Influence of seasonality on macroinvertebrate diversity associated with the aquatic fern *Salvinia biloba* Raddi

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**Abstract.** The genus *Salvinia* is composed of fast-growing floating ferns, capable of surviving in different environmental conditions. Some authors suggest that the relationships between this genus and macroinvertebrates may serve as water quality indicators. The present study aimed to determine the influence of seasonality and water quality on macroinvertebrate diversity associated with the *Salvinia biloba* Raddi. Water and fern were collected in rainy and dry seasons and was made by comparing values obtained in laboratory trials or instantaneous field measures.

Aquatic macrophytes are plants whose photosynthesizing structure is floating, permanently or periodically submerged (Cook 1996; Organs & Gastral 1996). Aquatic macrophytes provide fauna shelter, a refuge from predators, oviposition sites, and diversified food sources, given that they are also substrate for peripheral algae, and filter organic particles that can be used by detritivores (Tvinnihno-Strixino et al. 2000; Dornfeld & Fonseca-Gessner 2005).

Aquatic macroinvertebrates, such as arachnids, insects, crustaceans, and mollusks, are groups of invertebrates over one-millimeter-long at the end of the larval stage or in the imaginal phase and can be seen with the naked eye (Mungan et al. 2010; Buss et al. 2016). Aquatic macroinvertebrates can be classified based on their habitat, as follows: planktonic, nektonic, pleustonic or benthic, with variations such as epibenthic, which inhabit both water bodies and the substrate, normally in different stages of life (Mungan et al. 2010).

The macroinvertebrate community contributes to water quality since they are efficient bioindicators that describe all environmental stresses (Dornfeld & Fonseca-Gessner 2005). They are more effective than biological inferences made by comparing values obtained in laboratory trials or instantaneous field measures.

Aquatic ferns belong to the genera *Salvinia* and *Azolla* (Salviniaceae); *Marsilea*, *Pilularia* and *Regnellidium* (Marsileaceae) and *Isoëtes* (Isoëtaceae) (PPG I 2016). Species of the genus *Marsilea* are popularly known as four-leaf clovers or lucky clovers. Maiz & Reeder (2009) reported the occurrence of weevils (small beetles) that use sporocarps of *Marsilea mollis* B.L. Robins & Fern as a breeding site. In the Pantanal region of Mato Grosso state and Central Amazonia, Brazil, Sousa (2008) recorded aquatic and semi-aquatic species of Curculionoidea (Insecta, Coleoptera) associated with species of *Azolla*, *Salvinia auriculata* Aubl. and *Salvinia minima* Baker.

Most studies on the interaction between insects and aquatic ferns involve species of the genus *Salvinia* (Pelli & Barbosa 1998a, 1998b; Callisto et al. 2002; Prellvitz & Albertoni 2004; Dornfeld & Fonseca-Gessner 2005; Berivan et al. 2006; Sousa 2008). These species exhibit very fast growth, sometimes completely covering the water surface (Berforth 1992), making them an important substrate for establishing associations with fauna (Callisto et al. 2002).

The genus *Salvinia* contains 12 species worldwide (PPG I 2016), 10 of which can be found in Brazil (Salviniaceae in Flora do Brasil 2020). Interactions with aquatic insects were recorded in four of these: *S. auriculata* (Callisto et al. 2002; Prellvitz & Albertoni 2004; Berivan et al. 2006; Sousa 2008), *S. herzogii* de la Sota (Prellvitz & Albertoni 2004), *S. minima* (Sousa 2008) and *S. molesta* D.S. Mitch (Pelli & Barbosa 1998a, 1998b).
Table 1. Cover, *Salvinia biloba* Raddi leaf area and density of associated aquatic macroinvertebrates in different seasons of the year.

|               | Rainy 2016 | Dry 2017 |
|---------------|------------|----------|
| Cover area on the water surface | 100% | 30% |
| Submerged leaf length | 5.235 ± 2.55 cm | 3.23 ± 0.94 cm |
| Estimated submerged leaf area | 0.3268 m² | 0.2018 m² |
| No. of macroinvertebrates | 142 | 419 |
| Density | 434 individuals/m² | 2,076 individuals/m² |
| Richness | 12 | 14 |
compared to low and medium densities, likely caused by competition for nutrients in the water and the need to raise absorption. Medeiros et al. (2017) demonstrated experimentally higher S. auriculata in conditions of moderate shade compared to other light conditions, concluding that a shaded environment does not limit the clonal growth of this plant, but does produce more branches.

The rapid growth of some Salvinia species can pose a serious environmental threat by enabling them to spread across the entire water surface, restricting light penetration and removing nutrients. As a result, they compete with native plants, reducing habitat diversity and limiting food sources in the food chain, especially fish. However, they can also be used as bioremediators in sewage treatment (Robinson et al. 2010).

Macroinvertebrates associated with Salvinia biloba. The Simpson’s Diversity Index (1-D) didn’t show difference between rainy (0.9167) and dry (0.9286) seasons (Table 2). However, in the rainy season, 142 macroinvertebrates were identified, divided into 12 morphospecies, with a density of 434 individuals/m³. In the dry season, there were 419 individuals in 14 morphospecies, with a density of 2,076 individuals/m³ (Table 2). Prellvitz & Albertoni (2004), who analyzed a population of Salvinia spp. (S. auriculata e S. herzogii) for one year, found an decrease in macroinvertebrate density during the dry compared to the rainy season, correlating this fact to the hydrodynamics of the area affected by high rainfall and the non-destructuring of the community associated with the lack of substrate for short periods.

