PUBLISHED DATASETS OF AQUATIC INSECT ASSEMBLAGES FROM GEORGIA RIVERS AND STREAMS

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Abstract. Georgia's streams and rivers are dependent upon diverse assemblages of aquatic insects and other macroinvertebrates in order to function. However, in this current period of global change, efforts to conserve aquatic biodiversity often require more information than is currently available. Here, we compiled publications featuring studies of aquatic macroinvertebrate communities from various ecoregions and stream sizes across the state of Georgia to determine trends in analyses. We found that descriptions of Georgia's lotic insect assemblages are well-represented geographically, but less than half of studies include complete, detailed taxa lists. We provide suggestions for researchers studying aquatic invertebrate assemblages that would aid our understanding of the natural taxonomic variation across the state, in order to facilitate future comparisons and conservation efforts.

INTRODUCTION

Aquatic insects and other macroinvertebrates are essential components of lotic ecosystems and fulfill a variety of ecological roles within the food web network (Wallace & Webster 1996). Solely within the order Trichoptera, there are representatives of predators, detritivores, algal scrapers, filter-feeders, and collector-gatherers (Wiggins & Currie 2008). Aquatic insects also serve as connections between aquatic and terrestrial systems as they process in-falling terrestrial detritus (Wallace et al. 1997), then provide an important reciprocal subsidy as they emerge as adults into the riparian environment (Nakano & Murakami 2001).

Aquatic insects are routinely used as bioindicators of river health (Lenat 1988) by monitoring groups (such as Adopt-A-Stream and local environmental groups across the state). However, aquatic insects and other invertebrates are understudied in a conservation context with respect to their relative species abundance and diversity (Darwall et al. 2012).

As an example, the Georgia Department of Natural Resources lists 71 aquatic insect species as rare elements, meaning they are "considered important for biodiversity conservation" in the state (GA DNR 2017), yet little associated biological data is available to characterize these species and their occurrence in Georgia waterways. Approximately half this list consists of dragonflies and damselflies (Odonata). Roughly one-third of the list consists of mayfly (Ephemeroptera) species, and the remaining 18% is comprised of stoneflies (Plecoptera) and one caddisfly (Trichoptera) species. Odonates are the only species that have recorded occurrences, and therefore associated habitat data, in the statewide rare element survey database (housed by NatureServe.org; GA DNR 2017).

Over 40% of these species are classified as "unranked" due to lack of survey data or "unrankable" due to lack of basic information about their distributions (GA DNR 2017). In order to conserve Georgia's rare insect species, more information is needed about their state-wide distribution and habitat requirements.

Invertebrate populations are as vulnerable as vertebrate groups to disturbances caused by anthropogenic climate change and habitat alteration, though less attention is focused upon them (Dirzo et al. 2014). As various stressors continue to impact rivers and streams at state, national, and global scales (Vörösmarty et al. 2010), efforts to conserve aquatic insect communities, as well as rare species, will benefit from more knowledge about taxonomic distributions.

One method of assessing the condition of stream communities is comparing dissimilarity between reference and disturbed systems (as in Hawkins & Yuan 2016), but researchers must have knowledge of the regional diversity. A study of Southeastern river systems by Feminella (2000) demonstrated that aquatic macroinvertebrate communities significantly differed among ecoregions. Additionally, rivers and streams are expected to vary in their community composition along their lengths (Vannote et al. 1980).

Here, we present a summary of published studies of macroinvertebrate communities throughout the state of Georgia on an ecoregion and stream-order basis. Our aim is to elucidate trends in analysis of previously-studied river systems of Georgia and to indicate where future research may be especially effective in improving understanding abut the range of aquatic invertebrate biodiversity throughout the state.

METHODS

We performed a literature search to gather published aquatic macroinvertebrate community data in Georgia's lotic systems. Primarily using the Web of Science database (Thomson Reuters 2017), we entered search terms to locate literature on the basis of major river systems (e.g. "Chattahoochee") and physiographic provinces (e.g. "Blue Ridge") in Georgia. Other sources such as Google Scholar (Google 2017) and the Proceedings of the Georgia Water Resources Conference (GWRI 2015) were used to supplement this search. Only publications that considered multiple taxonomic groups (assumed to be representative of the aquatic insect community) were included.

We assigned each published study to its Level III Ecoregion (i.e. Blue Ridge, Coastal Plain, Piedmont, Ridge and Valley, or Southeastern Plains; Griffith et al. 2001) and eight-digit hydrologic code (HUC8) from the U.S. Geological Survey (e.g. Tennessee, Tugaloo, Upper Chattahoochee; USGS 2017). A few results compared data between HUC8s, but if a single publication compared data from different ecoregions, these data were treated as separate "studies."

The focal systems in each study were placed within a range of Strahler orders (1-4 vs. 5-7; Strahler 1952). Studies that used terms such as "headwaters" were assumed to be within the range of 1-4. Additionally, we noted the type of analysis used as a metric for aquatic macroinvertebrate community in each study and whether the publication included a complete list of invertebrate taxa collected and analyzed (either within the published manuscript or as online supplementary material).

RESULTS

Our search of published databases for community analyses of Georgia's streams and rivers returned 25 studies, ranging in publication date from 1984 to 2017. All of Georgia's Level III Ecoregions were represented except the Ridge and Valley. Studies focusing on Piedmont systems comprised 44% of the total; 28% of the studies were conducted in the Southeastern Plains region; 16% were conducted in the Blue Ridge; 12% were conducted in the Coastal Plain.

