

EFFECT OF ENVIRONMENTAL VARIABLES ON THE DISTRIBUTION OF TWO FRESHWATER CRABS (ANOMURA: AEGLIDAE)

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ABSTRACT

We evaluate whether the abundance of the freshwater crabs *Aegla itacolomiensis* and *A. platensis* is related to any or all of 11 environmental variables. We sampled 205 Surber samples (33 × 33 cm) in a stream five meters wide in southern Brazil. For each Surber sample we obtained measures of flow velocity, depth, type of substrate, and availability of coarse particulate organic matter. The relationships between abundances of the two species and the environmental variables were assessed by regression trees. Only 2 of the 11 environmental variables were important in describing the abundances of the two species, both of them related to availability of coarse particulate organic matter. The abundance of *Aegla itacolomiensis* was related positively to quantity of fragmented leaves and, to a lesser degree, to quantity of twigs. For the abundance of *A. platensis*, quantity of twigs, followed by fragmented leaves, were the most important environmental factors. The quantity of recently fallen, unfragmented leaves was unimportant. We conclude that the two species of *Aegla* select locations with abundant old plant fragments that are usually colonized by fungi and bacteria. This conclusion is corroborated by previous studies indicating that *Aegla* spp. feed mostly on plant fragments.

KEY WORDS: *Aegla*, ecology, fresh-water crabs, statistical analyses

INTRODUCTION

The anomuran crabs of the family Aeglididae are restricted to freshwaters of the austral South America. The family is represented by a single genus, *Aegla*, consisting of approximately 70 species and subspecies. However, descriptions of new species still appear regularly, indicating that the total number of species in the group may be considerably larger (Pérez-Losada et al., 2004). The family occurs in streams and lakes of Bolivia, Brazil, Chile, Uruguay, Paraguay, and Argentina (Bond-Buckup and Buckup, 1994). The known latitudinal distribution range of *Aegla* in Chile is the Choapa River in the north (32°S) and the Madre de Dios Island in the south (47°S) (Pérez-Losada et al., 2002a, b). The northernmost species is *A. franca*, which lives in the Rio Grande Basin, São Paulo state (20°S), Brazil (Bond-Buckup 2003).

Aeglids are found in streams, rivers, and lakes, with a few species recorded from limestone caves in southern Brazil (Bond-Buckup and Buckup, 1994). Individuals are collected year-round, although in lower densities after floods (Colpo et al., 2005). Females carry eggs beneath their pleon. In *A. uruguayana*, the incubation period extends up to 50 days, with juveniles spending 3–4 days beneath the female's pleon after they hatch (Greco et al., 2004). Rodrigues and Hebling (1978) observed that *A. perobae* carries eggs for six months, and that newly hatched juveniles remain beneath the female's pleon for 8–12 days. Previous studies of stomach contents revealed that aeglids are usually omnivorous, feeding on decomposing plant parts, macrophytes, and aquatic invertebrates. For instance, Castro-Souza and Bond-Buckup (2004) found that macrophyte tissue was the main item in the stomachs of the sympatric species *A. camargoi*

and *A. leptodactyla*, reflecting perhaps the high availability of this item in the stream site studied. Bueno and Bond-Buckup (2004) found that plant parts were the most important item in the diet of *A. platensis* and *A. ligulata*, followed in importance by aquatic insects, which were consumed mainly by adults. On the other hand, field and laboratory observations indicated that *A. perobae* is predominantly carnivorous, feeding on aquatic and terrestrial insects fallen into the water, and that individuals can walk out of water to forage (Rodrigues and Hebling, 1978).

These previous studies on the ecology of *Aegla* spp. have focused on population biology, feeding, development, and natural history observations. Despite the indirect results of these previous studies, we are not aware of any study dealing specifically with the microdistribution of *Aegla* in the aquatic environment. For instance, it is not clear whether aeglids select specific types of substrate or water velocity. Such information on habitat requirement is important for the conservation and restoration of aeglid populations as they can guide practical policies of stream management. Most species of aeglids are restricted to small streams of a single drainage basin, making them very susceptible to extinction due to intensive human land-use in the landscape.

Here we assessed the microdistribution of *Aegla itacolomiensis* Bond-Buckup & Buckup, 1994 and *Aegla platensis* Schmitt, 1942 in a stream site in southern Brazil. Specifically, we evaluated relationships between the abundances of the two species and environmental variables. We focused on characteristics thought to be relevant to individuals at a very fine scale (meters) within a single stream site. The 11 variables selected to study were those usually important for stream macroinvertebrates (velocity, depth, mineral substrate and availability of coarse organic matter).

