Verification of Bay Productivity Measurement by Remote Sensors

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FINAL REPORT

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Many people helped bring this project to fruition by their intense support of field operations and laboratory preparations. Mr. Rick Kalke, an outstanding field person was instrumental in completing this program. The work reported on in this study could not have been performed without him. Carrol Simanek also provided significant help in data management. We obviously are collecting and processing a large amount of data. Chris Kalke, Larry Hyde, and Jeff Baguley aided in field collections.

This work has also benefited by discussions with colleagues at the Texas Water Development Board (TWDB), in particular David Brock, who has provided much help and guidance. The study also benefited by partial support form the University of Texas at Austin, Marine Science Institute, in particular, a Lund Fellowship awarded to Marc Russell.

Abstract

Ecosystem function in estuarine environments is known to be an important indicator of ecosystem health and productivity. There is a need to quantify estuarine ecosystem function variability and link to freshwater inflow to enable better management of ecosystem health and productivity. An important and quantifiable component of ecosystem function is ecosystem metabolism. Results indicate that open water methods were more appropriate than light-dark bottle methods for measuring net ecosystem metabolism in shallow water estuarine ecosystems because of the large contribution of benthos, which is ignored in water bottles. Spatial and temporal variability in net ecosystem metabolism was found. Spatial variability was attributed to differences in benthic habitats and/or station locations with respect to freshwater inflow point sources. Temporal variability in net ecosystem metabolism may be driven by differences in seasonal temperatures and freshwater inflow differences on seasonal time scales. Net ecosystem metabolism was directly related to amounts of freshwater inflow. The strength of this relationship depended on proximity to freshwater sources. Future studies of whole ecosystem metabolism in shallow estuarine ecosystems should employ open water methods and should strive to link other dynamic environmental conditions, such as temperature or irradiance, to ecosystem health, function, and productivity.

Introduction

Ecosystem function in estuarine environments is known to be an important indicator of ecosystem health and productivity. Estuarine ecosystems, being areas of transition between freshwater inflows and oceanic waters, experience highly variable environmental conditions. There is, therefore, a need to quantify estuarine ecosystem function variability so that ecosystem health and productivity can be better understood and managed. An important and quantifiable component of ecosystem function is ecosystem metabolism.

Ecosystem metabolism is calculated by subtracting respiration from primary production. A positive ecosystem metabolism indicates that primary production exceeds respiration. A negative ecosystem metabolism means that respiration exceeds primary production. In the aquatic and terrestrial environments, ecosystem metabolism depends on a variety of physical and biological factors. Physical factors that influence ecosystem metabolism measurements include depth, surface wind speed, freshwater inflow, turbidity, substrate type, salinity, temperature, current flow rates, nutrient concentrations, detritus, dissolved and particulate organic matter, tidal cycles, sunlight, and cloud cover. Biological factors that influence ecosystem metabolism measurements include chlorophyll-a, amount of live biomass in the water column and sediment, photosynthesis rates, and respiration rates. The large number of highly variable factors influencing ecosystem metabolism in estuarine ecosystems requires that measurements of ecosystem metabolism take an integrative approach. Open water diurnal curve and light-dark bottle methods provide two alternate integrative measurement techniques that have had widespread use in quantifying ecosystem metabolism.

Open water dissolved oxygen measurements have been used to estimate whole ecosystem metabolism, providing spatially and temporally integrated estimates of metabolic processes, since Odum's seminal work in the 1950's (Odum 1956). Whole ecosystem metabolism involves calculating the change in dissolved oxygen concentration resulting from biological processes in an aquatic ecosystem over a period of 24 hours.

Atmospheric oxygen flux must, therefore, be estimated and adjusted for to separate physical and biological influences on dissolved oxygen concentration. Atmospheric oxygen flux is influenced by dissolved oxygen concentration gradients and near surface turbulence dynamics. The physical factors driving near surface turbulence must therefore be accounted for during calculations of whole ecosystem metabolism.

Light-dark bottle methods use water enclosures to estimate ecosystem metabolism and have had extensive use in limnology and oceanography. Odum and Hoskin (1958) found that bottle methods were not suitable in shallow marine bays for whole ecosystem metabolism, but did conclude that they were very useful in determining the planktonic portion of metabolism. Bottle measurements may also miss a substantial amount of short term variability encountered in estuaries. Normal turbulence and continuous nutrient flux from other parts of the ecosystem are eliminated in bottle enclosures. Phytoplankton trapped within bottles do not experience the natural variability in light levels that occurs as they are vertically mixed in turbulent waters.

We hypothesize that ecosystem metabolism in shallow water estuaries are both spatially and temporally variable and related to freshwater inflow. We also hypothesize that open water diurnal curve methods will provide a superior measure of ecosystem metabolism relative to light-dark bottle methods in shallow water estuarine ecosystems because of a large contribution by the benthos. We, therefore, hypothesize that benthos make a significantly larger contribution to whole ecosystem metabolism than the water column in shallow water estuaries. To test these hypotheses, open water diurnal curve and light-dark bottle methods were used to quantify spatial and temporal differences in ecosystem metabolism dynamics and to assess the contribution by the benthos to whole ecosystem metabolism in shallow water ecosystems.

Methods and Materials

Most Texas estuaries are divided into primary and secondary bays. Lavaca Bay, which is the secondary bay of the Lavaca-Colorado Estuary, was used to quantify intra-bay spatial

variability in ecosystem metabolism. Six stations were established in Lavaca Bay (Fig. 1). Corpus Christi Bay, a primary bay, Nueces Bay, the corresponding secondary bay, and the neighboring Laguna Madre were used to quantify broader scale spatial variability in ecosystem metabolism. Four stations were established in this bay system (Fig. 2). Temporal variability in ecosystem metabolism was measured through a quarterly sampling plan at all ten stations (Table 1).

Open Water Diurnal Curve Method

Dissolved oxygen and other water quality parameter measurements were taken every 15 minutes at mid depth using YSI series 6 multiparameter data sondes (Appendix UTSOP 03). Models 6920-S and 600XLM data sondes with 610-DM and 650 MDS display loggers were used. The series 6 parameters have the following accuracy and units: temperature (± 0.15^{o}C), pH (± 0.2 units), dissolved oxygen (mg l^{-1} ± 0.2), dissolved oxygen saturation (% ± 2%), specific conductivity (± 0.5% of reading depending on range), depth (± 0.2 m), and salinity (± 1% of reading or 0.1 ppt, whichever is greater). Salinity is automatically corrected to 25^{o}C.

The relatively high wind speeds that occur across the shallow water estuaries of Texas imply that wind will dominate the physical control of atmospheric oxygen flux. Texas estuaries experience sustained wind speeds commonly around 7-8 m s^{-1} (~13-18 mph), but can have daily variations in wind speed from 1-10 m s^{-1} (~2-23 mph) (Texas Coastal Ocean Observation Network data at http://lighthouse.tamucc.edu/TCOON/HomePage). Estuaries in other regions of the U.S. tend to have wind speeds in the range of 0-6 m s^{-1} (~0-12 mph) with maximum atmospheric oxygen exchanges measured at 8.6 m s^{-1} (~19 mph) (Kemp and Boynton 1980; Marino and Howarth 1993). Meteorological forcing dominates water exchange and circulation in South Texas estuaries because of shallow water depths (medium depth ~2-4 m), small tidal range (~0.25 m), little freshwater inflow (~0-800 million m^{3} y^{-1}), and long over-water fetches (Orlando et al. 1993). These characteristics when combined with ample sunlight, high temperatures, and relatively steady winds out of the South East make South Texas estuarine ecosystems particularly

amenable to open water methods of estimating whole ecosystem metabolism. Biological processes can still dominate dissolved oxygen concentration changes in South Texas estuaries even with the prevalence of high wind speeds. The physical features of South Texas estuaries, when combined with the highly dynamic and large influence of wind speed on surface turbulence, require that estimates of whole ecosystem metabolism in this region adjust for changes in atmospheric oxygen flux due to changing wind speeds.

The wind dependent diffusion coefficients given by D'Avanzo et al. (1996) were applied to calculations of whole ecosystem metabolism in Lavaca Bay. D'Avanzo et al.'s (1996) diffusion coefficients allowed for diffusion corrected calculations of dissolved oxygen concentration change that could vary over short temporal scales (hourly). The major physical influence on whole ecosystem metabolism calculations was thus removed by adjusting for atmospheric oxygen flux generated during undersaturated or supersaturated dissolved oxygen concentration conditions. Removal of the physical influences on dissolved oxygen concentration left just the biologically driven changes in dissolved oxygen concentration.

Net ecosystem metabolism was calculated using open water diurnal methods. Dissolved oxygen concentrations were taken every 15 minutes and converted to a rate of change in dissolved oxygen concentration. These rates of change were then adjusted to control for diffusion of oxygen between the water column and the atmosphere by using percent saturation of dissolved oxygen in the water column and the wind dependent diffusion coefficient K (g O_2 m^{-2} h^{-1}) at 0% saturation proposed by D'Avanzo et al. (1996) using the equation:

$R_{dc} = R - ((1-((S_1 + S_2) / 200)) * K / 4)$; where

R_{dc} = diffusion corrected oxygen concentration rate of change per 15 minutes,

R = observed oxygen concentration rate of change,

S_1 and S_2 = dissolved oxygen percent saturations at time one and two respectively,

K = diffusion coefficient at 0% dissolved oxygen saturation.

