surrogate pg amounts and percent recoveries

Quantities calculated via both methods were divided by the total volume of processed water to obtain final concentrations.

2.6. Sampling and analytical quality control

2.6.1. QC objectives

a) Sampling sites are representative of the local area.

b) Sampling protocol ensures no contamination of samples.

c) Sample integrity is maintained during storage and shipment.

d) Processing of samples is repeatable.

e) Blank values for sampling media and instrumental detection limits (IDLs) are below the level anticipated for samples.

f) Average analytical recoveries of added surrogate chemicals are 70% or better.

g) Positive identification of target chemicals during GC-MS analysis is achieved.

2.6.2. Sample collection and shipment

Selection of sampling sites (Section 2.2), collection of water samples (Section 2.3) and sample handling after collection (Section 2.3) are documented earlier.

2.6.3. Instrumental detection limits and blanks

Instrumental detection limits (IDLs) were estimated by injecting low concentrations of target analytes until a small peak at ~3:1 signal:noise ratio was obtained. These IDLs are expressed in pg/L.

Laboratory (n=4) and field (n=8) blanks were run. Field blanks consisted of XAD-2 resin added to the stainless-steel column used for water processing followed by pouring into a pre-cleaned glass bottle and glass fibre filters placed in the stainless-steel filter holder and then stored wrapped in solvent-rinsed Al foil in a refrigerator. Laboratory blanks consisted of the same but in the laboratory. No peaks for target pesticides were observed in blanks so only IDLs are reported.

2.6.4. Recovery of added surrogate compounds

Eight randomly-selected water samples in each sampling period (n=32 total) were spiked before filtering through XAD-2 resin and glass fibre filters with the labeled pesticides (atrazine (ethylamine-d5), [$^{13}C_6$]carbofuran, diazinon (diethyl-d10), malathion-d10). Mean recoveries ranged from 78% to 104% for the different compounds, with relative standard deviations from 6% to 22%. Sample concentrations were not adjusted for recoveries.

As part of our quality control, we spiked three PVC bottles containing HPLC-grade water with glyphosate and three with paraquat to make solutions of known concentrations. These were filtered through the appropriate cartridges and processed and extracted as normal samples. These solutions were also analyzed by the commercial laboratory to determine percent recovery. Results were unsatisfactory. For one paraquat and one glyphosate solution, percent recovery was in excess of 90%. However, for two paraquat solutions percent recoveries were below 25% and for two glyphosate solutions recoveries were in effect zero (results indicated below detection limits). We also had two solutions each of both herbicides of known concentrations prepared in HPLC-grade water analyzed by the commercial laboratory for quality control purposes. Percent difference between laboratory values and known concentrations were 56.2% for paraquat and 65.5% for glyphosate. Limits of detection reported by the contract laboratory were 0.003 ppm for paraquat and 0.010 ppm for glyphosate.

2.6.5. Identification of target analytes

Two criteria were used for identification, agreement of sample and standard retention times (within ±0.02 min) and ion ratios (IRs). Two ions were monitored for target analytes and one ion was monitored for labeled surrogates and the internal standard. Table 4 shows the target ions used in this study. Quantifying/qualifying IRs for target compounds were required to be within ±20% of standard IRs for a successful analysis. Compounds meeting this criterion were quantified using both ions and the mean result was taken. If agreement of sample and standard IRs was >20% but <30%, the compound was quantified using the ion giving the lower result. Agreement poorer than 30% was judged to be due to an interference and no quantitative result was calculated.

3. RESULTS AND DISCUSSION

3.1. Glyphosate and paraquat

Glyphosate and paraquat were below detection limits for all samples. This is despite that these two herbicides are by far the most heavily used in citrus and banana farms. There are two possible explanations for these results. First, both paraquat and glyphosate are known to degrade very quickly in the environment. By the time water that flows through farms reaches the coast it is possible that enough time has elapsed to degrade all of these herbicides. However, a second explanation is that the methodology employed in this study was not suitable for the extraction and measurement of glyphosate and paraquat. This is supported by the lack of satisfactory results

with regards to the samples and standards submitted to the contract laboratory for analysis. As discussed previously, recovery studies were poor and the results for the calibration solutions submitted were significantly different from the true values. As a result, we are unable to make definitive statements regarding the presence of these herbicides in coastal waters or any potential impact on offshore coral reefs. Further studies are certainly necessary in this area.
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3.2. Lead and Mercury

Tables 5 and 6 show the concentrations of lead and mercury, respectively measured during the May-June, August, and December sampling periods. Mercury levels were much lower than lead levels. Mercury levels were also fairly uniform, especially during the May-June and August sampling periods. In fact, during those sampling periods the levels of mercury were uniformly the same. This suggests that the source of the mercury being measured is natural and the levels represent background levels in the study area.

Lead levels showed some variation between transects and between sampling periods. In general, levels were higher during the May-June and August sampling periods and lower in December. This coincided with intense rainfall in Belize due to two tropical storms, which resulted in a 50-year flood event in May/June and with the rainy season in August. This suggests riverine input of lead as a major source, although atmospheric deposition cannot be ruled out. There are several unauthorized dumps in the study region where metallic objects are discarded in significant quantities. These may be the source of the lead in coastal waters, especially during intense rainfall and flooding as occurred during the May-June and August sampling periods. The point source hypothesis is supported by the higher values in river mouths of those rivers that are known to flow through populated areas with unregulated garbage dumps (e.g. NSC flows through Dangriga, SR flows through Sittee Village, MR flows through Monkey River Village, and SAR flows through many populated centers in Guatemala) compared with values at river mouths of rivers that do not.

3.3. Other Agricultural Pesticides

Of all the pesticides targeted in this study, the ones measured most frequently were trifluralin, chlorpyrifos, dacthal, chlorothalonil, atrazine, carbaryl, and oxamyl, and to a lesser extent chlorpyrifos methyl, parathion, fenamiphos, carbofuran, ethoprophos, acetochlor, diazinon, cadusafos, methyl parathion, and terbufos. Tables 7 – 10 show the concentrations of each pesticide at each station during the four sampling periods.

The results indicate that concentrations differed between sampling periods. In general, concentrations were higher during the August and May/June sampling periods and lower in December and February. We believe this is due in part to rainfall patterns in southern Belize. The February/March and May/June periods fall squarely during the dry season in Belize while the August period falls squarely during the rainy season in Belize. December varies somewhat but during 2008 there was little rainfall during the sampling days. A definite anomaly during 2008 was that during May-early June two tropical storms stalled over central and southern Belize, causing intense rainfall. This lead to a rarely-experienced episode of flooding, especially in

southern Belize where we sampled (a 50-year flood event). The result is that the May/June and August sampling periods occurred during times of intense rainfall and presumably increased runoff (actually flooding of rivers during the May/June sampling period) while the February/March and December sampling periods occurred during periods of no rainfall. As a result, it is not surprising that there should be increased runoff of pesticides from agricultural lands into coastal waters during the May/June and August periods.

