COLEOPTERA INDICATOR SPECIES IN WET VS. DRY CLIMATE REGIMES IN THREE SOUTHWESTERN GEORGIA WETLAND TYPES

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Abstract. Yearly variation in water availability has a profound effect on the presence and abundance of aquatic Coleoptera (beetles), particularly those dependent upon intermittent or seasonally inundated aquatic habitats. Thirty-four depressional wetlands, previously characterized as marshes, savannas or forested swamps, were sampled during above average and below average rainfall periods (1997-1998 and 2006-2007 respectively). Using Indicator Species Analysis, Coleoptera species were associated with wetland type and hydrologic regime linked to rainfall trends. Relying on species indicator values ($p<0.05$), marshes contained significantly higher numbers of indicator species compared to other wetland types during both wet and dry periods. Several indicator taxa were consistent within wetland type during the same hydrologic period, but these similarities were not consistent when compared across hydrologic regimes. Species diversity was higher during years with below normal rainfall. These findings indicate that marshes provide more suitable habitat and provide refugia that allow for survival and recovery beetle populations during unusually dry and wet periods. Faced with intermittent aquatic habitat and climate variation, Coleoptera taxa vary in life history characteristics and dispersal abilities which allow long term persistence within the larger landscape.

INTRODUCTION

Within the southeastern portion of the United States, seasonally flooded wetlands are an important landscape feature. These wetlands provide ecosystem services by providing wildlife habitat, improving water quality, by removing excess sedimentation and nutrient loads, controlling floodwater, and facilitating groundwater recharge (NRCS, 2007). Compared to perennial wetlands, these isolated ecosystems are at risk of degradation due to their small size and lack of legal protection (Kirkman et al., 2000). Variable hydroperiods, i.e. duration of wetland flooding and drying (due to climatic conditions and wetland morphology) are typical of southeastern landscapes and therefore have a profound effect on the abundance and persistence of aquatic invertebrates. Hydroperiod varys annually and with longer term climatic cycles but seasonal wetlands generally dry down during summer months and refill in the winter. To understand the suitability of seasonal wetlands for aquatic fauna, variation in hydrologic conditions, including constraints imposed by climatic variation, must be considered.

Varying water levels affect wetland invertebrate populations by causing variations in water quality and dissolved oxygen, shading, abundance of herbaceous vegetation and the presence and/or absence of fish (Fairchild et al., 2003). The duration of standing water habitat also influences community structure of intermittent aquatic habitats due to biotic interactions such as predation and competition (Schneider and Frost, 1996). Coleoptera comprise the largest order of insects and due to their diverse physiological and behavioral adaptations have an advantage over other macroinvertebrates in surviving periods of stress. Mobile adults are generally air breathers and can persist in shallow bodies of water with relatively low levels of dissolved oxygen. During periods of drying, adults also have the ability to effectively avoid drought by rapidly colonizing more permanent aquatic habitats (Wissinger, 1995). Batzer and Wissinger (1996) describe two strategies aquatic invertebrates use to colonize seasonal wetlands during and after inundation (i.e.the refilling of wetlands where standing water is above the soil surface). Desiccation resistance is the first strategy and has been documented in beetles that bury themselves in mud or crawl under rocks during dry periods (Lake et al., 1989; Jeffries 1994). Some species of Coleoptera also have drought resistant eggs that persist for varying periods of time in unflooded sediments (Wiggins et al., 1980). Immigration is a second strategy utilized by adult beetles. Cycles of migration occur between permanent and temporary aquatic habitats and are often referred to as “cyclic colonization” (Wiggins et al., 1980).

Cycles of wetting and drying pose a challenge to understanding community structure of intermittent aquatic habitats. Indicator species analysis is a multivariate analysis that measures the affinity of particular taxa to habitat type. Examining habitat preferences using Indicator Species Analysis provides insight into environmental conditions (i.e., habitat type and hydroperiod influence) associated with particular coleopteran families. Assigning general characteristics to such a diverse group of organisms is often difficult, but important; as it assists with prediction of the long-term effects natural climatic variation and human-caused change on wetland community structure.

