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Influence of the Annual Flood Pulse of the Atchafalaya River and Updates on the Ecology of Floodplain Aquatic and Semi-Aquatic Hemiptera and their Associates

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INFLUENCE OF THE ANNUAL FLOOD PULSE OF THE ATCHAFALAYA RIVER AND UPDATES ON THE ECOLOGY OF FLOODPLAIN AQUATIC AND SEMI-AQUATIC HEMIPTERA AND THEIR ASSOCIATES

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ABSTRACT

Understanding the biodiversity of insects in an area provides key insights into the health and uniqueness of an ecosystem. Here we increase the breadth of knowledge of Louisiana aquatic Hemiptera through field and natural history collection research.

The Atchafalaya River floodplain is variably inundated throughout the course of the year, peaking with the spring flood pulse, resulting in spatiotemporally dynamic habitats for aquatic organisms. Buffalo Cove Water Management Unit (BC) is within the river system, whereas Lake Fausse Pointe (LFP) has been leveed from the influence of the river for over 50 years.

We collected aquatic macroinvertebrates with quatrefoil light traps, a suitcase sampler, and sweep nets along transects in open water and water hyacinth-dominated habitats at both locations over the course of the 2018 and 2019 spring flood pulses, and measured water quality at trap locations. BC had higher biodiversity of invertebrates (55, compared to 25 in LFP) and Hemiptera (15 taxa opposed to 6) and double the number of hemipteran families (7 and 3, respectively). Although multiple water quality parameters were found to be significant in determining Hemipteran distribution between the two study areas, the most parsimonious explanation was the levee-caused lack of flooding in LFP.

Natural history collections are often overlooked sources of distributional data. The Louisiana State Arthropod Museum (LSAM) is an excellent example of a collection of potentially critical data regarding the distribution and species composition of the state’s arthropod fauna. Label data from these specimens were transcribed, and database and literature searches were conducted for all aquatic Hemiptera. Localities were manually geolocated and assigned GPS coordinates with ACMEMapper and mapped in GIS to provide species ranges for

the state fauna. Based on this effort, 4,300 specimens from LSAM were cataloged, dating back to 1905. Across 14 families, there were 296 previously unpublished parish species records.

In combination, this comprehensive study of the aquatic Hemiptera of Louisiana betters taxonomic understanding and provides key ecological insights for the order.

CHAPTER 1. INTRODUCTION AND LITERATURE REVIEW

1.1. Insects in Biological Assessment

Historically, invertebrates have been used, largely at the family and order level, in studying water quality (e.g. flow, turbidity, DO) implemented through scoring systems to establish trends and determine management plans. Insects are short lived, rapidly reproductive, and display diverse life history patterns that make study informative with minimum effort and overhead (Resh and Rosenberg 1984, Extence and Ferguson 1989). For example, EPT (Ephemeroptera, Plecoptera, Trichoptera) and Chironomidae-based metrics are implemented around the world in a wide variety of water bodies allowing standardization of systems (Lenat and Penrose 1996). Traditionally, the focus has rarely been on individual species or systems, rather on collections of sensitive families and orders (Karr and Chu 1999, Colon-Gaud et al. 2004, Kaller and Hartman 2004, Bonada et al. 2006, Maloney and Feminella 2006). Improved taxonomy and variability of habitats make the establishment and proper communication of new metrics beyond EPT and diversity of Chironomidae feasible and necessary for the establishment of accurate biometrics in unique systems (Barbour et al. 1992, Lenat and Resh 2001, Bressler et al. 2006). Given the widespread application of biological assessment to detect anthropogenic perturbation, robust understanding of insect biology and ecology is needed to interpret these assessments, particularly when applied in new circumstances.

Because Louisiana water resources, such as the Atchafalaya River and its floodplain, are extensively exploited and thus heavily managed, researchers have begun to address anthropogenic problems surrounding more charismatic, economically, and socio-culturally important biota, such as trees, fish, and birds (Piazza and Wright 2004, Troutman et al. 2011, Kozak et al. 2016). General knowledge of aquatic insects, however, lags behind that of fishes, plants, and even plankton. Compared with other river systems, relatively few published studies and reports document the insect fauna of the ARB (e.g. Barr and Chapin 1988, Bryan, Truesdale,

and Sabins 1975, Colon-Gaud et al., 2004, Colon-Gaud and Kelso 2003, Fisher and Kelso 2007, Goyer, Lenhard, and Smith 1990; Lockaby et al. 2002, Mihuc, Battle, Mihuc, and Bryan 2002), and no effort has been undertaken to systematically develop a set of baseline expectations (i.e., a reference condition) or an insect-based biological assessment for the ARB.. This potentially informative set of metrics is simply lacking for the system.

1.2. Hemiptera in Biological Assessment

Established metrics, such as EPT, do have their limitations (Karr and Chu 1999, North Carolina Department of Environment and Natural Resources 2006). EPT metrics are most valuable in cold water streams and rivers where taxa are abundant and lack thereof is easily noted. In warm water areas, such as Louisiana, metrics based on EPT taxa tend to fail as diversity of sensitive taxa diminishes. In Louisiana especially, Plecoptera are at the southern end of their natural range and found during limited periods of the year (Stewart et al. 1976). Moreover, because of their habitat associations, Plecoptera are limited in distribution (Felley 1992, Kaller et al. 2013) due to sandy sediment composition and lack of large substrate (Markos et al. 2016), as well as, the characteristically low dissolved oxygen of lotic systems in the region (Ice and Sugden 2003, Kaller and Kelso 2007), making EPT based assessments inconsistent (Kaller and Kelso 2010) and therefore not optimal in these systems

The insect order Hemiptera, or true bugs, are classified by their sclerotized beak which they use to feed on various plants, insects, and even vertebrates. Hemiptera is the largest hemimetabolous insect group taxonomically and is speculated to contain approximately 95,000 species. Hemiptera is considered a “major” insect order with only four of the thirty insect orders (Hymenoptera, Diptera, Lepidoptera, and Coleoptera) known to contain more species (Gullan and Cranston 2014). Over 400 species in North America are aquatic or semiaquatic, all

belonging to the suborder Heteroptera. These members can be found over a wide range of water conditions and multiple predatory niches; most have raptorial front legs and are powerful predators (Ward 1992, Polhemus 2008). Economically, these insects are pests of fish hatcheries and other anthropogenically impacted environments (e.g., docks and marinas), where Belostomatidae eat young fish and pool under artificial light, earning them the common names "electric light bugs" and "fish killers" (Gonsoulin 1973, Thorp and Rogers 2011). Hemipterans of most families also favor dipteran larvae, such as mosquitos (Culicidae), biting flies (Tabanidae), and midges (Chironomidae), limiting adult prey populations, occasionally to local extinction. In areas like Louisiana where vector disease is a concern, this natural control is crucial (Murdoch et al. 1984, Papacek 2001, Foltz and Dodson 2009, Thorp and Rogers 2011, Saha et al. 2014). The introduction of exotic Hemipterans is also worth noting. *Nertha fuscipes* (Gelastocoridae) (Guérin-Méneville) is now established in urban Florida (Halbert and Eger 2009), causing concern for potential introduction to Louisiana because of proximity and similarity of biomes.

Hemipterans also provide a key insight into water quality and ecosystem diversity, serving as both predators and prey for invertebrates and vertebrates (Polhemus 2008). Predators especially are typically of interest as they often become adapted to (morphologically and behaviorally) specific prey type and size. Hemipterans are less limited in prey size than insects with basal mandibular jaws. Belostomatids have been observed feeding on woodpeckers (Matheson 1907), large snakes (Wilson 1958) and large (7.5 cm total body length) fish, but these are extraordinary cases. More typically, true bugs are limited to prey that they can easily catch and hold with their raptorial forelegs (Peckarsky et al. 1990). Changes in distribution and prevalence of such organisms can indicate larger shifts in the system on a local and evolutionary scale. Generalists

and specialists alike impact densely packed areas of prey by reducing overall population size and changing sex and age structures. Hunting method and detection of prey is highly varied between and within families. Nepids and notonectids ambush prey, whereas Gerridae stalk. Cue types include chemical, tactile (i.e. differences in surface tension), and visual (Peckarsky 1984, Peckarsky et al. 1990, Lancaster and Downes 2013, Sullivan et al. 2016). Whereas flight ability varies among adults of different species and populations (e.g. Gerridae, which exhibit wing polymorphism) (Drake and Hottes 1952, Angerson 1993), hemipterans will often relocate rather than remain in an undesirable location, readily colonizing rice fields, drainage ditches, and other temporary habitats, especially in spring to mid-summer (Ward 1992, Foltz and Dodson 2009, Mercer et al. 2016, Peterson et al. 2017). Bugs in these seasonal areas will migrate to the closest stable habitat as waters dry, even if they are incapable of flight and highly vulnerable in the process (Boersma and Lytle 2014). Previous research showed that Hemipterans in general remained in the ARB through hypoxia, residing in the canopy of plants, indicating that true bugs of some sort are tolerant of low DO and may not relocate to escape it (Colon-Gaud, Kelso, and Rutherford 2004), also noted in ecosystems (Polhemus 2008, Roback 1974, Ward, 1992). Understanding when individuals migrate and why can provide valuable life cycle information for these large, predaceous insects and their prey (Boda and Csabai 2013).

Of the fifteen known families of aquatic and semiaquatic Hemiptera, fourteen reside in the state of Louisiana (Penn 1951, 1952, Ellis 1952, Gonsoulin 1973, Peckarsky et al. 1990). Incredible niche and morphological differences exist among and within these families. Belostomatidae, the giant water bugs, are the largest of the aquatic Hemiptera. They are known to consume a wide variety of prey, including fish and amphibians; they are typically found in association with aquatic vegetation, where they can use their breathing siphon to breathe

atmospheric oxygen (Polhemus 2008, Thorp and Rogers 2011). Corixidae, the water boatmen, are the anomaly of aquatic Hemiptera. Gregarious and with keen flight ability, these insects use their modified forelegs to consume periphyton and other organic matter and serve the ecosystem primarily as abundant prey for other taxa in addition to having predaceous species (Hungerford 1917, Griffith 1945, Peckarsky et al. 1990). Naucoridae, the creeping water bugs, are fast swimming, dorsoventrally flattened predators that prefer dipteran prey. Two species in the genus *Pelocoris* dominate much of the United States and are identified by male genitalia (McPherson et al. 1987, Epler 2006). Water scorpions (Nepidae) are one of the more easily identified members of the order, with elongated bodies and breathing siphons. These ambush predators are poor swimmers and are often found in dense vegetation, under stones, and in leaf packs (Sites and Polhemus 1994). Notonectidae, the backswimmers, feed on minute prey and exhibit modified hind legs for improved swimming. These surface dwellers get their name from swimming upside down so that they may breathe atmospheric oxygen as they move (Polhemus 2008). The closely related family Pleidae, the pygmy backswimmers, also demonstrates this behavior. They are the smallest of the aquatic Hemiptera, and feed on small planktonic invertebrates. Little research has been conducted on these creatures, in part due to their small size and aversion to most sampling methods (Ellis 1952, Epler 2006). The semiaquatic taxa, toad bugs (Gelastocoridae), velvet water bugs (Hebridae), shore bugs (Saldidae) and velvety shore bugs (Ochteridae) share many characteristics, including a generalist diet of invertebrates and legs adapted for running rather than swimming. Many are known to hunt on dense plant beds extending out into waterbodies. These families are not speciose, especially in Louisiana, but are present and of note (Ellis 1952, Gonsoulin 1973, Bobb 1974). Three families of striders are common in Louisiana and are represented by dozens of species. Gerridae, Veliidae,

Hydrometridae and Mesoveliidae are surface arthropod predators often found within emergent and mat vegetation by the hundreds. Ecologically near identical, the families are distinguished by morphological characteristics alone (Ellis 1952, Penn 1952, Polhemus 2008).

Aquatic Hemipteran have been avoided as an indicator group for several reasons. Biometrics established by the US Environmental Protection Agency have focused on EPT taxa and richness of Chironomidae, making adoption of those practices easier for managers to follow properly (Barbour et al. 1999). A preference for taxa easily sorted from woody debris has also been demonstrated (STAR 2002); nepids and hydrometrids are easily missed or confused for sticks and pleids are very small. Hemiptera are, however, catalogued in the STAR assessment, even though they are not focal taxa. Hemiptera are fast and live along shores and vegetation, making them difficult to sweep. This causes inaccuracies in sampling and can make them rare taxa, which are less useful for bioassessment (Guareschi et al. 2017); it is stated; however, that depending on the system and gear used, any taxa can be rare. In other systems, not only are Hemiptera rare, but they are reported to be too tolerant of changing environmental conditions to respond in an informative way beyond wetland type (Battle et al. 2001). It is also well recognized that outdated taxonomy and lack of proper taxonomic keys are a hurdle to identification and use in biological assessment (Epler 2006, Bright and Sites 2009, Tchakonté et al. 2015). Some studies have validated the use of Hemiptera, however, especially in combination with other predators (e.g. Coleoptera), (Tronstad et al. 2007, Tchakonté et al. 2015, Turić et al. 2015) Research on utilizing Hemiptera for bioassessment lags behind EPT taxa and Chironomidae, making research into their implications necessary (Bonada et al. 2006).

1.3.Floodplains and Hemiptera

Riparian wetlands are, by definition, areas where soils are influenced by water bodies (e.g. a stream or river). These dynamic ecosystems are crucial components of watersheds and larger landscapes, creating unique and highly productive systems, especially in coastal areas of the southeastern United States, which are dominated by bottomland hardwood forests (Mitsch and Gosselink 1993, King et al. 2005). In addition to important roles in carbon and nutrient cycling (Lindau et al. 2007), floodplain wetlands control erosion and allow ground waters to recharge, while also providing organisms habitat to reproduce in relative safety in the large variety of vegetation found in these ecotones (Junk et al. 1989, Faulkner et al. 2011) .

In regions affected by tropical storms, wetlands lessen damage to zones further inland by reducing storm surge, as was seen in Louisiana during Hurricane Andrew in 1992. Wetlands return to pre-storm conditions with relative ease, unlike upland areas unaccustomed to flooding (Costanza et al. 2008, Morton and Barras 2011). Their importance is easily seen in areas like the Mississippi Alluvial Valley, where wetlands have been largely destroyed and are in need of drastic restoration, leading to the destruction of infrastructure and loss of human lives in addition to ecological impacts (Faulkner et al. 2011, King et al. 2005).

Multiple past floodplain analyses have considered aquatic Hemiptera in their metrics. Often grouped with other predators (e.g. Odonata, Coleoptera), assemblages of Hemiptera have been shown to positively correlate to prolonged flood events and to be common across floodplain systems worldwide (Batzer and Ruhí 2013, Turić et al. 2015) Hemipterans readily colonize new habitats as adults, including temporarily flooded areas (Tronstad et al. 2007). Ruhi and Batzer (2014) even suggested that a new metric: Mollusca, Hemiptera, and Coleoptera (MHC) be established for wetlands, as these more tolerant taxa are often more representative in wetlands

than sensitive taxa. Mostly commonly, belostomatids, corixids, gerrids, and notonectids have been observed previously (Golladay and Taylor 1997, Tronstad et al. 2007, Batzer and Ruhí 2013) leaving ten of the families in Louisiana with little floodplain associated data.

1.4. The Atchafalaya River Basin

The Atchafalaya River is the fifth largest river by volume in the United States and is a part of the largest forested floodplain in North America. The Mississippi River watershed that feeds the Atchafalaya River is also the largest by area on the continent, encompassing much of the central United States and into Canada (Ford and Nyman 2011). Historically, the Atchafalaya Ridge made the Atchafalaya River and surrounding basin the most important outlet for the Mississippi River during high floods, but it quickly lost flow and became swamp in lower areas (Fisk 1944).

This waterway has been modified with artificial levees, canals, and other flow modifications resulting from multiple control measures. Large scale economic devastation and loss of life after the flood of 1927 initiated the management era in 1928, dividing the area into three sections: the West Atchafalaya Floodway, Morganza Floodway, and Atchafalaya Floodway System, which is now considered the Atchafalaya River basin (ARB). The Old River Control Project was implemented in 1963 and restricted water input to 30% of the Mississippi and Red River's output. The effects of this project, along with levee construction and modifications, are still felt throughout the ARB today. These artificial systems have constrained the wetland from the east and west to control flooding and allow large ships to pass (Ford and Nyman 2011, Piazza 2014, Mossa 2016). Canals have also been built for pipelines and fossil fuel access, which has caused natural channels to be abandoned, changing the hydrology and path of sediment. These new paths often lack the water velocity required for sediment to reach the Gulf of Mexico (hereafter Gulf), causing deposits and channel filling, which is a drastic change felt just within the last 150

years (Kolb and Van Lopik 1958, Kroes and Kraemer 2013). Through modification, the area of the ARB has been reduced to 838,000 acres, less than fifty percent of its original expanse (Piazza 2014).

Considered a working swamp, the ARB is split approximately in half between public and private land and is known for fishing, hunting, boating, and other recreation (Piazza 2014). It is also used extensively for fossil fuel extraction and serves as one of the largest oil exploration areas in the state. Pipeline construction contributes to wetland loss, resulting in an increase in open water acreage, in addition to the risk of leaks. The ARB contains numerous pipelines, as does much of southern Louisiana and the Gulf (Hartman and Reubsamen 1992, Louisiana Department of Natural Resources 2008). Despite the impacts of oil and gas exploration and extraction, the ARB houses over 100 known species of fish and crustaceans, including red swamp crayfish (*Procambarus clarkii*), largemouth bass (*Micropterus salmoides*), crappie (*Pomoxis spp*.), and other commercial and sport fish, promoted by the varying connectivity and nutrient cycling of the seasonal flood pulse and the diverse vegetation within the area (Castellanos and Rozas 2001, Alford and Walker 2013).

For approximately half of the year (January through July), much of the ARB is flooded and aquatic habitats are variably connected. As the water temperature surpasses 20°C in the summer and inundation is high, hypoxia sets in throughout (Sabo et al. 1999, Pasco et al. 2016) . Low oxygen conditions may be lengthened and exacerbated by invasive plant species (Kaller et al. 2015) like hydrilla (*Hydrilla verticillata*) and water hyacinth (*Eichhornia crassipes*), which occur in dense patches creating dissolved oxygen (DO) peaks and crashes (Caraco et al. 2006, Bradshaw et al. 2015). Hypoxia affects seasonal plankton species composition and development

of aquatic organisms, influencing the ecology of the ARB (Davidson et al. 1998, Fontenot et al. 2001, Rutherford et al. 2001, Bonvillain et al. 2015).

1.5. Buffalo Cove Water Management Unit and Lake Fausse Pointe

The US Army Corps of Engineers implemented Buffalo Cove Management Unit (BC) in 2004 in hopes of restoring water quality and circulation through the ARB via sediment and flow manipulations (*United States Army Corps of Engineers, Atchafalaya Basin Floodway System, Louisiana, Feasibility Study, Main Report and Final Environmental Impact Statement Volumes 1-4* 1982, *United States Army Corps of Engineers Atchafalaya Basin Master Plan* 2000, *United States Army Corps of Engineers Environmental Assessment, Atchafalaya Basin Floodway System, Buffalo Cove Management Unit, Water Circulation Improvements and Sediment Management Initiatives EA #366* 2003, *United States Army Corps of Engineers Environmental Assessment Atchafalaya Basin Floodway System Buffalo Cove Management Unit* n.d.). The plan was to initially improve 7,500 acres of active floodplain, and to expand drastically over the course of the project. BC is in the southwestern portion of the basin, within St. Mary, St. Martin, and Iberia parishes. Numerous public launches are available for fishermen and scientists alike within a short drive of the town of Butte la Rose. Six elements originally aided in the increased north-south connectivity of the floodplain, but storms and high water have caused many changes to elements and cuts in its 15 year life span. Researchers have been charged with cataloguing and understanding water quality changes and progress in accordance with this effort, making it an ideal research location. Consequently, a body of literature exists on the water quality, habitat, and biota of Buffalo Cove (e.g. Jones et. al. 2014, Kaller et. al. 2017, Kaller et. al. 2011, Kaller et al. 2015, Pasco et al., 2016, Scott et. al. 2014; Trumbo et al. 2016); however, no previous studies have examined floodplain use by Hemiptera. Modification and management is ongoing, with the

state of Louisiana responsible for 25% of this effort (Louisian Coastal Protection and Restoration Authority 2020).

The Lake Fausse Pointe region was historically part of the larger Atchafalaya River floodplain and received annual flooding, when river levels were sufficient. Lake Fausse Pointe was separated from the rest of the ARB by the West Atchafalaya Basin Protection Levee (WABPL) completed in 1958. Currently, the Fausse Pointe cut defines the western boundary of Buffalo Cove (Louisiana Department of Wildlife and Fisheries 2012). Lakes Fausse Pointe and Dauterive cover an area of 17,000 acres and were historically natural lakes that fed into the Atchafalaya Basin. Functionally, the two are one water body, but the northern Lake Dauterive has been utilized extensively for fossil fuel exploration, leading to the name distinction (Louisiana Department of Wildlife and Fisheries 2012). Due to the establishment of the WABPL, Lake Fausse Pointe now feeds into the Teche-Vermillion watershed. Hydrologic input and output are regulated by the anthropogenic control structures, and the system is regularly maintained for wildlife and vegetation control. One public pier exists for the lakes, in Lake Fausse Pointe State Park, which also provides camping, hiking, and kayaking opportunities for park guests (Louisiana Department of Wildlife and Fisheries 2012).

1.6. Research Goals

The wide variety of morphological, behavioral, and taxonomic diversity within the Hemiptera makes them an ideal candidate for study within the Atchafalaya River basin. As previously described, Hemiptera differ in their exploitation of prey resources and habitat associations; therefore, abundance and richness can be easily directly and indirectly affected by physiochemical and biological changes and monitored to reflect these changes and their potential effects on the larger ecosystem. Artificial structures, such as constructed canals and

intentional levee breaches, that change flow velocity and water quantity may affect movement of even the strongest swimmers and striders, much like they do in fish (Favaro et al. 2014). *Hydrilla* and other nonnative plants may provide the benefit of habitat for weak swimmers and ambush predators, but also contribute to the severity of DO fluctuations, selecting for highly tolerant groups in the summer months (Colon-Gaud et al. 2004). Sediment that is deposited due to human modification fills deep pools and affects vegetation (Kroes and Kraemer 2013, Latuso et al. 2017), which in turn causes a change in the distribution of hemipterans and their prey. Hemiptera is a large and diverse order that may provide a comprehensive insight into the dynamics of their floodplain habitat when analyzed on the family, genus, and even species level.

The following chapters of this thesis investigated three aspects of Hemipteran ecology that may contribute to deeper ecological understanding of the Atchafalaya River basin. Chapter 2 evaluated the influence of anthropogenic interruption of river-floodplain connectivity and impacts of natural variability in flood magnitude. Chapter 3 updated distribution and taxonomic information that are critical in understanding biotic expectations, which in turn are central to biological assessment.

CHAPTER 2. EFFECTS OF CONNECTIVITY AND FLOODPLAIN DYNAMICS ON AQUATIC HEMIPTERA IN BUFFALO COVE WATER MANAGEMENT UNIT AND LAKE FAUSSE POINTE

2.1. Introduction

2.1.1. Aquatic Hemiptera

The insect order Hemiptera, or true bugs, are classified by their sclerotized beak which they use to feed on various plants, insects, and even vertebrates. Hemiptera is the largest hemimetabolous group taxonomically and is speculated to contain approximately 95,000 species. Over 400 species in North America are aquatic or semiaquatic, all belonging to the suborder Heteroptera. These members can be found over a wide range of water conditions and niches, although most have raptorial front legs and are powerful predators (Ward 1992, Polhemus 2008).