The two most frequently measured pesticides were chlorpyrifos and trifluralin. Both are used extensively in the banana industries. In fact, the bases of banana trees and the hands of bananas on the trees are covered with a plastic device impregnated with chlorpyrifos. It is common practice to replace these often and simply discard remains into nearby streams. Previous studies in other regions of the world have indicated that these pesticides are persistent enough to be detected in surface waters quite readily. Chlorpyrifos levels ranged from bd – 1300 pg/L in February, 13 – 3625 pg/L in May, 13-12527 pg/L in August, and bd – 2182 pg/L in December. Excluding a few high values, trifluralin levels ranged from bd - 70 pg/L in February, bd – 13 pg/L in May, bd – 290 pg/L in August, and bd - 5 pg/L in December.

Chlorothalonil was frequently measured in August (range from bd – 14 pg/L) and, surprisingly, in February/March (range from bd – 29 pg/L), but rarely in May (range from bd – 38 pg/L) and December (range from bd – 25 pg/L). This may reflect usage patterns. This pesticide is applied more heavily during the early part of the year, probably accounting for its detection in February/March. Its presence in coastal waters in higher levels during August is likely due to increased runoff from soils into nearby streams.

Atrazine seems present in coastal waters year-round. It was detected very frequently during August (range from bd – 24 ng/L) and May/June (range from bd – 11 ng/L) and less frequently in December (range from bd – 10 ng/L). Unfortunately, due to analytical problems we do not have data for atrazine for the February/March period, but if the pattern holds it is probably present in coastal waters at that time. This is not surprising since atrazine is heavily used and previous studies have shown that its half-life in water is significant enough to persist for days or even weeks.

Dacthal is another heavily-used pesticide in southern Belize. It was detected frequently during the February/March (range from bd – 517 pg/L, with a couple of elevated concentrations), May/June (range from bd – 25 pg/L) and August (range from bd – 229 pg/L) sampling periods and infrequently during December (range from bd – 25 pg/L).

Oxamyl was detected frequently only during May/June (range from bd – 232 ng/L). Its presence may be due to the flooding events during this time. Carbaryl was measured at some stations during the three periods when it was analyzed for (excluding February/March), ranging from bd – 13 ng/L. Clorpyrifos methyl was detected frequently in August (range from bd – 9 ng/L) and infrequently in December (range bd – 9 ng/L). Ethoprophos and cadusafos were detected infrequently during May/June (range from bd – 0.055 ng/L and bd – 1.2 ng/L, respectively) and August (range from bd – 6 ng/L and bd – 18 ng/L, respectively). They were not detected in December and not measured in February/March. Terbufos was detected infrequently

and at low levels only during August (range bd – 10 ng/L); it was not targeted in February/March. Parathion was measured fairly frequently in August (range bd – 11 ng/L) and only rarely in December (range bd – 6 ng/L); it was not detected in May and not measured in February/March. Fenamiphos was also measured fairly frequently in August (range bd – 32 ng/L) and only rarely in May/June and December. Carbofuran was detected fairly frequently in August (range bd – 12 ng/L) and only rarely in May. Acetochlor was detected moderately frequently in August (range bd – 19 ng/L) and December (range bd – 21 ng/L) and only rarely and at much lower levels in May. Methyl parathion was detected only infrequently in August and December and diazinon was detected only in August (range bd – 15 ng/L).

Tables 7 – 10 indicate that some pesticides were present in much higher concentrations than others. Trifluralin, chlorpyrifos, dacthal, chlorothalonil were detected more frequently than other pesticides, but their levels were several orders of magnitude lower than other pesticides which were detected generally less frequently (e.g. atrazine, oxamyl, etc.). Thus, concentrations for the former are presented as pg/L while concentrations for the latter are presented as ng/L. These differences are due to the larger quantities of latter pesticides used as well as generally increased solubility (and thus susceptibility to surface runoff) of the latter group of pesticides.

Our results also indicate clearly that the circulation patterns in coastal waters of southern Belize result in mixing of the riverine plumes. Thus, stations along Golden Stream, which drains only protected areas with no agriculture along its watershed still had significant levels of pesticides compared with the other rivers. It is known that a southern current runs along the coast and this meets in the Gulf of Honduras a current from the Caribbean Sea which moves northward, creating an area of mixing along the study area. Thus, Tables 7 – 10 clearly indicate that in many cases there is no decreasing trend in pesticide concentrations as stations moved offshore, supporting the hypothesis that as waters are discharged from rivers into the coastal waters they undergo mixing, resulting in mixing of the pesticides being transported in the riverine plumes.

Our results indicate that at least some pesticides are persistent enough that they are transported offshore to waters overlying coral reefs. While this is not proof that pesticides necessarily have any adverse effect on the coral reefs it does point out for the need for more extensive studies to determine if this is indeed the case.

3.4. Comparison to other regions

Despite the intensive nature of pesticide usage in Central America, there has never been to our knowledge a systematic effort to determine the state of contamination of coastal waters with respect to these chemicals. A few studies have been carried out in the region, but they have focused primarily on streams near farms and within estuarine waters. Levels in these areas should be higher than those in coastal waters simply because of their closer proximity to source areas. A report from Kammerbauer and Moncada (1998) indicated that in the Choluteca River Basin of Honduras the most frequently organophosphate pesticides were chlorpyrifos, parathion and methyl parathion, while those detected less frequently were diazinon, dimethoate, malathion, terbufos and chlorothalonil. Concentrations of these pesticides were significant. For example, methyl parathion and parathion ranged from 20,000 – 100,000 ng/L while chlorpyrifos averaged

30,000 ng/L. A more recent study in Costa Rica (Castillo et al., 2006) measured levels of pesticides employed in banana farms in drainage canals at the farms and in streams close to the farms immediately after application. Among the pesticides measured most frequently were chlorpyrifos, terbufos, cadusafos and carbofuran. Average concentrations were: terbufos (40 ng/L), cadusafos (300 ng/L) and carbofuran (150 ng/L). The authors also reported that terbufos was still present in nearby streams and drainage canals 8 days after application and cadusafos after 15 days. This suggests that such pesticides are persistent enough to undergo transport to coastal areas and even offshore, as our results demonstrate.

