Influence of Productivity and Hydroperiod on Florida Everglades Food Webs

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Abstract

Food-web investigation and analysis are essential for the understanding of basic ecosystem processes. There is an abundance of both aquatic and terrestrial food-web literature, and the realized relationships between ecological variables and food-web dynamics have increased exponentially over time. The Florida Everglades are a protected wetland ecosystem that has been noted for its unique patterns of climate, hydrology, nutrient regime, and floral and faunal assemblages. This study will focus on the ecological determinants of aquatic wetland food webs in the Florida Everglades. I will measure productivity, determine hydroperiod, and sample representatives from each trophic group of the marsh food web in three freshwater marsh regions (20 sites) within the Everglades: Taylor Slough and Shark River Slough, located in the Everglades National Park (ENP) and in the Water Conservation Areas, north of ENP. I will estimate the length of marsh food webs using stable isotope and gut content analysis. These data will then be analyzed using an estimator of tropic position and an analysis of variance to test whether either of the two variables (productivity and hydroperiod) solely influence marsh food webs, or if it is a combination of the two factors which determines the food-web length and stability within each of the study sites.

Introduction

Food-web patterns provide a snapshot of the current status of an ecosystem, and can be indicators of change in the environment (Persson *et al.* 1992, Polis and Winemiller 1996, Post 2000). Food-web dynamics are a result of ecological processes and interactions within the ecosystem. Modification of ecosystems is often a product of three factors: gradual and continual change, discrete disturbances, and seasonal periodicities (Obeysekera *et al.* 2000). The Everglades is the largest sub-tropical wetland in the United States and is comprised of a unique assemblage of aquatic and terrestrial taxa (Figure 1) (Loftus and Elkund 1994). Turner *et al.* (1999) observed that patterns of standing crop in the Everglades suggest a distinctive food web. They noted unusually high standing crop of primary producers, accompanied by unusually low standing crops of aquatic consumers. Organisms are influenced not only by internal metabolic processes but, also, by external environmental factors, including companion organisms, weather events, and disturbance factors. Within the Everglades ecosystem, relationships among species composition, population dynamics and local abiotic factors have been demonstrated to shape trophic structure (Loftus and Eklund 1994, DeAngelis *et al.*1997, Loftus 2000).

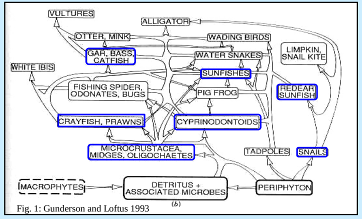

Fig. 1: Gunderson and Loftus 1993

Productivity:

Primary productivity corresponds to the amount of inorganic carbon fixed into organic compounds using external sources of energy, within a given time period (Valiela 1995). These photosynthetic processes provide energy used by all higher trophic levels and form the energy base of the food chain. It has been suggested that production at the base of the food chain is the limiting factor in controlling of food web length (*productivity hypothesis*) (Jenkins 1992, Vander Zanden *et al.*1999). Others investigators have not found a relationship between length and amount of production (Briand and Cohen 1987, Pimm and Kitching 1987, Post 2000). In the Everglades system, phosphorus inputs from agricultural runoff have increased the total phosphorus in some areas two-fold, producing a gradient of increased inputs to some areas (Davis 1994). Gradients of productivity are also produced naturally in the Everglades ecosystem, through hydroperiod effects, animal activities, and allochthonous nutrient input at the estuarine interface. Along with these documented productivity patterns, variation in productivity levels may give rise to other significant alterations within the ecosystem.

Hydroperiod:

Seasonal hydrologic patterns within the Everglades affect much of the structure, processes, and functioning of the system as a whole. A hydroperiod is defined as the number of days per year that an area of land is dry or the length of time that there is standing water at a location (Gaff *et al.* 2000). In the rainy season, water levels within the marsh rise and populations of aquatic species are able to grow, migrate, and flourish. As the water levels begin to taper off, populations must seek refuge along the receding water, and within depressed areas of the landscape (Gaff *et al.* 2000, Trexler *et al.* 2001). Disturbances are events that remove biomass from the population; therefore, seasonal dry-downs are disturbance events for aquatic fauna. Fairly abrupt changes in the environment can lead to changes within the normal functioning of the affected community. Such changes may produce variation in the food web ecology and functioning within marshes that experience hydroperiod effects.

Research Questions:

(1) How do natural productivity gradients affect seasonal and spatial patterns of food webs within the marsh?

(2) Does seasonal variation in water level affect food-web length? Also, are these patterns consistent between long and short hydroperiod marshes?

(3) Does the interaction between productivity and hydroperiod determine the complexity of Everglades food webs?

