Final Report

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Title: The paradox of the Delta: Protecting the biodiversity we do not yet understand
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Objective(s) of the Research Project

In 1995 Mobile Bay, Mobile, AL, became a part of one of the country's 28 National Estuary Programs (NEP). Included in the NEP study area is the Bay proper and a large section of the Mobile/Tensaw Delta. The Delta comprises over 250,000 acres of wetland habitat, particularly cypress-gum swamps and bottomland hardwood forest. While we know the MTD is one of the country's treasuries of biodiversity, little of this wealth has been documented. Because of this lack of basic knowledge, critical management decisions become little more than educated guesses. Of even greater concern is how our ignorance of the Delta's biota undermines our estimates of its health.

The results of our preliminary assessment of the insect biodiversity of the Mobile Tensaw Delta are the ***initial steps*** in a long term goal — the Total Insect Bioinventory Project (TIBP) of the delta. In its entirety, the TIBP will include the surveying, sorting, cataloguing, quantifying, and mapping of entities such as genes, chromosomal inversions, species, demes, populations, ecotypes, species, habitats, and communities. TIBP is intended to be a long-term program (20 years duration) and involve an international panel of expertise. Though neglected in many previous biological inventories, the importance of hyper-diverse groups, such as the insects, is now being recognized (e.g., Wilson 1987; Yoon 1993; Baldi 1999). We selected insects for study because i) they are major contributors to ecosystem processes; ii) they constitute the bulk of metazoan diversity; iii) they respond quickly to environmental changes; and iv) they are ubiquitous and easily collected (Longino & Colwell 1997).

Initially, the primary objective of this study was a preliminary assessment of the biodiversity of permanent running-water habitats of the MDT, using aquatic Diptera (two-winged flies) as the study animals. However, with no additional resources, we were able to expand the scope of work to include other aquatic insects. In addition, Malaise trap collections were undertaken to collect adult stages of many aquatic species. Our specific objectives, using insects as study animals were as follows: i) produce a preliminary inventory of aquatic insects of the MTD; ii) provide a preliminary assessment of the water quality based on the fauna collected; iii) establish a metric between habitat variation and faunal differences; iv) examine temporal changes in the insect community; v) model changes in biodiversity, species distributions, and genetic diversity among stream sites using site characters as predictors and; vi) link the patterns of biodiversity, species. Our report will concentrate on the following areas:

1. A preliminary survey of the aquatic and aerial insects of the MTD
2. Preliminary assessment of the water quality based on the fauna collected
3. The spatial-temporal ecology of waterscorpions

Progress Summary/Accomplishments

1. Methodology

The study area includes all waters and lands in the lower half of the Mobile/Tensaw Delta from 30.45° to 31.15° N and from 87.53° to 88.05° W.

Aquatic inventory: Permanent flowing water is the most pervasive aquatic habitat in the Delta and, therefore, was the main focus of interest for this preliminary study. Given the influence of stream size on insect communities (e.g., Allan 1995; McCreadie et al. 1995; McCreadie & Adler 1998) habitats were stratified on the basis of stream width. Thus, four small (< 10 m), four medium (ca. 20 - 40 m), and four large (> 60 m) streams were sampled monthly from June 2000 to May 2001. Streams were intentionally classified into three discrete, easily identified, non-overlapping sizes to prevent errors in site classification (e.g., McCreadie & Colbo 1991). Three sampling stations at each site were randomly chosen. Bank-side vegetation was sampled at each station with a standard D-net (Merritt et al. 1996) for 5 min. Thus, total sampling time per site was 15 min. Stream measurements were taken prior to sampling to ensure that subsequent sampling did not alter the readings. Water parameters measured were dissolved oxygen, pH, conductivity, depth, and temperature; width was taken from the Delorme® 3-D Topo Quad software for the state of Alabama.
An attempt was made to sample each of the 12 sites monthly for a year; however, due adverse weather this was not possible. Table 1 shows the achieved sampling schedule. Fig. 1 shows the location of the sampling sites.