Zulin et al. (2002) reported the presence of 19 organophosphate pesticides in the Jiulong River Estuary in China, with the five most frequently pesticides being methamidiphos, dichlorvos, malathion, omethoate and dimethoate. The concentrations of all pesticides ranged from 134.8 – 354.6 ng/L, levels similar in magnitude to many of the pesticides in our study. Other values for comparative purposes include: methyl parathion in streams in northern Germany at an average of 6,000 ng/L (Liess et al, 1999); malathion in estuarine waters in India at concentrations ranging from 1,373 – 13,013 ng/L (Sujatha et al., 1999); malathion in the Humber Estuary in the U.K. ranging from 1 – 9 ng/L (Zhou et al., 1999).

We include these numbers from streams and estuaries around the world to compare with our concentrations. The levels in rivers and estuaries are similar or much higher compared with those in coastal waters of Belize. The point is that our values are reasonable in this context since it should be expected that there will be dilution by the time pesticides are transported to the coast and farther offshore.

3.5. Development of a Box Model

One of the goals of this study was to develop a simple box model to account for pesticide input and output in the study region. Unfortunately, this is not possible at this time because critical parameters are unavailable. Even a simple box model would necessitate information on quantities being input via rivers, residence time of freshwater lenses in the study area, volume of freshwater lenses, concentrations of pesticides at the edge of the freshwater lens, and sedimentation/flocculation rates and quantities in the estuaries. As this study has progressed it has become painfully apparent that some of this information is simply not available, especially the volumes and residence times of the freshwater lens in the study region and the sedimentation rates. Thus, we have instead attempted to get an admittedly crude first estimate of the quantities of the main pesticides detected being discharged into coastal waters of southern Belize. This first approximation will at a minimum provide a good indication of the extent of the problem of coastal waters contamination due to some agricultural pesticides. It is also apparent that further studies are needed in the area to determine some of the missing parameters that will allow the creation of a box model or even a more sophisticated model for the study region.

Flow and discharge measurements are available from the National Meteorological Service of Belize for four of the rivers in our study. Discharge rates were as follows: NSC (35.4 m^3s^{-1}), SR (23.9 $m^3 s^{-1}$), MR (40 $m^3 s^{-1}$), and RG (24 $m^3 s^{-1}$). These rates can be translated to annual discharge volumes of: NSC (1.116 x 10^{12} L/yr), SR (7.537 x 10^{11} L/yr), MR (1.261 x 10^{12} L/yr),

and RG (7.569 x 10^{11} L/yr). Multiplying discharge volumes by concentrations measured at the river mouths should provide an estimate of annual loading of pesticides in the area. This is an admittedly crude method since the concentrations of given pesticides at specific rivers vary between sampling periods. As a first estimate we will use the highest and lowest (excluding "below detection") values to get a range of possible discharges. Employing this methodology results in the following quantities discharged annually:

- NSC: trifluralin (9.2 g – 324 g), chlorpyrifos (127 g – 4.4 kg), dacthal (5.5 g – 99 g), chlorothalonil (9.2 g), atrazine (11.9 kg – 17.5 kg), carbaryl (5 kg – 7.3 kg), oxamyl (126 kg)
- SR: trifluralin (1.5 g – 17 g), chlorpyrifos (105 g – 1.6 kg), dacthal (3.1 g – 36 g), chlorothalonil (12.5 g – 18.9 g), atrazine (4.1 kg – 8.7 kg), oxamyl (38 kg)
- MR: trifluralin (5.9 g – 17.4 g), chlorpyrifos (224 g – 4.1 kg), dacthal (9.1 g – 40.4 g), chlorothalonil (2.2 g – 36.4 g), atrazine (6.6 kg – 19.2 kg), carbaryl (8.2 kg – 10.6 kg), oxamyl (12 kg – 107 kg)
- RG: trifluralin (4.8 g), chlorpyrifos (280 g – 5.6 kg), dacthal (4.3 g – 67.4 g), atrazine (5.4 kg – 8.7 kg), oxamyl (57 kg)

These numbers are likely to be under-estimates since discharge volumes used are likely to be under-estimated. The reason for this hypothesis is because the discharge data is dated and most likely incorrect. This is supported by a report from Thiatta et al. (2003) who, among other things, estimated discharge volumes in the "Inner Gulf of Honduras," an area encompassing our study area along with large parts of Guatemala and Honduras. The authors point out that there is no consistent gauging of riverine discharge in the area. They used an empirical water balance model using annual precipitation and temperature data to calculate annual discharge values. Their model indicated that in the total region they studied total annual discharge into the coastal waters was approximately 1232 m^3 s^{-1}. Even accounting for the fact that the larger rivers in Guatemala and Honduras (e.g. Uloa, Motague, Polochich) dominate discharge into the region, it is unlikely that the rivers in Belize would account for 10% or less of this discharge (as would be indicated by the numbers we have used). The discharges are likely higher, as would be the quantities of pesticides discharged into the study region. Nonetheless, as a first estimate our numbers serve to highlight that at least for some pesticides significant quantities of pesticides are being discharged into coastal waters of Belize (e.g. chlorpyrifos, atrazine, oxamyl). This, coupled with their transport offshore even to areas with coral reefs highlights the need for a more extensive study.

3.6. Evaluating results as related to goals

Reproduced below is the table included in the original proposal indicating the Project Outcomes and their corresponding Products. We have added a third column indicating how successful we have been in delivering each product.

1 Project Outcome	2 Product	3 Outcome
1. Major types of pollutants and their levels identified in coastal	A report documenting comprehensively the types and	Completed

waters of southern Belize, including those with coral reefs.	levels of pollutants in the study area.	
2. Major sources of pollutants to coastal waters of southern Belize and its coral reefs identified.	An analysis report of product 1 to develop conclusions regarding most significant sources of pollutants to the study area.	Completed
3. Preliminary box model for pollutants in the study area developed.	Simple box model for given pollutants produced.	Not completed (see discussion above)
4. Recommendations to DoE and TIDE on strategies for reducing pollutant input.	(i) A report of recommendations to DoE and TIDE on best strategies to reduce pollution of coastal southern Belize from land-based sources, and (ii) a summary report on workshop with relevant stakeholders to jointly develop best management practices in pertinent industries.	(i) Report completed. (ii) Not completed (see discussion below)
5. Capacity-building in Belize.	(i) Training manual on field sampling techniques for organic and metal pollutants in surface waters to be used by local collaborators and (ii) training summary report for trained technician.	(i) Trained 3 staff members of TIDE and the Belize Fisheries Department. Training manual completed. (ii) Not accomplished. Due to serious instrumentation problems during this project (as well as limited funds) we could not schedule training time for any technician.
6. Involvement of stakeholders in best management practices to protect the environment.	Workshop(s) to share results and seek input on best management practices.	See #4(ii) above
7. Increased monitoring and scientific capacity in Belize	Formal agreements with TIDE and DoE to offer our laboratories at USF for any future analytical needs for which we have capabilities.	Only informal ties set up. We hope to obtain funding in the future for formal ventures.