Hemipterans provide a key insight into water quality and ecosystem diversity. The wide variety of sizes, swimming abilities, and habitats make them formidable predators to invertebrates and vertebrates alike. Belostomatids are generalists, feeding on fish, frogs, insect larvae, and even each other (Penn 1952). Even pleids, which are only 1-2 mm in length, are gregarious and capable of affecting zooplankton populations (Gittelman 1978). Corixids, the only filtering family of the order, are found in large, multispecies assemblages that migrate when stressed (Griffith 1945). The composition and evenness of these assemblages may be key in understanding water quality metrics. Whereas flight ability varies among adults of different genera and populations, Hemiptera of all families will often relocate rather than remain in an undesirable location and will readily colonize rice fields, drainage ditches, and other temporary habitats, especially in spring to mid-summer (Ward 1992, Foltz and Dodson 2009, Mercer et al.

2016, Peterson et al. 2017). Bugs in these seasonal areas will migrate to the closest stable habitat as waters dry, even if they are incapable of flight and highly vulnerable in the process (Boersma and Lytle 2014). Previous research has shown that hemipterans in general remain in the Atchafalaya River basin (ARB) through hypoxia, residing in the canopy of plants (Colon-Gaud, Kelso, and Rutherford 2004), indicating that true bugs are tolerant of low dissolved oxygen and may not relocate to escape it (Roback 1974). Understanding when individuals migrate and why can provide valuable life cycle information for these large, predaceous insects and their prey (Boda and Csabai 2013). In this study, we decided to utilize the variable life history patterns of this order to better understand the ARB. We hypothesized that like other taxa (e.g., fishes; Junk et al. 1989), Hemiptera abundance and assemblage diversity would be higher in river-floodplain connected areas (i.e. floodplain that is influenced by the Atchafalaya River; BC) than unconnected areas (i.e. inundated areas that have been separated from the river; LFP). Moreover, we hypothesized that although generally considered tolerant to a wide variety of conditions (Roback 1974, Polhemus 2008), physicochemical factors also may impact Hemiptera abundance and assemblage diversity (e.g., the well documented, potentially stressful hypoxia of the ARB).

2.1.2. Floodplain Connectivity

It has been well established that floodplains are vital components of wetland ecosystems, providing nursery habitat for fauna, protection from storms, and nutrient sinks for runoff (Resh and Rosenberg 1984, King et al. 2005, Troutman et al. 2011, Latuso et al. 2017). Floodplains are also some of the most endangered habitats, at risk from degradation from anthropogenic factors (e.g. filling, leveeing; Smardon et al. 1996, King et al. 2005, Latuso et al. 2017). In order to conserve and appropriately mitigate anthropogenic impacts to these habitats, we must first understand how and why organisms occupy them temporarily or as residents.

2.1.3. The Atchafalaya River basin

The Atchafalaya River is located in southern Louisiana and has been a regulated distributary for the Red and Mississippi rivers since the establishment of the Old River Control Structure in 1963. Without this structure, it is believed that the Atchafalaya River would have become the primary distributary of the Mississippi River, destroying multiple municipalities and potentially capturing the majority of water volume (Fremling et al. 1989). While the Atchafalaya River may be controlled, it still experiences an annual flood pulse, inundating its floodplain for approximately half the year. During this time, backwater habitats become connected to the main channel, allowing for hydrologic turnover. When water levels drop in the summer, however, hypoxia sets in, causing fish kills and stress on aquatic fauna (Fremling et al. 1989, Ford and Nyman 2011, Piazza 2014, Mossa 2016)

To better maintain elements and cuts made in the ARB, water management units (WMU) have been established. Buffalo Cove WMU is located just south of Butte La Rose and is connected hydrologically to the river (*United States Army Corps of Engineers Environmental Assessment Atchafalaya Basin Floodway System Buffalo Cove Management Unit* n.d.). As such, it experiences the annual pulse. Lake Fausse Pointe, a natural lake, has been leveed off from the watershed and no longer experiences this seasonal variation in water level (Louisiana Department of Wildlife and Fisheries 2012). These areas were chosen for research due to their proximity to one another and previous research in Buffalo Cove. This closeness of location limits potential confounding variables so that more direct conclusions regarding floodplain connectivity can be made.

2.2. Materials and Methods

2.2.1. Field Sites

Sample sites were established in Buffalo Cove Water Management Unit (BC) of the Atchafalaya River Basin and in Lake Fausse Pointe (LFP) (Fig. 1) to cover a variety of connected and unconnected habitats. LFP was an ideal location for sampling outside the influence of seasonal flooding due to its close proximity to BC. In each unit, multiple sampling transects were established to access the floodplains.

In BC, three samples sites were established along access points (i.e., breaches in the levee) off the main river channel (Fig. 1). These access points were selected for their differing physiological properties relating to their floodplains. Site 1, the south most cut, had an established floodplain that remained independent of other areas during high water events on the southern side of the channel, complete with a high embankment, and a mudflat that merged into one large area during high water on the northern side. Site 2, the middle access point, merged into a lake on both sides. Site 3, the northernmost access point, had an established mudflat that prevents boating on the southern side and an independent floodplain to the north. Other differences included the prevalence of water hyacinth (*Eichhornia crassipes*), which were more common to the south, and willow (*Salix* sp), which dominated Site 3.

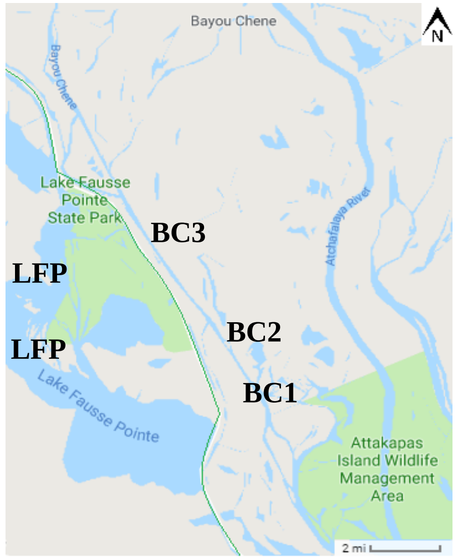

Figure 2.1. Sample sites in Buffalo Cove (BC) and Lake Fausse Pointe (LFP). Light traps were set in transects at each site location central to the river channel (BC) and inlet (LFP)

Specific site locations within these access points were determined by ability to penetrate the floodplain, prevalence of water hyacinth, crayfish traps (evidence of long-term accessibility; Bonvillain et al. 2013), and density of live trees capable of holding light traps in high flow conditions. Areas dense in water hyacinth were preferentially chosen to allow for active gear sampling. Active crayfish traps were given wide berth to prevent light trap manipulation and destruction by commercial harvesters.

Two low water sample sites were also established in Lake Fausse Pointe (LFP) (Fig. 2.1). These sites were only utilized when the National Weather Service hydrograph above Butte La Rose (https://water.weather.gov/) was below 10 feet (3.05 m) inundation mirroring low water in BC. Site 4 was placed in an access point similar to those in BC in the central part of the lake. Site 5 was located in Bird Island Chute, a southern area that is accessible year round and often occupied by water hyacinth. Sites LFP 4 and LFP 5 closely matched sites BC 3 and BC 2 respectively in latitude.

2.2.2. Gear

Quatrefoil light traps were modified for use in this study (Fig. 2.2). Traps were composed of two 30 cm x 30 cm sheets of Plexiglas combined by softened chloroform treated plastic to Plexiglas tubes, creating the trap (Floyd et al. 1984). Gaps between tubes were 16-20 mm. A chamber with a light stick hung from the center of the top Plexiglas sheet, and sheet insulation cut to size and attached with bolts served as a flotation device. Four-inch diameter PVC pipe cut into 38 mm sections were fixed with PVC glue to the center portion of the bottom sheet, which had a hole cut to size. Bolts threaded into holes on these sections allowed for a mini bungee cord to secure a one-gallon (3.78 L) paint strainer bag, in which samples were collected. Three meters of nylon rope with a carabiner was tied via a hole in the bottom sheet and used to secure traps to trees. Six inch (15.2 cm) green light sticks (Chemilure, World Plastics, San Carlos CA) were used. This model was selected because of their ability to withstand high temperatures that may be experienced in the Louisiana summer climate. After each randomized deployment, traps were washed to remove sediment that could affect effectiveness. Repairs were completed as needed using PVC glue and replacement parts.

Figure 2.2. Quatrefoil light trap post deployment. The light stick in the center lures aquatic organisms which become trapped in the clover shaped outer tubes.

The suitcase sampler used was constructed according to Colon-Gaud and Kelso (2003). After each deployment, the sampler was washed, and debris removed. Sweep samples were collected with a 45 cm x 25 cm rectangular kick net (0.5 mm mesh).

2.2.3. Sampling

High water sampling was conducted from March 7, 2018 to May 22, 2018 following by low water sampling from June 25, 2018 to September 16, 2018. Although water levels remained low after the conclusion of sampling, a reduction in average ambient air and water temperatures called for the end of data collection. The following season was unusually high, and only high water sampling could be conducted (March 7, 2019-August 2, 2019). The water would not meet the low water threshold until August 20, 2019, eliminating the possibility of thorough low water sampling in the timeframe.

During high water, light traps were deployed for approximately 24 hours in transects of six units centered on the channel of the cut. Subsites designated A and F were placed on the floodplain where water levels dropped close to the minimum required for the trap to work effectively (approximately 30 cm). Subsites C and D were secured to a large tree lining the channel, and subsites B and E were halfway points between A and C and D and F respectively (Fig 2.3). During low water, sites LFP 4 and LFP 5 were sampled in addition to sites BC 1-3, and only 4 traps (A, C, D, F) were deployed to satisfy spatial requirements in the reduced floodplain area. Trap sample bags were removed and placed in labelled jars with 90% ethanol on site. Time was recorded at light trap deployment and retrieval.

Figure 2.3. Light trap transects

Water flow velocity was measured at each trap subsite on day one of each sampling set, and a channel surface water quality measurement was taken with a portable water quality meter (ProDSS Multiparameter Water Quality Meter, YSI Incorporated, Yellow Springs, OH). Channel measurements were repeated on day 2 of sampling to confirm that there was no change during the sampling period.

Sweep netting and suitcase sampling were completed post trap retrieval. Sites with water hyacinth present but without a 1.5m x 1.5m mat or in deep water were swept twice aerially and once below the surface to standardize sweep size. These samples were placed in plastic bags on site, and the net rinsed with water after sampling. In shallow areas with intact hyacinth mats, a suitcase sampler was used in accordance with the protocol established by Colon-Gaud and Kelso (2003) to obtain one sample per subsite, which was placed in a large plastic bag. Both suitcase and sweep samples were frozen upon return to the lab. Suitcase sampling was not used in 2019 because the method requires standing in shallows

Arthropods were identified with a dissecting microscope (SZ61 Olympus, Inc., Shinjuku, Tokyo, Japan) and additional external light source following taxonomic guides (Gonsoulin 1973, Epler 2006, Polhemus 2008, Thorp and Rogers 2011) and the holdings of the Louisiana State Arthropod Museum. Hemipterans were identified to the lowest taxonomic practical level possible, often species, while all others were identified to family as allowed by life stage. Suitcase sample arthropod density and wet weight were calculated; plant material was then discarded. Other estimates were considered catch per effort, depending upon the gear type. All sorted and identified samples were stored in 90% ethanol to be deposited in the Louisiana State Arthropod Museum as vouchers. Hemipterans were catalogued and digitized as part of mapping the LSAM’s holdings (Appendix D).

2.2.4. Statistical Analysis

Prior to analyses, the number of organisms per trap was standardized to a 24 hour sample. For assemblages measures, Hemiptera per trap, arthropods per trap, Hemiptera richness per trap, arthropod (order) richness per trap, Hemiptera diversity (Shannon) per trap, and arthropod diversity (Shannon) per trap were analyzed by either linear mixed (LMM) or generalized linear mixed models (GLMM) with connectivity as a fixed effect (0, 1) and date and site as random effects (Program R vers. 3.6.1, package lme4, Bates et al. 2015; R Core Team 2019). Each response variable was evaluated by a set of candidate models that varied link transformation (none in LMM or log in GLMM) and error distribution (normal, Poisson, and negative binomial) with the Laplace approximation to ensure interpretable AIC. The final model was selected for inference was determined by the lowest AIC and deviance ratio closest to 1. This methodology was repeated for water year (0,1) and standardized water level.

Water quality analyses (connectivity, relative hydrograph level as measured at the Butte la Rose gauge compared to average, flow, surface temperature, dissolved oxygen, and vegetation density) were analyzed by either permutational multivariate analysis of variance (PERMANOVA) or multivariate GLMMs with an appropriate error distribution (normal, Poisson) with water quality parameter, date, and site (as the experimental unit) as fixed effects (Program R vers. 3.6.1, package vegan Oksanen et al. 2019, package mvabund;, Wang et al. 2012 R Core Team 2019). Final model was determined by examining Dunn-Smyth residual outputs and homogeneity of dispersion (Anderson et al. 2006). Influential taxa were determined by examining associations with the respective model.

2.3. Results

2.3.1. Taxonomy

Light trap samples contained 81 taxa including amphipods, shrimp, crayfish, fish, tadpoles, and numerous insects representing 48 families and 12 orders (Appendix A). This total number includes 25 taxa from eight families of aquatic Hemiptera identified to the genus and/or species level (Appendix A) All had been previously found in the state of Louisiana, but many were novel to the Atchafalaya River basin, including *Palmacorixa buenoi* (Hemiptera: Corixidae), which constituted a large portion of late summer samples. Suitcase sampling resulted in 20 arthropod families (three Hemiptera species) in 8 orders along with 11 non-insect associates. Sweeping resulted in 33 families (nine Hemiptera species) across 13 orders with 11 non-insect associates (Appendix B). Together, the three sampling methods produced 85 taxa in 52 families (25 Hemiptera taxa) across 13 orders.

Several taxa were found in only connected or disconnected habitats. *Belostoma lutarium* (Hemiptera: Belostomatidae) and *Ramphocorixa accuminata* (Hemiptera: Corixidae) were only found in the disconnected LFP. *Belostoma fusciventre, B. flumineum,* immatures (Hemiptera: Belostomatidae), *Trichocorixa reticulata, Sigaria* sp., *Corisella edulis, Sigaria virginiensis* (Hemiptera: Corixidae), *Limnogonus canaliculatus* (Hemiptera: Gerridae), *Notonecta* sp (Hemiptera: Notonectidae), *Neoplea striola* (Hemiptera: Pleidae), Culicidae, Stratiomyidae (Diptera), Tetrigidae (Orthoptera), Aeshnidae, Libellulidae, Cordulegasteridae (Odonata), Baetiscidae, Baetidae, Heptageniidae, Leptophlebiidae (Ephemeroptera), Noteridae, Scirtidae, Dryopidae (Coleoptera), Hydroptilidae, Philoptamidae, Hydropsychidae, Rhyacophilidae (Trichoptera), Corydalidae, Sialidae (Neuroptera), and Noctuidae (Lepidoptera) were found exclusively in the connected BC for a total difference of 32 taxa between sample habitats.

2.3.2. Vegetation

Vegetation at sample sites consisted primarily of water hyacinth (*Eichhornia crassipes*) (present at 100% of vegetated sites). Other taxa included salvinia (*Salvinia* sp.), duckweed (*Lemna* sp.), alligator weed (*Alternanthera philoxeroides*), frogbit (*Limnobium laevigatum*) and coontail (*Ceratophyllum demersum*). Vegetation was especially dense at BC 2, which was inaccessible for two weeks after Tropical Storm Barry (July 19, 2019) because of downed trees and dense hyacinth mats in the cut channel. Thirteen sweep samples were collected in 2018; 16 in 2019. Four suitcase samples were collected in the 2018 season. Statistical analysis was not completed on suitcase and sweep samples as too few were collected for proper modelling. Vegetation density was significant in determining taxa distribution of light trap samples (GLMM, log link, Poisson, X^2= 76.72, P < 0.01) The taxa most influenced by vegetation density were immature *Ranatra* (Hemiptera: Nepidae) (GLMM coefficient = -1.27), immature *Belostoma* (Hemiptera: Belostomatidae) (GLMM coefficient = +1.63), and Cordullidae (Odonata) (GLMM coefficient = -0.51).

2.3.3. Connectivity

Table 2.1. Summary statistics for richness, diversity, and density (animals per trap) for light traps comparing connected (Buffalo Cove) and unconnected (Lake Fausse Pointe) ecosystems.

Richness of Hemiptera	GLMM, negative binomial	X^2 = 1.51	P = 0.47
Richness of all invertebrates	GLMM, negative binomial	X^2 = 5.77	P = 0.02*
Diversity of Hemiptera	Linear Mixed Model	$F_{1,111}$ = 0.69	P = 0.41
Diversity of all invertebrates	Linear Mixed Model	$F_{1,111}$ = 3.26	P = 0.07
Hemiptera per trap	GLMM, negative binomial	X^2 = 0.52	P = 0.46
Invertebrates per trap	GLMM, negative binomial	X^2 < 0.01	P = 0.99

Richness of all invertebrates was significantly different between connected and disconnected habitats (connectivity estimate = -0.33, z = -2.39, P = 0.02). This GLMM; however, did not include a random effect for date, because date led to non-convergence.

Connected habitats had a back-transformed 0.71 (±1.13SE; effect size Cohen's d = 0.613) higher richness per trap than unconnected habitats.

2.3.4. Water Quality Variables

Water quality measures were relatively similar within BC and LFP (Table 2.4.). No summary assemblage measures were significant for either water level parameter, water year or water level (Table 2.2., 2.3.).

Table 2.2. Summary statistics for richness, diversity, and density (animals per trap) for light traps for varying water levels

Richness of Hemiptera	GLMM, negative binomial	$X^2 = 2.98$	P = 0.22
Richness of all invertebrates	GLMM, negative binomial	$X^2 = 3.28$	P = 0.19
Diversity of Hemiptera	Linear Mixed Model	$F_{1,111} = 3.47$	P = 0.17
Diversity of all invertebrates	Linear Mixed Model	$F_{1,111} = 2.84$	P = 0.24
Hemiptera per trap	Linear Mixed Model	$F_{1,111} = 0.18$	P = 0.91
Invertebrates per trap	GLMM, negative binomial	$X^2 = 0.57$	P = 0.75

Table 2.3. Summary statistics for richness, diversity, and density (animals per trap) for light traps between low (2018) and high (2019) water years

Richness of Hemiptera	GLMM, negative binomial	$X^2 = 2.48$	P = 0.12
Richness of all invertebrates	GLMM, negative binomial	$X^2 = 0.12$	P = 0.73
Diversity of Hemiptera	Linear Mixed Model	$F_{1,111} = 3.33$	P = 0.07
Diversity of all invertebrates	Linear Mixed Model	$F_{1,111} = 0.01$	P = 0.91
Hemiptera per trap	Linear Mixed Model	$F_{1,111} = 0.50$	P = 0.48
Invertebrates per trap	GLMM, negative binomial	$X^2 = 0.07$	P = 0.79

Table 2.4. Water quality measures for sampling locations in Buffalo Cove (BC) and Lake Fausse Pointe (LFP)

	BC 1 2018	BC 2 2018	BC 3 2018	LFP 4 2018	LFP 5 2018	BC 1 2019	BC 2 2019	BC 3 2019
Standardized Water Level (m)[1]	0.57 ± 0.30	0.59 ± 0.25	0.94 ± 0.27	-0.39 ± 0.01	-0.11 ± 0.01	0.02 ± 0.04	0.01 ± 0.05	0.10 ± 0.04
Average Water Level (m)	-0.46 ± 0.30	-0.45 ± 0.25	-0.10 ± 0.27	-1.16 ± 0.01	-3.82 ± 0.01	4.00 ± 0.04	3.96 ± 0.05	4.24 ± 0.04
Turbidity (NTU)	44.75 ± 7.84	26.14 ± 1.32	57.85 ± 9.82	56.87 ± 11.06	45.17 ± 5.43	14.44 ± 1.68	14.56 ± 1.44	18.01 ±1.07
Flow (cm/sec)	4.86 ± 1.46	7.79 ± 1.49	8.73 ± 1.85	2.75 ± 0.70	1.75 ± 0.33	8.61 ± 1.40	4.03 ± 0.68	9.22 ± 2.46
Specific Conductance	0.31 ± 0.02	0.31 ± 0.02	0.29 ± 0.02	0.27 ± 0.02	0.25 ± 0.01	0.31 ± 0.01	0.31 ± 0.01	0.33 ± 0.01
Temperature (C°)	23.63 ± 1.41	23.92 ± 1.12	21.82 ± 1.34	29.83 ± 0.43	29.4 ± 0.28	22.93 ± 1.11	21.86 ± 1.21	23.23 ± 1.47
Dissolved Oxygen	6.18 ± 0.164	4.92 ± 0.27	5.61 ± 0.29	3.51 ± 0.14	4.59 ± 0.23	3.75 ± 0.40	4.12 ± 0.40	4.90 ± 0.32

[1] Water level was standardized by averaging the hydrograph measurement above Butte la Rose for the entirety of the sampling period and calculating the difference in the water level on the day of sampling to that average

Table 2.5. Analysis of water quality variables on assemblage structure of all collected invertebrates

Standardized Water Level (m)	Multivariate GLMM, Poisson	$X^2 = 75.3$	$P < 0.01$*	Adult and Pupal Diptera (-9.84) Snails (+1.44) *Pelocoris* (Hemiptera: Naucoridae) (+2.67) *Ranatra* (Hemiptera: Nepidae) (-2.12) Baetiscidae (Ephemeroptera) (-1.06)
Average Water Level (m)	PERMANOVA	$F_{1,111}$ =3.29	$P < 0.01$*	Adult/Pupal Diptera (-0.82) Ephemeridae (Ephemeroptera) (-1.089) Caenidae (Ephemeroptera) (-2.17) Snails (+3.39) *Palmacorixa buenoi* (Hemiptera: Corixidae) (-1.13)
Turbidity (NTU)	PERMANOVA	$F_{1,111}$ =3.29	$P < 0.01$*	
Flow (cm/sec)	Multivariate GLMM, Poisson	$X^2 = 6.24$	$P < 0.01$*	*Trichocorixa* (Hemiptera: Corixidae) (-3.12) *Hesperocorixa nitida* (Hemiptera: Corixidae) (+4.01) *Trichocorixa reticulata* (Hemiptera: Corixidae) (-3.04) *Procambarus clarkii* (Decapoda: Cambaridae) (+0.79) Corduliidae (Odonata) (+1.63)
Temperature (C°)	PERMANOVA	$F_{1,111}$ = 5.48	$P < 0.01$*	*Palmacorixa buenoi* (Hemiptera: Corixidae) (-1.64) Snails (+2.32) Ephemeridae (Ephemeroptera) (+1.13) Caenidae (Ephemeroptera) (-0.977)
Dissolved Oxygen	PERMANOVA	$F_{1,111}$ =4.06	$P < 0.01$*	*Palmacorixa buenoi* (Hemiptera: Corixidae) (-6.47)

For assemblage structure measures, taxa that were most effected by the variables were determined (Table 2.5.). For turbidity and dissolved oxygen, taxa could not be determined due to their catch being zero at extremes (upper for turbidity, lower for dissolved oxygen).

2.4. Discussion and Application

This study improves our understanding of Hemiptera distribution as well as associations with aquatic vegetation, connectivity, water quality, and flooding magnitude. Connectivity between the Atchafalaya River with its floodplain did increase richness of Hemiptera and other taxa and was associated with specific taxa within the overall assemblage (30 taxa unique to connected habitats vs. 2 taxa unique to disconnected habitats). Similar to previous studies (e.g., Colon-Gaud et al. 2004), most water quality variables did not influence Hemiptera richness and diversity, however, water level was influential for several taxa, including multiple Hemiptera species.

