THE PRODUCTION ECOLOGY OF *Ranunculus penicillatus* var. *calcareus* IN RELATION TO THE ORGANIC INPUT INTO A CHALK STREAM

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Summary

The seasonal change in the standing crop of *Ranunculus penicillatus* var. *calcareus* in a section of a chalk stream was measured. The plant is a herbaceous perennial which regrows each autumn and winter. It grows rapidly in the spring, then flowers, this coincides with a decline in the growth rate, and results in a maximum biomass in mid-summer of 200 - 400 g dry weight m^2. After this the plant starts to decompose and the remainder (18%) is washed out in the first autumn rains. Although 10 - 15% of the maximum biomass of the plants is lost, mostly by damage to stems, about half of this is collected on plants immediately downstream and only 7% of the maximum biomass is lost as stems from the stretch. The leaf-fall was about 8.5% of the maximum standing crop and decomposed where it dropped. A decline in the maximum standing crop of the plant is found as a result of not removing the plant in the early summer, as is typical of normal river management to reduce flood risk.

This plant is as important in the organic budget of the chalk stream ecosystem, as terrestial leaf litter. The movement of organic materials from their site of supply or production, and their rate of fragmentation and decomposition, are dependant on the water velocity at the time of supply and the degree to which their movement is restricted by water plants. Surface drainage from land drains and ditches is a major source of material in streams although the degree to which this material was used was not determined.

It is suggested that the ideal system for the smaller chalk streams, reducing management and yet maintaining the level of organic material input, is for low density tree cover e.g. willows, to be

established on the banks of streams. These would restrict the summer growth of plants and therefore reduce flooding or backing-up of water. Winter growth of aquatic plants should be encouraged to help to maintain the organic material production and to retain most of the material near its site of origin for part of the year.

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Pocket folder on back cover has movable species group list with species for use on standard composition of screen material species tables.

1. INTRODUCTION.

A stream ecosystem is characterised by the uni-directional flow of water, nutrients and organic materials. The organic materials are derived from either autochthonous aquatic primary production by macrophytes or algae, or allochthonous debris from the banks of the stream, for example, tree leaves and marginal vegetation. These materials are cycled through animal and bacterial systems before being released to the atmosphere or washed to the sea. This is an open ecosystem, the cycling and re-cycling taking place being continually displaced downstream.

In southern English chalk streams, the dominant plant is the aquatic macrophyte *Ranunculus penicillatus* var *calcareus* (R.W. Butcher) C.D.K. Cook, (Butcher 1933, Westlake *et al* 1972) (refered to as *R. calcareus* for brevity) which is probably a major source of autochthonous material in these streams. Algae can also contribute a significant amount, especially where there are bare patches of gravel. The growth pattern of *R. calcareus* controls and is controlled by the physical system. Physical factors such as flow affect the growth and accumulation of biomass of the plant which in turn gathers silt which then controls the plant growth. Finally the seasonal increase in flow flushes all the material out making space for algal growth.

The aim of the project was to investigate the significance of *R. calcareus* as a primary producer and source of organic material in relation to other organic sources. Factors causing it to be a problem weed in river management were also considered. The object of efficient water weed management is to maintain the water ways free from weed and to keep the risk of flooding to a minimum. If, however, the plant is needed by the system as a source of organic material or as a habitat, then as little as possible should be removed in order to keep the dynamic balance of the ecosystem. Alternatively, if the allochthonous material, from leaf-fall, land drainage and surface run-off is sufficient to supply the needs of the ecosystem then all the aquatic plant could be removed.

2. REVIEW OF LITERATURE.

2.1. Aquatic plants.

There have been many recent discussions on aquatic plants and their role in the aquatic ecosystem, in particular, Sculthorpe (1967) and Hynes (1970).

Definition.

The definitions of an aquatic plant have been reviewed by Sculthorpe (1967). There are two main definitions:

(1) aquatic macrophyte is a term of convenience used by ecologists when referring to the larger aquatic plants, defined as vascular plants, bryophytes and the macroscopic algae,

(2) vascular hydrophyte is a more pedantic term and is defined as solely aquatic vascular plants whose seeds germinate in either the water phase or on the substrate of a body of water, and which spends part of its life-cycle in water.

Classification of communities.

There have been several attempts to classify the communities and individual species of river plants (Sculthorpe 1967). Butcher (1933) classified river communities, primarily by the calcium concentration of the water, and secondarily according to the water velocity. He made a distinction between rivers rising among mountains and those rising from

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Footnote.

1. This review of literature is intended to cover work up to the early part of 1973, and includes references to the author's published work and acknowledged contributions in his colleagues' papers, which will be also included in the discussion of the thesis.

2. This review is, unfortunately, biased in favour of papers in English (American), French and German, to the almost exclusion of papers in Russian, etc., with Russian only abstracts.

hills and springs. Hynes (1970) gives a modified version of this classification but considers it still an oversimplification, because no account is taken of differences between sizes of stream, or of the great variety of plants occurring on the banks of some rivers. The Rivers Piddle and Frome in Dorset, according to Butcher's system, would be considered as highly calcareous rivers, rising from springs and from hills and dominated by *Ranunculus pseudo-fluitans* (*R. calcareus*)with *Apium nodiflorum* and *Sium* (*Berula*)*erectum* in the fastest stretches, by *Hippurus vulgaris* and *Sparganium simplex* (*erectum*) in gravelly stretches with medium current and *Elodea canadensis* and *Callitriche stagnalis* in the slow flowing stretches. This classification is similar to that of Schmidt (1961).

Haslam (1971) has emphasised that the distribution of macrophytes in British water courses is greatly affected by many physical, chemical and biotic factors, not the least of which is management and any of which may be of overriding importance. She comments that the presence of a water plant shows that it can at least tolerate the prevailing levels of these factors, but she emphasises that the presence of a plant is more interesting than its absence, because this may be due to accident, for example, recent dredging or to pollution.

Westlake (1973) has suggested a hierarchy of limiting factors for aquatic macrophytes perhaps ranging from those which are more or less constant temporally for example, aspects of water chemistry, or spatially for example, insolation, to those which change markedly over short distances, for example, water velocity, or rapidly with time, for example, instantaneous solar irradiance. He considers that the water velocity is probably the most important factor affecting plant communities in rivers but comments that it is not clear whether the effects are direct through the physical control of establishment, physical damage or on the physical effects on the rates of metabolism, or indirectly through the effects of water movement on the substratum or fauna. There is little data on the effects of varying conditions of flow on the establishment of plants. He comments that *Rorippa nasturtium-aquaticum* can only develop near banks or where dense banks of other plants reduce the flow enough for seedlings or drifting pieces to take root. Sirjola (1969) considered the current tolerance of plants and found that the most evident ecological factor was the pull and turbulance exerted by the current. He gave the characteristics of a plant able to withstand high flow rates and turbulant water as having a rapidly growing and strongly developed subterranean system, the ability to develop adventitious roots from its nodes and a strong flexible shoot which does not resist the current.

The local seasonal variations in the distribution of plants have been considered by several authors and their observations are summarised in Hynes (1970), and Ladle and Casey (1971). Aquatic plants form open communities because of the instability of the plants themselves; a shoot when settled and attached produces a local reduction in current leading to the deposition of materials, which in turn leads to a build up of a sediment bank held together by adventitious plant roots. The water is diverted into channels between the sediment banks, increasing the errosive power of the water. In chalk streams these banks are subjected to an annual increase in discharge of about a factor of ten (Westlake et al 1972) which washes away the sediment bank completely leaving only the plants whose roots have spread out in the firm bed of the stream where the channels had been previously. (Ladle and Casey 1971).

The *individual species of macrophytes* have been classified in several ways, for example, den Hartog and Segal, (1964),classified plants by growth forms ranging from the firmly attached haptophytes such as *Fontinalis antipyretica* or members of the Podostemaeae and Hydrostychaceae found in fast flowing waters to pleustohalophytes such as *Eichhornia crassipes*,in very slow moving waters. The marginal vegetation of streams is normally composed of helophytes, Westlake, (1973), but of more restricted range than that found in lakes. In the summer there is often characteristic weak-stemmed, adventitiously-rooting dicotyledonous plants such as Rorippa nasturtium-aquaticum extending from the margins in shallow water or growing over other aquatic plants such as Ranunculus spp.

Olsen (1950) in order to emphasise another aspect of the complexity of factors involved in plant distribution classified individual plant species on the basis of the chloride content of the water in which they were found, The range of a species could be within the range from acid, although oligotrophic and eutrophic to brackish and sea-water.

The geographical distribution of aquatic plant species is influenced by the general level of temperature in the climate and particularly in the plants found at the margins of streams by the occurence of frosts. (Westlake 1973).

There have been several plant surveys of rivers; that of Whitton and Buckmaster (1970) being fairly typical. The 80 km of the River Wear was divided into 0.5 km sections and the species composition within each recorded.

The light regime.

The quantity and quality of incident light at the surface of the earth has been discussed by many authors, for example, Collingbourne, (1966), and Monteith, (1972). The light falling on the surface water of a stream not shaded by vegetation or by the banks, is reduced by reflection at the surface, by attenuation within the water and by the quantity of dissolved and suspended material present, before it reaches the plant. It undergoes a change in spectral composition with the type of shading that is present. (Westlake 1966 and 1973, Cumming 1963).

Self-shading is often very important because the biomass of plants in chalk streams can reach 25 kg fresh weight m^{-3}. (Edwards and Owens 1960). A plant growing under 1 m of clear river water receives about 50% of the incident visible irradiance because of attenuation of light by the water itself (Westlake 1966). The main factor in reducing light in rivers is turbulance as it suspends material which reduces light penetration. Many rivers have coloured water derived from leaching and erosion in the drainage basin, or from pollution, which also reduces light penetration. Conditions where only 1% of the surface irradiance reaches 1m are common and in many large rivers it may be negligible at 1 m. (Westlake 1966). The changes in the spectral distribution of irradiance at 1 m deep, relative to the sub-surface value, have been studied in detail by Spence <u>et al</u> (1971). The blue-green water of Loch Croispol in Scotland favoured the short wave-lengths while the converse was the case in the peaty brown water of Loch Uanagan. They also showed a significant increase in the ratio of red (660 nm) to far-red (730 nm) light from 1.3 to 4.5 at 1 m underwater; this wavelength ratio is responsible for photomorphogenic effects.

Plant growth.

In water of known nutrient and carbon substrate concentration, river plant growth in chalk streams is influenced, both spacially and temporally, by a series of limiting factors, light, flow, temperature and oxygen, any of which can dominate. The general environmental limits of plants in flowing waters are discussed by Whitton (1972).

The effect of flow on plant growth.

Photosynthesis and respiration of plants is affected by the rate of passage of water past them. Owens and Maris (1964) found a marked difference between respiration rates of hydrophytes in stirred and non-stirred chamber experiments. Westlake (1966) showed that, in laminar flows, typical of the littoral regions of lakes and rivers and probably those within dense weed beds, there was a significant decrease in photosynthesis and to a lesser extent respiration below 0.4 mm sec^{-1} in air saturated water;

the decrease was even more marked at low oxygen concentrations for Ranunculus pseudo-fluitans (R. calcareus). He discussed the ranges of water velocity found by other workers, for example, of the order of 10 mm sec^{-1} for weed beds and for wind-induced seiches and eddies in lakes. The usual theory for explaining the decrease in photosynthesis and respiration caused by a decrease in velocity is that the transfer of carbon source or oxygen to the plant is impeded by the extremely slow rate of diffusion of the substrates across the boundary layer or shell of stagnant water around plant's leaves. A physical rate-limiting process e.g. diffusion, was indicated because the temperature coefficient, Q_{10}, for light saturated photosynthesis experiments was 1.4 instead of the normal value of around 2. Westlake (1973) suggests that R. calcareus requires fast flowing hard waters because it has a high growth rate which can only be sustained by a clear water with a high concentration of available carbon. The latter is maintained close to the leaves by the high velocity reducing the boundary layer thickness.

The effect of temperature on plant growth.

The rates of respiration and photosynthesis increase with increasing temperature. Owens and Maris (1964) found temperature coefficients for respiration of 1.3 - 3.5 within a range of 10 - 20 °C for four river hydrophytes. Measurements were made in static and agitated water in respiration chambers, the oxygen concentration was determined using a polargraphic method. Westlake (1967) found an increase in photosynthesis with temperature, which had a temperature rate coefficient (Q_{10}) indicative of a diffusion rather than reaction rate. Owens and Maris comment that the acceleration of the respiration rate diminishes as higher temperatures are reached.

The effect of oxygen on plant respiration.

The concentration of oxygen in water is in equilibrium with the atmosphere by diffusion. This equilibrium value is refered to as 100% saturation; the maximum value to which water in equilibrium with pure oxygen could reach, is about 400% saturation, when compared to the air equilibrium. The concentration is reduced by the respiration of animals and plants and is increased by plant photosynthesis during daylight. The diffusion rate of oxygen across the air-water interface is very slow and this leads to a diurnal change in oxygen concentration in the water of lakes and rivers especially when plants are abundant. The normal pattern is for the oxygen concentration to start to rise in the early morning, reaching a maximum in the afternoon and falling steadily during the night as the plants change to exerting an oxygen demand on the water e.g. Edwards and Owens (1962).

The rate of respiration of hydrophytes increases with the oxygen concentration of the water up to 200% air saturation at 15 - 20 °C and in some species up to levels approaching 400%. However, the relative effect can be decreased to some extent by increased water velocity or agitation. (Gessner and Pannier 1958). Owens and Maris (1964) found that the relationship between oxygen consumption of the plant and the oxygen content of the water could be described by the equation: $R = a\ C^b$ where, R is the rate of respiration per unit dry weight per hour, C is the dissolved oxygen concentration and a and b are constants.

The mean oxygen consumption rates for R. pseudo-fluitans (R. calcareus) at 20 °C and 100% is given by Owens and Maris as 1.4 mg g^{-1} dry weight h^{-1}. for whole plants with a slightly higher value for excised shoots; most of their work is based on the latter. Westlake (1967) presents similar results but used a more elaborate respiration chamber. The respiration values change between 0.5 and 0.7% per percent change in oxygen concentration around the 100% saturation value at 15 °C. McDonnell (1971) studied the respiration rates of Elodea canadensis and Potamogeton crispus and found that they varied seasonally with the state of maturity of the plants.

The importance of lacunal oxygen supplies in meeting the needs of aquatic macrophytes in times of stress has been established. (Hartman and Brown 1967).

Standing crop.

The methods of measurement of standing crops or biomass of aquatic macrophytes are discussed by Westlake (1965) and Vollenweider et al (1969). Standing crops may also be measured by the integration of instantaneous production rates from, for example, oxygen or carbon dioxide balances. (Owens 1969 and Odum 1956). The history of methodology for primary production methods is reviewed by Wetzel (1964).

The seasonal maximum biomass of aquatic plants in streams and rivers has been reported by several authors, for example, Edwards and Owens (1960), gave a figure of 520 g dry weight m^{-2} for a chalk stream, the River Ivel. This crop increased from 160 to 520 g m^{-2} between June and September 1958 and was composed of typical chalkstream species. Odum (1957), records a crop of 809 g dry weight m^{-2} for *Sagittaria subulata* in Silver Springs, Florida; this however included a crop of 190 g dry weight m^{-2} of epiphytes. Westlake (1963) has compared the standing crops and productivities of many aquatic and terrestial systems. He characterises aquatic systems of temperate regions as relatively poorly productive, even on fertile sites, (about 6 mt. ha^{-1}) compared with terrestrial sites.

The production of aquatic plants.

The production of an aquatic plant is generally given as the net production over a defined season or a year. Net production can be obtained from the observed change in biomass, (Westlake 1963, 1965), if there are no losses from the plant and excluding, of course, respiration.

The maximum biomass in many aquatic macrophyte communities is the most generally useful parameter of production because there are few losses of the current years production before the maximum is reached. (Westlake 1965).

During production determinations by change in biomass, observations of the growth cycles and phenology of all parts of the plant must be made. (Westlake 1969). Borutskii (1950) measured the numbers, lengths and weights of dead and living stems, leaves, branches and buds, and, assuming that the total loss during a year was equal to the annual production, tried to determine the losses of biomass. Another problem in production studies may be the proportion of old growth carried over from the previous season or seasons, particularly rhizomes, which may persist for several years. Mann et al (1972) have taken the production of Acorus calamus and Nuphar lutea in the River Thames, near Reading, by adding the weight of the dead leafy material to the difference between the minimum and maximum standing crops, and gave a value of 1.1 kg dry weight m^{-2}.

Bernatowicz (1969) has discussed the losses from various plants, noting that they may range from 2 - 10% of the final biomass during the vegetative period,(Borutskii 1950), to very much higher values and can reach 20 - 50% of the maximum biomass. (Forsberg 1960 and others reviewed in Westlake 1965).

Another source of loss needed for the production estimate is the excretion of dissolved organic compounds, which is not so apparent for freshwater macrophytes, but, for example, in sea weeds can be 20 - 40% of the gross production. (Khailov and Burlakova 1969). Wetzel and Manny (1972) give a mean value of 4% of the net production as the loss of dissolved organic compounds, with a range of from 1 - 10%, for the submerged macrophytes (Najas flexilis) of Laurence Lake, Michigan. The carbon to nitrogen ratio was 11.4, indicating about 0.3% of the net production was lost as dissolved organic nitrogen.

Effect of biomass on oxygen balance.

Several papers have been written describing the oxygen balance in rivers, its production by plants (Edwards and Owens 1962) and the respiration of muds. (Edwards and Rolley 1965).

Westlake (1966 b) describes a graphical model for the hourly or daily production and consumption of oxygen by aquatic weeds in streams. The model is based on the weight of weed, its photosynthetic characteristics and some physical data about the stream. The results are not precise but are a good approximation to what is expected. A subsequent paper by Owens et al (1968) expands this approach to a particular situation in an attempt to predict the dissolved oxygen changes in the River Ivel, a shallow chalk stream. Edwards (1968) has discussed the effects that waterweeds have on rivers with reference to their uses as oxygenators. The control of water weed is expensive(£1 - 3 M)and it is undertaken mainly for flood relief control. He considered the case, that if the weed were not removed and the effect was simply of doubling the depth and halving the velocity, for typical mud and plant respirations there would be a considerable reduction in oxygen concentration, Surface diffusion of oxygen into the water, is directly related to the water depth and velocity. Weeds also collect debris and this increases the oxygen consumption. However, plants provide increased surface area for bacteria and the oxidation rate of organic substances is greatly accelerated. They are the most important sites for oxidation, despite the increase caused by accumulated mud. In the River Ivel, an unpolluted chalk stream, plants supply and utilise most of the oxygen. Therefore, when the removal of plants is necessary, for example, flood relief control, they should be cropped uniformly from the area of stream. In situations where the optical density of the water is such that little light penetrates to the river bed it is necessary to remove more plant. The result is an increase in the reaeration of the water by increasing the water velocity, and maintainance of the plants near their maximum photosynthetic oxygen production rate. (Edwards 1968 and Westlake 1966 b).

In the 'natural' situation, where water weeds are not removed, their effect in the autumn when they decay puts a very substantial demand on the oxygen balance of the system, which often results in very low oxygen concentrations in slow flowing rivers. (Edwards 1968).

