

# **The effect of macroinvertebrate activity on leaf decomposition in a tropical African stream**

**Student:** Derek C. West

**Mentor:** Catherine O'Reilly

## **Introduction**

Allochthonous inputs, especially leaf litter, have been shown to be the main source of energy for forested streams (Benfield 1996). Shading generally limits primary production in these streams, making detritus the most important carbon input. Energy and nutrients are transferred from leaves and other organic matter to the stream through leaching, microbial processing, and invertebrate activity. The vast majority of the study of leaf decomposition has been done in the temperate zone and it is possible that the process is very different in tropical streams. Microbial growth rates are much faster in low latitudes due to warmer temperatures (Mathuriau and Chauvet 2002, Webster and Benfield). Shredder abundances have been shown to be much lower at low latitudes (Dobson et al 2002). It is possible that the accepted mode of leaf litter breakdown with shredding macroinvertebrates playing a major role is actually an anomaly of the North Temperate Zone.

Studies in temperate systems have shown that breakdown rates differ greatly between different species of leaves. These differences have been attributed to differences in leaf nitrogen concentration, availability of carbon and a host of other factors including toughness and secondary compounds (Royer and Minshall 2001, Webster and Benfield 1986). It is generally accepted that leaves with higher initial nitrogen content decompose faster in streams (Webster and Benfield 1986). Recent studies, however, have found that carbon structure has a stronger affect than nitrogen measures (Royer and Minshall 2001). Leaves with high concentrations of carbon in complex structures such as lignin and cellulose have been shown to have slower breakdown rates (Ardon et al. 2006). Studies have also shown a large variation in breakdown rates across sites. One of the most consistent trends across sites shows that increasing temperature speeds leaf breakdown (Webster and Benfield 1986). This is consistent with the observation that leaf breakdown is generally faster in tropical streams than in the temperate zone (Benstead 1996).

A frequently observed difference in the mode of leaf breakdown between tropical and temperate streams is that shredders are relatively less important in the tropics (Dobson et al 2002). It is possible that microbial breakdown is relatively more important in tropical regions. High temperatures found at low latitudes would increase the rate of microbial activity and could explain this pattern. It is also possible that an important shredder in the tropics has been overlooked by researchers. Dobson et al. (2002) recognized that the benthic sampling approach used in their study may have underestimated the abundance of crabs, which were believed to be abundant in their system. Freshwater shrimp and crabs have been shown to be important consumers of stream detritus in some tropical streams (Wright and Covich 2005). Crabs from this system have been shown to eat leaves in a laboratory setting, strongly preferring some leaves to others (Wilton 2006).

The goal of this study was to assess the impacts of macroinvertebrates on leaf breakdown rates in an African tropical stream. Fine and coarse leaf litter bags to exclude and allow macroinvertebrate access, respectively were used to judge the impact of macroinvertebrates in this system. A similar study had been conducted in Ithaca, NY in the fall of 2006 using the same method. Alder (*Alnus glutinosa*) leaves used in that study were brought from Ithaca in order to increase the ability to compare processes between these systems. An additional experiment using cages to exclude crab access was conducted in order to assess the impact of crabs in this system. It was believed that macroinvertebrates may be relatively less important in this tropical stream than in the temperate zone, as found in other studies. Additionally, certain leaves that are preferred by crabs may break down much faster when crabs are given access to them.

## Methods

The study was conducted in Rutanga Stream, a forested third-order stream in Gombe Stream National Park, Tanzania. The study took place during the dry season, from July 15<sup>th</sup> to July 30<sup>th</sup>. The reach chosen for study was run habitat and stretched for approximately 15m. Substrate was primarily sand, cobbles and boulders. Woody debris and leaf litter were common through the stretch. Average water temperature for the course of the study was 20.8°C. The stream has a pH of 6.8, conductivity of 20 µs/cm and a discharge of 25 l/s.

Three local leaf species were chosen for study based on previous research in the area. All three species were common in the riparian vegetation and were picked live from near the stream and then air dried for five days before leaf pack preparation. The three species used were *Saba comorensis* var Florida (family Apocynaceae), *Pseudospondias microcarpa* (Anacardaceae) and *Monanthotaxis poggei* (Anonaceae). Black alder (*Alnus glutinosa*) leaves were picked in Ithaca, NY in mid June, air dried and brought to Tanzania.