2.4.1. Distributional Updates

Current publications on aquatic Hemiptera of Louisiana largely omit the Atchafalaya River basin (Penn 1951, Ellis 1952, Gonsoulin 1973), in part due to difficult accessibility and datedness of collection history. These samples fill in gaps to establish a better picture of Atchafalaya River invertebrate fauna and spatial variation.

Striders (Gerridae, Veliidae, Mesoveliidae, and Hydrometridae) along with semi-aquatics (Hebridae, Ochteridae, Saldidae, and Gelastocoridae) were not well represented in light trap samples. This is partially due to the rarity of semi-aquatics in the ecosystem, evidenced by previous collection history. Light traps are fully submerged, which may have biased the gear against these groups that are not found in that microenvironment. Sweeps and suitcases were

able to collect gerrids, veliids, and hydrometrids, so they were represented in this study. Therefore, conclusions related to taxonomic responses should be couched in terms of potential taxonomic biases.

2.4.2. Associations with Vegetation

Water hyacinth was commonly found at sample locations as individual plants, rafts, and mats, all with large densities of invertebrates. This is consistent with other vegetation studies, where organisms were stratified both within individual plants and the mats (Colon-Gaud et al. 2004, Troutman et al. 2011). Water hyacinth is detrimental to waterways, causing flooding and navigational difficulty (Penfound and Earle 1948) and is actively managed in the ARB. The tradeoffs between invertebrate habitat in areas where hyacinth has replaced native fauna and impacts of herbicide control have not been explored. Three taxa were of note in these analyses. *Ranatra* is an ambush predator and a mimic of vascular plants. Bulbous hyacinth may not provide adequate cover for these insects leading to a negative association (Sites and Polhemus 1994). Odonates (such as Corduliidae) are typically found in muddy littoral areas, where terrestrial native plants replace water hyacinth (Corbet 1999, Tennessen 2008) The opposing effect; however, was found in immature *Belostoma.* These generalist ambush predators are found in large numbers as early instars and may have less regard for vegetation type (Thorp and Rogers 2011)

2.4.3. Associations with Connectivity

Taxonomic richness was higher in connected BC than unconnected LFP. This was consistent with our hypothesis that connected environments support a higher biodiversity. The true difference could not be detected by statistics due to taxonomic replacement, but assemblage structure varied between environments and temporally. For example, *Palmacorixa buenoi*

(Hemiptera: Corixidae) was found in high numbers (>200) in LFP in July 2018, but was lacking in August and September, replaced in number by shrimp and amphipods. This peak and subsequent change is not reflected in summary measures, but is of note, nonetheless.

Differences in taxa distributions were noteworthy between connected (30 unique taxa, 9 Hemiptera) and unconnected habitats (2 unique taxa, both Hemiptera). *Belostoma lutarium* and *Ramphocorixa accuminata*, the two species found exclusively in LFP, were found in small numbers. *B. lutarium,* like most belostomatids is found in areas with dense vegetation (Thorp and Rogers 2011). LFP 5 had a high density of hyacinth, water lily, and hydrilla, which may have contributed to its habitat choice. *R. accuminata* was in an assemblage of over 200 individuals, including six other species of corixids. Little research has been completed on the ecology of this species, with the only known publication being in 1945 (Griffith) so it is difficult to make conclusions as to why they would be found only in LFP.

Thirty taxa were found exclusively in BC, including nine in the order Hemiptera. We hypothesize that this difference is due to the variation in habitats that having a connected floodplain provides, which is lacking in LFP. Notonectidae and Pleidae, the two backswimming families, have unique feeding habits due to their size (Pleidae) and swimming proficiency in open water (Notonectidae); their representation in one habitat but not the other may indicate lacking or differently structured food web dynamics, as annual flooding has been shown to generally increase productivity and prey availability. Tetrigidae, a semi-aquatic grasshopper, and other "bycatch" terrestrial taxa being more prevalent in BC may also key into differences in allochthonous input for the system (Bland 2008). While EPT metrics cannot be used due to lack of Plecoptera (Stewart et al. 1976), it is of note that four families of Ephemeroptera and four families of Trichoptera, two sensitive orders, were found exclusively in connected BC.

Access points for the two sampling locations (BC and LFP) are directly across the levee from one another, and sites are at similar latitudes. Because of this close proximity and knowing that aquatic insects are prone to fly when environments become stressful (Boersma and Lytle 2014), it is reasonable to conclude that the connected habitat is capable of maintaining higher invertebrate diversity than unconnected (i.e. leveed) habitats. If this were not the case, migration would be more prevalent between the two habitat types. Presumably, if flooding was stressful to Hemiptera, greater diversity would have been observed in LFP as Hemiptera fled the relatively short distance from BC; however, these data suggest the reverse and indicate that lack of annual flooding and associated benefits is more stressful.

Some invertebrates were widespread and appeared to have difficult to explain relationships with connectivity. Caenidae and Baetidae are incredibly tolerant families of Ephemeroptera that are common in areas where other families typically are not found (Waltz and Burian 2008). The stagnant backwaters of BC provide an ideal habitat for these organisms (Fisher and Kelso 2007, Fisher et al. 2012). *Macrobrachium* is known from the ARB (Truesdale and Mermilliod 1979, Walls 2009, Olivier and Bauer 2011) and was prevalent in both systems. *Palmacorixa buenoi* was found in both habitats but was the most common corixid in LFP, where over 200 were found in a single light trap sample. This species was not only previously unfound in the ARB but is the only member of the genus in Louisiana. This poses questions as to what is different ecologically about this species and how that may be used in future biological assessment.

2.4.4. Associations with Water Quality Variables and Inundation

Replacement of taxa within summary measures also impacted assessment of water quality and depth variables. In determining assemblage structure, however, both were significant.

This is consistent with other studies in floodplains, which have determined that the variable water level is influential in ecology at any level either directly (Davidson et al. 1998) or indirectly through determining habitat characteristics (Kaller et al. 2015, Pasco et al. 2016).

Within BC, the most turbid site (BC 3) consistently lacked taxa. Even vegetation sample density was lower than the other sites. This is consistent with the general understanding that suspended and accumulated sediment reduces biodiversity and causes respiratory stress (Newcombe and Macdonald 1991, Henley et al. 2000, Kaller and Hartman 2004). This site had a mudflat with as little as 30 cm of water at low water to the southern side with contributed to the consistently high turbidity.

Dissolved oxygen is negatively correlated with temperature in the ARB causing acute and chronic fish mortality (Guntenspergen and Vairin 1996, Perret et al. 2010) and ecosystem stress (Sabo et al. 1999, Bonvillain et al. 2015, Pasco et al. 2016). Dissolved oxygen had a similar effect to turbidity; low oxygen sites contained virtually no organisms, and only *P. buenoi* (Hemiptera: Corixidae) had a preference for low dissolved oxygen levels (Table 2.5.). High temperature sites and time periods held corixids, which breathe atmospheric oxygen and dwell close to the surface (Thorp and Rogers 2011) and tolerant culicids, caenids, and ephemerids (Eriksen 1963, Gaufin 1973, Waltz and Burian 2008). *Procambarus clarkii* was found early in the season, when temperatures and fishing pressure were low (Bonvillain et al. 2015, Vargas-Lopez 2018).

Surface flow was highly variable spatially and temporally. Flow is directly related to connectivity and vegetation density, so it is unsurprising that influential taxa overlap. Corixids were most affected by this variable (3 taxa), possibly due to their complex assemblages close to the surface, but the rarest of taxa (*Hesperocorixa nitida*) had a strong positive relationship,

differing from the rest of the family (Griffith 1945). High flows reduced catch by causing quatrefoil traps to tilt, which may have biased high flow samples. Insects are known to drift between habitat using surface flow, so those missed were mostly likely traveling to other locations in the floodplain (Brittain and Eikeland 1988).

2.4.5. Overview and Application

The relationship between water quality and connectivity metrics and assemblage structure provide key insight into the seasonal variation in the Atchafalaya and how anthropogenic effects may alter this unique and dynamic system. From this baseline, monitoring and biological assessment will help us to understand and protect the Atchafalaya and the fauna that live within it. Corixidae, especially *Palmacorixa buenoi* and *Ramphocorixa accuminata*, two species that demonstrated a response to leveeing, require further research to determine how their assemblages are formed and maintained. Trapping for semi-aquatics and striders specifically would allow for a total aquatic Hemiptera biometric system to be established for BC, which could then be expanded to other water management units and potentially other systems. Further vegetation sampling is suggested to apply statistical analyses and better understand the role that water hyacinth is playing in invertebrate communities in the ARB

CHAPTER 3. DISTRIBUTION OF THE AQUATIC HEMIPTERA OF LOUISIANA UTILIZING DATABASES, LITERATURE, AND THE LOUISIANA STATE ARTHROPOD MUSEUM

3.1.Introduction

Natural history collections typically manifest as large rooms containing voucher specimens, type series, and literature references. Most Carnegie R1 institutions have an insect collection, independent of or housed within larger natural history holdings. Because of the prevalence of technology and digitization, there has been a push for making these collections accessible from anywhere. The feasibility of this process, however, is questionable, as age has made specimens often difficult to geolocate, and the vast number of individuals is daunting.

Databases have been created to accommodate digital versions of collections in the United States and beyond, including iDigBio and Symbiota Collections Arthropod Network (SCAN). The National Science Foundation has funded multiple projects to restore, maintain, and update collections at institutions such as Clemson (DBI-1601002) and Virginia Tech (DBI-1458045). These projects, however, have focused on specific taxonomic groups of interest, such as pollinators, to make them more manageable and as a result have left other taxa behind.

The Louisiana State Arthropod Museum (LSAM) has been the state repository for insects and their kin since 1971. This research collection is housed in the Department of Entomology at Louisiana State University (Baton Rouge, LA) and occupies several lab spaces in Life Sciences Building. This collection is home to over one million specimens preserved in alcohol, on slides, or pinned. The largest room of the collection is occupied by beetles (Order: Coleoptera), as they have been a curatorial specialty for the last 25 years. Other room designations include literature, alcohol holdings, and Lepidoptera. The curator, along with collection manager and graduate

students, provides identifications, outreach, and guidance to individuals across the state and specimen loans around the world.

The LSAM uses Specify 6.1 (https://www.sustain.specifysoftware.org/) and SilverCollection (SilverBiology), to maintain a specimen database (data.lsuinsects.org) which is accessible from their website (lsuinsects.org). Specimens are photographed, assigned GPS coordinates when necessary, and their labels are transcribed in this program.

Hemiptera is an order that has not been a focus of digitization for the LSAM. One individual from each of the 14 semi-aquatic and aquatic families found in Louisiana had been added to the database at the start of this project. This is partially because of the coleopteran focus of the museum, but also to priorities being on museum services outside of digitization in recent years.

Literature for Louisiana was also lacking. The LSAM held a set of 1973 publications by Gene Gonsoulin (1973). Additional publications from the 1950s were obtained via LSU libraries (Penn 1951, 1952, Ellis 1952). All were missing families and areas of the state in addition to their dated taxonomy and lack of accessibility outside of the university library system. A guide to Florida aquatic Hemiptera (Epler 2006) was the most useful regional guide obtained for this study, though clearly not ideal due to geographical differences between Florida and Louisiana.

Vouchers from Gene Gonsoulin's publication were originally housed in the University of Louisiana at Lafayette (ULL)'s biological collection. In the mid-1990's, these specimens were transferred to the LSAM to prevent their destruction at ULL. Voucher records were not updated, and some specimens, along with Mr. Gonsoulin's notes on collection localities have been lost between their deposition in 1973 and the beginning of this project (Victoria Bayless, pers. com.).

Therefore, given the ecological importance and widespread distribution of aquatic Hemiptera (Chapter 1), the objectives were to geolocate and compile resources associated with the order.

3.2. Materials and Methods

3.2.1. Louisiana State Arthropod Museum Holdings

Natural history collections typically manifest as large rooms containing voucher specimens, type series, and literature references. Most Carnegie R1 institutions have an insect collection, independent of or housed within larger natural history holdings. Because of the prevalence of technology and digitization, there has been a push for making these collections accessible from anywhere. The feasibility of this process, however, is questionable, as age has made specimens often difficult to geolocate and the vast number of individuals is daunting.

Databases have been created to accommodate digital versions of collections in the United States and beyond, including iDigBio and Symbiota Collections Arthropod Network (SCAN). The National Science Foundation has funded multiple projects to restore, maintain, and update collections at institutions such as Clemson (DBI-1601002) and Virginia Tech (DBI-1458045). These projects, however, have focused on specific taxonomic groups of interest, such as pollinators, to make them more manageable and as a result have left other taxa behind.

The Louisiana State Arthropod Museum (LSAM) has been the state repository for insects and their kin since 1971. This research collection is housed in the Department of Entomology at Louisiana State University (Baton Rouge, LA) and occupies several lab spaces in Life Sciences Building. This collection is home to over one million specimens preserved in alcohol, on slides, or pinned. The largest room of the collection is occupied by beetles (Order: Coleoptera), as they have been a curatorial specialty for the last 25 years. Other room designations include literature, alcohol holdings, and Lepidoptera. The curator, along with collection manager and graduate

students, provides identifications, outreach, and guidance to individuals across the state and specimen loans around the world.

The LSAM uses Specify 6.1 (https://www.sustain.specifysoftware.org/) and SilverCollection (SilverBiology), to maintain a specimen database (data.lsuinsects.org) which is accessible from their website (lsuinsects.org). Specimens are photographed, assigned GPS coordinates when necessary, and their labels are transcribed in this program.

Hemiptera is an order that has not been a focus of digitization for the LSAM. One individual from each of the 14 semiaquatic and aquatic families had been added to the database at the start of this project. This is partially because of the Coleopteran focus of the museum, but also to priorities being on museum services outside of digitization in recent years.

Literature for Louisiana was also lacking. The LSAM held a set of 1973 publications by Gene Gonsoulin (1973). Additional publications from the 1950s were obtained via LSU libraries (Penn 1951, 1952, Ellis 1952). All were missing families and areas of the state in addition to their dated taxonomy and lack of accessibility outside of the university library system. A guide to Florida aquatic Hemiptera (Epler 2006) was the most useful regional guide obtained for this study, though clearly not ideal due to geographical differences between Florida and Louisiana.

Vouchers from Gene Gonsoulin's publication were originally housed in the University of Louisiana at Lafayette (ULL)'s biological collection. In the mid-1990's, these specimens were transferred to the LSAM to prevent their destruction at ULL. Voucher records were not updated, and some specimens, along with Mr. Gonsoulin's notes on collection localities have been lost between their deposition in 1973 and the beginning of this project (Victoria Bayless, pers. com.). Therefore, given the ecological importance and widespread distribution of aquatic Hemiptera (Chapter 1), the objectives were to geolocate and compile resources associated with the order.

3.2.2. Database Holdings

To better understand the distribution of Louisiana Hemiptera, databases were searched for holdings outside of the LSAM and published literature. Symbiota Collections of Arthropods Network (https://scan-bugs.org/portal/index.php), iDigBio (https://www.idigbio.org/), and the Global Biodiversity Information Facility (https://www.gbif.org/) were treated as key sources of this information.

On each database, the search terms for each family (e.g. Naucoridae) and the state (Louisiana) were applied and the spreadsheets updated following the same format as LSAM holdings, with the addition of a column for current specimen location. Those that required geolocation were assigned GPS coordinates in the same manner as LSAM specimens. This was impossible for some, where the only location identifier was the state.

3.2.3. Taxonomic Updates

Taxonomy of all specimens was updated to meet the Integrated Taxonomic Information System (ITIS) standard, including the addition of author and description year. For specimens where a species could not be found, perhaps due to use of shorthand or misspelling, the genus was used for the sake of accuracy and as a conservative measure. These updates were made in a new, separate spreadsheet to maintain the original records associated with the pinned specimens.

3.2.4. Mapping

QGIS (3.8.0 Zanzibar) was used for all map layers. It was chosen primarily due to the open access aspect of the software, allowing the general public to have access at a later date if needed. Coordinates were imported directly from the spreadsheet to create layers for individual species, genera, and families. LSAM holdings and database findings were also kept separate for the benefit of LSAM based users.

3.2.5. Checklist of the Aquatic Hemiptera of Louisiana

A classically formatted checklist for focal taxa was created by combining LSAM, database data, and publications found over the course of this study. Formatting followed Gonosoulin (1973) for the sake of simplicity and consistency and proper taxonomic order as found in the LSAM. Checklist maps were created in Simple Mappr (Shorthouse 2010), an open source application, so that only parish and state lines were featured.

3.3. Results

From the LSAM, 4,300 previously undigitized specimens were cataloged across the 14 families of interest. LSAM collections spanned back to 1905 and included 296 previously unpublished parish records. An inventory of these specimens, including collection intervals and events can be found in Appendix D. Databases contained specimens from the Snow Entomological Museum Collection (University of Kansas), New Mexico State Collection of Arthropods, American Museum of Natural History, Smithsonian, Mississippi Entomological Museum, North Carolina State Insect Collection, Oregon State Arthropod Collection, and the Illinois Natural History Survey.

Geospatial projections revealed stark differences in the number and spatial coverage of specimens (Figures 3.1.-126.). Asterisks (*) indicate that an individual from the parish cited in literature is currently vouchered in either a database or the LSAM. Solid circles are specimens currently in a database or the LSAM; open are literature references that lack a voucher known to currently exist and have only been geolocated to parish. Some families (e.g. Hydrometridae, Nepidae, Belostomatidae) have been sampled extensively and are amply represented in the LSAM and database collections. Conversely, other taxa (e.g. Notonectidae, Pleidae) are not as well represented. Some maps have been generated from only a few individual specimens with

low level accuracy geolocation (e.g. Saldidae, Ochteridae), whereas others had specimen counts in the hundreds between data sources (e.g. Belostomatidae, Corixidae). Collections from the early 20th century were biased towards town centers and drainage ditches with minimal locality information; many newer samples (1990-present) had street names, addresses, and even GPS coordinates, allowing greater accuracy for map points

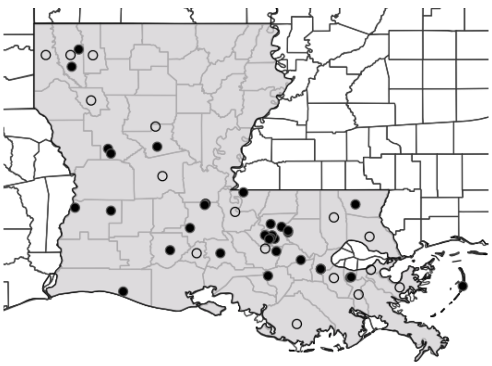

Figure 3.1. Mesoveliidae: *Mesovelia* Mulsant and Rey, 1852 containing *Mesovelia mulsanti* White, 1879 and *Mesovelia amoena* Uhler, 1894

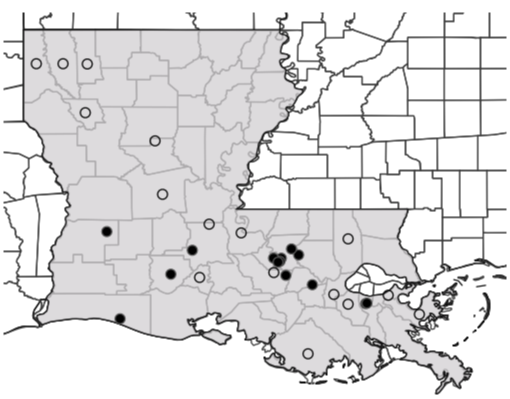

Figure 3.2. *Mesovelia mulsanti* White, 1879. Formerly *Mesovelia bisignata* Uhler, 1884. Previously Unpublished: Beauregard, Cameron, East Baton Rouge. Iberville, Livingston. Published: Ascension*, Avoyelles, Jefferson*, Orleans, Plaquemines, Pointe Coupee, St. Bernard, St. Charles, St. John the Baptist, St. Landry*, Tangipahoa, Terrebonne, West Baton Rouge* (Ellis, 1952) Acadia*, Bossier, Caddo, DeSoto, Grant, Lafayette, Rapides, Red River, Webster (Penn, 1952)

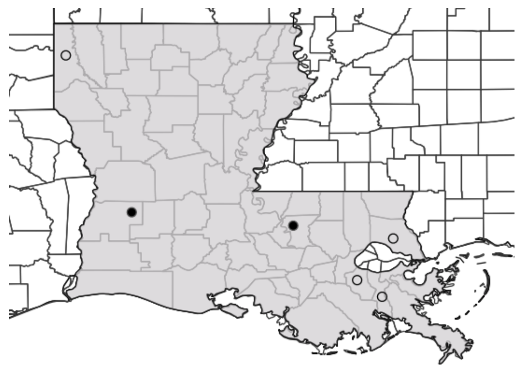

Figure 3.3. *Mesovelia amoena* Uhler, 1894. Formerly *Mesovelia douglasensis* Hungerford, 1924. Previously Unpublished: Beauregard, East Baton Rouge. Published: Jefferson (Ellis, 1952); Caddo, St. Charles, St. Tammany (Penn, 1952)

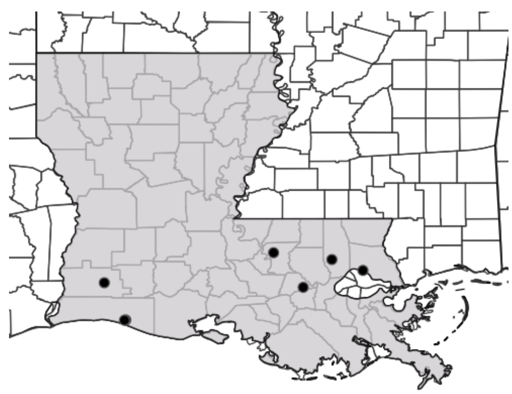

Figure 3.4. Hebridae: *Hebrus* Curtis, 1831 containing *H. buenoi* Drake and Harris, 1943, *H. burmeisteri* Lethierry and Severin, 1896, *H. concinnus* Uhler, 1894, and *H. consolidus* Uhler, 1894

Figure 3.5.. *Hebrus buenoi* Drake and Harris, 1943
Previously Unpublished: Cameron
Published: None

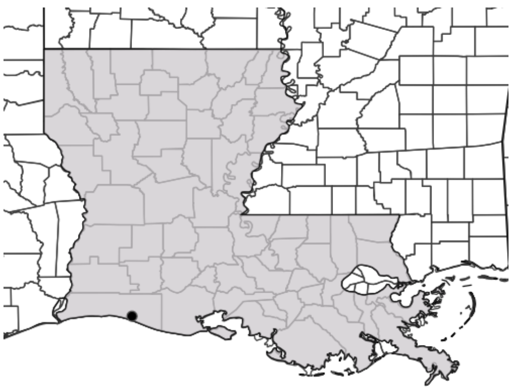

Figure 3.6. *Hebrus burmeisteri* Lethierry and Severin, 1896 Previously Unpublished: Cameron
Published: None

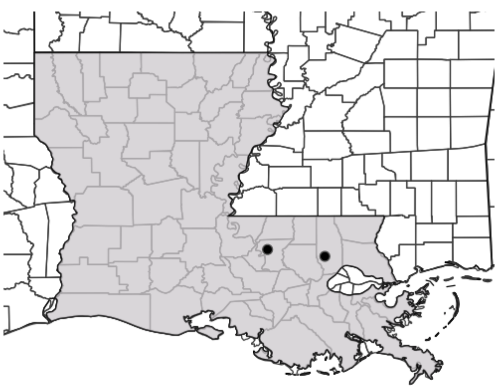

Figure 3.7. *Hebrus concinnus* Uhler, 1894 Previously Unpublished: East Baton Rouge, Tangipahoa
Published: None