Specific objectives included:

- Determining how variations in hydroperiod and habitat affect aquatic beetles
- Determining which families of Coleoptera are present and represented as indicator species within each hydrologic period and wetland type

STUDY SITE

Research was conducted on the Ichauway Ecological Reserve, an 11,800 ha longleaf pine ecosystem located in the Dougherty Plain of Baker county, Georgia. Thirty-four relatively undisturbed depressional wetlands previously characterized (based on soil characteristics and vegetation) as marshes, savannas or forested swamps (Kirkman et al., 2000) were sampled. Soil and vegetative characteristics of the three wetland types are as follows. Marshes contain sandy soils with panic grasses (*Panicum spp.*) and cut-grass (*Leersia hexandra* Sw.) dominating their ground-flora. Savannas have clayey soils with a sparse distribution of pond cypress (*Taxodium ascendens* Brongn.) and ground-flora consisting of panic grasses and broomsedge (*Andropogon virginicus* L.). Swamps contain organic soils with pond cypress and swamp tupelo (*Nyssa biflora* Walt.) canopies. Sparse midstory and ground-flora of various species are also present in swamp wetlands (Battle and Golladay, 2003).

METHODS

Wetlands were sampled during wetter and dryer than average climatic periods (1997-1998 and 2006-2007 respectively). Sampling was conducted twice in early and late spring during both periods (Figure 1). Sampling was not conducted later in the year as most wetlands dried during the summer months. Water depths at permanent staff gauges were recorded every other week for each of the wetlands. Beetles were collected by taking five random one meter sweeps over the same location at varying depths throughout the water column. This was done at three locations per wetland and then combined as one sample. All sweeps were collected with a 500-µm mesh D-frame sweep net. Captured specimens were preserved with 70% EtOH. They were then taken back to the laboratory, stained with rose bengal dye to facilitate sorting, and identified to the lowest possible taxonomic level. Specimens that could not be identified to genus were not included in the analysis.

PC-ORD Indicator Species Analysis (using 1000 randomizations in the Monte Carlo Test, MjM Software Design, Corvallis OR) was used to determine indicator taxa associated with wetland type and hydrologic condition. This method measures affinity based on abundance, presence, and frequency of a particular taxa for a group of sites. A perfect indicator species will always be present and exclusive to a group. The Shannon index score was used to assess species diversity among hydroperiods and sites. Since larval and adult stages often occupy different habitats and utilize different feeding strategies, taxa abundance was analyzed separately (adults vs. larvae) and together (adults plus larvae).

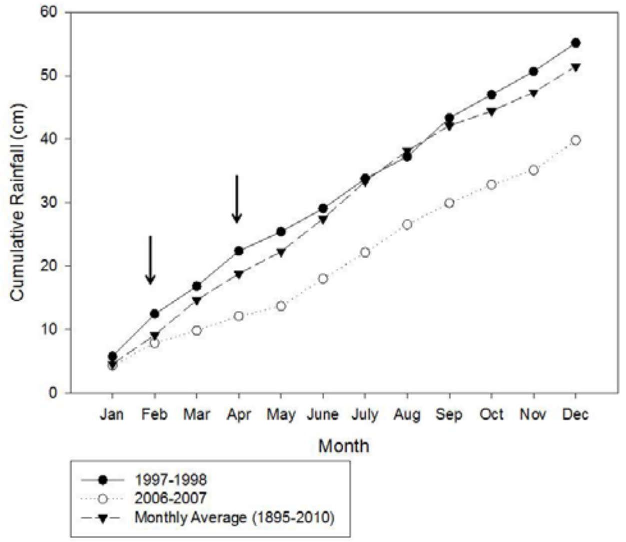

Figure 1. Average monthly rainfall during flood and drought years. Arrows represent sampling dates. Data are from the National Climate Data Center (NOAA) database.