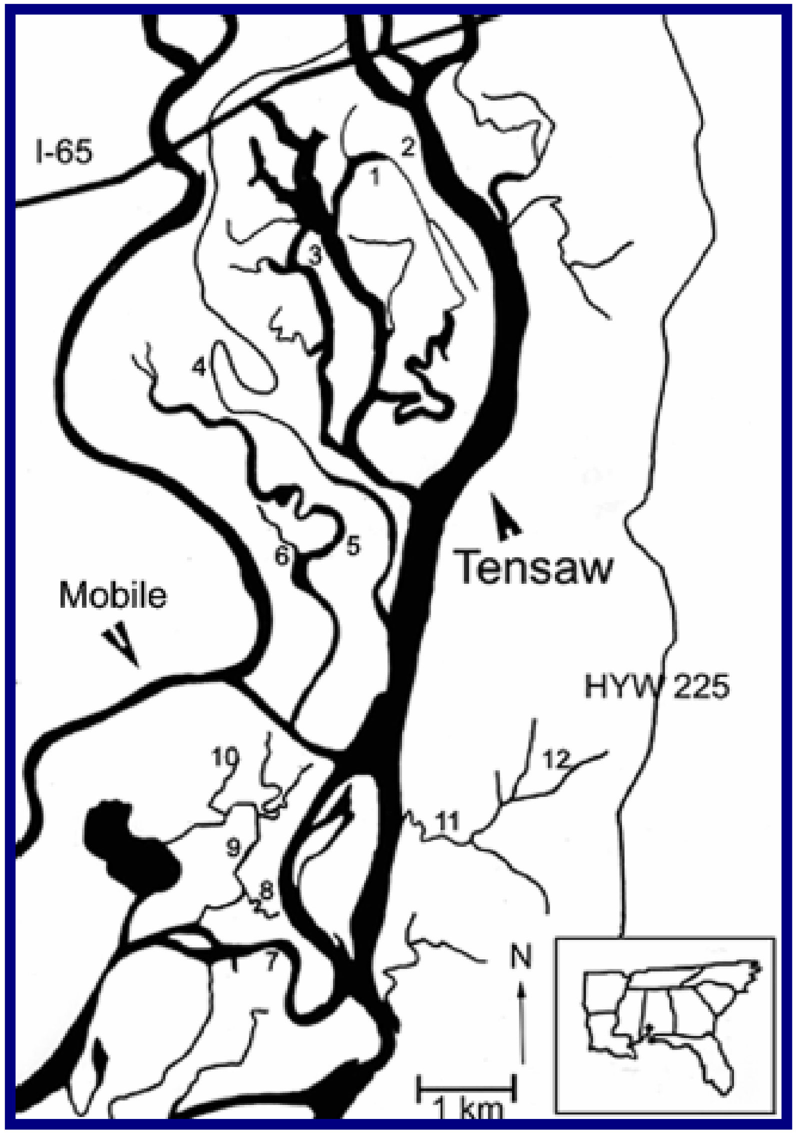

Figure1. Sampling site, Mobile / Tensaw Delta.

Terrestrial inventory: Many species of aquatic insects have adult stages that are terrestrial. Furthermore, many immature aquatic insects can only be identified in the adult stage. Thus, three Malaise traps were used to collect adult insects. Malaise traps were placed at Raft River, Byrnes Lake and Little Briar Creek (see Fig.1, Table 1).

The spatial-temporal ecology of waterscorpions: Waterscorpions (Hemiptera: Nepidae), are a taxonomically well known group of North American aquatic insects at the species level (Sites and Polhemus 1994). Given their taxonomic status and ubiquitous nature, waterscorpions are an ideal choice to examine the predictability of aquatic species distributions over a spatially heterogeneous landscape. The purpose of this study was to examine the spatial distribution of the waterscorpion, *Ranatra nigra*, in the lower Mobile/Tensaw Delta to determine if its distribution is predictable on the basis of select habitat parameters. In addition, the seasonal distribution of the parasitic mite *Hydrachna magniscutata (sensu lato)* associated with *R. nigra* was also examined.