Leaf packs were prepared and deployed for the two experiments simultaneously. For the macroinvertebrate exclusion experiment fine mesh bags were constructed from 0.5 mm mesh and coarse exclusion packs were constructed from heavy duty plastic mesh with a maximum diameter of 8mm. Packs were approximately 15 cm X 15 cm. Three grams ( $\pm 0.1$ g) of alder leaves were used to construct single species alder packs. One gram ( $\pm 0.1$ g) of each of the three local leaves was used to construct mixed packs. Twelve coarse and 12 fine packs were constructed each for alder and mixed packs and anchored in the stream to rebar.

Since crabs would not have full access to the coarse packs because of their large size, a separate exclusion experiment was carried out for investigating the effect of crabs. Since the crabs are larger than any other macroinvertebrates in the system, a cage system was devised to prohibit their access to leaves. Cages 20 cm X 20 cm X 10 cm were constructed of heavy duty plastic mesh with a maximum diameter or 8mm similar to the method of Reutz et al (2006). Control cages had only a bottom and two upstream sides, allowing access from downstream and the top. Inside each cage a mixed species leaf pack consisting of one gram ( $\pm 0.1$ g) each of the local leaves was placed inside nylon mesh that was 15 X 15 mm. Mesh packs were anchored in the center of the cages. Cages were weighted with a 20cm length of rebar. Nine closed and nine open cages were constructed and anchored in the stream to rebar.

For all treatments, handling controls were brought into the field and returned on the day of deployment. Collections of leaf packs were made on days 5, 10 and 15. Upon collection all debris and sediment that had collected on samples remaining in the field was cleared. In the lab invertebrates were collected on a 500µm sieve for each sample; leaves were sorted by species and rinsed of all debris. Leaves were oven-dried overnight at 60 °C and weighed. A portion of each sample was weighed and ashed at 500 °C for three hours to determine ash-free dry mass (AFDM). Samples were saved for later nutrient analysis.

A negative exponential decay model was used for the AFDM of leaves ( $M_t = M_0 e^{-kt}$ ).

Decomposition rates are reported as k-values, which is the rate constant in the preceding formula. All statistics were run using JMP version 5.1. Variance between treatments was tested by an ANOVA effects test.

## Results

K-values in the macroinvertebrate study ranged from a maximum 0.158 day<sup>-1</sup> for the course *A. glutinosa* packs to a minimum of 0.012 day<sup>-1</sup> for fine *S. comorensis* packs. *A. glutinosa* and *P. microcarpa* surpassed 50% decomposition within this time period. *A. glutinosa* and *P. microcarpa* decomposed significantly faster than *S. comorensis* and *M. poggei* (Tukey test,  $p < 0.05$ ). Decomposition was significantly faster in coarse packs than in fine packs for *A. glutinosa* and *P. microcarpa* (Figure 1) (ANOVA,  $p \leq 0.05$ ). No significant difference was seen between coarse and fine packs for the slower decomposing *S. comorensis* and *M. poggei*.

K-values for the crab exclusion study fell in the same range as for the macroinvertebrate exclusion experiment, with the exception of *P. microcarpa* which had substantially slower decomposition than in the coarse packs from the macroinvertebrate experiment. The crab exclusion study showed no significant difference between open and closed cages for any of the species studied (Figure 2). All three species broke down at significantly different rates, with *P. microcarpa* being the most rapid, followed by *M. poggei* and *S. comorensis* (Tukey test  $p < 0.05$ ). A crab with a carapace width of 17 mm was found in one of the open cages, indicating that they did at least use the structures.

## Discussion

Leaf breakdown was much more rapid in this study than in the similar study conducted in the temperate zone. The rate at which *A. glutinosa* decomposed was almost seven times greater for this study, and the difference was highly significant (ANOVA,  $p < 0.0001$ ). The decomposition rate for this temperate leaf was significantly faster than all but one tropical leaf used in this study. This difference could be due to the array of physical and chemical defenses that tropical leaves must possess in order to prevent herbivory. More about the differences between these leaves should be learned following nutrient analysis.

Macroinvertebrates appear to be important in the breakdown of some leaves in this tropical system. Significant differences in breakdown rates were seen for both *A. glutinosa* and *P. microcarpum*. Shredding activity was visually evident on *P. microcarpum* leaves from the day five through the end of the experiment. *M. poggei* and *S. comorensis* had very little visible evidence of shredding activity. Some leaves of *M. poggei* had semicircular pieces cut from the edges of the leaves, presumably for case building by caddis larvae, but this was not widespread. It is possible that if the experiment had been run for a longer period of time that more shredding would have been seen as leaves still did not seem fully conditioned by the end of 15 days. The decomposition rate for *M. poggei* was very similar to the rates seen in the other part of this study and in a previous study (Forsyth 2006). The decomposition rate for *P. microcarpa* in the coarse packs was much faster than that seen either in the cage exclusion part of this study or in the study done the previous year. Two replicates of *P. microcarpa* broke down almost completely over the fifteen days, leading to very fast rates seen and the high variance within this species (Figure 1). In both parts of this study *P. microcarpa* showed high variation, possibly indicating that the quality of the leaf varies substantially within the species. The difference in decomposition rates between the fine and the coarse packs for *A. glutinosa* were almost identical between the tropical and temperate studies, indicating that the effect of macroinvertebrates was about the same.

