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Leaf processing in streams and lakes of central Italy: role of some environmental factors

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Ecologia. — *Leaf processing in streams and lakes of central Italy: role of some environmental factors.* Nota di ALBERTO BASSET e LORETO ROSSI, presentata (*) dal Socio G. MONTALENTI.

RIASSUNTO. — Questo lavoro ha come oggetto una analisi comparativa dei processi di decomposizione del detrito vegetale in due ambienti d'acqua dolce dell'Italia centrale: il lago di Vico ed il suo emissario Rio Vicano.

Pacchi di foglie di faggio e di steli di giunco furono immersi, nell'ottobre 1981, nella zona litorale del lago di Vico e nel primo tratto del suo emissario. Ad intervalli successivi di 10 gg. venivano determinati temperatura dell'acqua e velocità di corrente, peso secco e contenuto in ceneri del materiale vegetale, numero e biomassa degli invertebrati presenti sui pacchi.

I risultati evidenziano in primo luogo differenze nella velocità dei processi decompositivi tra i due ambienti studiati. Sia i pacchi di faggio sia quelli di giunco vengono infatti decomposti nel lago di Vico più lentamente che nel Rio Vicano. I risultati suggeriscono inoltre che la differenza nella velocità dei processi decompositivi tra lago e fiume: 1) sia dovuta all'azione dei fattori biotici (microorganismi e detritivori bentonici) più che a quella dei fattori abiotici e 2) corrisponda a differenze nel ruolo svolto dalle due principali classi di organismi coinvolte in tale processo (microorganismi e detritivori). Infatti, mentre nei fiumi sembra che almeno il 20–30% del detrito vegetale sia decomposto dagli sminuzzatori bentonici o « shredders », i risultati ottenuti permettono di stimare che nei laghi gli « shredders » decompongano meno del 10% del detrito disponibile; la decomposizione del restante 90% sembra dovuta principalmente ad attività microbica.

1. INTRODUCTION

The early studies on decomposition processes in aquatic environments regarded streams more than lakes (Kaushik and Hynes, 1971; Petersen and Cummins, 1974). In fact, streams were considered eterotrophic systems, processors of organic materials, while lakes were considered chiefly autotrophic.

The importance of decomposition processes in lakes has been only recently emphasised. Now we know that plant detritus decomposition in lakes constitutes: 1) an important source of energy; 2) a source of nutrient for pelagic production; 3) a regulative mechanism for sediment deposition on lake bottoms.

Detritus processing in freshwater results from two successive steps: a first step of leaching, directly affected by abiotic factors, and a second step of biological decomposition when plant weight loss is primarily due to microbial

(*) Nella seduta del 24 novembre 1984.

and invertebrate activity (Reice, 1974). It seems, moreover, that detritus decomposition is greatly affected by eutrophication processes.

As regards streams, much evidence suggests that the invertebrate activity regulates the rate of detritus processing (Petersen and Cummins, 1974; Iversen, 1975; Pidgeon and Cairns, 1981); on the other hand, the importance of microorganisms, invertebrates and abiotic factors on decomposition rates in lakes is not yet clear. Furthermore, some authors observed that the rates of plant decay generally differ between streams and lakes (Witkamp and Frank 1969; Hodkinson, 1975; Gasith and Lawacz, 1976; Webster and Simmonds, 1978; Cummins, in Saunders 1980); however, it is not known if such differences are due to abiotic (Hodkinson, 1975) or biotic factors (Gasith and Lawacz, 1976) or both.

The subject of this paper is the comparative study in lakes and streams of both the decomposition processes and the role of benthic invertebrates in plant decay. We have studied the first processing stages (reduction of large plant material to < 0.1 mm particles) and the invertebrate colonization of *Fagus silvatica* and *Juncus conglomeratus* leaf packs in the littoral of Lake Vico and in the stream Rio Vicano which flows out of the lake. Both biotopes are at present in oligotrophic conditions.

SITES OF STUDY

The study was carried out in autumn 1981 in 5 stations at Lake Vico and in 2 at the Rio Vicano, 50 m and 100 m downstream from the lake.

Lake Vico is a small volcanic lake (perimeter $= 16.9$ km, area $= 12.1$ km^2, mean depth $= 21.5$ m). It is situated in the Cimini Mountains (Central Italy) at an altitude of 500 m a.s.l. The vegetation of the volcanic cone is characterized by beech woodlands; the emergent macrophyte communities are essentially constituted by *Juncus* and *Phragmites*. Recent studies on the physicochemical and biological features of the lake have proved that Vico is still an oligotrophic and undisturbed lake (Carollo *et al.*, 1974; Cordella, 1981).

