CHAPTER 2

LEAF RETENTION

ARTURO ELOSEGI

Departamento de Biología Vegetal y Ecología, Facultad de Ciencia y Tecnología
Universidad del País Vasco, C.P. 644, 48080 Bilbao, Spain.

1. INTRODUCTION

Allochthonous organic matter, especially leaf litter, is the main energy source of food webs in headwater forested streams (Vannote et al. 1980, Lohman et al. 1992, Cummins et al. 1989). Leaf litter enters streams mainly in a large burst during the period of leaf abscission (autumn in most temperate areas), and can be either trapped in the reach and thus become available for heterotrophs, or transported downstream. Therefore, the capacity of a stream reach to retain materials (retentiveness) is important for the productivity and ecosystem efficiency of streams (Bilby & Likens 1980, Pozo et al. 1997).

Channel morphology is a key factor determining the capacity of streams to retain leaf litter, with narrow, rough-bottom streams being most retentive (Webster et al. 1994, Mathooko et al. 2001). Wood, especially when forming debris dams, enhances leaf retention and storage (Bilby & Likens 1980, Raikow et al. 1995, Díez et al. 2000). Changes in stream stage produce temporal variations in retention capacity, as higher discharge results in larger depth and width, and higher hydraulic power, thus decreasing retentiveness (Ehrman & Lamberti 1992, Larrañaga et al. 2003).

Measuring leaf litter retention over short periods involves releasing leaves and estimating their downstream displacement. Four types of "leaves" may be used: (1) Natural leaves with some kind of mark that does not modify their short-term behaviour in water. Many paints affect leaf buoyancy and stiffness, so care must be taken to select a good dye; alternatively, a narrow line can be painted on both sides. The colours most easily recognized in streams are bright blue and blaze orange. (2) Leaves that do not occur naturally in the stream can sometimes be easily recognized. The bright yellow leaves of the exotic ginkgo tree (*Ginkgo biloba*), collected in autumn and stored dry between paper sheets, have often been used. (3) Artificial leaves of ornamental plastic plants, which can be painted in easily recognized colours. Although such artificial leaves may closely resemble natural ones, their floating behaviour can be different. (4) Any other material that is easily seen and

M.A.S. Graça, F. Bärlocher & M.O. Gessner (eds.), Methods to Study Litter Decomposition: A Practical Guide, 13 – 18.

behaves like leaves. Most commonly, strips (ca. 3 × 10 cm) from different types of plastic and in different colours are prepared.

Artificial materials are cheap and easily available throughout the year, whereas the use of natural leaves requires advanced planning, rather time-consuming collection, drying and storage. Furthermore, natural leaves tend to fragment easily, and may therefore not be used repeatedly. However, released "leaf" material can be lost in the study reaches, especially when single-point collections are made (see below). Artificial or painted leaves should therefore only be used if one is confident that all leaves will be recovered. If this is not the case, it is preferable to use natural exotic leaves.

It is important to check that the materials used behave like natural leaves in a stream (see Fig. 2.1). If the goal is simply to compare the retention capacity of different reaches, any material can be used, but if the goal is to simulate the retention of real leaves, different kinds of materials need to be calibrated against the riparian leaf species most abundant in the study area. This is a point worth exploring in detail, as differences between materials can be substantial (Fig. 2.1; Young et al. 1978, Prochazka et al. 1991, Canhoto & Graça 1998), and the relationship between retention and leaf morphology is not straightforward (Larrañaga et al. 2003). Thus, a great deal of caution is necessary when comparing streams based on results obtained with different materials.

This chapter presents a method to measure the capacity of stream reaches to retain leaf litter in the short term. This is done by monitoring the downstream displacement of leaves released at one point. The average travel distance of the leaves is calculated by plotting the proportion of leaves in transport at a given point against the measured travel distance and fitting the data to an exponential decay model. This approach assumes that the number of leaves retained at any one point along the experimental reach is directly proportional to the number of leaves in transport. Two methods are given here:

The multiple-point collection method is best suited for small clear-water streams. All leaves are retrieved, and the distance travelled by each leaf is measured. A net is placed downstream of the reach as a safety device, to prevent the loss of leaves drifting past this point.

The single-point collection method may be slightly less accurate but is useful in larger reaches or turbid waters where many leaves are unlikely to be recovered after release. Instead of measuring the distance travelled by individual leaves, the proportion of leaves reaching a net placed downstream of an experimental reach is measured. If differentially marked leaves are released at various distances from the net, an exponential regression can be calculated as with the multiple-point collection method. Unlike in multiple-point collections, the distance between release point and net is critical. The experiment is not valid if more than 90% or less than 10% of leaves reach the net (Lamberti & Gregory 1996). Whereas both natural and artificial leaves can be used with multiple-point collection, only natural leaves should be used with single-point collection, to avoid polluting the reach.

