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Effects of Exposure to Low Concentrations of Mercury on Glycine Alpha-3, -6 GABA-A Chloride and Glutamate-Gated Channel Receptors in the HepG2 Cell Line in Culture

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ABSTRACT

Neuronal networking in specific regions of the developing brain including the hippocampus is critically regulated by GABAergic signaling. Sequential progression in several stages of development during embryogenesis commence with first formation of functional GABAergic synapses and culminate in organized initial signals that play important regulatory roles in the growth of young neurons that lay the foundation for the normal establishment of central and peripheral networks necessary for brain activities. Normal development of the nervous system and certain forms of epileptogenesis, for instance, has a common pathway during growth of neurons and axons. This observation has led to the belief that there must be common molecular mechanisms for some aspects of normal development and epileptogenesis; indicating also that there must be some distinct paths between normality and abnormal neurogenesis. Developmental mechanisms therefore contribute to network changes associated with several CNS pathologies. This forms a useful strategy for identifying molecules that play a role in both of these processes. In the course of synapses formation exposure to xenobiotics, mercury in particular exerts maximal harm on growth patterns in the CNS and thus contributes to eventual dysfunctions in behavior at later years. Behavioral deficits reminiscent of low level mercury toxicity, that appear years after birth are difficult to be retrospectively associated with processes occurring in early developmental periods. Thus it is a challenge to decipher the molecular mechanisms underlying mercury-provoked neuropathies. We previously demonstrated through microarray analyses that exposure to mercury differentially influence activities of numerous genes including induction of cytotoxicity, apoptosis and activation of several genes in almost all human chromosomes via transcription. In this communication we hypothesize that developmental processes are influenced by specific regulatory molecules that play important roles; changes in their expression levels can lead to alterations in the signal transduction pathways influencing normal synapses formation or functions leading to pathology. We therefore used Affymetrix oligonucleotide microarray with minimal probe sets complementary to over 20,000 genes to demonstrate expression patterns of genes on human chromosomes that particularly regulate neuronal development and lead to behavioral deviations. We observed that GABAergic-associated signaling molecules, Glycine Alpha-3, -6 GABA-A Chloride and Glutamate-gated Channel receptors in HepG2 cells were highly overexpressed above background levels upon exposure to low doses of mercury (1-3μg/mL). These molecules are found in distinct areas of the brain and exposure to mercury in the perinatal period can lead to the induction of high expression levels of these receptors sufficient to guide pathological neuronal networking through effects on genes expressed on several chromosomes including 4 and 5.

INTRODUCTION

Brain activities depend among others, on signaling via the GABAergic system of neurotransmitters. Approximately nineteen (α_{1-6}, β_{1-3}, γ_{1-3}, δ, ε, θ, π, and ρ1-3) known GABA receptor subunits form varieties of functional clusters throughout areas of the brain. These clusters are involved in generating neurotransmitters for specific brain activities (Hevers and Luddens, 1998). Among these receptors we find $GABA_A$ glycine- and glutamate-gated receptors forming major inhibitory and excitatory signal transducing molecules respectively in regions of mammalian brains (Fritschy and Mohler, 1999; Collins et al., 2006). At least 15 of these subunits (α1-6, β1-3, γ1-3, θ, and ρ1-2) form clusters associated with various forms of neuropathy (Collins et al., 2006; Loup et al. 2000; Peng et al. 2004; Houser and Esclapez 2003; Narahashi et al. 1994). The $GABA_A$-receptors families are heterogeneously distinct structures expressed as heteromeric receptor complexes. Subunit composition of receptor subtypes determine physiological properties as well as their pharmacological profiles, thereby contributing to flexibility in signal transduction and allosteric modulation. The functional capabilities of individual receptor subunits influence the quality of signaling in different parts of the brain through formation of specific *pentamers* that display characteristic influence through release of neurotransmitters (Hevers and Luddens, 1998).

Yet a variety of chemicals influence and are capable of modifying the $GABA_A$ receptor-chloride channel complexes. Diverse forms of structurally unrelated chemicals do augment the GABA-induced chloride current, while others suppress the process. Mercury, like other heavy metals and a variety of polyvalent cations enhance or repress the current in a potent and efficacious manner. $GABA_A$–mediated responses are implicated in several dysfunctional behaviors observable in anxiety state, depressive moods, epileptic episodes, insomnia, learning and memory impairments. The glutamate (Glu)-gated responses, among others lead to major excitatory responses in the nervous system (Peng et al, 2004; Houser and Esclapez, 2003; Narahashi et al. 1994). Nevertheless, the functions of Glu are much more diverse and complex. Glu plays a significant role in brain development; it affects migratory properties of neurons and their differentiation, axon genesis, and neuronal survival (Erlander and Tobin, 1991). In the mature nervous system, Glu is pivotal in neuroplasticity, in which there are use-dependent changes in synaptic efficacy as well as alterations in synaptic structure (Tsai et al, 1995; Kristensen et al, 1993, Scimemi et al, 2005). Memory generation and cognitive functions depend on these activities. Persistent or overwhelming activation of Glu-gated ion channels can cause neuronal degeneration via necrosis or apoptosis (Loup et al., 2000). Neuronal ‘‘excitotoxicity,’’ is a described phenomenon linked to the final common pathway of death of neurons in described disorders including Huntington’s and Alzheimer’s diseases, amyotrophic lateral sclerosis (ALS), fragile X syndrome, the most common form of inherited mental retardation, and some autistic attributes that also result from synaptic inhibitions associated with the $GABA_A$ receptors/ligand interactions culminating in behavioral dysfunctions, strokes (Loup et al., 2000, Peng et al., 2004, Houser and Esclapez, 2003. Narahashi et al., 1994) and may play an important role in the etiology of schizophrenia (Tsai et al., 1995, Kristensen et al., 1993).

The subunit composition and stoichiometry of native $GABA_A$-receptor subtypes however remain unknown. Immunoperoxidase staining techniques reveal regional and cellular distribution of seven major subunits (α1, α3, α5, β2, 3, γ2, δ) expressed in adult rat brain and have been allocated to identified neurons (Collins et al., 2006). A cloned α-subunit isoform (α_6), which also confers unique pharmacology to recombinantly expressed $GABA_A$ receptors, is only expressed in a single neuron subtype- the cerebellar granule neuron (Scimemi et al., 2005). A combination of α-, β-, and γ- subunit variants are required in functional heterologous expression systems; for example the γ2- subunit is essential for the receptor to express a classical benzodiazepine site. Thus functional and morphologically diverse neurons have been characterized by a distinct $GABA_A$-receptor subunit repertoire. These data provide the basis for a functional and/or brain dysfunctional analysis of

$GABA_A$-receptor subtypes of known subunit composition that may reveal the path for yet to be substantiated therapeutic approaches relying on the development of subtype-selective drugs (Erlander and Tobin 1991; Olsen and Tobin 1990, Nakanishi, 1992, Vandenberg et al., 1992, Lüddens and Wisden 1991).

Albeit, mercury is recognized as an environmental teratogen that selectively affects the nervous and other systems of the body. Various investigations have attempted to establish a correlation between mercury level in humans and toxic reactions in the nervous system (Olsen and Tobin 1990, Nakanishi, 1992, Vandenberg et al., 1992, Lüddens and Wisden 1991, Philbert et al., 2000, Nierenberg et al., 1998). Contact with mercury at the time of neuronal networking has a profound neurotoxic effect on growing embryos particularly during organogenesis (Urbach et al., 1992). Mercury is a metal universally found in nature in the air, water, diet and other environmental pollutants that are public health hazards to which expecting mothers are constantly exposed. It has the potential at high doses to cause DNA damage to the growing fetus mainly by interacting with functional sulphydryl groups and enzymes in cells and thus influencing several metabolic pathways including cell cycle progression and/or apoptosis. Mercury grossly affects most genes involved in immune responses and induces various physical deformities: cleft lip and palate, rib defects, syndactylies, and abnormal skeletal calcification. Micrognathia and clubfeet are common during mercury intoxication in the fetal period. It inhibits *in vitro* microtubule formation and protein synthesis in neurons, alters membrane activity, and disrupts DNA synthesis (Fig 2). Mercury impairs mitosis and interferes with neuronal migration within the cell. Low levels of $HgCl_2$ or phenyl mercuric acetate induce abortion, growth retardation, and generate subcutaneous edema, excencephaly and anophthalmia (Chan 1998; Urbach et al., 1992, Goyer, 1996). Severe neurogenic pain syndrome develops in mercury neuropathy into a severe motor pain portraying signs and symptoms of both axonal degeneration and Güillain-Barré-like illnesses in humans (Adams et al. 1983, Urbach et al., 1992).

Intoxications simulating real ALS conditions are associated with mercury exposure; these individuals present a range of neurological symptoms from tremors, insomnia, polyneuropathy, paresthesias, emotional lability, irritability, personality changes, headaches, weakness, blurred vision, dysarthria or speech impairment, slowed mental responses ranging from insomnia, forgetfulness, and loss of appetite, as well as mild tremor that may be misdiagnosed as psychiatric illness to unsteady gait in movement (Urbach et al., 1992, Goyer, 1996). Despite such presentations, it has proved difficult to measure the threshold for reference dose (RFD) for mercury: the lowest dose tolerated by humans without any side effects with highest consideration to natal periods (Stem 1993). This is primarily due to the poorly understood individual susceptibility to mercury.

Humans with unique major histocompatibility complex (MHC) antigens are prone to develop characteristic autoallergies/immunity on exposure to mercury; but the general effect seen phenotypically as well as psychological abnormal behavioral deficiencies associated with neural attacks are not well explained and investigated. Here we attempt to show relative expressions of genes involved in brain homeostasis by measuring *in vitro* receptors expression levels in human liver $HepG_2$ cell-lines that are exposed to low levels of mercury [1-3μg/mL]; we explore possible mechanisms leading to disturbances in brain homeostasis in humans during exposure to this metal at embryogenesis. It is our hypothesis that mercury exerts dose-related disruptions through its selective effects on genes that have influence on time-dependent neuronal network formation and thus induce variations in the severity of diseases in susceptible individuals. We used Affymetrix oligonucleotide microarray studies to find out the relative effects of low doses of mercury on chromosomes that express genes influencing human behavior, the Glycine Alpha-3, -6 GABA-A Chloride and Glutamate-gated Channel Receptors.

MATERIALS AND METHODS

Cell culture and Harvesting: Standard solutions of 10, 20 and 30 μg/mL mercury concentrations in RNAse-free phosphate buffered solution pH 7.3 were prepared from stock solution of 10,000μg/mL

[in 10% HNO_3]. Tenfold dilution in RPMI growth medium, supplemented with 10%-15% Fetal Bovine Serum [FBS] and 1% penicillin-streptomycin were then prepared for culturing $HepG_2$ cell-line previously kept under liquid nitrogen. Cells were incubated for a total of 48 hours at 37^OC in a 5% CO2-humidified environment. After the first 24 hours cells were washed in appropriate media and further incubated for 24 hours to achieve approximately 95% confluence. RNEasy kits (Qiagen) were used to isolate and purify RNA from the test and control HepG2 cells. Samples were initially lysed and homogenized in the presence of a highly denaturing guanidine isothiocyanate (GITC)-containing buffer. Addition of equal volumes of ethanol provides appropriate binding conditions, the sample was then applied to an RNeasy mini column where the total RNA binds to the membrane and contaminations are efficiently washed away. High quality RNA was then eluted in 30 µl-100 µl of RNAse free deionized water. Concentration of extracted RNA was computed based on equivalency of 40 µg/mL of RNA per mL in RNAse free deionized water taking into account the amount of RNAse free deionized water used for the final elution (between 30-100 µl) dependent on amount of extract. Optical readings at A_{260} and A_{280} nm Absorbance (A) of RNA extracts were carried out using UV/VIS/NIR spectrophotometer Lambda 20 (Perkin Elmer) as previously described (Ayensu and Tchounwou 2006).

Probe Array Scan and Catching the Microarray Image: We utilized Affymetrix Microarray Suite scanner having argon-ion laser equipped with a safety interlock system to scan and interrogate the Streptavidin-stained genes hybridized to u133 series of Affymetrix chips. Scanner was set at 2 X image scan, 3 µm pixel values, at wavelength 570 nm for 50 µm probe arrays with probe cells 24 µm or less. For each gene, the relative expression in the exposed as compared to the control or baseline was determined for each cDNA. Internal controls employed during hybridization were kindly supplied by Affymetrix Inc. to normalize for differences in mRNA quality and efficiency of probe labeling. This procedure improves data quality used for downstream analysis. For each concentration, gene expression levels in control cells that have not been exposed to mercury were used to compare to test samples as described in Ayensu and Tchounwou 2006 and Affymetrix manual, 2002.

Statistical Analysis: Affymetrix Expression Batch Query was utilized employing the Wilcoxon's Signed Rank (WSR) test as a means for comparisons between mercury-treated (1-3µg/mL concentrations) test and control HepG2 gene expressions. Stat common pairs, the intersection of the probe pairs from the baseline and experiment that are used by the Expression algorithm to make the change call were generated as signal log ratio (SLR) from the fluorescence signals emitted by the probes; SLR correlates with measure of the abundance of a transcript reflecting the change in the expression level of a transcript between a baseline noise (control) versus an experimental array. A log_2 signal ratio of 1 is equal to a fold change of 2. SLR, the quantitative change in transcript abundance estimates the magnitude and direction of change of a transcript of two arrays; see Ayensu and Tchounwou 2006 and/or Affymetrix manual, 2002 for complete experimental procedure including the hybridization and staining techniques.

RESULTS

Our results show that low levels of mercury (1-3 µg/mL) has variable effects on stimulating haplotypes associated with human chromosomes 4, 5, 6, 15 and 17 that are associated with neurogenesis. There are enhanced expressions of genes located on *4p12, 4q33-q34, 4q34.1, 5q31.3, 6q22-q23, 15q21,* and *17p13.1* while *5q35* genes were down regulated. Genes on 4p12 haplotypes experienced increases of 6, 4 and 5 SLRs compared to controls. Haplotypes 4q33-34 and *5q34* carrying Glycine Alpha 3 GLRA3 HGNC, a GABA-alpha receptor ion-channel (receptor, alpha 3 subunit), glutamate-gated activity as well as Gamma Amino Butyric Acid A receptor, an alpha 6 (GABARA6 HGNC) activity, respectively experienced fold changes of 64, 1024, and 256 equivalent to SRL levels of 6, 10 and 8 respectively relative to the concentration ranges 1, 2 and 3µg/mL of mercury exposure. Haplotype *4q* is highly susceptible to mercury exposure resulting in folds higher than its effect on *5q*. On the other hand the effect of mercury on *17p13.1* haplotypes was rather mild with only doubling from the background counts while expressions of haplotype *5q35* were rather downregulated with respect to background

counts on concentrations of 2 and 3µg/mL. No changes in levels were seen at 1µg/mL mercury exposure.

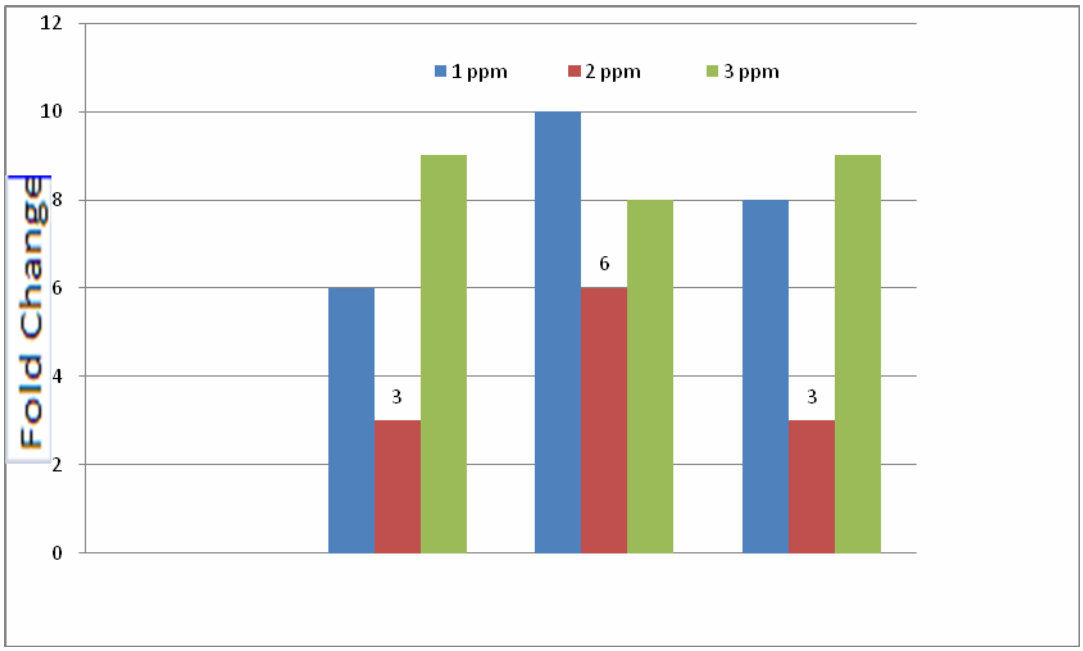
On average linked genes on chromosomes *4* and *5* were up-regulated with greater than a 6- and 3-SLR differences, respectively ($p \leq 0.002$) showing a clear separation in their gene expression profiles; Table 1; Figures 1, 2 and 3. Responses of these genes to mercury exposure in this study could be exploited to elucidate molecular mechanisms involved in receptors' role in mercury induced selective injury of the CNS that culminates in both physical and psychosocial disorders like Huntington's and Alzheimer's diseases, amyotrophic lateral sclerosis (ALS), fragile X syndrome, the most common form of inherited mental retardation, autistic behaviors and strokes. Genes located on chromosome 4 express GABA-A receptor subtype 3 while genes on chromosome 5 regulate expressions of GABA-A receptor subtype 6. Further analysis of mercury's role in influencing the alpha subunit levels in these molecules will be an added help to explain the role of mercury in CNS toxicopathogenesis. On probe set *207182_at* chromosome *5q34*, the expression levels were 3 SLR or 8 folds, 8 SLR or 256 folds, 3 SLR or 8 fold increases in expressing Gamma-aminobutyric acid (GABA) A receptor, alpha 6 (GABRA6 HGNC). This differential increases in the activities of subunits of glycine receptor alpha 3 and alpha 6 indicates the capability of mercury in influencing activities in the CNS as well as the PNS that may lead to several phenotypic expressions in behavior. By increasing receptor sites for alpha 3 and 6 it is possible to influence excitatory as well as inhibitory pathways. The behavioral consequences of such pharmacologically induced changes in the balance between inhibition and excitation are often profound (e.g., following administration of convulsant or anesthetic drugs which are known to alter GABAergic or glutamatergic neurotransmission).