MATERIALS AND METHODS

Study Site and Field Work

The stream study site was Arroio Solitária Alta (29°33'S, 50°51'W, 103 m asl), a tributary of the Rio Paranhana, municipality of Igrejinha, Rio Grande do Sul, Brazil. The climate in the region is subtropical. The stream site is on average five meters wide. The stream bed is composed of sand, gravel, and leaves in pools; and stones, boulders, and bedrock in riffles. The catchment area of Arroio Solitária Alta harbors many small farms, and in some places pasture extends to the stream bank. However, riparian vegetation was present along most of the reach that was studied.

Samples were obtained from April to December 2005. A total of 205 sampling units were obtained in a stream reach of 674 m. Sampling units were obtained using a Surber sampler (33 × 33 cm) placed randomly in all stream microhabitats. The area covered by the Surber sampler was fully disturbed using hands during 1-2 min. The material retained in the net was transferred to a white tray, and all *Aegla* spp. individuals were sorted and fixed in ethanol. In the laboratory, individuals were measured and classified as juveniles (< 6 mm) or adults. Adults were sexed and identified. Coarse particulate organic matter was brought to the laboratory; dried for one week at 50°C; classified as twigs, recently fallen material, usually consisting of nearly entire leaves, and fragments of leaves in advanced decomposition; and then weighted.

At each sampling point, we measured water velocity, depth, and organic and inorganic substrate characteristics. Depth was recorded as the mean of measurements obtained at each Surber sampler corner and in the center. Inorganic substrata relying in the surface (to a depth of around 5 cm) were removed from the streambed and transferred to a white tray. Cobbles (> 40 mm) were removed and measured (largest axis). Coarse gravel (11-40 mm) and, subsequently, fine gravel (2-10 mm) were hand picked and semi-quantified by volume. The remaining material was assigned as sand (< 2 mm) and also semi-quantified by volume. The variables used in the modeling of *Aegla* spp. micro-distribution were: 1) water flow, 2) mean depth, 3) quantity of sand, 4) quantity of fine gravel, 5) quantity of coarse gravel, 6) number of cobbles, 7) mean size of cobbles, 8) size of the largest cobble, 9) quantity of twigs, 10) quantity of recently fallen leaves, and 11) quantity of small fragments of advanced decomposing leaves.

Statistical Analysis

We evaluated the relationship between the abundances of the two species of *Aegla* and the environmental variables using Regression Tree (De' Ath and Fabricius, 2000). This analysis selects the explanatory variable that best partitions the data in two homogeneous groups in respect to the values of the response variable. Each subgroup is then partitioned again, using the explanatory variable that best reduces the error within the two subgroups of data. The explanatory variable used in this second partition may be that used in the first split. This process of partitioning is known as *growing the tree* and continues until the number of observations in each subgroup is considered small. This usually overlarge tree is then pruned to the size in which the splits significantly reduce the variability within subgroups. The method used to prune trees is cross-validation, and uses a random subset of the data to grow the tree and predict the response in a second subset.

Trees were obtained using the package *rpart* (Therneau and Atkinson, 2006) run under the R environment (R Development Core Team, 2006). We used the Poisson method, appropriate for our counts of individuals in each observation. In this method, leaves of the tree are characterized by an estimate of the mean number of individuals. This estimate is usually close to the sample mean (Therneau and Atkinson, 1997, p. 37). The criterion used to prune trees was the lowest value of the cross-validation error. As mentioned above, the cross-validation procedure uses randomly obtained subsets of the data. Accordingly, different error values will be obtained each time the cross-validation is run. Thus, the size of the tree that corresponds to the lowest cross-validation error may vary. We followed the suggestion of De' Ath and Fabricius (2000) and computed the cross-validation 200 times, storing the size of the tree with the smallest cross-validation error. The most common size obtained in the 200 cross-validations was used to prune the final tree. The analysis was applied to each species separately. Individuals smaller than 6 mm, for which sexing was not possible, were classified as juveniles, and these were not included in the analysis.

RESULTS

Adults of *Aegla* spp. occurred in 140 of the 205 sampling units. *Aegla itacolomiensis* occurred in 133 sampling units,

with a total of 460 individuals. A total of 81 individuals of *A. platensis* were observed in 44 sampling units. Adults of both species were associated positively in terms of occurrence (Pearson chi-square test with Yates' continuity correction = 8.034, $P = 0.005$) and abundance (Spearman rank correlation = 0.322, $P < 0.001$). Unidentified juveniles of both species occurred in 86 observations with 243 individuals.