Overall, we have achieved most of the objectives we set out to accomplish. We have identified the major pesticides that are contaminating the coastal waters of southern Belize and proven that they are the same ones used in the citrus and banana farms (indicating source). We have measured levels of total mercury and lead in coastal waters of southern Belize and shown that mercury is likely due to natural sources while lead has point sources. We have completed

this report to detail these findings. We have also completed a preliminary report to TIDE and DoE indicating results and some recommendations. We trained three good staff members of TIDE and the Belize Fisheries Department on techniques for sampling for metals and pesticides. The two major Products we have been unable to deliver are the box model for the study region and a workshop with relevant stakeholders. The latter is simply due to the political dynamics on the ground. We are prepared to make a presentation to relevant stakeholders. However, the two major stakeholders would be the Banana Growers Association and Citrus Growers Association in Belize. For some months there has been a serious conflict at the managerial level in the latter association (many of whose members also belong to the former) and our workshop is not a priority until that conflict is resolved. We have been in touch with relevant people and are sure that in the near future we will be able to have a workshop to detail our results. The box model cannot be completed for valid reasons detailed previously. In numerical terms, we have delivered products #1,2, 4(i), 5(i); we will complete 4(ii), 6 once the political dynamics permit it (we are in the position now to complete these products but the situation is beyond our control); we only were unable to deliver on #3 and #5(ii). We believe, therefore, that this project has been quite successful and should serve as a basis for further work in the region.

4. CONCLUSIONS

Several pesticides that are known to be used in the banana and citrus industries were measured in coastal waters of southern Belize. These included some that were measured frequently (i.e. in all or most sampling stations) and in all four sampling periods (e.g. chlorpyrifos), some frequently in some sampling periods (e.g. trifluralin, dacthal, chlorothalonil, atrazine, oxamyl, parathion, and cadusafos), and others which were occasionally measured (e.g. malathion, malathion, etc.)

Some pesticides were consistently measured in higher levels than others. For example, chlorpyrifos, dacthal, chlorothalonil and trifluralin were present in pg/L quantities while atrazine, oxamyl, carbaryl, etc. were measured in ng/L quantities.

Results indicate that once discharged into coastal areas pesticides undergo mixing due to dominating circulation patterns in the area. They also indicate that some pesticides are being transported offshore into waters with coral reefs.

Mercury and lead were also measured in the study area. Mercury was present in uniformly lowere concentrations than lead. The uniform levels of mercury suggests that its presence is due to natural input from the region. Concentrations of lead, on the other hand, varied between sampling periods and between rivers. Concentrations of lead were lower in December compared with May/June and August, suggesting greater input during periods of rainfall and increased riverine discharge. In addition, concentrations at the beginning of each transect (i.e. at the river mouths) were higher in those rivers that are known to traverse populated areas with known problems of unregulated garbage dumps. Thus, levels were consistently higher in NSC, SR, MR and SAR compared to the other rivers.

5. RECOMMENDATIONS

This study has provided baseline data on concentrations of pesticides and lead and mercury in coastal waters of southern Belize. However, a more extensive study is needed in order to obtain better spatial coverage. Expanded coverage is needed to characterize the spatial variability and identify "hot spots" that may be in need of action by protection organizations and concerned stakeholders. The following recommendations are suggested in light of these initial studies.

- A larger study should be carried to obtain both more extensive coverage and more spatial resolution of the area.
- Any future study should also include documentation of pesticide levels in sediments in estuarine areas to determine the extent to which pesticides may be removed by sedimentation.
- Future studies should document levels of pesticides in organisms in the study area, perhaps even in corals.
- Banana and citrus farmers should be trained on ways to minimize pesticide runoff into nearby streams and the coastal areas.
- Utilizing local personnel in more extensive studies would be beneficial. This would allow more extensive and intensive work and would also train local personnel on this type of monitoring studies. The local universities would be ideal for this purpose.

7. ACKNOWLEDGMENTS

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9. TABLES

Table 1. Personnel involved in the study		
Person	**Institution**	**Roles and responsibilities**
Dr. Henry Alegria halegria@mail.usf.edu	ESPG University of South Florida St Petersburg, FL	Principal investigator. Responsible for overall project direction and outcome. Laboratory for analysis of pesticides.
Dr. Kathy Carvalho-Knighton carvalho@mail.usf.edu	ESPG Univ of South Florida St Petersburg, FL	Assisted with project planning.
Mr. Victor Alegria valegria09@yahoo.com	ESPG Univ of South Florida St Petersburg, FL	Primary responsibility for sampling and analysis of pesticides, preparation and shipping of sampling media to field sites.
Mr. Joseph Villafranco	TIDE	Assisted with logistics of field sampling.
Mr. Juan Chub	TIDE/Fisheries Department Belize	Assisted with sampling and processing of samples.
Mr. Marlon Williams	TIDE	Assisted with sampling and processing of samples.
Mr. Isani Chan	Fisheries Department Belize	Assisted with sampling and processing of water, packaging and shipping samples.
Mr. Luke Talalaj	ESPG Univ of South Florida St Petersburg, FL	Assisted with analysis of samples.
Ms. Vaiva Gustainyte	ESPG Univ of South Florida St Petersburg	Undergraduate student assisted with sample extraction and analysis.

Table 2. Sampling sites coordinates

Site Name	Latitude	Longitude		Site Name	Latitude	Longitude
NSC 1	16 58 116	088 13 258		MR 1	16 21 922	088 29 143
NSC 2	16 58 146	088 10 512		MR 2	16 21 733	088 26 430
NSC 3	16 57 891	088 07 772		MR 3	16 21 347	088 23 741
NSC 4	16 57 641	088 05 032		MR 4	16 21 376	088 21 015
NSC 5	16 57 474	088 02 771		MR 5	16 21 594	088 18 296
SR 1	16 48 519	088 15 417		GS 1	16 13 513	088 44 053
SR 2	16 48 646	088 12 727		GS 2	16 13 494	088 41 338
SR 3	16 48 752	088 10 041		GS 3	16 13 420	088 38 600
SR 4	16 48 701	088 07 292		GS 4	16 13 048	088 35 910
SR 5	16 48 560	088 04 978		GS 5	16 12 733	088 33 210
SSC 1	16 43 427	088 18 067		RG 1	16 08 535	088 45 551
SSC 2	16 43 219	088 15 316		RG 2	16 08 355	088 42 799
SSC 3	16 43 173	088 12 578		RG 3	16 08 290	088 40 513
SSC 4	16 42 878	088 09 838		RG 4	16 08 173	088 38 253
SSC 5	16 42 478	088 07 114		RG 5	16 08 157	088 35 969
MC 1	16 32 865	088 24 666				
MC 2	16 32 369	088 23 714		SAR 1	15 53 668	088 54 951
BC 3	16 30 664	088 24 039		SAR 2	15 55 398	088 52 885
MBC 4	16 29 884	088 21 413		SAR 3	15 57 517	088 51 214
MBC 5	16 29 646	088 18 629		SAR 4	15 59 197	088 49 137
MBC 6	16 28 854	088 13 238		SAR 5	16 00 581	088 46 842