All studies within the Blue Ridge physiographic province were conducted in headwater streams (orders 1-4). Conversely, within the Coastal Plain, all rivers studied were orders 5-7. The patterns of studies taking place in the Piedmont and Southeastern Plains were similar: orders 1-4 comprised 73 and 71% of studies, respectively. Sixteen HUC8-level watersheds in Georgia were represented (Table 1).

The presentation and choice of analysis of aquatic macroinvertebrate data varied greatly among publications. Forty percent of the studies evaluated included a complete representation of taxonomic data. If a full taxa list was lacking, publications typically showed percent composition of major insect orders or made note of indicator taxa.

About half of the studies (52%) indicated the percent composition of Ephemeroptera-Plecoptera-Trichoptera (EPT) groups. Other focal representations of invertebrates included: Family Biotic Index, North Carolina Biotic Index, Functional Feeding Groups and other functional trait metrics, and Bray-Curtis dissimilarity between communities.

Table 1. Studies of Georgia's stream macroinvertebrate communities, organized by ecoregion and HUC8 watershed. (*) = Complete taxa list associated with the study

Level III Ecoregion	HUC8	Strahler Order	Citation
Blue Ridge	Tennessee	1-3	Feminella 2000
	Tugaloo	1-3	Churchel et al. 2011
		1-3	Longing et al. 2010
		3	Pitt & Batzer 2015*
Coastal Plain	Lower Ogeechee	6	Benke & Wallace 2015
		6	Mullis et al. 2015
	Satilla	5	Benke et al. 1984*
	Lower Savannah	7	Mullis et al. 2015
Piedmont	Upper Chattahoochee	5	Holt et al. 2015a*
		5	Holt et al. 2015b*
	Mid Chattahoochee	1-3	Helms et al. 2009
	Etowah	1-3	Roy et al. 2003a*
		1-3	Roy et al. 2003b
		1-3	Roy et al. 2005
	Upper Ocmulgee	1-3	Feminella 2000
	Upper Oconee	1-3	Churchel & Batzer 2006*
		1-3	Harper et al. 2012*
		5	Holt et al. 2015b*
		1-3	Sterling et al. 2016*
		5-6	Wood et al. 2016
SE Plains	MidLower Chattahoochee	1-3	Maloney & Feminella 2006
	Lower Chattahoochee	1	Muenz et al. 2006
	Lower Flint	1	Griswold et al. 2008*
		6	Smith et al. 2015
	Mid Savannah	7	Battle et al. 2007
	Suwannee	1-3	Davis et al. 2003
	Withlacoochee	1-4	Bielmyer-Fraser et al. 2017

DISCUSSION

Our results demonstrate the range of published macroinvertebrate community data in Georgia rivers and streams. Though the major ecoregions and stream systems of varying size in Georgia are mostly represented by literature published to date, further research, especially when including finer-scale taxonomy, will be valuable in the context of ongoing environmental change. In addition to the published studies summarized in this review, genus-level macroinvertebrate community data from Georgia streams is available from the Environmental Protection Agency's National Aquatic Research Surveys (U.S. EPA 2016). The EPA surveyed aquatic habitats across the nation, and twenty-three out of thirty-four streams sampled in Georgia are also associated with macroinvertebrate data.

Approximately 40% of streams surveyed through EPA were located in the Piedmont region, while the streams in Ridge and Valley and Southeastern Plains each comprised about 20% of the survey sites, and streams in the Blue Ridge and Coastal Plain comprised less than 10% of the survey sites. The Strahler order of the majority of streams surveyed ranged from 1-4; hopefully any future sampling efforts within this national project will include more surveys in Georgia's large rivers.

The community data from studies in our analysis were represented by a range of taxonomic and trait metrics due to the differing aims of each study, ranging from rapid bioassessment of impaired streams (e.g. Davis et al. 2003) to analyses of functional trait composition (e.g. Griswold et al. 2008). The overall goal of an individual research endeavor will determine how to present results in a peer-reviewed manuscript, meaning that coarse metrics such as %EPT are sometimes the most suitable. However, we suggest that also publishing finer-level identifications in online supplementary materials (or possibly on biodiversity-focused websites, such as iNaturalist.org, that host taxonomic, geographic, and temporal data) will aid our understanding of aquatic insect distributions in this state.

While aquatic insect conservation efforts may require species-level data, this is not always feasible to produce (Bailey et al. 2001). However, family and genus-level identifications associated with publications can be a starting point for further survey efforts within a particular watershed. In fact, some rare elements listed by the GA DNR are the only species representative in their respective genera [e.g. *Dolania americana* (Ephemeroptera: Behningiidae), *Viehoperla ada* (Plecoptera: Peltoperlidae); ITIS 2017].

If finer-level identifications are not feasible to conduct within the scope of a single study, another option for researchers is to compile a reference collection of morpho-species. Such collections could later be identified by experts if the need arises, or submitted to a regional natural history museum. Natural history museum collections can be valuable resources for conservation-focused research, permitting comparisons of representatives of a community across time periods (Shaffer et al. 1998, Holmes et al. 2016).

Indeed, donations of macroinvertebrate samples that were collected during studies in the 1980s (summarized by Benke & Wallace 2015) to the Georgia Museum of Natural History are allowing us to conduct comprehensive comparisons with current and past communities in the Ogeechee River. Ultimately, understanding patterns of change within Georgia's rivers and streams by evaluating aquatic invertebrate communities will require knowledge of natural taxonomic variation; continued assessment by researchers across the state will contribute towards this goal.

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