To calculate daily net ecosystem metabolism, the 15 minute diffusion corrected rates of dissolved oxygen change were then summed over a 24 hour period, starting and ending at 8AM. Open water dissolved oxygen methods similar to those used here have been used in a variety of estuaries to calculate net ecosystem metabolism (Kemp et al 1992; D'Avanzo et al. 1996; Borsuk et al. 2001; Caffrey 2003).

Light-Dark Bottle Method

Net ecosystem metabolism will be measured using a modification of the University of Texas standard operating procedures (Appendix SOP UT05). Four light-dark bottle replicates per station will be deployed at mid depth so as to correspond with the mid depth open water sonde measurements. Net ecosystem metabolism will be estimated from the dissolved oxygen change in light bottles.

The following null hypotheses were tested:
H_{01}: The water column contribution to whole ecosystem metabolism is less than that contributed by the benthos.
H_{02}: There are no spatial or temporal differences in whole ecosystem metabolism in shallow water estuaries.

The first null hypothesis was tested by comparing net ecosystem metabolism measurements using light bottles to open water measurements of net ecosystem metabolism (2-tailed, paired t-test). The second null hypothesis was tested for significant main effects using a 2-way ANOVA of open water net ecosystem metabolism by station and date with no interaction term. Station and dates are fixed effects, however, date is a block variable that controls for differences between dates, but does not have an interactive effect with stations. Means were compared using Tukey's post hoc pair-wise comparison test.

Results

Ecosystem metabolism measured with light bottle methods yielded water column contributions to whole ecosystem metabolism from 1.03% – 94.68%. This implies that benthic contribution to whole ecosystem metabolism ranges from 5.32% - 98.97% in these shallow estuaries. Results from 28 out of 37 (76%) samples indicate the benthic contribution to whole ecosystem metabolism is greater than 50% (Table 2). The benthic contribution to whole ecosystem metabolism was significantly higher (21.3% – 54.6%) than that contributed by the water column ($p < 0.001$) (Table 3). Light-dark bottle methods consistently gave lower net ecosystem metabolism rates than open water methods (Figs. 2a-2d). Open water measurements that include the important contribution by benthos in these shallow water systems were, therefore, used to assess the spatial and temporal variability in whole ecosystem metabolism.

Spatial and temporal differences were found between whole ecosystem metabolism measurements. There were significant differences in net ecosystem metabolism between stations ($p = 0.041$) and dates ($p = 0.005$) (Table 4). No overall interaction between stations and dates was present (Fig 3a-3b). There was a significant difference between stations 1 and 8 ($p = 0.019$) as well as 7 and 8 ($p = 0.026$) in post hoc pair-wise comparisons. There were significant differences between dates 17 June 2003 and 23 September 2003 ($p = 0.015$), and 23 September 2003 and 3 December 2003 ($p = 0.004$). Net ecosystem metabolism on September 23rd was significantly lower than for June 17th and December 3rd.

Visual representation of the net ecosystem metabolism within a geographic information system revealed seasonal trends. Net ecosystem metabolism rates in spring tend to be relatively balanced, near a value of zero, except at the seagrass dominated station 8, which was markedly positive, i.e., primary production is greater than respiration (Fig. 4a-4b). Stations close to freshwater point sources were more negative, i.e., respiration dominated, than stations further down estuary. Water column metabolism also becomes more dominant as one moves down estuary with the exception of station 8.

Net ecosystem metabolism rates in summer tends to be positive, i.e., photosynthesis dominates, with only one station (station 8) having a negative net ecosystem metabolism (Fig. 5a-5b). Dominance in the contribution to net ecosystem metabolism switches from the benthos to the water column as one move away from freshwater point sources in Lavaca Bay. However, lower bay stations (8, 9, and 10) in Corpus Christi Bay had large positive net ecosystem metabolisms dominated primarily by the benthos.

Net ecosystem metabolism rates in fall tend to be relatively negative (Fig. 6a-6b). All stations close to freshwater point sources had large negative net ecosystem metabolism rates driven primarily by the benthos. Lower estuary stations tended to be positive except for station 9 with all stations net ecosystem metabolism being driven primarily by the benthos.

Net ecosystem metabolism rates in winter tend to be largely positive (Figs. 7a and 7b). Lavaca bay stations had positive net ecosystem metabolism rates driven by a large contribution from the benthos. Stations in Nueces and Corpus Christi bay (stations 7 and 10), which are located in the line of freshwater flow from Nueces River were negative, with contributions to net ecosystem metabolism being fairly balanced between the water column and the benthos. Stations 8 and 9 which are located away from the line of freshwater flow were positive, with a large contribution to net ecosystem metabolism from the benthos.

Discussion

Historically, whole ecosystem metabolism estimates have been calculated using the light-dark bottle methods. Only recently, with advent of continuously recording multiparameter sondes, have open water diurnal curve methods become practical to estimate whole ecosystem metabolism. We can infer from our results that open water diurnal curve methods are preferable to light-dark bottle methods in shallow water systems. The large benthic surface area relative to the water column volume in shallow

water estuarine ecosystem results in benthos dominating whole ecosystem metabolism (Table 2). We advise that future studies of whole ecosystem metabolism in shallow estuarine ecosystems should employ open water methods because they incorporate the benthic component of these ecosystems.

Open water calculations of community gross primary production assume that respiration remains at the same level through the daily light-dark cycle. This assumption is necessary to calculate gross primary production by subtracting respiration during the day from net ecosystem metabolism. Night-time community respiration rates, however, have been found to reach a maximum just after dusk (Odum and Hoskin, 1958). This finding implies that respiration rates are not constant. Sediment oxygen consumption, a large component of community respiration, also increases as a linear function of temperature (Hargrave 1969). Stations in this study were located where daily water temperature fluctuations can be as high as 5 ^{o}C (Montagna and Russell unpublished data). Using a constant respiration rate derived from night time values can result in estimates of gross primary production that are greatly underestimated because of changes in benthic respiration rate resulting from fluctuating temperatures. Net ecosystem metabolism rates provide more realistic estimates of community function than those resulting from the artificial separation of net ecosystem metabolism into gross primary production and respiration rates. Until better estimates of daily respiration rate changes are available, we conclude that net ecosystem metabolism rates are preferable to separate estimates of gross primary production and respiration and are thus reported so.

Within-bay spatial variability appeared to be relatively small in this study with no significant pair-wise differences in net ecosystem metabolism between stations on any particular date. This implies that a single mid-bay station would be representative of an entire bay. Caffrey (2004) used a single station to represent an entire estuarine ecosystem in her study of net ecosystem metabolism at NERR sites. Grouping stations by geographic location, however, may result in significant differences between upper and lower bay groups net ecosystem metabolism response to freshwater inflow (Appendix 3: Russell et al. 2004).

Between-bay spatial variability exists with significant differences between station 1 in upper Lavaca Bay, station 7 in upper Nueces Bay, and station 8 in northern Laguna Madre. The location in relation to freshwater inflow point sources may be the factor determining these between-bay differences because both stations 1 and 7 are located near river mouths while station 8 was relatively isolated from freshwater inflows (Fig 1-2). Russell et al. (2004) concluded that net ecosystem metabolism is related to freshwater inflow in upper Lavaca Bay but not in lower Lavaca Bay (Appendix 1).

Within and between-bay temporal variability in net ecosystem metabolism was present during 2003 (Table 4). September 23rd samples from Lavaca Bay were found to have significantly lower net ecosystem metabolisms than June 17th samples from Corpus Christi, Nueces, and Laguna Madre and December 3rd samples from Lavaca Bay. A large freshwater inflow event into Lavaca Bay, daily mean inflow = 1173.25 $ft^3 s^{-1}$ compared to the 66 year historical daily mean inflow = 408.75 $ft^3 s^{-1}$, took place during the four days prior to the September 23rd sampling date (USGS website, http://waterdata.usgs.gov/tx/nwis/sw). This freshwater inflow event may have driven net ecosystem metabolism down as a consequence of allochthonous organic matter loading and subsequent *in-situ* decomposition. Freshwater inflow has been shown to drive net ecosystem metabolism down into negative rates in Lavaca Bay (Russell et al. 2004). This connection between freshwater inflow and net ecosystem metabolism is supported in this study by the relatively negative net ecosystem metabolism results from upper Lavaca Bay (Stations 1-3) (Table 2) that imply that location in relation to a freshwater source may be important because of loading of autochthonous organic matter.

We conclude that open water diurnal curve methods are more inclusive and probably more accurate than light-dark bottle methods to estimate whole ecosystem metabolism in shallow water estuarine ecosystems. The benthic contribution to whole ecosystem metabolism was significantly larger than the contribution from the water column, which indicates the light-dark bottle methods for estimating whole ecosystem metabolism that exclude benthic processes are inappropriate. This conclusion corresponds with that from

Odum and Hoskin (1958). We also conclude that spatial and temporal variability in net ecosystem metabolism is present in shallow water estuarine ecosystems. Spatial variability may be driven by benthic community type and/or geographic location with respect to freshwater point sources. A geographic information system representation of the spatial results by season was helpful in uncovering some interesting seasonal trends in net ecosystem metabolism. Temporal variability in net ecosystem metabolism was found, but may be more related to freshwater inflow events than other seasonally changing environmental conditions. Net ecosystem metabolism can be used as an indicator of ecosystem function. A model of the relationship between net ecosystem metabolism and freshwater inflow could be used to enable better management of ecosystem health and productivity.

Table 1. Station locations within Lavaca, Corpus Christi, and Nueces Bays and Laguna Madre.

