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Nutrient Flux Associated with the Emergence of *Quesada gigas* Olivier (Hemiptera: Cicadidae) in an Urban Ecosystem

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Abstract

Large-bodied arthropods, such as cicadas, can be able to reallocate significant amounts of nutrients during adult emergence. Evidence suggests that *Quesada gigas* Olivier emergence constitutes an important nutrient flux from belowground to aboveground. The purpose of this study was to estimate the amount of nitrogen, proteins, and lipids resulting from the emergence of *Q. gigas* in an urban ecosystem in Central Brazil. Adult specimens captured from September to November 2006 were weighed and submitted to biochemical analysis. Population density was approximately 4,200 individuals per hectare. Mean individual dry mass was 1.03 g and contained 12.6% proteins, 8.4% lipids, and 5% nitrogen. Total biomass input from the species was 4.3 kg ha^{-1} y^{-1}, with a consequent annual reallocation of approximately 545 g of proteins, 363 g of lipids, and 216 g of nitrogen per hectare. The data obtained suggest that *Q. gigas* emergence can cause significant translocation of nutrients from belowground to aboveground, and is therefore an important biological event for ecosystem function.

Introduction

Arthropods constitute the majority of herbivores and detritivores in many ecosystems (Seastedt & Crossley 1984), influencing the amount of living and dead organic matter in a given system and consequently, the nutrient cycling (Seastedt 1984, 1988, Naiman 1988). Previous studies suggested that nutrients, mass and energy released by arthropods activities do not represent significant resource pulses in ecosystems (Schowalter & Crossley 1983, Seastedt & Crossley 1984). However, other studies have indicated that arthropods play a major role in plant productivity and nutrient cycling processes (Seastedt & Tate 1981, Brown & Gange 1989, Bardgett & Wardle 2003, Whiles & Charlton 2006).

Insect emergence has more often been associated with nutrient flux in terrestrial and aquatic ecosystems (Nakano *et al* 1999, Collier *et al* 2002, Sabo & Power 2002, Ballinger & Lake 2006), but practically nothing is known about the importance of these animals with respect to nutrient and energy fluxes from belowground to aboveground in terrestrial ecosystems (Callaham Jr *et al* 2000).

In several cicada species emergence can be viewed as a resource pulse, available at high densities for a short period of time (Ostfeld & Keesing 2000). Due to their relatively large bodies, these arthropods are able of reallocate significant amounts of matter and energy during adult emergence (Callaham Jr *et al* 2000, Whiles *et al* 2001, Whiles & Charlton 2006). In addition, they cause an important translocation of nutrients from belowground to aboveground because cicada nymphs feed on plant root xylem whereas adults are aboveground feeders (Young 1980, Williams & Simon 1995).

Studies on the role of subterranean herbivorous insects, including cicadas, in tropical regions are scarce, and are virtually unknown in South American species (Blossey & Hunt-Joshi 2003). *Quesada gigas* Olivier is an annual cicada species with a wide geographic distribution (Aoki *et al* 2010). Adults have a large body size (~ 46 mm) and emerge at relatively high densities, suggesting that this species transfers nutrients and energy from belowground to aboveground.

The purpose of this study was to estimate the level of total nitrogen, total soluble proteins and total lipids associated to *Q. gigas* tissues which would correspond to their translocation from belowground to aboveground during species emergence in an urban ecosystem.

Material and Methods

Specimens were collected from September to November 2006 from six randomly selected 2,500 m^2 plots (1.5 ha in total). These plots were located in cultivated areas harboring native and introduced plant species, distributed among lawns and buildings at the campus of the Universidade Federal de Mato Grosso do Sul (UFMS), Campo Grande (MS), Brazil (20°29"59'S, 54°36"42'W). Climate in the region is Köppen's Aw (tropical savanna) subtype (Köppen 1948), with two well-defined seasons: dry and cold from May to September and rainy and hot from October to April. Average annual rainfall is 1,532 mm and relative air humidity is generally low, rarely reaching 80%. Average annual temperature range from 20°C to 22°C (Embrapa-CNPGC 1985).

To estimate species density, all *Q. gigas* exuviae found in the plots were manually collected every three days. Although other species of cicada emerge at the same time, morphological differences between exuviae ensure their correct identification. Adults were collected during the emergence period with the aid of an entomological net. These specimens were frozen, then weighed on a precision balance (0.01 g) and processed for biochemical analysis. Dry weight was determined after the specimens had remained in an incubator for four days at 50°C.

To estimate protein content, 0.4 g of dry material was homogenized in 20 ml of phosphate buffer (0.1 M, pH 7.0), centrifuged (1.850 *g* at 10°C for 30 min) and filtered through a 10 μm nylon mesh. Soluble protein content was determined according to Bradford (1976), using bovine serum albumin as the standard. Extraction of total lipids was carried out in a Soxhlet apparatus for 1h at 105°C, using petroleum ether. The solvent was subsequently evaporated and cooled in a desiccator and the resulting material was weighed and used for total lipid determination (Pregnolatto & Pregnolatto 1985). Nitrogen content was measured using the Kjeldahl method (Nelson & Sommers 1973), which involves digestion of the material followed by colorimetric analysis.

