Leaf Litter Transport and Retention in the South Fork Eel River

Cassandra Liu

Abstract This study examines leaf retention within the South Fork Eel River. Leaf retention reflects the geomorphological and hydrological characteristics of the stream. Further leaf retention impacts the presence of macroinvertebrate functional feeding groups and thus affects the food web dynamics of a river ecosystem. The absence of leaf retention is an indicator to the consumption of predatory organisms, whether or not the source of food is terrestrial or aquatic. Release of *Ginko biloba* leaves upstream was used to examine leaf retention along the various tributaries of the South Fork Eel River. Comparing the drainage area of these tributaries and morphological characteristics, factors affecting leaf retention can be understood as well as the effect of retention upon organisms. Results indicate that the presence of large woody debris is a great indicator of leaf retention capabilities where as morphological characteristics of the habitat are not as strong. Retention is highly influence further by stream flow and velocity thus being affected seasonally.

Introduction

The input of litter from riparian vegetation has a strong influence on the stream ecosystem process (Schade and Fisher 1997). The majority of the litter fall is made up of leaves, which play an important role in nutrient cycling and energy flow, and as food and habitat for macroinvertebrates (Schade and Fisher 1997; Webster and Benfield 1986).

The majority of energy input into streams comes from riparian vegetation (Lemly and Hilderbrand 2000). Input into the stream occurs in short pulses from the autumn littler-fall (Cuffney and Wallace 1989; Lemly and Hilderbrand 2000) and retention is dependent on the geomorphological characteristics of the stream (Vannote *et al.* 1980; Webster *et al.* 1994). Large woody debris (LWD) is a very important retention device within streams, by being a food reservoir in itself as well as providing a food reservoir from the trapped debris throughout the year (Lemly and Hilderbrand 2000). The LWD creates areas of low flow between twigs and branches for coarse particulate organic matter (CPOM) to settle allowing for more leaf processing by shredders (Lemly and Hilderbrand 2000; Pretty and Dobson 2004; Trotter 1990), a macroinvertebrate group that depends on the CPOM as a direct food source (Schade and Fisher 1997). With more leaf processing by shredders more fine particulate organic matter is available for other functional feeding groups such as collector-gatherers and collector-filterers (Richardson and Neill 1991).

The vast amount of allochthonous inputs, leaves and woody debris from riparian vegetation Pretty and Dobson 2004), into the stream are retained through the hydrological and geomorphological characteristics of the stream and can be consumed by the invertebrate fauna, creating a critical link between the primary consumers in the stream food web and their main food source (Pretty and Dobson 2004). Invertebrate communities of forested streams rely heavily on the basis of detritus processing of allochthonous inputs from surrounding vegetations, a very important energy source that drives community structure (Cummins 1974; Vannote *et al.* 1980). Allochthonous inputs accounts for as much as 99 % of energy available in streams.

Studies that looked at the retentiveness of different leaf species indicated that the surface area of the leaf and its shape determines the retention potential of individual leaves (Young *et al.* 1978). Leaf area is the most important factor in determining how far the leaves will travel downstream (Young *et al.* 1978). Leaves that are more compact have a lower chance of retention because of their ability to escape through small crevices whereas broader leaves have a higher chance of retention in LWD or other structures within the channel (Young *et al.* 1978). Varying hydrological characteristics of the stream also influences how well an individual leaf can be retained. In general, leaf retention is decreased with increased stream velocity and discharge (Snaddon *et al.*1992), usually after a natural occurrence, such as heavy rainfall or flooding, or human-created occurrence.

Though studies have been conducted to examine the retentiveness of streams for leaf litter (Schade and Fisher 1997) there has been little study that looks at the effect of retention on food-web dynamics. Leaf retention affects various invertebrate functional feeding groups that are present within streams (Lemly and Hilderbrand 2000). In the absence of these leaves, when all are flushed out, these invertebrate populations may decline and thus affect various predatory organisms (Limm 2005, pers. comm.).