Station Number	UTMSI Station Name	Short Description	Latitude (N)	Longitude (W)
1	LB 1	Lavaca Bay So. of Garcitas Cove	28.69683	96.64499
2	LB 2	Lavaca Bay West of Point Comfort	28.67436	96.58280
3	LB 3	Lavaca Bay at SH 35	28.63888	96.60916
4	LB 4	Lavaca Bay East of Noble Point	28.63933	96.58449
5	LB 5	Lavaca Bay at 'Y' at CM 66	28.59583	96.56250
6	LB 6	Lavaca Bay South of Rhodes Pt.	28.59769	96.51602
7	NCA	Middle Nueces Bay	27.84685	97.46913
8	LM1	North Laguna Madre	27.59688	97.28070
9	H24	Corpus Christi Bay Hypoxia Site	27.69552	97.20298
10	NCE	North Corpus Christi Bay	27.79722	97.15083

Table 2. Net ecosystem metabolism (NEM) results from light-dark bottle methods and open water sonde methods as well as water column (WC) and benthic (B) percent contribution to whole ecosystem metabolism listed by date, station (Sta), and depth.

Date	Sta	Depth	Bottle NEM	Sonde NEM	WC % Contrib	B % Contrib
3/18/2003	1	1.4	1.09	-1.03	33.93	66.07
3/18/2003	2	1.5	1.15	0.05	51.11	48.89
3/18/2003	3	2.2	-0.16	-0.04	57.39	42.61
3/18/2003	6	2.4	1.01	-0.12	47.21	52.79
3/26/2003	7	1.2	2.94	-0.2	48.08	51.92
3/26/2003	8	1	-0.29	4.64	5.55	94.45
3/26/2003	9	3	0.58	0.7	82.73	17.27
3/26/2003	10	3	0.30	0.49	62.12	37.88
5/28/2003	1	1.5	0.12	-0.48	20.59	79.41
5/28/2003	2	1.5	0.24	1.15	20.99	79.01
5/28/2003	3	2.25	0.26	1.53	17.10	82.90
5/28/2003	4	2	1.71	0.8	66.53	33.47
5/28/2003	5	1.4	0.48	0.51	94.68	5.32
5/28/2003	6	2.3	1.49	0.06	51.03	48.97
6/17/2003	7	1.2	1.05	0.74	73.55	26.45
6/17/2003	8	0.85	-0.42	5.17	7.64	92.36
6/17/2003	9	3.1	-0.12	3.34	3.37	96.63
6/17/2003	10	3	-0.42	0.65	28.26	71.74
9/23/2003	1	1.8	-1.03	-3.12	36.98	63.02
9/23/2003	2	1.8	0.44	-2.75	12.18	87.82
9/23/2003	3	2.5	-0.36	-3.11	11.65	88.35
9/23/2003	4	2.4	0.76	-0.33	35.66	64.34
9/23/2003	6	2.6	2.17	3.57	60.87	39.13
10/1/2003	7	2.2	0.64	-0.93	29.10	70.90
10/1/2003	8	1.6	0.52	2.11	21.66	78.34
10/1/2003	9	3.8	-0.02	-0.78	3.07	96.93
10/1/2003	10	3.7	-0.24	0.69	19.99	80.01
12/3/2003	1	1.4	0.42	3.03	13.94	86.06
12/3/2003	2	1.4	0.04	2.92	1.38	98.62
12/3/2003	3	2.1	-0.34	2.54	10.61	89.39

12/3/2003	4	2	-0.02	1.92	1.03	98.97
12/3/2003	5	1.5	0.34	2.63	13.01	86.99
12/3/2003	6	2.2	-0.18	1.98	7.73	92.27
12/10/2003	7	1.4	0.58	-0.72	44.47	55.53
12/10/2003	8	1	-0.06	2.02	2.82	97.18
12/10/2003	9	3	0.10	0.64	15.72	84.28
12/10/2003	10	3	0.22	-0.13	34.71	65.29

Table 3. Paired sample two-tailed t-test between water column and benthic percent contribution to whole ecosystem metabolism.

Mean	Std. Deviation	Std. Error Mean	95% Confidence Lower	Upper	t	df	Sig. (2-tailed)
-37.922	49.938	8.210	-54.572	-21.272	-4.619	36	< 0.0001

Table 4. Two-way ANOVA of open water net ecosystem metabolism by date and station with no interaction term ($r^2 = 0.706$, adjusted $r^2 = 0.496$)

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	88.556	15	5.904	3.358	0.006
Intercept	20.411	1	20.411	11.610	0.003
DATE	46.964	6	7.827	4.452	0.005
STATION	35.814	8	4.477	2.547	0.041
Error	36.918	21	1.758		
Total	151.072	37			
Corrected Total	125.474	36			

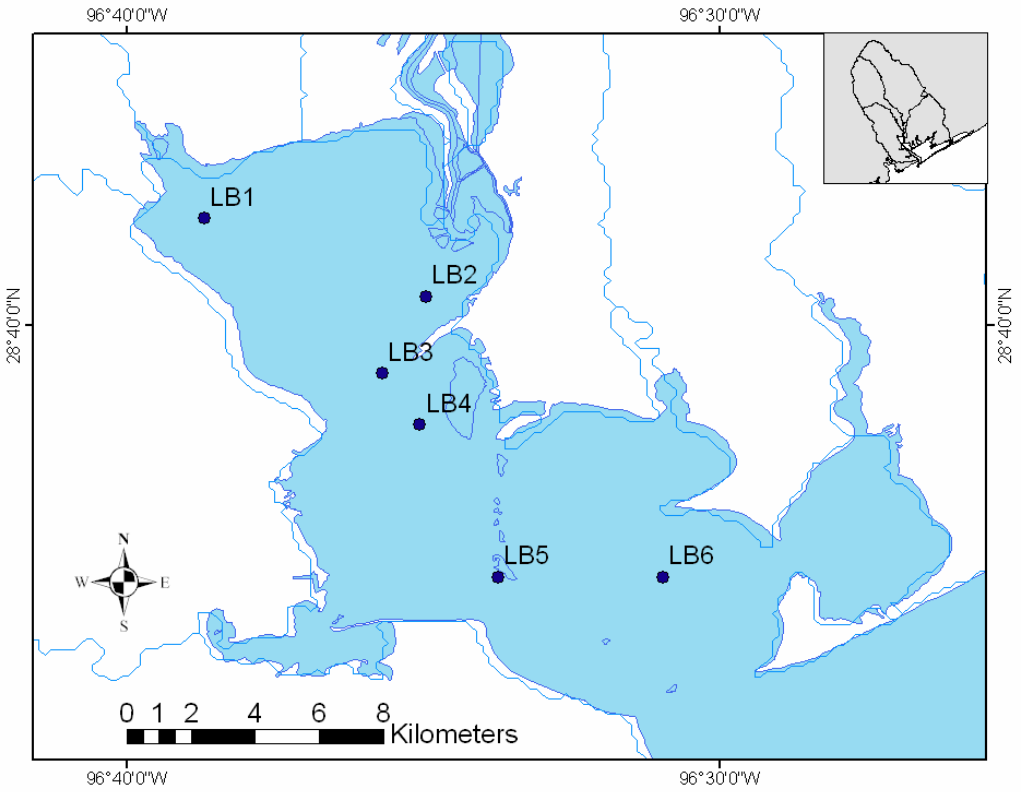

Figure 1. Lavaca Bay station locations.

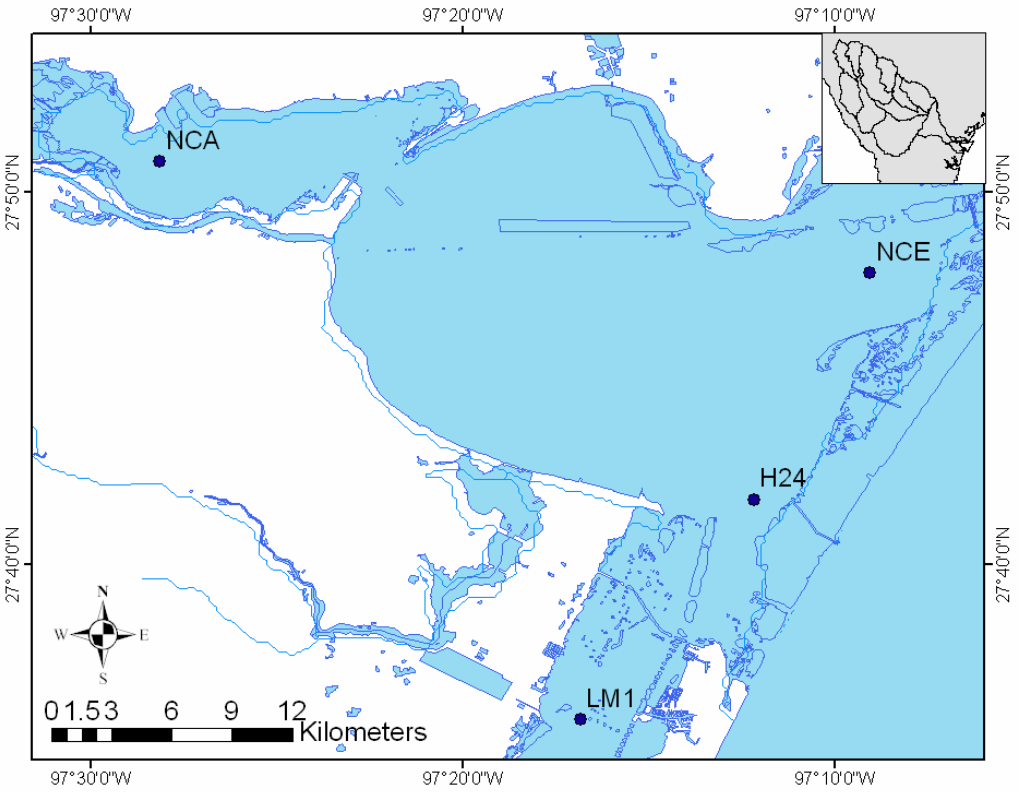

Figure 2. Corpus Christi, Nueces, and Laguna Madre station locations.