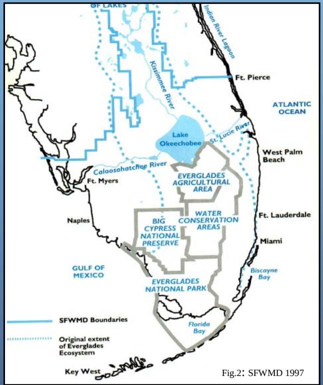

Fig.2: SFWMD 1997

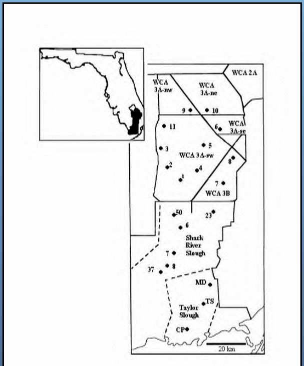

Fig. 3: Trexler *et al.* 2002

Study Site

The Everglades is one of the most unique ecological landscapes in the world. A portion of this ecosystem is federally protected land, designated as a National Park, World Heritage Site and International Biosphere Reserve. It is located in the subtropical climate zone of southern Florida, surrounded by the Gulf of Mexico and the Atlantic Ocean (Figure 2). The Everglades ecosystem is comprised of seasonally fluctuating oligotrophic freshwater marshlands, an estuarine mangrove interface zone, and eventually the system flows through outlets into the marine environment. The extensive freshwater marsh landscape is dotted with cypress and tropical hardwood hammocks. The combined climate, hydrologic, and nutrient regimes have yielded a very unique system, leading to interesting species diversity within plant communities and standing stocks of aquatic fauna. The freshwater marsh is separated into three study sites: Taylor Slough (TS), Shark River Slough (SRS), and the Water Conservation Areas (WCA) (Figure 3). TS and SRS sites are located in the Everglades National Park (ENP). The WCA sites are located north of ENP, just south of the Everglades Agricultural Area. Sampling will occur at 20 different sites within the three study areas. TS and SRS are within the federally protected areas, therefore, these sites are optimal for research studies.

Methods

To estimate spatial variation in the length of Everglades marsh food webs, samples of representative groups from basal, intermediate, and top trophic levels will be collected two times during the year (February – dry season, September – wet season). Animals will be collected (sample size to be determined by pilot studies, Loftus 2000) using throw traps, sweep nets, and electrofishing for the larger specimens (Trexler *et al.* 2001). Productivity and hydroperiod data will be collected concurrently. I will estimate primary production at each study site during the two sampling periods using the light/dark bottle method. Hydroperiod data for each study site will be estimated two ways: as the number of days the site was dry in the 12 months prior to sample collection, and as the average number of days dry per year for the preceding 10 years. Hydrological data are collected from multiple water gauge stations throughout the Everglades and those data have been calibrated to depth measurements taken at the 20 study sites over the past six or more years. I will estimate the length of marsh food webs using stable isotope and gut content analysis to depict the species and number of trophic levels involved in feeding interactions both seasonally and in relation to hydroperiod and productivity.

Stable Isotopes:

In food-web studies, stable isotopes can provide a uniform, time-integrated measure of feeding relationships and energy flow between groups or individual organisms (Peterson and Fry 1987, Vander Zanden *et al.* 1999). Stable nitrogen isotopes have been suggested to display a 3-4 ‰ enrichment in $\delta^{15}N$ from prey to predator. The evaluation of this $\delta^{15}N$ relationship of a consumer relative to an appropriate baseline measurement allows for accurate determination of the trophic position of the organism based upon the trophic energy transfers between the basal level and the consumer (Cabana and Rasmussen 1996, Fry *et al.*1999). Carbon isotope ratios of consumers to the signatures of their prey are relatively constant (~1‰ variation) (Peterson and Fry 1987), but the basal producers for each food web do vary. This variation in basal production between food webs allows for determination of the specific producers for each food web, but as these producers are consumed, the $\delta^{13}C$ ratio shows little variation with increasing trophic position. Conservation of $\delta^{13}C$ values up the food chain allows for consistent information about the sources of energy within differing food webs as well as the position of higher consumers (France and Peters 1997).

Trophic position:

$$\lambda + (\delta^{15}N_{organism} - \delta^{15}N_{base\ of\ food\ web}) / 3.4$$

λ = trophic position of the organism used at the base of the food web

3.4 = the average $\delta^{15}N$ enrichment per trophic level

Post *et al.* 2000

I will estimate the length of marsh food webs using stable isotope and gut content analysis to depict the species and number of trophic levels involved in feeding interactions both seasonally and in relation to hydroperiod and productivity. Analysis of food chain length by isotopes will follow Vander Zanden and Rasmussen (1999) and Post *et al.*(2000), and from gut contents will follow Adams *et al.*(1983), Loftus (2000), and Winemiller (1990). Equation 1 (above) will be used to determine the trophic position of each specimen with its food web at each site. These relationships will then be analyzed using an analysis of variance to determine if either productivity or hydroperiod are solely influencing marsh food webs or if it is a combination of the two factors which determines food-web length and stability within each of the study sites.

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