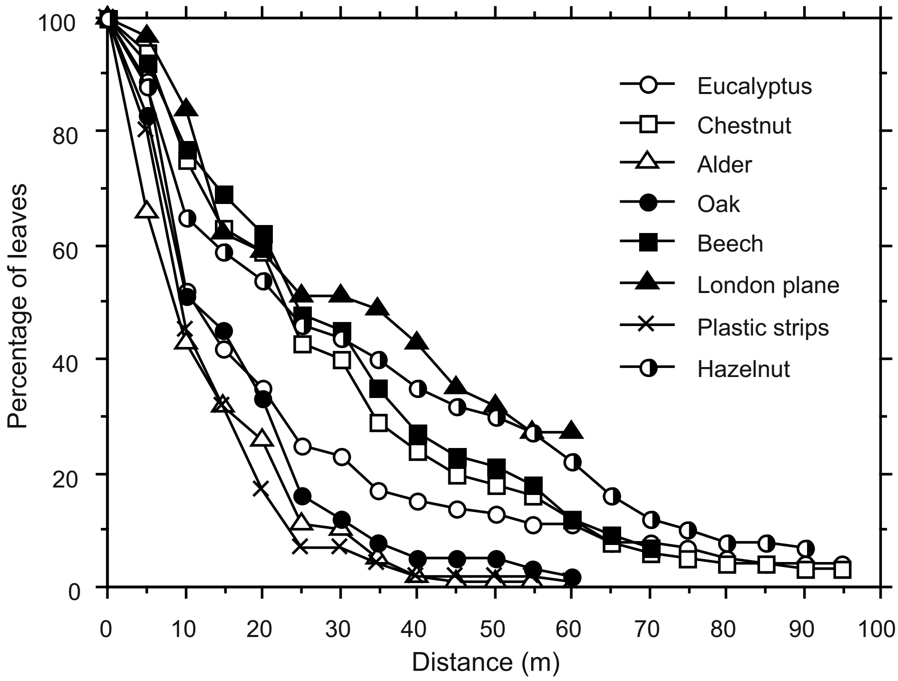

*Figure 2.1. Downstream decrease in the number of leaves transported in a third-order stream, expressed as a percentage of leaves released. Note that alder and plastic strips (3 × 10 cm) were most readily retained (average travel distance = 11.2 m), whereas London plane (*Platanus × acerifolia*) leaves travelled furthest (average travel distance = 50 m). Data from Larrañaga et al. (2003).*

Because retention distance varies with stream stage, inter-stream comparisons should be performed under similar hydrological conditions. This is most easily done during base-flow conditions, but distances so measured can grossly underestimate average retention efficiency, as leaves are more easily scoured during high flow. The relationship between travel distance and discharge can be studied for each reach by repeating retention experiments under different discharge conditions. In this case, results from different reaches can be compared even if they do not correspond exactly to the same hydrological condition.

2. SITE SELECTION AND EQUIPMENT

2.1. Site Selection

Leaf retention can be measured in almost any stream or river, but measurements are easier in wadeable streams with clear water. In first- to second-order streams most leaves are retained within a few metres during base-flow, but retention distance can increase to some tens of metres at higher discharge. Appropriate reach lengths are therefore normally 10—50 m. In larger streams and rivers, reaches 100—500 m long are recommended. As a rule of thumb, reach length should be 10 times the wetted channel width (Lamberti & Gregory 1996), but especially with the single-point collection method, it is worth running preliminary experiments to determine the most appropriate length.

2.2. Equipment and Material

- Collect and air-dry recently fallen *Gingko biloba* leaves. Store groups of 100 leaves.
- Alternatively, use 3 × 10 cm plastic strips. Different kinds of flexible plastics can be used. Select the one behaving similarly to the most abundant riparian leaf species in the study area. Store in groups of 100 strips.
- Stop net (1—2 cm mesh-size) per reach, wider than the stream channel
- Measuring tape
- Rope to tie the stop net to trees or other features
- Current meter
- Measuring stick and ruler

3. EXPERIMENTAL PROCEDURES

3.1. Field Procedures

1. The day before the experiment, soak the leaves overnight in water to give them neutral buoyancy.
2. Block the downstream end of the reach with the stop net.
3. Standing in the upstream end of the reach, release leaves or plastic strips one by one into the water. One hundred leaves are normally enough for first-order reaches, 500 for third-order reaches. Larger numbers are necessary with the single-point collection method.
4. Allow the stream to disperse leaves for one hour.

3.1.1. Multiple-Point Collection:

1. Extend measuring tape along the reach.
2. One hour after release, recover leaves that reached the stop net. Keep the net in place. Record the number of leaves.
3. Walking upstream from the net, recover all leaves. Record to the nearest metre (5 m in reaches >100 m) the distance travelled by each leaf.
4. For more exhaustive analysis, record the structure retaining each leaf (e.g. pool, riffle, channel margin, wood piece, roots, debris dam, boulder, gravel, sand).
5. After recovering all leaves, remove the stop net.