Effect of biomass on flow.

The biomass of plants, affects the hydraulic characteristics of a river; for instance, the Chezy - Manning coefficient, a resistance coefficient reflecting the backing-up of water, can be changed in a small river by a factor of 4 - 6 between the time of bare gravel and of dense weed. (King and Brater 1963).

Hillebrand (1950) studied the hydraulic effects of aquatic plants, in particular Ranunculus fluitans, during the growing season for several years in the River Eder, in Germany. He considered that the hydraulic coefficients normally used considerably underestimated the effect of weeds in rivers. The plant population may occupy from 1 - 4% and rarely up to 10% of the total volume of a river, but this density of plants is known to reduce the maximum velocity of the current to less than 75% of that in uncolonised areas. At the same time they can cause the water level to rise at a rate of more than 1 cm day^{-1} and to reach a height as much as 80 cm above the normal level.

There have been no studies reported relating seasonal changes in biomass to the Chezy - Manning, or other hydraulic coefficients.

Sediment.

The increase of plant biomass increases the accumulation of sediments. (Ladle and Casey 1971). The organic fraction of sediments plays a part in the respiration of the stream and also a somewhat unknown part in the supply of nutrients to plants associated with them.

2. 2. Water Chemistry and Nutrients.

The limiting nutrients in most rivers are likely to be the macro-nutrients of plants, carbon, nitrogen, phosphorus or potassium. Iron deficiences are not apparent, as would be expected at the pHs of 7.5 - 8.5, but little is known about its concentration and supply in rivers, (Westlake 1973). The ratio of materials needed, is roughly 250 Carbon: 20 Nitrogen: 15 Potassium: 1 Phosphorus, but except in low calcium water, carbon is often in greater relative concentration (Westlake 1973). The source of nutrients is related to the chemistry of the water and the sediments, and to their relative rate of movement and the physical surroundings of the plants. In general these nutrients are concentrated, many thousands of times, especially from the poorer lake waters by plants. (Forsberg 1960).

The chemistry of two southern chalk streams is given by Casey (1969) but a more detailed study of the River Frome and its main tributaries is given by Casey and Newton (in press). The annual mean values of chemical data varied with mean annual flows ranging from 0.07 - 5.2 m^3 sec^{-1}. (Table 2.1.).

Table 2.1.

The chemical composition of River Frome and its tributaries, based on mean annual values.

pH	7.8	-	8.3	
alkalinity	4.2	-	4.7	meq l^{-1} HCO_3
Calcium	105	-	120	mg l^{-1}
Magnesium	3.6	-	5.6	mg l^{-1}
Sodium	8.5	-	10.1	mg l^{-1}
Potassium	1.1	-	2.7	mg l^{-1}
Phosphorus	42		197	µg $PO_4 - P\ l^{-1}$
Nitrogen	1.3	-	2.7	mg $NO_3 - N\ l^{-1}$

One of the main tributaries, Sydling Water, in which the phosphate was reduced to 9 μg l^{-1} in April and May while potassium was not detectable is excluded from this table (2.1.); this situation was probably due to low flows and large amounts of weed growth.

The annual production of weed, mainly R. calcareus, in the River Frome, 43 km between Dorchester and the sea, was calculated by Westlake (1968) as 209 Mg dry weight y^{-1}. This weed would require 11 Mg y^{-1} of nitrate-nitrogen (2% of the total passing) and 0.5 Mg y^{-1} of phosphate-phosphorus. The phosphate-phosphorus and potassium levels vary greatly and are generally related to the use of fertilisers close to the rivers or in commercial cress beds. (Westlake et al 1972). At a site close to the study area, Bere Heath, (see section 3.3.) an even smaller proportion of the nutrients nitrogen, phosphorus and potassium was accumulated by the plants. (Ladle and Casey 1971). Peltier and Welch (1969) found a similar situation in the River Holston, and suggest that the biomass of aquatic plants was limited to the amount of light reaching the plants because of turbidity and attenuation of light in the water.

The source of nutrients in chalk streams are springs and land drainage, that is, indirect and direct run off from the land; calcium carbonates are supplied by dissolution of chalk hills. (Westlake et al 1972). Crisp (1970) records the remarkable stability in composition of elements in the spring water from a chalk bore hole, or spring, near Bere Heath. (Table 2.2.) Phosphorus varied more than the other elements but Crisp suggests that this is due to the use of fertiliser near the bore hole.

Table 2.2.

Nutrient concentrations in spring water, Doddings Farm, Bere Heath.

	mg l^{-1}		mg l^{-1}
Potassium	0.87 ± 0.027	Nitrogen	3.70 ± 0.12
Phosphorus	0.001 ± 0.0015		

Cooke and Williams (1970) discussed the relative importance of nutrients from farm land, by drainage water percolating through soil , by keeping animals in the proximity of water-courses and by the influx of nutrients as particles, by wind or water action. The role and fate of nitrogen and phosphorus in flowing waters have been discussed by several authors. (Kemp 1968, Stake 1967, 1968).

Nutrient uptake by plants.

There are two possible sites for the supply of nutrients to aquatic plants, the water and the bottom substratea. Denny (1972) points out that there is a distinction between the evidence for and the proof of the type of conclusion drawn in particular by Pearsall (1920). Pearsall concludes that the correlation found between the distribution of the plants and the soil or sediment-type, and not with the lake water-type, indicates that plants must obtain their nutrient requirements from the soil through their roots. Spence (1964) found that in a survey of Scottish lakes, associations based on ranges of calcium carbonate, showed that only half conformed to this species/soil grouping of Pearsall. Denny (1971) found a similar lack of agreement for a lake in Uganda.

Denny (1972) found in an experiment with the rootless species *Ceratophyllum demersum* and the rooted species *Potamogeton thunbergii*, grown on mud and sand substrates, that nutrients, as measured by increase in biomass, may enter through either roots or shoots. Depending on the conditions, nutrients can enter solely through either roots or shoots. In laboratory experiments Bristow and Whitcombe (1971), have shown that in the long term (10 days) more nutrient was derived from the rooted lower half, rather than from the upper parts of complete shoots for several aquatic plants. They noted, however, that the non-rooted half was able to take up nutrients more rapidly, in 1 hour experiments, but did not continue to do so for long periods. The uptake rate has generally been over-estimated by shoot experiments and the long term uptake is generally low as was found by Mulligan and Baranowski (1969). They found relatively low nutrient uptake rates for several mixed and pure cultures, of algae and hydrophytes, in long term experiments. McRoy and Barsdale(1970) have shown that with eel grass *Zostera marina*, phosphate could be taken up by either shoots or roots. The uptake was greatest in the light. Phosphate taken up by the roots could be transported through the leaves and returned to the water. Spence *et al* (1971) also found that shoots and roots were able to take up nutrients but there was no subsequent release of nutrients by the four species studied.

There have been studies relating the growth of aquatic plant species with nutrients, nitrates for example were studied by Misra (1938). Goulder and Boatman (1971) showed that the distribution of *Ceratophyllum demersum* is influenced by nitrate and that it requires high concentrations for at least part of the season.

Chemical Composition of plants.

The need for basic data, in particular the chemical composition of organisms, in ecological investigations, has been emphasised by Lund (1964) and by Westlake (1965). The available data for aquatic macrophytes has been reviewed by Boyd (1967 and 1970), Straskraba (1966) and Westlake (1965). Boyd (1970) points out that, though there have been several papers dealing with chemical analyses but they have been mainly concerned with nitrogen, phosphorus or proximate analyses, with little information on levels of minerals, the other macro and micro nutrients, and almost nothing regarding the concentrations of pigment, of protein or of carbohydrates. A study on the main macro- nutrients and micro-nutrients of six submersed, four floating and eight emergent plants, was undertaken by Boyd (1970) on plants from Par Pond, South Carolina. No correlation was found between the macro-nutrient concentration in *Eichhornia crassipes* and the environmental levels at many sites, even though it dominates many aquatic ecosystems.

Bernatowicz (1969) after measuring and analysing the biomass, considered the plants of Lake Warniak, Poland, to contain such large quantities of nutrients in their tissues, as to significantly influence the nutrient circulation in overgrown waterbodies.

Crisp (1970) reported that mature water-cress *Rorippa nasturtium-aquaticum*, a typical stream emergent plant, but taken from a commercial cress bed, had 4 - 6% nitrogen, 2 - 5% potassium, 0.6 - 0.8% phosphorus, 0.6 - 0.9% sodium, 1.5 - 2.5% calcium. 0.15 - 0.20% magnesium and 0.02 - 0.6% iron of the dry weight when harvested. The roots were significantly richer in calcium and iron, whereas the tops were richer in potassium, nitrogen, magnesium, sodium and phosphorus. The relatively higher proportion of iron in aquatic plants rooted in mud has been reported by Oborn (1960).

The nutrient composition, to some extent, increases with increasing environmental levels but the relationship is not clear, as the composition differs seasonally and with the state of maturity. (Stake 1967, 1968 and Gosset and Naris 1971). In *Justicia americana* and *Alternathera philexeroides*, the maximum rate of uptake of mobile mineral nutrients, occurs prior to the time of maximum growth. The greatest quantity of nutrients were taken up early and then utilised for subsequent growth. The percentage composition declined as the growing season progressed (Boyd 1970 a).

The encrustation by calcium carbonate and other substances is reviewed by Wetzel (1960).

The nutritive value of aquatic plants has been discussed by Boyd (1969) though their success as green manure may mainly be limited because of their high fresh to dry weight ratio. Some of the species studied by Boyd have relatively high amounts of crude protein, but their chances of use as fodder is again reduced because of the large amounts of water present.

The role of various aquatic plants for the deliberate removal of nutrients from the water has been reviewed by Schwoebel (1968) and Boyd (1970).

The principle underlying such operations is the removal of the crop before significant decomposition has taken place.

2.3. Invertebrate distributions on plants.

The distribution of invertebrates on aquatic plants in chalk streams was studied quantitativly by Harrod (1964). She suggests that the observed difference in populations can be accounted for by the morphological differences between the plants, the periphyton and the chemical nature of the plants and the habits of the animals present. Simuliid larvae were found on *Ranunculus fluitans* and on *Carex* spp.,plants typical of high flows where filter feeders can catch suspended materials passing; Oligochaetes and Molluscs on *Callitriche* spp. and *Veronica* spp.; *Gammarus pulex*, *Hydropsyche* spp. on *Callitriche*.Whitcombe (1963,1965) has also described the distribution of aquatic animals within plants and plant beds.

In general invertebrates eat emergent and floating aquatic plants but probably not the submerged ones to any great extent before they reach the detritus cycle. Smirnov (1961) has reviewed the very variable rates at which insects eat emergent plants. The association of particular species of aquatic plants and their consumers has been reviewed in great detail by Gaevskaya (1966).

2.4. Litter fall.

The amount and composition of the annual litter fall in the forests of the world have been discussed and reviewed by Bray and Gorham (1964). The annual litter production was estimated to be from 330 - 350 g dry weight m^{-2} for deciduous woods in the cool temperate zone, though soil quality and the ages of stands and of species , are important when considering this mean value. Sykes and Bunce (1970) found little variation between years for non-woody litter, 363 - 393 g dry weight m^{-2} , in deciduous woodland growing on a calcareous site in Northern England. Eighty one percent of the total annual litter fell in the period, September to November.

The leaching and decomposition of water soluble substances from different coniferous and deciduous tree leaves was considered by Nykvist (1963). He took samples of just fallen leaves and subjected them to anaerobic leaching for a day at a time, at 25 °C. The anaerobic conditions were to reduce the decomposition and uptake by fungi and bacteria during the experiment. Leaching was complete in most species within five days though a large proportion of the soluble material was lost in the first day. (Table 2.4.1.)

Table 2.4.1.

The loss in weight by leaching (% in 1 day) of some species of tree leaves.

Species	Percentage of dry weight. leached in first day.
Fraxinus excelsior	16.5
Alnus glutinosa	12.0
Betula verrucosa	10.7
Quercus rober	7.1
Fagus silvatica	3.8
Pinus sylvestris	0.9

Similar results were found by Kaushik and Hynes (1971) for North American tree species. Maistrenko et al (1968) found that the leachates of deciduous trees are higher in organic and ammoniacal nitrogen, phosphorus, carbohydrates and amino acids than coniferous ones.

Kaushik and Hynes (1971) in an extension of previous work in 1968 and Hynes and Kaushik (1969), found that the rate of decomposition of Ulmus americana, Alnus rugosa, Quercus alba, Fagus grandifolia and Acer saccharum were enhanced by the addition of nitrogen, and also phosphate. The quality of the water alters the decomposition rate of leaves, possibly by the change in microflora. Fungi were found to be far more important in the initial period of leaf decay than bacteria. They also observed that the calorific value remained unaltered as the leaves decomposed and decreased in weight. The protein content, however, increased during this period and provides a better quality food for growing animals.

The leaves from Alnus tenuifolia are four times richer in nitrogen than other deciduous species and Goldman (1961) found that they increased the general productivity of Castle Lake, California.

The effect of leaf fall on a small forest stream can be extreme (Slack and Feltz 1968). They noted that when leaf fall occured at a time of low flow, the pH changed from 6.8 to 5.8 and the dissolved oxygen fell to near zero towards the end of the end of leaf fall resulting in a fish - kill.

2.5. Allochthonous and autochthonous inputs.

Hynes(1970) has discussed the fact that many workers have shown the ratio between gross primary production and that of community respiration is nearly always less than one, even in summer time (Odum 1956, Odum and Hoskin 1957, - Nelson and Scott 1962, Tominago and Ichimura 1966 and others). This indicates the importance of allochthonous material, supplied from outside the system considered, and generally from terrestial primary production, in any flowing water ecosystem even when it has a large autochthonous production of material.

The importance of allochthonous organic material entering streams was pointed out by Thienemann in 1912, though quantitative studies were not made until after the 1950's. The significance of this source of material has been substantiated by the study of the feeding habits of benthic animals.

The role and fate of leaves in particular has been considered by several authors and is reviewed by Kaushik and Hynes (1971). Mathews and Kowalczewski (1969) considered the input of leaves into a stretch of the River Thames, near Reading, England. They recorded 1.59 kg dry weight m^{-1} of the river bank y^{-1} for a mixed deciduous line of trees. They considered the distribution of leaves as equal on either side of the river bank and collected samples from a line of transects on the river bank and at right angles to it. Szczepanski (1965) found 0.5 kg dry weight m^{-1} of shore line y^{-1} for Mikolajki, Poland, but considered the fall and drift of leaves on and over the lake.

The magnitude of the one way passage of leaves into lakes and streams does not seem to have been studied. There is an undetermined fraction of leaf fall near water bodies which is captured by the water and sinks, this is unlike a forest where leaves can blow about freely. Leaf fall determinations near water tend to be under estimates of the true value.

The disappearance of fresh tree leaf litter was also studied by Mathews and Kowalczewski, using the rate of loss of litter from bags of varying mesh size. The disappearance was considered to be principally due to microbial activity, although significantly different numbers of animals were present. This is however in contrast to observations by Van der Drift and Witcamp (1960) who found that carbon dioxide was produced more rapidly by mechanically fragmented leaves than by whole leaves. Minshall (1968), in a study of a woodland stream in Kentucky, considered terrestrial leaf detritus to be the most important source of plant material eaten by herbivors; Hynes (1963) reached the same conclusion, the importance of such sources because he says generally plants in streams are limited to small particularly favourable areas.

There has been much emphasis on the importance of allochthonous materials especially from forest streams but very little on streams flowing through open or grass land.

The role of terrestrial organic detritus has been studied quantitatively, by several authors working on specific groups of benthic animals and the work is summarised in Kaushik and Hynes (1971). A close correlation was found between terrestrial biomes and the distribution of Tricoptera (Ross 1963). He suggests that this is probably due to the dependence of different species on terrestrial leaf litter as a food source.

Nelson and Scott (1962) found that two thirds of the net production by primary consumers, originated outside the stream. Teal (1957) found that three quarters of the material in a stream, was leaves and twigs produced outside the stream. Cummins et al (1966) found equal proportions of biomass of primary macro-consumers and detrital macro-consumers. Fisher and Likens (1972) found 99% of the input to a section of Bear Brook, New Hampshire, was allochthonous in origin. Half of this was recognisable fragments, leaves and twigs and half was as soluble organic carbon. Mann (1969) describes this type of river as heterotrophic because their communities are consuming more than they produce and the difference is made up by imports from upstream. It would appear that utilisation of these extra materials increases secondary and tertiary production and gives extra stability to the system.

Decomposition of aquatic plants.

The decomposition of aquatic plants in the field has been studied by two main techniques, the return to the system of fresh plant material in mesh bags (Burkholder and Bornside 1957) and the use of pure cellulose (Golley 1960, Boyd 1970). The measure of decomposition used in these methods was by the loss caused by decomposition by enzymes of the natural microflora, fungi and bacteria, by the dissolution of soluble substances and by loss of fragments through the pores of the container used. In estuarine ecosystems detritus from benthic macro-vegetation is a major link between primary and secondary production (Odum and de la Cruz 1967, Darnell 1967). Odum and de la Cruz and Teal (1962) found similar rates of oxygen consumption for Spartina detritus. The decomposition of Thalassia is much faster than Spartina but the oxygen uptake of their detritus is similar (Fenchel 1970). He estimated the number of organisms harboured in one gram of detritus as about 3×10^9 bacteria, 5×10^7 flagellates, 5×10^4 ciliates and 2×10^7 diatoms. They comsumed 0.7 - 1.4 mg oxygen h^{-1} g dry weight^{-1}. The oxygen consumption was approximately proportional to the total surface area of the particles of detritus

Macro-fauna play an important part in the mechanical breakdown of plant material, for instance Fenchel (1970) showed that in four days the activity of amphipods had increased the detrital oxygen uptake by 110% of their own metabolic rate. He points out that the respiration rates of amphipods by themselves will be a gross under-estimate of their total role in the ecosystem (also Darnell 1967).

2.6. Soluble organic material.

Soluble organic material can be excreted by macrophytes and algae (Wetzel and Manny 1972). It can be leached from leaves on land and in water (Thomas 1970). The latter author considers that the leaching of leaves on land is a continuous source of leachate to water courses thoughout the year in contrast to the more rapid leaching of leaves on water. Manny (1972) has reported seasonal changes in dissolved organic material (D O M), for six Michigan lakes, which are related to the seasonal allochthonous input and autochthonous production. Thomas, and others, consider that the input of soluble organic material, especially from forests must be very high. The potential amount of leachate from a temperate deciduous forest may be about 10% of the leaf fall, or 30 g m^{-2}.

Leaves of Carya glabra and Acer saccharum were subjected to leaching in a recirculating stream, by Wetzel and Manny (1972 b). A ten-fold increase in the dissolved organic carbon (D O C) was found and the bacterial population, which developed rapidly decomposed the labile carbon and nitrogen compounds within three days. There were two fractions of D O C found, a labile one, which had a decomposition half life (1st order) of two days, and a refractory one, whose half life was eighty days. The refractory dissolved organic nitrogen (D O N) persisted unmodified for twenty four days. Manny (1972) suggests that only highly refractory components of D O N remain in the stream water and that their concentration is a function of the distance travelled and the residence time. D O C and D O N (labile) are rapidly

decomposed in hard

water streams. Wetzel and Manny (1972) say macrophytes only release labile D O N and this gives rise to the seasonal changes in D O N (. Manny 1972), because refractory D O N arises from allochthonous materials. The crux of the above arguements rely on the methods of analysis, that is, it is assumed that chemical and biological lability are related.