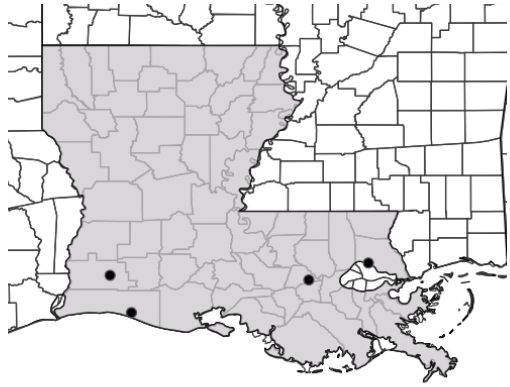

Figure 3.8. *Hebrus consolidus* Uhler, 1894
Previously Unpublished: Ascension, Calcasieu, Cameron, St. Tammany
Published: None

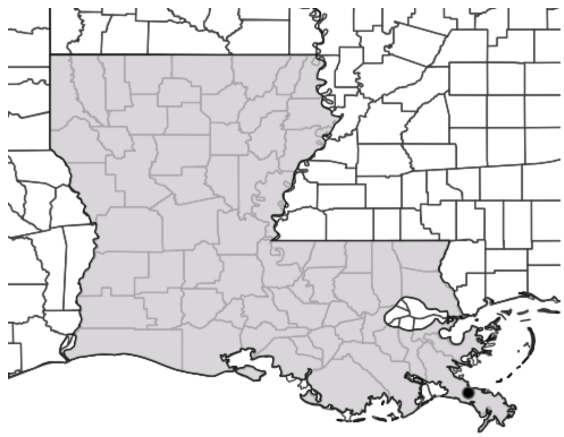

Figure 3.9. Hebridae: *Lipogomphus brevis* (Champion, 1898) Previously Unpublished: Plaquemines Published: None

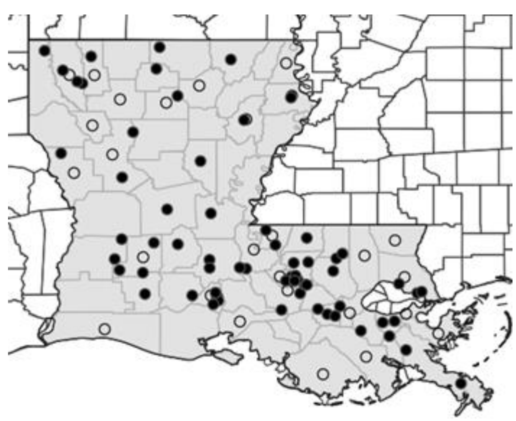

Figure 3.10. Hydrometridae: *Hydrometra* Latrielle, 1797 including *H. martini* Kirkaldy, 1900, *H. australis* Say, 1832, *H. hungerfordi* Torre-Bueno, 1926, and *H. wileyae* Hungerford, 1923

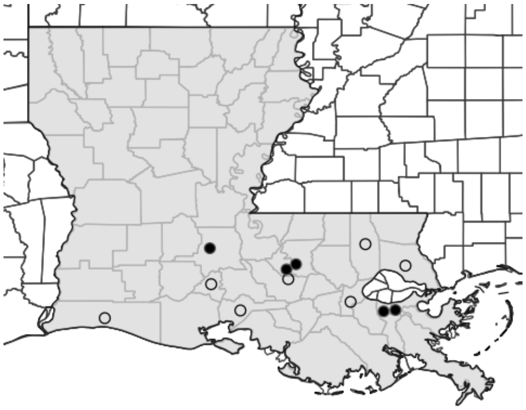

Figure 3.11. *Hydrometra martini* formerly *Hydrometra lineata* Say, 1832 Distribution: Previously Unpublished: East Baton Rouge, Jefferson, St. Landry, West Baton Rouge Published: Iberia, Lafayette, Plaquemines (Gonsoulin, 1973); Orleans*, Plaquemines, St. John the Baptist, St. Tammany, Tangipahoa (Ellis, 1952); Lafayette (Penn, 1952); Cameron (Hine, 1906)

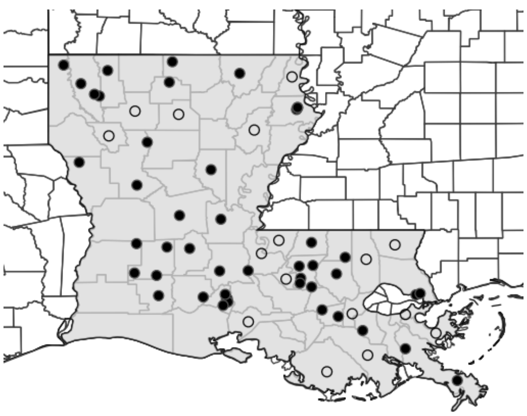

Figure 3.12. *Hydrometra australis* formerly *Hydrometa myrae* Torre-Bueno, 1926 Distribution: Previously Unpublished: Evangeline, Jefferson Davis, LaSalle, Lincoln, Livingston, St. Helena, Tensas Published: Allen*, Beauregard*, Bienville, Bossier*, Caddo*, East Baton Rouge*, East Feliciana*, Iberia, Jackson, Lafayette*, Madison*, Morehouse*, Natchitoches*, Plaquemines*, Rapides*, Sabine*, St. Charles*, St. James*, St. Landry*, St. Tammany*, Union* (Gonsoulin, 1973); Ascension*, Avoyelles*, East Feliciana*, Iberia, Jefferson, Lafourche, Orleans, Plaquemines*, Pointe Coupee, St. Bernard, St. Charles*, St. John the Baptist, St. Tammany*, Tangipahoa, Terrebonne, Washington, West Baton Rouge, West Feliciana (Ellis, 1952); Acadia*, Bienville, Bossier*, Caddo*, Claiborne, DeSoto, East Carroll, Franklin, Lafayette*, Natchitoches*, Rapides*, Red River, Sabine*, Union*, Webster* (Penn, 1952)

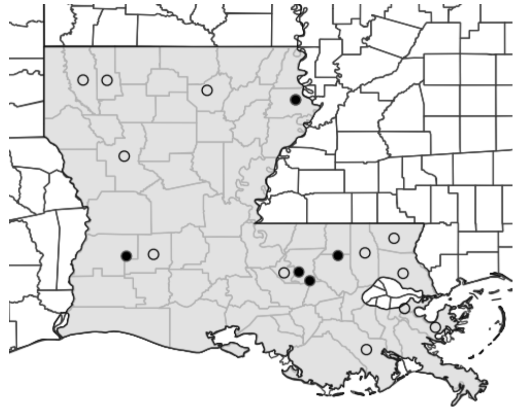

Figure 3.13. *Hydrometra hungerfordi* formerly *Hydrometra australis* Torre-Bueno, 1926, *Hydrometra australis* Hungerford, 1923 Distribution: Previously Unpublished: Beauregard, East Baton Rouge, Livingston, Madison Published: Allen, Webster (Gonsoulin, 1973); Ascension*, Lafourche, Orleans, St. Bernard, St. Tammany, Tangipahoa, Washington, West Baton Rouge (Ellis, 1952); Bossier, Claiborne, Natchitoches (Penn, 1952)

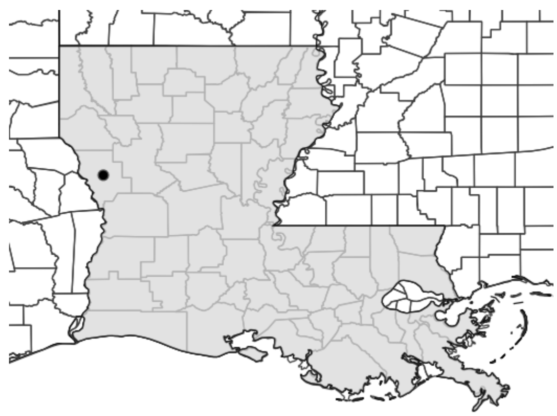

Figure 3.14. *Hydrometra wileyae* formerly *Hydrometra wileyi* Hungerford, 1923, *Hydrometra beameri* Mychajiliw, 1961 Distribution: Previously Unpublished: Published: Sabine

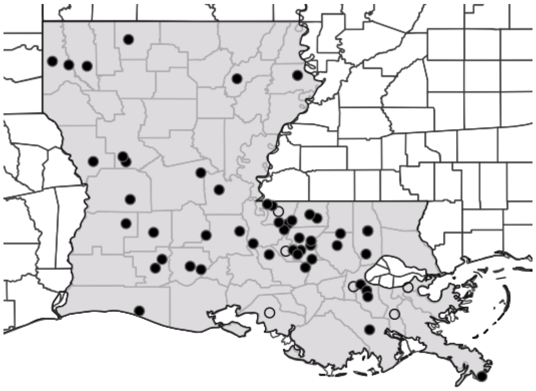

Figure 3.15. Veliidae including *Microvelia* Westwood, 1834, *Paravelia, Platyvelia, Rhagovelia, Steinovelia*, and *Velia*

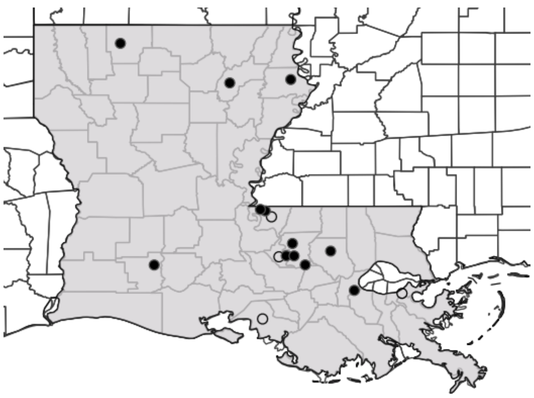

Figure 3.16. *Microvelia* Westwood, 1834 including *Microvelia americana* (Uhler, 1884), *Microvelia pulchella* Westwood, 1834, *Microvelia hinei* Drake, 1920, *Microvelia paludicola* Champion, 1898,

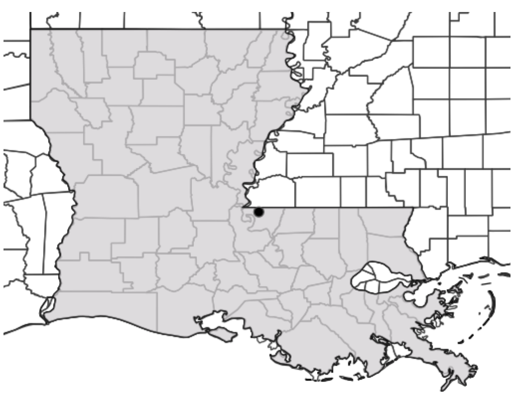

Figure 3.17. *Microvelia americana* (Uhler, 1884) Previously Unpublished: None Published: West Feliciana* (Ellis, 1952)

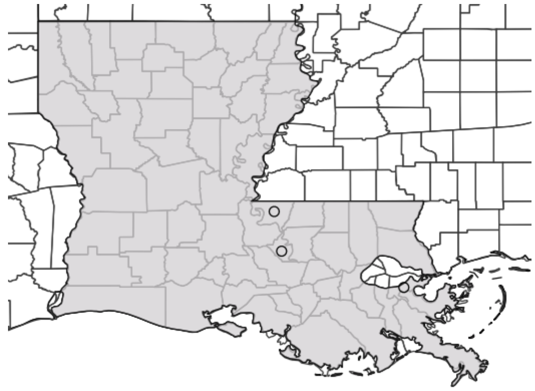

Figure 3.18. *Microvelia pulchella* Westwood, 1834 formerly *Microvelia borealis* Torre-Bueno, 1916, *Rhagovelia incerta* (Kirby, 1890), *Microvelia incerta* Kirby, 1890 Previously Unpublished: Published: Orleans, West Baton Rouge, West Feliciana (Ellis, 1952)

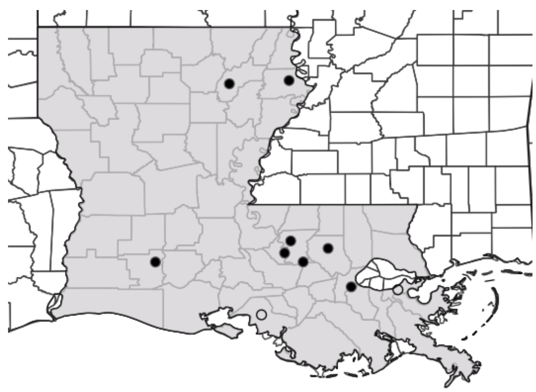

Figure 3.19. *Microvelia hinei* Drake, 1920. Previously Unpublished: East Baton Rouge, Jefferson, Livingston, Madison, Richland, St. John the Baptist, West Baton Rouge Published: Orleans, St. Mary (Ellis, 1952)

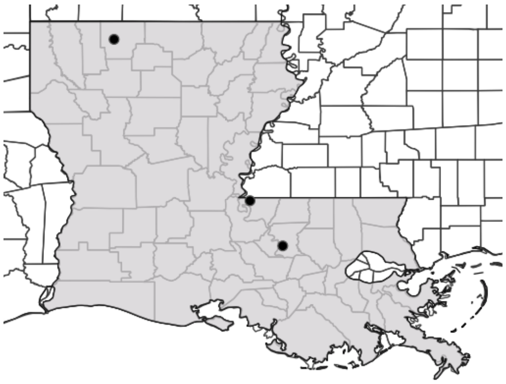

Figure 3.20. *Microvelia paludicola* Champion, 1898 formerly *Microvelia alachuana* Hussey and Herring, 1950 Previously Unpublished: Claiborne, East Baton Rouge, West Feliciana Published: None

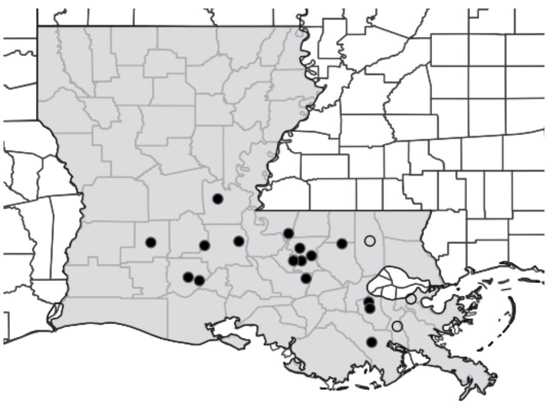

Figure 3.21. Veliidae *Platyvelia brachialis* (Stal, 1860) formerly *Paravelia brachialis* (Stal, 1860) Previously Unpublished: Acadia, Allen, Beauregard, East Baton Rouge, East Feliciana, Evangeline, Lafourche, Livingston, St. Charles, St. Landry, West Baton Rouge Published: Avoyelles*, Iberville*, Jefferson, Orleans, Tangipahoa (Ellis, 1952)

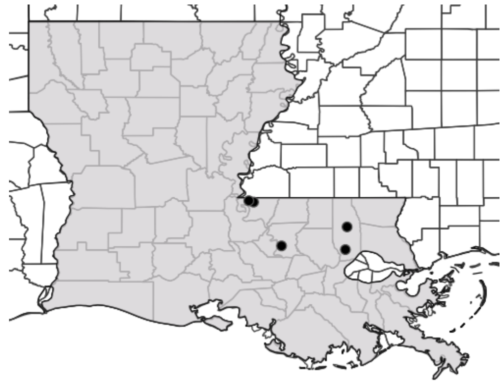

Figure 3.22. Veliidae *Rhagiovelia choreutes* Hussey 1925 Previously Unpublished: East Baton Rouge, Tangipahoa, West Feliciana Published:

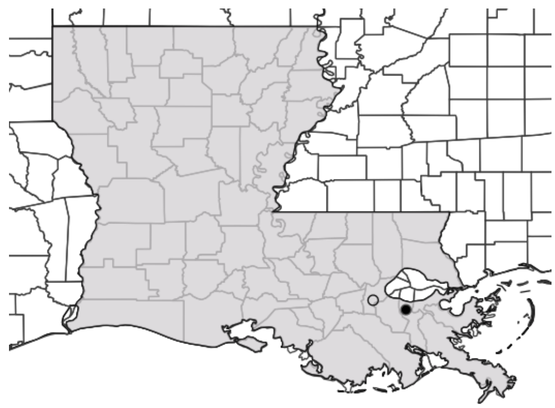

Figure 3.23. Veliidae *Steinovelia stagnalis* (Burmeister, 1835) formerly *Paravelia stagnalis* (Burmeister, 1835), *Velia watsoni* Drake, 1919, *Velia paulineae* Wilson, 1953 Previously Unpublished: Jefferson Published: St. John the Baptist (Ellis, 1952)

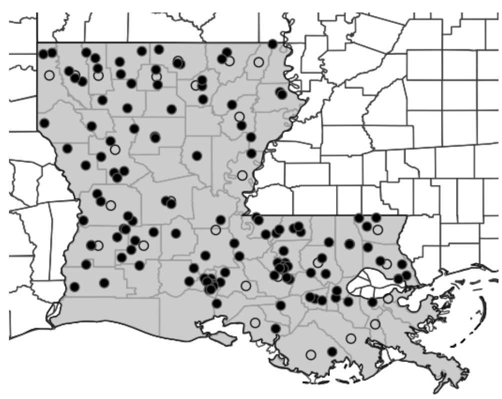

Figure 3.24. Gerridae Leach, 1815 including *Aquarius* Schellenberg, 1800, *Gerris*, *Limnoporus*, *Metrobates*, *Neogerris*, *Rheumatobates*, and *Trepobates*

Figure 3.25. *Aquarius* Schellenberg, 1800 including *A. remigis* (Say, 1832), *A. conformis* (Uhler, 1878) and *A. nebularis* (Drake and Hottes, 1925)

Figure 3.26. *Aquarius remigis* (Say, 1832) formerly *Gerris remigis* Say, 1832 Previously Unpublished: Published: Lafayette (Ellis, 1952)

Figure 3.27. *Aquarius conformis* (Uhler, 1878) formerly *erris conformis* (Uhler, 1878) Previously Unpublished: East Baton Rouge Published: St. Landry (Ellis, 1952)

Figure 3.28. *Aquarius nebularis (*Drake and Hottes, 1925) formerly *Gerris nebularis* Drake and Hottes, 1925 Previously Unpublished: Published: Lincoln, Webster (Gonsoulin, 1973); Caldwell, St. Landry, Washington (Ellis, 1952)

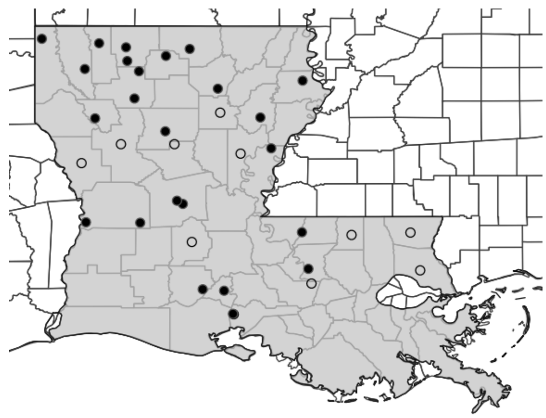

Figure 3.29. Gerridae: *Gerris* Fabricius, 1794 including *G. marginatus* Say, 1832 and *G. argenticollis* Parshley, 1916

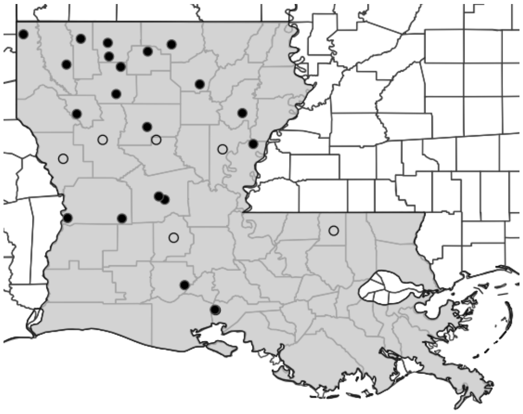

Figure 3.30. *Gerris marginatus* Say, 1832 Previously Unpublished: Acadia, Franklin, Iberia, Webster Published: Bienville*, Bossier*, Caddo*, Catahoula, Claiborne*, Concordia*, Evangeline, Grant, LaSalle, Lincoln*, Natchitoches, Ouachita*, Rapides*, Red River*, Sabine, Union*, Vernon*, Winn* (Gonsoulin, 1973); St. Helena (Ellis, 1952)

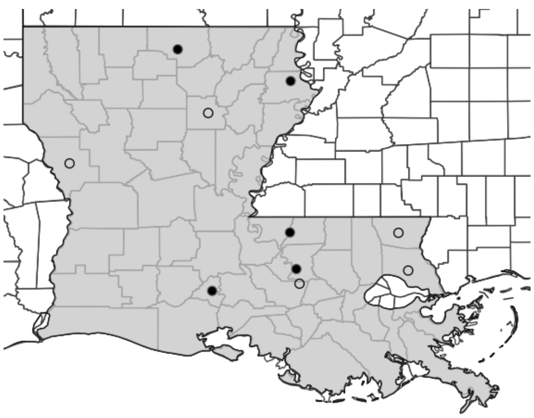

Figure 3.31. *Gerris argenticollis* Parshley, 1916 Previously Unpublished: East Baton Rouge, East Feliciana, Madison Published: Caldwell, Sabine (Gonsoulin, 1973); Iberville, St. Tammany, Washington (Ellis, 1952)

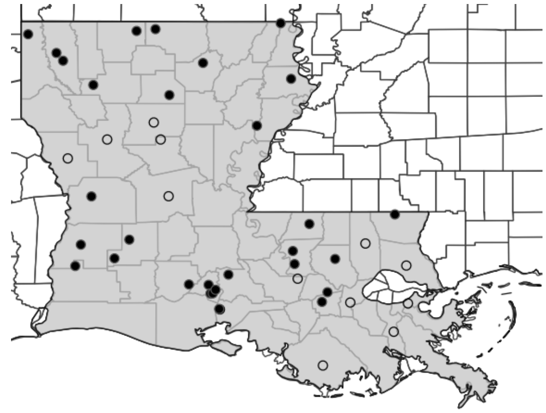

Figure 3.32. *Limnoporus canaliculatus* (Say, 1832) formerly *Gerris canaliculatus* Say, 1832 Previously Unpublished: Acadia, East Baton Rouge, Madison Published: Allen*, Beauregard*, Bienville*, Bossier*, Claiborne*, East Feliciana, Franklin*, Grant, Iberia*, Iberville, Jackson*, Lafayette*, LaSalle, Livingston*, Natchitoches, Ouachita*, Rapides, Sabine, St. James*, St. Martin*, Tangipahoa, Union*, Vernon*, Washington*, West Carroll;*, Winn (Gonsoulin, 1973); Ascension*, Jefferson, Lafayette*, Orleans, St. John the Baptist, St. Tammany, Tangipahoa, Terrebonne, Washington* (Ellis, 1952)

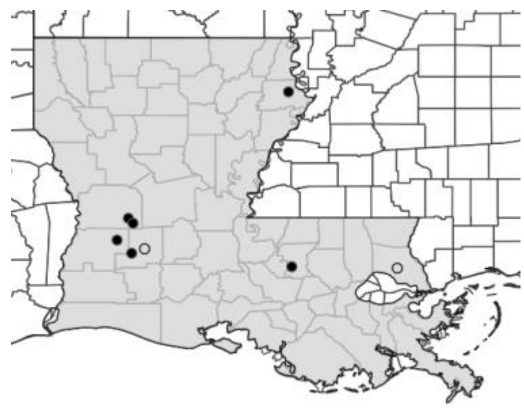

Figure 3.33. Gerridae: *Metrobates* Uhler, 1871 including *M. alacris* Drake, 1955 and *M. hesperius* Uhler, 1871