The cross-validation procedure indicated that the best tree for *A. itacolomiensis* in 197 of the 200 repetitions had two splits. Both splits were related to availability of coarse particulate organic matter (Fig. 1A). Quantity of fragmented leaves split the 205 observations in two sets. Those sampling units containing less than 2.6 g of fragmented leaves had an estimate of 1.394 individuals, while those containing more than 2.6 g had an estimate of 4.196 individuals. For the 143 sampling units containing less than 2.6 g of fragmented leaves, quantity of twigs was important. Eight sampling units containing more than 22.7 g of twigs had an estimate of 6.394 individuals. Sampling units with low quantities of fragmented leaves (< 2.6 g) and low quantities of twigs (< 22.7 g) had an estimate of only 1.085 individuals.

In contrast to *A. itacolomiensis*, the cross-validation procedure applied to *A. platensis* resulted in trees varying from 0 (no split) up to 12 splits. The modal number of splits was 1 (69 repetitions), followed by 2 splits (44 repetitions). Given the usually conservative result of the cross-validation method to Poisson models (Therneau and Atkinson, 1997, p. 37), we opted to retain the tree with two splits, both related to availability of coarse organic matter (Fig. 1B). The 15 sampling units containing more than 22.7 g of twigs contained an estimate of 1.768 individuals. Sampling units with low quantities of twigs had an estimate of 0.27 individuals. However, sampling units with low quantities of twigs but with large quantities (> 2.8 g) of fragmented leaves had an estimate of 0.566 individuals. The lowest estimate of number of individuals was for those sampling units with low quantities of twigs and fragmented leaves.

DISCUSSION

Only 2 of the 11 environmental variables were important in the description of the abundances of *A. itacolomiensis* and *A. platensis* in microhabitats, both of them related to the availability of coarse particulate organic matter. Previous studies on stream macroinvertebrates in temperate (Egglishaw, 1964) and tropical streams (Huamantínco and Nessimian, 1999) have shown that individuals are usually concentrated in locations with abundant leaf material. Richardson (1992) tested whether macroinvertebrates use leafpacks as substratum or food. He found many more individuals in natural leafpacks than in leafpacks made of polyester cloth, suggesting that leafpacks are used mostly for their food value. Bueno and Bond-Buckup (2004) observed that plant fragments of terrestrial origin constituted the item most commonly found in the stomachs of *A. platensis* and *A. ligulata* living in streams that are draining forested areas. In a large stream site draining a grassland landscape, where the input of terrestrial material is very small, Castro-Souza and Bond-Buckup (2004) observed that the sympatric *A. camargoi* and *A. leptodactyla* feed mostly on the abundant macrophytes available. Thus, despite the