RESULTS

Taxa. Twelve indicator genera were identified in our study (Table's 1-3). During flood years a total of 683 individuals belonging to 9 families were collected. *Haliplus* was the most common genus with a total abundance of 18%. Subdominant genera included *Coptotomus* (16%), *Berosus* (10%) and *Tropisternus* (9%). During drought years a total of 902 individuals belonging to 6 families were collected. *Coptotomus* was the most frequent genus with a total abundance of 14%. Subdominant taxa included *Tropisternus* (13%), *Haliplus* (10%) and *Berosus* (8%). *Celina* was exclusively a drought indicator during the adult phase whereas *Hydrochus* and *Tropisternus* were only indicators when both life stages were analyzed together

Table 1. Abundance of indicator taxa captured per hydroperiod. (Abbreviations: A=Adult, L=Larvae)

Indicator Species		Wet			Dry		
Family	Genus	A	L	A+L	A	L	A+L
Dytiscidae	*Celina*	4	3	7	7	0	7
Dytiscidae	*Agabus*	0	49	49	1	0	1
Dytiscidae	*Agabates*	0	14	14	1	13	14
Dytiscidae	*Coptotomus*	57	51	108	121	4	125
Dytiscidae	*Ilybius*	0	0	0	0	55	55
Dytiscidae	*Neoporus*	0	0	0	4	42	46
Haliplidae	*Haliplus*	107	16	123	87	0	87
Hydrochidae	*Hydrochus*	12	1	13	0	0	0
Hydrophilidae	*Berosus*	58	2	60	73	0	73
Hydrophilidae	*Paracymus*	32	0	32	7	0	7
Hydrophilidae	*Tropisternus*	44	15	59	109	5	114
Noteridae	*Hydrocanthus*	20	11	31	31	0	31

Table 2. Indicator species analysis associated with taxonomic stage and hydroperiod (wet climate regime)

Indicator Taxa		Larvae		Adult		Combined	
Family	Genus	Indicator value	*p* value	Indicator value	*p* value	Indicator value	*p* value
Dytiscidae	*Agabus*	59.4	0.011	-	-	59.4	0.009
Dytiscidae	*Agabates*	42.8	0.018	-	-	42.8	0.02
Dytiscidae	*Coptotomus*	46.2	0.048	60	0.01	46.2	0.045
Hydrochidae	*Hydrochus*	-	-	-	-	37.6	0.048
Hydrophilidae	*Berosus*	-	-	60	0.012	48.5	0.02
Hydrophilidae	*Paracymus*	-	-	60	0.011	60	0.002
Noteridae	*Hydrocanthus*	-	-	-	-	48.8	0.016

Table 3. Indicator species analysis associated with taxonomic stage and hydroperiod (dry climate regime)

Indicator Taxa		Larvae		Adult		Combined	
Family	Genus	Indicator value	*p* value	Indicator value	*p* value	Indicator value	*p* value
Dytiscidae	*Celina*	-	-	36.4	0.047	-	-
Dytiscidae	*Coptotomus*	-	-	64.9	0.012	73.4	0.002
Dytiscidae	*Ilybius*	74.6	0.003	-	-	67.6	0.003
Dytiscidae	*Neoporus*	59.3	0.032	-	-	61.5	0.011
Haliplidae	*Haliplus*	-	-	56	0.019	56	0.009
Hydrophilidae	*Berosus*	-	-	68	0.024	68.7	0.017
Hydrophilidae	*Tropisternus*	-	-	-	-	59.7	0.044

Hydroperiod and Habitat. Average wetland depth was significantly greater during flood (.68 m) than drought years (0.21 m) years (p<0.001). In comparing water depth by habitat type, swamps differed by 0.23 m, savannas differed by 0.26 m, and marshes differed by 0.85 meters (Figure 2) across years. Species richness and diversity were higher during years of extended drought (Table 4).