Table 1: Human Chromosomes Responses to Low Levels of Mercury

PROBE SET ID	Gene Title (target Description)/symbol	Chromosome Location	SLR Change/ Fold Change (Affy)	SLR Change/ Fold Change (Affy)	SLR Change/ Fold Change (Affy)
			1µg/mL Hg	2µg/mL Hg	3µg/mL Hg
207009_at	Paired-like homeobox 2b; PHOX2B HGNC; 6355 regulation of transcription, DNA dependent; 7275 development; 7399 neurogenesis; 5634 nucleus; 3700 transcription factor activity; 3712 transcription cofactor activity.	4p12	6/64	4/16	5/32
207928_s_at	Glycine receptor, alpha 3; GLRA3 HGNC; GABA-A receptor activity; ion channel activity; extracellular ligand-gated ion channel activity, glycine binding (receptor, alpha 3 subunit), glutamate - gated chloride channel activity; neurotransmitter receptor activity; synaptic transmission	4q33-q34	6/64	10/1024	8/256
213963_s_at	Sin3-associated polypeptide, 30kDa; histone deacetylase complex; transcription corepressor activity corepressor activity	4q34.1	4/16	3/8	1/2
215378_at	Ankyrin repeat and KH domain containing 1; ANKHD1 HGNC; nucleic acid binding; cell cycle inhibitor p16ink4A; immunoglobulin heavy chain variable domain, VH; transcription factor NusA, receptor, different EGF domains; Class II MHC alpha chain, C-terminal domain; Silencer of death domains, Sodd (Bag 4); Staphylokinase.	5q31.3	2/4	2/4	2/4
207182_at	Gamma-aminobutyric acid (GABA) A receptor, alpha 6 (GABRA6 HGNC)	5q34	3/8	8/256	3/8

203812_at	Slit homolog 3 (Drosophila/SLIT3 HGNC); neurogenesis, calcium ion binding, protein binding.	5q35	0/1	-1/-2	-1/-2
205029_s_at	Fatty acid binding protein 7, brain; FABP7 HGNC; 6631FA metabolism; 6810 transport; 7399 neurogenesis; 8285 negative regulation of cell proliferation; 5215 transporter activity; 5478 Intracellular transporter activity; 8289 lipid binding.	6q22-q23	7/128	5/32	8/256
219196_at	Secretogranin III SCG3 HGNC; Transcript alignment(s)- NM_013243 NCBI-Homo sapiens secretogranin III (SCGS), mRNA.	15q21	9/512	8/256	9/512
207704_s_at	Growth arrest-specific 7/GAS HGNC; 7050 cell cycle arrest; 7275 development; 7399 neurogenesis; 8151cell growth and/or maintenance; 3700 transcription factor activity: Database ID: d1srda_SCOP:b.1.8.1:| Cu, Zn superoxide dismutase, SOD.	17p13.1	1/2	1/2	2/4

SLR: signal log ratio; Affy: affymetrix.



207928_s_at: Glycine receptor, alpha 3; GLRA3 HGNC	4q33-q34	6/64	10/1024	8/256
207182_at: Gamma-aminobutyric acid (GABA) A receptor, alpha 6 (GABRA6 HGNC)	5q34	3/8	6/64	3/6
219196_at Secretogranin III SCG3 HGNC; Transcript alignment(s) - NM_013243 NCBI-Homo sapiens secretogranin III (SCGS), mRNA.	15q21	9/512	8/256	9/512

Figure 1: Genes Up-regulated on Human Chromosomes in Responses to Low Levels of Mercury (1-3 µg/mL)

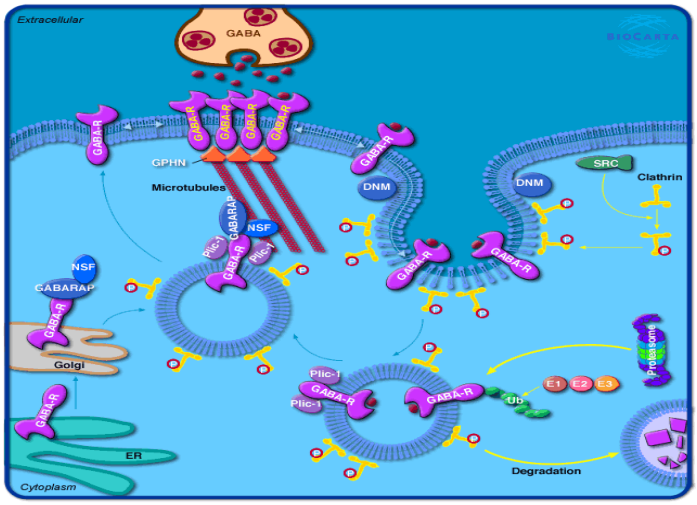


Figure 2 GABA R-Ligand Pathway Interactions: BioCarta Mode
Ref: http://www.biocarta.com/genes/expression.asp

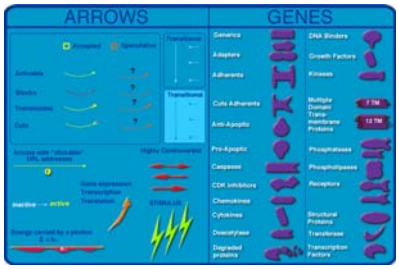


Figure 3 Legend to Fig 2: Gamma-aminobutyric Acid Receptor Life Cycle
Ref: http://www.biocarta.com/genes/expression.asp

DISCUSSION

GABA and glycine are probably the most important inhibitory neurotransmitters in the brain, specifically brainstem and spinal cord, respectively. Glycine is the major inhibitory neurotransmitter that participates in a variety of motor and sensory functions. Glycine is also found in the forebrain, where it has recently been shown to function as a coagonist at the N-methyl-D-aspartate [NMDA] subtype of glutamate receptor. Glycine promotes the actions of glutamate, the major excitatory neurotransmitter and therefore subserves both inhibitory and excitatory functions within the CNS. Current thoughts indicate that most GABAergic neurons in the brain are probably interneurons and are therefore uniquely able to alter the excitability of local circuits within a given brain region (Olsen and Tobin 1990). It has previously been shown that mercury chloride augments the GABA-induced current to 115% of control at 0.1 microM and to 270% of control at 100 microM and generated a slowly developing inward current carried by a variety of ions. In contrast, methylmercury suppressed the GABA-induced current. The potent stimulation of the GABA system by mercuric chloride is deemed important in mercury intoxication (Narahashi et al., 1994). Close to 30–40% of all CNS neurons utilize GABA as their primary neurotransmitter.

Animal models and humans with temporal lobe epilepsy (TLE) show alterations in relative ratios of $GABA_A$ receptor ($GABA_AR$) subunits (Hevers and Luddens, 1998, Fritschy and Mohler 1995, 1999, Collins et al., 2006, Loup et al., 2000; Peng et al., 2004, Houser and Esclapez, 2003). These changes are complex and may involve both increased and decreased expressions of several $GABA_AR$ subunits (Figure 1). The functional consequences of these changes are likely to depend not only on the specific subunits that are altered but also on the cell types and cellular domains (e.g., soma and dendrites) in which the alterations occur at the location of the subunits in synaptic, perisynaptic, or extrasynaptic sites; and the resulting subunit composition of the modified receptors. It is for instance proposed that an altered expression of the $GABA_A$ receptor has neurophysiologic and functional consequences that might relate to the behavioral and neurological phenotype associated with fragile X syndrome (Collins et al., 2006). Interestingly, some neuropsychiatric disorders, such as anxiety, epilepsy and sleep disorders, are effectively treated with therapeutic agents that act on the $GABA_A$ receptor.

Many psychoactive drugs which enhance or decrease CNS excitability operate through GABAergic or glycinergic neurotransmission. Some of these drugs for example benzodiazepine and nonbenzodiazepine anxiolytic–hypnotics are routinely prescribed for a variety of disorders. Studies in how mercury affects behavioral alterations by its genetic upregulation of the alpha 3 and 6 subunits may assist in evaluating these receptor properties. The expression of the γ subunit seems to be essential for conferring the modulatory actions of benzodiazepines on recombinant $GABA_A$ receptors and it appears that α-subunit heterogeneity determines the diversity of physiological and pharmacological responses characteristic of native $GABA_A$ receptors (Burt and Kamatchi 1991; Nakanishi 1992; Olsen and Tobin 1990; Vandenberg et al. 1992; Betz 1992). When coexpressed with $\beta 1$ subunits, for example, the widely distributed cerebral $\alpha 1$ subunit yields a receptor with a relatively high affinity for GABA. By contrast, coexpression of the $\alpha 2$ or $\alpha 3$ subunits (with the $\beta 1$ subunit) results in $GABA_A$ receptors with far lower affinities for GABA. Thus, the subunit composition of a given receptor may determine the local "response" to synaptically released GABA.

There are also multiple forms of the β subunit expressed in brain (Vandenberg et al., 1992). Although their exact role in $GABA_A$ receptor function has yet to be determined, each contains a consensus sequence for phosphorylation by protein kinase A. There is some evidence that phosphorylation of the β subunit may result in receptor desensitization seen with continuous exposure to GABA. The pharmacological differences seen between drugs, such as the benzodiazepines, which interact with $GABA_A$ receptors, also depend on subunit heterogeneity. Receptors which are composed of $\alpha 3$ subunits (together with $\beta 1$ and $\alpha 2$ subunits) yield much greater responses to benzodiazepines than do

receptors which contain α1 or α2 subunits (Vandenberg et al., 1992, Betz 1992). It can be inferred that mercury's role in enhancing the effects of genes that synthesize these receptors is associated with increased inhibition or excitation of these receptors activities and cause disturbances in homeostatic mechanisms. This will be reflected in behavioral alterations in individuals translating into temporal lobe epilepsy, amyotropic lateral sclerosis, Güillain-Barré-like illnesses in humans, Huntington's and Alzheimer's diseases and fragile X syndrome, the most common form of inherited mental retardation, and some autistic attributes that also result from synaptic inhibitions associated with the $GABA_A$ receptors/ligand interactions. These activities culminate in behavioral dysfunctions, strokes and may explain an important role in the etiology of schizophrenia as well as etiopathogenesis of infant type 1diabetes seen in pancreatic beta cells destructions (Nicoletti et al., 1986; Baekkeskov et al. 1987).

The importance of glycine and glutamate is reflected in the fact that many of the therapeutically useful drugs work by selectively affecting these two neurotransmitter systems.

Conclusion

Mercury exposure at low levels (maximal of 2 and 3 μg/mL concentrations) induces enhanced expression of genes located on chromosomes 4 and 5 with much increased expression of genes on chromosome 4 than that of chromosome 5 that express GABA-A subtypes 3, 6 and glutamate -gated chloride channel receptors respectively. Further analysis of mercury's role in influencing the alpha subunit levels in these molecules will be an added help to explain the role of mercury in CNS toxicopathogenesis. This differential increases in the activities of subunits of glycine receptor alpha 3 and alpha 6 indicates the capability of mercury in influencing activities in the CNS as well as the PNS that may lead to several phenotypic expressions in behavior. By increasing receptor sites for alpha 3 and 6 it is possible to influence excitatory as well as inhibitory pathways. The behavioral consequences of such pharmacologically induced changes in the balance between inhibition and excitation are often profound (e.g., following administration of convulsant or anesthetic drugs which are known to alter GABAergic or glutamatergic neurotransmission).

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The Demographic Effects of Hurricane Katrina on the Mississippi Gulf Coast: An Analysis by Zip Code

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Abstract

This paper provides an estimate of the effects of Hurricane Katrina on the population of 20 selected zip code areas in Hancock, Harrison and Jackson counties, Mississippi, that were at or near the epicenter of Hurricane Katrina. The effects are examined by using 1990 and 2000 census data, information from a special data collection funded by the National Science Foundation, and special county-level "Katrina impact" 2006 population estimates prepared by the U. S. Census Bureau. The Cohort Change Ratio Method is applied to 1990 and 2000 census data to generate 2007 population estimates in the absence of Katrina. These estimates are then adjusted to take Katrina's effects into account. By comparing the adjusted to the unadjusted estimates an idea of the absolute and relative impact of Katrina is gained. The comparison suggests that Katrina's demographic effects are profound and not only likely to affect the 2010 census counts in these areas, but that they may persist well beyond. Given the long-lasting demographic effects of such disasters, I suggest that these methods be used in the future and provide specific recommendations on how this can be accomplished

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Introduction

As noted by Chappell et al. (2007: 344), the landfall of Hurricane Katrina on the Gulf Coast on August 29th, 2005 represented the greatest natural disaster in American history. The geographic spread of the disaster stretched 90,000 square miles, roughly the size of Great Britain. In human terms, at least 1,836 people lost their lives from Katrina while only 65 did so due to Hurricane Andrew in August of 1992 and 265 from Hurricane Camille in August of 1969 (Chappell et al., 2007: 344). Swanson et al. (2007) note that while the preceding numbers are staggering and likely in the general ballpark, they are only estimates and because of the ephemeral nature of the data and the high costs, it is not surprising that estimates rather than complete counts are made in regard to the damage from hurricanes and other large scale disasters. Unfortunately, many of these estimates are not informed by on-the-ground research, one exception to this being those developed by Swanson et al. (2007).

This paper extends the work of Swanson et al. (2007) by providing estimates of the effect of Hurricane Katrina on the populations of 20 selected zip code areas of Hancock, Harrison and Jackson counties, Mississippi. These zip codes are of interest for two reasons. First, zip codes are used by many private and public sector entities for planning (Pol and Thomas, 1997, 2000; Siegel, 2002; Thomas, 2005); and second, these 20 zip codes were at or near the epicenter of Hurricane Katrina in that they cover the Mississippi Gulf Coast from Alabama to Louisiana in an area extending north from the Gulf Coast approximately 15 miles. The

general dimensions of the study area are provided in Exhibit 1.

EXHIBIT 1. THE GENERAL AREA COMPRISING THE TWENTY ZIP CODES
(The Black Line running east from Louisiana to Alabama represents the approximate northern boundary of the area, with the Alabama and Louisiana state lines representing the eastern and western boundaries, respectively).

The demographic effects of Katrina are examined on populations in of each of the twenty zip codes displayed by county in Exhibit 2

EXHIBIT 2. ZIP CODES CONTAINED IN THE STUDY BY COUNTY

HANCOCK
39520
39525
39556
39572
39576

HARRISON
39501
39503
39507
39530
39531
39532
39540
39560
39571
39574

JACKSON
39562
39564
39565
39567
39581

THE DEMOGRAPHIC EFFECTS OF KATRINA

The examination of the demographic effects of Katrina starts by using 1990 and 2000 census data to develop "Cohort Change Ratios" (Smith, Tayman, and Swanson, 2001: 127-128), which are then used to project the 2000 populations by age and sex to form a set of 2007 population estimates in the absence of Katrina. These estimates are then adjusted to develop 2007 population estimates that account for the effects of Hurricane Katrina. The adjustments are accomplished using either one of two data sets: (1) a special census conducted under the auspices of a study funded by the National Science Foundation (Swanson et al., 2007); or (2) special "2006 Katrina-impacted estimates" done by the U. S. Census Bureau for counties (2006). A more complete description of these data and the methods are described later.

Table 1 provides the estimated population in 2007 of the five zip codes in Hancock County by age and sex as affected by Hurricane Katrina. Tables 2 and 3 provide this same information for the ten zip codes in Harrison County and the five zip codes in Jackson County, respectively. Tables 4, 5, and 6 provide 2007 estimates of these same populations by age and sex in the absence of Hurricane Katrina.

Table 1. The Estimated Katrina-impacted 2007 Populations by Age and Sex for the Five Zip codes in Hancock County.