The stream Rio Vicano is an effluent of the lake and it is part of the catchment basin of the river Tevere. In the study sites the stream is about 3 m wide and 80 cm deep. Current velocity, determined at 10 d intervals, ranged from 10 to 30 cm/sec. The water temperature, which also was assessed at 10 d intervals in both biotopes, ranged from 21.5 to 16.5 °C remaining always 2-3 °C higher in the lake.

MATERIALS AND METHODS

The study was performed using the leaf-pack technique (Petersen and Cummins, 1974). Beech leaves and *Juncus* stems were collected; the *Juncus* stems were cut in 10 cm-long pieces and then all the plant material was oven-dried at 60 °C for 72 h and weighed in 7.0 gr monospecific lots. Beech leaves of each lot were tied together by their stalks to form a pack and a similar procedure was used for the *Juncus* packs. The mean ash contents of the packs was assessed by the combustion of 20 packs per plant species in a muffle furnace at 600 °C for 5 h.

In October 1981, 50 beech and 50 *Juncus* packs were placed 15 cm deep on each station bottom. At 10 d intervals a sample of 10 packs per species was collected from each station. The packs were utilized to assess, during the experimental period, the changes in: 1) dry weight and ash contents of plant material and 2) number and biomass of the invertebrates collected from the packs.

The packs were brought into the laboratory in nylon sacks (1 pack per sack); there, they were individually washed more than once with well water to remove both organic and inorganic sediments and the invertebrates which colonized the detritus. The macroinvertebrates, which were removed by washing or under stereoscope, were then counted, classified and divided per taxa. The plant material of each pack and the invertebrates collected from the same pack, divided per taxa, were singly oven-dried at 60 °C for 72 h; they were then weighed to the nearest 0.01 mg. The ash contents was then assessed by combustion in a muffle furnace at 600 °C for 5 h.

All the invertebrate taxa were divided into three functional groups according to bibliographic data and stomachal contents: collectors, shredders and predators.

The results reported below are expressed as mean values for each biotope studied.

Results

The rates of leaf pack decay differ significantly between both biotopes and leaf species. Linear regressions, following log transformation, between *F. silvatica* and *J. conglomeratus* weight retained and days of experiment are shown in fig. 1 ($y = -0.0251\,x + 4.551$, $r = -0.985$, $P < 0.01$; $y = -0.0096\,x + 4.160$, $r = -0.977$, $P < 0.01$, in Lake Vico for *Fagus* and *Juncus* litter respectively and $y = -0.0393\,x + 4.679$, $r = -0.968$, $P < 0.01$; and $y = -0.0158\,x + 4.657$, $r = -0.969$, $P < 0.01$ in the Rio Vicano).

Beech packs decay faster than *Juncus* packs both in Lake Vico and in Rio Vicano (fig. 1, Table I); however, the decay rates of leaf packs are always higher in the stream than in the lake (fig. 1, ANCOVA test, $P < 0.01$).

The difference in the weight loss of leaf packs between the two biotopes significantly increases with time ($y = 0.392\,x - 4.260$, $r = 0.850$, $P < 0.05$). In facts, no statistical differences occur between biotopes in the values of k's_{0-10} coefficients which represent the rates of leaching; these rates are 0.0436 and 0.0423 for beech packs and 0.0133 and 0.0116 for *Juncus* packs in the lake and the stream respectively. On the other hand, significant differences occur among k's_{10-50} representing the rates of biological decomposition; these are 0.0227