Figure 3.34. *Metrobates alacris* Drake, 1955
Previously Unpublished: East Baton Rouge
Published: Allen, Beauregard*, Vernon (Gonsoulin, 1973); Madison* (Drake, 1955)

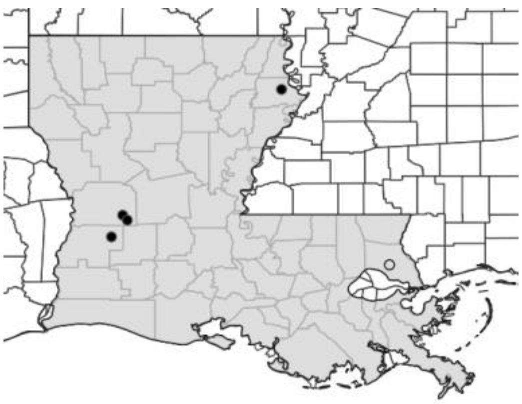

Figure 3.35. *Metrobates hesperius* Uhler, 1871
Previously Unpublished: Beauregard, Madison, Vernon Published: St. Tammany (Ellis, 1952)

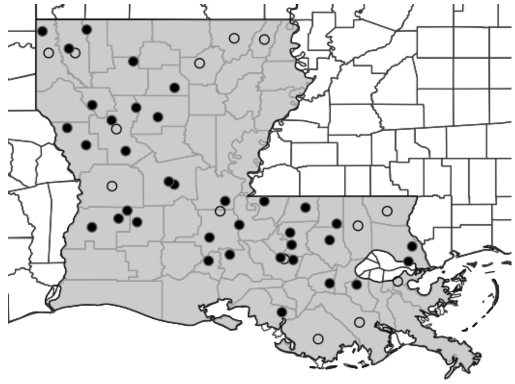

Figure 3.36. *Neogerris hesione* (Kirkaldy, 1902) formerly *Limnogonus hesione (*Kirkaldy, 1902)
Previously Unpublished: St. Charles Published: Allen*, Ascension*, Avoyelles*, Beauregard*, Bienville*, Bossier, Caddo, Cameron*, Claiborne, DeSoto, East Baton Rouge*, East Feliciana*, Iberville*, Jackson*, Lafayette*, Lafourche, Livingston*, Morehouse, Natchitoches, Rapides*, Red River*, Sabine*, St. Helena*, St. James*, St. Landry*, St. Martin*, St. Mary*. St. Tammany*, Terrebonne, Union*, Vernon, Washington, Webster*, West Carroll, West Feliciana*, Winn* (Gonsoulin, 1973); Orleans, Plaquemines, St. Mary*, St. Tammany*, Tangipahoa (Ellis, 1952)

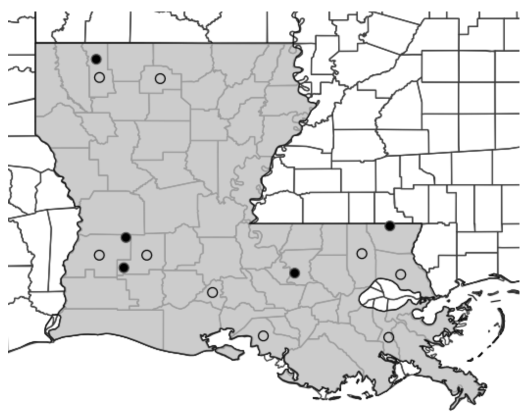

Figure 3.37. Gerridae: *Rheumatobates* Bergoth, 1892 including *R. hungerfordi* Wiley, 1923, *R. tenuipes* Meinert, 1895, *R. trulliger* Bergoth, 1915, and *R. palosi* Blatchley, 1926

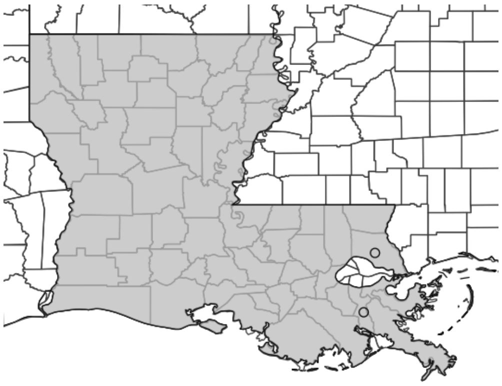

Figure 3.38. *Rheumatobates hungerfordi Wiley, 1923*
Previously Unpublished: Published: Jefferson, St. Tammany (Ellis, 1952)

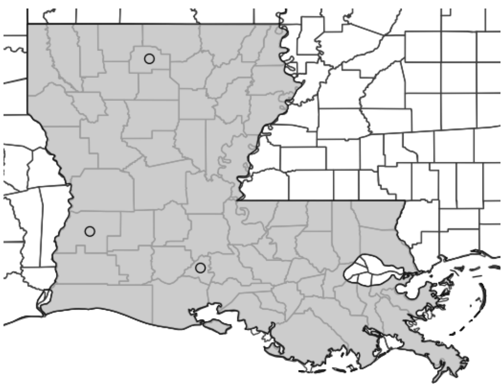

Figure 3.39. *Rheumatobates tenuipes* Meinert, 1895
Previously Unpublished: Published: Beauregard, Lafayette, Lincoln (Gonsoulin, 1973)

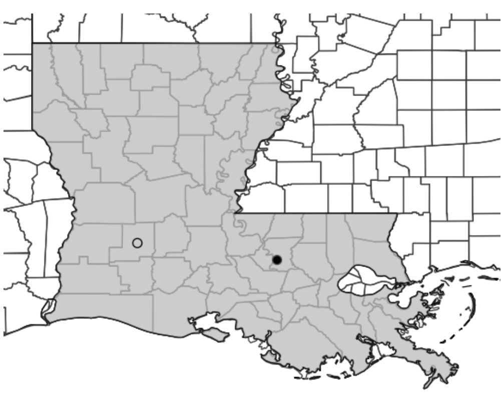

Figure 3.40. *Rheumatobates trulliger* Bergoth, 1915
Previously Unpublished: East Baton Rouge
Published: Allen (Gonsoulin, 1973)

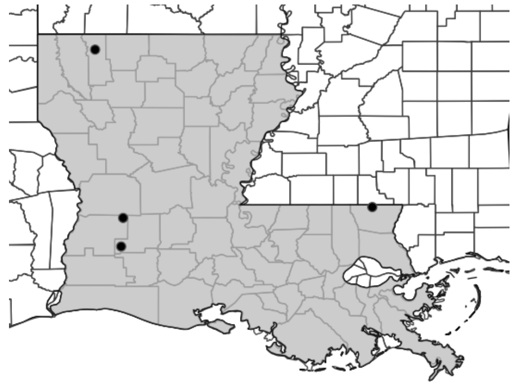

Figure 3.41. *Rheumatobates palosi* Blatchley, 1926
Previously Unpublished: Allen, Beauregard, Washington, Webster Published: None

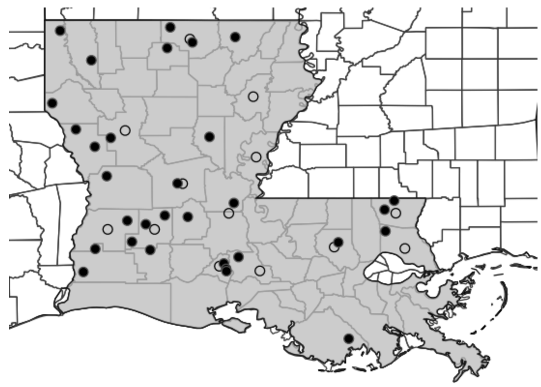

Figure 3.42. Gerridae: *Trepobates* Uhler, 1883 including *T. subnitidus* Esaki, 1926, *T. pictus* (Herrich-Schaeffer, 1847), *T. inermis* Esaki, 1926, *T. knighti* Drake and Harris, 1928

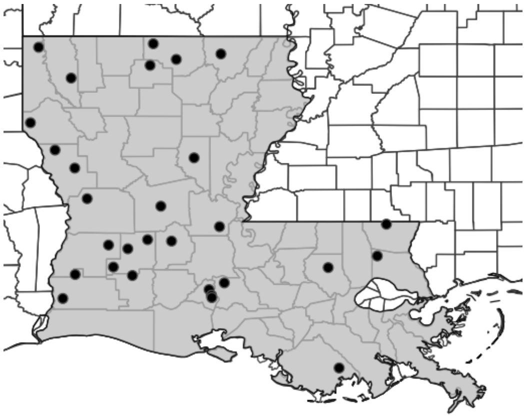

Figure 3.43. *Trepobates subnitidus* Esaki, 1926 formerly *Trepobates citatus* Drake and Chapman, 1953 Previously Unpublished: DeSoto, Franklin Published: Allen*, Avoyelles*, Beauregard*, Bienville*, Bossier*, Caddo*, Calcasieu*, Evangeline*, Lafayette*, LaSalle*, Lincoln*, Livingston*, Morehouse*, Rapides*, Sabine*, St. Martin*, St. Mary, St. Tammany*, Terrebonne*, Union*, Vernon*, Washington*, Webster (Gonsoulin, 1973); St. Tammany*, Tangipahoa (Ellis, 1952)

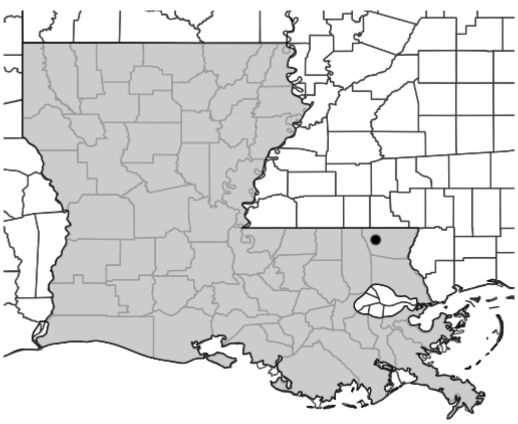

Figure 3.44. *Trepobates pictus (Herrich-Schaeffer, 1847)* formerly *Halobates pictus* Herrich-Schaeffer, 1847 Previously Unpublished: Washington Published: None

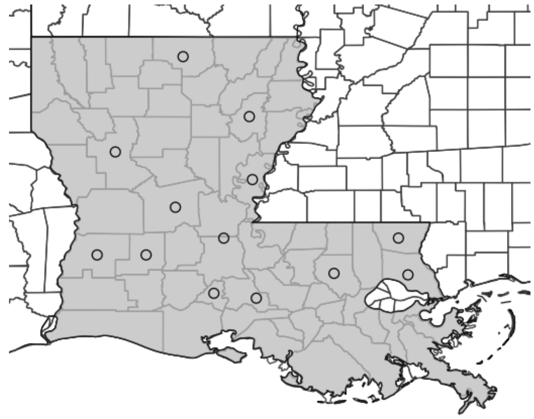

Figure 3.45. *Trepobates inermis* Esaki, 1926 Previously Unpublished: None Published: Allen, Beauregard, Concordia, DeSoto, Franklin, Lafayette, Livingston, Natchitoches, Rapides, St. Martin, St. Tammany, Union, Washington (Gonsoulin, 1973)

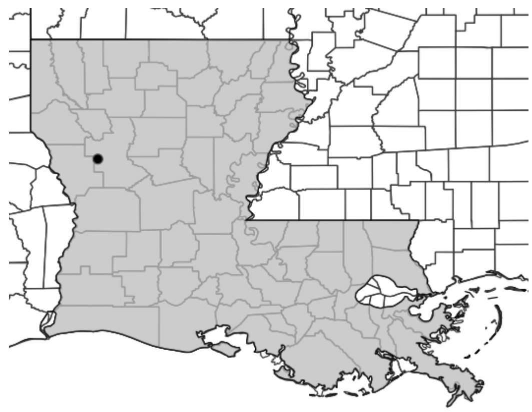

Figure 3.46. *Trepobates knighti* Drake and Harris, 1928 Previously Unpublished: Natchitoches Published: None

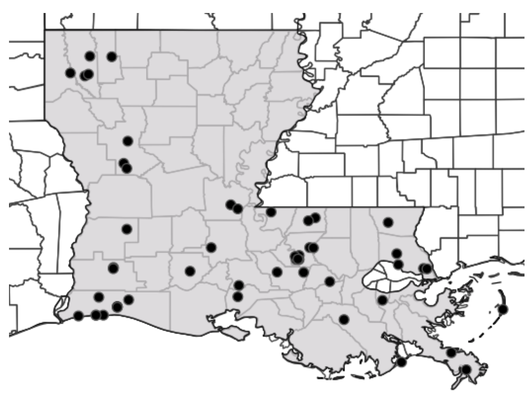

Figure 3.47. Saldidae including *Micracanthia* Reuter, 1912, *Pentacora* Reuter, 1912, *Salda* Fabricius, 1803, *Saldoida* Osborn, 1901, and *Saldula* Van Duzee, 1914

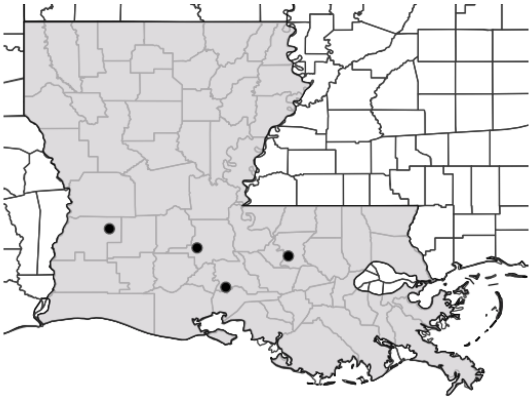

Figure 3.48. *Micracanthia* Reuter, 1912 including *M. humilis* (Say, 1832) and *M. husseyi* Drake and Chapman, 1952

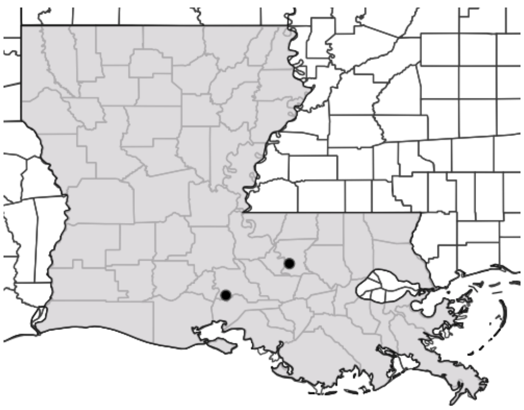

Figure 3.49. *Micracanthia humilis* (Say, 1832) Previously Unpublished: East Baton Rouge, St. Martin Published:

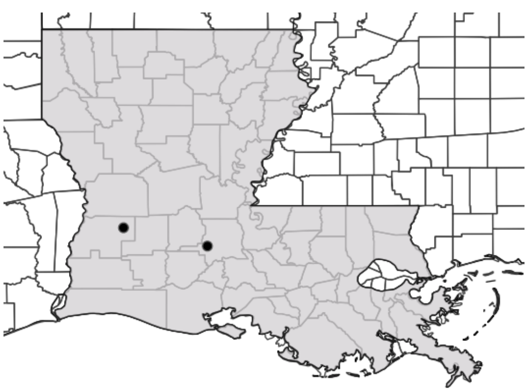

Figure 3.50. *Micracanthia husseyi* Drake and Chapman, 1952 Previously Unpublished: Ascension, Beauregard, St. Landry Published: None

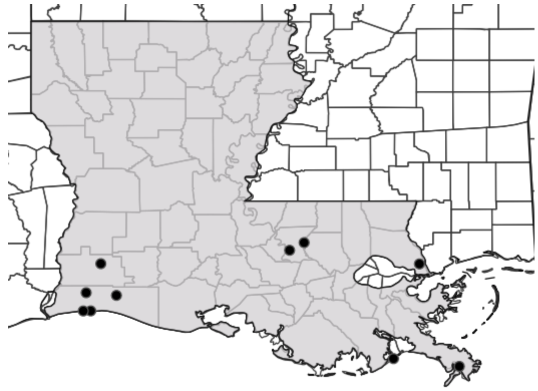

Figure 3.51. *Pentacora* Reuter, 1912 including *P. signoreti* (Guerin-Meneville, 1857), *P. sphacelata* (Uhler, 1877), *P. hirta* (Say, 1832), and *P. ligata* (Say, 1832)

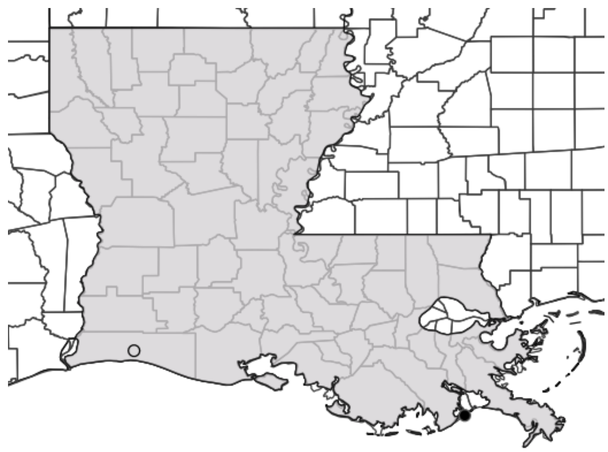

Figure 3.52. *Pentacora signoreti* (Guerin-Meneville, 1857) formerly *Salda signoreti* Guerin-Meneville, 1857 Previously Unpublished: Jefferson Published: Cameron (Ellis, 1952)

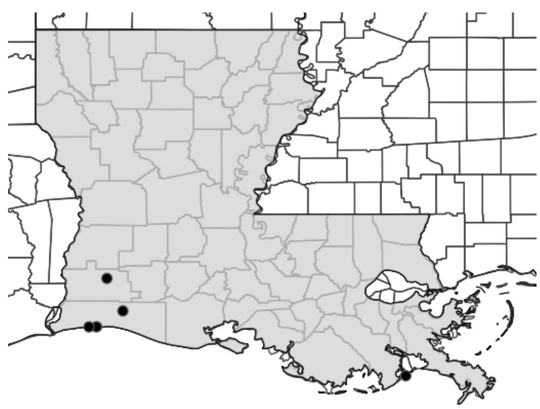

Figure 3.53. *Pentacora sphacelata* (Uhler, 1877) Previously Unpublished: Calcasieu, Jefferson Published: Cameron* (Ellis, 1952)

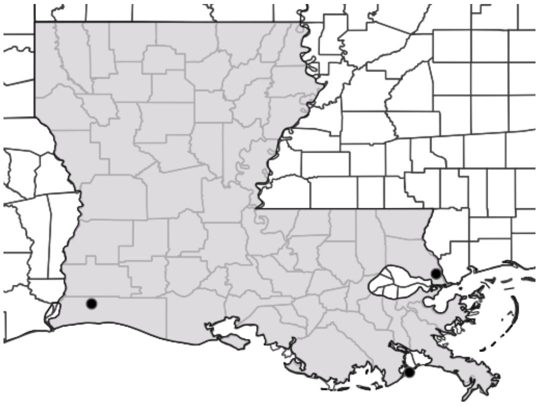

Figure 3.54. *Pentacora hirta* (Say, 1832) Previously Unpublished: Cameron, Jefferson, St. Tammany Published: None

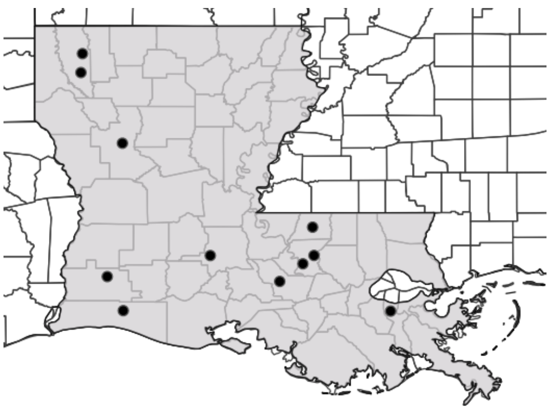

Figure 3.55. Saldidae: *Saldula* Van Duzee, 1914 including *S. pallipes* (Fabricius, 1794), *S. laticollis* (Reuter, 1875), and *S. lomata* Polhemus, 1985

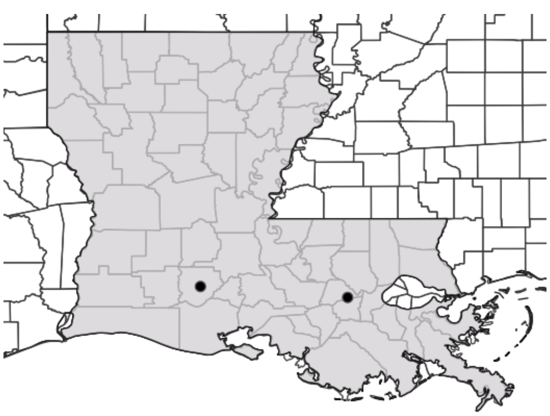

Figure 3.56. *Salda lugubris* (Say, 1832) formerly *Salda major* Provancher, 1872 *Saldula major* (Provancher, 1872) Previously Unpublished: Acadia, Ascension Published: None

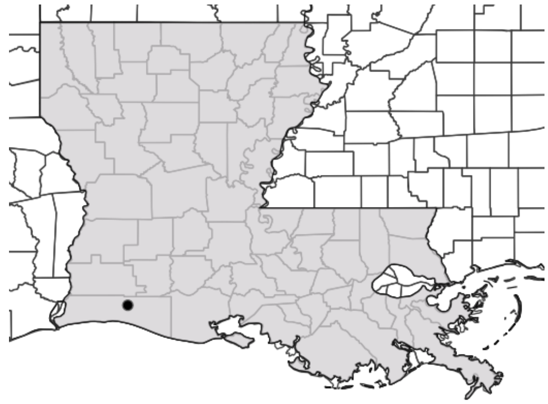

Figure 3.57. *Saldoida cornuta* Osborn, 1901 Previously Unpublished: Cameron Published: None

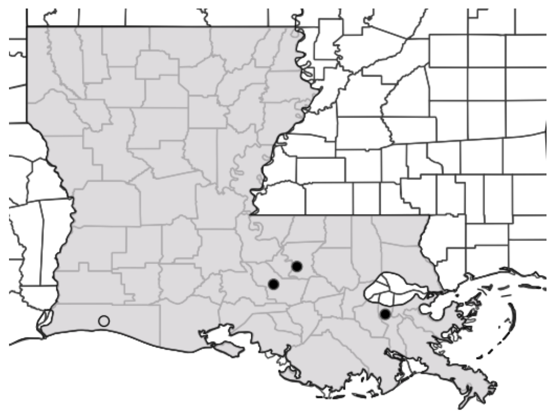

Figure 3.58. *Saldula pallipes* (Fabricius, 1794) formerly *Saldula interstitialis* (Say) Previously Unpublished: East Baton Rouge, Iberville, Jefferson Published: Cameron (Ellis, 1952)

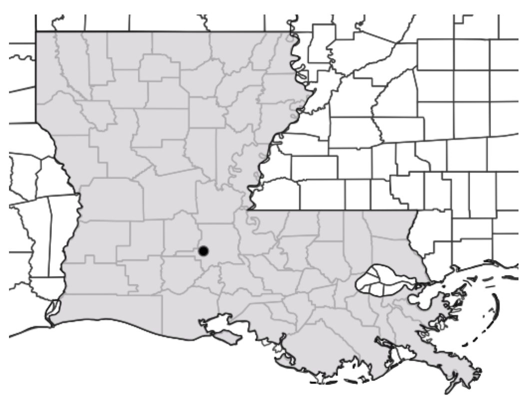

Figure 3.59. *Saldula laticollis (Reuter, 1875)* Previously Unpublished: St. Landry Published: None