In this study, *Ginko biloba* leaves was released along various stretches of four tributaries, McKinley, Fox, Elder, and Skunk Creek, of the South Fork Eel River in California to examine leaf retention of the stream. *Ginko biloba* leaves are used because they are easily identified from the various leaves that may be present in the river. By looking at leaf retention, hydrological characteristics and substrate abundance within the channel can be determined. The influence of drainage area can also influence the amount of leaves that are retained. Future studies can examine the abundance of various invertebrate functional feeding groups based on areas of retention (Vannote *et al.*1980). This study can aid restoration efforts in various rivers striving to restore biological diversity. A better understanding of how hydrological characteristics influence retention can help re-establish riparian habitats that provide niches for various invertebrate communities that occupy different areas of the river.

Methods

Study Site The study was conducted in various tributaries of the South Fork Eel River (watershed area, 140 km^2) in Medocino County, California, USA (39°44’ N, 123°39’ W) (Finlay *et al.* 2002), in April 2005 (Figure 1). The four tributaries, McKinley, Fox, Elder, and Skunk Creek (Figure 2), were selected based on their variable drainage area: Elder Creek = 17 km^2, Fox Creek = 2.75 km^2, McKinley Creek = 0.6 km^2, and Skunk Creek = 0.5 km^2. In addition to the varying drainage areas, these creeks also have different geomorphological characteristics.

Though most have a step-pool characteristic the width of each creek varies according to its drainage area and habitat characteristics.

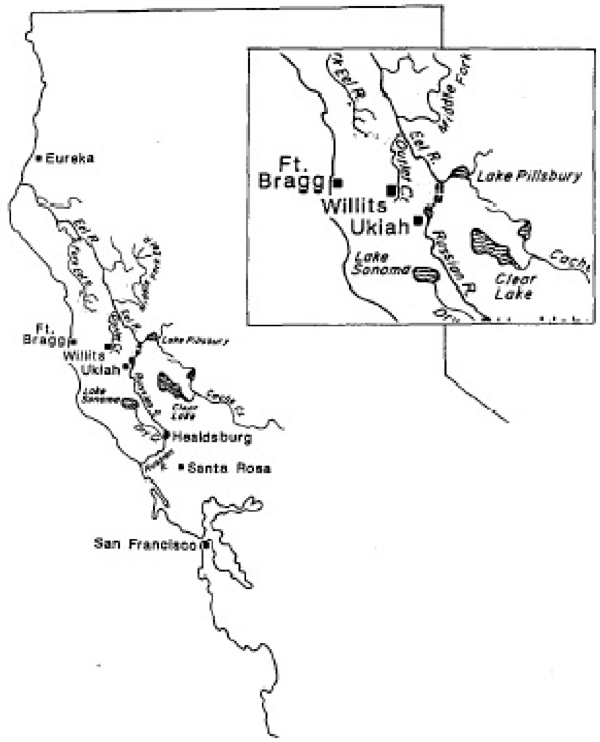

Figure 1: Location of South Fork Eel River (Power 1992).