Twenty-seven sites in the Delta were selected ranging from large rivers (450 m wide) to small bayous (10 m wide); all sites were accessible only by boat (Fig. 1). Sites were sampled once in the fall (10 - 16 October 2000) and again the following spring (22 May - 5 June 2001). Three sampling stations at each site were randomly chosen. Bank-side vegetation was sampled at each station with two types of nets for 5 min each. Thus, total sampling time per site was 30 min. The first net, with a 500 um mesh, measured 41 cm (length) x 30 cm (width) x 27 cm (depth of net) and was used for sampling in the heavy aquatic vegetation. The second net was a standard D-net (Merritt et al. 1996). Stream measurements were taken prior to sampling to ensure that subsequent sampling did not alter the readings. Water parameters measured were dissolved oxygen, pH, conductivity, and temperature; width was taken from the Delorme® 3-D Topo Quad software for the state of Alabama.

Prevalence (percent of infected *R. nigra*) and abundance (number of mites/infected host) of *Hydrachna magniscutata* were examined to determine if either varied with season. At each of the four sites selected for study, the dominant aquatic vegetation was sampled for *R. nigra* hosts. Sampling was conducted from 1 June 2000 to 5 June 2001. From October 2000 to February 2001 samples were taken monthly; in all other months sampling was conducted bi-weekly. At two sites (Maple Bayou, Smith Bayou; see Fig 1 and Table 1) both *Eichhornia crassipes* (water hyacinth) and *Ludwigia uruguayensis* (alligator weed) were sampled. In Big Briar Creek and Little Briar Creek only *Heteranthera dubia* and *Zizaniopsis miliacea* (wild southern rice) were sampled, respectively (Fig 1; Table 1). Five 5-min samples in each vegetation type at each site were conducted, with a 500 um aquatic net. Thus, net samples were undertaken for a total of 50 min each at Maple and Smith Bayou, and 25 min at Big and Little Briar Creek. Live *Ranatra* hosts were transported to the laboratory on ice, preserved in 80% ethanol, adults identified to species, and the number of mites on each specimen (nymphs and adults) counted. As above, it was assumed nymphs associated with adult *R. nigra* were also this species.

Because habitat variables in streams are typically correlated (e.g., Ciborowski and Adler 1990, McCreadie and Adler 1998), a principal components analysis (PCA) was used to collapse these variables into a smaller number of statistically independent principal components (PCs). PCs with eigenvalues greater than 1.0 (Norüsis 1985) replaced the original stream variables in all further analysis. Interpretation of each PC was based on correlations ($P < 0.01$) between the PC and the original stream variables (Ludwig and Reynolds 1988).

The first response (dependent) variable considered was the occurrence of *R. nigra* at each site. Because this is a binary variable, where 1 = the presence of *R. nigra* in a sample and 0 = absence in a sample, forward logistic multiple regression was used to estimate the probability of *R. nigra* being present at a site, given the measured stream conditions. Under the logistic function the probability that a species is present at the ith site is estimated using predictor variables, now expressed as PCs. Significance (at $P < 0.05$) of each predictor was entered into a model that was assessed using maximum likelihood estimation (Hosmer and Lemeshaw 1989). Season (0 = spring, 1 = fall) was used as a dummy variable. The second response (dependent) variable considered was the abundance of *R. nigra* at each site. A stepwise (ordinary least squares) multiple regression routine was used to relate abundance to PCs and second order terms of these PCs. Season was also used as a dummy variable.

Species identifications and data base: In the laboratory, specimens were identified to the lowest taxonomic unit (LTU), which is preferentially the species level. Identifications were conducted either by the authors of this report or by other taxonomic authorities. All specimens identified to date, along with all relevant collection data, have been entered into a FILE MAKER PRO v 6.0 data base. Voucher specimens from identifications have been deposited in both the University of South Alabama Arthropod Depository as well as the institutes of the assisting taxonomic authorities.

Quality Assurance: Concerns for quality control came from two broadly different areas. First, and of prime importance was accuracy in insect identification. Quality assurance was achieved in this area via two mechanisms. First, many specimens were identified by the leading taxonomic authorities for each particular group (usually family) of insects. Secondly, representative specimens identified by the authors of this report were confirmed, again by taxonomic authorities. The second major area of concern for quality control was in the measurement of stream habitat parameters. Quality assurance was achieved here by calibrating both the pH and oxygen meters before each measurement. The conductivity/temperature and depth meters were checked monthly. The GPS units were checked against known positions monthly.