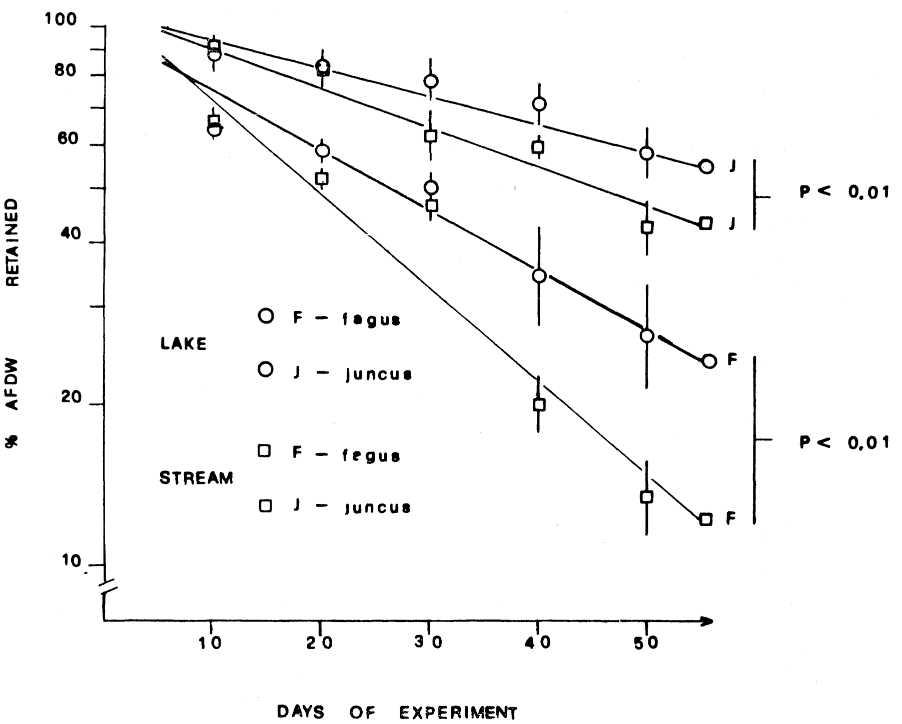

Fig. 1. – Linear regression, following log transformation, for *Fagus silvatica* and *Juncus conglomeratus* weight retained. Vertical bars on circles and squares represent $\pm$ 2 S.E. of mean experimental values. The differences among the slopes of linear regressions were analyzed with the ANCOVA statistics.

TABLE I.

Exponential decay parameters of F. silvatica *and* J. conglomeratus *leaf packs in the two biotopes. The percentual differences between* k^*_s *of stream and of lake are shown* (% Δk^*).

Species	Sites of study	k^*	% Δk^*	k^{**} $t_{0\text{-}10}$	95% C.L	k^{**} $t_{10\text{-}50}$	95% C.L.
F. silvatica . .	Lake	0.0251	36.2	0.0436	0.0012	0.0227	0.0021
	Stream	0.0393		0.0423	0.0008	0.0394	0.0028
J. conglomeratus	Lake	0.0096	39.2	0.0133	0.0019	0.0102	0.0019
	Stream	0.0158		0.0116	0.0012	0.0181	0.0011

k^* = values calculated from the exponential equation $W_t = W_o\, e^{-kt}$

k^{**} = values directly obtained from experimental data $k = -\dfrac{1}{t} \ln \dfrac{W_t}{W_o}$.