3.1.2. Single-Point Collection:

1. One hour after release, recover and count the leaves that reached the net.
2. With either method, measure stream discharge after the retention experiment.
3. Additional information of interest may be channel gradient, average width and depth, bank slope, area covered by riffles and pools, or area covered by different substrate categories (sand, gravel etc.). Of particular significance is the abundance of woody debris, as it is one of the most retentive structures found in stream channels.

3.2. Calculations

1. The number of released leaves in transport is plotted against travel distance and the data are fitted to the exponential decay model (Young et al. 1978):

$$L_d = L_0 \cdot e^{-k \cdot d} \qquad (2.1)$$

2. In the single-point collection method, L_d is the number of leaves recovered at the net, L_0 is the number of leaves released, d is the distance in metres between the release-point and net, and k is the instantaneous retention rate, which is independent of reach length and number of released strips.
3. In the multiple-point collection, L_0 is the total number of leaves recovered (which should be close to the number released), and L_d the number of leaves still in transport at distance d. This is calculated by subtracting the number of leaves retained between release point and distance d from the total number of leaves recovered in the experiment.
4. Calculations can be made with any standard statistical software or a calculator. Exponential regressions are calculated by first linearizing the data by applying the natural logarithm, and then calculating the linear regression. Alternatively, and more accurately, non-linear curve-fitting may be used (see Chapter 6). The slope of the regression is the instantaneous retention rate.
5. Calculate the average travel distance as $1/k$ (Newbold et al. 1981).
6. Analysis of covariance (ANCOVA) or other approaches (see Chapter 6) can be used to test for statistically significant differences between slopes. When the multiple-point collection is chosen, the percentage of leaves retained by different channel structures can also be calculated.
7. Additionally, the relative retention efficiency of each substrate structure can be determined. To do this, simply divide the percentage of strips retained by a given structure by the percentage of wetted streambed area covered by the same structure.

4. REFERENCES

Bilby, R.E. & Likens, G.E. (1980). Importance of organic debris dams in the structure and function of stream ecosystems. *Ecology*, 61, 1107-1113.

Canhoto, C. & Graça, M.A.S. (1998). Leaf retention: a comparative study between two stream categories and leaf types.*Verhandlungen der Internationalen Vereinigung für Limnologie*, 26, 990-993.

Cummins, K.W., Wilzbach, M.A., Gates, D.M., Perry, J.B. & Taliaferro, W.B. (1989). Shredders and riparian vegetation. *BioScience*, 39, 24-30.

Díez, J.R., Larrañaga, S., Elosegi, A. & Pozo, J. (2000). Effect of removal of wood on streambed stability and retention of organic matter. *Journal of the North American Benthological Society*, 19, 621-632

Ehrman, T.P. & Lamberti, G.A. (1992). Hydraulic and particulate matter retention in a 3rd-order Indiana stream. *Journal of the North American Benthological Society*, 11, 341-349.

Lamberti, G.A. & Gregory, S.V. (1996). Transport and retention of CPOM. In: F.R. Hauer & G.A. Lamberti (eds.), *Methods in Stream Ecology* (pp. 217-229). Academic Press. San Diego.

Larrañaga, S., Díez, J.R., Elosegi, A. & Pozo, J. (2003). Leaf retention in streams of the Agüera basin (northern Spain). *Aquatic Sciences*, 65: 158-166.

Lohman, K., Jones, J.R. & Perkins, B.D. (1992). Effects of nutrient enrichment and flood frequency on periphyton biomass in northern Ozark streams. *Canadian Journal of Fisheries and Aquatic Sciences*, 49, 1198-1205.

Mathooko, J.M., Morara, G.O. & Leichtfried, M. (2001). Leaf litter transport and retention in a tropical Rift Valley stream: an experimental approach. *Hydrobiologia*, 443, 9-18.

Newbold, J.D., Elwood, J.W., O´Neill, R.V. & VanWinkle, W. (1981). Measuring nutrient spiralling in streams. *Canadian Journal of Fisheries and Aquatic Sciences*, 38, 860-863.

Pozo, J., González, E., Díez, J.R. & Elosegi, A. (1997). Leaf litter budgets in two contrasting forested streams. *Limnética*, 13, 77-84.

Prochazka, K., Stewart B.A. & Davies, B.R. (1991). Leaf litter retention and its implications for shredder distribution in two headwater streams. *Archiv für Hydrobiologie*, 120, 315-325.

Raikow, D.F., Grubbs, S.A. & Cummins, K.W. (1995). Debris dam dynamics and coarse particulate organic matter retention in an Appalachian Mountain stream. *Journal of the North American Benthological Society*, 14, 535-546.

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

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

Young, S.A., Kovalak, W.P. & Del Signore, K.A. (1978). Distances travelled by autumn leaves introduced into a woodland stream. *American Midland Naturalist*, 100, 217-222.