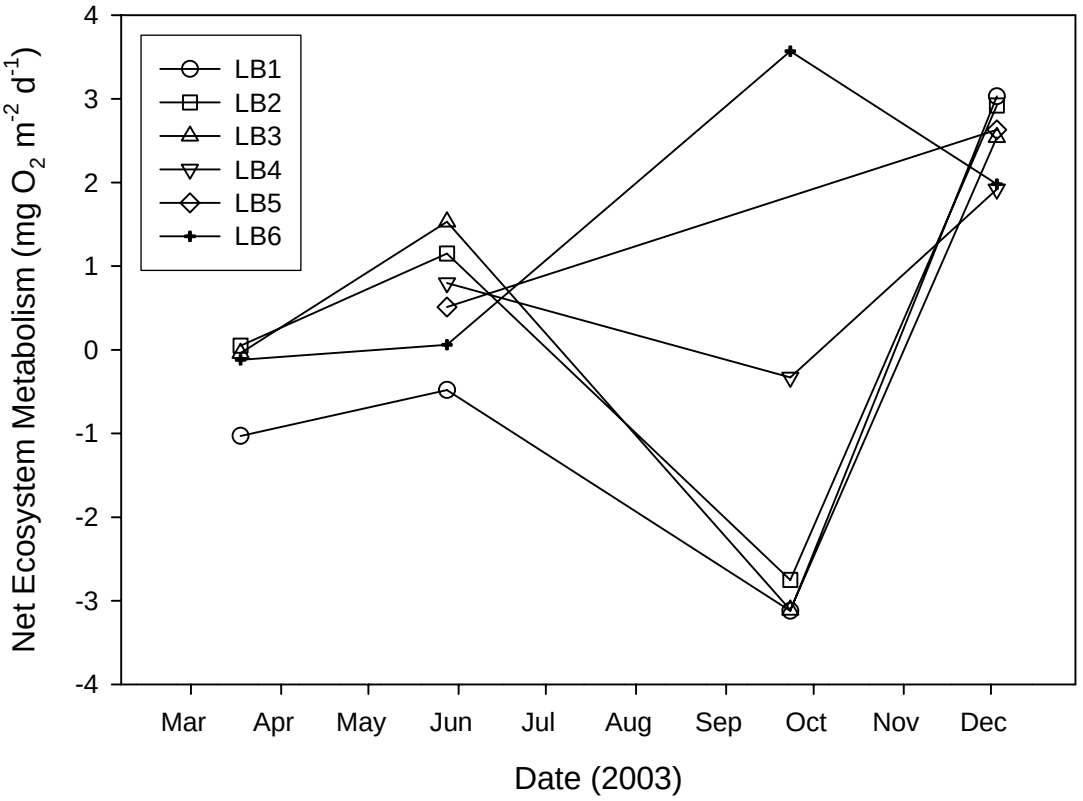

Figure 3a. Net ecosystem metabolism from open water methods in Lavaca Bay.

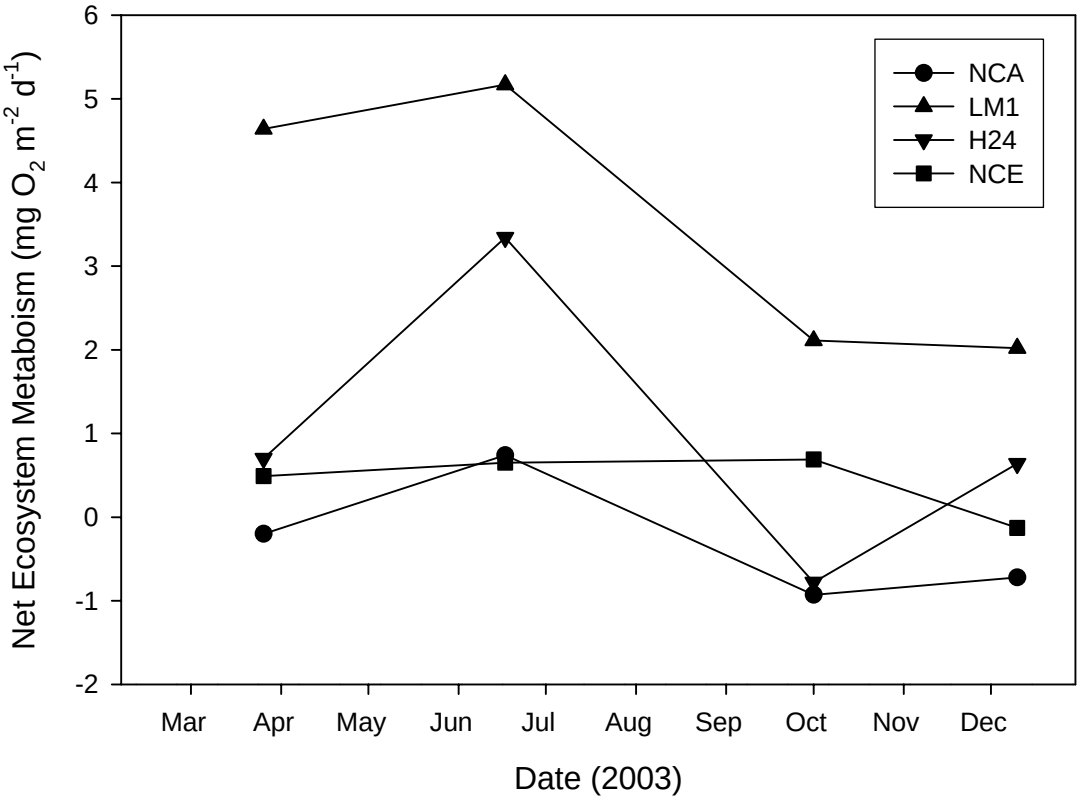

Figure 3b. Net ecosystem metabolism from open water methods in Corpus Christi, Nueces, and Laguna Madre.

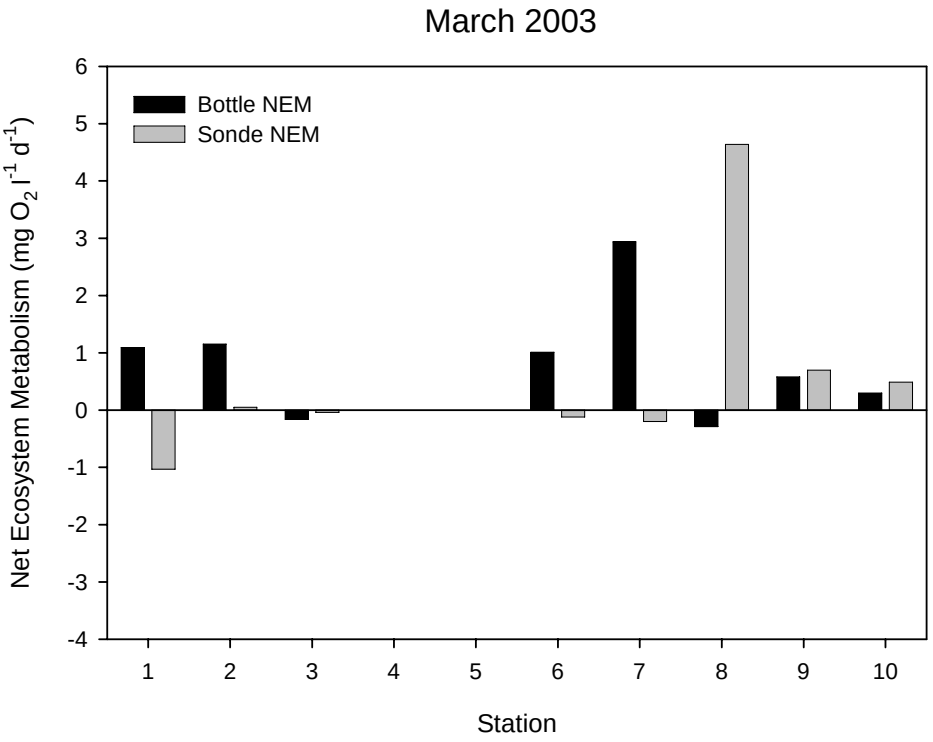

Figure 4a. Net ecosystem metabolism comparison between March bottle and open water methods.