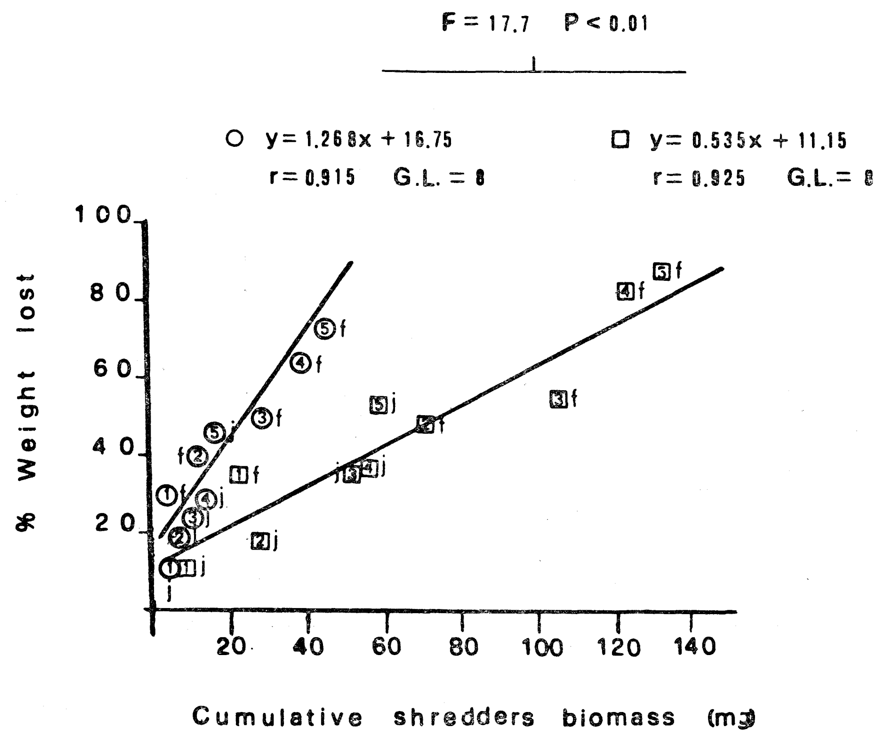

Fig. 2. – Correlation between weight lost (%) and shredders colonization of leaf packs in the stream Rio Vicano (□) and in Lake Vico (O). Eeach point indicates the % weight lost and the cumulative shredders biomass recorded for leaf packs of *F. silvatica* (f) and *J. conglomeratus* (j) at each sampling time (1 to 5). The linear regressions are significantly different (ANCOVA - test, $P < 0.01$).

and 0.0394 for *Fagus* and 0.0102 and 0.0181 for *Juncus* in the lake and in the stream respectively.

The values of pack colonization by benthic invertebrates, particularly by shredders, show quantitative differences which correspond to those observed for decomposition rates. The loss in weight of plant detritus and the shredder biomass collected from packs are two directly related parameters both in Lake Vico and in Rio Vicano (fig. 2). Shredder biomass is in fact higher on beech than *Juncus* packs and in the stream, where it represents 88.8% ± 4.4 of the overall collected biomass, than in the lake, where it accounts for 48.1% ± 5.2 (Table II). However, the pooled linear regression, when all data are analyzed together, has no statistical relevance. The slopes of linear regressions relative to each biotope are in fact significantly different (fig. 2, ANCOVA test, $P < 0.01$).

On the other hand, only small qualitative differences occur between lake and stream shredder " guilds ". Five of the 6 dominant taxa, each representing at least 5% of shredder biomass at each sampling, are common to lake and stream: *Lymnaea sp.*, *Proasellus coxalis*, *Bithynia tentaculata*, *Caenis gr. macrura*, *Planorbis sp.* (Table II). Only one taxa, *Baetis sp.*, is dominant in the Rio Vicano and not frequent in Lake Vico (Table II).

Table II.

Mean invertebrates and shredders biomass (mg AFDW *per pack) and dominant shredders taxa, each representing at least* 5% *of invertebrate biomass at each sampling, collected from* F. silvatica *and* J. conglomeratus *leaf packs. Taxa are ranked according to decreasing biomass.*

	STREAM				LAKE		
	Fagus		Juncus		Fagus		Juncus
« MEAN INVERTEBRATE BIOMASS »	28.87	←	12.93	←	18.33	←	6.39
« MEAN SHREDDER BIOMASS »	26.29	←	11.20	←	9.30	←	2.91
« DOMINANT SHREDDER TAXA »:	*Lymnaea* sp. *Proasellus coxalis* *Bithynia tentaculata* *Caenis* gr. *macrura* *Baetis* sp. *Planorbis* sp.				*Lymnaea* sp. *Bithynia tentaculata* *Planorbis* sp. *Proasellus coxalis* *Caenis* gr. *macrura*		

The arrows are oriented on the higher value ← = $P < 0.05$ (*t* Student' test).

Discussion

The results obtained emphasize: 1) that decomposition rates of plant detritus in Lake Vico are significantly lower than in Rio Vicano, and 2) a more important role of biotic than abiotic factors in the regulation of decomposition processes.

The existence of differences in the rates of decomposition processes between lakes and streams has already been observed by some authors. Witkamp and Frank (1969) proposed in fact decay rates to be intermediate among those in terrestrial and running water biotopes; Cummins (in Saunders, 1980) observed in Michigan a 75% reduction of decomposition rates in a lake with respect to a stream biotope having the same trophic structure of the lake. A rate reduction of decomposition processes in lakes compared to streams has generally been observed also comparing bibliographic and experimental data relative to the two classes of environments (Hodkinson, 1975; Gasith and Lawacz, 1976; Webster and Simmonds, 1978).

The difference in decomposition rates of plant detritus between streams and lakes probably constitutes a rule which is strongly affected by the climatic features of geographic regions, by the trophic state in lakes (Rossi *et al.*, 1983) or by the order in streams (Cummins *et al.*, 1980; Rounick and Winterbourn, 1983). In fact, we observe a higher rate of beech decay in Lake Vico than in streams comparing our results with the bibliographic data referred to *F. silvatica* and *F. grandifolia* decay in streams (Kaushik and Hynes, 1971; Iversen, 1973, '75). This is probably due to the low thermal regime of the biotopes studied by the aforementioned authors (Canada and Denmark) compared to that of Lake Vico (Central Italy). Our hyphotesis is supported by the observations of Pidgeon and Cairns (1981). They have noted that a faster rate of plant decay occurs in temperate regions with respect to northern ones.