The Sørensen similarity index indicated a similarity of 53.84% in macroinvertebrate diversity between the dry and rainy seasons (Table 2). The morphospecies Chironomidae sp.1 (Diptera) had higher relative species density in the rainy season (57.71%), followed by Odonata Zygoptera sp.1 (17.44%). In the dry season, Chironomidae sp.2 displayed the highest density (73.98%), followed by Gerromorpha sp.1 (9.54%) (Table 2). Dornfeld & Fonseca-Gessner (2005) report a predominance of mosquitoes from the family Chironomidae associated with aquatic macrophytes, including aquatic ferns. SILVEIRA et al. (2016) also report Chironomidae as an indicator taxon in different stages of leaf decomposition in S. auriculata.

Hemiptera Gerromorpha density was higher in the dry season, a period with the lowest pollution index (175 UFC/mL). According to Silva (2009), the richness of the family Gerromorpha showed a positive relation with the Habitat Integrity Index, that is, a rise in environmental integrity raises the species richness of this family.

The family Culicidae (Diptera) are known to be vectors of human and animal diseases, typically associated with the family Flaviviridae, which cause diseases such as yellow fever, dengue fever and Nile fever (Clairouin 2009; Flores & Weiblen 2009). The family Ceratopogonidae is associated with Salvinia infestation (Parys & Johnson 2013).

Dornfeld & Fonseca-Gessner (2005) compared the eating habit predominance of Diptera associated with Salvinia sp. and Myriophyllum sp. (Haloragaceae), where predators and detritivore collectors predominate in the Salvinia, due to the facility of submerged leaves to retain organic matter, which justifies the abundance of Odonata and Chironomidae, predators and detritivores, respectively.
Microbiological analyses demonstrated a difference in water quality between the dry and rainy seasons, the latter with worse water quality. There was a greater percentage of *S. biloba* cover in the rainy season, likely due to the poor water quality, since this species benefits from the higher organic matter content in the water. Greater species richness associated with *S. biloba* stands was found during the dry season. However, the decline in stand cover in the dry season promoted higher macroinvertebrate density. The family Chironomidae exhibited greater relative density in both seasons, but in the dry season, with less pollution, the morphospecies with the second highest density was Gerromorpha sp. 1 (Hemiptera). Studies indicate that an increase in environmental integrity raises the species richness of this family, corroborating the results found here. A greater sampling effort should be undertaken to broaden knowledge regarding the association between macroinvertebrates and *Salvinia* species, in order to determine their correlation with water bodies.

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| Classes          | Morphospecies                          | Rainy season | Relative density | Dry season | Relative density |
|------------------|----------------------------------------|--------------|------------------|------------|------------------|
| Arachnida        | Araneae sp. 1                          | 1            | 0.67             | 1          | 0.23             |
|                  | Acariformes sp.1                       | 0            | 0                | 1          | 0.23             |
|                  | Acariformes sp.2                       | 0            | 0                | 1          | 0.23             |
| Coleoptera       | Coleoptera Dystiscidae (*Celina* sp.)  | 1            | 0.67             | 0          | 0                |
|                  | Coleoptera sp.1 larva                  | 0            | 0                | 1          | 0.23             |
|                  | Coleoptera sp.2 larva                  | 0            | 0                | 1          | 0.23             |
| Diptera          | Diptera Ceratopogonida                 | 4            | 2.68             | 0          | 0                |
|                  | Diptera Chironomidae sp.1              | 86           | 57.71            | 20         | 4.77             |
|                  | Diptera Chironomidae sp.2              | 9            | 6.04             | 310        | 73.98            |
|                  | Diptera Culicidae sp.1                 | 1            | 0.67             | 9          | 2.14             |
| Hemiptera        | Hemiptera (Hebridae)                   | 1            | 0.67             | 0          | 0                |
|                  | Hemiptera Gerromorpha sp. 1            | 0            | 0                | 40         | 9.54             |
|                  | Hemiptera Gerromorpha sp. 2            | 0            | 0                | 14         | 3.34             |
|                  | Hemiptera sp.3                         | 0            | 0                | 1          | 0.23             |
| Lepidoptera      | Lepidoptera larva                      | 3            | 2.01             | 0          | 0                |
| Odonata          | Odonata Zygoptera sp.1                 | 26           | 17.44            | 10         | 2.38             |
|                  | Odonata Anisoptera sp.1                | 9            | 6.04             | 4          | 0.95             |
|                  | Odonata Anisoptera sp.2                | 1            | 0.67             | 6          | 1.43             |
| Maxillopoda      | Copepoda                               | 7            | 4.69             | 0          | 0                |
| Total of individuals |                                     | 149          |                   | 419        |                  |
| Richness         |                                        | 12           |                   | 14         |                  |
| Simpson's Diversity Index (1-D) |                                  | 0.9167       |                   | 0.9286     |                  |
| Sørensen similarity index |                                | 53.84%       |                   |            |                  |

**Table 2.** Number of individuals and relative density of macroinvertebrates found in *Salvinia biloba* Raddi in the Aldeia River, São Gonçalo, RJ, Brazil.
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