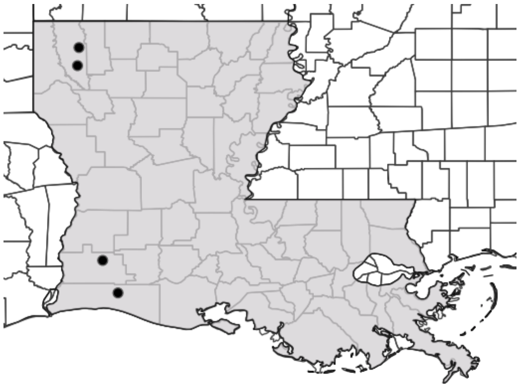

Figure 3.60. *Saldula lomata* Polhemus, 1985 Previously Unpublished: Bossier, Calcasieu, Cameron Published: None

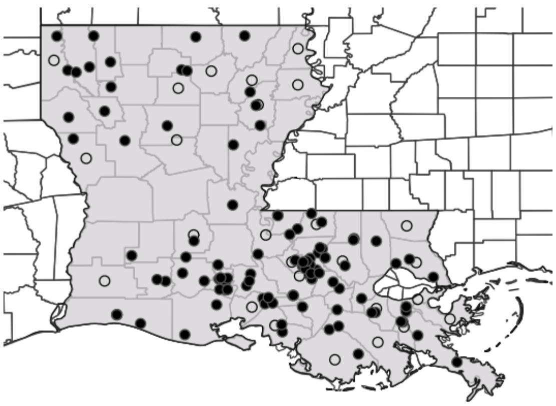

Figure 3.61. Nepidae, including *Ranatra* Stal, 1861 and *Curicta*

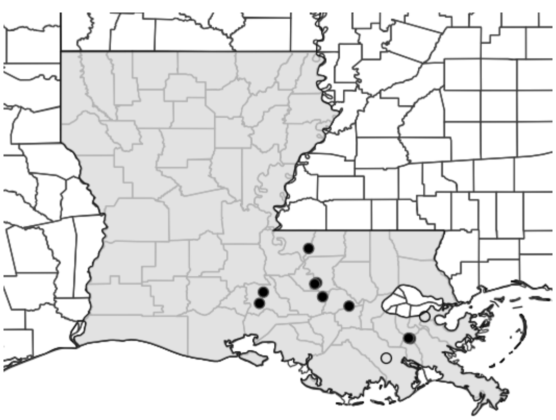

Figure 3.62. Nepidae: *Curicta scorpio* Stal, 1861, formerly *Curicta drakei* Hungerford, 1922, *Curicta howardi* Montandon, 1910, *Nepoidea montandoni* Martin, 1898 Previously Unpublished: Ascension, East Baton Rouge, Grant, St. Martin Published: Jefferson*, Lafourche*, Orleans (Ellis, 1952)

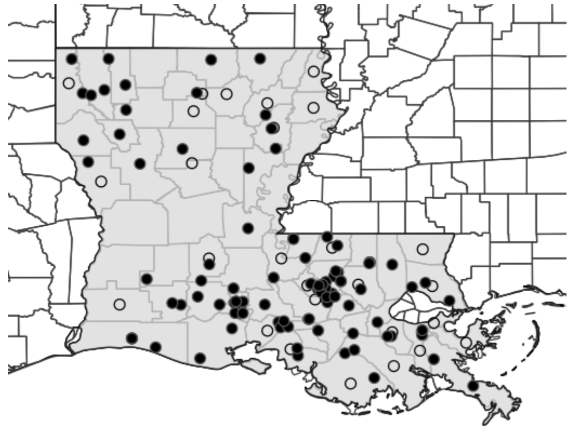

Figure 3.63. Nepidae: *Ranatra* Fabricius, 1790 including *R. attenuata* Kuitert, 1949, *R. buenoi* Hungerford, 1922, *R. nigra* Herrich-Shaffer, 1849, *R. australis* Hungerford, 1922, *R. fusca* Palisot de Beauvois, 1820, *R. quadridentata* Stal, 1862

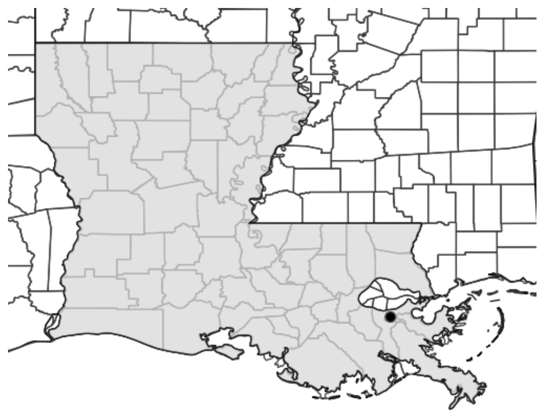

Figure 3.64. *Ranatra attenuata* Kuitert, 1949 Distribution: Orleans (one specimen held at the Kansas University Museum)

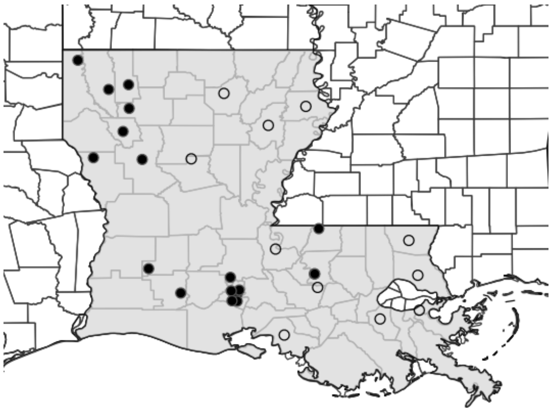

Figure 3.65. *Ranatra buenoi* Hungerford, 1922 Distribution: Previously Unpublished: East Baton Rouge, Natchitoches, Red River, Webster Published: Allen*, Bienville*, Bossier*, Caddo*, Claiborne, Jefferson*, Lafayette*, Sabine*, St. Landry* (Gonsoulin, 1973); Iberville, Madison, Orleans, Pointe Coupee, St. Charles, St. Mary, St. Tammany, Washington (Ellis, 1952); Franklin, Grant (Penn, 1952)

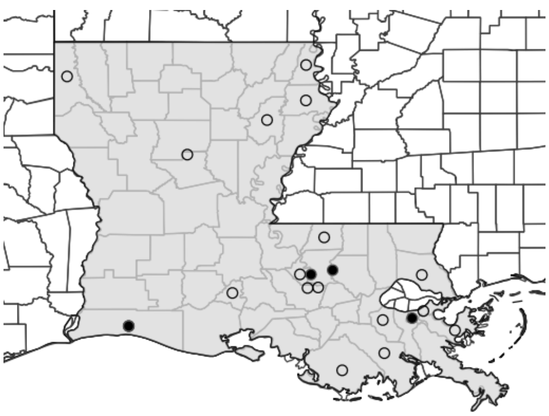

Figure 3.66. *Ranatra nigra* Herrich-Schaffer, 1849 Distribution: Previously Unpublished: St. Martin, Vermilion Published: DeSoto*, East Baton Rouge*, East Feliciana, Grant, Iberville, Lafayette, St. Mary*, Terrebonne, Webster* (Gonsoulin, 1973); Cameron, Iberia*, Iberville, Jefferson, Lafourche, Madison, Orleans, Plaquemines, St. Bernard, St. Mary*, St. Tammany, West Baton Rouge (Ellis, 1952); Caddo, East Carroll, Franklin, St. Bernard, St. Charles (Penn, 1952)

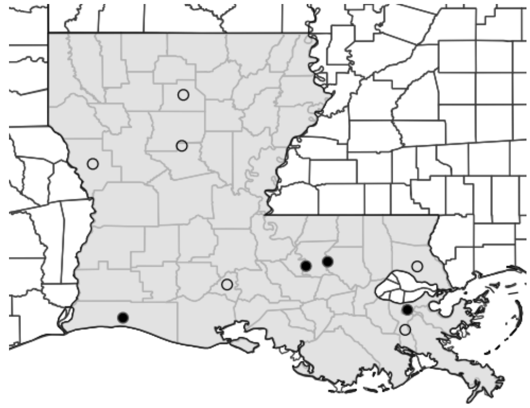

Figure 3.67. *Ranatra fusca* Palisot de Beauvois, 1820 formerly *R. Americana* Montandon, 1910 Previously Unpublished: Cameron, East Baton Rouge, Livingston, Orleans, Published: Jefferson (Ellis, 1952); Grant, Jackson, Lafayette, Sabine, St. Tammany (Penn, 1952)

Figure 3.68. *Ranatra quadridentata* Stal, 1862 Distribution: Previously Unpublished: Published: Lincoln (Bright & Sites, 2008)

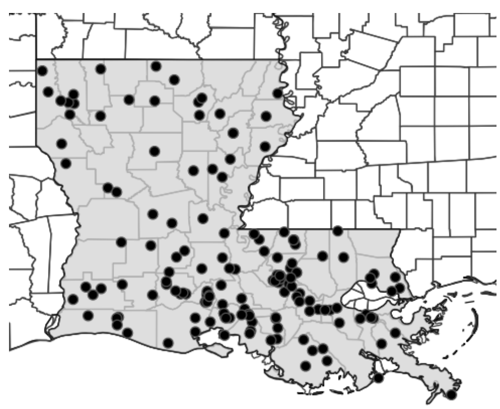

Figure 3.69. Belostomatidae, including *Benacus* Stal, 1861, *Belostoma* Latrielle, 1807, *Lethocerus* Mayr, 1853

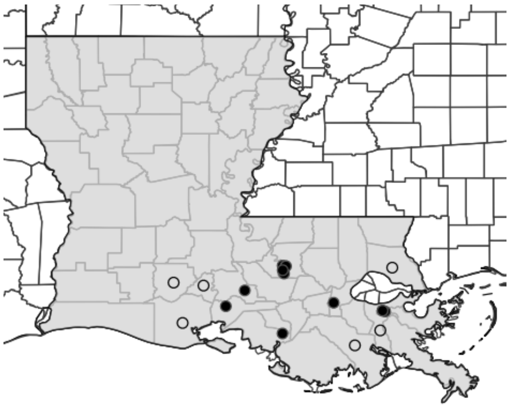

Figure 3.70. *Benacus griseus* (Say, 1832) formerly *Lethocerus griseus* (Say, 1832) Previously Unpublished: Cameron, East Baton Rouge, Iberia, St. Martin, St. Mary Published: Acadia, Lafayette, Lafourche, Vermilion (Gonsoulin, 1973); Jefferson, Orleans*, Pointe Coupee*, St. Tammany (Ellis, 1952)

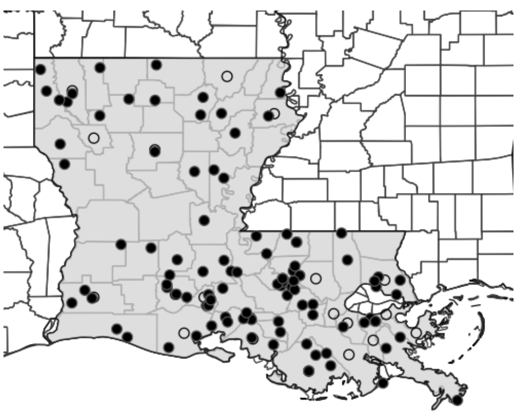

Figure 3.71. *Belostoma* Latrielle, 1807 including *B. testaceum* (Leidy, 1847), *B. flumineum* Say, 1932, *B. fusciventre* (Dufour, 1863), *B. lutarium* (Stal, 1856), *B. bakeri* Montandon, 1913

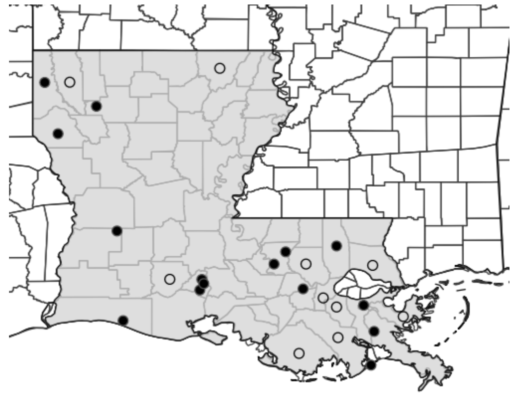

Figure 3.72. *Belostoma testaceum* (Leidy, 1847) Previously Unpublished: Ascension, Caddo, Cameron, Tangipahoa Published: Beauregard*, Bienville*, Bossier, DeSoto*, East Baton Rouge*, Lafayette*, Plaquemines* (Gonsoulin, 1973); Jefferson*, Lafourche, Livingston, Morehouse, Orleans*, Plaquemines*, St. Bernard, St. Charles, St. John the Baptist, St. Tammany, Terrebonne (Ellis, 1952); Acadia, Lafayette* (Penn, 1952)

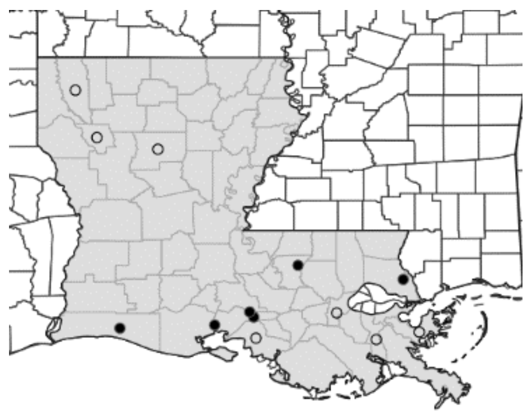

Figure 3.73. *Belostoma flumineum* Say, 1832 Previously Unpublished: Iberia, St. Martin, Vermilion Published: Cameron*, East Baton Rouge*, St. Mary (Gonsoulin, 1973); Jefferson, St. Bernard, St. John the Baptist (Ellis, 1952); Bossier, Red River, Winn (Penn, 1952)

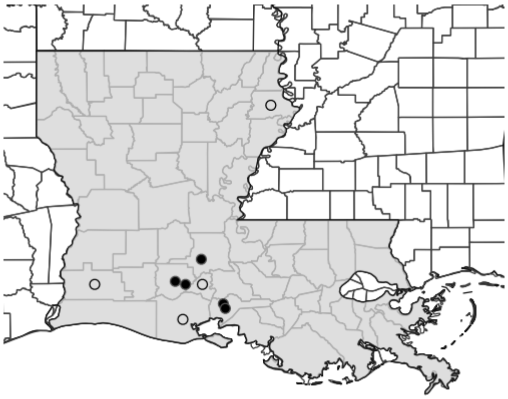

Figure 3.74. *Belostoma fuscivientre* (Dufour, 1863) Previously Unpublished: Acadia, St. Landry Published: Calcasieu, Iberia*, Lafayette, Madison, Vermilion (Gonsoulin, 1973)

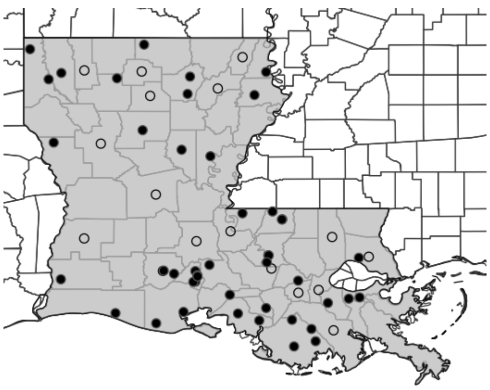

Figure 3.75. *Belostoma lutarium* (Stal, 1856) Previously Unpublished: Ascension, Cameron, Catahoula, Madison Published: Beauregard, Bienville*, Bossier*, Calcasieu*, East Carroll*, East Feliciana*, Iberville, Lafayette*, LaSalle*, Natchitoches, Ouachita*, Sabine*, St Charles*, St. James, St. Martin*, St. Mary*, Terrebonne*, Union*, Vermilion* (Gonsoulin, 1973); East Baton Rouge*, Iberville, Jefferson*, Lafourche, Orleans*, Pointe Coupee, St. Charles*, St. John the Baptist, St. Mary*, St. Tammany, Tangipahoa, Terrebonne, West Baton Rouge*, West Feliciana* (Ellis, 1952); Acadia, Bienville*, Bossier*, Caddo*, DeSoto*, Iberia*, Jackson, Lafayette*, Lincoln, Natchitoches, Ouachita*, Rapides, Richland, St. Landry, St. Martin*, Webster, West Carroll, Winn* (Penn, 1952)

Figure 3.76. *Belostoma bakeri* Montandon, 1913 Previously Unpublished: Published: Lafourche, Orleans (Ellis, 1952)

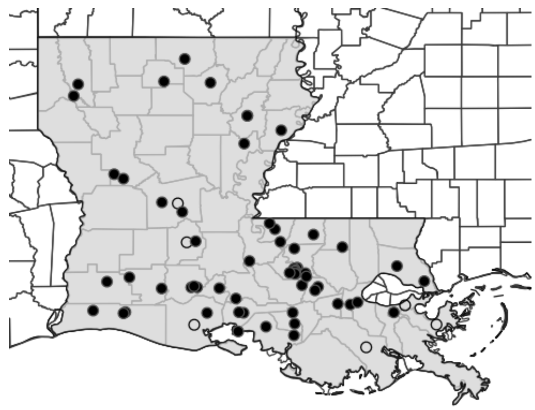

Figure 3.77. *Lethocerus* Mayr, 1853 including *L. uhleri* (Montandon, 1896) *L. americanus* (Leidy, 1847)

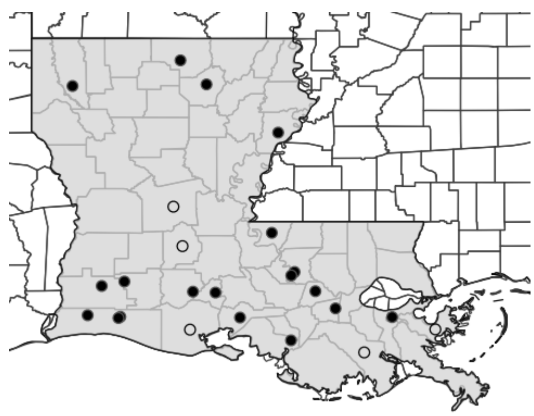

Figure 3.78. *Lethocerus uhleri* (Montandon, 1896) Previously Unpublished: Ascension, Bossier, Calcasieu, East Baton Rouge, St. Mary, St. Tammany, Tensas, West Feliciana Published: Acadia*, Evangeline, Iberia*, Lafayette*, Lafourche, Rapides, Vermilion (Gonsoulin, 1973); Orleans* (Ellis, 1952); St. Bernard (Penn, 1952)

Figure 3.79. *Lethocerus americanus* (Leidy, 1847) Previously Unpublished: Published: Orleans (Ellis, 1952)

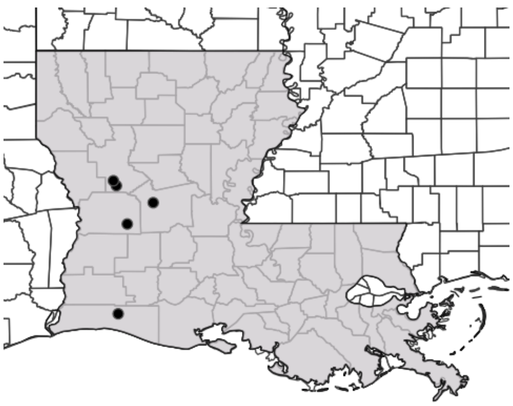

Figure 3.80. Ochteridae: *Ochterus* Latrielle, 1807 including *O. americanus* (Uhler, 1876) and *O. banksi* Barber, 1913

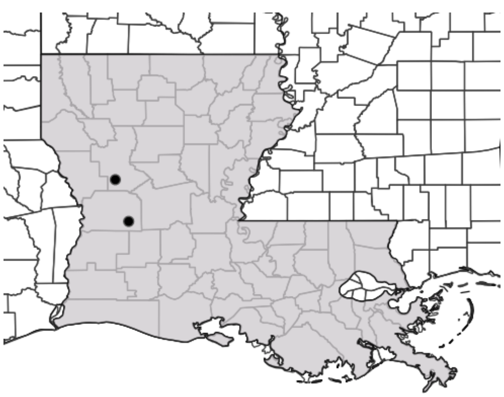

Figure 3.81. *Ochterus americanus* (Uhler, 1876) Previously Unpublished: Natchitoches, Vernon Published: None

Figure 3.82. *Ochterus banksi* Barber, 1913 Previously Unpublished: Natchitoches

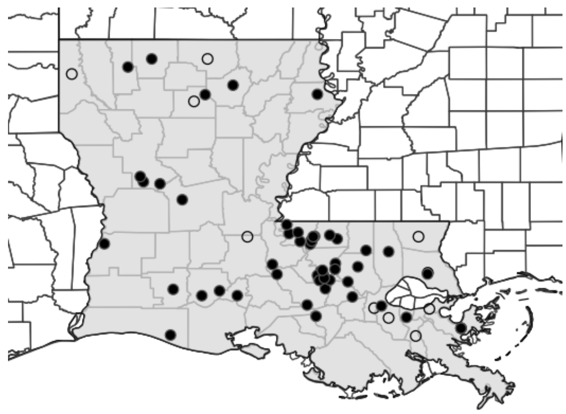

Figure 3.83. Gelastocoridae: *Gelastocoris* Kirkaldy, 1897 including *G. oculatus* (Fabricius, 1798) *G. vicinus* Champion, 1901

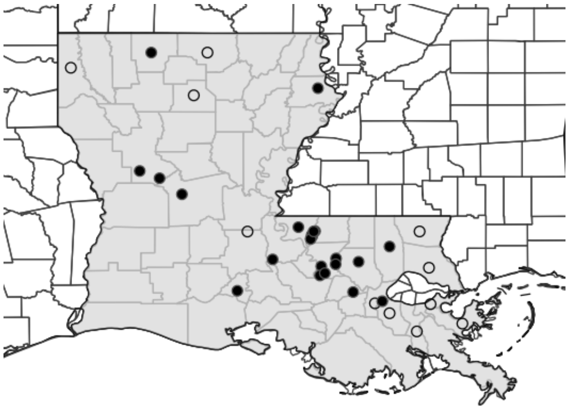

Figure 3.84. *Gelastocoris oculatus* Kirkaldy, 1897 formerly *Naucoris oculata* Fabricius, 1798 Previously Unpublished: East Baton Rouge, Lafayette, Madison, Natchitoches, Pointe Coupee, West Feliciana Published: Ascension*, Jefferson, Orleans, St. Bernard, St. John the Baptist, St. Tammany, Tangipahoa*, Washington (Ellis, 1952); Caddo, Claiborne*, DeSoto, Jackson, Livingston*, Rapides*, St. Charles, Union (Penn, 1952)

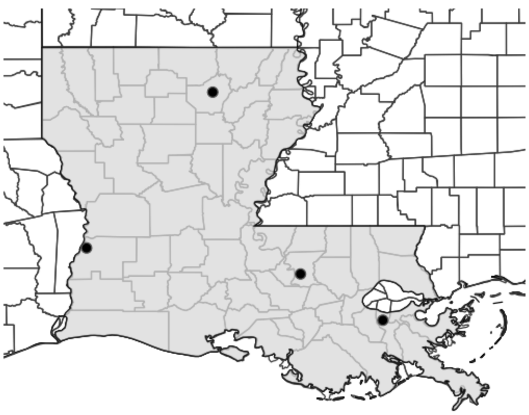

Figure 3.85. *Gelastocoris vicinus* Champion, 1901 Previously Unpublished: Beauregard, East Baton Rouge, Jefferson, Ouachita Published: None

