THE SPATIO-TEMPORAL DYNAMICS OF LARVAL DRAGONFLY (ODONATA:ANISOPTERA) ASSEMBLAGES IN RELATION TO HABITAT VARIABLES IN THE FRESHWATER MARSHES OF THE FLORIDA EVERGLADES

RAUL URGELLES

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FLORIDA INTERNATIONAL UNIVERSITY

Introduction

The Florida Everglades is a large and unique subtropical wetland covering most of the southern portion of the state. It is part of a watershed that for many years has been threatened by anthropogenic stress such as drainage, nutrient pollution, and non-native wildlife introductions. As a part of efforts to rehabilitate this ecosystem, a long-term, landscape-scale monitoring project has been developed that focuses on small fish and aquatic invertebrates. Over the years, the Trexler laboratory has collected a large amount of data, as part of this on-going monitoring, which provides information on the environmental effects on aquatic macroinvertebrate communities. Aquatic macroinvertebrates are essential tools for characterizing habitat quality because they are sensitive indicators of environmental stressors, such as altered hydrology and phosphorus enrichment. Long-term monitoring of aquatic macroinvertebrates, such as dragonfly naiads (larvae), may be useful to assess the progress of restoration initiatives such as the one being conducted in the Florida Everglades.

A large number of environmental factors at different spatio-temporal scales are linked to the complex habitat requirements of dragonflies (order Odonata, suborder Anisoptera) during all developmental stages (Corbet 1999). Many species are habitat generalists while others are highly specific in their ecological requirements (Corbet 1999). The aquatic naiads of certain dragonfly species are susceptible to specific types of habitat changes induced by human activities, making them reliable indicators of biotic health (Schmidt 1985, Corbet 1993, Samways 1993, Chovanec and Waringer 2001). Dragonfly naiads occupy a wide range of habitats along a 'water-persistence' gradient. Freshwater marshes in the Everglades are characterized by the amount of time surface water persists in a region; this is termed 'hydroperiod'. Thus, these freshwater marshes offer a continuum of hydroperiod lengths that determine the degree of structural habitat heterogeneity as well as the species composition for a particular region. Species inhabit parts of this continuum because they differ in their abilities to deal with the physical and biotic factors affecting each part (Johansson and Suhling 2004).

While temporary waters usually limit the distribution of taxa because of harsh physical conditions, such as drying, the distribution of taxa in permanent waters is usually limited by biotic factors such as predation and competition (Williams 1996, Wellborn et al. 1996, Stoks and McPeek 2003, Johansson et al. 2006). In the freshwater marshes of the Everglades, dragonfly naiads are among the most conspicuous aquatic invertebrates. Their dual role in the aquatic food web as both predators and prey of other aquatic animals can have a significant impact on total benthic productivity and community dynamics (Benke 1976). Dragonflies also form a strong link between aquatic and terrestrial food webs. Large naiads are readily taken as food by wading birds and some waterfowl species, while terrestrial adults are an important diet component of several migratory bird species (e.g. Purple Martin, Mississippi Kite). In less direct ways, interactions between naiads and other aquatic organisms can have cascading effects in adjacent terrestrial food webs (Knight et al. 2005). It is because of these key roles in food webs that dragonfly naiads can be used as 'performance measures' of ecosystem function. In biodiversity conservation, dragonflies serve as umbrella species (Noss 1990, Lambeck 1997), species whose conservation confers protection to a large number of naturally co-occurring species.

Key factors that help shape the structure of dragonfly naiad assemblages are present in the form of biotic interactions, such as interspecific and intraspecific competition, intraguild predation, and even parasitism, as well as in certain physical properties of the environment, such as pH and salinity. However, alterations in hydrology, or increases in nutrient levels, can bring about dramatic changes in habitat structure and eventually have an effect on overall community composition. Studies conducted in the littoral zone of lentic habitats have documented the life histories, dynamics, and production of co-existing naiad populations (Benke and Benke 1975, Benke 1976). Surprisingly, no studies have been done in the Florida Everglades to obtain quantitative data on the population dynamics of dragonfly naiads and, currently, little is known about their spatio-temporal distribution, relative abundance, and trophic interactions.

Preliminary analyses

The initial purpose of this study is to use existing data to provide the first comprehensive spatial and temporal survey of dragonfly naiad assemblages for Everglades freshwater marshes, illustrate the spatial extent of each species, and categorize them according to their relative densities across sites and through time (with special emphasis on seasonality). As part of the FIU long-term monitoring study, we sample twenty sites scattered across three water management units (Water Conservation Area 3, Shark River Slough, and Taylor Slough) five times a year. Data exist from 1997 through the present. Using a 1-m^2 throw-trap, we collect 75-

105 samples from each site in each year (depending on water levels). The sampling is done across broad spatial scales, encompassing wet- and dry-season dynamics. The sites consist of 1-hectare plots that vary in hydroperiod and vegetation. The resulting data provide information on each site, such as parameters (water depth, percent vegetation cover, vegetation types, stem height, stem density, etc.) and fauna collected (fish, other vertebrates, and invertebrates).