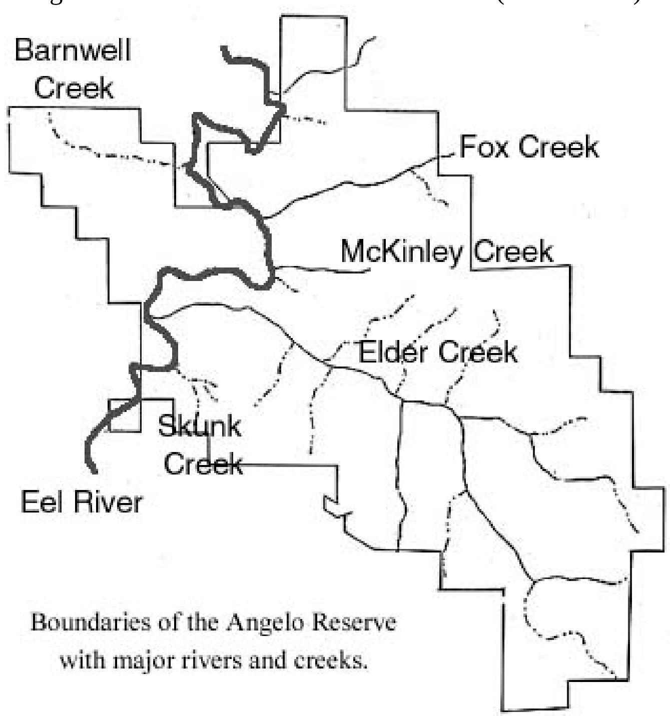

Figure 2: Map of Angelo Reserve. Location of Fox, McKinley, Elder, and Skunk Creek along the South Fork Eel River (Power *et al.* 2003)

The South Fork Eel River is part of the Angelo Coast Range Reserve, which is part of the University of California Natural Reserve System. It is a forested watershed in the California costal range with a Mediterranean climate (Bastow *et al.* 2002). Rainy winters range from October-March and dry summers from April-October (Bastow *et al.* 2002; Finlay *et al.* 2002). Average annual rainfall is approximately 150 cm; causing winter floods of the river channel (Bastow *et al.* 2002). Contrary to the rainy winters, the river is warm and productive during the dry summers (Finlay *et al.* 2002). The South Fork Eel drains through forest and pastureland, passing through coastal redwood (*Sequoia sempervirens*), Douglas fir (*Pseudotsuga menziesii*), and oak (*Quercus* spp.) (Power 1990; Sabo *et al.* 2002).

Experimental Design *Ginko biloba* leaves were collected from San Rafael, California and Berkeley, California in span of 1.5 years. The leaves were dried and stored in large garbage bags. *Ginko biloba* leaves were used because of their easily identifiable characteristics relative to other leaves that are present within the tributary. In the bags of leaves, 1000 leaves were picked out and placed in the microwave for one minute to ensure that no Sudden Oak Death spores (*Phytophthora*) are dispersed into the nature reserve. Leaves were selected based on their bright color and that both petal and stem are intact.

In April 2005, the discharge and velocity of the water was measured with the Flow-Mate 2000 by Marsh-McBierney Inc. Going upstream from the road bridge as far as possible, approximately 300 meters or less, the *Ginko* leaves were emptied out of their containers in the center of the creeks. The *Ginko biloba* leaves were released in the center of the creek to ensure that they would not be trapped at the banks upon release. Further, handfuls were released at a time to ensure that the *Ginko* leaves were not stuck to each other. After release the *Ginko* leaves were allowed two hours time to flow. After two hours, going downstream from the point of release, the distance at which *Ginko biloba* leaves were spotted was recorded. Being as careful as possible, *Ginko* leaves found clumped together were lifted out and counted by hand, dropping the counted leaves within a bucket rather than the creek so that they will not be counted a second time if retained. The two hours travel time ensured that most leaves have had ample time to be removed from transport and that there are no further transport of leaves after its retention (Schade and Fisher 1997).

The amount of leaves remaining in transport at each distance was log-transformed and regressed against distance. The retention rate coefficient (k_r) represents the slope of the regression line. The k_r is the rate an individual leave is retained and removed from transport, thus the higher k_r value indicates a higher rate of retention (Schade and Fisher 1997).

Results

Within McKinley Creek the 79 % of the *Ginko biloba* leaves released remained in transport after two hours 300 m downstream from the release point. (Figure 3). Observations show that at the point of release the area was densely packed with LWD, in the form of fallen trees. There were not many LWD and debris dams present beyond the release point. McKinley Creek has a step-pool characteristic, however, this did not increase the retention rate due to the high discharge rate, 0.05 m^3s^{-1}.