The D O C in the River Piddle, a chalk stream in Dorset, was found to be 0.4 - 0.8 mg C l^{-1} in the spring sources and increased from this value to about 1.8 mg C l^{-1} downstream in the main river, a rise of about 0.03 mg C l^{-1} Km^{-1}. (I.S. Farr pers. comm.).

2.7. Suspended Materials.

The passive transport of small suspended material, detritus and sand, by moving water, is affected by many factors, the most important of which is the velocity of the water. Particles are transported individually or collectively. The transport of individual particles is characterised by four main methods, sliding, rolling, saltation, along the stream bed and suspension in the water. As the velocity increases the mode of transport passes successively through the four states. Particles may also move in masses, and in this way ripples, bars and banks are formed. Hjulström (1939) also states that for particles larger than 0.5 mm, increases in velocity increase the size of particles that can be put in motion. With smaller particles however, the minimum velocity needed to put particles in motion, increases, not decreases, with decrease in size. Thus it is easier to move sand off the bottom than silt. Once in suspension the velocity required is about 30% less than the velocity needed to move particles from the bed, for deposition. For progressively smaller particles, the minimum transporting velocity becomes increasingly less in proportion to the suspension velocity.

The nature of suspended matter in streams has been studied, though special emphasis has been in small groups of animals in particular, rather than on the whole of the material passing. The larger invertebrates of the stream bed have been studied by Waters (1961) and Eliott (1967). There are fewer studies on rich streams, e.g. chalk streams, than on the generally poor streams, e.g. mountain streams, though this is probably because there are fewer of the former.

Suspended organic particles are important as food supplies to filter feeders. The particles are captured using either mouth fans, as in the larvae of the Simuliidae, or nets, as in the larvae of Hydropcychidae and Polycentropidae. The food consumption of, and the passage of suspended materials through Simuliid larvae were determined by Ladle _et al_ (1972) using charcoal particles. The rate of passage of food was estimated as about 20 - 30 min. Suspended material was ingested at the rate of 12.8 g m^{-1} day^{-1}, of which 0.64 was assimilated, assuming a value of 5% of the total collected, produced organic material at the rate of 0.066 g m^{-2}. The total annual production of the larvae was 5.9 g dry wt m^{-2} in three main generations. The activity of feeding larvae was calculated to complete theoretical clearance of suspended material in a distance of 0.6 km at a time of peak population density in the summer months. (found also by Maciolek and Tunsi 1968).

The _composition of the smaller material_ in streams, has been studied in a fast flowing Scottish stream, by Egglishaw and Shackley (1971). They collected fractions of material on a quantitative basis and found non-cellular detritus, with stream bed diatoms in low flows. When the stream was in flood, a lot of monocotyledonous tissue and non-cellular dertitus was evident. Maciolek and Tunzi (1968), noticed a change in the quality of seston from a lake outlet, along a stream. A decrease in phytoplankton was observed, probably by its decomposition within the stream, including digestion by Simuliid larvae. There was also considerable addition of detritus from the bank of the stream.

The concentration and natural variations in small suspended material have been discussed by Cairns (1965). The seasonal variation in small suspended material in the Bere Stream, a small chalk stream, is given by Ladle and Casey (1971). A graph is presented, which shows that the concentration of suspended material increases rapidly with slight increases in flow and falls rapidly if the flows remain at a particular level. The majority of material is moved in the late winter and spring.

The composition of the larger suspended materials has rarely been studied, though it is mentioned in studies on reservoirs used for generating hydro-electric power. Odum (1967) used a gill net stretched across the upper part of the stream flowing from Silver Springs to capture the large clumps of plants drifting down stream. He obtained a mean loss of 216 g y^{-1} from the area, based on three days results, in spring. There have been no studies in rich chalk streams either to determine the loss from sections or to correct production losses from fluviatile aquatic plants. Odum in Efford (1971) studied the input of particles (> 1 mm; the upper size limit is not given.) to Marion Lake, British Columbia. He found that this was about 6% of the small particulate organic input and 0.7% of the dissolved organic carbon input for a six month period. Odum emphasised that 70% of this small material and 94% of the dissolved, left the lake during this period. No large particles left the lake.

Large and small suspended organic materials have been considered in watershed budgets, for instance, the Hubbard Brook, New Hampshire, Borman et al (1969). The large particulate losses were estimated by settlement in a stilling pit; the small particles were filtered out on membrane filters from weekly samples as used by Ladle and Casey (1971). They found that most of the particulate matter was lost in the spring run-off, as already mentioned for the Bere Stream. However, an autumn storm accounted for half of the total particulate matter passing during the two year study period.

Sedimented material.

The distribution, seasonal pattern and composition of sediment in chalk streams has been reported by Ladle (1971) and Ladle and Casey (1971).

In the Bere Stream, a small chalk stream, they found a seasonal build-up o sediment which was related to the plant distribution. The majority of this sediment was washed out annually by the autumn floods.

The species composition of the Brule River sediments were examin by Evans (1946). He found that most of the debris was of allochthonous origin and identified the bulk of it as coming from the immediate vicinity of the river; although it flowed through a Sphagnum bog, few fragments of moss were found, despite the durability of their leaves. Evans suggested that this is because material was not eroded away from the banks in the bog and the material fell in no faster there than at other places on the river bank.

The oxygen consumption of the river muds has been discussed by Edwards and Rolley (1965). They found that the oxygen consumption was independent of depth, when the mud was deeper than two cm. A numerical equation is given relating the oxygen consumption to the oxygen concentration in the overlying water. The temperature coefficient of muds was about $0.07^{\circ}C^{-1}$ between 10 and 20 °C. They noticed that animals increase the respiration rate in muds, as Fenchel (1970) describes with detritus of known origin.

2.8. The Ecosystem.

Hynes (1970) has reviewed the traditional ecosystem concept and points out the undoubted oversimplification of the model when stream systems are considered. The model is described as a self-contained complex to which energy is supplied as insolation. It then passes through a series of trophic levels, primary producer, primary consummer, secondary consummer, etc. and returns the basic materials to their original form and as it were, drives cycles of carbon, nitrogen, phosphorous, sulphur and other elements. This model does not apply to the running water system, where materials tend to be recycled downstream having little opportunity of being re-cycled on the spot. (Shadin, Schmidt after Hynes 1970).

Streams do not derive their energy solely from autochthonous production within the stream but also from outside from leaf-fall, blow-in the wash-in of decomposing materials from ditches and sub-soil drainage. The ratio of autochthonous to allochthonous materials is very much related to individual situations. This ratio ranges from near total heterotrophically based growth, that is, the material driving the system is almost entirely from outside the stream, to an autotrophically based one, that is, the vast majority of the material is produced within the stream. The former situation is typical of nutrient poor streams, often arising in mountains, and supplied with organic material from forests or moors. The latter are clear waters rich in nutrients and inorganic carbon, supporting dense aquatic plant growth. The chalk stream found in Great Britain, France and New Zealand, is the major example. Hynes (1963) considers that allochthonous inputs impart greater stability to running water systems as a whole. However, as the majority of streams studied are generally poorer in nutrients than chalk streams, this only is a valid argument based on the data available but shows the need for ecosystem studies on richer waters.

There have been two main studies published of calcareous river ecosystems, that of the River Thames, Mann _et al_ (1972) and the Bere Stream, Dorset, England, Westlake _et al_ (1972). The former site is a lowland river maintained to a minimum depth of 2 m, and with a fairly low light transmission value, about 23% at 1 m on average, thus making it difficult for the river to be dominated by fluviatile aquatic plants. The Bere Stream at Bere Heath is a clear shallow stream of 0.5 - 1 m deep dominated by a seasonal succession of aquatic plants, starting with R. _calcareus_ in the winter and spring followed by _Rorippa nasturtium-aquaticum_ in the summer. The production in the Bere stream of submerged macrophytes and benthic algae (epilithic and epiphytic) were each about a third of that produced by the emergent macrophytes. (Table 2.3.). The total net macrophyte production was approximately similar to that of the planktonic algae in the River Thames above the junction with the River Kennet (3 - 4 000 kcals y^{-1}); there are few macrophytes present in this section of the Thames and they contribute little to the general production.

The organic budget calculated for the Bere Stream above Bere Hea showed the tremendous importance of the input from minor effluents and drainage ditches and the export as dissolved and small suspended material. (Table 2.4.) The estimate of secondary respiration is based on a rate of 0.1 oxygen m^{-2} h^{-1} obtained in a similar chalk stream by Edwards and Owens (1962).

Table 2.3.

Biomass and production at Bere Heath (1), 1969. Westlake *et al* (1972) Revised October 1972.

Community (or source)	Midsummer biomass (& organic deposits) g organic wt/m^2	Annual net production (& annual organic throughput) g organic wt/m^2 yr.
Submerged macrophytes	100	120
Emergent macrophytes	290	400
Algae	3	140
Total primary production	-	660
Mobile organic[2,3]	4	31 000
Fine detritus	2300	40 000
Invertebrates[1]	17	130
Fish - food requirements	-	40
- biomass and production	3	7

Note 1. Invertebrate values assume production to biomass ratio of eight.

2. Mobile organic biomass includes dissolved, small and large suspended drift.

Note 3. The annual throughput of mobile organic material is dissolved and large suspended drift. The small suspended is treated as fine detritus.

Table 2.4.

Speculative organic budget for the Bere Stream, upstream of Bere Heath.

Westlake *et al* 1972. Revised October 1972.

	Input Mg		Output Mg
Submerged macrophytes	8	Dissolved organic	51
Emergent macrophytes	5	Suspended organic	72
Algae	6	Large drift	5
Total autochthonous	19	Total export	128
Trees	2		
Marginal plants	1		
Cress-beds	38		
Major effluents	0		
Spring water	17		
Balance(Prob.allochthonous: drains,minor effluents etc.)	81 ?		
Total allochthonous	139	Secondary respiration	30 ?
Total	158		158

3.1. OUTLINE OF INVESTIGATION.

The production study of *Ranunculus penicillatus* var *calcareus* and its relative magnitude compared to allochthonous organic material input was carried out as a field based study. A stretch of a chalk stream was selected for intensive study. The balances of inputs to outputs, after incorporating material produced within the study reaches, were then related to laboratory studies on the rate of respiration and the induction of flowering under controlled conditions. The study was based on a carbon cycle as well as total organic matter and the appropriate analyses made; some nitrogen data were also available.

Field Studies.

The production was estimated from changes in biomass of the macrophyte, obtained by quadrat sampling, with corrections for losses of stems and leaves occuring during the growth season. The seasonal changes in biomass were also related to production estimates, giving the biomass to production ratio. Detailed study of individual plants during the season (individual plant losses) and isolation of an open treeless section of stream with screens (loss from the study section) were used for the estimation of losses required to determine the corrected net production. The loss from the standing crops of materials such as leaves which were shed or broken off and were fragmented or decomposed on site, was estimated by labelling studies and also by considering the small suspended material balance and the seasonal pattern of silt build up in an organic budget.

The seasonal pattern of plant growth was related to changes in water flow and hydrodynamic factors, combined with the temperature and chemical composition of the water.

The ratio of organic matter of allochthonous and autochthonous origin, nominally larger than 5 mm, was estimated by identifying and sorting material from a series of three sets of screens, the upper at the outlet of a small lake feeding the stream, the <u>middle</u>, downstream of a wood and the <u>lower</u>, downstream of the open macrophyte dominated section. The areas of origin of the tree leaves over the stream were calculated and the allochthonous input to the stream area estimated using leaf baskets.

The change from vegetative to reproductive growth is accompanied by morphological changes a long time before flower and seed production. The apparent growth rate decreased over two months, the crop declined and was finally washed out. The time of flowering may thus affect maximum biomass and total production in a season. The relationship between water temperature and the different flowering times at different stations was therefore investigated.

Laboratory Studies.

The respiration rate was measured seasonally over the range of temperatures prevailing at each time, to determine any seasonal effects of decrease in the maximum biomass, for example, by elevation of the respiration rate during the periods of high biomass.

Plants were subjected to differing controlled photoperiods under similar flow conditions to determine the cause of flower-induction and the rate of response. Flower buds from sites with differing times of flowering and temperatures were examined to determine the time of initiation and subsequent expansion or development rates.

3.2. DESCRIPTION OF RANUNCULUS PENICILLATUS VAR CALCAREUS.

Introduction.

A study of the difference in growth form seasonally and in different habitats was essential in interpreting the changes in biomass. The length to weight relationship of stems and of plants, together with the area occupied was considered in an attempt to measure the standing crop indirectly, as an alternative to direct measurement by quadrats. Plants were labelled in order to determine the loss of stem and leaf from individuals as opposed to the loss from the stream as a whole which was measured by the use of screens. Serial cropping of similar plants during the season also aided this investigation.

Description.

The plant studied was Ranunculus penicillatus var. calcareus (R.W. Butcher) C.D.K. Cook. Cook (1966) describes the plant as a long lived perennial with stems up to 3 m long in flowing waters. The leaves are divided into capillary segments which are obconical in outline, equal to or shorter than the mature internodes: the segments are rigid or flacid, slightly divergent, much branched, with up to 150 ultimate segments, entire leaves absent. The peduncle in the fruit is 50 - 100 mm long, and usually longer than the petiole of the opposed leaf. The sepals are 3 - 7 mm long, greenish and spreading. The petals are white and (5) 10 - 15 (20) mm long, broadly obovate, contiguous during anthesis; the nectar-pits are elongate and more or less pyriform. The stamens number (8) 20 - 40. There are (15) 50 - 80 carpels which are hairy or glabrous; the style is lateral to subterminal. The receptacle is distinctly hairy, remaining globose in fruit. The achenes have a characteristic pattern of ridges and a beak. It is thought to be distributed throughout Europe except in the extreme North and on the Balkan Peninsular. The preferred ecological habitat is flowing water.

It is found in streams and rivers that are normally slow flowing but are subject to frequent flooding especially in winter and where the water may flow very swiftly, but with a fairly stable stream bed.

The phenotypic and genetic variation of the R. penicillatus group is a long way from being understood and requires more study. With a conservative treatment, it is not possible to recognise the several different races because their phenotypic variation in field and herbarium material is too great.(Cook 1966). The total variation of the R. penicillatus group ranges from strains which resemble R. peltatus to R. fluitans. The former types are difficult to differentiate but the latter differ in having a densely pubescent receptacle, in not forming a prostrate state and having oval to suborbicular stipules. R. penicillatus differs from R. peltatus, being larger and in having more stamens and carpels, but these are under environmental control; the whole range of floral characteristics of the former embracing the latter species. There are also many hybrids which, like their parents, are perennial. Vegetative spread is more frequent in short range and downstream dispersal in rivers (Cook 1970) and therefore even sterile hybrids may be well established.

Growth Habit.

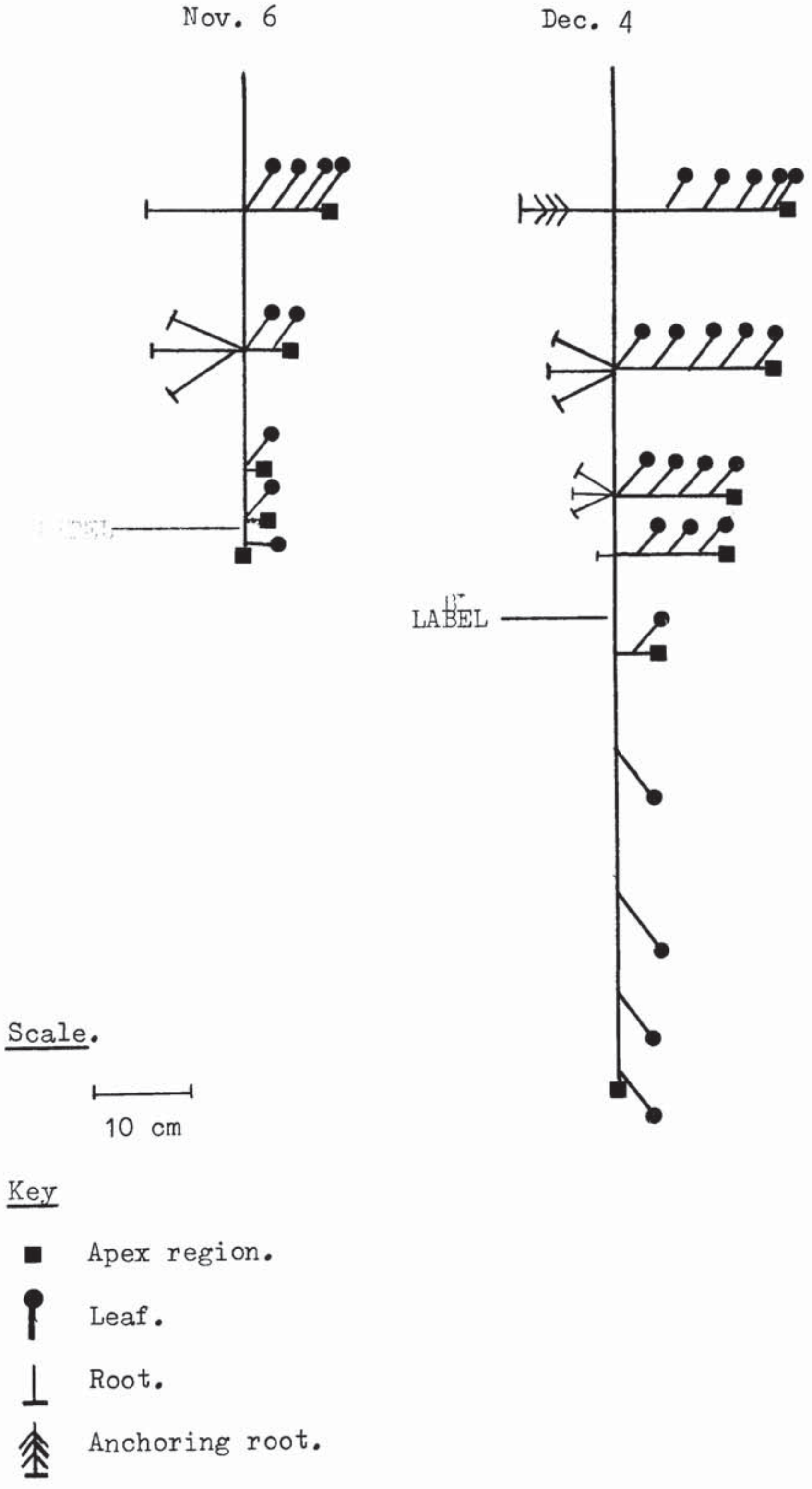
The plants grow in the direction of flow, starting to regrow in the autumn or early spring depending particularly on local conditions of water temperature and current velocity. Flow rates of 20 - 50 cm $\sec^{-1}$ and water temperatures of 10 - 15 ^{o}C are conducive to rapid growth (see later sections). Typical vegetative growth is by tufty or tassel-like leaves borne at intervals of 10 - 20 cms on tough flexible stems. Regrowth in the late autumn takes place from the white roots and rhizomes buried just below the surface of the stream bed, extending downstream from this source area.