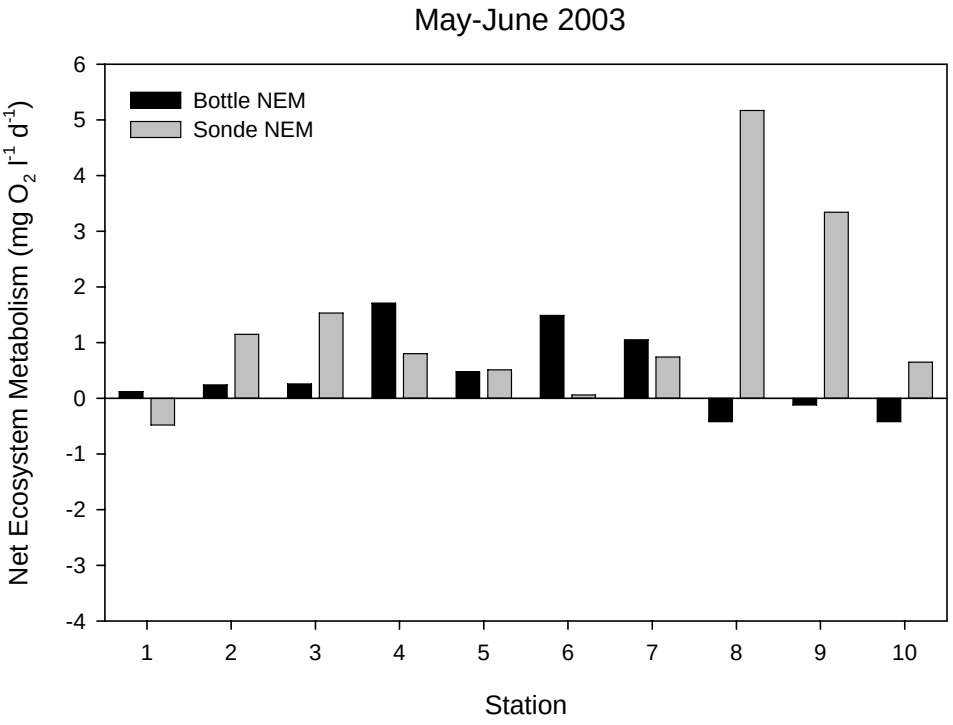

Figure 4b. Net ecosystem metabolism comparison between May-June bottle and open water methods.

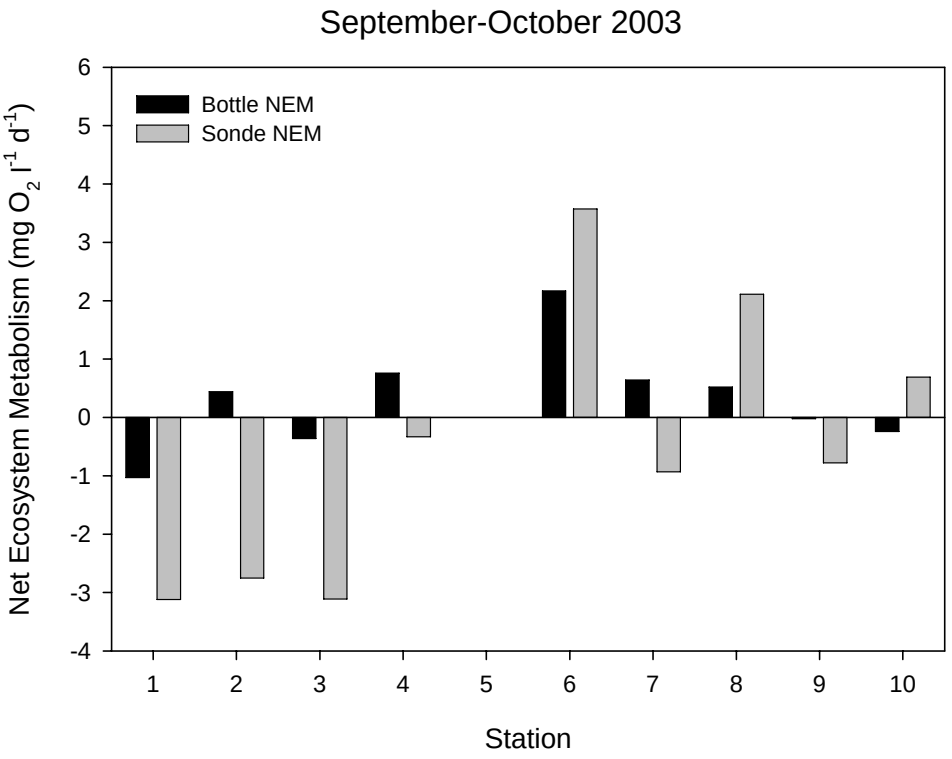

Figure 4c. Net ecosystem metabolism comparison between September-October bottle and open water methods.

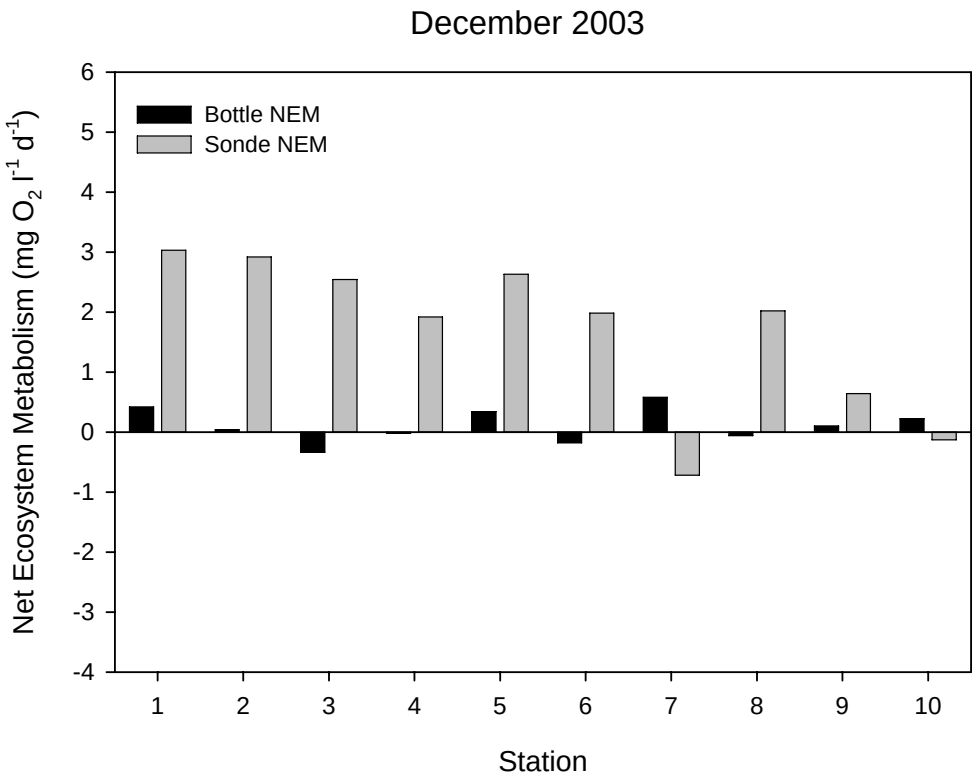

Figure 4d. Net ecosystem metabolism comparison between December bottle and open water methods.

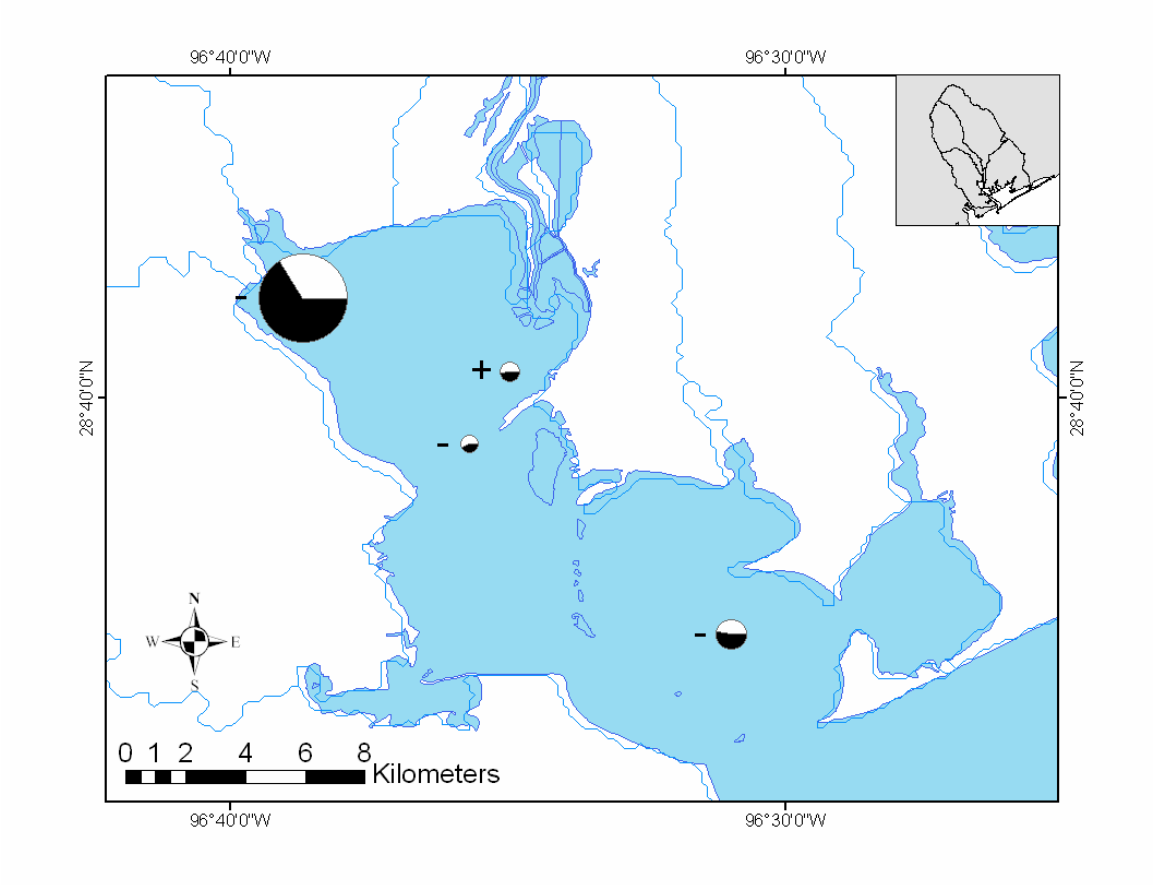

Figure 5a. Lavaca Bay Spring whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