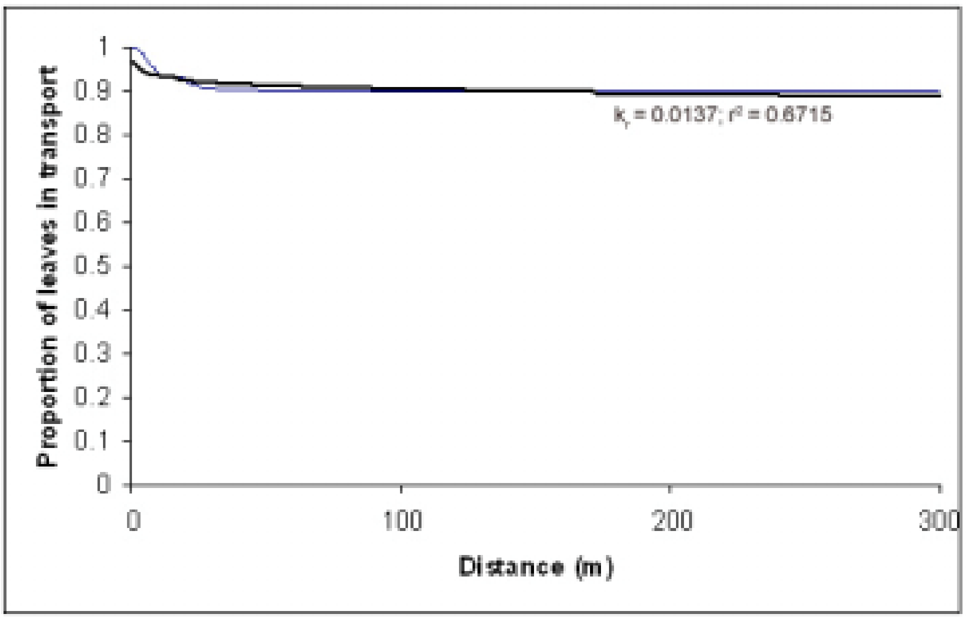

Figure 3: Proportion of *Ginko biloba* leaves remaining in transport, flowing downstream, as a function of distance from the release point at McKinley Creek.

In Fox Creek, 36 % of the leaves remained in transport after 300 m (Figure 4). There were fewer LWD present at the release point of Fox Creek compared to McKinley Creek. Much of the leaves were caught along the banks, where the velocity of the water was greatly decreased from the center of the creek, and against stones.