The movement of plants was observed at the Upper Bere Stream by marking the upstream edges of source areas with large nails driven into the stream bed. Plants were numbered by attaching embossed plastic tape to these nails and were observed from early 1969 to late 1972. Three rows of nails without plants were used as controls to determine whether the nails accumulated drifting material causing plants to be established. After the three year period, 70% of the plants were still in or near their original positions. Downstream movement of several centimetres was common though upstream movement occured occasionally and usually resulted in two plant groups probably derived from the separation of the single original. 30% of plants were not associated with labels though 20% of the labels were not discovered. Only 5% of the control labels had plants associated with them.

Plants grow by expansion of the apex region which is at any instant of time a conglomerate of buds in various stages of development. Ten primordia are normally present (see section 6.1.) and are differentiated from the apical cells or cell at a rate of one every four to eight days. The internodes and leaves expand to about 5 – 15 cm as the plant grows downstream. The leaves are about the same length as the associated internode before the time of flower initiation. Several changes in morphology occur after flower initiation; the developing stems increase in diameter and develop a hollow centre which causes the stems to rise to the surface allowing the flower stems to raise the flowers into the air. The stems themselves are, however, more fragile and easily broken off.

The typical plant in the early spring, before any intra-specific competition is apparent, has a long stem with leaves subtending lateral buds in various stages of development progressively increasing towards the base. The expansion phase of stems and leaves is complete by about the fourth node. Fig. 3.2.1 shows the development of a plant stem or sub-plant unit under cool water but suitable velocity conditions in one month, November – December. The gain in size of the section harvested in December was a 42 cm expansion of the apex (1.5 cm day^{-1}), with the development of four main stem leaves. There was a loss of four leaves, making no change in leaf

Fig. 3.2.1. An example of the development of growing part of a single main stem in a month , Nov. 6 - Dec. 4, 1969.



number, but a total extension of the stem of 58 cm (2.1 cm day^{-1}). The four laterals each developed an average of 11 cm in length and with four leaves each, only one leaf was lost from the oldest lateral. The main stem leaves are heavier and more robust than lateral leaves (see later).

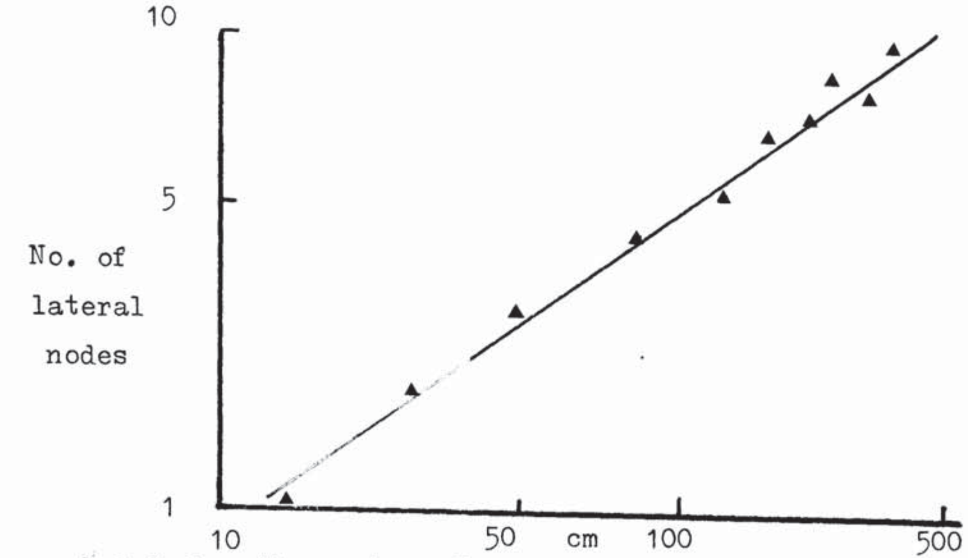
The greater the distance from the apex region the greater the number of nodes there are on the laterals, up to about a stem length of two metres, or about 8 - 10 nodes, after which there is a more rapid increase in numbers of nodes on laterals. This may be due to a decrease in apical dominance or the laterals themselves may become more self-sufficient. (Fig. 3.2.2a) In practice there is difficulty in associating laterals with their main stems near the rooting area, i.e. at the oldest nodes over about 10 nodes. The linear regression line of lateral to main stem nodes has a very highly significant correlation, the gradient being 20% lower than expected for equipotential growth of lateral nodes and after allowing for a lag in the initiation of lateral branches. There is increasing variation in the number of nodes developed by older branches because of different growth regimes. Lateral branches towards the outside of the plant complex grow much better than shaded ones within.

A logarithmic increase in lateral bud number per length of stem from the apex region was obtained using the previous data combined, as the mature internodal distances are nearly equal. (Fig. 3.2.2b.)

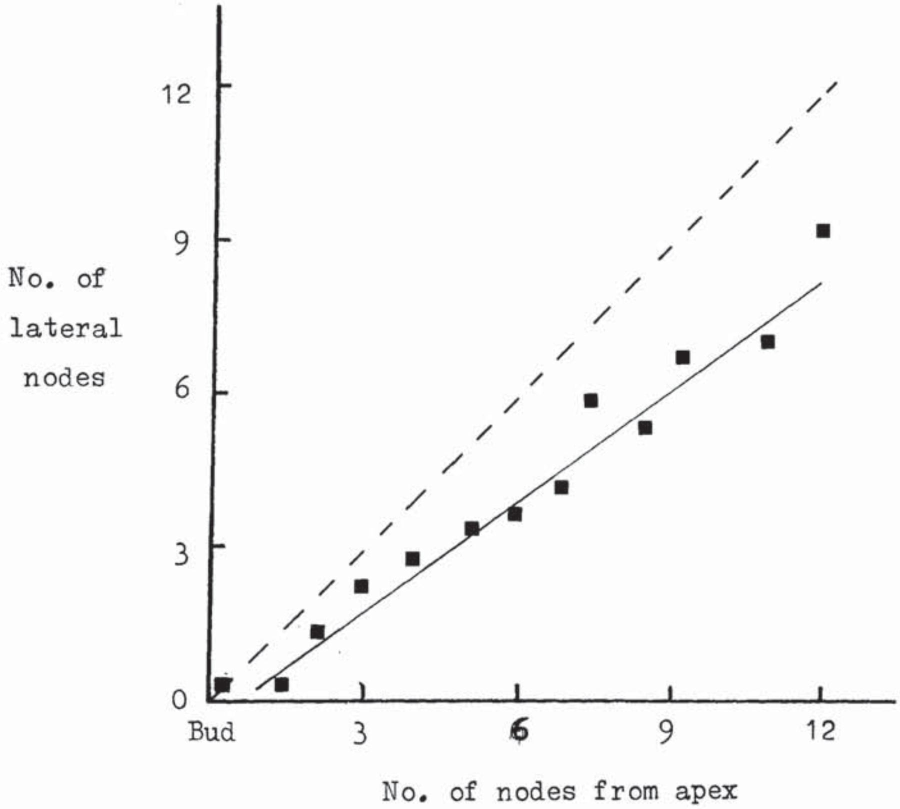
In February 1969 stems and roots of plants in typical habitats at the Upper Bere Stream showed a range in the ratio of length to width of from 5:1 in slack water marginal areas to 10:1 in central medium/fast flow plants (Fig.3.2.3.) This difference was not apparent during most of the growing season as intra-specific competition increased and cover of the stream bed reached its maximum during April. If therefore plants were to be classified into types these would need to be seasonally variable to take into account the changes in surface area occupied.

The analysis of a medium fast zone plant (Fig. 3.2.4.) showed that

Fig. 3.2.2.



3.2.2. b. The number of nodes on laterals in relation to to their distance from the apex.



3.2.2. a. The number of nodes on laterals in relation to their position from the main stem apex.

Fig. 3.2.3. Shoot and root areas of plants in typical habitats of Bere Stream at Holly Bush, February 1969.

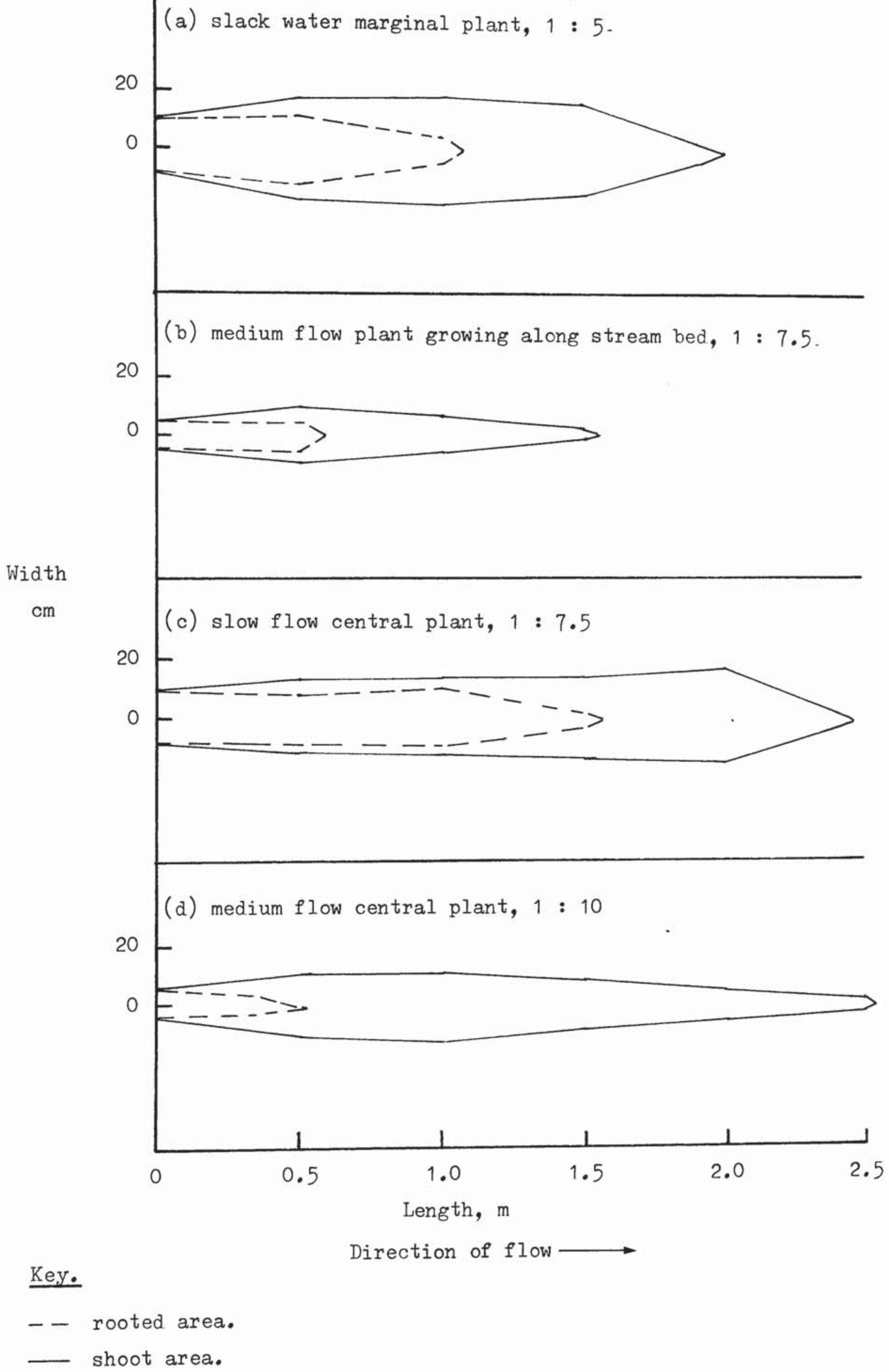
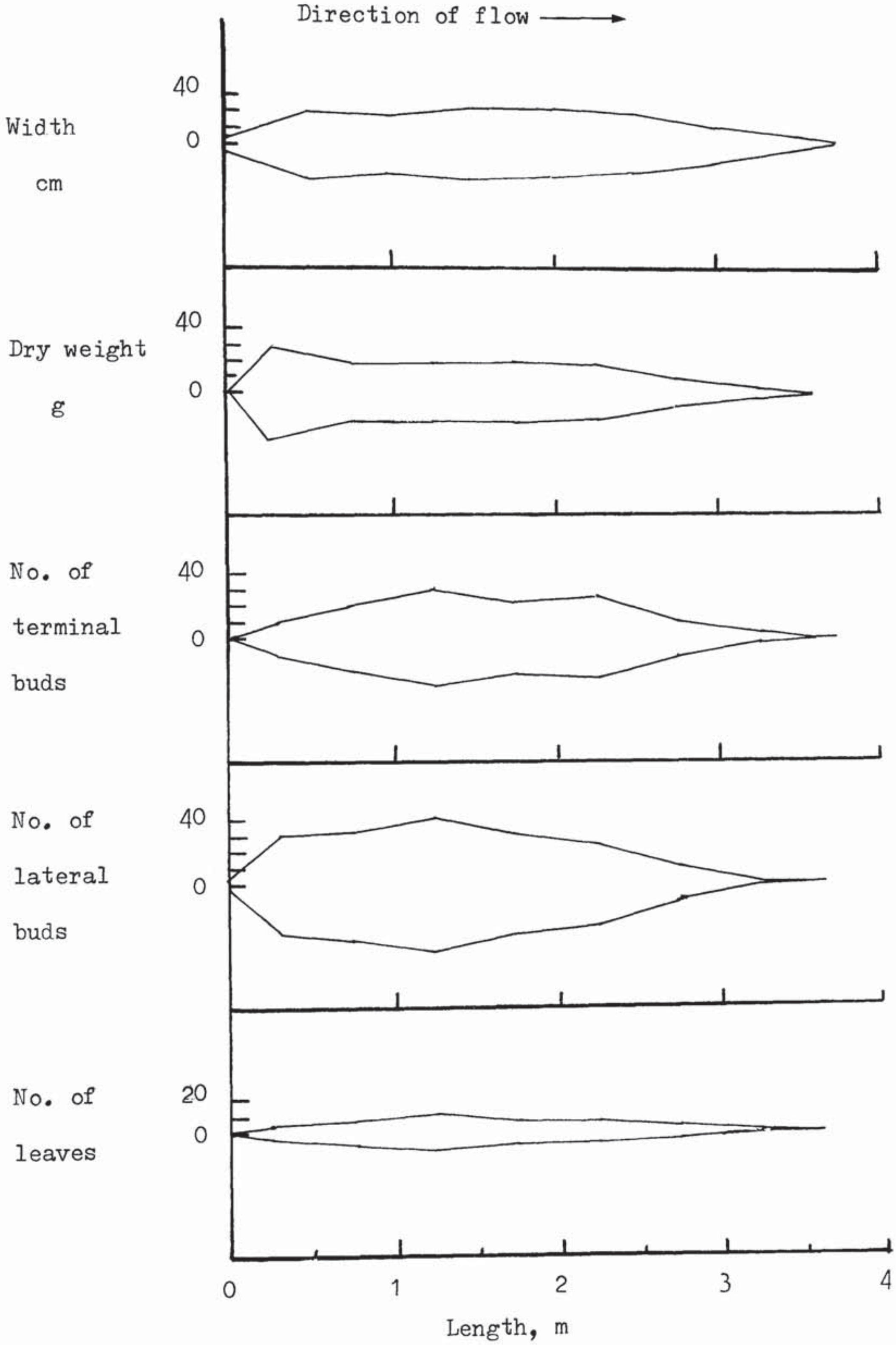


Fig. 3.2.4. Analysis of medium fast zone plant, area, weight and numbers of buds and leaves. February 17 1969.



it covered a roughly parallel sided area with a short tapering tip. The area with the greatest density was the upstream rooted area but the greatest number of buds was one metre downstream. This plant was sectioned every 50 cm downstream. The numbers of laterals and terminal buds was determined, arbitrarily, by assuming those of the former were connected with a stem which was cut on the downstream side of the section while the latter were those which terminated in an apex region within the section, not being connected to a stem which was cut on leaving the section.

The estimation of standing crop by lengths of the plants was considered and plants were therefore analysed in detail in an attempt to correlate a length to weight relationship for the complete lengths of plants. The length and the width of the plant every 25 cm were measured to estimate the areas of stream bed covered by plants. The depth of water and plant were compared with the flow in and around the plant and in the main stream. The plants were then removed and put in polythene bags or trays. The length of stems, the numbers of nodes with and without leaves on the main stems and on laterals were measured and counted. Stems were paired according to size and one from each pair was dried and the other was divided into its separate components, then also dried and weighed. The data available was thus

(a) the number of nodes per square and cubic metre

(b) the number of bare nodes per square metre and hence leaf loss

(c) the dry weight for individual plants per unit area and volume

(d) the ratio of mainstem to lateral branch production

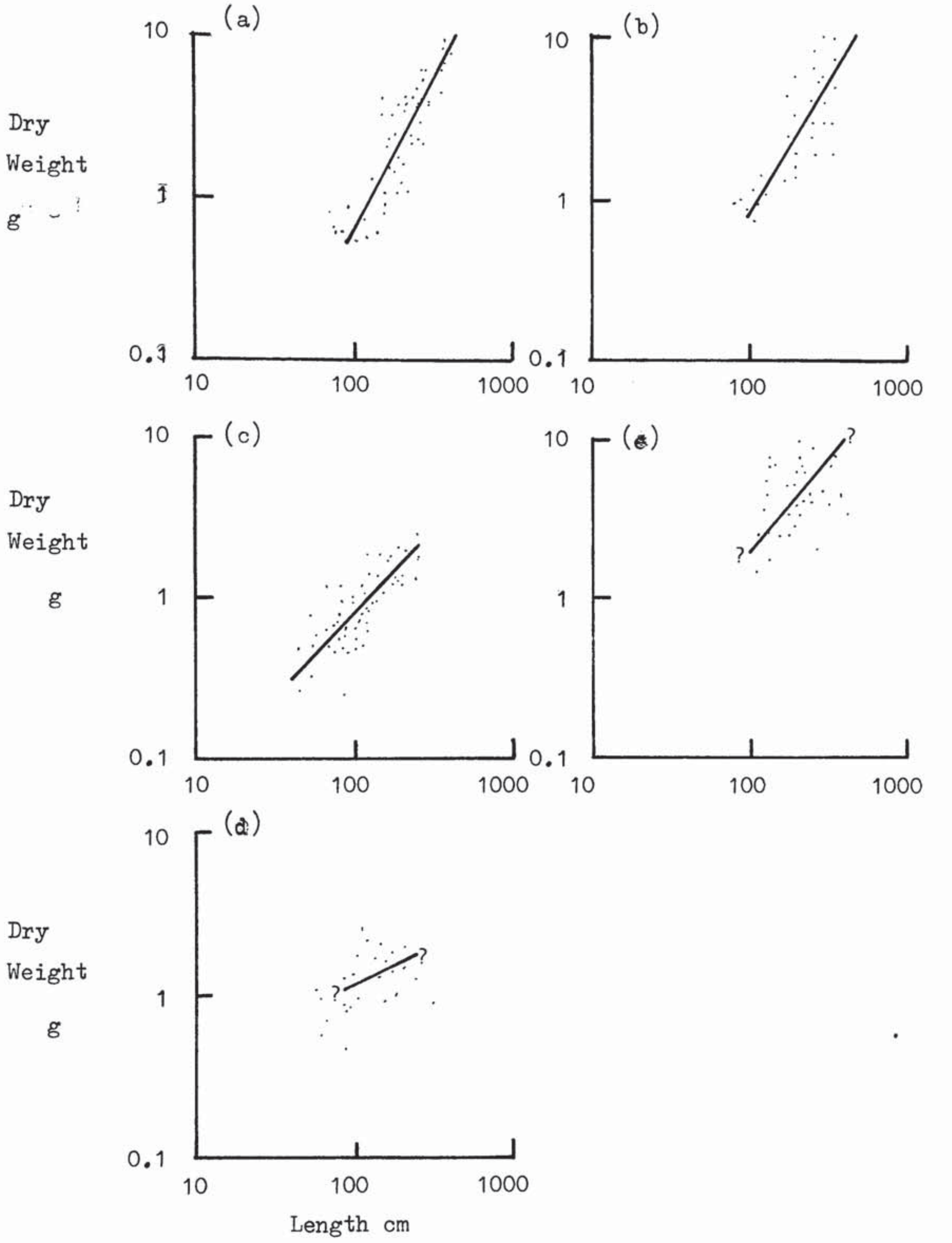
(e) length of stem to its weight relationship

(f) correction factor for loss by broken stems (see also screening operations section 4.2.)