Results and Discussion

Emergence of *Q. gigas* on the UFMS Campus lasted for approximately 10 consecutive weeks, from early September to middle November. An average of 4,200 adults emerged per hectare (0.42 individuals/m^2).

Mean adult fresh weight was 3.7 g (± 0.75), 72.3% (± 4.50) of which consisted of water. While seemingly a high percentage, this is within the 70-75% range typical for insects (Bell 1990). Mean dry weight was 1.0 g (± 0.25), comprising 12.6% (± 5.40) proteins, 8.4% (± 5.50) lipids, and 5% (± 0.90) nitrogen. Each adult consisted of approximately 129.8 mg of proteins, 86.5 mg of lipids, and 51.5 mg of nitrogen. The only previous investigation on cicadas which calculated protein and lipid content was the study by Brown & Chippendale (1973) on *Magicicada cassini* (Fisher). This species emerges at 17-year intervals and contains 51-110 mg of proteins and 19-58 mg of lipids per individual.

With regard to nitrogen content, Fagan *et al* (2002) conducted a comprehensive review of studies on a large number of orders of herbivorous insects and found a mean level of 9.6% (± 0.15%) of nitrogen per gram of dry weight, which falls within the 7-14% range reported earlier by Mattson (1980). While some of the reviewed studies were based on the Dumas combustion method for nitrogen quantification, the differences found in the concentrations of nitrogen were unlikely to have resulted from the choice of method (Dumas or Kjeldahl), since the results were sufficiently similar to allow for comparisons regardless the method adopted (Perez *et al* 2001, Watson & Galliher 2001). The relatively low level of nitrogen found in tissues of *Q. gigas* may stem from the low availability of nitrogen in their food source, since insects feeding on nitrogen-deficient matter usually have low nitrogen content in their tissues (Fagan *et al* 2002).

Despite the low percentage of nitrogen, adults of *Q. gigas* adults contribute with high amounts of nitrogen to the ecosystem due to their relatively large bodies. Each individual provides 14 folds more nitrogen than *Cicadetta calliope* (Walker) and twice as much as *Tibicen aurifera* Say and *M. cassini* (Callaham *et al* 2000, Whiles *et al* 2001), indicating the higher contribution neotropical cicadas may give aboveground by transferring nutrients from belowground as compared to other cicadas.

The estimated total dry mass associated with the emergence of *Q. gigas* was 4.3 kg ha^{-1} y^{-1}, with a consequent yearly reallocation of approximately 545 g of protein, 363 g of fat, and 216 g of nitrogen per hectare. Overall, the species reallocates up to 3% as much of the estimated nitrogen input for a neotropical savanna area from precipitation, which is a major source for this nutrient in the ecosystem (Lima 1985).

Moreover, among soil-dwelling insects such as cicadas, emergence constitutes one of the few processes of nongaseous nitrogen flux from belowground to aboveground (Whiles *et al* 2001). In the same way that nitrogen translocation is effected by plants, nitrogen flux associated with the emergence of cicadas is not an input of "new" nitrogen into a system. Both nymphs and adults of *Q. gigas* obtain nutrients from the xylem of host plants. While plants are deprived of these nutrients for developing leaves, flowers, fruits, and seeds, all of which would be available aboveground, cicadas later serve as a food source for a wide variety of animals (e.g. spiders and insectivore birds) which do not feed directly on these plant structures. Furthermore, insect-derived proteins are preferred by birds because of their higher quality in relation to seed and fruit-derived proteins (Robbins *et al* 2005). These macronutrients are essential for growth and reproduction of most animals. Birds are key predators of cicadas in the study area, and a wide variety of species consume these cicadas (Aoki C., personal observation), similar to verified by Sazima (2009) at the urban Parque Ecológico Prof. Hermógenes F. Leitão Filho, in Campinas (SP). Lipid levels can affect clutch size (Ankney & Afton 1988), whereas the addition of proteins in the pre-reproductive diet may also augment the mass and size of eggs (Selman & Houston 1996, Williams 1996), which further influence on offspring survival (Bolton 1991, Magrath 1992, Blomqvist *et al* 1997). Given that most bird species breed in the rainy months (Matarazzo-Neuberger 1995, Sick 1997) and that *Q. gigas* emerges in the early period of this season, exhibiting scant anti predation behavior and producing no apparent toxic compounds, it may act as a key species during breeding season of local bird populations.

Quesada gigas emergence can also alter nutrient cycling ecosystem, since most nutrients released by this species reach at least one additional trophic level as they are consumed by a wide variety of predators, comprising both vertebrates (birds, mammals, and reptiles) and invertebrates (ants and spiders) (Aoki C., personal observation). Emergence can also alter the rate of nutrient cycling because decomposition of insect bodies usually occurs faster than does that of leaf litter, because degradation of complex organic matter such as plant cell walls are not involved (Schowalter *et al* 1986), allowing insects to be categorized as elements of the "fast cycle" of nutrient release (McNaughton *et al* 1988).

Although studies suggested that nutrients, mass and energy released by arthropods do not represent significant resource pulses in ecosystems (Schowalter & Crossley 1983, Seastedt & Crossley 1984, Wheeler *et al* 1992), our data show that *Q. gigas* represents an important pulse of resources from belowground to aboveground, releasing essential nutrients for a wide range of secondary consumers and detritivores, and ultimately influencing nutrient cycling in the area investigated.

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