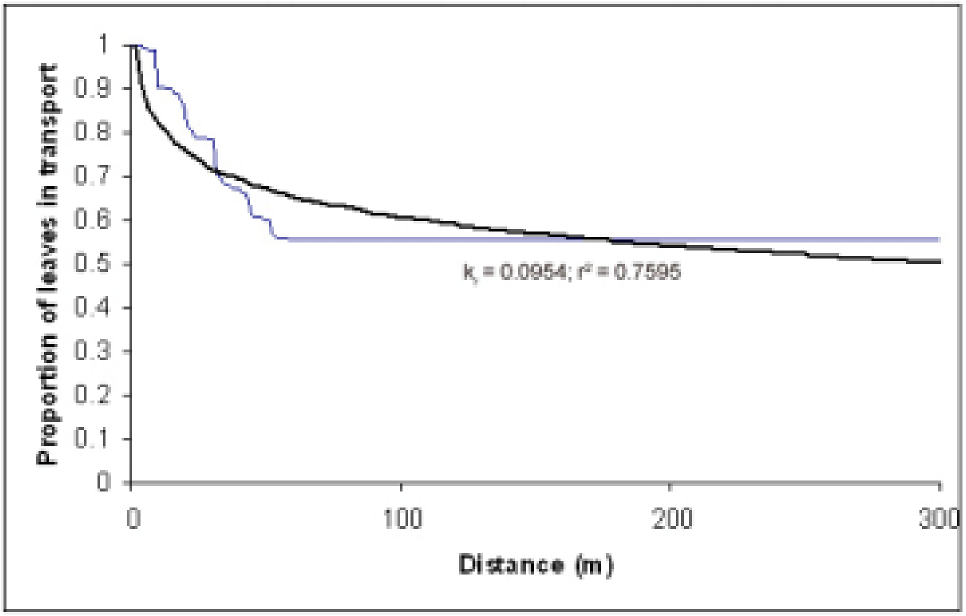

Figure 4: Proportion of *Ginko biloba* leaves remaining in transport as a function of distance from the release point at Fox Creek.

In Elder Creek, 70 % of the leaves flowed remained in transport after 230 m (Figure 5). The release point was near a large pool of water. LWD was not present along the creek and does not have a step-pool geomorphological characteristic like the other three creeks. Elder Creek rather consists of large pools and riffles. Most of the leaves were caught in eddies along the banks, within sedges.

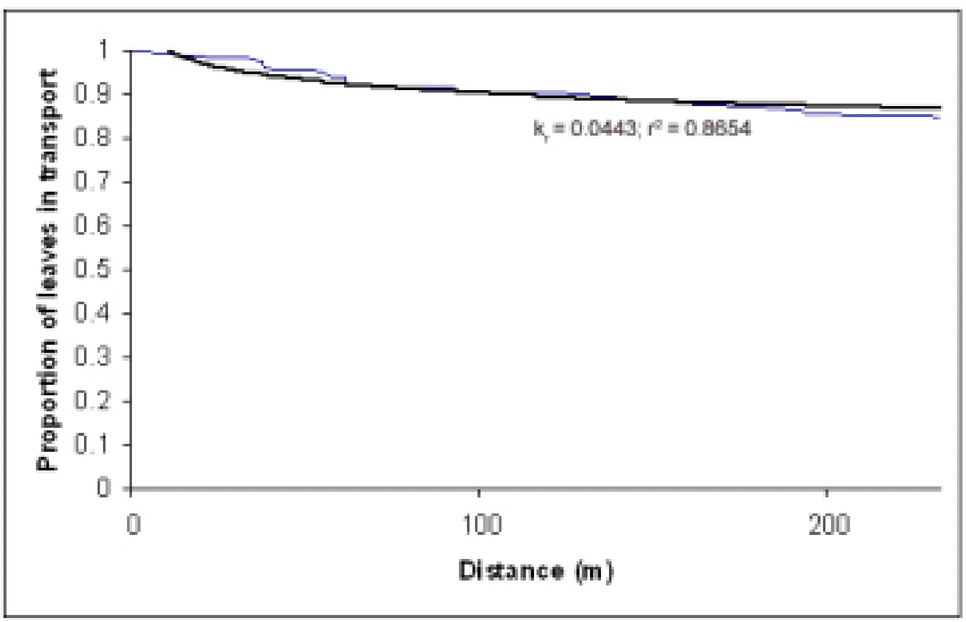

Figure 5: Proportion of *Gink biloba* leaves remaining in transport as a function of distance from the release point at Elder Creek.

In Skunk Creek 41 % of the *Ginko biloba* leaves remained in transport beyond the road bridge (Figure 6). Much of the leaves were retained upon release. Being a narrow creek, LWD and debris dams were effective in preventing the *Ginko biloba* leaves from flowing downstream.