The crab exclusion experiment did not show any significant differences in breakdown rates between cages where crabs were excluded and where they were allowed. This indicates that crabs were not an important factor in the breakdown of the three leaves tested in this study. Decomposition rate for *P. microcarpa* was substantially faster for open cages, but due to a large amount of variation this difference was not significant. This result is not unexpected since both *P. microcarpa* and *M. poggei* were used in the previous lab study and were not preferred by crabs (Wilton 2006). Unfortunately the leaf that crabs readily consumed, *Tabernaemontana holstii* was not found in order to be used in this study.

Much work remains to be done on this project. Macroinvertebrates from all leaf packs will be identified and counted. Crabs collected from the stream will be analyzed for their stable isotope signature to determine their trophic position. Nutrient analysis will be done on all leaves used in this project to determine C:N ratios of the leaves both initially and as they decomposed. Carbon quality will also be measured based on percentage lignin in the leaves. The difference in breakdown rates will be compared to these different measures in an effort to determine what the best predictor is of leaf quality in this system. Temperature data will be used to calculate decomposition rates based on a negative exponential model using degree days, which has been suggested to be a better model of leaf breakdown (Webster and Benfield 1986). This model may give a better comparison between the temperate and tropical systems since they varied greatly in temperature, with the tropical stream averaging 14.5°C warmer than the temperate stream.

As expected, decomposition rates in the tropics were rapid and significantly faster than those found in the temperate zone. Macroinvertebrates did have a significant effect on the decomposition of some leaf species in the tropics. The strength of this affect was similar to that found in the temperate zone. No affect of crabs on leaf breakdown was detected in this study, indicating that they may not be an important factor in leaf decomposition.

### **Acknowledgments**

I owe a great amount of thanks to my mentor Catherine O'Reilly for her intellectual support as well as her patience and assistance throughout this project. I would also like to thank Mer Mietzelfeld for her help in the field and in constructing leaf packs. Alex Flecker provided funding for the project run in Ithaca, NY and materials for both projects. I am very grateful to TACARE employees Anton Collins and Grace Gobbo for their help identifying leaf species. Thanks also to the Gombe Stream National Park for allowing this research to be conducted in the park and to TAFIRI for the use of facilities and equipment in Kigoma, Tanzania. Funding for this research was made possible by the Nynaza Project NSF grants ATM 0223920 and DBI-0608774.

### **Literature Cited**

- Benfield E. F. 1996. Leaf Breakdown in Stream Ecosystems. *Methods in Stream Ecology*. Academic Press, 1996.
- Benstead, J. P. 1996. Macroinvertebrates and the processing of leaf litter in a tropical stream. *Biotropica*. 28: 367-375.
- Dobson, M., Magana, A, Mathooko, J. M and F. K. Ndegwa. 2002. Detritivores in Kenyan highland streams: more evidence for the paucity of shredders in the tropics? *Freshwater Biology*. 47: 909-919.
- Forsyth, J. 2006. Leaf breakdown and retention of four different sized leaf species in Rutanga Stream, Gombe Stream National Park, Tanzania. Nyanza Project 2006 Annual Report.
- Mathuriau, C. and E. Chauvet. 2002. Breakdown of leaf litter in a neotropical stream. *Journal of North American Benthological Society*. 21: 384-396.
- Reutz, C.R. III, Breen, M.J. and D.L. Vanhaitsma. 2006. Habitat structure and fish predation: effects on invertebrate colonization and breakdown of stream leaf packs. *Freshwater Biology*. 51: 797-806
- Royer, T.V. and G. W Minshall. 2001. Effects of nutrient enrichment and leaf quality on the breakdown of leaves in a hardwater stream. *Freshwater Biology*. 46: 603-610.
- Webster, J.R. and E.F. Benfield. 1986. Vascular plant breakdown in freshwater ecosystems. *Annual Review of Ecology and Systematics*. 17: 567-594.
- Wilton, C. 2006. Leaf preference and choice of the macroinvertebrate shredder *Potomonautes emini* in Gombe Stream National Park, Tanzania. Nyanza Project 2006 Annual Report.
- Wright, M.S. and A.P. Covich. 2005. The effect of macroinvertebrate exclusion on leaf breakdown rates in a tropical headwater stream. *Biotropica* 37: 403-408.