The linear regressions of weight on length of stem which were obtained for all stems of three plants typical of those present in March gave significant correlations ($P > 0.05$) with a logarithmic conversion of lengths and weights (Fig. 3.2.5abc). In fast flow plants grew well, they were long and not very dense. The slopes varied widely from 1.9 for a fast zone plant with very large stems and little self-shading through 1.8 for a medium fast zone plant with some self-shading but with long stems with terminal leafing, to 1.0 for a slack zone, marginal, but with few long stems. As the water velocity decreased there was greater variability in stem lengths and weights though considered as a whole the stems were lighter than plants growing in fast flows. In March, the plants for the length weight relationship showed much local variation and also that if subjective judgements of a group were made, it would cause large errors. Seasonal changes were also anticipated as the plant grew and backed up water, so that even fast zone plants would be growing in slack water. The plant cover of the stream bed was nearly complete by May and indivdual plants were difficult to separate. A length weight relationship for two plants in May, the former a shallow water plant similar to the fast water types of March but now in slack flow, had a much reduced estimated slope and as there was greater scatter of points, the correlation was insignificant. (Fig.3.2.5d.) Many stems were broken as a result of the greater fragility at the flowering time which caused an increase in the weight relative to unit length if these heavy accidentally shortened stems were included. The other plant considered in May was a central deep water plant from the downstream third of the screened off section. It took a long time to reach the surface and was in consequence very heavy apically. The gradient of the regression line was lower than previous and showed the greatest scatter of points of any plant analysed. (Fig. 3.2.5e.)

The stems were breaking freely by July and no length weight estimates were attempted. The plants often broke into 10 - 20 cm pieces by August and were washed out freely by slight increases in flow (see screen operations).

Fig. 3.2.5. (a - e). Length weight relationship of stems of *R. calcareus*.



(a) March 1969 Fast zone plant, $\log W = 1.93 \log l - 4.02$, $r = 0.90$

(b) " Medium fast zone plant, $\log W = 1.83 \log l - 3.78$, $r = 0.81$

(c) " slack zone plant, $\log W = 1.03 \log l - 2.16$, $r = 0.76$

(d) May 1969 as (a), but now in slack water, $\log W = 1.08 \log l - 1.85$

$r = 0.30$

(e) " central deep water plant, $\log W = 0.58 \log l - 0.90$, $r = 0.34$

Leaves.

Only divided leaves are present. They have typically three trichotomies, followed by dichotomies, the length between each successive division typically decreases from the length of the 'petiole'. In submerged leaves the trichotomies and dichotomies are under environmental control, the number of trichotomies varies from rarely two, normally three, to occasionally four in very large autumn specimens. The fourth may not be a true trichotomy but an uneven dichotomy within 1 - 2 mm. The number of filaments is about 150; this, however, means an uneven number of dichotomies after the three trichotomies. Usually one of the first trichotomies was found to develop slower than the other two.

The normal leaf is about 10 - 20 cm long, occasionally reaching 25 cm in fast flow in the autumn (50 cm sec^{-1}). Leaves grown in conditions of slow flow (10 cm sec^{-1}) were shorter, 5 - 15 cm and contained many less filaments.

The slack water form (0 - 5 cm) is very small and resembles the terrestial leaves (2 - 10 cm) but with a comparatively long petiole (3 cm). The slack water leaf is light green and flacid, floating in a near semi-circle of thin filaments.

The terrestial leaf is rigid and slightly flattened(similar to Callitriche spp), three times wider than the filament bearing it. There are many stomata on the upper surface which is like other aquatic floating - leaved plants such as Nuphar lutea (Sculthorpe 1967).

The site of nutrient uptake by these plants is not known; there has been much controversy about nutrient uptake and it has been recently discussed by Sculthorpe (1967) and Denny (1972). The leaf cuticle in this plant was not demonstrable by the usual techniques and must therefore be very thin or absent; this would present little difficulty to salt passage to the cells over the entire leaf. The uptake is probably limited by physical availability, the diffusion of salts from the main body flow of water through the static water film next to the plant (Westlake 1973).

The tips of aquatic leaves have normally three to five (occasionally 10) leaf hairs up to 150 µ long. These terminal leaf hairs may take part in nutrient absorption. A vital stain, light green, was taken up in this region far more markedly than the remainder of the filament. This was demonstrated by two hours exposure to an aqueous solution of the dye after which the chlorophyll was cleared by an alcohol-acetone mixture.

The leaves are initiated at a rate of one every 4 - 8 days (see flowering section) during November to June but the ultimate length and filament number is under environmental control. The apex region may contain up to ten buds in successive stages of development, the largest expanding leaf covering the inner. As the outer leaf expands the internode elongates. This continual leaf production and leaf elongation produced problems in estimating the life of leaves. Internodes were labelled with small colour coded plastic split rings; used on budgerigars' legs.

A comparison of leaf length with successive numeric position on the stem shows that expansion was complete by the 'second leaf', that is, the third obvious node (Fig. 3.2.6.)

The duration of leaves in January was estimated from an examination of the stems of a typical plant. Leaves started to die about 3 - 5 nodes from the bud complex and death was complete by the eleventh. (Fig. 3.2.7a, b). The mean life was about 9 nodes indicating a life after development of 1 - 2 months or 3 - 4 months in all from the time of initiation. The growth during this particular season started in the previous autumn. A similar plant was sampled in March and showed a similar life pattern for leaves but as more leaves had been initiated by this time there were many more nodes.

The condition of leaves was estimated in terms of length rather than physiological condition and comparison was made with mature size as determined by labelling studies and periodic on-site measurements. Leaves

Fig. 3.2.6. Length distribution of leaves for numerically successive positions on stem, March 1969.

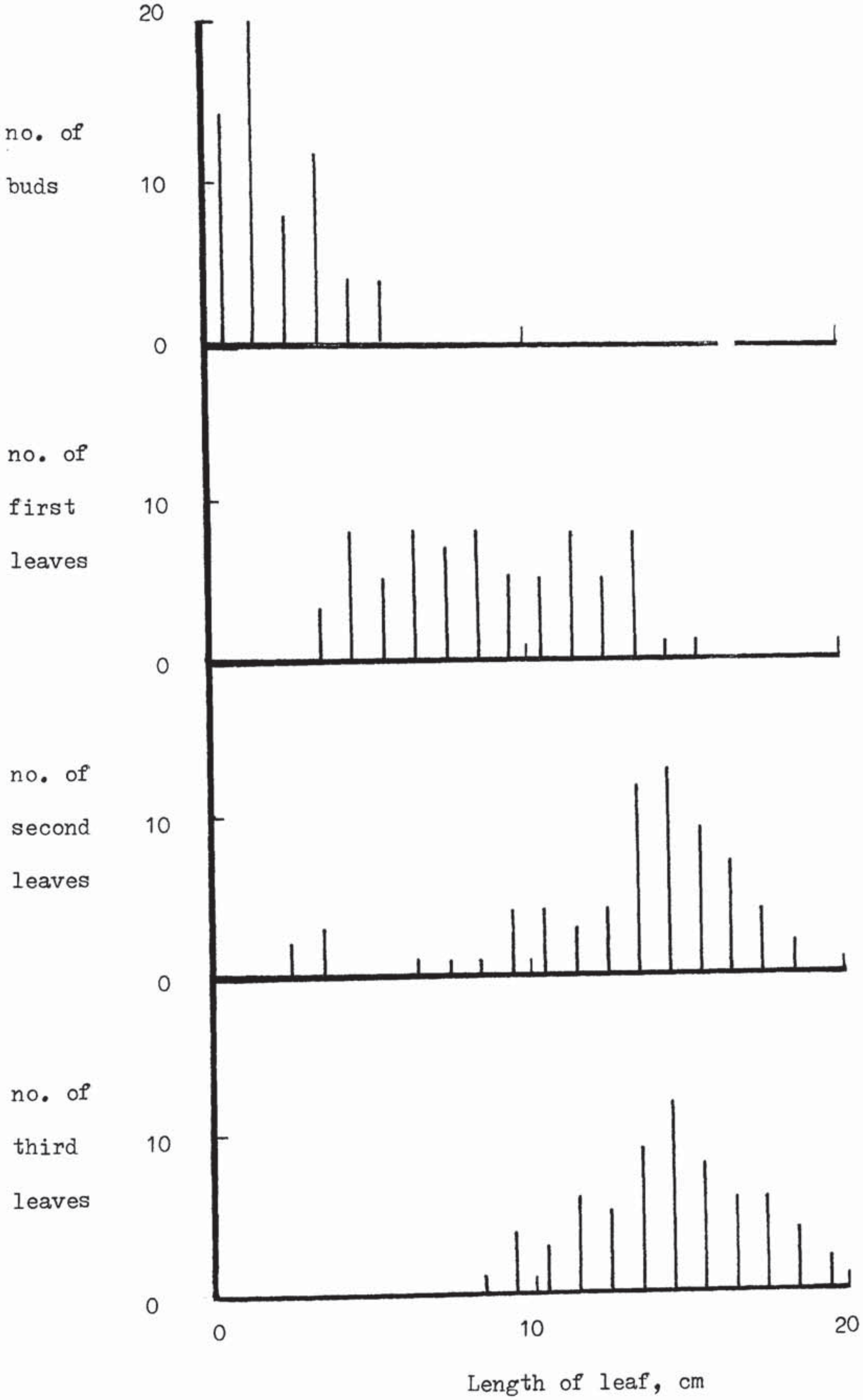
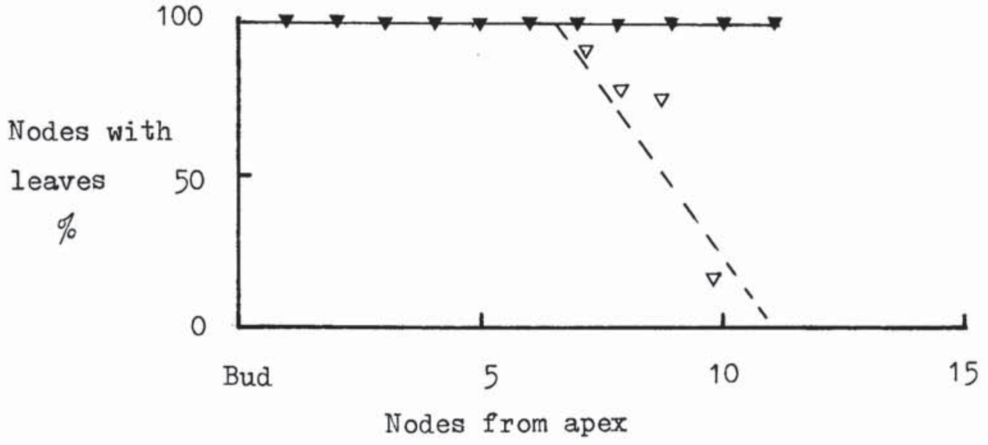
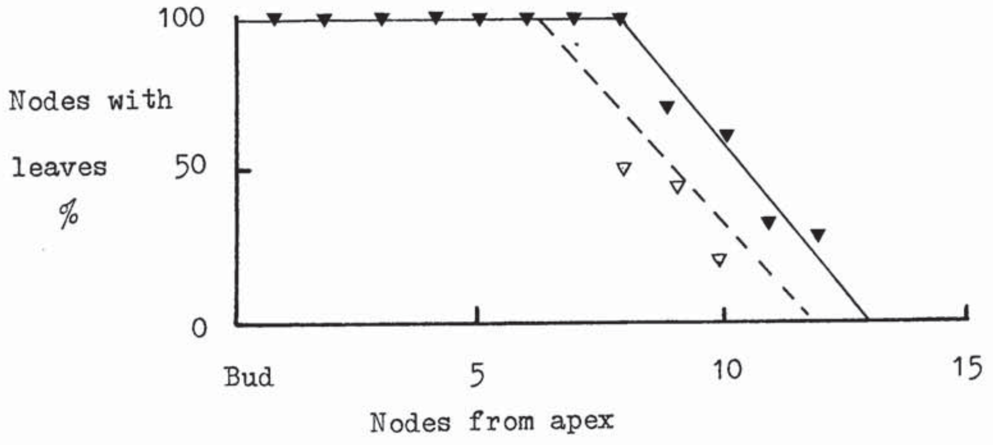


Fig. 3.2.7. The ratio of nodes with living and moribund leaves on main stems to the total number of nodes

(a) 27 January 1969.



(b) 14 March 1969.



Key

▼ Fresh and moribund leaves.

▽ Fresh leaves only.

became shorter after the fourth node, becoming increasingly moribund from the tips and fragmenting down to about one half to two thirds of their mature size before being lost. Fragmentation from the leaf tips may be caused by flow or animal action, especially by the larvae of Chironomidae, though which causes significant damage at a particular time or place was not determined.

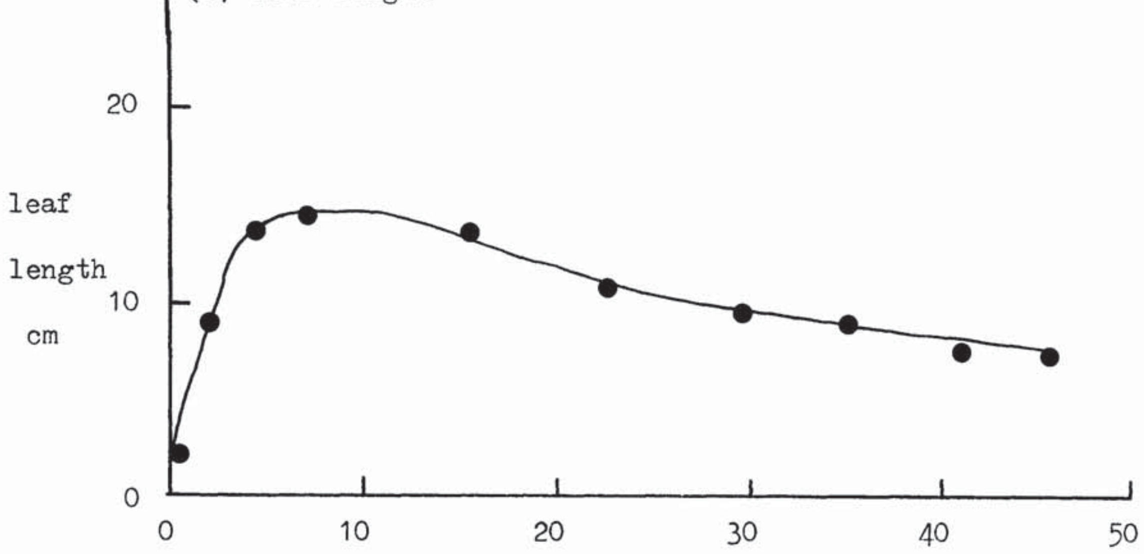
When the variation in mean weight of leaves is also considered as a condition factor of leaves, a rapid decrease in weight per unit length of leaf is seen for the first two nodes as further expansion and development is taking place. Following this, however, the weight per length falls gradually until the leaf is about two thirds its length and half its weight (Fig. 3.2.8a, b, c) after which it is generally shed.

Analyses in January and March show similar results. There is less decrease in weight for older leaves because continually lighter leaves were being produced as the season progressed. The average leaf weight of mature leaves for January and March 1969 were 41 mg and 22 mg respectively. Further analyses of the March plant (Fig. 3.2.9. and Table 3.2.1.) showed the mean dry leaf weight as 14 mg; the internode length gradually decreased with age indicating more vigorous recent growth; the weight of these internodes was however consistent. The laterals grew less rapidly and started some way behind the apical region, but rapidly increased in weight with a maximum near the seventh node from the apex. The lateral buds developed and produced a similar system to the main stem, with very short and heavy apical regions. These developed further and were then regarded as, or were, inseparable from, mature stems and hence a fall-off in weight per lateral was observed.

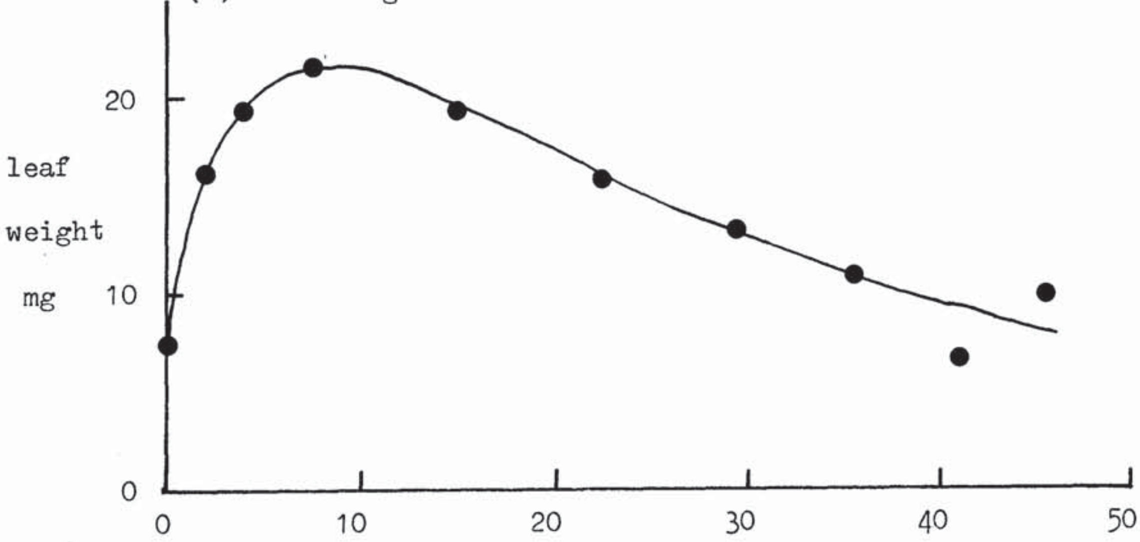
<u>Roots</u> develop as uniform cylinders starting about four nodes from the apex, and extending several centimeters before producing secondary roots, which were considered to be for anchorage rather than for absorption. These secondary roots were developed only when the 1 y roots were in

<u>Fig.</u> 3.2.8. Relationship of leaf length, leaf weight and their ratio to the average distance from the apex region.