KATRINA IMPACT: HANCOCK COUNTY ZIPCODES							
SEX & AGE GROUP	2007 39520	2007 39525	2007 39556	2007 39572	2007 39576	2007 TOTAL	SEX & AGE GROUP
m0_4	618	294	233	48	75	1,268	m0_4
m5_9	647	129	213	40	72	1,101	m5_9
m10_14	722	269	256	46	72	1,365	m10_14
m15_19	654	287	252	48	72	1,313	m15_19
m20_24	487	101	175	34	44	841	m20_24
m25_29	503	174	196	35	58	966	m25_29
m30_34	582	180	185	37	55	1,040	m30_34
m35_39	714	272	240	47	66	1,340	m35_39
m40_44	737	280	258	58	69	1,402	m40_44
m45_49	801	344	253	61	65	1,525	m45_49
m50_54	933	334	230	71	77	1,645	m50_54
m55_59	772	289	214	82	66	1,423	m55_59
m60_64	657	407	152	68	62	1,346	m60_64
m65_69	533	270	140	42	50	1,035	m65_69
m70_74	348	251	79	32	32	743	m70_74
m75_79	210	165	48	22	24	468	m75_79
m80_84	135	87	13	14	11	261	m80_84
m85ovr	84	85	14	9	11	204	m85ovr
f0_4	575	195	224	50	71	1,114	f0_4
f5_9	593	154	211	44	70	1,071	f5_9
f10_14	658	250	237	51	69	1,265	f10_14
f15_19	614	263	216	46	68	1,207	f15_19
f20_24	512	126	224	37	53	952	f20_24
f25_29	566	230	189	36	70	1,092	f25_29
f30_34	587	225	239	37	65	1,153	f30_34
f35_39	685	252	243	45	68	1,293	f35_39
f40_44	700	333	237	52	77	1,399	f40_44
f45_49	857	335	240	62	89	1,583	f45_49
f50_54	855	394	198	56	100	1,603	f50_54
f55_59	736	383	197	81	89	1,485	f55_59
f60_64	707	372	147	55	71	1,352	f60_64
f65_69	493	319	105	48	52	1,018	f65_69
f70_74	348	256	75	22	44	744	f70_74
f75_79	262	160	52	20	26	520	f75_79
f80_84	186	161	26	12	21	406	f80_84
f85ovr	198	144	21	7	18	388	f85ovr
P0_4	1,192	489	457	97	147	2,382	P0_4
P5_9	1,240	283	424	84	142	2,172	P5_9
P10_14	1,380	519	493	97	142	2,631	P10_14
P15_19	1,269	550	468	93	140	2,520	P15_19
P20_24	999	227	399	71	97	1,794	P20_24
P25_29	1,069	405	385	71	129	2,058	P25_29
P30_34	1,169	405	425	75	120	2,193	P30_34
P35_39	1,399	525	483	93	133	2,633	P35_39
P40_44	1,437	613	495	110	146	2,800	P40_44
P45_49	1,658	680	493	123	154	3,108	P45_49
P50_54	1,788	729	428	127	177	3,248	P50_54
P55_59	1,507	672	411	163	155	2,908	P55_59
P60_64	1,365	779	299	123	132	2,698	P60_64
P65_69	1,026	589	245	90	103	2,053	P65_69
P70_74	696	507	153	54	76	1,486	P70_74
P75_79	473	325	100	41	49	988	P75_79
P80_84	321	248	39	26	32	667	P80_84
P85ovr	283	229	35	16	29	592	P85ovr
TOTAL	**20,270**	**8,773**	**6,231**	**1,554**	**2,103**	**38,931**	**TOTAL**
POP 55+	**5,670**	**3,350**	**1,283**	**514**	**577**	**11,393**	**POP 55+**
POP 65+	**2,798**	**1,898**	**573**	**228**	**289**	**5,786**	**POP 65+**
ZIPCODE	**39520**	**39525**	**39556**	**39572**	**39576**	**TOTAL**	**ZIPCODE**

Table 2. The Estimated Katrina-impacted 2007 Populations by Age and Sex for the Ten Zip codes in Harrison County.

HARRSON COUNTY ZIPCODES												
SEX & AGE GROUP	2007 39501	2007 39503	2007 39507	2007 39530	2007 39531	2007 39532	2007 39540	2007 39560	2007 39571	2007 39574	2007 TOTAL	SEX & AGE GROUP
m0_4	798	1,362	532	533	648	808	251	565	165	441	6,104	m0_4
m5_9	662	1,345	475	388	568	788	252	627	174	475	5,754	m5_9
m10_14	675	1,315	481	285	467	863	273	640	181	641	5,821	m10_14
m15_19	971	1,252	516	849	491	974	245	619	152	497	6,568	m15_19
m20_24	1,117	1,126	653	938	653	647	234	529	133	393	6,422	m20_24
m25_29	816	1,282	665	451	766	692	263	514	133	407	5,988	m25_29
m30_34	773	1,503	557	392	613	855	260	509	146	516	6,125	m30_34
m35_39	679	1,385	580	346	604	869	282	561	149	532	5,986	m35_39
m40_44	571	1,381	540	366	514	939	249	588	177	546	5,873	m40_44
m45_49	688	1,399	586	426	579	1,062	273	559	184	507	6,263	m45_49
m50_54	644	1,220	591	418	486	921	220	596	195	466	5,756	m50_54
m55_59	567	924	454	368	409	729	174	452	170	346	4,594	m55_59
m60_64	510	764	401	273	383	605	154	400	155	283	3,928	m60_64
m65_69	329	561	289	228	236	443	102	316	111	198	2,813	m65_69
m70_74	238	383	276	194	190	334	95	240	83	119	2,152	m70_74
m75_79	178	248	220	139	173	233	51	161	59	102	1,565	m75_79
m80_84	102	118	136	86	108	92	27	97	30	40	836	m80_84
m85ovr	82	51	98	67	84	66	14	48	17	23	551	m85ovr
f0_4	773	1,242	468	500	627	732	224	526	180	451	5,723	f0_4
f5_9	738	1,263	493	401	520	775	205	584	148	456	5,583	f5_9
f10_14	697	1,235	488	266	478	857	246	645	165	514	5,590	f10_14
f15_19	748	1,243	481	559	465	792	266	603	169	478	5,804	f15_19
f20_24	757	1,015	587	626	756	655	228	523	136	404	5,688	f20_24
f25_29	744	1,369	670	482	695	833	253	491	166	442	6,146	f25_29
f30_34	670	1,382	525	359	640	806	249	609	156	456	5,851	f30_34
f35_39	660	1,339	598	312	555	954	290	644	163	497	6,012	f35_39
f40_44	621	1,323	545	305	502	943	249	632	178	519	5,819	f40_44
f45_49	678	1,313	604	389	553	1,020	253	600	192	425	6,026	f45_49
f50_54	693	1,227	588	380	469	885	243	614	192	426	5,716	f50_54
f55_59	616	1,002	524	341	418	744	206	490	173	338	4,852	f55_59
f60_64	472	864	465	290	359	641	192	486	154	242	4,165	f60_64
f65_69	405	616	366	256	277	495	118	346	120	155	3,153	f65_69
f70_74	315	459	352	216	235	386	114	309	89	127	2,602	f70_74
f75_79	265	301	288	209	238	244	53	223	73	71	1,965	f75_79
f80_84	226	192	220	165	166	150	37	155	51	41	1,404	f80_84
f85ovr	253	125	146	176	144	135	28	121	42	27	1,197	f85ovr
P0_4	1,571	2,604	1,000	1,033	1,275	1,540	475	1,091	345	892	11,827	P0_4
P5_9	1,400	2,607	968	789	1,088	1,564	457	1,211	322	931	11,337	P5_9
P10_14	1,372	2,550	969	551	946	1,720	519	1,285	346	1,154	11,411	P10_14
P15_19	1,719	2,496	997	1,408	957	1,766	512	1,222	321	976	12,373	P15_19
P20_24	1,874	2,141	1,240	1,564	1,409	1,302	462	1,052	269	797	12,111	P20_24
P25_29	1,560	2,651	1,335	933	1,462	1,525	516	1,005	298	849	12,134	P25_29
P30_34	1,443	2,885	1,082	752	1,253	1,661	509	1,117	302	972	11,975	P30_34
P35_39	1,340	2,723	1,178	658	1,159	1,823	572	1,206	311	1,029	11,998	P35_39
P40_44	1,192	2,705	1,086	671	1,017	1,882	498	1,220	356	1,066	11,692	P40_44
P45_49	1,366	2,712	1,189	815	1,132	2,082	526	1,159	376	933	12,289	P45_49
P50_54	1,337	2,446	1,178	798	955	1,806	463	1,210	387	891	11,473	P50_54
P55_59	1,184	1,926	978	710	827	1,473	380	942	342	684	9,446	P55_59
P60_64	982	1,628	866	562	742	1,247	346	886	310	525	8,093	P60_64
P65_69	733	1,177	654	484	513	939	220	662	231	353	5,966	P65_69
P70_74	554	842	628	409	425	720	209	549	172	246	4,754	P70_74
P75_79	443	549	508	348	412	478	104	384	132	173	3,529	P75_79
P80_84	328	310	357	252	274	242	64	252	80	82	2,240	P80_84
P85ovr	335	176	244	244	227	201	42	169	59	50	1,749	P85ovr
TOTAL	**20,733**	**35,128**	**16,458**	**12,981**	**16,070**	**23,970**	**6,873**	**16,620**	**4,959**	**12,604**	**166,396**	**TOTAL**
POP 55+	**4,559**	**6,608**	**4,236**	**3,009**	**3,419**	**5,299**	**1,364**	**3,843**	**1,326**	**2,113**	**35,777**	**POP 55+**
POP 65+	**2,393**	**3,054**	**2,392**	**1,737**	**1,851**	**2,579**	**638**	**2,015**	**674**	**904**	**18,238**	**POP 65+**
ZIPCODE	**39501**	**39503**	**39507**	**39530**	**39531**	**39532**	**39540**	**39560**	**39571**	**39574**	**TOTAL**	**ZIPCODE**

Table 3. The Estimated Katrina-impacted 2007 Populations by Age and Sex for the Five Zip codes in Jackson County

KATRINA IMPACTED: JACKSON COUNTY ZIPCODES							
SEX & AGE GROUP	2007 39562	2007 39564	2007 39565	2007 39567	2007 39581	2007 TOTAL	SEX & AGE GROUP
m0_4	553	923	691	383	376	2,927	m0_4
m5_9	607	964	804	311	368	3,055	m5_9
m10_14	673	1,166	909	337	498	3,583	m10_14
m15_19	646	1,121	773	410	379	3,329	m15_19
m20_24	480	792	654	742	371	3,039	m20_24
m25_29	499	816	679	450	348	2,792	m25_29
m30_34	577	1,016	772	540	343	3,248	m30_34
m35_39	631	1,172	797	392	367	3,359	m35_39
m40_44	591	1,088	817	370	371	3,236	m40_44
m45_49	635	1,246	809	398	355	3,442	m45_49
m50_54	634	1,071	709	358	323	3,094	m50_54
m55_59	472	924	587	314	257	2,554	m55_59
m60_64	499	708	428	240	180	2,055	m60_64
m65_69	320	536	349	173	154	1,533	m65_69
m70_74	274	366	186	152	105	1,083	m70_74
m75_79	134	311	149	97	74	766	m75_79
m80_84	76	172	47	78	37	411	m80_84
m85ovr	42	101	30	55	22	250	m85ovr
f0_4	531	872	645	348	381	2,777	f0_4
f5_9	538	987	661	273	364	2,824	f5_9
f10_14	636	1,168	883	304	420	3,411	f10_14
f15_19	605	1,080	779	358	392	3,213	f15_19
f20_24	533	789	691	329	393	2,735	f20_24
f25_29	504	917	613	300	382	2,717	f25_29
f30_34	586	1,057	696	325	388	3,053	f30_34
f35_39	595	1,200	739	326	344	3,205	f35_39
f40_44	615	1,167	835	326	337	3,280	f40_44
f45_49	641	1,252	819	305	306	3,324	f45_49
f50_54	604	1,073	686	328	301	2,992	f50_54
f55_59	531	872	469	298	258	2,428	f55_59
f60_64	460	758	444	223	206	2,091	f60_64
f65_69	353	545	285	234	177	1,594	f65_69
f70_74	259	487	244	193	135	1,319	f70_74
f75_79	155	358	143	194	108	958	f75_79
f80_84	117	279	89	153	70	707	f80_84
f85ovr	87	297	80	191	57	712	f85ovr
P0_4	1,085	1,795	1,336	732	757	5,704	P0_4
P5_9	1,145	1,951	1,466	584	732	5,878	P5_9
P10_14	1,309	2,335	1,791	641	919	6,994	P10_14
P15_19	1,252	2,201	1,552	768	771	6,543	P15_19
P20_24	1,013	1,581	1,345	1,071	764	5,774	P20_24
P25_29	1,003	1,733	1,291	750	730	5,508	P25_29
P30_34	1,164	2,073	1,468	865	731	6,300	P30_34
P35_39	1,226	2,373	1,537	718	711	6,564	P35_39
P40_44	1,206	2,255	1,652	696	708	6,516	P40_44
P45_49	1,276	2,498	1,628	703	661	6,766	P45_49
P50_54	1,238	2,144	1,395	686	623	6,086	P50_54
P55_59	1,003	1,796	1,056	612	515	4,983	P55_59
P60_64	959	1,466	872	463	386	4,146	P60_64
P65_69	673	1,081	635	407	332	3,128	P65_69
P70_74	533	853	430	345	241	2,402	P70_74
P75_79	289	669	292	291	182	1,723	P75_79
P80_84	193	451	137	231	106	1,118	P80_84
P85ovr	129	398	110	246	78	961	P85ovr
TOTAL	**16,697**	**29,654**	**19,992**	**10,807**	**9,946**	**87,095**	**TOTAL**
POP 55+	**3,780**	**6,715**	**3,532**	**2,594**	**1,840**	**18,461**	**POP 55+**
POP 65+	**1,818**	**3,453**	**1,603**	**1,520**	**939**	**9,332**	**POP 65+**
ZIPCODE	**39562**	**39564**	**39565**	**39567**	**39581**	**TOTAL**	**ZIPCODE**

Table 4. The Estimated 2007 Population of the Five Zip codes in Hancock County by Age and Sex in the Absence of Hurricane Katrina.

NO KATRINA IMPACT: HANCOCK COUNTY ZIPCODES							
SEX & AGE GROUP	2007 39520	2007 39525	2007 39556	2007 39572	2007 39576	2007 TOTAL	SEX & AGE GROUP
m0_4	631	364	285	49	285	1,614	m0_4
m5_9	661	160	261	40	271	1,393	m5_9
m10_14	737	334	313	47	273	1,703	m10_14
m15_19	668	356	308	49	273	1,653	m15_19
m20_24	498	125	213	35	167	1,039	m20_24
m25_29	514	216	239	36	220	1,225	m25_29
m30_34	594	224	227	38	208	1,291	m30_34
m35_39	729	338	293	48	249	1,658	m35_39
m40_44	752	347	315	59	262	1,736	m40_44
m45_49	818	427	310	63	247	1,865	m45_49
m50_54	952	414	282	72	290	2,011	m50_54
m55_59	788	359	262	84	250	1,742	m55_59
m60_64	671	504	186	70	233	1,664	m60_64
m65_69	544	335	171	43	189	1,282	m65_69
m70_74	356	311	96	33	121	917	m70_74
m75_79	215	204	59	22	89	589	m75_79
m80_84	138	108	16	14	42	319	m80_84
m85ovr	86	106	18	9	42	260	m85ovr
f0_4	587	241	273	51	270	1,422	f0_4
f5_9	605	191	257	45	264	1,363	f5_9
f10_14	672	310	290	52	263	1,586	f10_14
f15_19	627	326	264	47	257	1,522	f15_19
f20_24	523	156	274	38	200	1,191	f20_24
f25_29	578	286	232	37	266	1,397	f25_29
f30_34	599	279	292	38	246	1,455	f30_34
f35_39	699	313	298	46	255	1,611	f35_39
f40_44	715	413	290	53	291	1,761	f40_44
f45_49	875	416	293	63	335	1,982	f45_49
f50_54	873	489	242	57	379	2,040	f50_54
f55_59	751	474	241	83	338	1,886	f55_59
f60_64	722	462	180	56	267	1,687	f60_64
f65_69	504	395	129	49	198	1,275	f65_69
f70_74	355	317	91	22	168	953	f70_74
f75_79	268	198	64	20	98	648	f75_79
f80_84	190	200	31	13	80	513	f80_84
f85ovr	203	179	26	8	66	481	f85ovr
P0_4	1,218	606	558	99	555	3,036	P0_4
P5_9	1,266	351	518	85	535	2,756	P5_9
P10_14	1,409	644	603	99	535	3,290	P10_14
P15_19	1,295	682	572	95	530	3,175	P15_19
P20_24	1,020	282	488	73	367	2,230	P20_24
P25_29	1,091	502	471	72	486	2,623	P25_29
P30_34	1,193	502	519	76	455	2,745	P30_34
P35_39	1,429	650	591	94	504	3,269	P35_39
P40_44	1,467	760	605	112	554	3,497	P40_44
P45_49	1,693	843	603	126	582	3,847	P45_49
P50_54	1,825	903	524	129	669	4,051	P50_54
P55_59	1,539	833	502	166	588	3,629	P55_59
P60_64	1,394	966	366	126	500	3,351	P60_64
P65_69	1,047	730	300	92	388	2,557	P65_69
P70_74	711	628	188	55	289	1,870	P70_74
P75_79	483	402	123	42	187	1,237	P75_79
P80_84	327	308	48	27	122	832	P80_84
P85ovr	288	284	43	17	108	741	P85ovr
TOTAL	**20,696**	**10,877**	**7,622**	**1,587**	**7,954**	**48,735**	**TOTAL**
POP 55+	**5,789**	**4,153**	**1,569**	**524**	**2,181**	**14,217**	**POP 55+**
POP 65+	**2,857**	**2,353**	**701**	**232**	**1,094**	**7,237**	**POP 65+**
ZIPCODE	**39520**	**39525**	**39556**	**39572**	**39576**	**TOTAL**	**ZIPCODE**

Table 5. The Estimated 2007 Population of the Ten Zip codes
in Harrison County by Age and Sex in the Absence of Hurricane Katrina.