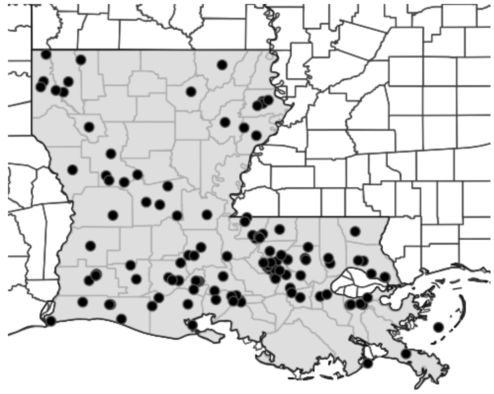

Figure 3.86. Corixidae including *Corisella* Lundblad, 1928, *Hesperocorixa* Kirkaldy, 1908, *Palmacorixa* Abbott, 1912, *Ramphocorixa* Abbott, 1912, *Sigaria* Fabricius, 1775, *Trichocorixa* Kirkaldy, 1908

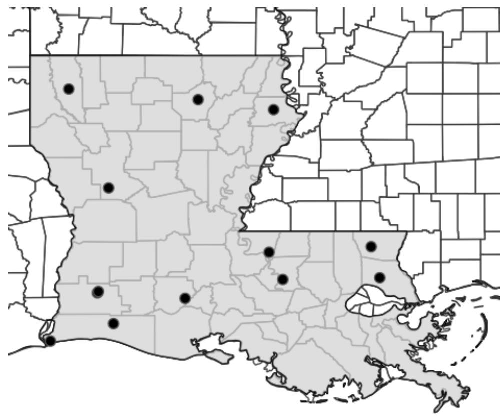

Figure 3.87. *Corisella edulis* (Champion, 1901) Previously unpublished: Acadia, Bossier, Calcasieu, East Baton Rouge, Natchitoches, Ouachita, St. Tammany, Terrebonne, Washington, West Baton Rouge, West Feliciana

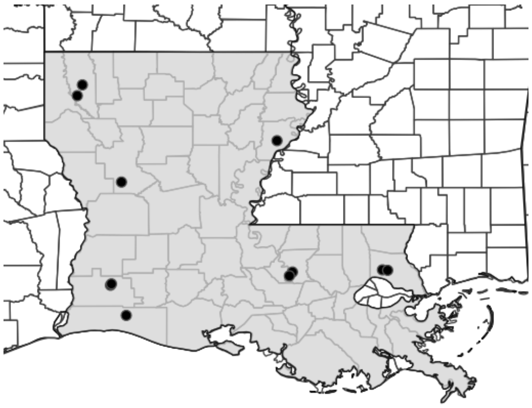

Figure 3.88. *Hesperocorixa* Kirkaldy, 1908 inclusing *H. lucida* (Abbott, 1916), *H. nitida* (Fieber, 1851), *H. obliqua* (Hungerford, 1925), *H. scabricula* (Walley, 1936)

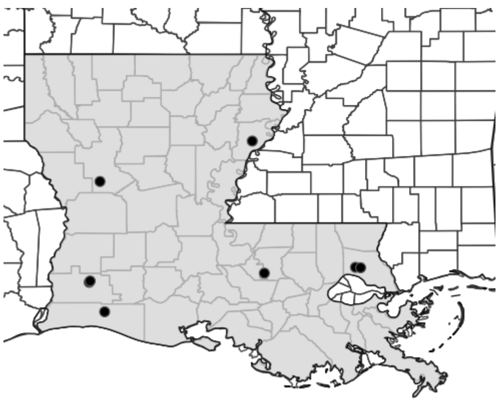

Figure 3.89. *Hesperocorixa lucida* (Abbott, 1916) formerly *Arctocorisa lucida* Abbott, 1916 Previously unpublished: Calcasieu, Cameron, East Baton Rouge, Natchitoches, St. Tammany, Tensas

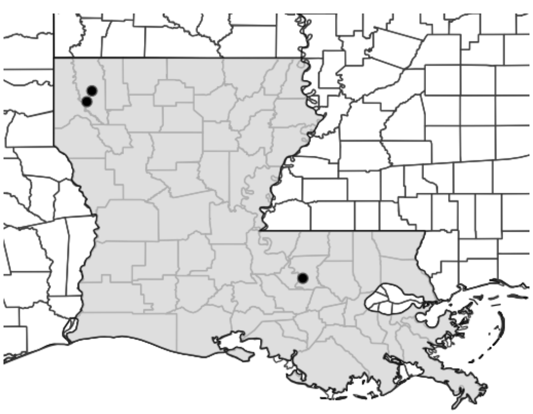

Figure 3.90. *Hesperocorixa nitida* (Fieber, 1851)formerly *Corisa nitida* Fieber, 1851 Previously unpublished: Bossier, East Baton Rouge, Iberia

Figure 3.91. *Hesperocorixa obliqua* (Hungerford, 1925) formerly *Arctocorisa obliqua Hungerford, 1925, Arctocorixa obliqua* Hungerford, 1925 Previously unpublished: East Baton Rouge

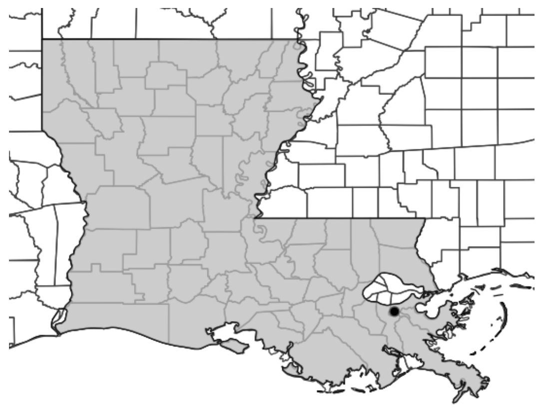

Figure 3.92. *Hesperocorixa scabricula* (Walley, 1936) formerly *Arctocorixa scabricula* Walley, 1936 Previously unpublished: Orleans

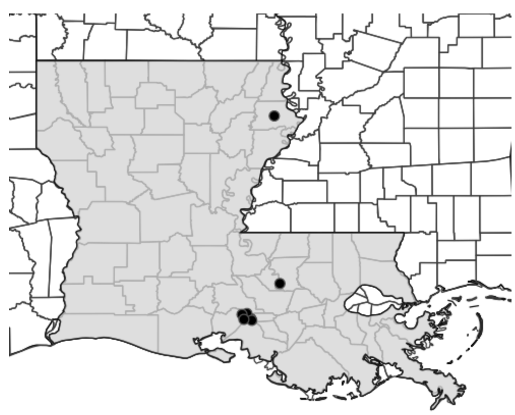

Figure 3.93. *Palmacorixa buenoi* Abbott, 1913 Previously unpublished: East Baton Rouge, Iberia, Madison, St. Martin Published: None

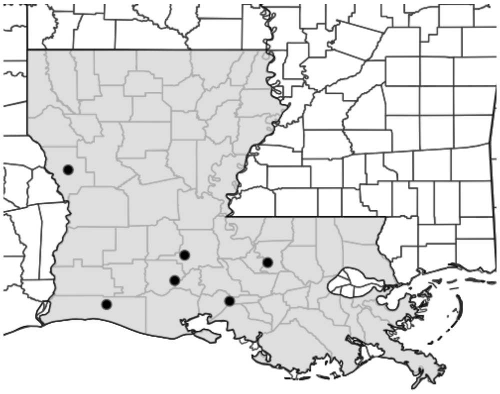

Figure 3.94. *Ramphocorixa accuminata* formerly *Ramphocorixa balanodis* Abbott, 1912, *Corixa acuminata* Uhler, 1897 Previously unpublished: Acadia, Cameron, East Baton Rouge, Iberia, Sabine, St. Landry

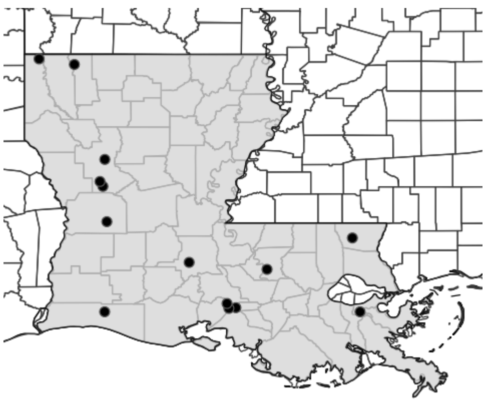

Figure 3.95. *Sigaria* Fabricius, 1775 including *S. alternata* (Say, 1825), *S. bradleyi* (Abbott, 1913) *S. hubbelli* (Hungerford, 1948), *S. mississippiensis* Hungerford, 1942, *S. modesta* (Abbott, 1916), *S. virginiensis* Hungerford, 1948

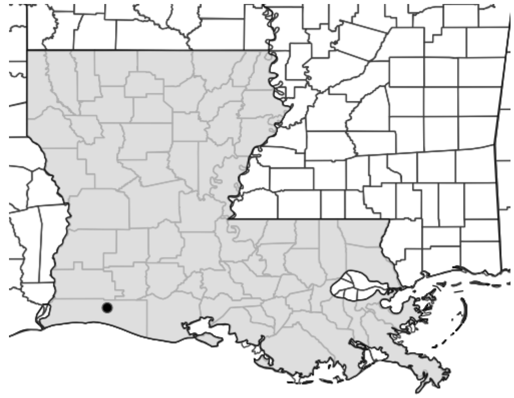

Figure 3.96. *Sigara alternata* (Say, 1825) formerly *Arctocorisa alternata* (Say, 1825) *Corixa alternata* Say, 1825 Previously unpublished: Cameron

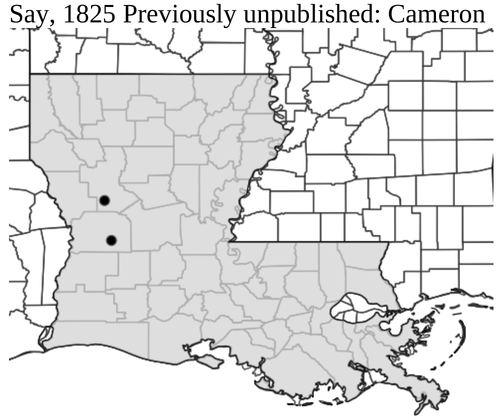

Figure 3.97. *Sigara bradleyi* (Abbott, 1913) formerly *Arctocorisa bradleyi* Abbott, 1913 Previously unpublished: Natchitoches, Vernon Published: None

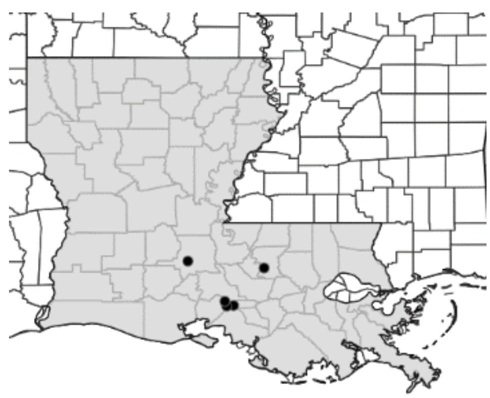

Figure 3.98. *Sigara hubbelli* (Hungerford, 1948) formerly *Arctocorixa hubbelli* Hungerford, 1928 Previously Unpublished: East Baton Rouge, Iberia, St. Landry Published: None

Figure 3.99. *Sigara mississippiensis* Hungerford, 1942 Previously unpublished: Natchitoches

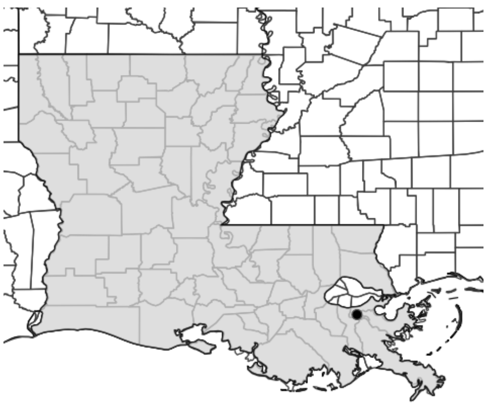

Figure 3.100. *Sigara modesta* (Abbott, 1916) formerly *Arctocorixa modesta* Abbott, 1916 *Arctocorisa modesta* Abbott, 1916 Previously unpublished: Orleans Published: None

Figure 3.101. *Sigara virginiensis* Hungerford, 1948 Previously unpublished: Caddo, Natchitoches, Washington Published: None

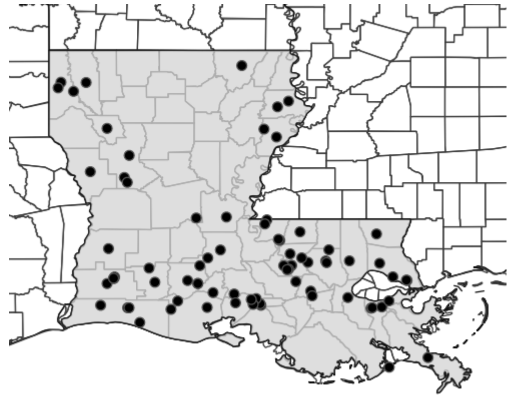

Figure 3.102. *Trichocorixa* Kirkaldy, 1908 including *T. sexcincta* (Champion, 1901), *T. louisianae* Jaczewski, 1931, *T. reticulata* (Guerin-Meneville, 1857), *T. minima* (Abbott, 1913), *T. calva* (Say, 1832), *T.verticalis* (Fieber, 1851) *T. kanza* Sailer, 1948

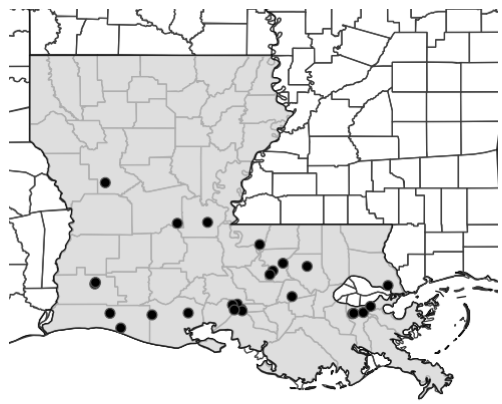

Figure 3.103. *Trichocorixa sexcinata* (Champion, 1901) formerly *Trichocorixa naias* (Kirkaldy and Torre-Bueno, 1909) *Corixa sexcincta* Champion, 1901 Previously unpublished: Ascension, Calcasieu, East Baton Rouge, Iberia, Jefferson, Livingston, Natchitoches, Orleans, St. Martin, Vermilion, West Feliciana Published: None

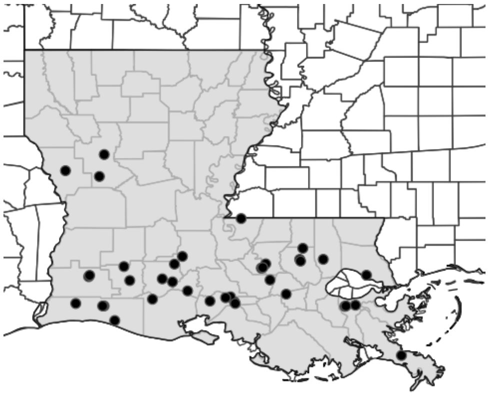

Figure 3.104. *Trichocorixa louisianae* Jaczewski, 1931 Previously unpublished: Acadia, Allen, Calcasieu, East Baton Rouge, Iberia, Iberville, Jefferson, Jefferson Davis, Lafayette, Livingston, Natchitoches, Plaquemines, Sabine, St. James, St. Landry, St. Martin, St. Tammany, Tangipahoa, Vermilion, West Feliciana Published: None

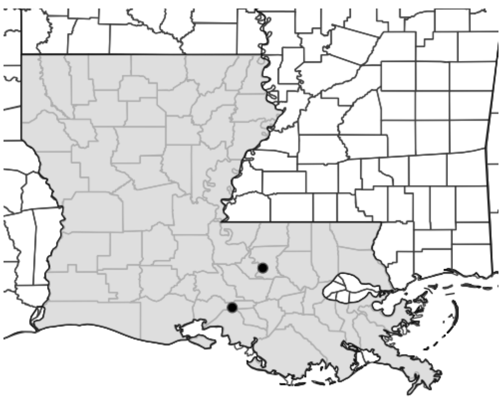

Figure 3.105. *Trichocorixa reticulata* (Guerin-Meneville, 1857) formerly *Corisa reticulata* Guerin-Meneville, 1857 Previously unpublished: East Baton Rouge, Iberia Published: None

Figure 3.106. *Trichocorixa minima* (Abbott, 1913) formerly *Corixa minima* Abbott, 1913 Previously unpublished: Cameron Published: None

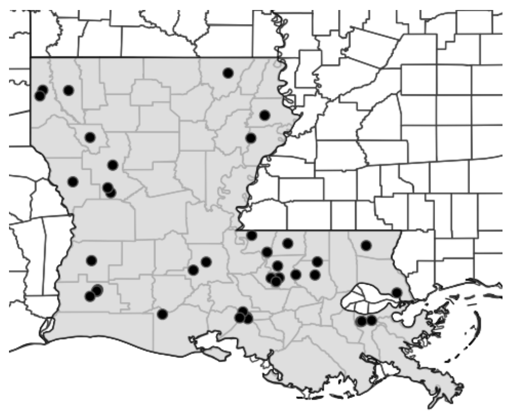

Figure 3.107. *Trichocorixa calva* (Say, 1832) formerly *Corixa calva* Say, 1832 Previously unpublished: Beauregard, Bossier, Caddo, Calcasieu, DeSoto, East Baton Rouge, East Feliciana, Iberia, Jefferson, Livingston, Madison, Natchitoches, Orleans, Red River, Sabine, St. Landry, St. Martin, Vermilion, Washington, West Baton Rouge, West Feliciana Published: None

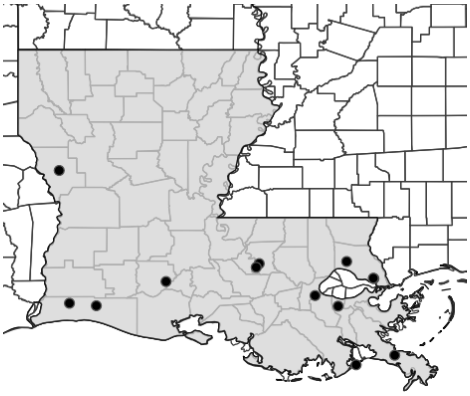

Figure 3.108. *Trichocorixa verticalis* (Fieber, 1851) formerly *Trichocorixa pygmaea* (Fieber, 1851) *Corisa pygmaea* Fieber, 1851 *Corisa verticalis* Fieber, 1851 Previously unpublished: Acadia, Cameron, East Baton Rouge, Jefferson, Plaquemines, Sabine, St. John the Baptist, St. Tammany Published: None

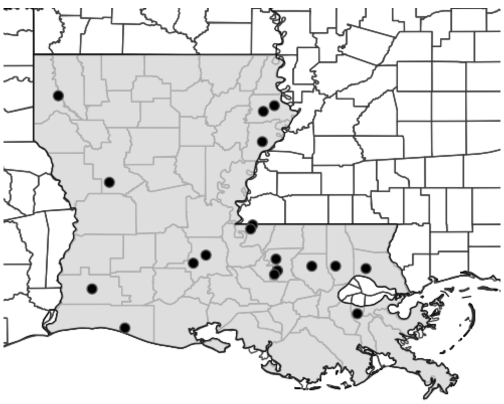

Figure 3.109. *Trichocorixa kanza* Sailer, 1948 Previously unpublished: Caddo, Calcasieu, Cameron, East Baton Rouge, Jefferson, Livingston, Madison, Natchitoches, St. Landry, St. Tammany, Tangipahoa, Tensas, West Feliciana Published: None

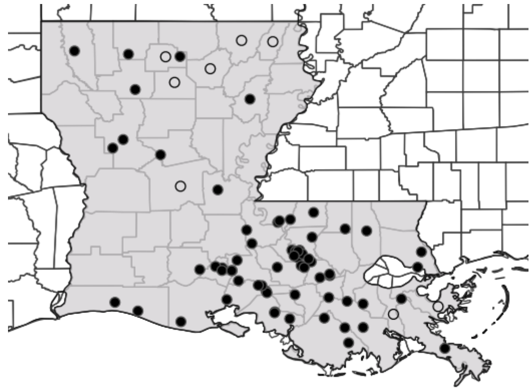

Figure 3.110. Naucoridae: *Pelocoris* Stal, 1876 including *P. femoratus* (Palisot de Beauvois, 1820), *P. carolinensis* Torre-Bueno, 1907

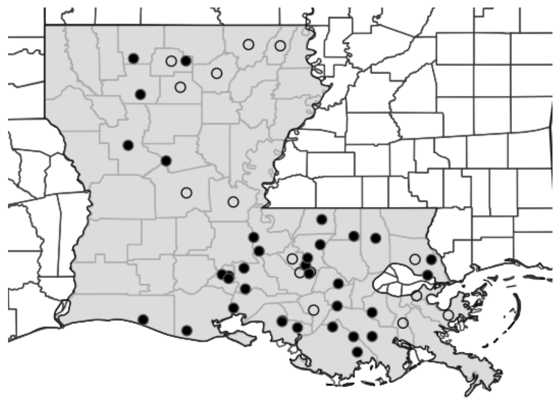

Figure 3.111. *Pelocoris femoratus* (Palisot de Beauvois, 1820) Previously Unpublished: St. Helena, Tangipahoa Published: Ascension*, Bienville*, Cameron*, Claiborne*, East Baton Rouge*, East Feliciana*, Grant*, Iberia*, Jackson*, Lafayette*, Lafourche*, Natchitoches*, St. James*, St. Landry*, St. Martin*, St. Mary*, St. Tammany*, Terrebonne*, Vermilion*, West Baton Rouge (Gonsoulin, 1973); Avoyelles, East Baton Rouge*, Iberville, Jefferson, Lafourche*, Morehouse, Orleans, Plaquemines, Pointe Coupee*, St. Bernard, St. Charles*, St. James*, St. Martin*, St. Mary*,St. Tammany*, West Baton Rouge (Ellis, 1952); Assumption, Jackson, Lincoln, Ouachita, Rapides, West Carroll (Penn, 1952); St. Tammany (LaRivers, 1948) Published: None

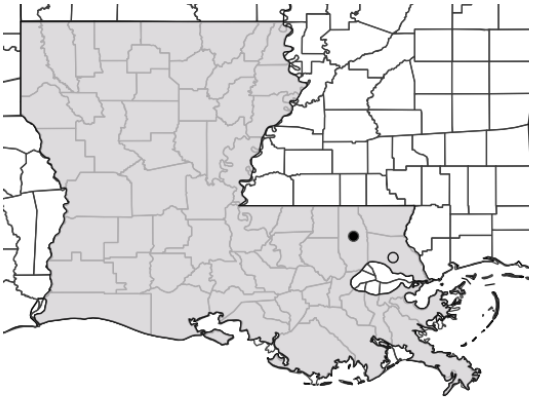

Figure 3.112. *Pelocoris carolinensis* Torre-Bueno, 1907 Previously Unpublished: Tangipahoa Published: St. Tammany (Gonsoulin, 1973); St. Tammany (Penn, 1952)

Figure 3.113. Notonectidae: *Anisops elegans* Fieber, 1852 formerly *Buenoa elegans* Fieber, 1852 *Anisops apicalis* Stal, 1855 *Anisops hungerfordi* Poisson, 1935 Previously unpublished: NonePublished: Lafourche, St. Charles, St. Tammany, Terrebonne (Ellis, 1952)