(a) leaf length



(b) leaf weight



(c) weight to length ratio

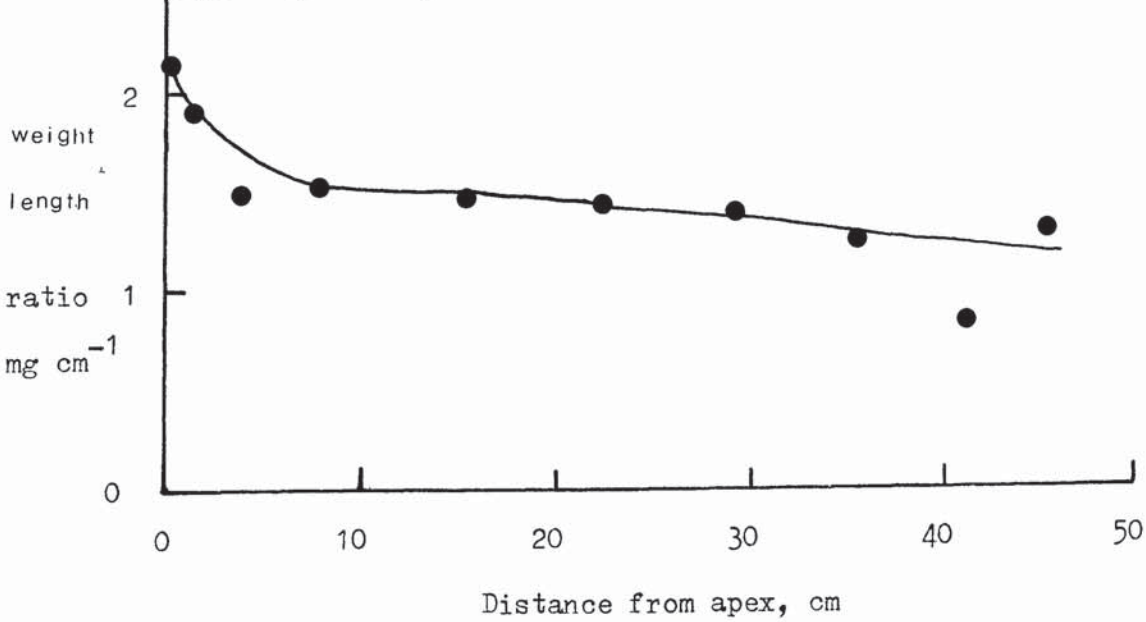
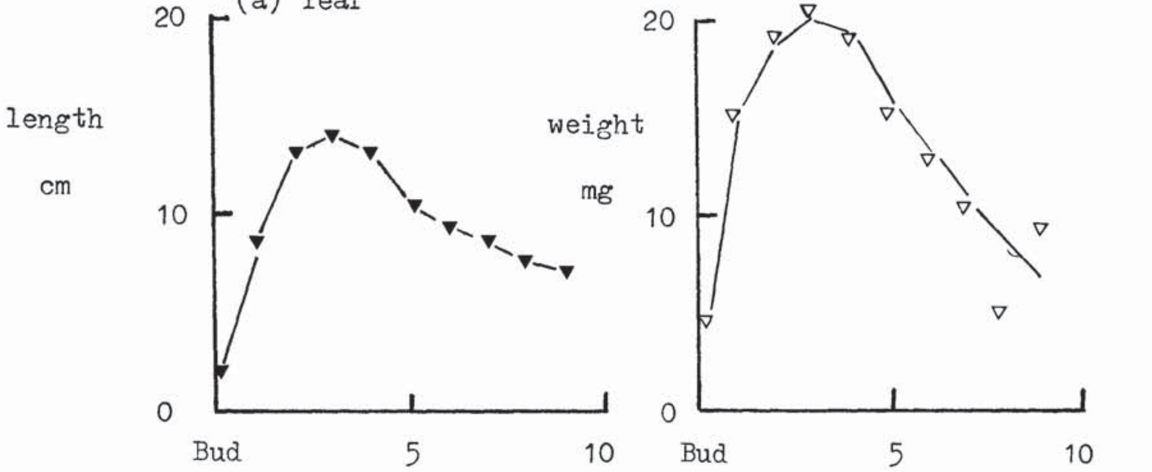
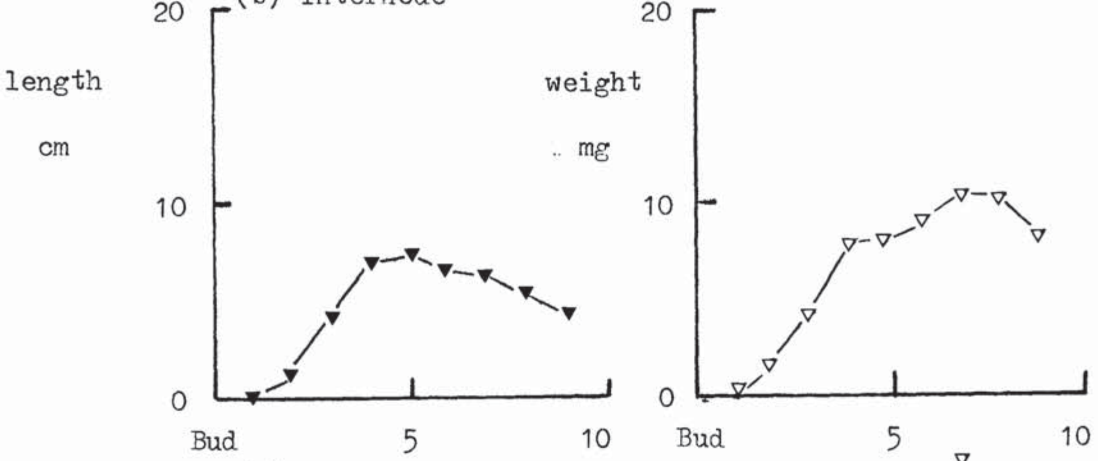


Fig. 3.2.9. The length and weight relationships of leaves, internodes, laterals and roots for a typical plant, March 1969.

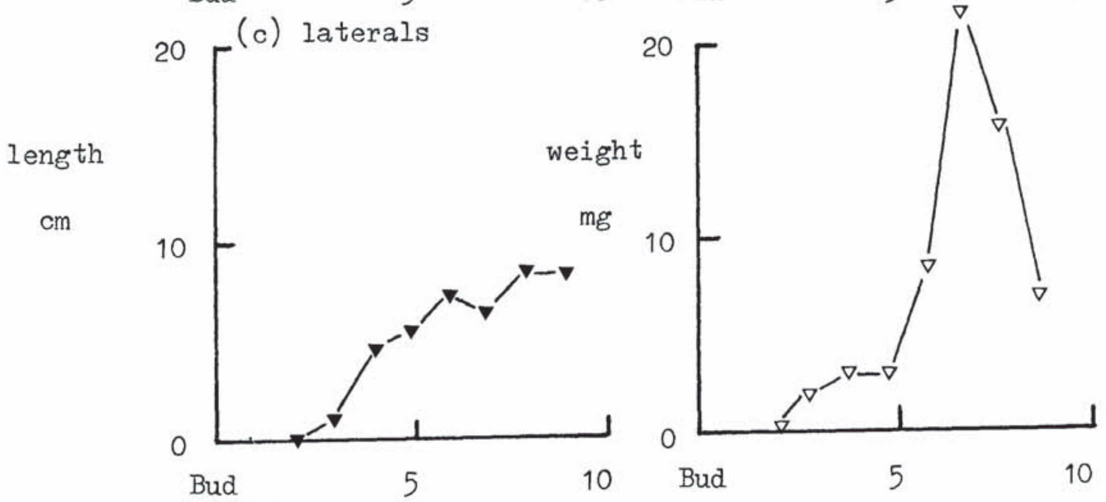
(a) leaf



(b) internode



(c) laterals



(d) roots

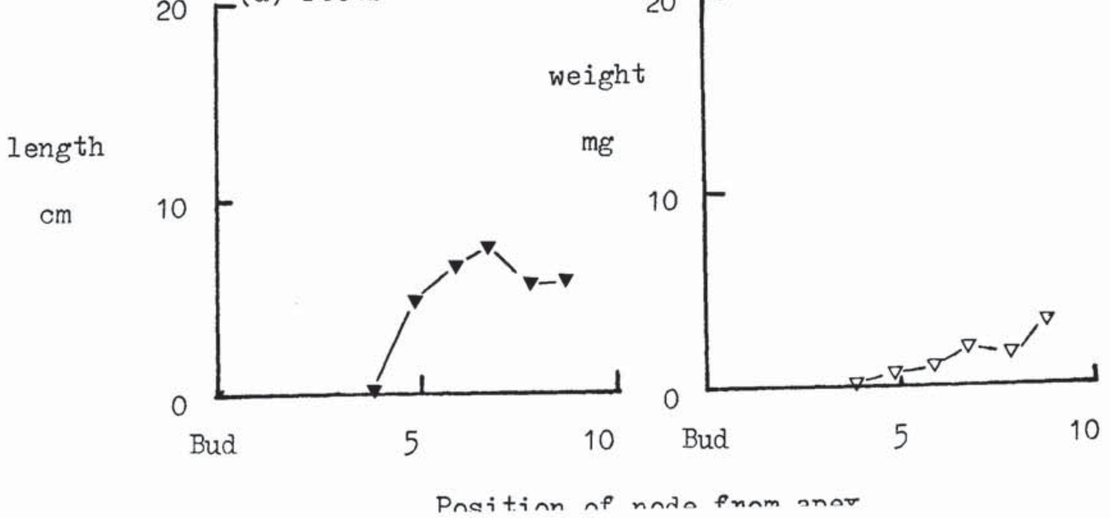


Table 3.2.1.

Fractional analysis of a plant. March 1969.

(excluding laterals under 5 mm.)

	Mean	Mean	Main stem nodes.				Leaf.
	length	weight	number	with leaves	with laterals	distance from apex	weight to length ratio
	cm	mg		%	%	cm	mg cm^{-1}
Bud	2.1	4.5	68	100			2.14
Internode						2.1	
1st Leaf	8.8	16.3	68	100			1.85
Laterals							
Roots							
Internode	1.7	2.0				3.8	
2nd Leaf	13.2	19.5	68	100			1.48
Laterals							
Roots							
Internode	4.2	4.4				8.0	
3rd Leaf	14.3	21.8	68	100			1.52
Laterals	1.4	2.1			22		
Roots							
Internode	7.1	8.0				15.1	
4th Leaf	13.2	19.6	67	97			1.48
Laterals	4.8	3.4			65		
Roots							
Internode	7.5	8.3				22.6	
5th Leaf	10.9	15.9	62	90			1.46
Laterals	5.8	3.4			66		
Roots	4.7	1.0					
Internode	6.9	9.6				29.5	
6th Leaf	9.5	13.3	53	81			1.40
Laterals	7.2	8.8			47		
Roots	6.2	1.2					
Internode	6.4	10.8				35.9	
7th Leaf	9.0	11.0	26	73			1.22
Laterals	6.5	22.0			58		
Roots	7.3	2.2					
Internode	5.3	10.4				41.2	
8th Leaf	7.9	6.6	22	41			0.84
Laterals	8.8	16.2			41		
Roots	5.4	2.0					
Internode	4.4	8.3				45.6	
9th Leaf	7.6	10	9	44			1.33
Laterals	8.3	7.5			44		
Roots	5.9	3.8					

contact with the subtratum. The number of roots produced from any node is usually about three.

Leaf fall estimates.

A seasonal variation in leaf size and weight was observed, as mentioned above, the largest leaves being those developed under high flow conditions in the late autumn and the smallest in late summer when wash-out was starting, or during the regrowth phase in autumn under slow flow conditions e.g. autumn 1972. There is little variation in leaf size in any particular autumn because of low intra-specific competition but is very large as the maximum crop and cover is reached. The leaf weight is halved as the number of nodes is doubled.

Leaf fall was estimated from the normal analysis of plants at several times during the 1969 growing season in an attempt to quantify this loss from the standing crop (see standing crop study) and thus the true production. The numbers of nodes bearing leaves steadily increased during the season but the ratio of leafy nodes to the total decreased. The number of leafless nodes reached a third of the total in May from a tenth in the previous November (Table 3.2.2). The area covered by the plants increased from 20 - 25% to 75%, an increase in area of 350 m^2 in the study section. The average leaf weight varied from 40 mg for those maturing in late autumn to 20 mg for those in the spring. The loss of leaves by the time of the maximum standing crop reached in May to June is the change from 1300 nodes per m^2 with a tenth leafless nodes and covering 150 m^2, to 3200 nodes per m^2 with a third leafless nodes covering 550 m^2 with an average mature leaf weight of 25 mg, which is 18 gm dry weight per m^2. This is 5 - 12% of the maximum standing crop, depending on the seasonal variation shown by leaf weights.

Labelling experiments indicate that about a quarter of all main stems are damaged to varying degrees by June; the weight loss was not

Table 3.2.2.

Estimates of the number of nodes with and without leaves, Upper Bere Stream, 1968/69 season.

Date	No. of nodes.		%	No. of nodes m^{-2}
	Leafless	Total	Leafless	(weed covered area only)
Nov. 6	13	112	11.6	
Nov. 6	8	128	6.3	
Dec. 4	160	476	10	1340
Jan.27	21	238	8.8	
Feb.17				3720
Mar.17	47	511	9.2	
Mar.18	30	193	15.5	
May 27	86	275	31.2	2600
May 27	85	253	33.6	2850

Note.

- samples obtained from several sources, total analysis of plants and node counts, from, plant maps (e.g. Fig. 3.2.1.) and from length weight relationships.
- March 17, 14.3% leafless on main stem
  3.9% leafless on laterals

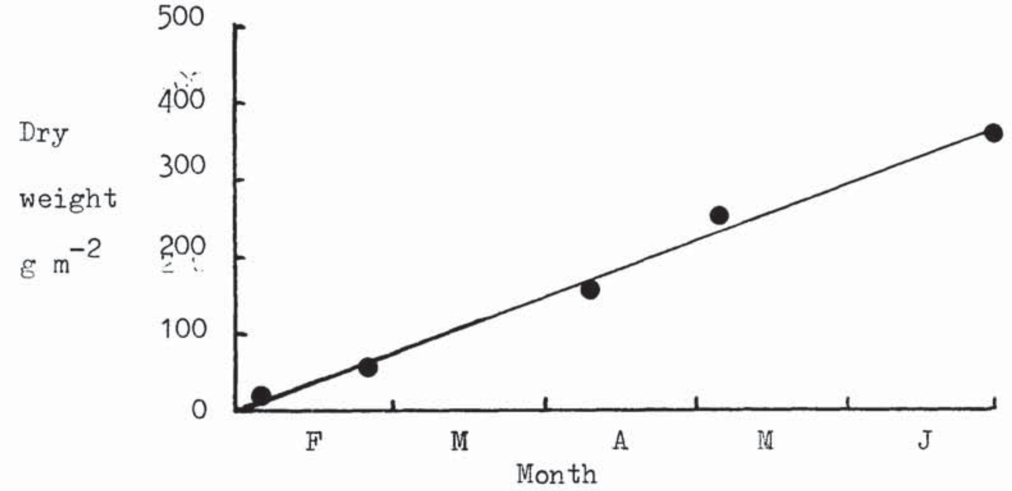
estimated in detail, though it is in the order of one eighth of the maximum standing crop. The stems which were broken off often became intermixed with the plants downstream, and were therefore not lost from the study area.

The effect of partial and near total removal of the plant by cutting demonstrated the rapid regrowth rate if cut during the middle of the growing season, when compared with the rate in the main section. The crop in a small area adjacent to the main study site was 340 g m^{-2} (section D) before it was reduced to 16 g m^{-2} in February. The change in biomass was estimated by taking quadrat samples at monthly intervals. The regrowth was rapid at an approximately linear rate of 2.3 g m^{-2} day^{-1} for four months without a detectable lag phase in growth (Fig. 3.2.10a).

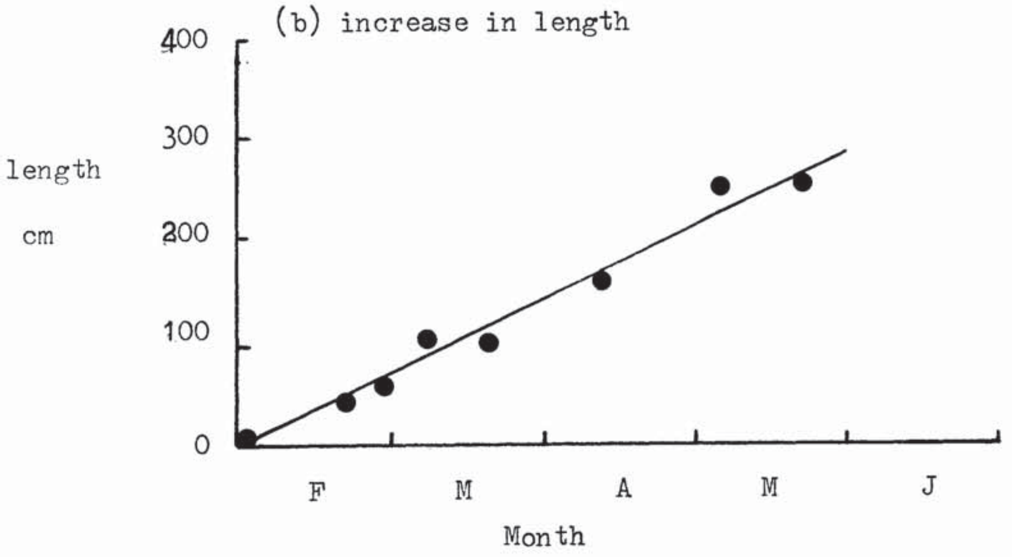
The upstream edge of the site mentioned above was cleared of plant material transversely across the stream, midway through several plants. The growing front extended at a rate of 2.9 cm day^{-1} (Fig. 3.2.10b) for three months. The increase in cover at the end of this period was double that at the start, a rate of 0.0058 of the total day^{-1}. In May the plants from the area were harvested and the apparent growth rate was found to be 1.4 g m^{-2} day^{-1}. This was low compared to 2.7 g m^{-2} day^{-1} for the stream as a whole; however, this expansion phase was the period in which cover was being established with little increase in density of standing crop. The rate of increase in cover was 30% higher than for the main study area during the same period.

Fig. 3.2.10. Increase in weight and length after partial cutting and removal of a section of *R. calcareus*, 1969.