Table 3. Instrument Detection Limits (IDLs)

Pesticide	IDL (pg/L)
Phorate	2
Simazine	10.4
Atrazine	2.1
Diazinon	2.14
Alachlor	2.04
Metolachlor	0.35
Disulfuton	10
Terbufos	3.36
Trifluralin	0.16
Dimethoate	52
Chlorothalonil	0.81
Dacthal	1.04
Metribuzin	1.02
Malathion	1.06
Chlorpyrifos	1.001
Chlorpyrifos methyl	33.6
Acetochlor	125.6
Carbofuran	134
Oxamyl	145
Ethoprophos	156
Cadusafos	75
Parathion	89
Fenamiphos	156
Carbaryl	178

Table 4. Target ions used in quantifying pesticides

Pesticide	Ions
Phorate	75, 121
Simazine	201, 186
Atrazine	200, 215
Diazinon	179, 137
Alachlor	160, 188
Metolachlor	162, 238
Disulfuton	88, 89
Terbufos	57, 231
Trifluralin	335, 336
Dimethoate	157, 159
Chlorothalonil	266, 264
Dacthal	332, 330
Metribuzin	198, 199
Malathion	157, 172
Chlorpyrifos	313, 315
Chlorpyrifos methyl	125, 286
Acetochlor	146, 162
Carbofuran	164, 149
Oxamyl	72
Ethoprophos	158
Cadusafos	159
Parathion	139
Fenamiphos	154
Carbaryl	144, 115
mirex	404

Table 5. Concentrations of mercury (ppm)

	May-June	August	December
NSC1	0.001	0.001	0.002
NSC2	0.001	0.001	0.008
NSC3	0.001	0.001	0.007
NSC4	0.001	0.001	na
NSC5	0.001	0.001	0.006
SR1	0.001	0.001	0.004
SR2	0.001	0.001	0.006
SR3	0.001	0.001	0.007
SR4	0.001	0.001	0.007
SR5	0.001	0.001	0.006
SSC1	0.001	0.001	0.002
SSC2	0.001	0.001	0.005
SSC3	0.001	0.001	0.005
SSC4	0.001	0.001	0.004
SSC5	0.001	0.001	0.004
MC1	0.001	0.001	0.006
MBC2	0.001	0.001	0.005
MBC3	0.001	0.001	0.006
MBC4	0.001	0.001	0.005
MBC5	0.001	0.001	0.006
MBC6	0.001	0.001	0.004
MR1	0.001	0.001	0.002
MR2	0.001	0.001	0.003
MR3	0.001	0.001	0.005
MR4	0.001	0.001	0.004
MR5	0.001	0.001	0.005
GS1	0.001	0.001	0.006
GS2	0.001	0.001	0.005
GS3	0.001	0.001	0.006
GS4	0.001	0.001	0.004
GS5	0.001	0.001	0.005
RG1	0.001	0.001	0.003
RG2	0.001	0.001	0.006
RG3	0.001	0.001	0.003
RG4	0.001	0.001	0.004
RG5	0.001	0.001	0.006
SAR1	0.001	0.001	0.006
SAR2	0.001	0.001	0.007
SAR3	0.001	0.001	0.005
SAR4	0.001	0.001	0.006
SAR5	0.001	0.001	0.007

Table 6. Concentrations of lead (ppm)

	May-June	August	December
NSC1	0.080	0.200	0.002
NSC2	0.080	0.156	0.059
NSC3	0.068	0.130	0.083
NSC4	0.056	0.055	na
NSC5	0.043	0.010	0.071
SR1	0.140	0.200	0.310
SR2	0.130	0.223	0.067
SR3	0.255	0.200	0.050
SR4	0.134	0.114	0.069
SR5	0.154	0.160	0.068
SSC1	0.150	0.180	0.002
SSC2	0.130	0.211	0.053
SSC3	0.125	0.190	0.053
SSC4	0.111	0.076	0.055
SSC5	0.145	0.180	0.045
MC1	0.130	0.028	0.034
MBC2	0.098	0.050	0.061
MBC3	0.046	0.125	0.033
MBC4	0.080	0.238	0.057
MBC5	0.050	0.160	0.052
MBC6	0.032	0.200	0.062
MR1	0.190	0.180	0.087
MR2	0.130	0.093	0.064
MR3	0.100	0.180	0.047
MR4	0.113	0.139	0.059
MR5	0.087	0.180	0.064
GS1	0.140	0.120	0.031
GS2	0.140	0.276	0.081
GS3	0.110	0.120	0.046
GS4	0.123	0.234	0.069
GS5	0.079	0.120	0.077
RG1	0.090	0.210	0.002
RG2	0.080	0.134	0.056
RG3	0.070	0.140	0.022
RG4	0.043	0.187	0.028
RG5	0.040	0.110	0.066
SAR1	0.140	0.010	0.350
SAR2	0.120	0.222	0.042
SAR3	0.090	0.120	0.061
SAR4	0.058	0.098	0.054
SAR5	0.002	0.180	0.068

Table 7. Concentrations of pesticides in February/March 2008 (pg/L)

	Trifluralin	Chlorothalonil	Dacthal	Malathion	Chlorpyrifos
NSC1	33.97	23.77	4.93	272.42	113.75
NSC2	27.14	bd	43.84	bd	165.80
NSC3	58.54	16.53	220.27	89.87	108.80
NSC4	4.55	18.40	2.72	bd	10.76
NSC5	3.38	7.08	11.60	bd	37.70
SR1	5.73	6.29	1.84	bd	35.52
SR2	4.76	6.63	7.44	bd	35.21
SR3	5.59	9.13	9.45	bd	218.97
SR4	21.24	1.70	40.54	bd	32.80
SR5	4.32	4.39	1.85	bd	31.22
SSC1	2.84	16.56	4.87	bd	516.12
SSC2	758.96	10.33	1669.74	133.81	255.25
SSC3	4.98	5.88	14.02	bd	59.84
SSC4	4.61	10.96	11.12	bd	38.75
SSC5	5.72	21.14	12.91	bd	514.66
MC1	bd	13.55	10.37	bd	57.85
MBC2	7.28	7.66	19.87	234.79	457.60
MBC3	2481.66	bd	239760.78	316.64	36.64
MBC4	12.02	11.11	15.20	bd	50.12
MBC5	15.91	bd	28.51	bd	39.85
MBC6	bd	bd	bd	bd	bd
MR1	4.64	28.90	32.03	bd	846.32
MR2	14.37	25.12	380.18	222.21	654.42
MR3	4.30	15.26	5.01	bd	178.74
MR4	3.46	23.78	1.77	bd	207.66
MR5	bd	bd	bd	bd	bd
GS1	bd	bd	bd	bd	bd
GS2	16.64	14.02	50.55	bd	45.45
GS3	5.45	8.01	3.85	bd	1303.80
GS4	12.15	bd	45.84	bd	262.74
GS5	5.14	8.38	9.75	bd	97.36
RG1	7.02	bd	15.57	bd	117.87
RG2	27.68	11.32	62.32	bd	59.34
RG3	3.84	6.97	1.24	bd	13.36
RG4	6.83	bd	28.91	bd	55.71
RG5	bd	bd	bd	bd	bd
SAR1	5.45	10.33	2.74	bd	694.53
SAR2	17.06	22.24	43.51	bd	1118.35
SAR3	70.29	19.89	516.88	bd	825.22
SAR4	12.69	16.47	35.43	bd	35.81
SAR5	4.38	6.11	6.10	bd	54.79