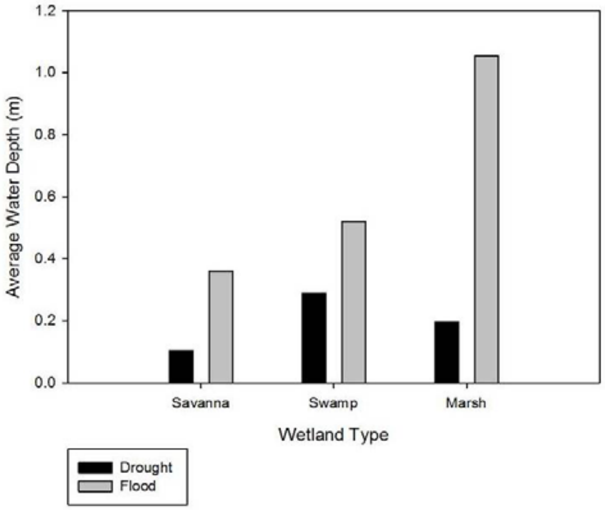

Figure 2. Average water depths per wetland type during flood and drought years.

Table 4. Diversity parameters for each hydroperiod

	Wet	Dry
Number of Taxa	36	40
Number of Individuals Collected	683	902
Shannon Diversity Score	2.765	2.975

Coptotomus and *Berosus* were marsh indicator species in both flood and drought years. *Ilybius*, *Neoporus*, *Haliplus* and *Tropisternus* were exclusively found as marsh indicators during drought years and *Celina* was exclusively found as a swamp indicator during drought years. *Agabates*, *Paracymus*, *Hydrocanthus* and *Hydrochus* were exclusively found as marsh indicators during flood years and *Agabus* was exclusively found as a savanna indicator during flood years. Exclusivity trends can be seen in Table 5.

Table 5. Occurrence of indicator species by life stage, hydroperiod and exclusivity to wetland type, hydroperiod and life stage. (Abbreviations: L=Larvae, A=Adult, WT=Wetland Type, HP=Hydroperiod, TS=Taxonomic Stage, IS=Indicator Species)

Habitat	Indicator Species		Taxonomic Stage			Hydroperiod			Exclusivity of IS		
WT	Family	Genus	L	A	L+A	Dry	Wet	Both	WT	HP	TS
Swamp	Dytiscidae	Celina	-	x	-	x	-	-	x	x	x
Savanna	Dytiscidae	Agabus	x	-	x	-	x	-	x	x	-
Marsh	Dytiscidae	Agabates	x	-	x	-	x	-	x	x	-
Marsh	Dytiscidae	Coptotomus	x	x	x	x	-	x	x	-	-
Marsh	Dytiscidae	Ilybius	x	-	x	x	-	-	x	x	-
Marsh	Dytiscidae	Neoporus	x	-	x	x	-	-	x	x	-
Marsh	Haliplidae	Haliplus	-	x	x	x	-	-	x	x	-
Marsh	Hydrochidae	Hydrochus	-	-	x	-	x	-	x	x	x
Marsh	Hydrophilidae	Berosus	x	x	x	-	x	x	x	-	-
Marsh	Hydrophilidae	Paracymus	x	x	x	-	x	-	x	x	-
Marsh	Hydrophilidae	Tropisternus	-	-	x	x	-	-	x	x	x
Marsh	Noteridae	Hydrocanthus	x	-	x	-	x	-	x	x	-

DISCUSSION

Taxa. Dytiscidae and Hydrophilidae are the two most abundant families of aquatic beetles and both had indicator taxa during flood and drought years. The high diversity within these families allows them to use diverse resources and persist in both drought and flood condition across a variety of wetland types. Dytiscidae are often abundant and considered important predators regulating community structure in temporary and seasonally flooded wetlands (Batzer and Wissinger, 1996). They are also excellent fliers and can easily move between water bodies. Hydrophilids are another diverse group that have the ability to live in various aquatic habitats as well as nutrient rich soils (Arnett and Thomas, 2001).