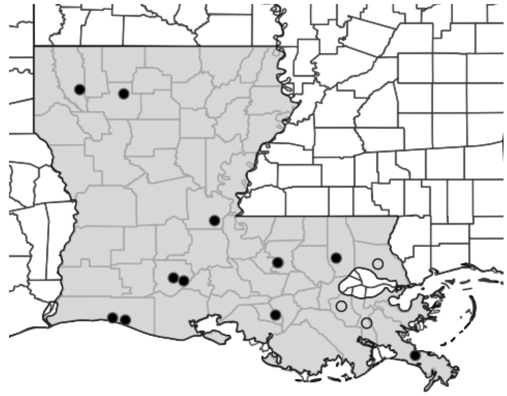

Figure 3.114. Notonectidae: *Buenoa* Kirkaldy, 1904 including *B. confusa* Truxal, 1953, *B. limnocastoris* Hungerford, 1923, *B. margaritacea* Torre-Bueno, 1908, *B. omani* Truxal, 1953, *B. platycnemis* (Fieber, 1851), *B. scimitra* Bare, 1925

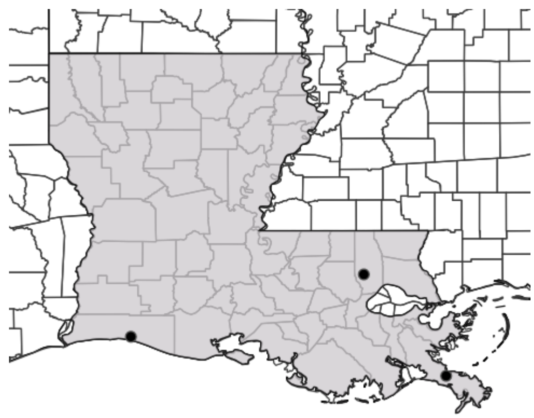

Figure 3.115. *Buenoa confusa* Truxal, 1953 Previously unpublished: Cameron, Plaquemines, Tangipahoa Published: None

Figure 3.116. *Buenoa limnocastoris* Hungerford, 1923 Previously unpublished: None Published: St. Charles (Ellis, 1952)

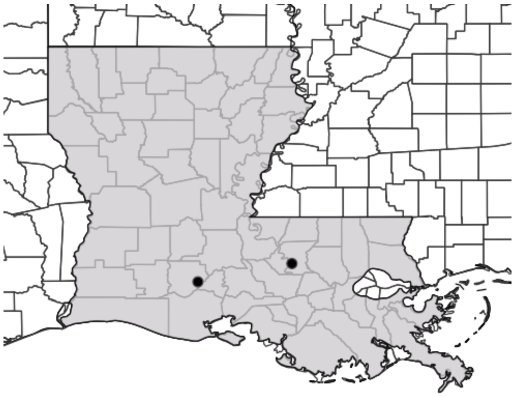

Figure 3.117. *Buenoa margaritacea* Torre-Bueno, 1908 Previously unpublished: Acadia, East Baton Rouge
Published: None

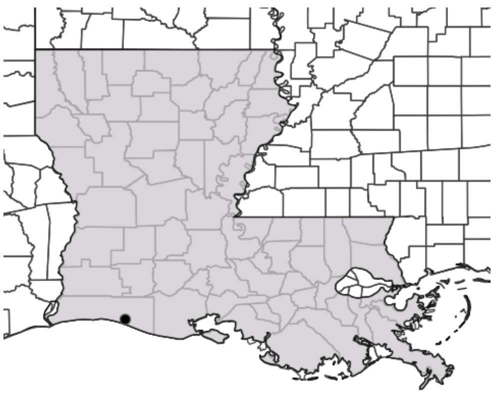

Figure 3.118. *Buenoa omani* Truxal, 1953 Previously unpublished: Cameron Published: None

Figure 3.119. *Buenoa platycnemis* (Fieber, 1851) Previously unpublished: Tangipahoa
Published: None

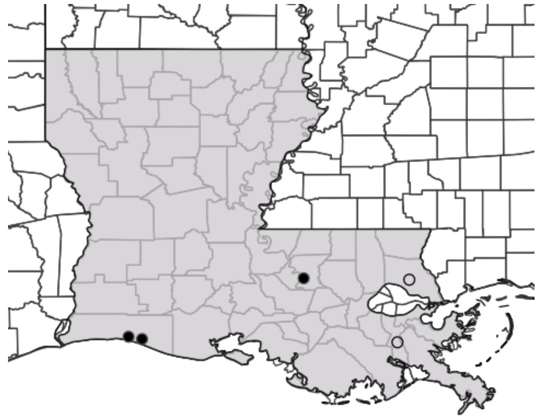

Figure 3.120. *Buenoa scimitra* Bare, 1925 Previously unpublished: Cameron, East Baton Rouge
Published: Jefferson, St. Tammany (Ellis, 1952)

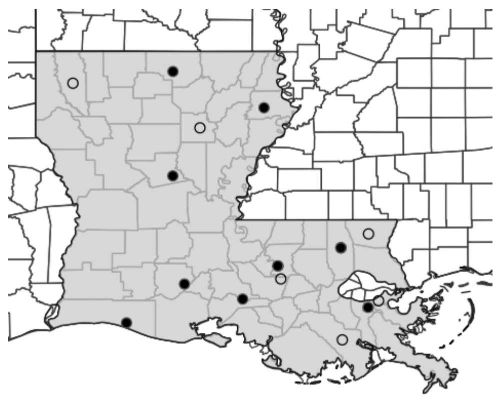

Figure 3.121. Notonectidae: *Notonecta* Linnaeus, 1758 including *N. indica* Linnaeus, 1771, *N. irrorata* Uhler, 1879, *N. uhleri* Kirkaldy, 1897, *N. undulata* Say, 1832

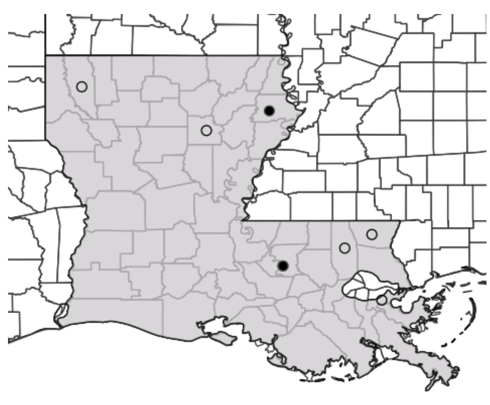

Figure 3.122. *Notonecta indica* Linnaeus, 1771 formerly *Notonecta howardii* Torre-Bueno, 1905 Previously Unpublished: Madison Published: Bossier, Caldwell, East Baton Rouge*, Orleans, Tangipahoa, Washington (Ellis, 1952)

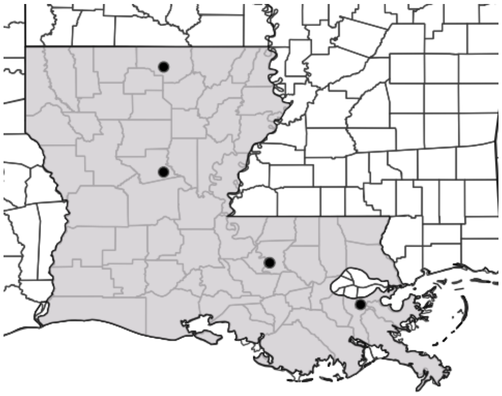

Figure 3.123. *Notonecta irrorata* Uhler, 1879 Previously unpublished: East Baton Rouge, OrleansPublished: None

Figure 3.124. *Notonecta uhleri* Kirkaldy, 1897 Previously unpublished: Tangipahoa Published: Iberville, Lafourche, Orleans (Ellis, 1952)

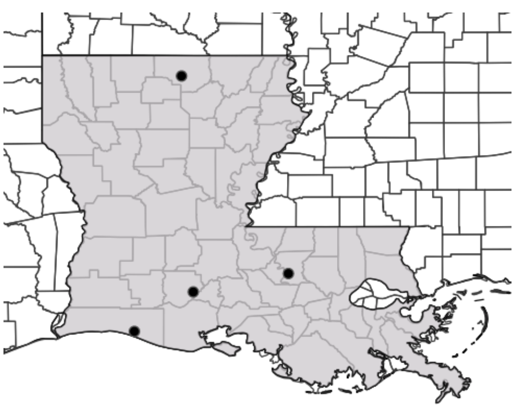

Figure 3.125. *Notonecta undulata* Say, 1832 Previously unpublished: Acadia, East Baton Rouge Published: Cameron* (Ellis, 1952)

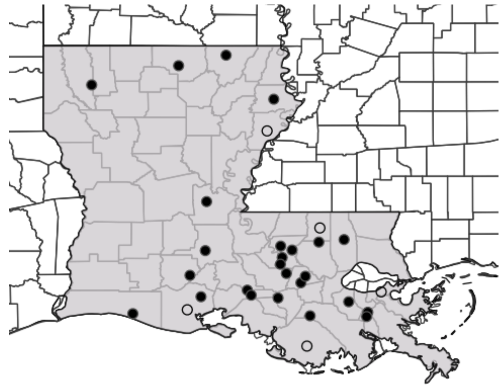

Figure 3.126. Pleidae: *Neoplea striola* (Fieber, 1844) formerly *Plea striola* Fieber, 1844 Previously unpublished: Assumption, Avoyelles, Iberia, Iberville, Livingston, Madison, Morehouse, St. Landry, St. Martin Published: East Baton Rouge*, Jefferson*, Orleans, St. Charles*, St. Helena, Tensas, Terrebonne, Vermilion (Ellis, 1952)

3.4 Discussion

Combining LSAM and database data, this study added 296 previously unpublished parish records with specimens collected from 1905 to 2019, bettering our understanding of Louisiana hemipteran diversity and distribution. This is the first known analysis of Corixidae, Saldidae, and Hebridae specific for the state, and while it is far from complete, the map layers and checklist created will allow hobbyists and scientists access to records previously unavailable outside of the LSAM. Moreover, this study has added greater understanding of spatial distributions. Some taxa varied in their ranges widely. In Belostomatidae, *Benacus griseus,* the sole member of its genus in the state, was only found in southern Louisiana, contrary to the rest of the family's cosmopolitan distribution (Figs 3.68.-78.). The notonectid genera *Buenoa* (Fig. 3.112.) and *Anisops* (Fig. 3.111.) are also primarily southern, with few collections in the north. *Notonecta*, the remaining genus, displays an opposing pattern (Fig. 3.119.). Pleidae, a family with only one species in the state, is primarily found east of the Mississippi (Fig. 124.). Potentially, these differences may be the result of collecting effort, or rare taxa may be indeed rare. Nevertheless, these updated checklists and maps advance distributional knowledge and will be useful in several applications (e.g., biological assessment, taxonomy, and trophic ecology).

Biological monitoring and other biological assessment incorporate aquatic insects and descriptive aquatic insect assemblage metrics (e.g., EPT (Ephemeroptera, Plecoptera, and Tricoptera) richness; Resh and Rosenberg 1984, Kaller and Hartman 2004, King et al. 2011) due to their response to small and large disturbances. Whereas a fish may take years to experience mortality, display physiological responses, or population shifts, insects' shortened generation time provide nearly instantaneous results (Karr and Chu 1999). Moreover, insects included in many common metrics, such as EPT richness or %EPT, are not widely distributed and in great

abundance in Louisiana (e.g., Plectoptera; Stewart et al. 1976) resulting in inconsistencies in interpreting their application (e.g. inconsistent in Kaller and Kelso (2010) vs. strongly correlated in Markos et al. (2016)). To understand how an ecosystem is affected by disturbances (e.g. anthropogenic effects, climate change, temperature shifts), a baseline of what can be expected in the ecosystem must first be established. By making these maps, a baseline for Louisiana aquatic Hemiptera has been established such that they can be used as a metric for assessment. Because an updated guide to aquatic Hemiptera of Louisiana has not been published, maps like these aid researchers in navigating existing keys to make accurate conclusions.

Hemiptera is an incredibly diverse order, with members that feed on a variety of trophic levels, from phytoplankton to fish. Understanding where each taxonomic unit exists in the space aids in understanding how feeding dynamics vary between systems (Foltz and Dodson 2009). Belostomatids are large, generalist predators that can survive in virtually any ecosystem (Boersma and Lytle 2014). Hydrometrids and other striders require cover, and areas of flow slow enough to establish surface tension, providing food for large fish that utilize undercut banks and other refuges (Epler 2006, Polhemus 2008). Mustering at multiple taxonomic levels, corixids are gregarious, living in large multispecies assemblages that vary in richness and density depending on the area. They readily fly to new habitats as adults and their establishment could be a valuable tool for biological assessment and ecosystem management (Hungerford 1917, Griffith 1945, Polhemus 2008, Rosenburg et al. 2008)

A major goal of this project was to update the taxonomy of the LSAM's holdings to ITIS standards. Scientific names were created to better communicate with scientists around the world by generating a common language. If this language is not updated, the purpose is defeated; keys become difficult to use and vouchers virtually useless. Taxonomy may be changing all the time,

but with online databases, scientists have the power to update many collections at once as new information is published. The digital files created in this project not only updated the LSAM's aquatic Hemiptera to the 2019 standard, but also allows for future revision with relative ease.

APPENDIX A. INVERTEBRATES SAMPLED VIA LIGHT TRAPS IN BUFFALO COVE WMA AND LAKE FAUSSE POINTE

Hemiptera

Family	Genus	Species	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018
Veliidae			0	1	0
	Juvenile		0	1	0
Gerridae			0	1	0
	Limnoporus	*canaliculatus*	0	1	0
Saldidae			0	0	0
Nepidae			6	9	5
	Ranatra		0	0	4
		nigra	6	9	1
Belostomatidae			27	55	1
	Belostoma		21	47	0
		flumineum	6	3	0
		fusciventre	0	4	0
		lutarium	0	1	1
Ochteridae			0	0	0

Family	Genus	Species	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018
Gelastocoridae			0	0	0
Corixidae			358	1438	398
	Juvenile		163	1257	45
	Corisella	*edulis*	0	1	0
	Hesperocorixa	*nitida*	0	8	1
	Palmacorixa	*buenoi*	79	84	325
	Ramphocorixa	*accuminata*	0	0	1
	Sigaria			2	
		hubbelli	4	0	5
		virginiensis	0	3	0
	Trichocorixa		7	4	0
		calva	5	14	7
		louisianae	75	34	8
		reticulata	1	5	0
		sexcincta	24	26	6
Naucoridae	*Pelocoris*		25	17	1
Notonectidae	*Notonecta*		2	0	0
Pleidae	*Neoplea*	*striola*	2	0	0

Invertebrate Associates

Subphylum	Order	Family	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018
Hexapoda					
	Ephemeroptera		53	272	75
		Baetidae	26	158	0
		Baetiscidae	0	8	0
		Caenidae	7	87	15
		Ephemeridae	18	9	60
		Heptageniidae	1	10	0
		Leptophlebiidae	1	0	0
	Odonata		10	61	17
		Aeshnidae	2	0	0
		Calopterigidae	6	53	16
		Coeagrionidae	0	1	0
		Corduliidae	2	3	1
		Gomphidae	0	1	0
		Libellulidae	0	1	0
		Petaluridae	0	1	0
	Coleoptera		221	161	45
		Curculionidae	4	4	1
		Dryopidae	0	16	0
		Dytiscidae	11	38	1
		Gyrinidae	34	35	23

Subphylum	Order	Family	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018
		Haliplidae	19	26	3
		Hydrophilidae	150	42	17
		Noteridae	2	0	0
		Scirtidae	1	0	0
	Neuroptera		1	5	1
		Corydalidae	1	2	0
		Sisyridae	0	0	1
		Terrestrial	0	3	0
	Hymenoptera		5	3	0
		Brachonidae	0	3	0
		Formicidae	5	0	0
	Trichoptera		8	34	3
		Adult	0	27	0
		Hydropsychidae	4	0	0
		Hydroptilidae	0	2	0
		Leptoceridae	2	0	2
		Philopotamidae	2	0	0
		Phyganeidae	0	4	1
		Rhyacophilidae	0	1	0
	Lepidoptera		0	3	0
		Noctuidae	0	3	0

	Order	Family	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018
	Diptera		334	110	59
		Adult	128	50	48
		Ceratopogonidae	0	1	1
		Chaoboridae	50	15	2
		Chironomidae	148	42	8
		Culicidae	6	1	0
		Stratiomyidae	2	1	0
Myriapoda			1	1	0
	Polydesmida	Polydesmidae	1	1	0
Crustacea			1257	2151	467
	Amphipoda		504	1246	177
	Arguloida	Argulidae	4	1	7
	Decapoda		746	385	283
		Cambaridae	10	1	0
		Palaemonidae	736	384	283
	Isopoda		3	35	0
Mollusca	Gastropoda		6	139	3

APPENDIX B. INVERTEBRATES SAMPLED IN ASSOCIATION WITH WATER HYACINTH

Subphylum	Order	Family	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018	Lake Fausse Pointe 2019
Hexapoda						
	Ephemeroptera		6		0	
		Unidentifiable	2		0	
		Baetidae	3		0	
		Caenidae	1		0	
	Odonata		15		4	
		Unidentifiable	2		0	
		Calopterigidae	11		4	
		Corduliidae	2		0	
	Orthoptera	Acrididae	1		0	
	Hemiptera		4		0	
		Belostomatidae	1		0	
		Corixidae	1		0	
		Naucoridae	2		0	
	Coleoptera		69		2	
		Curculionidae	36		1	
		Dytiscidae	1		0	
		Haliplidae	2		0	

Subphylum	Order	Family	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018	Lake Fausse Pointe 2019
		Hydrophilidae	27		1	
		Lampyridae	1		0	
		Staphylinidae	2		0	
	Neuroptera		2		0	
		Corydalidae	1		0	
		Sialidae	1		0	
	Hymenoptera		2		2	
		Brachonidae	1		0	
		Formicidae	1		2	
	Trichoptera		1		0	
		Philopotamidae	1		0	
	Lepidoptera		0		1	
		Noctuidae	0		1	
	Diptera		111		11	
		Pupa	1		1	
		Ceratopogonidae	13		1	
		Chironomidae	96		7	
		Culicidae	0		1	
		Psychodidae	0		1	

Subphylum	Order	Family	Buffalo Cove 2018	Buffalo Cove 2019	Lake Fausse Pointe 2018	Lake Fausse Pointe 2019
		Stratiomyidae	1		0	
Crustacea			2548		82	
	Amphipoda		2492		75	
	Decapoda		27		7	
		Cambaridae	15		0	
		Palaemonidae	12		7	
	Isopoda		38		0	

APPENDIX C. INVENTORY OF THE LOUISIANA STATE ARTHROPOD MUSEUM

Family	Genus	Species	Subspecies	Specimen Count	Collection Interval	Collection Events
Belostomatidae				466	1906-2018	324
	Unidentified			6		
	Belostoma			111	1948-2018	87
		flumineum		12	1967-2018	10
		fusciventre		14	1966-1975	8
		lutarium		169	1906-2018	75
		testaceum		37	1923-2010	31
	Benacus	*griseus*		10	1916-1999	10
	Lethocerus			81	1973-2016	81
		uhleri		26	1917-2010	22
Corixidae				1335	1905-2018	434
	Unidentified			418	1951-2018	173
	Corisella	*edulis*		18	1961-1994	16
	Hesperocorixa	*lucida*		7	1973-1985	4
		nitida		11	1961-2018	8
		obliqua		21	1961	6
	Palmacorixa	*buenoi*		399	1930-2018	35
	Ramphocorixa	*accuminata*		3	1928-2018	3
	Sigaria	*bradleyi*		3	1985	2
		hubbelli		9	2018	4
		virginiensis		3	1980-1990	3
	Trichocorixa			9	1995-2018	5
		calva		127	1928-2018	44
		kanza		51	1928-2018	29

Family	Genus	Species	Subspecies	Specimen Count	Collection Interval	Collection Events
		louisianae		184	1939-2018	60
		reticulata		2	1983-2018	2
		sexcincta		59	1905-2018	33
		verticalis	*verticalis*	11	1961-1994	7
Gelastocoridae				104	1916-2018	72
	Unsorted			59	1976-2018	47
	Gelastocoris	*oculatus*		45	1916-2009	25
Gerridae				506	1905-2016	241
	Unsorted			135	1905-2016	89
	Aquarius	*conformis*		1	1941	1
	Gerris			1	2010	1
		argenticollis		15	1941-1977	7
		canaliculatus		100	1930-2010	46
		marginatus		40	1958-1975	22
	Limnogonus	*parvulus*		1	1934	1
	Limnoporus			1	2011	1
	Metrobates	*alacris*		20	1930-1967	2
		hesperius		4	1967	1
	Neogerris	*hesione*		121	1936-1967	37
	Rheumobates	*palosi*		10	1967	4
		trulliger		1	1930	1
	Trepobates	*knighti*		2	1967	1
		pictus		1	1967	1
		subnitidus		53	1966-1967	26

Family	Genus	Species	Subspecies	Specimen Count	Collection Interval	Collection Events
Hebridae				179	1934-2016	37
	Unsorted			14	1975-2016	12
	Hebrus	*concinnus*		3	1934	1
		consolidus		160	1975-2010	22
	Lipogomphus	*brevis*		1	1948	1
	Merragata			1	1975	1
Hydrometridae				763	1917-2016	158
	Hydrometra			110	1979-2016	61
		australis		613	1930-2010	76
		hungerfordi		23	1917-2010	11
		martini		17	1961-2007	10
Mesoveliidae				175	1934-2018	76
	Mesovelia			107	1974-2018	54
		amoena		2	1934	1
		mulsanti		66	1961-2009	21
Naucoridae				270	1935-2018	117
	Unsorted			66	1967-2013	49
	Pelocoris			24	2003-2018	11
		carolinensis		1	1977	1
		femoratus		179	1935-2010	56

Family	Genus	Species	Subspecies	Specimen Count	Collection Interval	Collection Events
Nepidae				239	1930-2018	180
	Curicta			12	1984-2016	7
		scorpio		16	1984-2016	11
	Ranatra			105	1948-2018	97
		australis		37	1930-1981	24
		buenoi		29	1941-1980	22
		fusca		3	1999-2018	3
		nigra		37	1961-2018	16
Notonectidae				416	1915-2016	188
	Unsorted			291	1928-2016	151
	Buenoa			30	1961-1995	5
		margaritacea		7	1975	1
		omani		13	1974-1975	4
		scimitra		41	1961-1974	10
	Notonecta			2	2018	1
		indica		1	1961	1
		irroata		9	1915-1967	5
		uhleri		1	1977	1
		undulata		21	1917-1975	9
Ochteridae				33	1969-1990	8
	Unsorted			6	1969-1990	4
	Ochterus	*americanus*		1	1990	1
		banksii		26	1990	3

Family	Genus	Species	Subspecies	Specimen Count	Collection Interval	Collection Events
Pleidae				71	1930-2018	29
	Unsorted			53	1979-2016	17
	Neoplea	*striola*		18	1930-2018	12
Saldidae				65	1930-2010	32
	Unsorted					
	Micracanthia	*humilis*		2	1966-1995	2
		husseyi		29	2009-2010	8
	Pentacora	*hirta*		4	1942-1982	3
		ligata		5	1930-1932	2
		signoretti		4	1940-1943	3
		sphacelata		2	1942	2
	Salda	*lugubris*		7	1975-2010	4
	Saldula			7	1979-2009	3
		pallipes		5	1972-1982	5
Veliidae				317	1911-2013	89
	Unsorted			181	1975-2013	41
	Microvelia			18	2009-2010	6
		americana		4	1978	1
		hinei		35	1930-1983	9
		paludicola		16	1925-1983	4
	Platyvelia	*brachialis*		30	1911-1992	20
	Rhagiovelia			3	1990	2
		choreutes		30	1930-1983	6

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VITA

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