Table 8a. Concentrations of pesticides in May/June 2008 (pg/L)

	trifluralin	chlorothalonil	dacthal	malathion	chlorpyrifos
NSC1	8.24	23.78	6.28	bd	732.54
NSC2	6.55	bd	0.75	bd	633.82
NSC3	7.58	bd	6.52	bd	421.20
NSC4	5.88	bd	bd	bd	112.35
NSC5	6.06	bd	16.77	bd	217.12
SR1	3.41	bd	3.69	bd	2782.33
SR2	5.43	bd	11.98	bd	1469.58
SR3	2.89	bd	4.26	bd	531.25
SR4	bd	bd	9.28	bd	529.88
SR5	3.05	4.15	4.70	bd	281.93
SSC1	6.07	bd	4.11	bd	139.57
SSC2	4.91	bd	5.74	bd	103.79
SSC3	4.30	bd	10.49	bd	23.98
SSC4	2.65	3.89	7.20	bd	30.65
SSC5	1.86	1.28	2.20	bd	12.98
MC1	2.12	9.01	14.59	bd	300.48
MBC2	bd	bd	1.22	bd	68.19
MBC3	3.74	bd	22.40	66.23	1300.82
MBC4	bd	bd	bd	bd	124.77
MBC5	6.65	15.59	12.39	bd	758.97
MBC6	6.11	bd	12.98	52.30	296.17
MR1	11.02	bd	7.25	bd	3222.98
MR2	1.65	8.82	1.60	bd	164.03
MR3	2.98	bd	4.98	bd	131.42
MR4	5.56	bd	7.09	bd	528.14
MR5	12.96	bd	bd	bd	2491.83
GS1	6.28	bd	5.67	bd	746.14
GS2	1.31	bd	11.69	bd	120.04
GS3	12.72	bd	8.80	bd	939.05
GS4	bd	bd	3.19	bd	130.62
GS5	**9.23**	12.34	7.76	bd	2475.22
RG1	5.98	bd	4.35	461.58	1538.10
RG2	4.62	12.45	24.93	56.67	574.54
RG3	6.09	bd	4.03	68.87	233.61
RG4	2.75	38.03	bd	bd	3625.42
RG5	4.18	bd	1.02	24.08	20.42
SAR1	bd	bd	9.96	bd	91.05
SAR2	bd	bd	19.21	199.62	1103.60
SAR3	6.27	1.53	5.89	bd	198.64
SAR4	bd	bd	2.71	bd	126.57
SAR5	9.10	bd	15.95	37.99	149.24

Table 8b. Concentrations of pesticides in May/June 2008 (ng/L)

	atrazine	carbaryl	oxamyl	ethoprophos	cadusafos	fenamiphos	carbofuran	acetochlor
NSC1	10.665	4.445	113.0	bd	0.507	bd	bd	0.003
NSC2	5.765	3.678	87.2	bd	bd	bd	bd	bd
NSC3	8.166	5.221	57.0	bd	bd	bd	bd	bd
NSC4	4.322	bd	35.0	bd	bd	bd	bd	bd
NSC5	3.445	bd	22.0	bd	bd	bd	bd	bd
SR1	6.443	3.221	231.2	bd	0.171	0.015	bd	0.002
SR2	6.778	3.112	165.1	bd	0.123	bd	bd	bd
SR3	4.212	bd	89.0	bd	0.057	bd	bd	bd
SR4	bd	2.677	50.8	bd	0.023	bd	bd	bd
SR5	1.211	2.443	24.3	bd	0.043	bd	bd	bd
SSC1	5.445	bd	50.4	0.055	0.392	bd	0.005	0.003
SSC2	5.111	bd	22.2	0.014	0.286	bd	bd	bd
SSC3	bd	4.334	bd	0.004	0.223	bd	bd	bd
SSC4	6.332	5.776	bd	bd	0.046	bd	bd	bd
SSC5	1.212	bd	bd	bd	0.063	bd	bd	bd
MC1	9.005	bd	187.9	0.005	0.087	bd	bd	bd
MBC2	8.789	4.987	34.7	bd	0.045	bd	bd	bd
MBC3	10.055	6.789	158.2	0.003	0.272	bd	bd	bd
MBC4	3.334	1.112	13.9	0.003	0.08	bd	bd	bd
MBC5	3.123	1.223	9.2	0.004	bd	bd	bd	bd
MBC6	bd	2.223	bd	bd	bd	bd	bd	bd
MR1	5.234	8.443	84.7	0.013	0.821	0.073	bd	0.01
MR2	bd	2.987	66.0	0.009	1.234	bd	bd	bd
MR3	4.223	3.442	44.6	0.008	0.675	bd	bd	bd
MR4	6.123	2.112	22.8	0.002	0.022	bd	bd	bd
MR5	1.456	bd	9.9	0.004	0.087	bd	bd	bd
GS1	7.123	bd	74.9	0.009	0.152	bd	0.018	bd
GS2	7.998	2.111	94.3	0.012	0.088	bd	bd	bd
GS3	9.23	3.223	109.6	0.007	0.155	bd	0.014	0.021
GS4	4.665	1.445	6.4	bd	0.165	bd	bd	bd
GS5	3.786	bd	11.0	bd	0.311	bd	bd	0.013
RG1	5.344	4.332	27.0	0.008	0.17	0.055	bd	bd
RG2	4.887	2.334	bd	0.008	bd	bd	bd	bd
RG3	bd	4.876	24.0	0.004	0.046	bd	bd	bd
RG4	bd	6.876	16.2	bd	bd	bd	bd	bd
RG5	3.445	1.321	8.0	bd	bd	bd	bd	bd
SAR1	bd	bd	175.5	0.005	bd	bd	0.007	bd
SAR2	bd	bd	124.0	bd	bd	bd	bd	bd
SAR3	3.678	bd	53.9	bd	bd	bd	bd	bd
SAR4	5.334	bd	bd	bd	bd	bd	bd	bd
SAR5	4.345	5.887	73.1	bd	0.117	bd	bd	bd