2. Results

Bio-inventory: Table 1.1 provides the names and locations of all sites sampled and the D-net sampling schedule. Inclement weather prohibited sampling in November and February. Also, at some sites, vegetation disappeared during January and March, precluding sampling. Given in Table 2 is a preliminary list of the families of insects identified to date from the D-net and Malaise traps samples to date.

Table. 1. Sampling schedule of D-nets samples.

Site Name	Map No.	Size Class	June	July	Aug.	Sept.	Oct	Dec.	Jan.	March	April	May
Byrnes Tributary 30.98°N, 87.90°W	12	small	✓	✓	✓	✓	✓	✓	✓	no vegetation	✓	✓
Byrnes Lake 30.79°N, 87.91°W	11	medium	✓	✓	✓	✓	✓	✓	no vegetation	no vegetation	✓	✓
Raft River 30.77°N, 87.95°W	7	large	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oak Bayou Tributary 30.78°N, 87.95°W	9	medium	✓	✓	✓	✓	✓	✓	no vegetation	✓	✓	✓
Oak Leaf Bayou Tributary 30.81°N, 87.95°W	10	small	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Maple Bayou Tributary 30.90°N, 87.90°W	2	small	✓	✓	✓	✓	✓	stream dry	stream dry	no vegetation	✓	✓
Maple Bayou 30.90°N, 87.91°W	1	medium	✓	✓	✓	✓	✓	✓	✓	no vegetation	✓	✓
Negro Lake 30.89°N, 87.93°W	3	large	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Big Lizard 30.88°N, 87.96°W	4	medium	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Oak Bayou 30.79°N, 87.95°W	8	large	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
Big Briar Creek 30.84°N, 87.93°W	5	large	✓	✓	✓	✓	✓	no vegetati on	no vegetation	✓	✓	✓
Little Briar Creek 30.84°N, 87.94°W	6	small	✓	✓	✓	✓	✓	✓	no vegetation	✓	✓	✓

Temperature, pH, conductivity, oxygen, and depth data at the time of collection are available for each site either as FILE MARKER PRO v. 6.0 file or MS-DOS text. Figure 2 provides an example of this type of data. In this case, seasonal variation in conductivity is presented for three sites (one small , one medium, one large) from June 2000 - June 2001.

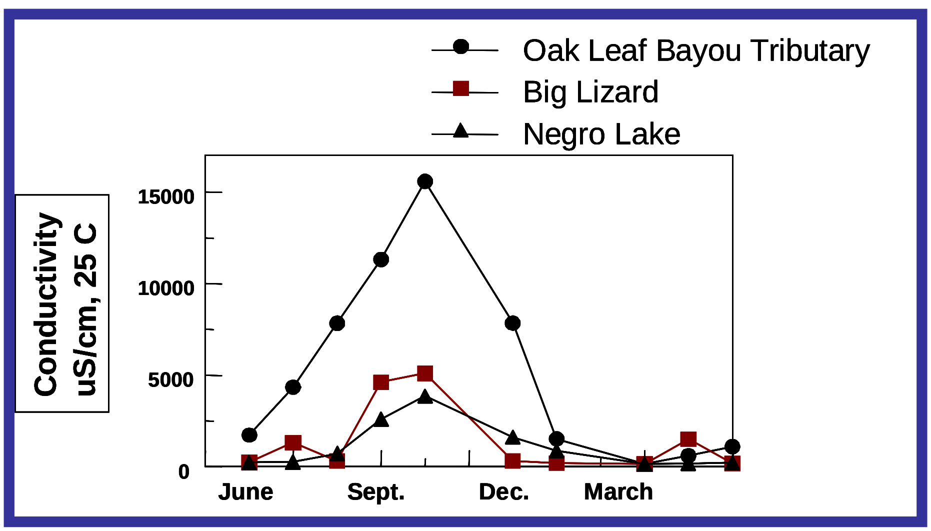

Figure 2. Seasonal variation in conductivity at three select sites on the Mobile Tensaw Delta, June 2000 – June 2001.