NO KATRINA IMPACT HARRSON COUNTY ZIPCODES												
SEX & AGE GROUP	2007 39501	2007 39503	2007 39507	2007 39530	2007 39531	2007 39532	2007 39540	2007 39560	2007 39571	2007 39574	2007 TOTAL	SEX & AGE GROUP
m0_4	989	1,712	660	661	803	1,016	316	701	625	555	8,038	m0_4
m5_9	821	1,691	589	481	704	991	317	777	658	597	7,626	m5_9
m10_14	836	1,653	597	354	580	1,086	343	793	684	806	7,731	m10_14
m15_19	1,204	1,575	640	1,053	609	1,225	309	767	577	625	8,583	m15_19
m20_24	1,385	1,416	809	1,163	809	813	294	656	503	494	8,342	m20_24
m25_29	1,012	1,611	825	559	950	870	331	637	501	512	7,807	m25_29
m30_34	958	1,890	690	486	760	1,076	327	630	552	649	8,019	m30_34
m35_39	842	1,741	719	429	749	1,093	355	696	562	669	7,853	m35_39
m40_44	708	1,737	670	453	637	1,181	313	729	671	687	7,787	m40_44
m45_49	853	1,758	726	528	718	1,335	344	692	696	638	8,289	m45_49
m50_54	798	1,534	732	518	602	1,158	277	739	738	585	7,682	m50_54
m55_59	704	1,161	563	457	507	917	219	561	641	435	6,164	m55_59
m60_64	633	961	497	338	474	761	193	495	588	356	5,297	m60_64
m65_69	408	706	358	283	293	557	129	392	419	249	3,792	m65_69
m70_74	296	482	342	240	236	420	119	298	314	150	2,896	m70_74
m75_79	221	312	273	172	215	293	64	200	221	129	2,100	m75_79
m80_84	126	148	169	107	134	115	34	120	112	51	1,116	m80_84
m85ovr	102	64	122	84	104	82	18	60	66	29	730	m85ovr
f0_4	959	1,562	580	620	778	920	282	652	680	567	7,599	f0_4
f5_9	915	1,587	612	497	644	975	258	725	559	573	7,344	f5_9
f10_14	864	1,553	605	329	593	1,078	309	800	623	646	7,399	f10_14
f15_19	927	1,563	596	693	577	995	335	748	639	602	7,674	f15_19
f20_24	939	1,276	728	776	938	824	287	648	514	508	7,438	f20_24
f25_29	923	1,721	831	598	862	1,047	319	609	627	555	8,092	f25_29
f30_34	830	1,737	651	446	794	1,013	313	754	589	573	7,700	f30_34
f35_39	819	1,683	741	387	688	1,199	364	799	616	625	7,921	f35_39
f40_44	770	1,664	676	379	623	1,185	313	783	675	653	7,721	f40_44
f45_49	840	1,651	749	482	685	1,282	318	744	726	535	8,012	f45_49
f50_54	860	1,542	729	471	582	1,113	305	761	725	535	7,623	f50_54
f55_59	764	1,260	649	423	519	936	259	607	653	425	6,495	f55_59
f60_64	585	1,086	577	359	445	806	241	603	583	304	5,590	f60_64
f65_69	502	774	453	317	343	623	148	430	453	195	4,237	f65_69
f70_74	391	577	437	267	291	485	144	383	338	160	3,472	f70_74
f75_79	329	378	357	259	295	307	66	276	277	89	2,634	f75_79
f80_84	280	241	273	205	206	189	46	192	192	52	1,878	f80_84
f85ovr	314	158	181	219	178	170	35	150	158	34	1,596	f85ovr
P0_4	1,948	3,274	1,240	1,281	1,581	1,937	598	1,352	1,305	1,122	15,637	P0_4
P5_9	1,736	3,278	1,200	979	1,348	1,966	575	1,501	1,217	1,171	14,970	P5_9
P10_14	1,700	3,206	1,201	683	1,173	2,163	652	1,593	1,307	1,451	15,130	P10_14
P15_19	2,131	3,138	1,236	1,745	1,186	2,220	643	1,515	1,216	1,226	16,257	P15_19
P20_24	2,323	2,692	1,537	1,939	1,747	1,637	581	1,304	1,017	1,002	15,780	P20_24
P25_29	1,934	3,333	1,655	1,157	1,812	1,917	649	1,246	1,129	1,068	15,899	P25_29
P30_34	1,788	3,627	1,341	932	1,553	2,089	640	1,385	1,141	1,223	15,719	P30_34
P35_39	1,661	3,424	1,460	816	1,437	2,292	719	1,495	1,178	1,293	15,774	P35_39
P40_44	1,478	3,401	1,346	832	1,260	2,366	626	1,512	1,346	1,340	15,508	P40_44
P45_49	1,694	3,409	1,474	1,011	1,403	2,617	661	1,437	1,421	1,173	16,301	P45_49
P50_54	1,658	3,076	1,461	989	1,184	2,271	582	1,501	1,463	1,121	15,305	P50_54
P55_59	1,467	2,421	1,213	880	1,025	1,853	477	1,168	1,294	860	12,659	P55_59
P60_64	1,218	2,047	1,074	697	920	1,567	435	1,098	1,171	660	10,886	P60_64
P65_69	909	1,480	811	600	635	1,180	277	821	872	444	8,030	P65_69
P70_74	686	1,058	779	508	527	905	263	680	652	310	6,368	P70_74
P75_79	549	690	630	431	510	600	131	476	499	218	4,734	P75_79
P80_84	406	390	442	312	340	304	80	312	304	103	2,994	P80_84
P85ovr	416	222	303	302	282	253	53	209	224	63	2,327	P85ovr
TOTAL	**25,704**	**44,166**	**20,405**	**16,094**	**19,924**	**30,137**	**8,641**	**20,606**	**18,756**	**15,846**	**220,278**	**TOTAL**
POP 55+	**5,652**	**8,308**	**5,252**	**3,731**	**4,239**	**6,662**	**1,715**	**4,765**	**5,016**	**2,657**	**47,997**	**POP 55+**
POP 65+	**2,967**	**3,840**	**2,965**	**2,154**	**2,294**	**3,242**	**803**	**2,499**	**2,551**	**1,137**	**24,451**	**POP 65+**
ZIPCODE	**39501**	**39503**	**39507**	**39530**	**39531**	**39532**	**39540**	**39560**	**39571**	**39574**	**TOTAL**	**ZIPCODE**

Table 6. The Estimated 2007 Population of the Five Zip codes in Jackson County by Age and Sex in the Absence of Hurricane Katrina.

NO KATRINA: JACKSON COUNTY ZIPCODES							
SEX & AGE GROUP	2007 39562	2007 39564	2007 39565	2007 39567	2007 39581	2007 TOTAL	SEX & AGE GROUP
m0_4	576	1,145	719	475	466	3,381	m0_4
m5_9	632	1,195	837	386	457	3,506	m5_9
m10_14	701	1,446	946	418	618	4,127	m10_14
m15_19	672	1,390	804	508	470	3,845	m15_19
m20_24	499	982	680	920	460	3,542	m20_24
m25_29	519	1,011	706	558	432	3,226	m25_29
m30_34	601	1,260	803	669	425	3,757	m30_34
m35_39	657	1,453	829	486	454	3,880	m35_39
m40_44	614	1,349	850	458	460	3,731	m40_44
m45_49	660	1,545	842	493	440	3,980	m45_49
m50_54	660	1,328	737	443	400	3,568	m50_54
m55_59	491	1,146	611	390	318	2,956	m55_59
m60_64	519	878	445	297	223	2,363	m60_64
m65_69	333	665	364	215	191	1,767	m65_69
m70_74	285	453	193	188	130	1,251	m70_74
m75_79	140	386	155	121	92	893	m75_79
m80_84	79	213	49	97	46	485	m80_84
m85ovr	44	125	31	69	27	295	m85ovr
f0_4	553	1,081	671	432	472	3,208	f0_4
f5_9	560	1,224	688	339	451	3,262	f5_9
f10_14	661	1,449	918	377	521	3,926	f10_14
f15_19	630	1,339	810	443	486	3,708	f15_19
f20_24	555	979	719	408	487	3,147	f20_24
f25_29	525	1,137	637	372	474	3,146	f25_29
f30_34	610	1,311	724	403	481	3,529	f30_34
f35_39	619	1,488	769	404	427	3,707	f35_39
f40_44	640	1,447	869	405	418	3,778	f40_44
f45_49	667	1,552	853	378	379	3,830	f45_49
f50_54	629	1,331	714	407	373	3,452	f50_54
f55_59	553	1,081	488	369	320	2,811	f55_59
f60_64	479	940	462	276	255	2,412	f60_64
f65_69	367	676	297	290	220	1,850	f65_69
f70_74	270	604	254	239	168	1,535	f70_74
f75_79	161	444	149	240	133	1,128	f75_79
f80_84	121	346	93	189	86	835	f80_84
f85ovr	90	369	83	237	70	849	f85ovr
P0_4	1,129	2,225	1,390	907	938	6,589	P0_4
P5_9	1,192	2,419	1,525	725	908	6,767	P5_9
P10_14	1,362	2,894	1,864	794	1,139	8,053	P10_14
P15_19	1,302	2,729	1,614	952	956	7,553	P15_19
P20_24	1,054	1,960	1,400	1,328	947	6,689	P20_24
P25_29	1,044	2,149	1,343	930	906	6,372	P25_29
P30_34	1,211	2,570	1,527	1,072	906	7,286	P30_34
P35_39	1,276	2,941	1,599	890	881	7,587	P35_39
P40_44	1,255	2,795	1,719	863	877	7,509	P40_44
P45_49	1,328	3,097	1,694	871	819	7,809	P45_49
P50_54	1,288	2,658	1,451	850	772	7,020	P50_54
P55_59	1,044	2,227	1,099	759	639	5,767	P55_59
P60_64	998	1,818	907	574	479	4,775	P60_64
P65_69	700	1,341	660	504	411	3,617	P65_69
P70_74	555	1,058	447	427	298	2,786	P70_74
P75_79	301	830	304	361	225	2,021	P75_79
P80_84	201	559	142	286	132	1,320	P80_84
P85ovr	134	493	114	305	97	1,144	P85ovr
TOTAL	**17,372**	**36,764**	**20,800**	**13,399**	**12,331**	**100,666**	**TOTAL**
POP 55+	**3,932**	**8,325**	**3,674**	**3,217**	**2,281**	**21,430**	**POP 55+**
POP 65+	**1,891**	**4,281**	**1,668**	**1,884**	**1,164**	**10,888**	**POP 65+**
ZIPCODE	**39562**	**39564**	**39565**	**39567**	**39581**	**TOTAL**	**ZIPCODE**

Two zip codes containing low-lying areas along the Gulf Coast around the Bay of St. Louis bore the brunt of Katrina's landfall and its demographic impact. Zip code 39571 (Pass Christian, Harrison County) is estimated to have been reduced by 13,797 people, from 18, 756 to 4,959, while zip code 39576 (Waveland, Hancock County), is estimated to have been reduced by 5,861 people, from7, 965 to 2,103.[1]

Generally, as one moves north away from

the coast and to the east, the effects are lessened. The population of zip code 39565 (north of Ocean Springs, Jackson County), for example, is estimated to have been reduced by Katrina from 20,800 to 19,992, a 3.9 percent loss.[1] However, the effects are conditioned by many factors, including elevation, the shape of the ocean floor, and the presence of bayous and other points of access for the storm surge cased by Katrina. One observed effect of interest is in Gulfport, where in an area of approximately two square blocks, small single family homes made of wood south of the railroad tracks survived Katrina mainly intact. This area was presumably protected by the presence on the coast of a set of large structures associated with a major casino. Immediately to the east and west of this area, housing and other structures, were largely destroyed.

Another observed area of interest is in the town of Bay St. Louis in Hancock County. Although virtually all of the housing was destroyed that was on the western edge of the entrance to the Bay of St. Louis, south of the U. S. highway 90 bridge, immediately behind this area, many housing units survived, presumably due to some gains in elevation, the presence of sturdy structures near the coast associated with a parochial school, and its location relative to the rotation of Katrina around its eye as it made landfall. The town of Pass Christian (Harrison County) immediately across the Bay from the town of Bay St. Louis is estimated to have been impacted much more by Katrina than was the town of Bay St. Louis. Presumably, this was due to its consistently low elevation and its location relative to the rotation of Katrina around its eye.

Table 7.1 provides the summary effects of Katrina by examining the difference between the Katrina-impacted estimate of the total population and the estimate in the absence of Katrina for the five zip code areas in Hancock County. Tables 7.2 and 7.3 provide this same information for Harrison and Jackson counties, respectively, while table 7.4 provides a summary across all 20 zip codes.

Table 7.1. Estimated Effect of Katrina on the Total Population of Each of the Five Zip codes for Hancock County

HANCOCK COUNTY ZIPCODE	2007 KATRINA IMPACTED ESTIMATE	2007 ESTIMATE IN THE ABSENCE OF KATRINA	2007 ABSOLUTE DIFFERENCE	2007 RELATIVE DIFFERENCE
39520	20,270	20,696	-426	-2.06%
39525	8,773	10,877	-2,104	-19.34%
39556	6,231	7,622	-1,390	-18.24%
39572	1,554	1,587	-33	-2.06%
39576	2,103	7,954	-5,851	-73.56%
ALL 5 ZIPCODES	**38,931**	**48,735**	**-9,804**	**-20.12%**

Table 7.2. Estimated Effect of Katrina on the Total Population of Each of the Ten Zip codes for Harrison County

HARRISON COUNTY ZIPCODE	2007 KATRINA IMPACTED ESTIMATE	2007 ESTIMATE IN THE ABSENCE OF KATRINA	2007 ABSOLUTE DIFFERENCE	2007 RELATIVE DIFFERENCE
39501	20,733	25,704	-4,972	-19.34%
39503	35,128	44,166	-9,038	-20.46%
39507	16,458	20,405	-3,947	-19.34%
39530	12,981	16,094	-3,113	-19.34%
39531	16,070	19,924	-3,853	-19.34%
39532	23,970	30,137	-6,167	-20.46%
39540	6,873	8,641	-1,768	-20.46%
39560	16,620	20,606	-3,985	-19.34%
39571	4,959	18,756	-13,797	-73.56%
39574	12,604	15,846	-3,243	-20.46%
ALL 10 ZIPCODES	**166,396**	**220,278**	**-53,882**	**-24.46%**

Table 7.3. Estimated Effect of Katrina on the Total Population of Each of the Five Zip codes for Jackson County

JACKSON COUNTY ZIPCODE	2007 KATRINA IMPACTED ESTIMATE	2007 ESTIMATE IN THE ABSENCE OF KATRINA	2007 ABSOLUTE DIFFERENCE	2007 RELATIVE DIFFERENCE
39562	16,697	17,372	-675	-3.89%
39564	29,654	36,764	-7,111	-19.34%
39565	19,992	20,800	-809	-3.89%
39567	10,807	13,399	-2,591	-19.34%
39581	9,946	12,331	-2,385	-19.34%
ALL 5 ZIPCODES	**87,095**	**100,666**	**-13,571**	**-13.48%**

Table 7.4. Estimated Effect of Katrina on the Total Population of the 20 Zip codes Taken Altogether

	2007 Katrina Impacted Estimate	2007 Estimate in the Absence of Katrina	Absolute Difference	Relative Difference
Hancock Co. (5 Zip codes)	**38,981**	**48,735**	**-9,804**	**-20.12%**
Harrison Co. (10 Zip codes)	**166,396**	**220,278**	**-53,882**	**-24.46%**
Jackson Co. (5 Zip codes	**87,095**	**100,666**	**-13,571**	**-13.48%**
TOTAL (20 Zip codes)	**292,472**	**369,679**	**-77,207**	**-20.89**

I estimate that Hurricane Katrina led to a reduction of 9,804 people in the five zip codes in Hancock County, 20.1 percent less than the 48,735 people that were likely to have been in these five zip codes in the absence of Katrina as of 2007 (Table 7.1). For the ten zip codes in Harrison County, the effect is estimated to be a reduction of 53,882 people, 24.5 percent less than the 220,278 that were likely to have been in these ten zip codes in the absence of Katrina (Table 7.2). The effect of Katrina on the five zip codes in Jackson County is less than in Hancock and Harrison counties, both absolutely and relatively: a reduction of 13,571, 13.5 percent less than the 100,666 that were likely to have been in these five zip codes in the absence of Katrina.

Over all twenty zip codes, Katrina is estimated to have reduced the population by 77,207. This represents a 20.9 percent reduction from the 369, 679 that were likely to have been in these 20 zip codes in the absence of Katrina (Table 7.4).

As noted in endnote #1, the complete 2007 Katrina-impacted population estimates for each of the 20 zip codes along with the estimates of the 2007 populations in these zip codes expected in the absence of Katrina are not provided in this report due to space limitations. They are available on request from the author.

DATA

The 2007 population estimates made in the absence of Katrina are based on 1990 and 2000 census data developed by Pitney Bowles MAPINFO. The 2007 Katrina-impacted population estimates are based on the 1990 and 2000 data, the U. S. Census Bureau, and data collected under grant #0555136 from the National Science Foundation.

1990 and 2000 Pitney Bowles MAPINFO Data. This is an international corporation that provides demographic and related information for clients in the private and government sectors (See, e.g.: http://www.mapinfo.com/location/integration). One of the primary products of companies like Pitney Bowles MAPINFO is the provision of demographic information by zip code. For this project, Pitney Bowles MAPINFO provided the 1990 and 2000 population data by age and sex for the 20 zip codes.