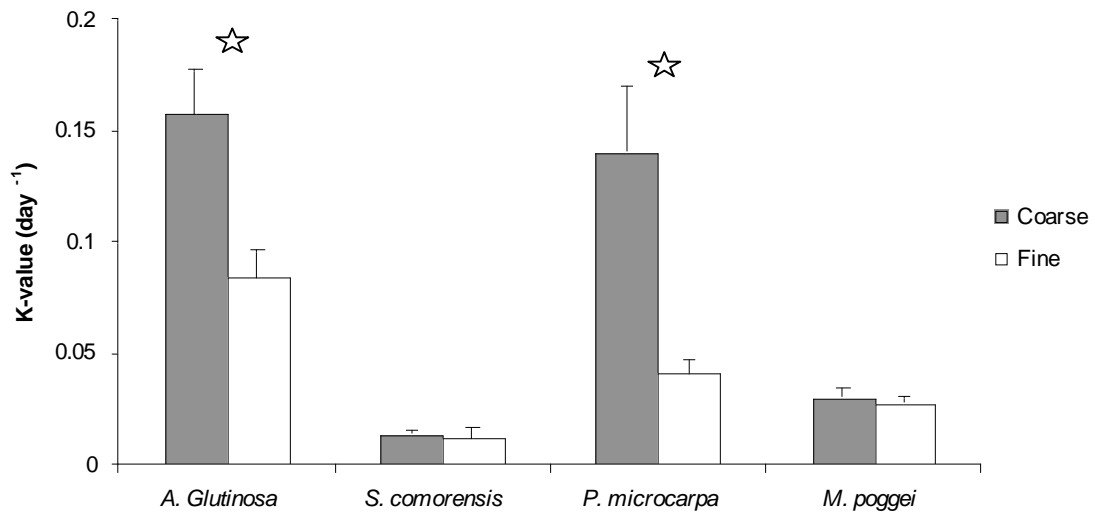


Fig 1. Breakdown of leaves over a 15 day period for a macroinvertebrate exclusion experiment calculated with a negative exponential model. Error bars show one standard error. Significant differences between coarse and fine indicated by star ( $p \leq 0.05$ ).

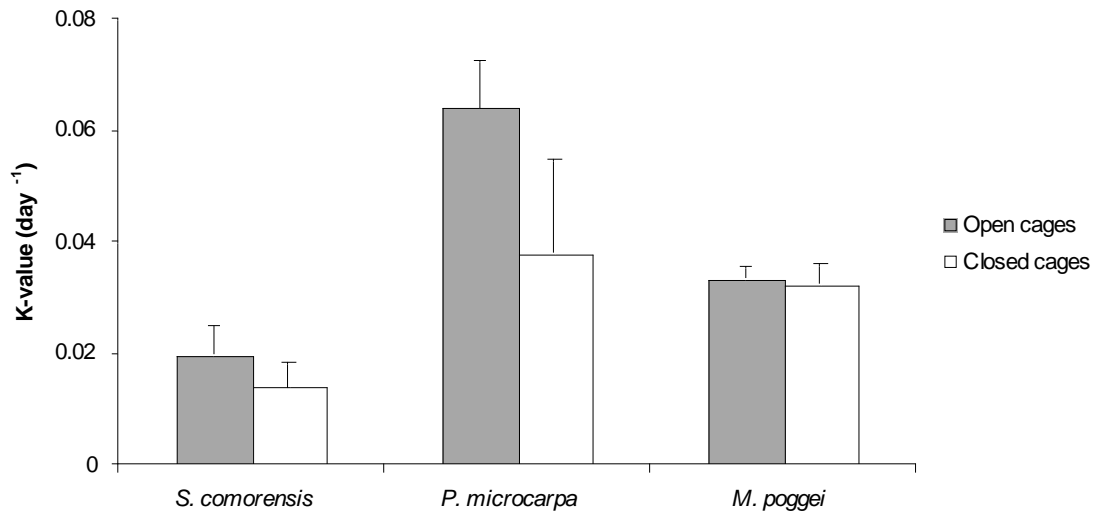


Fig 2. Decomposition rates of leaves for crab exclusion experiment over a 15 day period calculated with a negative exponential model. Error bars show one standard error.