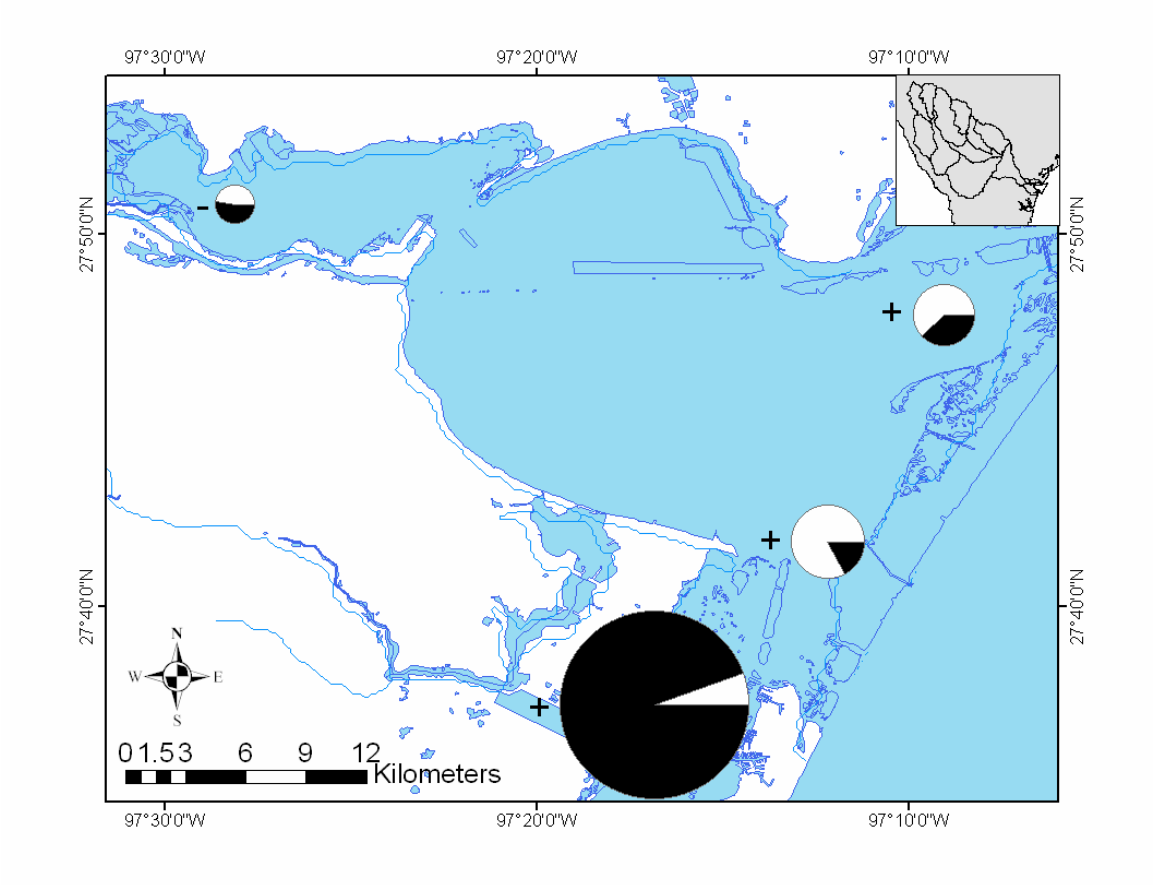

Figure 5b. Corpus Christi, Nueces, and Laguna Madre Spring whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

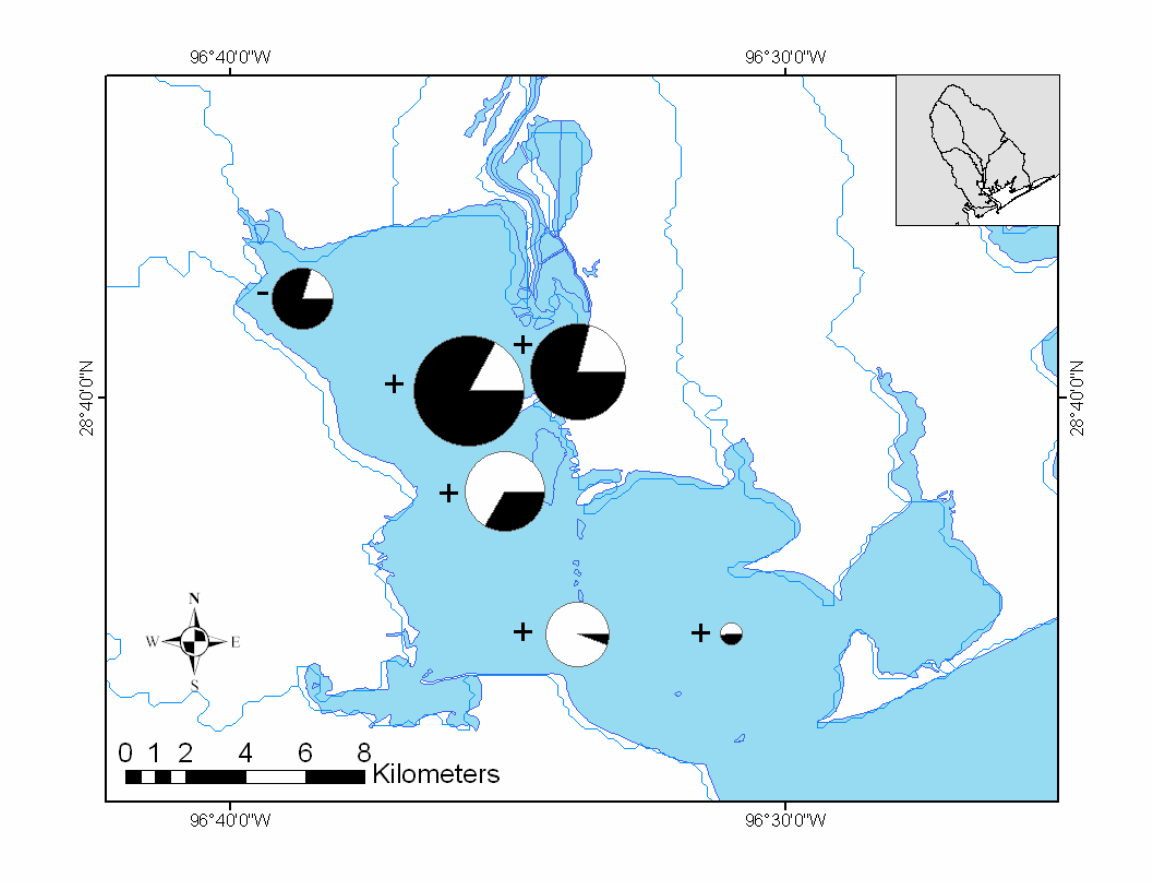

Figure 6a. Lavaca Bay Summer whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

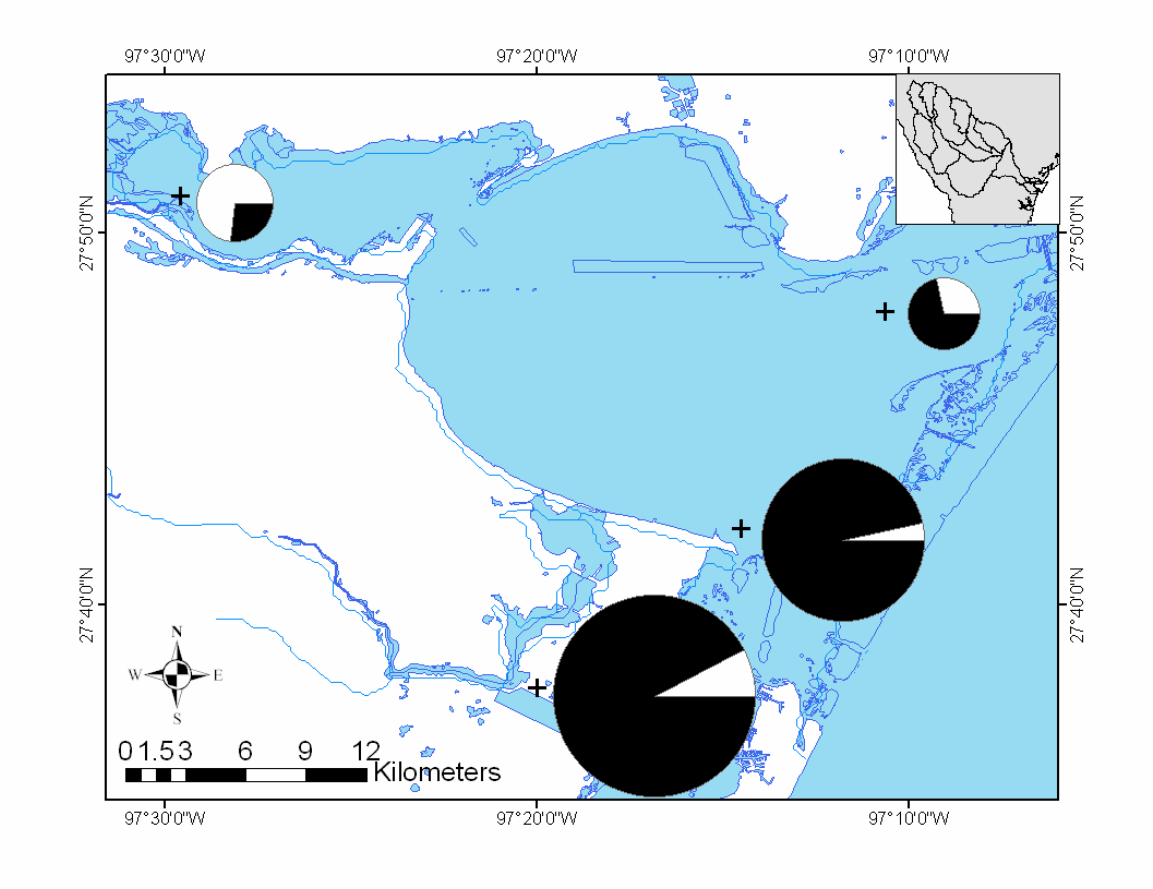

Figure 6b. Corpus Christi, Nueces, and Laguna Madre Summer whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