More than 50,000 insects have been sorted to the level of family. Many of these specimens have been sent to the leading taxonomic specialists. At the time of this report insects from 9 orders, 43 families, 170 genera, and 240 species have been identified. Table 2 shows our current (as of March 20, 2003) list of identified species. This list will continue to grow as our collaborating taxonomic authorities return their identifications. About 6% of these species are completely new to science, never before seen. Many additional species are state records for Alabama, and some represent the southernmost distribution records. For example, in the Chironomidae, a group of insects for which distribution records are well known, more than 50% of the species are state records.

To date, our data base contains over 900 entries and continues to grow as taxonomic authorities return their identifications to us. A list of species identified to date will be available upon request. as either FileMaker Pro or MS-DOS files.

Table 2. Summary of insect identifications from the Mobile / Tensaw Delta, as of March 20, 2003.

Collection Method	Order	Family	No. of Genera	No. of species
Malaise trap	Blattaria	Blattellidae	1	1
Malaise trap	Coleoptera	Anobiidae	1	1
		Cerambycidae	2	2
		Lampyridae	1	1
		Melandryidae	1	1
		Mordellidae	1	1
Malaise trap	Diptera	Athomyiidae	5	5
		Bibionidae	2	2
		Calliphoridae	1	1
		Ceratopogonidae	11	23
		Chaoboridae	1	1
		Chironomidae	23	45
		Corethrellidae	1	1
		Culicidae	3	3
		Dolichopodidae	16	41
		Drosophilidae	1	1
		Empididae	4	4
		Ephydridae	5	5
		Heleomyzidae	1	1
		Micropezidae	1	1
		Odiniidae	1	1
		Phoridae	3	3
		Psychodidae	11	20
		Ptilodactylidae	1	1
		Ptychopteridae	1	1
		Rhagionidae	1	1
		Rhinophoridae	1	1
		Sciomyzidae	2	2
		Stratiomyidae	1	2
		Syrphidae	3	3

		Tabanidae	2	2
		Tachinidae	13	15
		Tipulidae	16	29
D-net	Hemiptera	Belostomatidae	1	2
		Naucoridae	1	1
		Nepidae	1	4
Malaise trap	Hymenoptera	Formicidae	7	9
		Mutillidae	2	2
		Sphecidae	1	1
		Vespidae	1	1
Malaise trap	Lepidoptera	Arctiidae	1	1
		Noctuidae	2	2
		Nymphalidae	1	1
Malaise trap	Neuroptera	Hemerobiidae	1	1
D-net	Odonata	Aeshnidae	3	3
		Coenagrionidae	2	12
		Lestidae	1	1
		Libellulidae	6	6
Malaise trap	Trichoptera	Leptoceridae	1	3

The spatial-temporal ecology of waterscorpions: Sixty-two percent of the 53 collections contained *R. nigra*. Logistic regression (Equation 1) shows that *R. nigra* is more likely to occur in smaller, cooler streams, with lower oxygen and pH levels and higher conductivity (PC1) and at sites that are closer to Mobile Bay (PC3). The regression was highly significant (G = 15.56, df = 2, $P < 0.001$) and concordance was 80.8%, indicating the model was a good fit to the observed data.

$$Y = 0.73 - 0.48\, PC_1 - 1.19\, PC_3 \quad (1)$$

The number of *R. nigra* at each collection varied from 0 - 30. Stepwise regression (Equation 2) indicated this species tends to be most abundant closer to the Mobile Bay (PC3) and decreased in numbers further into the delta. This regression was highly significant (F = 7.48, df = 1,26, $P < 0.001$) although predictive ability was low (R^2 = 20.0%). Regression diagnostics indicate that the model is a good fit to the data, i.e., there is no lack of fit or observations with undue influence.