During an eight-year period (1997-2004), 27,924 dragonfly naiads in 11,467 samples were collected and preserved. Naiads were then identified to species using the latest identification keys available (Needham et al. 2000). Over the course of the sampling, I identified sixteen species of dragonfly, approximately 25% of the known resident species in the southern portion of Florida. Several specimens of each species were sent to Dr. Michael L. May of Rutgers University Entomology Department to confirm my identifications. I have described the distributions and abundance of the sixteen species based on their spatial extent (# of sites at which they were collected) and density (annual average # individuals/m^2). Two species, *Celithemis eponina*, Halloween Pennant, and *Libellula needhami*, Needham's Skimmer, were the most abundant and most-frequently encountered dragonfly species throughout all years. Both dominated the assemblage at most sites and showed considerable inter-annual dynamics. Together, they represented approximately 80% of all specimens collected during the eight-year period.

My analyses indicated marked seasonal variation for most species collected. All taxa were least abundant in July, and many were most abundant in December through April. These seasons correspond to the wet season and dry season, respectively, in south Florida, and are times of deepest and shallowest water depths in the Everglades. Thus, dragonfly naiad survival may be greatest in times when drying conditions are concentrating their prey and confining large, insectivorous fish to deeper water. Long-term patterns of population dynamics were most marked in Water Conservation Area 3 (*C. eponina*'s density decreased sharply there in 2002, while *L. needhami* and *Brachymesia gravida*, Four-spotted Pennant, increased steadily from 1998 to 2001). None of the three species displayed similar changes in Shark River Slough or Taylor Slough. All three species showed similar seasonal effects where their densities decline sharply in July, and all three showed a general relationship between density and days following a regional drought. *C. eponina* showed the strongest relationship with days since the marsh last reflooded. At a site highly stressed by anthropogenic nutrient-enrichment, the normally dominant *C. eponina* was completely absent, and *Pachydiplax longipennis*, Blue Dasher, a species at low densities or absent from all other sites, dominated the assemblage with extremely high densities.

Future research

As the primary objective for the completion of my thesis, I will perform statistical analyses of dragonfly data to identify relationships between their community composition and physical and biotic parameters. From the existing long-term monitoring data, I will consider hydrologic parameters (water depth and days since last dry-down, for the remaining species), fish species composition and density, aquatic macrophyte species composition and stem density, and floating mat volume. I am interested in identifying correlations between these specific habitat variables and the naiads of individual dragonfly species and correlations between the habitat variables and the naiad assemblage composition at each site for the water years beginning in July, 1996, and ending in April, 2006.

I believe that examination of the data in this manner will provide insight into the response of dragonfly naiad assemblages to specific changes in their environment. The distribution patterns of species are usually governed by habitat requirements and spatial aspect of population dynamics (Johansson and Suhling 2004). Preliminary results indicate that naiads may be sensitive to water management and eutrophication in the Florida Everglades. Shifts in dominance may indicate a greater ability by one species to tolerate conditions associated with lengthening hydroperiod. I will continue to analyze and focus on the long-term responses of naiad assemblages to dry-down and re-wetting conditions.

Dragonfly life history is well documented in other studies (Benke and Benke 1975, Wissinger 1988) and is essential to the understanding of assemblage dynamics. A thorough review of the existing literature on dragonfly research conducted in other areas will provide me with the necessary life-history information on our species. Finding correlations between a species' life-history trait and environmental variables may allow me to make predictions about naiad assemblages over broader spatial and temporal scales. Anthropogenic stressors such as nutrient enrichment and hydrologic regime can yield about changes in structural habitat (e.g. the quality and quantity of aquatic macrophytes) and alter the species composition of the aquatic community. By determining how dragonfly naiad assemblages react to these changes, I can provide useful information to management agencies on biological responses to undesirable habitat.

Dragonfly naiads are known to be important predators of other aquatic animals, and can have significant impacts on community and food-web structure. Future efforts to monitor Everglades restoration should consider dragonfly naiad assemblages as part of an evaluation of management impacts on aquatic communities found there. An increased understanding of water level and eutrophication effects on a naiad assemblage and how changes in an assemblage affect food web dynamics in the Everglades ecosystem can have implications for adaptive management.

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