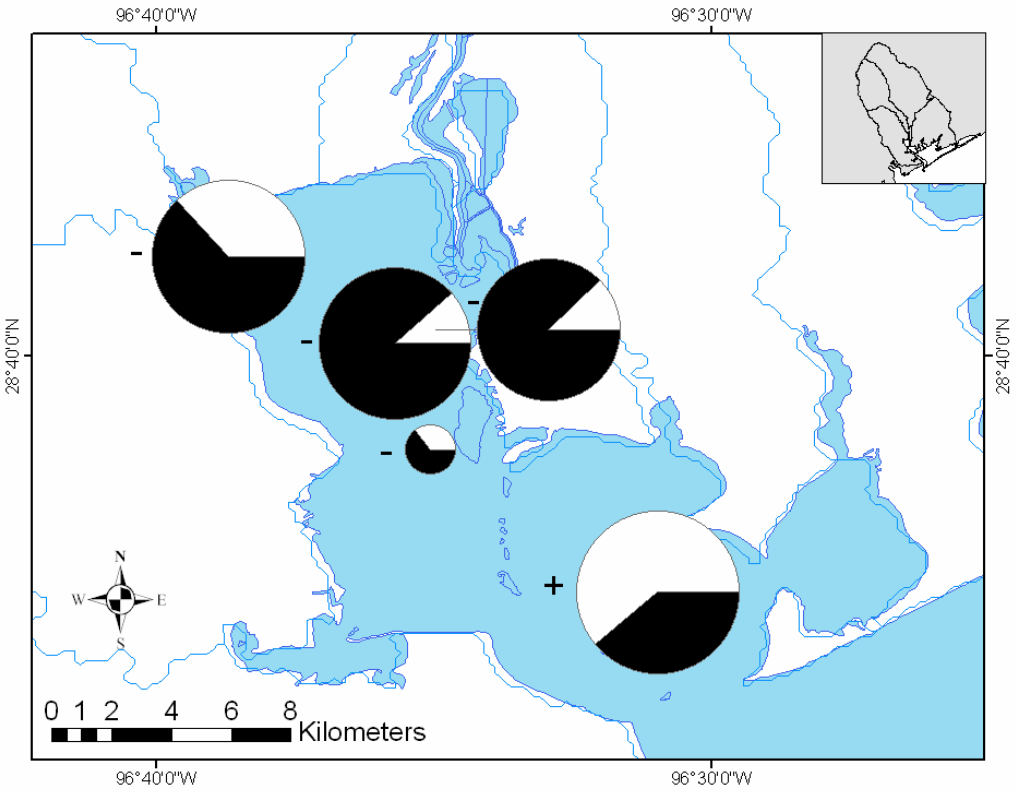

Figure 7a. Lavaca Bay Fall whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

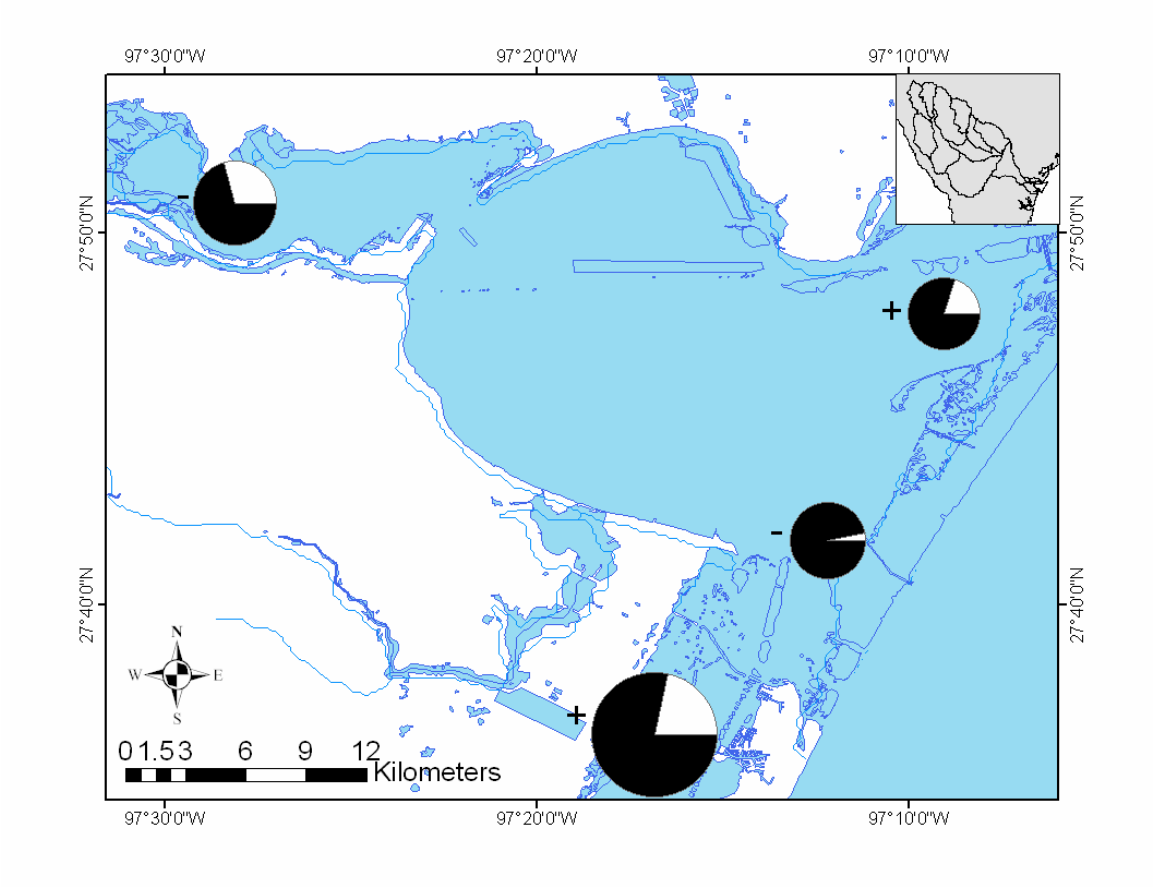

Figure 7b. Corpus Christi, Nueces, and Laguna Madre Fall whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

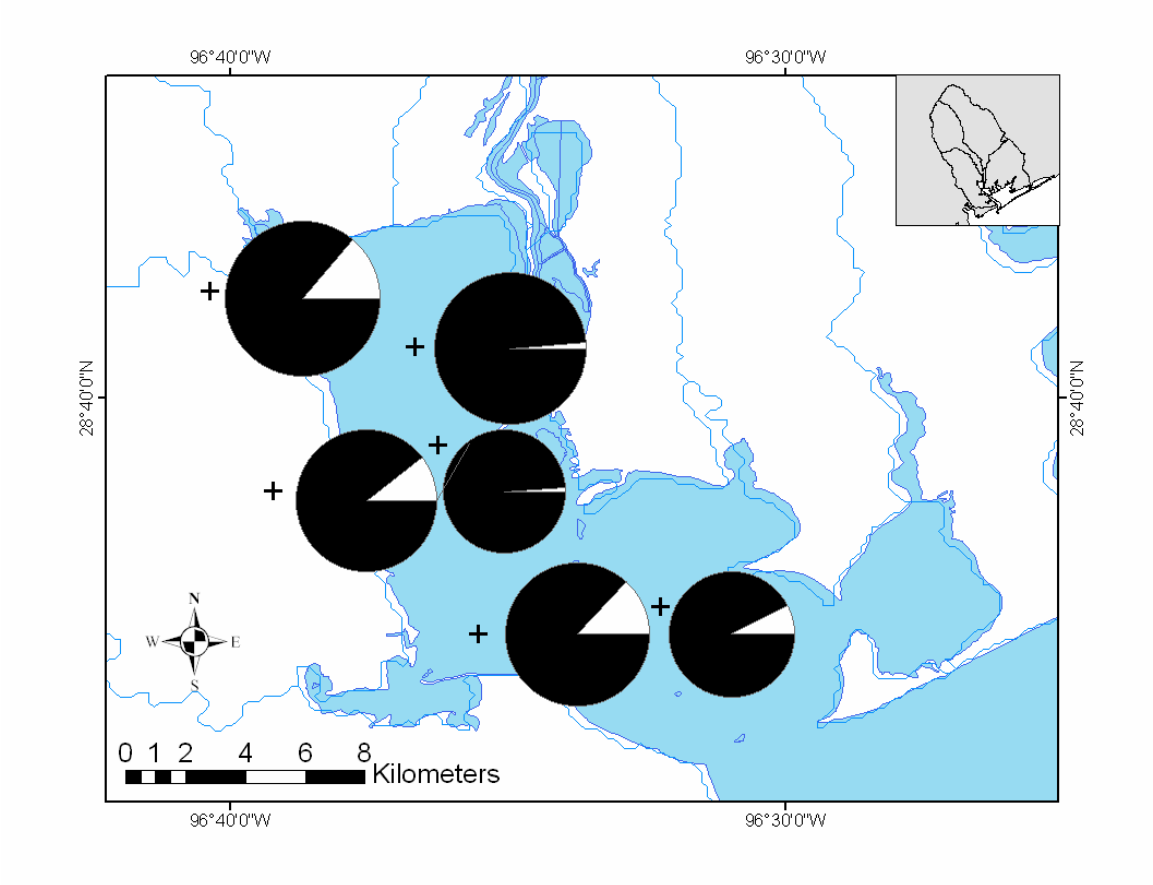

Figure 8a. Lavaca Bay Winter whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