Census Bureau Data. In late 2006, the U. S. Census Bureau developed a set of special population estimates for counties impacted by Hurricane Katrina (http://www.census.gov/Press-Release/www/emergencies/impacted_gulf_estimates.html). The January 1st, 2006 population estimate for Hancock County, Mississippi is 35,129 (as found in the file, Gulfcoast Impact Estimates.xls, U. S. Census Bureau, 2006). In 2000, the population of Hancock County was determined by the U. S. Census Bureau to be 42,967 (US Census Bureau, 2000).The January 1st, 2006 population estimate for Harrison County, Mississippi is 155,871 (as found in the file, Gulfcoast Impact Estimates.xls, U. S. Census Bureau, 2006). In 2000, the population of Harrison County was determined by the U. S. Census Bureau to be 189,601 (U. S. Census Bureau, 2000). The January 1st, 2006 population estimate for Jackson County, Mississippi is 126,311 (as found in the file, Gulfcoast Impact Estimates.xls, U. S. Census Bureau, 2006). In 2000, the population of Jackson County was determined by the U. S. Census Bureau to be 131,420 (US Census Bureau, 2000).

Data Collected under NSF Grant # 0555136. The "census tract" level data used in this report to make adjustments to selected zip codes. For zip codes 39501, 39507, 39525, and 39560, data collected in census tracts 27 and 28, Harrison County, were used. For zip code 39520, data collected in census tracts 301 and 302, Hancock, County, were used. For zip code 39571, data collected in census tracts 39 and 30, Harrison County, were used.

These census tract data were gathered under the auspices of one of nine post-Katrina research projects funded by the National

Science Foundation under the provisions of the SGER program.[2] Specifically, the data reported here are taken from work done by the recipients of SGER Grant #0555136, which:

(1) gathered pre- and post-Katrina information on housing and population from 573 targeted census blocks at the epicenter of Katrina's impact on the Mississippi gulf coast that the 2000 census showed as containing people (the "Short Form"); and

(2) employed a random start, systematic selection, cluster sample targeting 126 of these 573 blocks for administration of a 115-item questionnaire (the "Long Form"), such that at least 350 completed questionnaires would be obtained. The Long Form was designed for several purposes, one of which was to collect retrospective information on the roles that social and kinship networks played in determining respondents' success (i.e., the capacity for respondents to sustain their physical and emotional well-being after Hurricane Katrina).

The geographic context of the Study Area for NSF SGER Grant # 0555136 is provided in Exhibit 3 and the specific blocks are shown in Exhibit 4. Details of the data collection are found in Swanson et al. (2007).

EXHIBIT 3. THE NSF STUDY AREA AND ITS GEOGRAPHIC CONTEXT

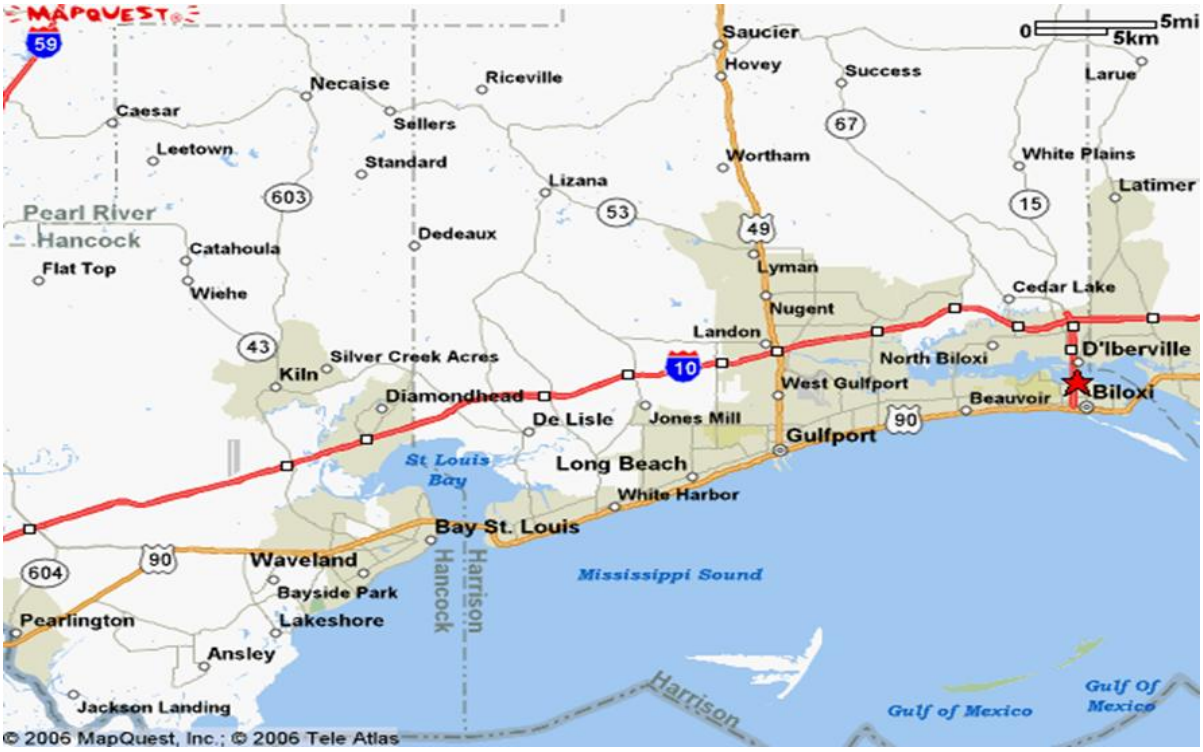
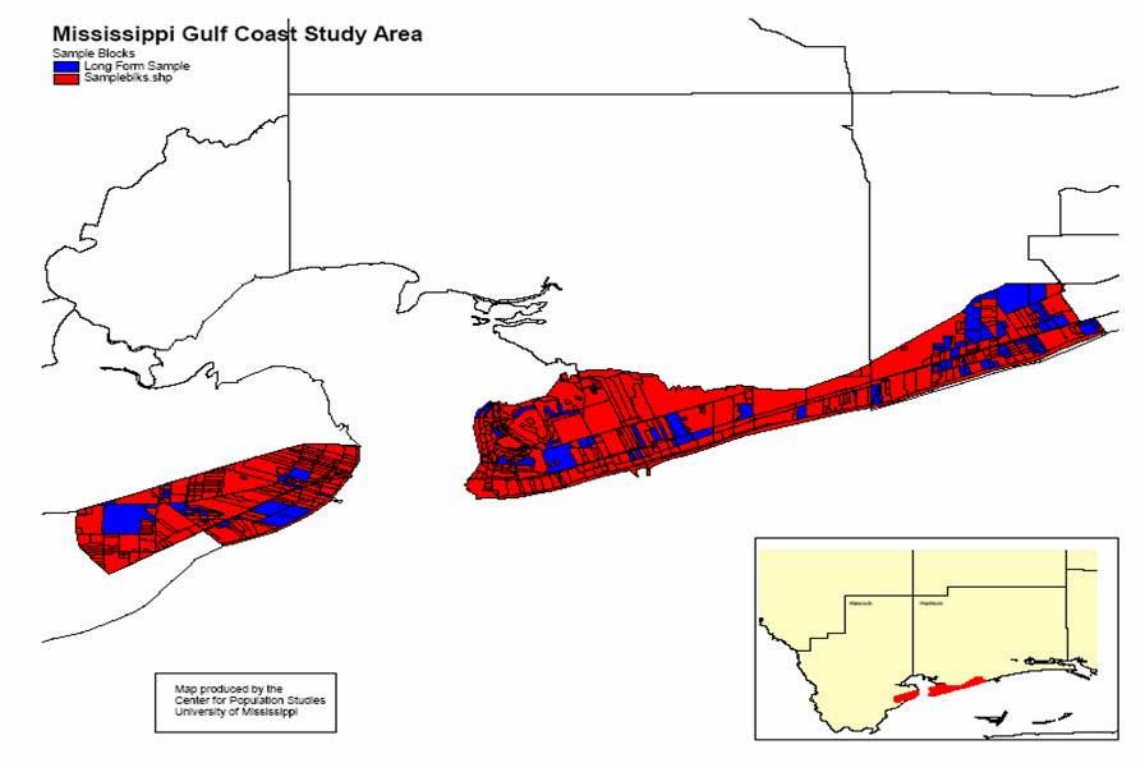


EXHIBIT 4. THE NSF STUDY AREA AND ITS TARGET BLOCKS



METHODS

The housing unit counts described in this report were taken from the "short form" data described by Swanson et al. (2007)[3,4,5]. The population estimates found in the census tract files were generated by the "Housing Unit Method," a generally accepted technique used by demographers (Bryan, 2004). The full form of the Housing Unit Method is defined as:

P = GQ + (PPH)(H)(OR)
where
P = Total Population
GQ = Population in Groups Quarters
PPH = Persons Per Household
H = Total Number of Housing Units
OR = Occupancy Rate

Note that (H)(OR) = Total Number of Households and that (H)(OR)(PPH) = Population in Households

The Housing Unit Method (HUM) implemented here was used to estimate the population in households ((H)(OR)(PPH)= Household Population). The 2006 counts of housing units and occupied housing units are taken directly from the data collected under the auspices of the NSF SGER study (Short form data) as was the Persons Per Household (Long form data). The 2005 counts of housing units and occupied housing units were developed by combining the counts of destroyed and habitable housing found in the NSF SGER study to reconstruct the counts of total housing units.

The 2000 census provided the occupancy rate and Persons Per Household used to estimate the 2005 household population in conjunction with the reconstructed housing unit counts. The 2000 counts of housing units and occupied housing units were taken from the 2000 census.

Three steps were used to develop the 2007 population estimates made in the absence of Katrina. An additional fourth step to develop the Katrina-impacted 2007 population estimates.

Step 1. The 1990 and 2000 populations by age and sex provided by MAPINFO were used to generate "cohort change ratios" (Smith, Tayman, and Swanson, 2001: 127-128) for the population in each of the 20 zip codes.

Step 2. The cohort change ratios (CCRs) were then applied to the 2000 populations (by age and sex) of each of the 20 zip codes to generate 2010 populations by age and sex.

Step 3. The 2010 age and sex data were interpolated to get 2007 age and sex data. The interpolation used a factor of 0.7 to weight the number in a given age group generated for 2010 in the preceding step and a factor of 0.30 to weight the number of people in the same age group found in 2000. The two weighted numbers were then added together to obtain the interpolation for the age group in question for 2007.

Step 4. Once the interpolated age groups were obtained (the 2007 population estimates in the absence of Katrina), the results for the Katrina-impacted 2007 population estimates were developed using one of the following two procedures: (1) an adjustment in accordance with estimates of Katrina's demographic impact as found at the county level by the U. S. Census Bureau; or (2) an adjustment in accordance with the block/block group/census tract level in the study funded by the National Science Foundation. The decision about which adjustment factor to use was based on geography.

Step 4. Census Bureau Adjustment. For those zip codes that did not match to any of the areas covered by the National Science Foundation grant, the U. S. Census Bureau county level estimates were used as adjustment factors. Zip codes to which this adjustment was applied include 39503, 39532, 39540, 39556, 39562, 39565, and 39574.

In Hancock County, the county level adjustment factor was used for only one of its five zip codes, 39556. In Harrison County, the county level adjustment factor was used for four of its ten zip codes, 39503, 39532, 39540, and 39574. The county level adjustment factor was used for two of the five zip codes in Jackson County, 39562 and 39565.

The county level adjustment factor for Hancock County is $(35{,}129)^* (35{,}129/42{,}967)^{(1/6)}$, where 35,129 is the population of Hancock County, as estimated by the U. S. Census Bureau (2006) for January 1st, 2006, and 42,967 is the population of Hancock County, as counted in census 2000 (US Census Bureau, 2000). By taking the ratio of the 2006 population to the 2000 population to the $1/6^{th}$ power, the geometric rate of change is found (0.967). Multiplying this rate by the 2006 population of 35,129 yields 33,969, the estimated population of Hancock County in 2007, as impacted by Hurricane Katrina. This value is then divided by the 2000 population (42,967) to get the ratio of 0.791, which is then multiplied by the population in a given age sex group as found in step 3.

For Harrison County, the county level adjustment factor is $(155{,}817)^* (155{,}817/189{,}601)^{(1/6)}$, where 155,817 is the population of Harrison County, as estimated by the U. S. Census Bureau (2006) for January 1st, 2006, and 189,601 is the population of Harrison County, as counted in census 2000 (US Census Bureau 2000). By taking the ratio of the 2006 population to the 2000 population to the $1/6^{th}$ power, the geometric rate of change is found (0.968). Multiplying this rate by the 2006 population of 155,817 yields 150,803, the estimated population of Harrison County in

2007, as impacted by Hurricane Katrina. This value is then divided by the 2000 population (189,601) to get the ratio of 0.795, which is then multiplied by the population in a given age sex group as found in step 3.

The county level adjustment factor in Jackson County is (126,311)* $(126,311/131,420)^{(1/6)}$, where 126,311 is the population of Harrison County, as estimated by the U. S. Census Bureau (2006) for January 1st, 2006, and 131,420 is the population of Harrison County, as counted in census 2000 (US Census Bureau, 2000). By taking the ratio of the 2006 population to the 2000 population to the 1/6th power, the geometric rate of change is found (0.993). Multiplying this rate by the 2006 population of 126,311 yields 125,479, the estimated population of Harrison County in 2007, as impacted by Hurricane Katrina. This value is then divided by the 2000 population (131,420) to get the ratio of 0.955, which is then multiplied by the population in a given age sex group as found in step 3.

Step 4 NSF Adjustment. For those zip codes that did contain areas covered by the National Science Foundation grant, data from the study were used as adjustment factors. As stated earlier, zip codes to which this adjustment was applied were: 39501, 39507, 39520, 39525, 39530, 39531, 39560, 39564, 39567, 39571, 39572, 39576, and 39581.

For zip codes 39501, 39507, 39525, 39530, 39531, 39560, 39564, 39567, and 39581, data from census tracts 27 and 28 in Harrison County were used. Specifically, it was found that the 2006 household population in the blocks of these two census tracts covered in the NSF study found a population of 4,554 compared to the 2000 population of 5,646. The number in each age/sex group as found in step 3 was multiplied by the ratio 4,554/5646 to get the final age-sex numbers for 2007 in these four zip codes.

For zip codes 39520 and 39572, data from census tracts 301 and 302 in Hancock County were used. Specifically, it was found that the 2006 household population in the blocks of these two census tracts covered in the NSF study found a population of 2,855 compared to the 2000 population of 2,915. The number in each age/sex group as found in step 3 was multiplied by the ratio 2,855/2,915 to get the final age-sex numbers for 2007 in zip code 39520.

For zip codes 39571 and 39576, data from census tracts 29 and 30 in Harrison County were used. Specifically, it was found that the 2006 household population in the blocks of these two census tracts covered in the NSF study found a population of 970 compared to the 2000 population of 3,669. The number in each age/sex group as found in step 3 was multiplied by the ratio 970/3,669 to get the final age-sex numbers for 2007 in zip code 39571.

DISCUSSION

The estimates presented here suggest that at least in the case of Katrina's impact on the Mississippi gulf coast, the effects of a disaster can be long-lasting. In a similar vein, Cossman (2007) finds that "agents of delay" have served to extend Katrina's effects on this same area and he argues that these same agents will be associated with future disasters, both natural and man-made. The demographic impacts of Katrina on the Mississippi gulf coast will be apparent when data from the 2010 census are released. They are likely to be seen in the 2020 census.[6]

With the potential for such long-lasting impacts, research clearly has a role to play in attempting not only to gauge, but ameliorate the impacts of disasters. However, doing on-the-ground research in the aftermath of a disaster is a challenging task (Kinnell and Dellinger, 2007; Knack et al. 2006). The task is made easier by having "pre-positioned" funding available, such as the NSF SGER grant that funded research used in part to develop the estimates presented here. To the extent that other resources can be

so pre-positioned, the task would be made even more tractable. Thus, in the last part of this discussion, I present suggestions on what these resources might be and how they could be pre-positioned.

The two most important resources are: (1) subjects; and (2) survey team members. Because Kinnell and Dellinger (2007) cover many of the issues involved in recruiting subjects and offer suggestions aimed at locating them and gaining their participation, I will focus on the second resource, survey team members.[7]

The recruitment of survey team members may not be as difficult as the recruitment of subjects, but it is not an easy task. Who is available on short-notice? Of those who are, how can those who would serve as good survey team members be identified? When they are identified, how can adequate training be effected? These are three key questions and I believe there is a single answer to each of them: Have a team trained in advance and ready to go. This is not a new suggestion in that the Disaster Research Centers largely have this capability with disaster researchers with whom the centers are affiliated. However, what I suggest is that the U. S. Census Bureau consider taking on this task by using a segment of its permanent field work staff. In particular, I am thinking of the field workers who carry out work in regard to the American Community Survey and the Current Population Survey. From these groups, a cadre could be recruited and trained that would serve as the core of a rapid response survey research team. The team could be supplied with "pre-positioned" equipment, to include self-contained living and working quarters that could be "dropped in" following a disaster. The self-contained living quarters would have power, water, food service, health, security and sanitary facilities to go along with the power, security, work stations, supplies, and communication capabilities of the self-contained working quarters. The major disaster research centers (e.g., the universities of Colorado and Delaware) could develop training programs that would be implanted by researchers who have experience "on-the ground" with data collection following a disaster (see, e.g., Kinnell and Dellinger, 2007 and Swanson et al., 2007). The logical organization to provide funding for this activity is FEMA and because FEMA has been identified as one of the agents of delay (Cossman, 2007), funding this type of research may be a way for FEMA to help move itself into a more positive role.