Table 9a. Concentrations of pesticides in August 2008 (pg/L)

	trifluralin	hlorothalonil	dacthal	malathion	hlorpyrifos
NSC1	290.545	bd	88.864	1125.729	3955.013
NSC2	184.327	14.339	229.354	bd	1624.251
NSC3	148.122	4.642	101.462	588231.412	6548.232
NSC4	bd	bd	43.776	bd	1243.500
NSC5	1.268	bd	13.334	bd	2467.357
SR1	28.384	0.864	14.691	bd	2094.244
SR2	11.384	bd	15.345	bd	1834.231
SR3	34.646	2.926	7.241	1175.235	557.311
SR4	3.869	bd	5.704	bd	181.447
SR5	1.753	bd	8.884	bd	290.877
SSC1	22.445	bd	47.765	bd	278.847
SSC2	14.102	bd	28.149	bd	15.482
SSC3	16.433	bd	24.000	bd	51.266
SSC4	9.762	bd	26.600	bd	191.176
SSC5	6.756	bd	1.800	bd	45.221
MC1	2.812	bd	2.355	bd	417.541
MBC2	7.857	bd	8.477	bd	490.142
MBC3	21.107	bd	6.845	bd	453.665
MBC4	6.554	bd	4.999	bd	34.197
MBC5	18.876	bd	7.076	bd	580.853
MBC6	12.222	bd	bd	bd	18.327
MR1	13.796	1.784	8.767	bd	177.801
MR2	16.709	bd	34.466	bd	119.740
MR3	22.569	bd	18.269	bd	882.672
MR4	9.023	bd	12.333	bd	70.085
MR5	8.596	bd	19.728	bd	30.254
GS1	bd	bd	89.000	bd	370.076
GS2	bd	1.697	35.715	bd	5534.212
GS3	12.000	bd	23.300	bd	1499.202
GS4	6.773	bd	8.979	bd	442.173
GS5	19.198	bd	85.638	bd	3919.452
RG1	21.106	bd	141.132	2274.229	10772.003
RG2	bd	bd	bd	bd	501.537
RG3	bd	bd	11.389	bd	883.554
RG4	bd	bd	68.656	bd	12527.102
RG5	12.191	bd	118.161	997.237	3993.066
SAR1	bd	bd	181.017	1412.163	601.007
SAR2	14.303	bd	7.569	bd	2840.529
SAR3	14.584	bd	190.921	bd	5494.317
SAR4	25.095	bd	40.081	1152.268	5031.882
SAR5	8.876	4.716	31.591	1062.198	2011.799

Table 9b. Concentrations of pesticides in August 2008 (ng/L)

	atrazine	carbaryl	oxamyl	thoprophos	cadusafos	terbufos	chlorp me	parathion	enamiphos	arbofuran	cetochlor	diazinon	me para
NSC1	15.68	6.508	34.113	bd	5.782	bd	5.643	bd	10.155	6.292	bd	4.959	bd
NSC2	9.742	bd	41.114	bd	5.419	bd	2.864	5.545	10.322	bd	bd	5.14	bd
NSC3	8.166	6.491	31.404	bd	5.425	4.78	bd	bd	30.291	bd	12.497	bd	bd
NSC4	6.999	bd		bd	bd	bd	bd	bd	bd	bd	bd	bd	bd
NSC5	bd	6.468	33.386	5.278	5.413	bd	5.641	bd	10.116	bd	14.55	bd	2.982
SR1	10.411	6.483	18.464	bd	11.209	bd	3.039	5.526	bd	bd	5.782	bd	2.982
SR2	11.596	bd	14.415	5.509	5.605	bd	2.827	5.666	10.15	bd	bd	5.026	bd
SR3	5.878	6.494	8.739	bd	bd	bd	2.902	5.53	bd	6.264	5.367	4.972	2.978
SR4	15.147	6.537	18.076	bd	bd	9.764	5.721	5.621	10.133	6.325	bd	4.998	bd
SR5	5.717	12.987	9.198	5.34	5.938	4.793	8.592	5.503	bd	6.266	bd	4.987	2.977
SSC1	11.571	bd		bd	5.546	bd	2.813	bd	10.056	6.324	5.368	9.95	bd
SSC2	5.905	bd		bd	bd	bd	bd	5.591	10.055	bd	bd	5.077	2.974
SSC3	bd	bd	11.374	bd	bd	bd	5.647	5.614	20.089	6.281	bd	5.006	bd
SSC4	6.117	12.953	18.806	5.815	bd	bd	5.693	5.572	10.096	bd	5.414	bd	2.973
SSC5	24.052	13.137	9.816	bd	5.521	bd	bd	bd	bd	6.252	bd	bd	2.972
MC1	11.768	bd	13.087	5.31		4.776	2.988	5.578	20.151	bd	bd	4.967	bd
MBC2	bd	14.632	25.818	bd	5.414	9.608	2.947	bd	bd	bd	18.875	bd	6.032
MBC3	5.702	6.469	32.343	5.283	17.903	bd	2.867	5.547	20.036	12.628	5.44	bd	2.983
MBC4	12.388	bd	10.764	5.698	bd	4.775	5.881	bd	bd	bd	10.73	bd	8.941
MBC5	5.691	bd	22.975	bd	5.734	bd	2.847	5.601	bd	bd	bd	bd	bd
MBC6	17.359	bd	9.62	bd	5.421	4.773	2.949	5.575	20.372	bd	bd	bd	bd
MR1	15.257	6.482	8.409	bd	bd	bd	bd	5.515	bd	bd	bd	5.115	bd
MR2	bd	bd	11.145	5.185	10.832	bd	2.807	bd	10.06	bd	bd	bd	5.955
MR3	11.401	6.479	22.932	5.38	bd	bd	bd	bd	20.244	6.272	5.378	5.115	bd
MR4	11.462	bd		5.201	bd	4.774	2.847	5.601	bd	6.234	bd	bd	2.971
MR5	6.412	bd	35.78	bd	5.998	4.778	2.927	11.221	bd	6.267	5.346	bd	2.97
GS1	11.502	bd	10.362	bd	bd	bd	bd	bd	10.193	bd	5.592	bd	2.974
GS2	14.485	bd	30.163	5.293	5.516	4.781	2.978	bd	bd	bd	bd	5.17	bd
GS3	11.642	12.982	17.411	bd	bd	bd	bd	11.103	10.025	bd	5.425	15.06	2.975
GS4	11.39	bd	8.452	5.332	bd	bd	2.829	5.533	10.374	bd	bd	bd	2.98
GS5	11.505	bd	12.795	bd	5.508	4.815	3.252	5.551	10.064	bd	5.533	bd	2.975
RG1	5.981	12.994	10.497	5.393	bd	4.784	2.879	bd	bd	bd	bd	bd	bd
RG2	bd	bd	12.904	bd	11.068	4.883	5.635	5.601	20.595	bd	bd	4.969	bd
RG3	bd	6.491	29.773	bd	bd	bd	2.964	5.759	10.954	12.535	bd	4.962	2.974
RG4	11.597	6.507	13.782	bd	bd	bd	bd	5.513	bd	bd	9.018	5.007	2.974
RG5	11.519	bd	29.636	bd	5.483	4.774	bd	5.617	32.328	bd	10.734	5.119	bd
SAR1	bd	bd	18.884	5.325	bd	4.827	5.693	bd	10.536	6.477	bd	bd	2.972
SAR2	8.666	bd	23.457	bd	5.448	4.8	bd	bd	bd	6.275	bd	bd	5.944
SAR3	7.231	bd	17.656	5.184	5.505	4.789	bd	5.534	bd	bd	bd	bd	bd
SAR4	3.123	6.499	30.938	bd	12.082	bd	2.852	bd	bd	bd	bd	4.963	5.994
SAR5	3.989	bd	8.447	bd	bd	bd	2.865	11.379	10.243	bd	bd	bd	5.952