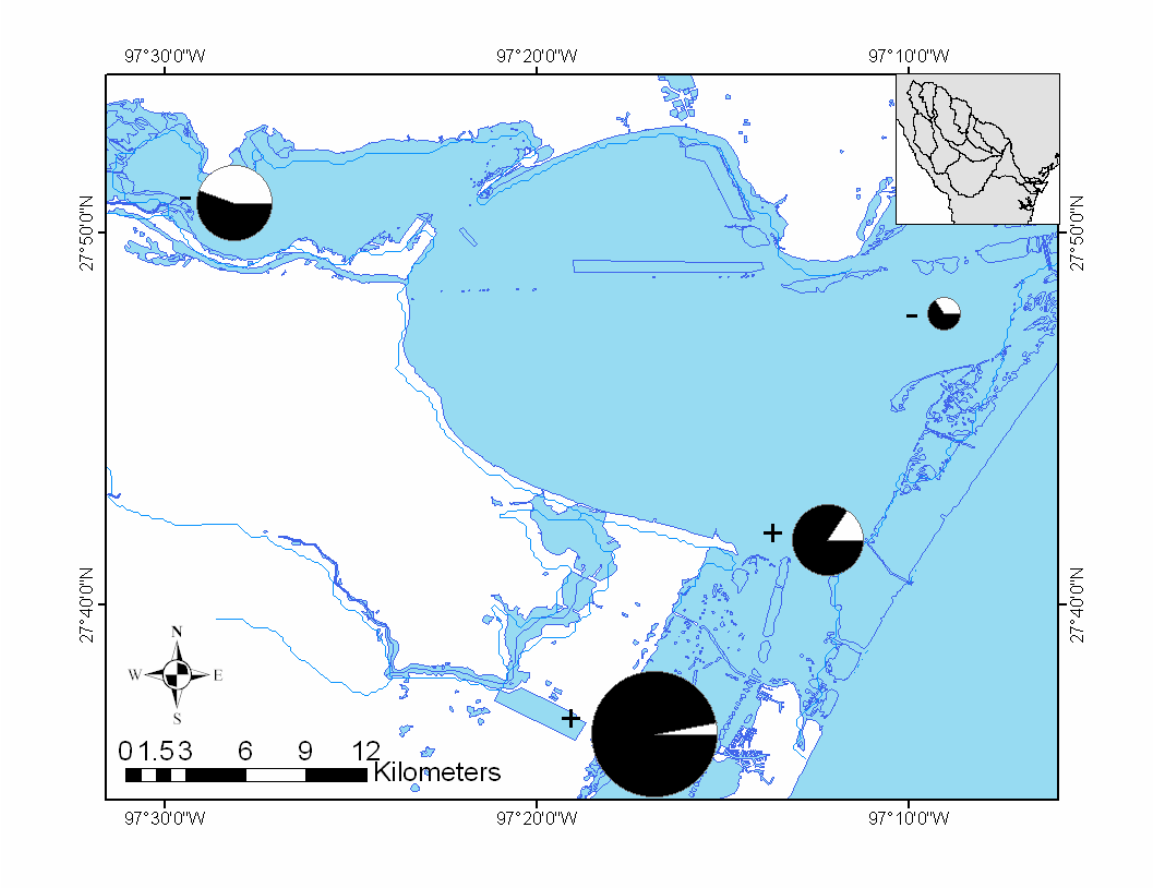

Figure 8b. Corpus Christi, Nueces, and Laguna Madre Winter whole ecosystem metabolism (size of pie) and percent contribution by the water column (white) and the benthos (black).

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X-Mailer: Novell GroupWise Internet Agent 6.5.4
Date: Tue, 01 Nov 2005 10:17:11 -0600
From: "Carla Guthrie" <Carla.Guthrie@twdb.state.tx.us>
To: <paul@utmsi.utexas.edu>
Subject: Remote Sensors report

Hi Paul,

I received the final report packet for the Remote Sensors project from our contracts division. I have been asked to review the final report and determine if all comments were addressed. Before you submitted the contract, I was under the impression that there had been no comments to address. And, I vaguely recall you saying you never received any comments. Well, there appear to be comments for the report. The contract division had these, but never told me that they did.

I am sending the comments to you, and I want you to decide if any of these are important enough (in your opinion) to change for the Final Report. If you want to make changes, then you can do so and send me the updated pages, which I will then fit into the final report. If you do not want to make any changes, I am fine with the report as is, under the circumstances. However, I may not have the final say ..we will have to wait and see.

Let me know what you think. Sorry about this surprise.

Carla

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Sensors Comments.PDF

Entire document needs to be changed to consistently hyphenate "light-dark"

Page 4:

1st paragraph: Delete the 3 sentences starting with "The appropriateness of light-dark..." to "...freshwater inflow was estimated." Start following sentence with: "Results indicated that open water methods were...."

1st paragraph: "Temporal variability may be driven by differences in freshwater inflow amounts at different time scales". Spell out more clearly what is meant by different time scales of freshwater inflow.

Page5:

1st paragraph, 3rd sentence: change sentence to read: "There is, therefore, a need to quantify estuarine ecosystem function variability so that ecosystem health and productivity can be better understood and managed."

2nd paragraph, 4th sentence: put comma between "environment, ecosystem". Also you could add a parenthetical comment that this applies to all environments, not just aquatic ones.

2nd paragraph, 5th sentence: is freshwater inflow different from flow rates in the list? Also, water/soil pH, and sunlight/clouds also could/should be listed.

2nd paragraph, 6th sentence: the amount of dead organic material (i.e., food) also influences rate of respiration.

2nd paragraph, 7th sentence: change sentence to read: "The large number of highly variable factors influencing ecosystem...."

2nd paragraph, last sentence: "measurements" should be singular.

3rd paragraph, 1st sentence: put a comma between "processes, since"

3rd paragraph, 2nd sentence: change sentence to read: "Whole ecosystem metabolism involves calculating the change in..."

Page 6:

1st paragraph, 1st full sentence on page: change sentence to read: "Atmospheric oxygen flux is influenced by dissolved oxygen..."

2nd paragraph, last sentence: remove semicolon between "bottles; also"

3rd paragraph, 2nd sentence: change sentence to read: "We also hypothesize that open water diurnal curve methods will provide a superior measure of ecosystem metabolism relative to light dark bottle..."

3rd paragraph, 3rd sentence: change sentence to read: "We, therefore, hypothesize that benthos make a significantly larger..."

3rd paragraph, 4th sentence: change sentence to read: "To test these hypotheses, open water diurnal curve and light dark bottle methods, were used to ...."

Page 7:

1st paragraph, 1st full sentence: add "Bay" after "Corpus Christi", and a comma between "bay, Nueces Bay..."

Page 8:

2nd paragraph, 2nd sentence: put "(1996)" after "D'Avanzo et al.'s"

Page 9:

1st paragraph, 1st sentence: put a comma between "metabolism, the 15"

Page 9:

4th paragraph: I wonder if this analysis should have used a repeated measures ANOVA instead of just a straight 2-way?

Page 10:

2nd paragraph, last sentence: change sentence to read: "Net ecosystem metabolism on September 2003 was significantly lower than for June 2003 and December 2003."

3rd paragraph, 2nd sentence: insert "(i.e., primary production > respiration)" before "(Fig 4a-4b)."

3rd paragraph, 4th sentence: insert "(i.e., respiration dominated)" between "negative" and "than".

3rd paragraph, last sentence: change sentence to read: "Water column metabolism also becomes...."

4th paragraph, 1st sentence: change sentence to read: "Net ecosystem metabolism in summer tends to be positive (i.e., primary production dominates) with only ..."

4th paragraph, last sentence: start sentence with "However, lower bay..."

Page 11:

2nd paragraph, last sentence: end sentence with a period.

3rd paragraph, 1st and 2nd sentence: "Historically, whole ecosystem metabolism estimates have been calculated using the light-dark bottle method. Only recently, with the advent of...."

3rd paragraph, 4th sentence: should there be some hyphens between "benthic surface to water column volume ratio"

Page 12:

2nd paragraph, 1st sentence: change sentence to read: "Within-bay spatial variability appeared to be relatively small in this study with no significant pair-wise..."

3rd paragraph, 2nd sentence: change sentence to read: "The location in relation to freshwater inflow point sources may be the factor determining these between-bay differences because both stations 1 and 7 are located near river mouths while station 8 was relatively..."

Page 13:

1st paragraph, 5th sentence: It seems like a big inflow event would also cause a lot of allochthonous organic matter loading too, in addition to reducing photosynthesis through turbidity.

2nd paragraph, 1st sentence: change sentence to read: "...light-dark bottle methods for estimating whole ecosystem..."