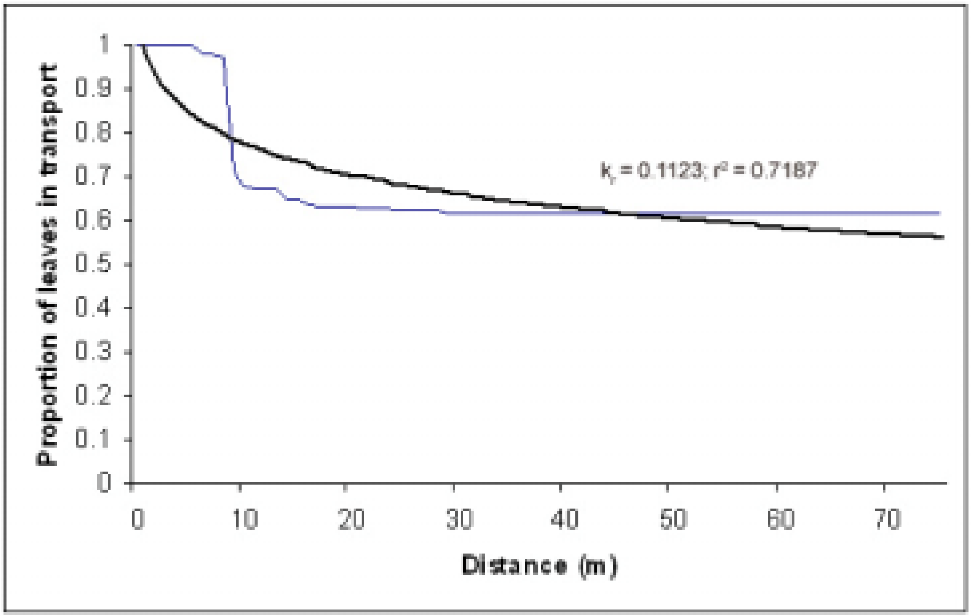

Figure 6: Proportion of *Gink biloba* leaves remaining in transport as a function of distance from the release point at Skunk Creek.

Overall data indicates the Skunk Creek had the greatest rate of retention followed by Fox, Elder, and McKinley Creek.

Discussion

As the leaves progressed further downstream from the release point there were less leaves visible and present. The areas of release were either densely covered with fallen trees or completely bare. In creeks that contained debris dams and LWD there was a greater amount of retention at the initial release point in comparison to creeks without the presence of debris and LWD. This indicates that habitat structure has a heavy impact on how well leaves are retained within the stream. The presence of logs indicates that LWD debris plays a key role in leaf retention and therefore is an indicator of macroinvertebrate presence within those areas. However, further study needs to be conducted to quantify the amount of LWD present.

The morphological characteristic of McKinley, Fox and Skunk Creek is predominately step-pool. Steps are generated in areas congested by large sediment that results in further accumulation of debris (Montgomery and Buffington 1997). Results indicate that LWD influences the rate of retention. With smaller drainage areas, such as with Skunk Creek, there is great retention; however, in creeks with larger drainage areas, Fox and McKinley, there is a greater area where water flow is greater and thus less retentive. With greater drainage areas, the width of the stream tends to be greater and many times the LWD or debris dams present do not run the entire width of the creek but rather small segments of the entire width.

Elder Creek, which has a pool-riffle morphological characteristic, different from the other three creeks, has the least retention when the data was compared with Skunk and Fox Creek; all three creeks were tested the same weekend. The leaves that remained in transport were sighted flowing downstream in the Eel River in bits and pieces. Due to that fact, it is also a possibility that some of the missing leaves may have remained in the creek, however, were too beaten-up to be sighted and possibly caught within cascades present in the creeks with the step-pool geomorphological characteristic.

Additional long-term studies need to be conducted to examine the effect of seasonality on retention. During rainy periods, periods of high water levels, retention may be greatly decreased where as during the dry summer seasons retention may be higher due to the lower and slower flow of the water.

In this study only the leaves belonging to the *Ginko biloba* plants were examined however studies have indicated that the size and other characteristics of the leaf does have an impact on how easily they can be retained. Pine needles for instance may flow through any form of debris whereas large oak leaves may be easily retained (Young *et al.* 1978). More studies need to be conducted to understand retention along the South Fork Eel River using the riparian vegetation present.