Haliplidae were exclusively found as indicator species in drought years suggesting that they may benefit during periods of low water and short hydroperiods, possibly because of less competition and/or reduced predation from other beetle species. Haliplidae are commonly found along the margins of wetlands (Epler, 2010) thus, the shallow semi-aquatic conditions found during drought years could favor increased foraging and movement by this group. Noteridae and Hydrochidae were exclusively indicators in flood years. Unlike other indicator families that pupate in moist soil or plant matter, Noteridae require standing water for pupation (Arnett and Thomas, 2001). Wetter than average conditions and extended hydroperiods likely favor life-cycle completion of Noterids. Although poorly studied, Hydrochidae are not known for having exceptional flight capabilities (Steiner et al., 2003) and possibly favor wetlands with higher water levels and longer hydroperiods that would reduce the necessity for frequent migration.

Larval and adult Coleoptera can occupy different habitats within a wetland and have differing food habits, thus it is useful to consider them separately. Using this approach, one additional indicator taxa was identified that would have otherwise been overlooked. Likewise, examining the life stages together provided two indicator taxa that would have been missed had life stages only been examined individually. Examining these stages separately is also important because larval beetles are considered “durational” and limited to pools with hydroperiods that exceed the time required to complete their larval development (Schneider, D.W. and T.M. Frost, 1996). This suggests that specific conditions characteristic of a wetland type are essential for reproduction.

Hydroperiod and Habitat. Certain groups of Coleoptera appear better able to survive and use habitat niches based on wetland type and hydrologic levels. While some taxa are more adapted to living in longer hydroperiods with high water levels, others prefer or persist in shallower water with shorter hydroperiods. Higher diversity and abundance during drought years may also be influenced by low water levels, reduced habitat availability and therefore concentrating effect of taxa within limited available habitat. Another factor, although one that has been poorly studied, is the impact floods may have on fish colonization of wetlands. Fish presence is dependent on heavy rain and flood runoff that connects otherwise isolated wetlands with permanent bodies of water. The long-term persistence of fish, however, is prevented by periodic drying (Liner, 2006). Many fish are predaceous, and their presence in wetlands can have a strong affect on macroinvertebrate community structure (e.g. Mallory et al. 1994). The absence of fish predation during drought years likely contributed to the increased abundance of beetles.

Overall, marshes provide suitable habitat and possess characteristics that allow for persistence and richness of beetles during both dry and wet periods as is evident by positive correlations between aquatic vegetation and macroinvertebrate diversity (Battle and Golladay, 2001;Stewart and Downing, 2008). Generally, the spatial complexity and physical heterogeneity of emergent aquatic vegetation increases habitat diversity and favors greater macroinvertebrate abundance (Battle and Golladay, 2001)

Our results suggest that genera of Coleoptera are better suited for specific hydroperiods and that they may be useful indicators of long-term climate change or hydrologic change associated with landscape development. It should also be noted that while Coleoptera can be found in multiple wetland types they are most abundant and diverse in marshes. It is known that certain beetlesare important regulators of wetland macroinvertebrate and amphibian community structure (Henrikson, 1990). However, their importance to other wetland functions (i.e. food web structure, energy and nutrient transformation) remains uninvestigated (Opsahl et al., 2010). The diversity of coleopterans, along with ease of sampling and relatively well-developed taxonomy, suggests that this group could be valuable in the development of wetland assessment tools as well as evaluation and prioritization of regional wetland conservation efforts. Our results represent a valuable approach for classifying wetlands and attempting to predict hydrologic history within a region not previously examined. Coleoptera are important in that they can withstand diverse environmental pressures and can be indicators of varying hydrologic conditions.

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