(a) increase in weight



(b) increase in length



3.3. DESCRIPTION OF THE AREA AND STREAM.

The general area has been fully described by Westlake *et al* 1972 and only a summary follows :-

The Southern English chalk stream is the result of a fairly stable combination of human management imposed on the particular geology, flora and fauna for hundreds of years. The streams typically drain widespread deposits of soft permeable fine grained calcareous rock of the Upper Cretaceous period which lacks the extensive fissuring common in limestones. (Paolillo 1969). The Rivers Frome and Piddle flow 60 and 30 km, respectively, south easterly to join the sea in Poole Harbour. The streams which feed them rise in the chalk but flow across valley gravels and alluvium. The stream beds are, of coarse gravel with many flints often cemented together by calcareous deposits and having banks of mud, silt or sand deposited on top. The rain, about 900 mm $year^{-1}$, falling on the chalk, percolates rapidly and accumulates in large aquifers, with little running off. The downwards passage of water is slow and may take several years to resurface. However many springs do respond within a day or so to rainfall because of the increased head of water. The highest rainfall is in the autumn, with the highest evaporation (500 mm) in the summer, resulting in the discharge of streams following a seasonal climatic pattern normally increasing rapidly in the autumn to a maximum and then steadily decreasing until late summer.

The normal velocity range is about one order of magnitude, varying from 0.1 - 1 metre per second. The retention time for the rivers varies from 1 - 7 days. The range of water temperature varies from nearly stable in the springs, typically 10 $\pm$ 0.5 °C, to a maximum range of 22 °C in the main rivers, with the maximum daily range of up to 12 °C.

The typical flora of the streams changes downstream. The head waters are dominated by the plants *Apium nodiflorum* (L.) Lag and *Rorippa* *nasturtium-aquaticum* (L.) Hayek var *siifolium* Rchb. with *Berula erecta* (Huds.) Coville at some sites. In the early spring or further downstream *Ranunculus* subgenus *Batrachium* dominate,in particular R. *penicillatus* var. *calcareus*. In the slower deeper waters *Potamogeton pectinatus* L. , *P. lucens* L. , *P. perfoliatus* L. , *Nuphar lutea* (L.) Sm. and *Sparganum erectum* L. appear. In shallow streams, a summer community of *Callitriche* spp. *Chara fagilis*, *Zannichellia palustris* develops, if the first mentioned marginal-emergent plants do not invade.

At the site selected for intensive study, Holly Bush on the Bere Stream, the dominant plant was maintained by management as R. *penicillatus* var. *calcareus*; it was naturally dominant at the other temperature and flowering survey sites, except at Piddletrenthide, where a few plants had been previously reintroduced, from the River Piddle.

Study sites.

The study sites are listed below and their relative positions are shown on map (Fig. 3.3.1.).

1. *The Bere Stream at Holly Bush.* SY836958

This stream is small and shallow 4.5 m x 0.1 - 0.7 m; fed from springs within a lake, Millum Head. In the past it was managed by frequent cutting and hoeing but it is at present managed for experimental purposes by removing emergent plants by hand.

2. *The River Frome.*

The River Frome from below Dorchester, to East Stoke, near Wareham, includes slow silted stretches behind weirs and in pools and fast gravelly riffles. When flowing in a single channel it is 5 - 15m x 0.5 - 2.5m.

3. *Temperature and flowering survey sites on the River Piddle.*

The sites were chosen to be as comparable as possible, gravel with flint stream beds, rapid flow, not too silty and fairly shallow. The length and width sizes refer to the typical stream area at the site chosen.

A. Piddletrenthide. SY708985.

A small stream 1.0m x 0.1 - 0.3m, mainly surface land drainage, seasonally very silty. Overgrown during the summer and cleared during late summer.

B. Waterston. SY744953.

A small spring-fed stream originally used as a commercial cress bed source, now used for experimental purposes, 1.5 - 2.0m x 0.05 - 0.2m deep. Erratically managed.

C. Puddletown. SY754948.

A stream 3.0 x 0.05 - 0.2m deep, managed intensively, cleared 2 - 3 times a year to stream bed level.

D. Athelhampton. SY771942.

A stream 3.0 x 0.1 - 0.4m deep, managed once a year after flowering, part of an ornamental garden.

E. Throop SY825933.

A small river 4.0 - 6.0 x 0.1 - 0.6m, managed once a year at flowering time for flood control.

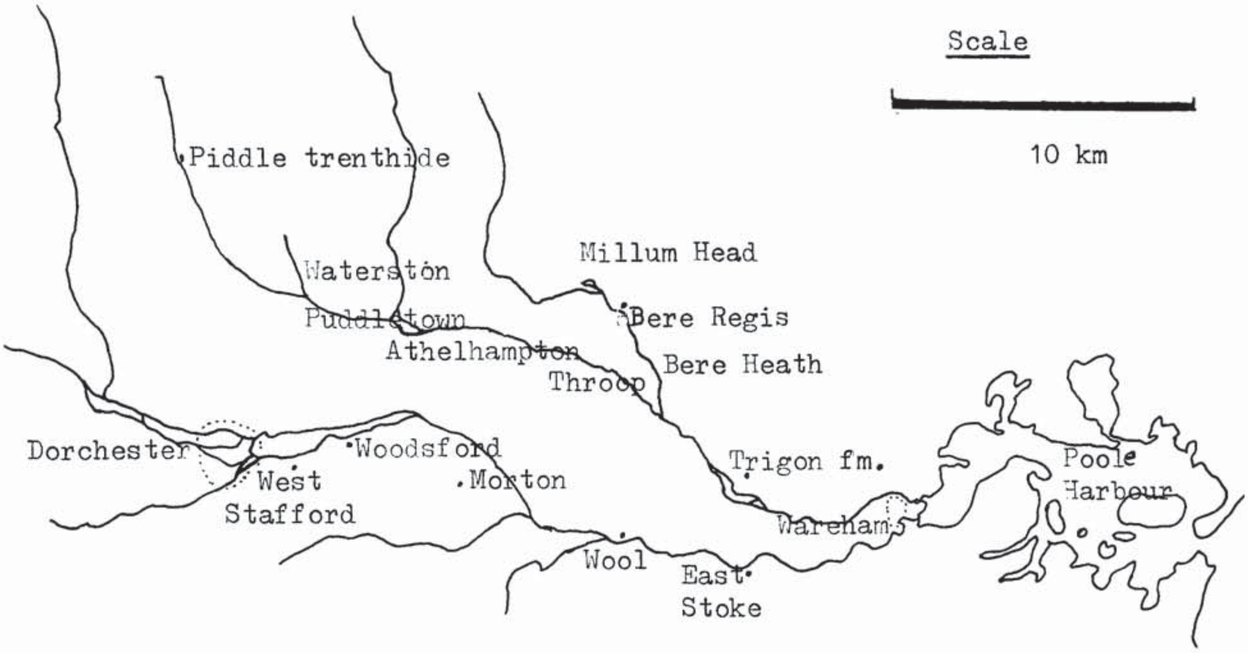
F. Trigon Farm, Wareham. SY877893.

A river 4 - 10m x 0.5 - 1.5m, immediately above equal division of river. Partially managed once a year for flood control.

G. North Mill Bridge, Wareham. SY921877.

A river 6 - 10m x 0.5 - 2.0m, managed once a year for flood control. Tidal influence was limited by a flume at this point.

Fig. 3.3.1. Map of River Piddle and part of River Frome river systems.



3.4. DESCRIPTION OF SELECTED STRETCH OF STREAM.

The considerations leading to selection of the study reach of the Bere Stream at Holly Bush (Fig. 3.4.1.) as a site for intensive study were that :-

(a) The headwaters were considered to have the least problems with which to start a chalk stream ecosystem study.

(b) The area necessary must be under the experimenter's control and a place where flooding could occur without much harm;

(c) The site must also be of proportionally similar size to the larger rivers.

(d) Part of its area must be without a tree canopy.

Water flowed from several springs within the deep silt bed of the lake known as Millum Head, 0.753 ha. in area. The water flowed over an artificial sluice for only two thirds of the year (see later). The lake had a 10% canopy of Acer pseudoplanatus L. , on the North West margin, with occasional Salix cinerea ssp. atrocinerea (Brot.) Silva and Sobro on the southern margin. The lake was dominated by Fontinalis antipyretica L. and Hippurus vulgaris L. with Schoenoplectus lacustris (L.) Palla on the East shore. The south eastern edges were dominated by Epilobium hirsutum L. The lake was used as a small duck-shoot, receiving about 50 - 100 kg barley grain (Hordeum vulgare) every month of the duck season, but it was never managed in any other way.

The lake provided most of the water during late autumn, winter and spring. During the summer leakage through the dam and water from the cattle drink combined with a little drainage from Roke Pond entering at the bend, the junction of section B and C, provided the flow to the stream.

The stream bed was of chalk covered with silt above this bend and large gravel with flints below the junction. For convenience the upper straight section, 154 x 3.1 mm, was considered in two parts. The upper section A was dominated by emergent plants notably Rorippa nasturtium - aquaticum (L.) Hayek. with some canopy cover by A. pseudoplanatus. The lower section B had considerable tree cover of Fraxinus excelsior L. with Salix fragilis L. , S. purpurea L. , and S. viminalis L. and hybrids present. The banks of the stream were densely covered with E. hirsutum with scattered areas of R. nasturtium-aquaticum in summer. R. calcareus was re-established after extensive management in 1969, although it was not very successful.

The lower section C, 155 x 4.0 m, was dominated by S. viminalis and hybrids, with S. cinerea var atrocinerea, Corylus avellana L. and Alnus glutinosa (L.) Gaertn. The lower 20 m below the road bridge was more open and dominated by R. penicillatus var calcareus in the spring and R. nasturtium-aquaticum in the summer.

The main sources of organic material to this section A - C were the allochthonous ones (tree leaves, twigs and reproductive structures and herbaceous plants near the stream); and the autochthonous materials,(aquatic macrophytes, mainly R. calcareus, with F. antipyretica, Lemna spp. and algae).

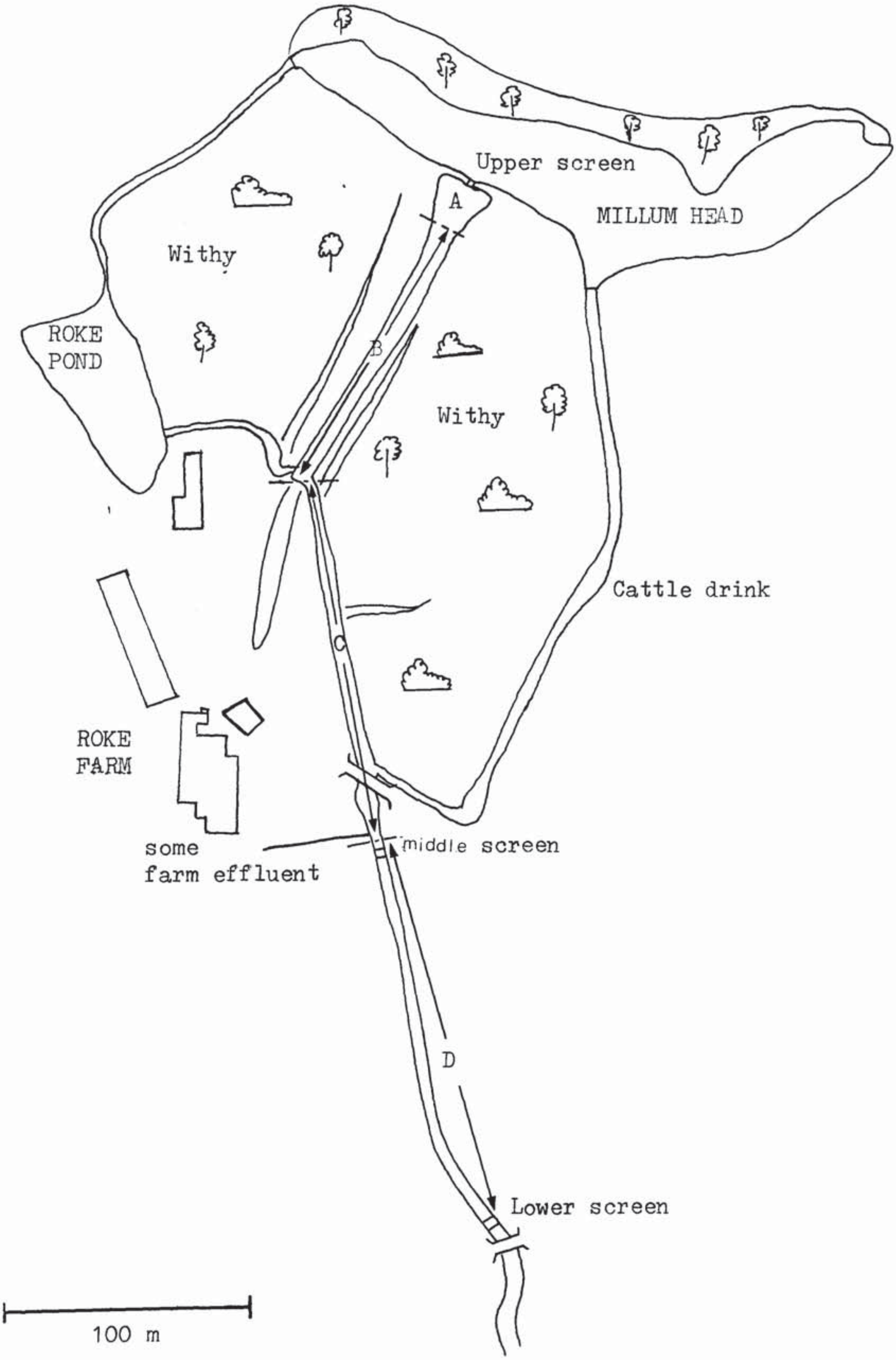
Seasonal management was necessary, particularly of the cattle - drink stream, but was always kept to a minimum. Trees which fell across the stream or lake were removed. The small section between the road bridge and the middle screen was cleared in the autumn every year before the floods.

The area, below this wooded area, (section D) was the site of the intensive production study. It was 165 m x 3.9 - 4.3 m wide with a large gravel bottom with flints, and had no tree or shrub cover. The upper straight section of 120 m was shallow compared with the lower 45 m which was slightly deeper and retained some silt when the upper section was washed clear in the autumn.

The study section was managed to maintain the dominance of

R. calcareus by hand-weeding the emergent species once a month. During late summer 1969, the crop was removed as a check of sampling technique.

Fig. 3.4.1. Map of Holly Bush study site, Bere stream, Bere Regis.



3.5. DESCRIPTION OF THE SCREENS.

Organic budgets were required to elucidate the origin and fate, of organic materials in the Bere Stream at Holly Bush. These materials could come from the lake, the wooded margins of sections A - C, the grassy margins of section D or from the river itself. Screens were necessary between these sections to measure the outputs and the potential inputs from upstream, and were therefore installed at the lake (upper screen), below the road bridge at the bottom of section C (middle screen) and below section D (lower screen). The losses of R. calcareus from section D of the stream were required to correct the estimates of biomass to obtain the net production. The removal of material collected on the middle screen for part of the study period reduced the degree to which sorting of material on the lower screen was necessary.

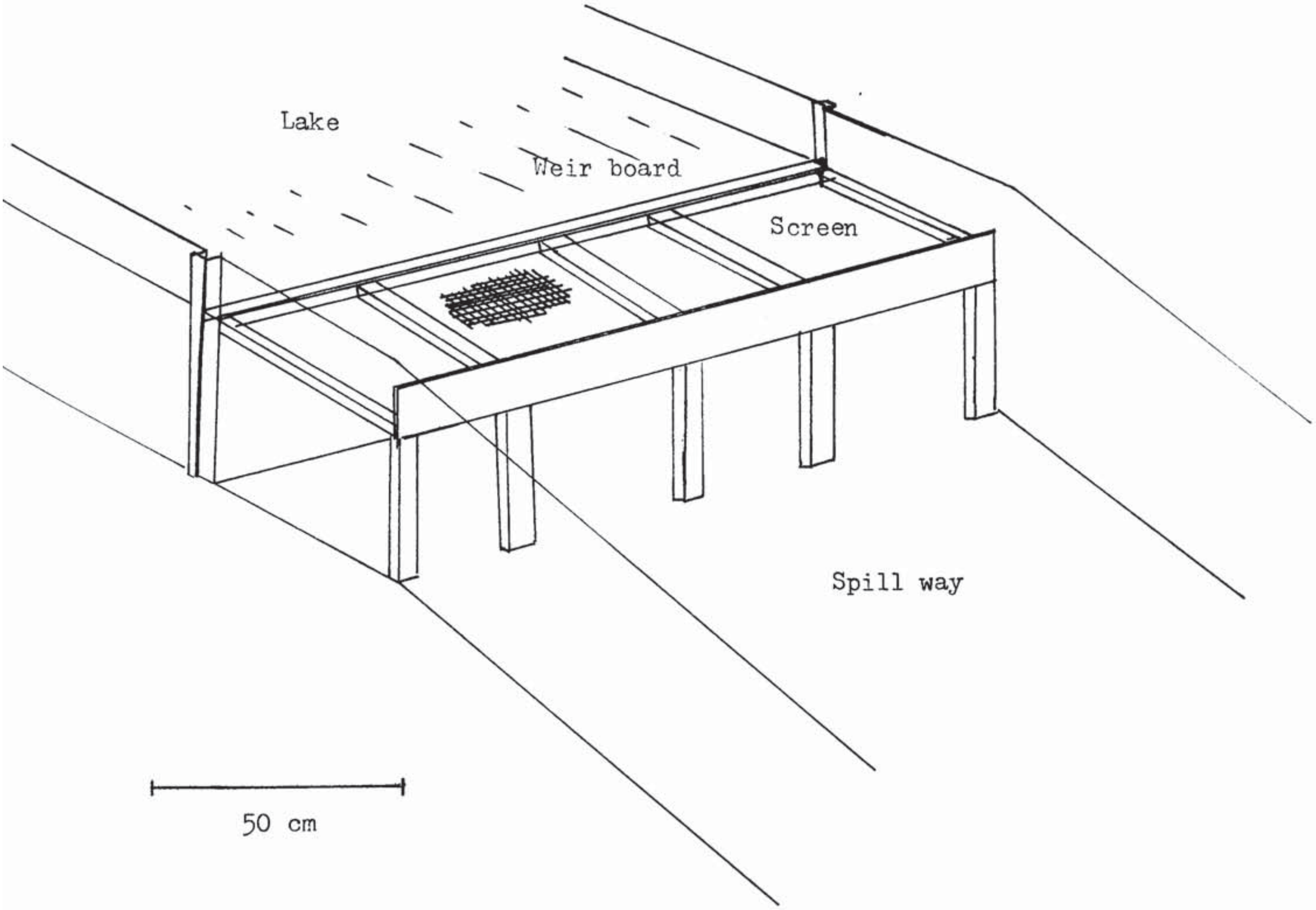
The upper screen (Fig. 3.5.1) was a simple flat-bed screen of nominally 5 mm, of square holed zinc-coated steel weldmesh held in a wooden frame ,on supports and situated on the downstream side of the sluice board. This screen type was possible as a back- up of water was unimportant.