$$Log\, (Y+1) = 0.52 - 0.17\, PC_3 - 0.11\, (PC_3)^2 \quad (2)$$

Both adult and immature waterscorpions were infected with mites. Chi-square analysis showed that the highest proportion of infected waterscorpions was found in the fall and the lowest incidence occurred in the spring ($\chi^2 = 24.71$, $P < 0.001$). Chi-square analysis compiled from the spatial data set indicated that there was a greater proportion of infected waterscorpions in the fall than the spring ($\chi^2 = 18.75$, $P < 0.001$). The analysis of the abundance of mites on waterscorpions over three seasons revealed no significant difference (F

= 0.04, *P* = 0.956, *df* = 2,70) in abundance of mites on infected waterscorpions among season. A *t-test* conducted on the spatial data for the fall (2000) and spring (2001) also indicated no significant difference (*t* = 0.49, *P* = 0.63, df = *21*) in mite abundance between these two sets of samples. Accordingly, the proportion of infected hosts with mites varied with season; however, the mean number of mites on each infected host remained constant over time.

3. Significance

In any field of science, there are certain quantities that are crucial to know in order to understand complex systems. Astoundingly, we lack one of the most basic quantities of biology, the number of species currently living on the planet (Wilson 1985). We do not even know this figure within an order of magnitude. Even at a local scale, such as a state or county, we rarely, know the approximate number of species present. Recent studies show that current human exploitation and destruction of biodiversity is so high that biological surveys are essential if catastrophic losses of species are to be prevented (Stork et al. 1996). The need for biological inventories has spawned the formation of a variety of programs such as the All Taxa Biodiversity Inventory of the Great Smoky Mountains National Park (ATBI), the Biological Observatory Network (BON), and the Biological Resource Division (BRD) of the Department of Interior (Dalton, 1999; Wagner, 1999).

Our study is the first detailed insect survey of the Mobile/Tensaw Delta. Of particular interest was the running water habitats of the delta. Large rivers, like many channels of the Mobile/Tensaw Delta, with its associated sloughs, backwater areas and forested floodplains, have been especially problematic to study. Hence, few studies on running-water systems have been devoted to large river habitats (Hynes 1989). It is only recently that studies are starting to focus on these large river ecosystems (Benke 2001; Dettmers et al. 2001; Lewis et al. 2001). Examination of these areas has been slow due to the difficulty of working in these habitats (Johnson et al. 1995). The current study is the first detailed study of insects in the Mobile/Tensaw Delta. Most aquatic insect studies in lotic habitats have been conducted in the faster flowing streams of the higher elevations, with relatively little work in the slower moving rivers and streams close to the coasts (Batzer and Wissinger 1996, Smith 1988). Near the coast, many freshwater systems are unique in that they share characteristics of lakes/ponds and rivers/streams. For example, many channels in the Delta show lentic characteristics, such as very slow moving water with quiet littoral margins.

Of particular concern in this study was the low diversity of insects found in the part of the delta we examined. Given the high diversity of insects in the southeastern part of the United States, we would have expected a much greater number of species. We propose two possibilities that could account for this low insect diversity:

i) the lower part of the delta may be naturally low in insect diversity due to factors such as saltwater intrusion into both the aquatic and terrestrial habitats.

ii) the lower part of the delta may be low in insect diversity due to anthropogenic influences such as pollution from upstream industries.

It should also be noted that we have only examined the lower part of the Mobile Tensaw Delta (i.e., south of Interstate 65). The upper part of the delta presents somewhat different habitats, such as drier more upland forested areas, and it might be in this area where biodiversity flourishes. Clearly, further study on both the upper and lower delta are justified, including detailed analysis of water quality for potential indicators of anthropogenic influences.

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Future activities

We intend to expand the survey of delta arthropods to include additional taxa such as other insects, millipedes, and opiliones, and to continue to build the reference collection of delta arthropods currently housed at the University of South Alabama. We will compare the arthropod fauna of the delta with that of the Great Smoky Mountains National Park, the only other nearby area where an intensive survey of arthropods has been conducted. This comparison will provide insight into north-south latitudinal trends in arthropod biodiversity and suggest which arthropods might be at the southern limit of their ranges. Additional emphasis will be placed on the new species that have been discovered in the delta, with particular attention to their life histories and the potential that they might be endemic to the delta.

Supplemental Keywords

aquatic, survey, faunistics, insects, lotic

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