The first step in effectively dealing with a disaster is the presence of a plan. As noted by Sokura and Cosby (2007: 250), it is typical of organizations to have both "disaster recovery" plans and "business continuation" plans. Given the long term demographic effects of Katrina and other disasters, I suggest that the U. S. Census Bureau, with financial assistance from FEMA and technical assistance from the Disaster Research Centers and individual researchers, help communities develop similar plans to those of organizations by having not only having historical data available, but by having the capacity to estimate the demographic impacts of a disaster immediately in its aftermath and over its subsequent "effects horizon."

ACKNOWLEDGMENTS

The author thanks Angelina Tofolli and Tom Exter of Pitney Bowles MAPINFO for assistance in obtaining the 1990 and 2000 zip code data. This material is partly based upon work supported by the National Science Foundation under Grant No. 0555136. Any opinions, findings, and conclusions are those of the author and do not necessarily reflect the views of the National Science Foundation.

ENDNOTES

1. The detail data for each of the 20 zip codes are available from the author (David.swanson@ucr.edu). These tables represent the estimated populations based on Katrina's impact

and the estimated populations that would have resulted had Katrina not occurred.

2. The work supported by the National Science Foundation under Grant No. 0555136 was awarded to the University of Mississippi (D. Swanson (Sociology & Anthropology), PI; Mark Van Boening (Economics) and Rich Forgette (Political Science), Co-PIs). The Acronym "SGER" stands for "Small Grants for Exploratory Research." Very soon after Katrina struck the Mississippi Gulf Coast, The National Science Foundation issued a call for "SGER" grants to assess its impact.

3. The definition of a housing unit follows that of the U. S. Census Bureau's definition as used in the 2000 Decennial Census. However, the U. S. Census Bureau has no definition for a "damaged" or "destroyed" housing unit. Given the intent of our study, we needed such a definition. Therefore, we defined a "damaged housing unit as one that had received observable damage, but was still standing and appeared to be structurally sound. For example, a house with a blue tarp for a roof and all of the doors, windows, and interior walls missing was defined as damaged. A Destroyed house was one that was either completely gone (e.g., only a slab remained) or sustained structural damage (e.g., supporting beams for the roof had collapsed, a wall was caved in). In cases where it was difficult to distinguish whether a house was damaged or destroyed, we classified it as damaged.

4. The U. S. Census Bureau technically does not distinguish between a temporary and permanent housing unit, although it does have definitions that exclude counting structures that could potentially serve as "temporary" housing units if they are not occupied. That is, if a structure is not intended for long term occupancy it is only counted as a housing unit if it is occupied; if this same structure is not occupied, it is not counted. Specifically, the U. S. Census Bureau defines a housing unit as a shelter intended for "separate use' by its occupants such that there is independent access to the outside and the shelter is not a group quarters (Swanson and Stephan, 2004: 762). Given the intent of our study we needed to identify temporary housing units. Therefore, we defined temporary housing units using the following protocol. First, we defined as temporary housing units, any non-permanent structure in which people were residing. This included tents, lean-to, campsites, motor vehicles, recreational vehicles, travel trailers, house trailers and mobile homes with their axles and wheels in place. The recreational vehicles, travel trailers, house trailers, and mobile homes classified as temporary housing units generally were on lots next to destroyed or damaged permanent housing units or in parks and usually were connected to power and other utilities. In such cases, even if they were not occupied, we counted them as temporary housing units. If we encountered tents, cars, and trucks that were not occupied, we did not count them as housing units. Similarly, if we encountered un-occupied recreational vehicles, travel trailers, house trailers, and mobile homes on sales lots we did not count them (these were usually either heavily damaged or destroyed anyway)

5. The household population is comprised of those who live in housing units (as opposed to those who are homeless or living in group quarters – prisons, long-term care hospitals, military barracks, and school and college dormitories (Swanson and Stephan, 2004: 762)

6. The U. S. Census Bureau (2006) found that the city of New Orleans lost nearly 280,000 people, about two-thirds of its pre-Katrina population and in the process found a dramatic alteration of its racial composition. The impact of Katrina on New Orleans will be felt well beyond the 2020 census.

7. Besides covering issues related to recruiting subjects, Kinnell and Dellinger (2007) also cite other studies aimed at this goal.

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Water Quality Studies of Nworie River in Owerri, Nigeria

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ABSTRACT

Nworie River is a first order stream that runs about a 5km course across Owerri metropolis in Imo State, Nigeria before emptying into another river, the Otamiri River. Its watershed is subject to intensive human and industrial activities resulting in the discharge of a wide range of pollutants. The river is used for various domestic applications by inhabitants of Owerri. When the public water supply fails, the river further serves as a source of direct drinking water, especially for the poorer segment of the city. Studies of water quality parameters are therefore necessary to determine the extent of pollution so as to monitor likely danger, not only to the human population but also to the aquatic life. A total of eleven (11) water quality parameters were investigated during the month of January 2007, which fell within the dry season in Nigeria. The parameters investigated were dissolved oxygen, carbon dioxide, pH, chloride, nitrate-nitrogen, nitrate, ammonia-nitrogen, hardness, orthophosphate, sulfide and silica. With the exception of dissolved oxygen and carbon dioxide, other chemical parameters did not exceed the water quality standards, suggesting that the river was relatively unpolluted chemically when surveyed. However, the low dissolved oxygen concentrations and high carbon dioxide concentrations strongly implicate pollution by organic wastes. Further, the study demonstrated significant longitudinal variations in the water quality parameters along the course of the river, reflecting differences in quality and quantity of pollutants at various locations. It is recommended that further studies be conducted that include the biological profile of the River.

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Introduction

Nworie River, a typical freshwater resource under high urban pressure, runs an approximately 5.0km course through Owerri, the capital of Imo State in southeastern Nigeria (Fig.1). The river is of enormous economic importance to inhabitants of Owerri metropolis as it serves as a water source for various domestic uses and is also a channel of sewage disposal from Owerri. The river also supports a substantial recreational and part-time fishing for youths. Some segments of the human population in Owerri use it as a direct source of drinking water, especially during failures of the public water supply.

Nworie River is potentially vulnerable to a variety of polluting influences. All through its course, there is a steady input of large quantities of detergents from laundry activities (Fig. 2). At several points, the river receives large quantities of sewage and solid wastes, especially plastic water sachets (Figs. 3 and 4). Further, when it rains, large volumes of run-off carrying agricultural and human wastes are discharged directly into the river.

Figure 1 Map of Nigeria showing Imo State

Figure 2. Washing clothes in the river

Figure 3. Pipe carrying water for home use

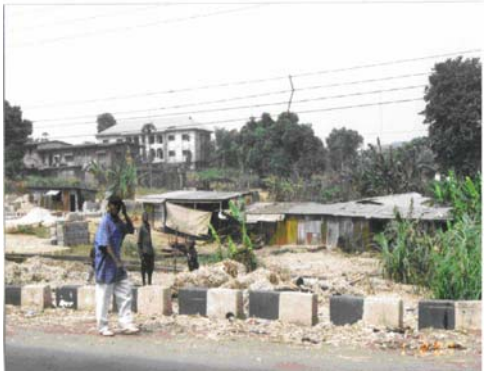

Figure 4. Water sachets left along river

It is a generally accepted view that tremendous organic loads imposed by urban sewage and other wastes constitute a major cause of pollution of natural water bodies (Hynes, 1960). There is hardly a major river today that flows into the sea unmodified. Health hazards previously unsuspected have come to light in recent decades, and 'allowable' quantities of once rare trace metals appear in modern-quantity standard lists. In view of the public apprehension of the hazards of water pollution, regular water quality monitoring of inland water bodies is highly necessary (Renn, 1970). To reveal the exact identity of pollutants, chemical analysis of a water body needs to be made. The purpose of this study was to determine the values of several chemical parameters at five sampling stations along the longitudinal course of the Nworie River; it was to determine the chemical profile of Nworie River

Material and Methods

Five sampling sites were chosen along the longitudinal stretch of the river: two sites upstream; two sites midstream; and one site downstream towards the confluence of Nworie River and Otamiri River.

Water samples were collected in the sites for two consecutive days during the month of January, 2007, which fell within the dry season in Nigeria. Water collection was done using clean plastic containers. These sample bottles were immersed below the water surface, filled to overflowing, and the cap affixed securely to eliminate the possibility of an air bubble in the container. The water samples were transported immediately to the laboratory at Imo State University, Owerri. In the laboratory the LaMotte test kits were used to perform various chemical pollution tests as directed by the

manufacturer. The LaMotte test kits operated on a combination of titration and colorimetric procedures.

The chemical parameters tested were dissolved oxygen, carbon dioxide, pH, chloride, nitrate-nitrogen, nitrate, ammonia-nitrogen, hardness, orthophosphate, sulfide and silica. The test results were analyzed and compared with World Health Organization (WHO)/Environmental Protection Agency, USA (EPA) water quality standards.

Results and Discussion

Table 1 and Figures 5-6 show the results of the water analyses for the five sampling stations, namely, Upstream I, Upstream II, Midstream I, Midstream II, and Downstream compared with WHO/EPA water quality standards. Figure 5 shows the longitudinal variations of some key chemical parameter readings.

Table 1

Sampling Sites

S/N	Parameters	Upstream I	Upstream II	Midstream I	Midstream II	Downstream	WHO/EPA Standard
1	Dissolved Oxygen	3.0	1.2	3.2	1.1	3.0	4.0-5.0
2	CO_2	20.2	30.3	18.5	27.5	13.0	10.0
3	pH	5.5	5.8	6.0	6.0	5.8	6.5-9.0
4	Chloride	20.5	15.0	12.0	12.0	12.0	250
5	Nitrate-Nitrogen	0.4	0.6	0.1	0.1	0.2	10
6	Nitrite	1.76	2.64	0.44	0.44	0.88	1
7	Ammonia-Nitrogen	<1.0	<1.0	4.0	4.0	3.0	N/A
8	Hardness (total)	28	16	8	8	8	50
9	Orthophosphate	0.2	0.3	<0.2	<0.2	0.2	N/A
10	Sulfide	<0.3	0.3	<0.2	<0.2	0.2	2.0
11	Silica	3.5	4.0	3.2	4.0	4.0	2-25.00+

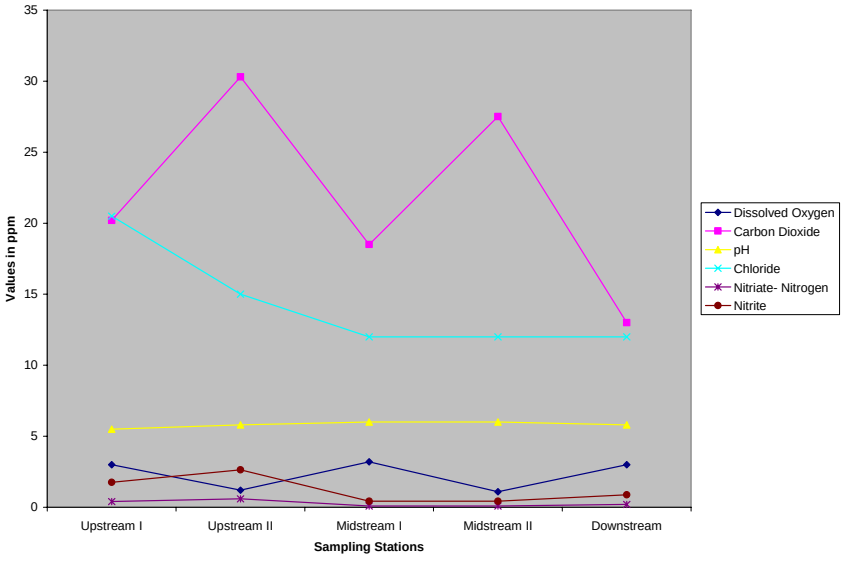

Figure 5. Longitudinal Variation of Chemical Parameter Readings from Nworie River

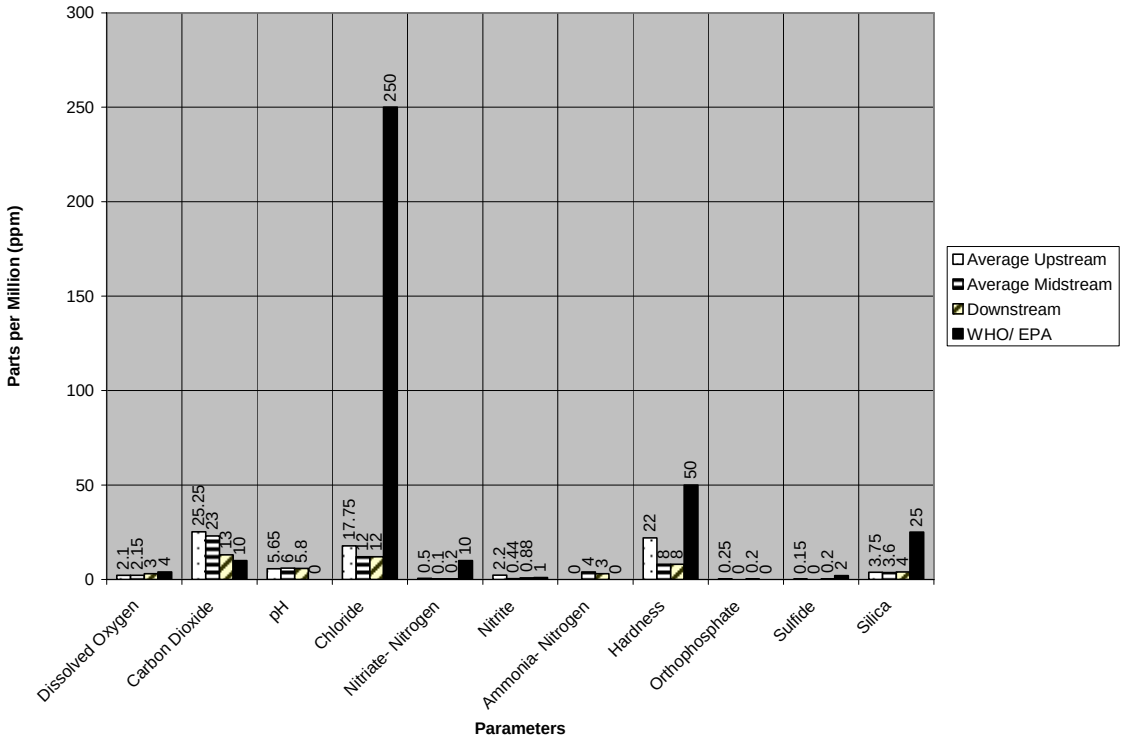

Figure 6. Chemical parameter readings from Nworie River compared with WHO/EPA standards

With the exception of dissolved oxygen and carbon dioxide, the water quality parameters of Nworie River did not exceed the thresholds of WHO/ EPA water quality standards. Thus, generally speaking, the chemical pollutants in the river did not exceed water quality standards. Judging from the physical appearance of the River at various sites, it was expected that the chemical contaminants in the water would be high. This could be attributed to the fact that lotic bodies of water are in constant flow and that contaminated spots or areas eventually become clear or less turbid. However, in terms of organic wastes, this study showed that the river was under pressure and could be classified as polluted. This assertion is obvious from the dissolved oxygen and carbon dioxide concentrations and the refuse dumps in or near the banks of the water at various locations (see Figures 7--9).

Figure 7 right to left Dr. Acholonu and Dr. Okorie and his assistant showing refuge strewn at the river edge

Figure 8 Area where young boy was swimming in what could be polluted water

Figure 9. Huts and businesses along river

Oxygen and CO2 contents are some of the practical indications of water purity. Oxygen concentrations in all the sampling studies of Nworie River were below the 5.00 ppm threshold, below which several fish species may not survive. The low oxygen concentrations were most probably a result of decay of large quantities of organic material discharged into the river. Dissolved oxygen is depleted by the decaying process. Similarly and strongly further supporting this view, the carbon dioxide concentrations were remarkably higher than thresholds in all sampling stations. High carbon dioxide concentrations usually indicate increased respiratory process, as well as increased microbial decomposition of dead organic materials. Thus a fall in dissolved oxygen concentration with a corresponding increase in carbon dioxide concentration is to be expected in situations of large inputs of organic wastes into an aquatic ecosystem. Polluted or enriched waters, will most likely, show great changes in dissolved oxygen and carbon dioxide.

Further indicators of the large inputs of organic wastes into the river were the existence of some phosphates and chlorides in the sampling stations. Most domestic wastes contain chlorides and phosphates. Contamination of domestic sewage can, in fact, be monitored by chloride assays. This is

because human and animal excretions contain, on the average, 5 g Cl-1 per liter (Coles, 1979). Concentrations of phosphates and chlorides observed in this study, though lower than water quality standards, were seemingly significant.

Silica concentration, hardness and pH, all fall within range of what might be expected of a freshwater system. In rivers and lakes, silicon commonly ranges from 2-25.0 ppm, and is usually expressed as silica (Si02) in water analysis. There is a relationship between silica and biotic segment of the aquatic ecosystem, especially the diatom crop (Lund, 1964). The slight acidity of the river all through its course is not surprising. Rainwater is slightly acidic with pH of 5.5-6.0. If it reacts with soils and minerals containing weak alkaline materials, the hydroxyl ions will increase and the hydrogen ions decrease. As a result, the water may become slightly alkaline with a pH of 8.0-8.5. Thus, most natural waters will have pH values ranging from 5.0-8.5 (Renn, 1968). Nworie River is on the acidic end of this range. The catchment's area of the river is distinctly acidic, with a pH of 4.9 reported by Enwezor et al (1981). This, therefore, largely explains why the river is acidic all through.