Hodkinson (1975) proposed that the difference in decomposition rates between lakes and streams depends on the action of current velocity in running waters whereas Gasith and Lawacz (1976) emphasize the role of micro-organisms and benthic invertebrates. The great difference we have observed (about 38%) between decomposition rates in the lake and in the stream is probably not affected by the peculiar abiotic features of the two biotopes. They really appear similar, the study sites being no more than a few hundred metres apart. We observe only few differences in the abiotic parameters determined in Lake Vico and in the stream Rio Vicano. On the other hand, it is already known that temperature (Petersen and Cummins, 1974) and current velocity (Reice, 1974) have limited direct influence on decomposition rates although they have an important role in the regulation of microbial and invertebrate activity. Therefore, in the present study it has not been possible to emphasize a differential role of abiotic factors on the rates of detritus decomposition in the two biotopes.

The difference in decomposition rates between Lake Vico and the stream Rio Vicano seems otherwise to be highly affected by biotic factors. Decomposition processes do not differ between the biotopes in leaching rates, which are affected by abiotic factors (Reice, 1974), but in the rates of biological decomposition. This is also supported by the direct correspondence observed between decomposition rates of plant detritus and its animal colonization. Moreover, many authors have already shown that the speed of decomposition processes in running waters is regulated by the benthic invertebrate activity (Iversen, 1975; Pidgeon and Cairns, 1981); a reduction in shredder density has often been observed to reduce the rates of detritus decomposition (Rounick and Winterbourn, 1983). Only in rivers or pastureland streams, where shredders constitute a small fraction of the benthic biomass, does invertebrate activity seem not to affect decomposition rates (Paul *et al.*, 1978). It has also been suggested that shredder density is generally lower in lakes than in streams, probably as a consequence of a lower density of detritus dams on lake bottoms (Hodkinson, 1975; Gasith and Lawacz, 1976). So, the linear regression between the weight loss of plant detritus and the shredder biomass (fig. 2) could suggest that the difference in the rate of detritus decay between Lake Vico and the Rio Vicano depends completely on the difference in the shredder biomass which colonizes the detritus. We think, however, that the linear regression overestimates the real animal influence on processing rates in Lake Vico. The statistical difference between the slopes of linear regression relative to the two biotopes supports this point. It may be noted that at the same value of detritus weight loss, there is a much lower shredder biomass in Lake Vico than in the stream Rio Vicano.

We think that the difference between linear regressions indicates a microbial activity increase in the lake despite the fact that we did not actually assess it. In fact, the subtle difference in the thermal regime existing between biotopes, which does not directly affect decomposition rates, can otherwise stimulate the microbial activity in the lake where the temperature is higher. The lack of significant differences between lake and stream species composition of shredder " guild " supports this point. Only quantitative differences occur between the two " guilds ", the stream " guild " having numerical prevalence. Moreover, Paul *et al.* (1978) have already shown that a 7° C increase in water temperature can stimulate the microbial activity and this can result in an increase of decomposition rates. The reduction in shredder biomass between stream and lake could also have caused by itself an increase in the activity of micro-organisms in the lake. It has already been ascertained that micro-organisms and shredders interact as competitors on fast substrates such as beech and *Juncus* in the present research (Barlocher, 1980; Rossi, 1985). The statistical relevance of linear regression between plant weight loss and shredder biomass in Lake Vico probably depends chiefly on the existing relationship among microbial colonization, stage of plant breakdown and shredder distribution (Barlocher and Kendrick, 1981; Basset and Rossi, 1981; Rossi, 1985). So, whereas in streams it seems that at least 20-30% of plant material is processed by invertebrates (Petersen and Cummins, 1974) we can estimate that in lakes less than 10% of plant material is processed by benthic shredders; the remaining 90% is chiefly decomposed by micro-organisms, since leaching accounts for only 15-30%.

We think that our results emphasize an important feature of detritus processing, namely the importance of biotic factors on plant detritus decomposition in freshwater. Results also suggest that differences in mechanisms of decomposition correspond to the differences in decay rates of plant detritus between streams and lakes. The major role of micro-organisms in lakes seems to be the result of physiological responses and competitive interactions rather than a simple consequence of the low shredder biomass colonizing the detritus in such environments.

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