Overall, retention is affected by the characteristics of the habitat as seen by the influence of the presence of LWD. The presence of LWD impacts the abundance of benthic macroinvertebrate communities present in the stream and thus how much food is available for predatory organisms.

Acknowledgements

Mike Limm for his help, guidance and discussions on the topic of leaf retention. Mary Power for her inputs onto the direction of this study. John Schade for explaining possible statistical analysis methods for the data gathered as well as his suggestions and ideas about the study in terms habitat characteristics. Further I would like to thank the advisors of ES196 for their guidance and instruction to conducting scientific research.

Reference

Bastow, J.L., J.L. Sabo, J.C. Finlay, and M.E. Power. 2002. A basal aquatic-terrestrial trophic link in rivers: algal subsidies via shore-dwelling grasshoppers. Oecologia 131:261-268.

Cuffney, T.F. and J.B. Wallace. 1989. Discharge-export relationships in headwater streams: the influence of invertebrate manipulations and drought. Journal of the North American Benthological Society 8:331-341.

Cummins, K.W. 1974. Structure and function of stream ecosystems. Bioscience 24:631-641.

Finlay, J.C., S. Khandwala, and M.E. Power. 2002. Spatial scales of carbon flow in a river food web. Ecology 83(7):1845-1859.

Lemly, A.D. and R.H. Hilderbrand. 2000. Influence of large woody debris on stream insect communities and benthic detritus. Hydrobiologia 421:179-185.

Montgomery, D.R. and J.M. Buffington. 1997. Channel-reach morphology in mountain drainage basins. Geological Society of American Bulletin 109(5):596-611.

Power, M.E. 1990. Benthic turfs vs. floating mats of algae in river food webs. Oikos 58:67-79.

Power, M.E. 1992. Hydrologic and trophic controls of seasonal algal blooms in northern California rivers. Archivs fur Hydrobiologie 125:385-410.

Power, M.E., J. Latto, P. Steel, and C. Bode. California Biodiversity Center World Wide Web site. Draft Management Plan for the Angelo Reserve. 2003. http://cbc.berkeley.edu/manplan/index.html, accessed April 29, 2005.

Pretty, J.L. and M. Dobson. 2004. Leaf transport and retention in a high gradient stream. Hydrology and Earth System Sciences 8(3):560-566.

Richardson, J.S. and W.E. Neill. 1991. Indirect effects of detritus manipulations in a montane stream. Canadian Journal of Fisheries and Aquatic Sciences 48:776-783.

Sabo, J.L., J.L. Bastow, and M.E. Power. 2002. Length-mass relationships for adult aquatic and terrestrial invertebrates in a California watershed. Journal of the North American Benthological Society 21:336-343.

Schade, J.D. and S.G. Fisher. 1997. Leaf litter in a Sonoran desert stream ecosystem. Journal of the North American Benthological Society 16(3):612-626.

Snaddon, C.D., B.A. Stewart, and B.R. Davies. 1992. The effect of discharge on leaf retention in two headwater streams. Archives of Hydrobiologia 125:109-120.

Trotter, E.H. 1990. Woody debris, forest-stream succession and catchment geomorphology. Journal of the North American Benthological Society 9:141-156.

Vannote, R.L., G.W. Minshall, K.W. Cummins, J.R. Sedell, and C.E. Cushing. 1980. The river continuum concept. Canadian Journal of Fisheries and Aquatic Sciences 37:130-137.

Webster, J.R. and E.F. Benfield. 1986. Vascular plant breakdown in freshwater ecosystems. Annual Review of Ecology and Systematics 17:567-594.

Webster, J.R., A.P. Covich, J.L. Tank, and T.V. Crockett. 1994. Retention of coarse organic particles in the southern Appalachian Mountains. Journal of the North American Benthological Society 13:140-150.

Young, S.A., W.P. Kovalak, and K.A. Del Signore. 1978. Distances traveled by autumn shed leaves introduces into a woodland stream. American Midland Naturalist 100:217-222.