Finally, the longitudinal variations of chemical parameters along its course provide an insight into the dynamics of anthropogenic perturbations of lotic freshwater bodies. There are spatial variations in concentrations of pollutants reflecting differences in quality and quantity of organic waste inputs at various locations in the river. For instance, the river midstream shows a higher concentration of ammonia, suggesting a steady input of fresh sewage, which was not the case upstream. The human population in Owerri metropolis is mainly concentrated around midstream of this river, hence the higher pollution rate midstream (see Table I). As the human population of Owerri grows, so also will the intensity of water pollution, perhaps up to a breaking point for the river. Survival of rivers faced with similar threats can be enhanced by deliberate measures that ensure that solid wastes and untreated sewage are not directly discharged into such river. Also attempts need be made to protect their watersheds in terms of re-forestation and discipline in construction works in their watershed.

This study was conducted during the dry season and did not include microbial analysis. It is recommended that further studies be conducted that include the microbial or biotic profile of the River as was done by Acholonu and Jenkins (2007) and also carried out during the rainy season.

It is recommended that Nworie River be dredged and with the involvement of seasoned technocrats. It may do more harm than good if improperly conducted by raking up pollutants that settled at the bottom of the river and consequently, increasing or causing the resurgence of water-borne diseases such as typhoid, cholera, dysentery and some intestinal parasitic diseases. The former river course deserves to be re-established and its esthetic beauty and cleanliness restored. Any bridge crossing the river that impedes its free flow as is presently the situation in some areas, needs to be re-constructed.

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Infraspecific Systematic Relationships Of *Sarracenia Alata* Wood. (Sarraceniaceae) Inferred From Nuclear Ribosomal DNA Sequences

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ABSTRACT

Yellow trumpets, *Sarracenia alata*, is an insectivorous perennial herb that occurs infrequently in acidic hillside seepage bogs and wet savannas from central Texas to southern Alabama. Its overall range is disjunct with the western portion extending from central Texas to western Louisiana and the eastern portion extending from southeastern Louisiana to southern Alabama. Phylogenetic analysis using combined nuclear ribosomal Internally Transcribed Spacer 2 and large ribosomal subunit 26S rRNA gene DNA sequences suggest that the two disjuncts are not phylogenetically distinct from each other. It is speculated that the present range of *S. alata* is the result of recent migrations facilitated by rare long-distance seed dispersal events. Because these events likely have occurred only since the beginning of the Holocene, insufficient time has elapsed to bring about detectable evidence of molecular divergence between the two disjuncts of *S. alata*, at least with the two genes used in this study.

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Introduction

Yellow trumpets, *Sarracenia alata*, is an insectivorous perennial herb that occurs infrequently in acidic hillside seepage bogs and wet savannas from central Texas to southern Alabama (Wherry, 1929; McDaniel, 1971; MacRoberts and MacRoberts, 1988). Its range is disjunct with the western portion extending from central Texas to western Louisiana and the eastern portion extending from southeastern Louisiana to southern Alabama (Fig. 1). The closest distance between these two disjuncts is approximately 310 km. According to Sheridan (1991), the two disjuncts are separated by alluvial soil of the Mississippi River basin that is unsuitable for *S. alata* and is the primary factor for its absence there.

Although there are no obvious morphological characters that consistently distinguish eastern from western disjuncts of *Sarracenia alata* (Sheridan, 1991), various leaf color forms among individual populations occur. Mature leaves are typically green with reddish veins near the peristome and hood. However, some Mississippi populations in the eastern disjunct exhibit distinctive dark rose coloration.

Of the named species of *Sarracenia*, only *S. purpurea* and *S. rubra* have been divided into subspecific taxa. In the case of *S. rubra*, each of five recognized subspecies (sensu Kartesz & Meacham, 1999) are disjunct and can be distinguished morphologically (Schnell, 1977)

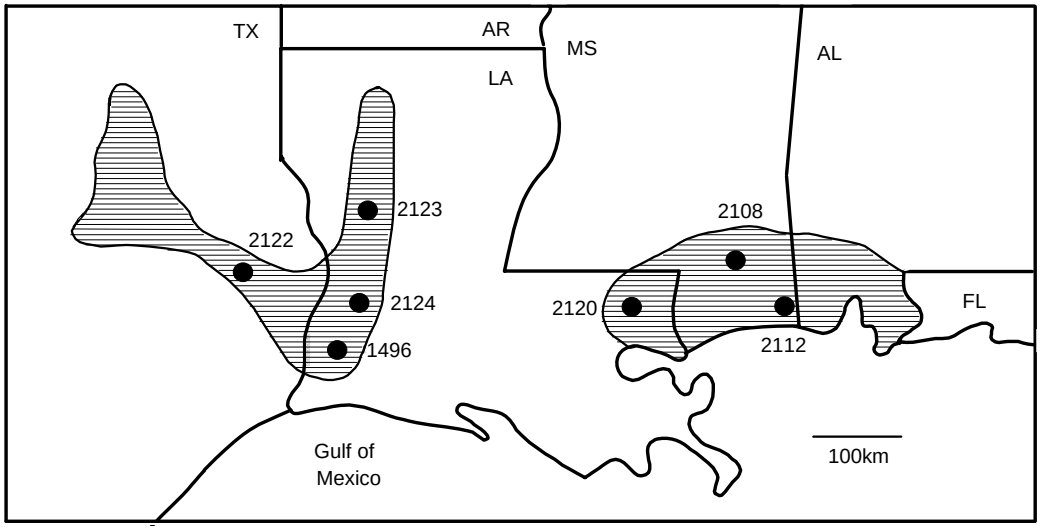

Fig. 1. Shaded areas illustrate the range of *Sarracenia alata*. The voucher number and location for each individual sequenced are indicated.

The two recognized subspecies of *S. purpurea* (sensu Kartesz & Meacham, 1999) are morphologically distinct (Wherry, 1972, 1973; Schnell 1979; Ellison & Parker, 2002) but they are not disjunct (Kartesz & Meacham, 1999). However, two morphologically distinct varieties, *S. purpurea* ssp. *purpurea* var. *montana* (Cf. Schnell & Determann, 1997) and *S. purpurea* ssp. *purpurea* var. *burkii* (Cf. Ellison et al., 2004) each occupy disjunct ranges.

The purpose of this study is to investigate the infraspecific systematics of *Sarracenia alata*. Because this species occurs in two widely separated disjuncts, molecular divergence, as evidenced by phylogenetic distinction, may have occurred. This investigation is based on a phylogenetic analysis of combined nuclear ribosome Internally Transcribed Spacer 2 (ITS2) and large ribosomal subunit gene (26S) DNA sequences. The outcome of this study may impact the ecological, taxonomic and systematic understanding of this species.

MATERIALS AND METHODS

Vouchers and GenBank accessions for the taxa included in this study are listed in Table 1. The ingroup consists of 18 representatives from *Sarracenia*. Following (Albert et al., 1992; Beyer et al., 1996; Neyland & Merchant, 2006), *Heliamphora* was selected as outgroup (Table 1). Representatives from each of the two disjuncts of *Sarracenia alata* are included in the analysis (Table 1).

The two representatives from southern Mississippi (vouchers 2112 and 2108) exhibit the distinctive dark rose-colored form, whereas all other representatives exhibit the typical coloration.

For enhanced context, other members of *Sarracenia* are included. Specifically, a single individual from each of the four named taxa of the *S. purpurea* complex also are included in this analysis (Table 1). Additionally, three individuals representing widely separated populations of *S. leucophylla* are included (Table 1). Unlike that of *S. alata* and *S. purpurea*, *S. leucophylla* has a range that is continuous and extends from northwestern

Florida to southern Mississippi. No infraspecific taxa of *S. leucophylla* have been named.

An approximate 1kb DNA segment of the 26S gene combined with an approximate 245 base-pair length nuclear ribosomal ITS2 region for each representative listed in Table 1 was analyzed in this study. The 26S segment, which spans base positions 4-958 in *Nicotiana tabacum* (GenBank Accession AF479172), is characterized by conserved segments and more variable expansion segments (Kuzoff et al., 1998). The rate of divergence in this 26S segment has been shown to be informative at the infraspecific level in previous plant systematic studies (e.g. Neyland, 2004, Neyland & Hennigan, 2004; Neyland & Merchant, 2006). Additionally, the ITS2 region has been shown to be informative at the infraspecific level in previous plant systematic studies (e.g. Wilson, 2003).

DNA sequences were used to infer systematic relationships through a maximum parsimony phylogenetic analysis using the heuristic search algorithm with Phylogenetic Analysis Using Parsimony (PAUP version 4.0b10) software (Swofford, 2002). Searches employed 1000 random stepwise addition replications. All characters including transitions and transversions were weighted equally. Gaps were treated as missing data. Disk copies of aligned sequences are available from the author. As a measure of clade stability or robustness, bootstrap support (Felsenstein, 1985) was calculated. Ten thousand bootstrap replications were employed in this analysis (MulTrees option in effect).

Total DNA was extracted from tissue using the CTAB method (Doyle & Doyle, 1987). DNA sequences were amplified via polymerase chain reaction (PCR) (Mullis & Faloona, 1987) with combinations of forward and reverse primers referenced in Neyland (2002).

DNA was amplified with Tfl enzyme (Epicentre Technologies, Madison, WI), using the following thermocycling protocol: a hot start at 94º C for 3 minutes; 30 amplification cycles of 94º C for 1 minute, 55º C for 1 minute; 72º C for 3.5 minutes, a terminal extension phase at 72º C and an indefinite terminal hold at 4º C. The double-stranded PCR product was purified with QIAquick (Qiagen, Hilden, Germany) using the manufacturer's protocol. Two µl of each sample was electrophoresed in a 1.0% agarose mini-gel for quantification against a known standard. Automated sequencing was conducted on an ABI Prism 377 Sequencer with XL Upgrade (housed at Louisiana State University, Baton Rouge, LA, USA) using ABI Prism, Big Dye Terminator cycle sequencing protocol (P.E. Applied Biosystems, Foster City, CA, USA). Sequences have been deposited in the GenBank database (Table 1).

Table 1. Taxa analyzed in this study. All ingroup representatives are from *Sarracenia* with *Heliamphora heterodoxa* as outgroup. All sequences have been deposited in GenBank. Vouchers are housed at the McNeese State University herbarium (MCN). Location data for wild-collected specimens are indicated. Taxonomy follows Kartesz and Meacham (1999). Representatives of *Sarracenia alata* from the eastern and western disjuncts are so designated.

Taxon	*Voucher*	GenBank Accession
Sarracenia alata Wood (Western Disjunct)	Neyland 1496 Calcasieu Parish, LA	AY795884
Sarracenia alata Wood (Eastern Disjunct)	Neyland 2112 Jackson County, MS	AY789969
Sarracenia alata Wood (Eastern Disjunct)	Neyland 2120 Tangipahoa Parish, LA	AY789968
Sarracenia alata Wood (Eastern Disjunct)	Neyland 2108 Stone County, MS	AY795883
Sarracenia alata Wood (Western Disjunct)	Neyland 2122 Hardin County, TX	AY796054
Sarracenia alata Wood (Western Disjunct)	Neyland 2123 Natchitoches Parish, LA	AY795885
Sarracenia alata Wood (Western Disjunct)	Neyland 2124 Beauregard Parish, LA	DQ646479
Sarracenia flava L.	Neyland 2109 Santa Rosa County, FL	DQ017391
Sarracenia leucophylla Raf.	Neyland 2113 Jackson County, MS	AY796055
Sarracenia leucophylla Raf.	Neyland 2110 Santa Rosa County, FL	DQ088065
Sarracenia leucophylla Raf.	Neyland 2117 Baldwin County, AL	DQ088066
Sarracenia minor Walt.	Neyland 2139	DQ073470
Sarracenia psittacina Michx.	Neyland 2121 Tangipahoa Parish, LA	AY967802
Sarracenia purpurea L. ssp. *gibbosa* (Raf.) Wherry	Neyland 2137	DQ028630
Sarracenia purpurea L. ssp. *purpurea* var. *burkii* Schnell	Neyland 2142 Escambia County, FL	DQ088067
Sarracenia purpurea L. ssp. *purpurea* var. *montana* Schnell & Determann	Neyland 2136 Henderson County, NC	DQ028631
Sarracenia purpurea L. ssp. *purpurea* var. *purpurea*	Neyland 2154	DQ098117
Sarracenia rubra Walt. ssp *rubra*	Neyland 2135	DQ028629
Sarracenia rubra Walt. ssp. *wherryi* (F.W. & R.B. Case) Schnell	Neyland 2153	DQ076326
Heliamphora heterodoxa Steyerm.	Neyland 1809	AY796056

RESULTS AND DISCUSSION

Sequences were aligned by visual inspection. Gaps were introduced to accommodate six single-point insertions/deletions (INDELS) in the data set. INDELS were not included as informative characters. The largest absolute pairwise distance between any two members in the data set is 74 between *Heliamphora heterodoxa* and *Sarracenia purpurea ssp. purpurea* var. *burkii*. The largest absolute distance between any two members of *Sarracenia alata* is 3 between representatives 2112 and 1496. There were 0 differences between representatives 2124 and 2112, 1496 and 2112, and 2124 and 2108. Unambiguous transitions and transversions numbered 34 and 9 respectively. Therefore, transitions outnumbered transversions by a factor of nearly 4 to 1.

Phylogenetic analyisis resulted in the recovery of three most-parsimonious trees. Each tree is 108 steps with a consistency index of 0.8981 and a retention index of 0.8804. The strict consensus tree indicates that all seven *Sarracenia alata* representatives appear in an unresolved polytomy (Fig. 2). Therefore, the eastern and western disjuncts of *Sarracenia alata* are not phylogenetically distinct from each other. The systematic relationships among the *S. leucophylla* representatives are, likewise, unresolved. However, the four representatives from the *S. purpurea* complex are completely resolved with strong bootstrap support (Fig. 2). This suggests that the phylogenetic structure of *S. alata*, a species with a disjunct range is more similar to that of *S. leucophylla*, a species with a continuous range than it is to *S. purpurea*, a species with a disjunct range.

Results from this study suggest that the two *Sarracenia alata* disjuncts are not phylogenetically distinct. However, the two disjuncts are likely reproductively isolated with no appreciable gene flow between them. *Sarracenia* seeds are small (about 2mm long in *S. alata*) (Ellison, 2001) and they have no obvious ornamentation, eliasomes or other structures to attract potential long-distance dispersers (Schnell, 1976; Godt & Hamrick, 1998; Ellison & Parker, 2002). Because seeds are hydroscopic, they are dispersed by flotation and typically are found within a few centimeters of the mother plant (Ellison & Parker, 2002). Therefore, the wide area of alluvial soil in the Mississippi River basin is unsuitable for intermediate colonization and presents a formidable barrier between the two disjuncts. Additionally, the normal pollination vectors of *Sarracenia* are bees (Schnell, 1976 1978; Slack, 1979; O'Neil, 1983) including *Bombus* that has a foraging range of only a few kilometers (Kreyer et al., 2004). Therefore, it appears unlikely that gene flow between the two disjuncts occurs through pollination.

It remains an open question why two apparently reproductively isolated disjuncts of *S. alata* exhibit little or no molecular divergence from each other. One possibility is that the two disjuncts were isolated only recently with the moderation of the global climate in the Holocene starting about 11,000 years ago.

During the maximum southern limit of the Wisconsin-stage glaciation about 18,000 years ago in the Pleistocene, the area now occupied *by Sarracenia alata* was considerably colder and drier than at present (Gulf of Mexico Program, 2004). The vegetation landscape at that time was substantially different than that of today. Little is known about how this and other species of *Sarracenia* were distributed in the Gulf Coast area during the Pleistocene. However, once the climate began to moderate in the Holocene, this and other species of *Sarracenia*, perhaps surviving in refugia, began migrating into newly suitable habitat. The most extensive of these post ice age migrations is that by *Sarracenia purpurea*, which has become established along much of the eastern coast of

the United States and across southern Canada presumably through rare
long-distance dispersal events (Ellison and Parker, 2002).

Because the seeds of *S. alata* are so poorly adapted for long distance dispersal, the migration across the alluvial barrier between the modern disjuncts likely occurred through rare long-distance seed dispersal events (Cf. Higgins & Richardson, 1999; Ellison, 2001; Ellison & Parker, 2002,). Because these events likely have occurred only since the beginning of the Holocene, insufficient time has elapsed that would bring about detectable evidence of molecular divergence between the two disjuncts of *S. alata*, at least with the two genes used in this study.