Table 10a. Concentrations of pesticides in December 2008 (pg/L)

	trifluralin	chlorothalonil	dacthal	chlorpyrifos
NSC1	bd	bd	bd	306.251
NSC2	2.526	bd	25.204	855.462
NSC3	2.882	1.403	20.059	524.582
NSC4	bd	bd	bd	bd
NSC5		bd	bd	20.214
SR1	bd	bd	bd	172.273
SR2	bd	bd	bd	bd
SR3	bd	5.907	bd	423.253
SR4	bd	bd	5.328	316.116
SR5	bd	bd	bd	353.840
SSC1	1.968	25.065	bd	2181.674
SSC2	bd	bd	bd	bd
SSC3	bd	bd	bd	15.387
SSC4	bd	bd	bd	358.313
SSC5	bd	bd	1.777	1023.684
MBC1	bd	bd	bd	119.742
MBC2	bd	bd	bd	bd
MC3	bd	bd	3.133	828.128
MC4	bd	bd	bd	12.656
MC5	bd	bd	bd	260.815
MC6	bd	bd	bd	
MR1	5.176	4.969	19.603	1633.333
MR2	bd	bd	bd	27.803
MR3	bd	bd	bd	83.689
MR4	bd	1.837	5.830	350.964
MR5	bd	bd	3.511	774.511
RG1	bd	bd	bd	bd
RG2	bd	bd	bd	bd
RG3	bd	bd	bd	bd
RG4	bd	bd	bd	bd
RG5	bd	bd		bd
GS1	bd	bd	bd	bd
GS2	bd	bd	bd	bd
GS3	bd	bd	bd	bd
GS4	bd	bd	bd	bd
GS5	bd	bd	bd	bd
SAR1	bd	bd	bd	bd
SAR2	bd	bd	bd	bd
SAR3	bd	bd	bd	bd
SAR4	bd	bd	bd	bd
SAR5	bd	bd	bd	bd

Table 10b. Concentrations of pesticides in December 2008 (ng/L)

	atrazine	carbaryl	oxamyl	chlorp me	parathion	fenamiphos	acetochlor	me para
NSC1	bd	bd	bd	bd	bd	bd	bd	bd
NSC2	bd	6.519	8.95	bd	bd	bd	5.726	8.942
NSC3	bd	bd	bd	2.911	bd	bd	5.732	bd
NSC4	bd	bd	bd		bd	bd	bd	bd
NSC5	5.771	bd	14.104		bd	bd	bd	2.971
SR1	bd	bd	bd	2.8	bd	bd	bd	2.981
SR2	6.17	6.594	9.001	bd	bd	bd	12.365	bd
SR3	bd	6.478	bd	bd	bd	bd	11.103	bd
SR4	bd	6.479	11.273	bd	bd	bd	bd	bd
SR5	bd	bd	bd	bd	bd	bd	bd	5.957
SSC1	bd	bd	bd	8.738	bd	bd	bd	bd
SSC2	bd	bd	bd	bd	bd	bd	bd	2.975
SSC3	bd	bd	bd	5.809	bd	bd	bd	bd
SSC4	bd	bd	10.805	2.841	bd	bd	bd	bd
SSC5	bd	bd		2.901	bd	bd	bd	bd
MBC1	bd	bd	bd	bd	bd	bd	5.802	2.986
MBC2	6.32	bd	bd	bd	bd	bd	bd	bd
MC3	bd	bd	bd	5.626	bd	bd	5.355	bd
MC4	bd	bd	8.508	5.896	5.615		5.357	2.972
MC5	9.859		37.352	bd	bd	10.134	bd	bd
MC6	7.305	6.482	14.629	bd	bd	bd	bd	bd
MR1	5.742	6.548	9.518		5.513	10.415	11.349	bd
MR2	6.155	bd	bd	bd	bd	bd	bd	2.973
MR3	bd	bd	bd	5.679	bd	bd	bd	bd
MR4	bd	bd	bd	bd	bd	bd	bd	bd
MR5		6.474	bd	bd	bd	bd	bd	bd
RG1	bd	bd	bd	bd	bd	bd	5.508	bd
RG2	bd	6.495	bd	2.907	bd	bd	15.336	2.98
RG3		6.589	bd	bd	bd	bd	20.644	bd
RG4	8.358	bd	bd	2.876	5.524	bd	8.458	bd
RG5	bd	bd	bd	bd	bd	bd	bd	bd
GS1	bd	bd	bd	bd	bd	bd	bd	bd
GS2	bd	bd	bd	2.835	bd	bd	5.342	bd
GS3	7.067	bd	bd	bd	bd	bd	11.654	bd
GS4	bd	bd	8.508	5.896	5.615	bd	5.357	2.972
GS5	8.468	6.548	13.096	bd	5.512	10.037	bd	2.971
SAR1	bd	bd	bd	bd	bd	bd	5.693	bd
SAR2	bd	bd	bd	5.709	bd	bd	bd	bd
SAR3	bd	6.519	bd	5.647	bd	bd	11.438	bd
SAR4	bd	6.474	bd	bd	bd	bd	bd	bd
SAR5	bd	6.483	8.683	bd	bd	bd	bd	bd

10. FIGURES

Figure 1. Sampling sites in Belize.