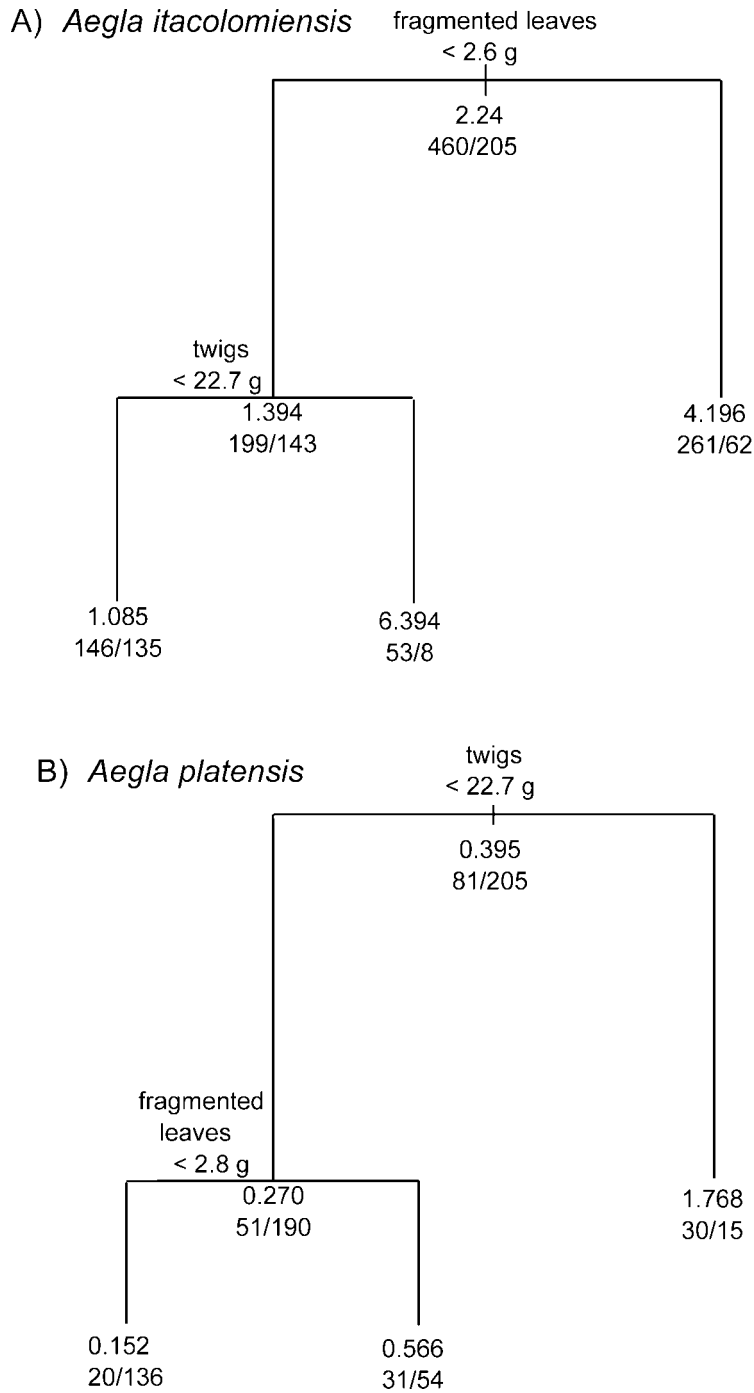


Fig. 1. Regression trees obtained for A, *Aegla itacolomiensis* and B, *Aegla platensis* in the stream Solitária Alta, Igrejinha, Brazil. Trees are split according to environmental variables. Values below each environmental variable in the splits or immediately below the leaves indicate the estimated number of individuals. Also shown are the total numbers of individuals (Y) and sampling units (N) in each split and leaf (in the form Y/N). Notice that estimated number of individuals are not exact, but only approximate, to the total number of individuals in a split (or leaf) divided by the total number of sampling units of the split (or leaf). See methods section for reference.

lack of any experimental study evaluating the reason for the occurrence of *Aegla* spp. in locations with abundant plant material, we suggest that the occurrence of *A. itacolomiensis* and *A. platensis* in these locations is due to feeding preferences.

Kelly et al. (2002) showed that *Gammarus pulex*, an amphipod commonly assigned as shredder, is able to predate

mayfly nymphs. Whitledge and Rabeni (1997) showed that 30-50% of two crayfish production was derived from feeding on animals. The positive association of *Aegla* spp. and plant detritus in our study is in accordance to the general belief that freshwater crustaceans are mostly shredders. However, Bueno, and Bond-Buckup (2004) found many insect fragments in the stomachs of *A. platensis* and

A. ligulata, indicating perhaps that aeglids, as well as amphipods (Kelly et al., 2002) and crayfish (Whitledge and Rabeni, 1997), would be best interpreted as omnivorous.

Interestingly, leaf material recently fallen into the stream was not important. This finding indicates that individuals of *Aegla* spp. select organic material containing a biofilm of bacterial and fungi. In fact, previous studies have shown that stream macroinvertebrates usually prefer plant material submerged for long periods of time over recently fallen material (Graça, 2001). For instance, Graça et al. (2001) showed that, when offered conditioned and unconditioned leaves, the two neotropical caddisflies *Nectopsyche argentata* and *Phylloicus priapulius* clearly preferred the conditioned leaves. Also, individuals feeding on conditioned leaves grew better than those feeding on unconditioned leaves.

Previous studies showed that some species of crayfishes and shrimps are of fundamental importance to decomposition of plant material in streams (March et al., 2001; Usio and Townsend, 2001). We are not aware of any study assessing the ecological significance of aeglids to the decomposition process of detritus. Aeglids are larger than most stream invertebrates and usually are found in high density. According, future studies should investigate whether aeglids play the same key role in the decomposition of plant material as observed for species of shrimps (Usio and Townsend, 2001) and crayfishes (March et al., 2001).

Our results indicate that the microdistributions of *A. itacolomiensis* and *A. platensis* are positively associated, in terms of both occurrence and abundance. The likely causal mechanism for this association is the requirement for similar food items. For instance, Castro-Souza and Bond-Buckup (2004) studied the diurnal and seasonal feeding period and items ingested by *A. camargoi* and *A. leptodactyla* and concluded that the two species did not show differences in periods of the day, of the year, or in items ingested. Our results and those of Castro-Souza and Bond-Buckup (2004) indicate that sympatric species of *Aegla* do not show segregation in space or time.

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