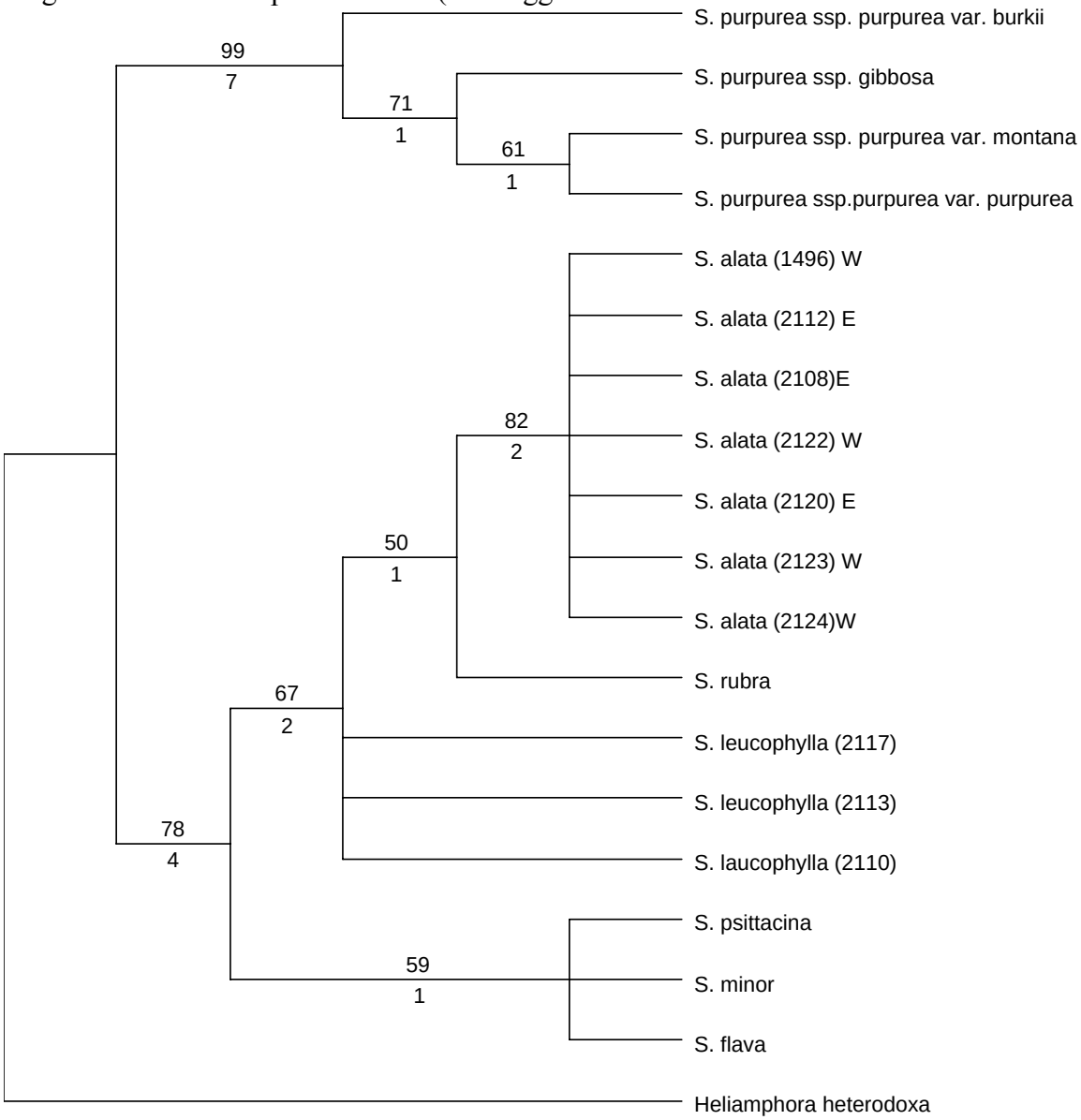

Fig. 2. Strict consensus cladogram from a heuristic maximum parsimony search using combined ITS2 and 26S rRNA gene sequences. Bootstrap values greater than 50% are indicated above each branch; synapomorphies are indicated below each branch.

ACKNOWLEDGEMENTS
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The Bird Tick, *Ixodes brunneus* Koch (Acari: Ixodidae): a Rare and Unusual Tick in Mississippi

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Introduction

The bird-feeding tick, *Ixodes brunneus*, Koch (Acari: Ixodidae) (Figure 1), is an interesting tick which occurs in primarily in North America. All active stages of *I. brunneus* have been collected on birds of many species, but commonly reported hosts include blackbirds, jays, robins, sparrows, thrashers, thrushes, towhees, waxwings, and wrens (Bishopp and Trembley 1945, Cooley and Kohls 1945). It does not bite humans. Although this species likely occurs throughout Mississippi, it has been collected only rarely (Goddard and Layton 2006). Numerous drag-cloth tick surveys by the author in Mississippi, conducted weekly for years, failed to find *I. brunneus* (Goddard 1992, 1997, Goddard et al. 2003, Goddard and Paddock 2005). This paper presents new records for the bird tick, description of a site where specimens may be readily collected, and comments on an apparent bacterial symbiont associated with the tick.

Tick collections and seasonality. All collections were made by dragging a 1-m^2 white flannel cloth through the woods, roadsides, and game/nature trails. Tick collections were made year-round and were performed as part of statewide tick/disease and ecology surveys; no systematic or targeted efforts were made to collect this particular species. A total of 52 *Ixodes brunneus* specimens have been collected to date in Mississippi (see records section for data) – 38 females and 14 males. Identification of 10 of the specimens was confirmed by personnel at the U.S. National Tick Collection, Georgia Southern University, Statesboro, GA and deposited there as voucher specimens. Mississippi records of *I. brunneus* consist of specimens collected from Choctaw, Marshall, Oktibbeha, and Scott counties from February – April, with the majority (41/52; 79%) collected in March. This is consistent with other studies in the U.S. which reported them collected in almost every month (Bishopp and Trembley 1945, Cooley and Kohls 1945), although predominantly between October and April.
Interestingly, 48/52 (92%) total adult specimens ever collected in Mississippi were taken from one spot, a 30-m section of nature trail at Wall Doxey State Park, near Holly Springs, MS (see records section for lat/long data). This section of trail, approximately 2-m wide and mowed regularly, was surrounded by kudzu vines with a few large pine and hardwood trees nearby. It looked no different than other areas along the 4-km trail. Throughout the year, the spot was approximately 20% shaded.

Figure 1. Male and female *Ixodes brunneus*, showing relative size.

Unidentified bacteria in *I. brunneus.* During a survey for tick-borne disease agents, 17 of the 52 ticks reported in this paper were analyzed for *Rickettsia, Ehrlichia,* and *Borrelia* species (Goddard et al. 2003). Abundant bacilliform bacteria were found in 12 of the 17 (71%) of *I. brunneus* tested. These organisms appeared to be concentrated in the salivary glands or midgut tissues, where massive infections were observed (Figure 2). Sometimes the organisms appeared "hooked" on the ends or linked together, resembling spirochetes. For this reason, PCR was used to rule out a *Borrelia* species, such as *B. anserina*. PCR amplification of DNA from a single *I. brunneus* that contained the unidentified bacteria was performed using universal primers for the 16S rRNA gene, as well as with *Borrelia*-specific primers. All tests were negative. The predominant sequence obtained using universal 16S rRNA primers did not closely match any sequences in GenBank. The most similar sequences, derived by comparison using the Basic Local Alignment Search Tool program (BLAST), showed identities of 90 or 91% and were from endosymbionts of *Acanthoamoeba* (accession numbers AF069962 and AF069963). Other sequences represented in the top 50 scores were primarily from *Anaplasma* species, although *Ehrlichia risticii* was indicated. The sequence obtained from the *I. brunneus* tick was deposited in GenBank and assigned accession number AY167034. The significance of this bacterial infection in *I. brunneus* remains undetermined.

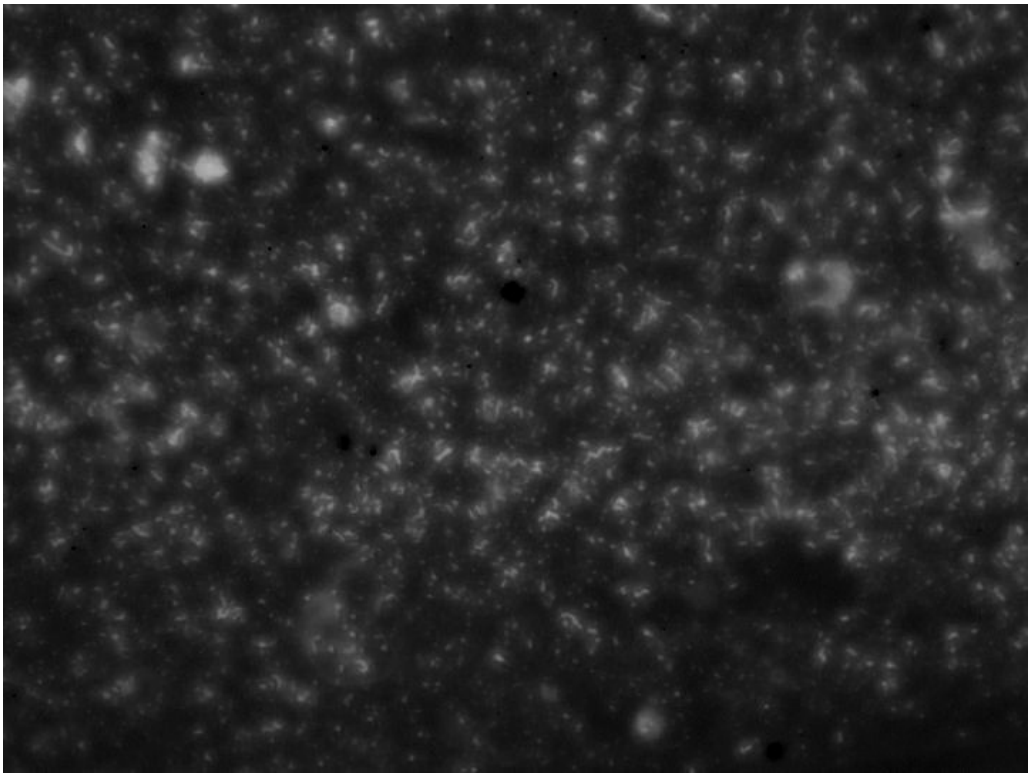

Figure 2. Bacilliform bacteria found in *Ixodes brunneus* specimens.

NEW RECORDS

CHOCTAW: 20-II-1985, Choctaw Wildlife Management Area near Louisville, N 33^0 12.079, W 089^0 07.918, J. Goddard, 1 female. MARSHALL: 6-III-1997, Wall Doxey State Park (WDSP), N 34^0 39.868, W 089^0 28.199, J. Goddard, 1 female. 7-III-1997, WDSP, J. Goddard, 1 male. 24-III-1997, WDSP, J. Goddard, 4 females, 2 males. 18-IV-1997, WDSP, J. Goddard, 3 females, 1 male. 17-III-2000, WDSP, J. Goddard, 12 females, 5 males. 27-III-2001, WDSP, J. Goddard, 10 females, 3 males. 19-IV-2001, WDSP, J. Goddard, 1 male. 6-IV-2006, WDSP, J. Goddard, 3 females. 23-II-2007, WDSP, J. Goddard, 1 male. 18-IV-2007, WDSP, J. Goddard, 1 female. OKTIBBEHA: 29-III-1985, Starkville, J. Goddard, 1 female. SCOTT: 20-II-1985, Bienville National Forest near Morton, N 32^0 21.901, W 089^0 33.674, J. Goddard, 2 females.

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White Flowered *Centrosema virginianum* in Mississippi

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Centrosema means spur on the back of the standard (Dean et. al 1973). Throughout the world, this genus exhibits flowers in white, violet, rose, pink, or blue on a total of 50 shrub and herb species, of which 45 are in the American tropics with approximately 30 being vines; three of which occur in the southeastern states with only one species being outside Florida (Small 1933, Gerth Van Wijk 1971, Willis 1973, Allen and Allen 1981, Venning 1984).

Spurred butterfly pea (*C. virginianum*) is common in Mississippi. A white flower form may be rare (Ronald Wieland, Minnesota Department of Natural Resources, John McDonald, Mississippi State University, Alan Weakley, University of North Carolina Herbarium, Paul Fantz, North Carolina State University, Steve Leonard, consulting botanist, Wiggins, MS, Heather Sullivan, Mississippi Museum of Natural Science, and Gail Barton, Mississippi Native Plant Society, personal communications, 2006-2008). It commonly has been reported to have violet, purple, or blue flowers (Gray 1870, Robinson and Fernald 1908, Britton and Brown 1913, Dormon 1934, Gleason 1952, Greene and Blomquist 1953, Gleason and Cronquist 1963, Long and Lakela 1971, Dean et. al 1973, Stones and Urbatsch 1991, Timme and Timme 2000) and also lavender flowers (Dormon 1958, Wilbur 1963, Radford et al. 1964, Dormon 1965, Timme 1989), additionally, "nearly white" (Correll and Johnston 1970), and "occasionally whitish" (Brown 1972), and pink-purple and pink-white (Isely 1990). The University of South Florida Herbarium website list 6 specimens with notworthy color variations: purple and brown with white spot, lavender with pale yellow center, bluish and blotched with white/yellow, blue with broad yellow band, and purple with yellow crest with pink wings and keel. This species is highly polymorphic, widely distributed, and highly deserving of additional study (Wilbur 1963).

A single white flowered specimen occurred in 2006 five miles Southwest of Brandon, Rankin County, Mississippi. Numerous populations have been examined in Mississippi, Georgia, Oklahoma, and South Carolina with color variation including faint colors, but never pure white. This specimen is uniformly white with no visible nectar guide or spot in the center.

Its description is typical for the species with a slender, climbing, twining stem. Three leaflets of normal shape and texture. Flowers are inverted with nine fused stamens and 1 free, 3 - 4 cm corolla, and 2.5 – 3(4) cm wide standard with spur that is covered by the caylx. The wing and keel petals are nearly equal. The flat, legume has many seeds and twists open when ripe.

The site was mid-slope, naturally regenerated pine-hardwoods. It was hit by a tornado in 1992 and the timber was salvaged. A permanent fire line was installed in 1997, and several late winter burns were conducted. The subject was located on the immediate edge of the fireline.

Later in 2006, two seed pods were collected and the seeds were scattered on the ridge top of the same property. Several spurred butterfly pea seedlings grew the next summer. Many remained small and did not flower. All that did, except one, had the same pure white

flowers. The original plant was located repeatedly in 2007 and again had only white flowers.

In the fall of 2007, seeds of seedlings with white flowers were collected and scattered around in similar fashion as in winter 2006. This summer, 2008, several new white flowered and at least some new seedlings with blue-violet (in natural lighting, lavender under florescent lighting) flowers occurred around the home.

Comments are solicited. Has it been documented with pure white flowers? Could this be an escaped exotic white flowered species of *Centrosema*? Is this a maverick form of spurred butterfly pea? Two citations reporting near-white color are location specific to the western range; therefore, could the white color be endemic to Mississippi-Louisiana-Texas region?

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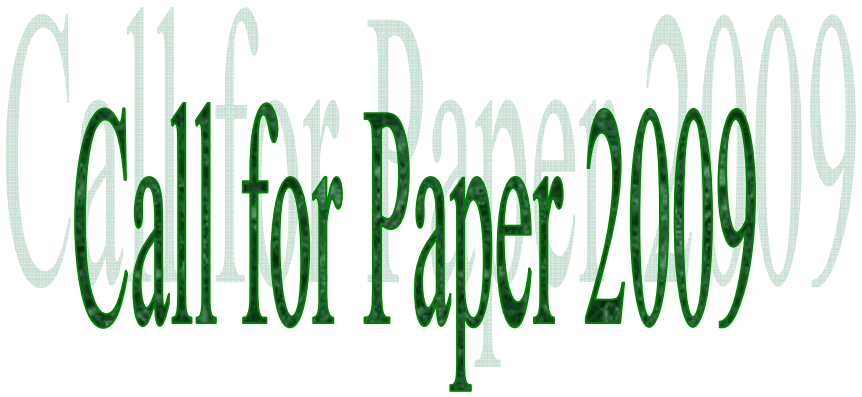
DIVISIONAL REPORTS

Physics and Engineering Division.

Chair: Dr. Alina Gearba, Assistant Professor, Department of Physics and Astronomy, University of Southern Mississippi
Vice-Chair: Dr. Hazar Dib, Assistant Professor, School of Construction, University of Southern Mississippi
2008 MAS Annual Meeting Highlights: - 22 research presentations-
***Best Undergraduate Student Presentation*: Joshua Etchison**, Department of Computer Engineering, Jackson State University for *A HILS System for UAV Attitude Data Synchronization*.
Advisor: Dr. Kamal Ali-
***Best Graduate Student Presentation*: Mallika Dhar,** Department of Physics and Astronomy, University of Southern Mississippi for *Solving Schrodinger Equation in Position, Momentum and Mixed Spaced Representation*. A**dvisor: Dr. Khin Maung Maung**



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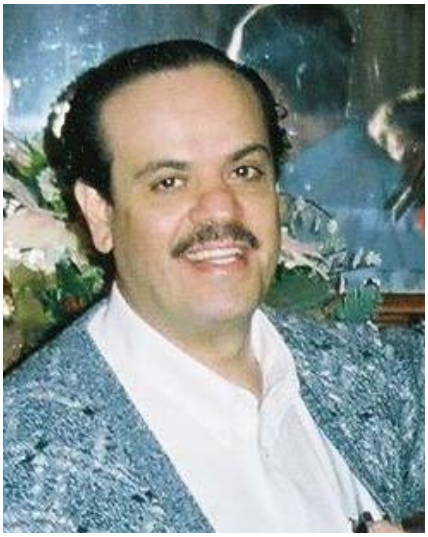

Executive Director Column

by

Dr. Ham Benghuzzi

We are looking forward to seeing the research that is taking place all over Mississippi. Please contact your division chairs to see how you can participate in this years meeting.

We are at **the point where it all begins. That point is the submission of your research for the upcoming meeting**. Dr. Rodney Baker has been working hard in setting up the Dodgen Lecture and Plenary Speakers for this years meeting. The Dodgen Lecture will feature new technology to evaluate the role of gaseous mediators of inflammation. This topic should draw a lot of attention from several divisions and spark ideas and conversation.

It is everyone working together that will result in a successful meeting. **If you are a Chair or Co-Chair of a Division remember you have made a commitment to your colleagues and they are counting on you to provide the leadership for your group**. Let us **all** remember **if we point a finger to blame someone else for a shortcoming there are three fingers pointing back in our direction**.

I leave you with a quote from -- ***George Henry Lewes (1817-78)***. Science is the systematic classification of experience.

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