The middle screen, (Fig. 3.5.2. and Plate 1), contained seven double sets of 5 mm square-holed zinc-coated weldmesh screens, 0.61 m wide and1.83 m long, framed on either side by 0.05 x 0.025 m timber. The screens were supported at an angle of 22° to the stream bed by 'ladders', 3.7 m long, made of 0.05 m square timbers, held obliquely by 0.025 m thick marine grade plywood, forming a channel behind each screen pair. This type of screen was used to cause minimum interference with flow and back-up of water. The base of the marine plywood was kept level by three equally spaced 0.23 x 0.15 m timbers across the stream. The stream bed was excavated mechanically and the screen base let into it, until flush. The base was subsequently covered by $\frac{1}{4}$" butyl rubber sheeting, extended 1 m upstream and buried in order to prevent water from forcing its way underneath the screen.

The double set of screens enabled the upstream pairs of the set to be removed and cleaned, after insertion of the downstream pairs, preventing the passage of material during the operation. The upstream screen pairs were then replaced and the downstream set cleaned.

The lower screen was narrower than the middle one having only five sets. The same construction was used but during times of high flow or much backing-up, a supplementary set of screens were used on the upper halves of the ladder supports. This necessitated two screens for each downstream set to be inserted before clearing. This situation was avoided as much as possible, by periodically managing the stream below this screen to keep the water level low enough for only one set of screens to be necessary.

Fig. 3.5.1. The upper screen, Millum Head.



Vertical section of screen and supports

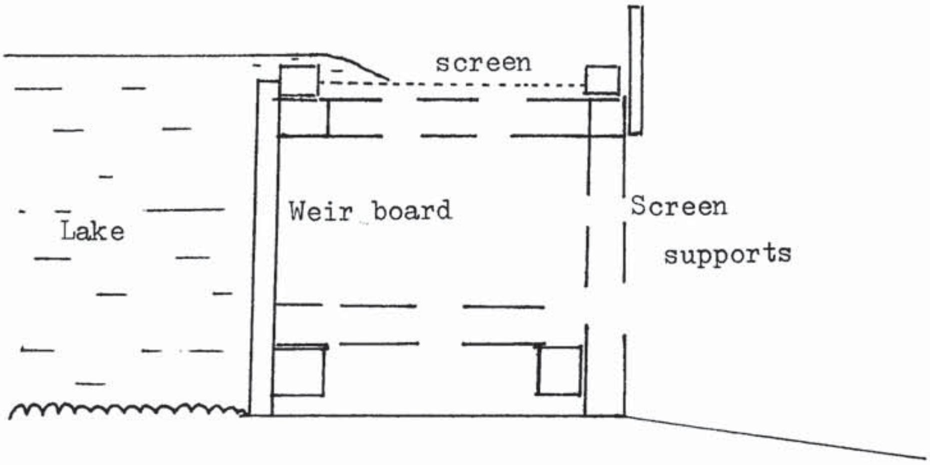
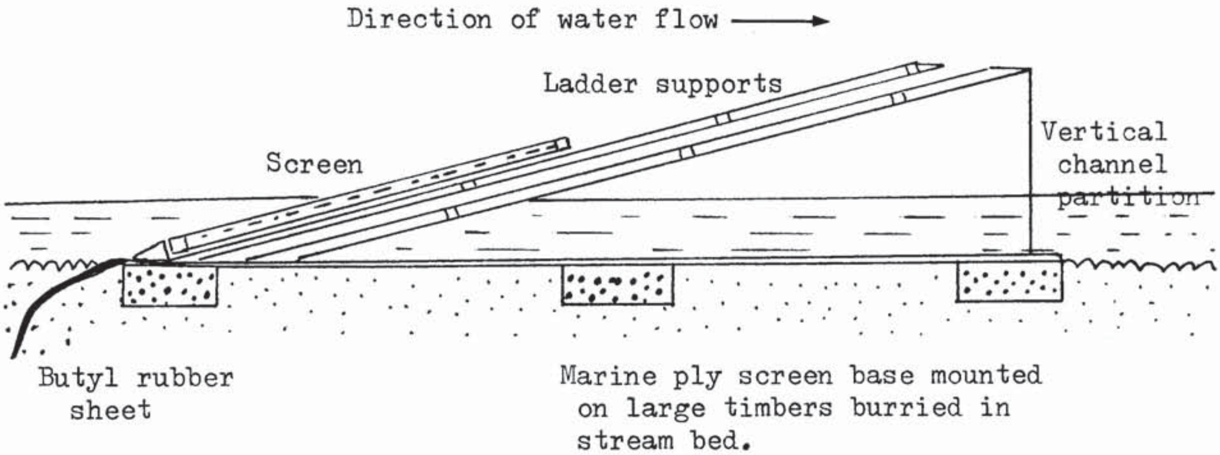
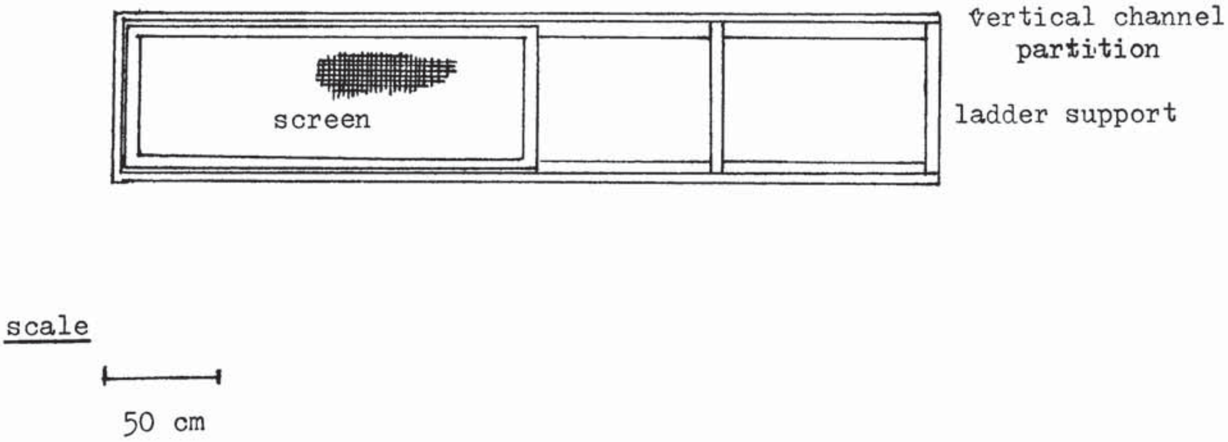


Fig. 3.5.2. The Middle screen, downstream of section C, Holly Bush.

(a)Screen,vertical section.



(b) section of screen



<u>Plate</u> 1a. Middle screen, Holly Bush, looking upstream towards road bridge and lower part of section C.

<u>Plate</u> 1b. Middle screen, in normal operating mode collecting material from stream water.

Plate 2a. Middle screen, during cleaning, downstream screen pairs collecting material while upstream pairs are cleaned.

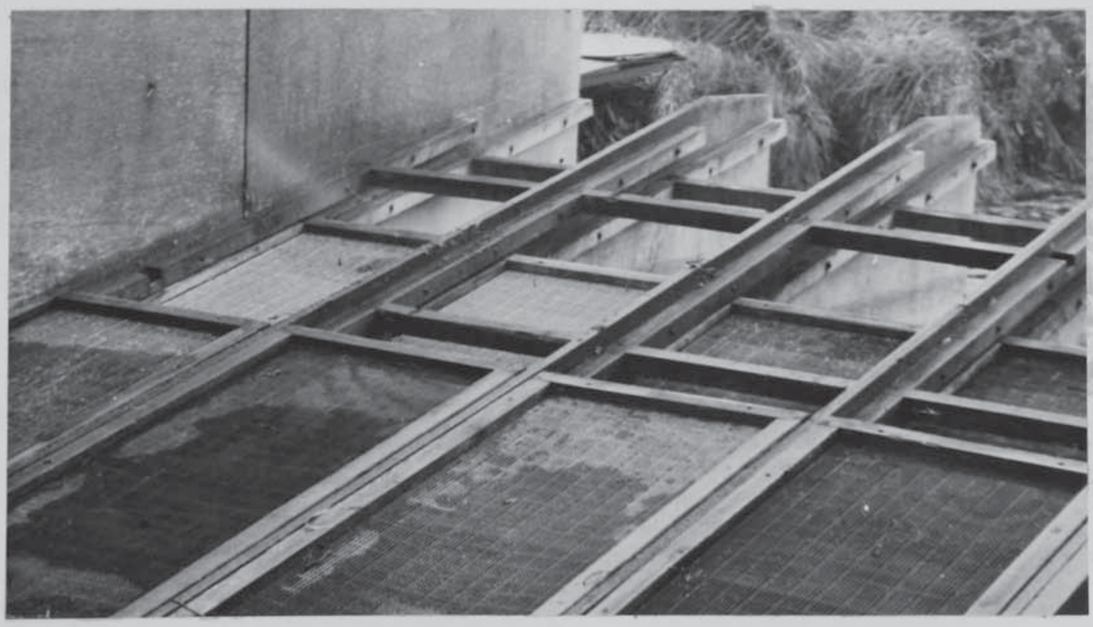


Plate 2b. Detail of screen construction, showing ladder supports. Upstream screen pairs in normal collecting position, downstream pairs moved out of water.

4. FIELD INVESTIGATIONS.

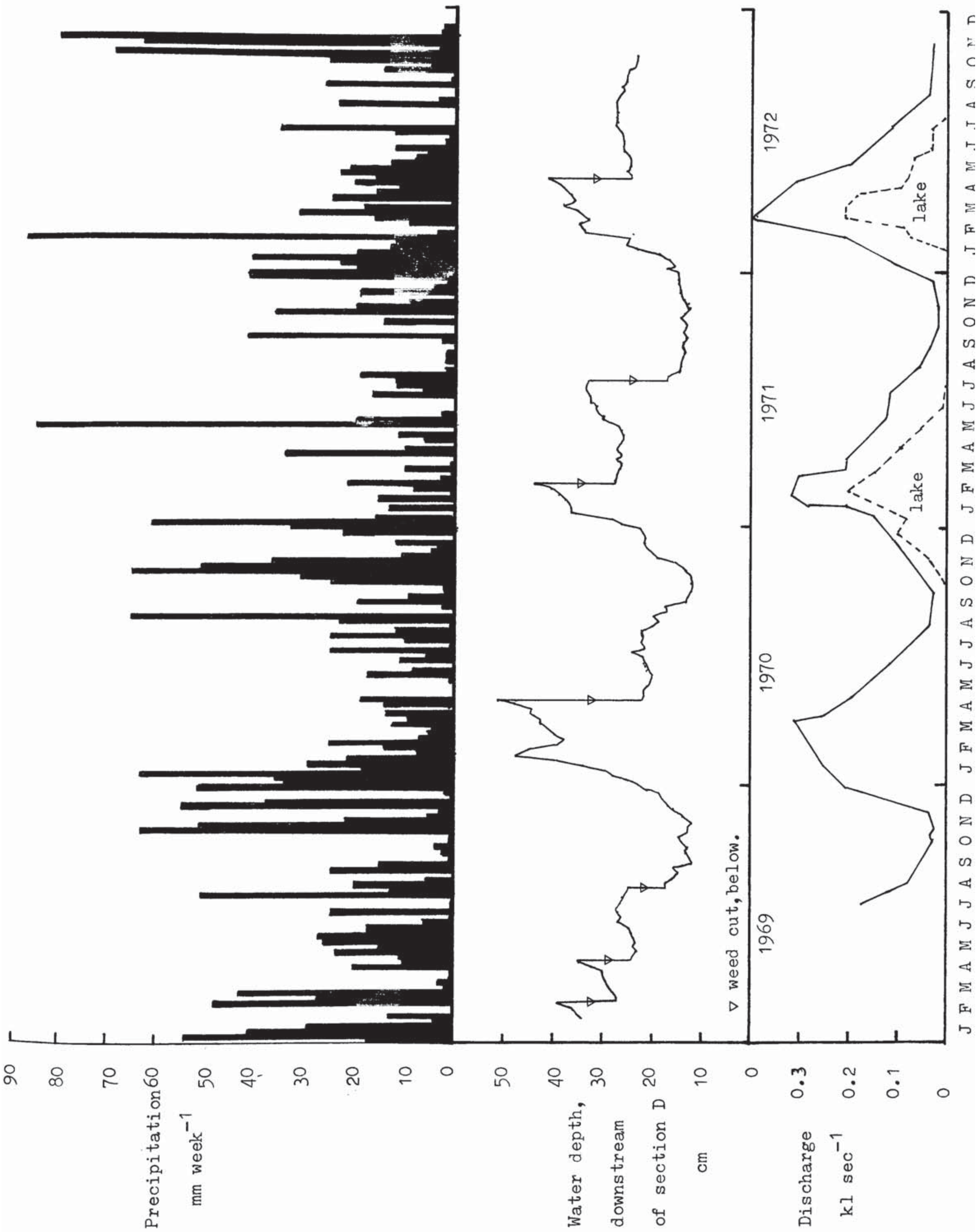
4.1. THE PHYSICAL AND CHEMICAL ENVIRONMENT.

4.1.a. Precipitation

The average precipitation in Dorset is about 900 mm per year. Precipitation as snow is on average one day a year. The mean for the period 1960-72 recorded in the lower catchment and at the River Laboratory is 867 mm year^{-1}. There is local variation, for example, at Dorchester in the upper catchment area, slightly further from the study site than the River Laboratory, the precipitation is on average 16% higher. (Casey and Newton in Press). During the years 1969-72 the annual precipitation was 853, 863, 612 and 912 mm respectively. The year 1971, was considerably drier than average, but this is best seen in terms of seasonal rather than annual precipitation. A displacement of the normal precipitation cycle caused the wet season to occur earlier in 1970-71 than in either 1969-70 or 1971-2.

A hydrological balance for the study area catchment was not attempted because of its small size, the highly retentive chalk rock and the resultant long retention or passage time, and the delimitation of the actual catchment area. The changes in discharge in relation to rainfall periods were a result of a continuous change from a little run-off, with only a change in hydrostatic pressure at springs and boreholes, to much run-off, after the imposition of the seasonal evaporation regime on the catchment area.

Fig. 4.1.1. Precipitation, water height and discharge for section D of Bere Stream, Holly Bush, and discharge for Millum Head.



4.1.b Hydrology.

Introduction.

The discharge of the stream and its daily changes were needed to determine the interrelationships of water velocity, depth and the rate of growth of R. calcareus and the balance of accumulation and loss of small suspended material and to calculate the seasonal hydrodynamic coefficients of the stream and its plant population.

At regular intervals, particularly near changes in management and flow, measurements of discharge were obtained which were then related to the height of water, which was continuously measured. The water depth was frequently measured at several datum points along the length of the study section of stream to show the pattern of change due to plant growth and to silt accumulation.

The discharge of the major water source Millum Head, was calculated from measurements of water height over the weir board.

4.1.b.(i) Review of the methods of measuring stream discharge.

The discharge of a stream is the volume of water passing a point in unit time. This volume is equal to a cross-sectional area of stream multiplied by the mean velocity of water through it. The section of stream measured must be free of side streams and discharges.

There are three main groups of methods for measuring discharge;

1. This is based on the properties of an artificial section of known characteristics, for example, a weir, a flume or a flow nozzle, or on a section of stream of uniform gradient and characteristics. (Francis 1962 and Vennard 1963)

2. involves a velocity measurement, for example, a current meter, Pitot tube, or floats or the introduction of a soluble tracer substance and the timing the passage of it through a section of stream of known cross-section area.

3. this is a modification of the tracer technique of 2. , the level of the tracer substance is maintained at a constant level and its dilution is measured giving the discharge directly.

The methods of stream flow measurements have been reviewed several times by King and Brater (1963) and Pilgrim and Summersby (1966); the indirect methods by Cragwall (1951) and gauging stations by Oates (1962).

1. The construction of artificial sections e.g. weirs, is unsatisfactory in lowland streams as they involve unnatural restrictions on water movement causing increases in the head of water. Their exits must be free of all restriction to flow in order to work accurately (Barsby 1965).

The alternative is to calculate the flow through a natural section of stream which is of uniform gradient and characteristics and to consult tables to find the recommended hydraulic coefficient.

Flow in open channels is usually steady turbulent, however, in short channels, i.e. small areas of stream, for example between weed beds, uniform conditions will never be obtained because of the long reach of channel needed to establish it, nevertheless, open channel flow calculations are solved by assuming this uniform flow. The normal formula used is the Chezy-Manning equation, this is based on the Chezy equation and combined with the formula proposed by Manning (1889) for determining the water velocity in channels. The Chezy equation, is a fundamental equation for uniform open-channel flow derived by equating the equal and opposite force components of gravity and resistance and applying the fundamentals of fluid mechanics.

The Chezy-Manning equation is thus :-

Eq.(1). $$Q = \frac{1.49}{n} \cdot A.R_h^{0.667}.So^{0.5}$$

<u>where,</u>

Q = Discharge in $ft^3 \ sec^{-1}$

n = Chezy-Manning coefficient

A = Cross-sectional area ft^2

R_h = Hydraulic radius (cross-sectional area/wetted surface)ft

So = Slope of stream bed or stream surface, the latter is suggested by Grover and Harrington (1943)

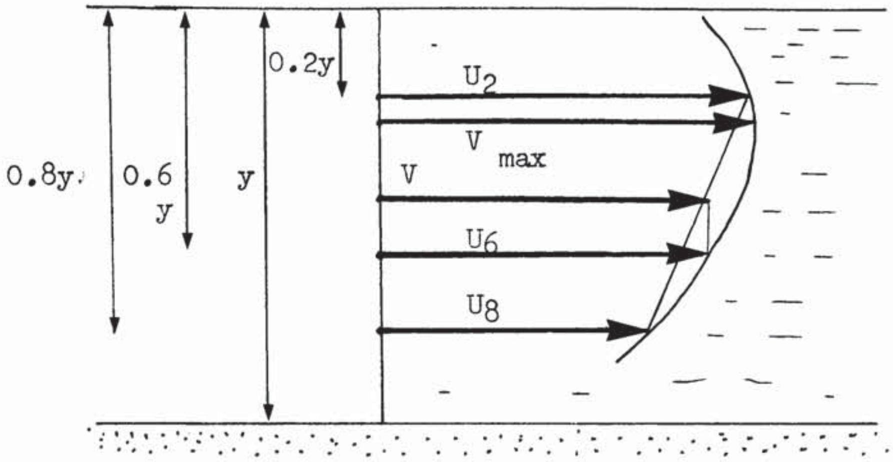
Unfortunately a dimensional investigation of the Chezy-Manning formula shows that the left hand term has the dimension l/t but the right is $l^{\frac{2}{3}}$; the equation is therefore dimensionally non-homogenous and can only conveniently be compared with other work, at present, when used in the conventional foot-pound-second system; Manning used both sets of units.

2. The second group of methods involve either the measurement of the velocity at one point and its cross-sectional area or, more accurately, the mean velocity of a typical section and the mean cross-sectional areas. The method of velocity measurement is usually a current meter e.g. Ott propellor type or the miniature propellor type of Eddington and Molyneux (1960); however, these have limitations (Pilgrim and Summersby 1966) particularly in weeded areas of stream. In order to obtain satisfactory results, adjacent velocity measurements must not vary more than 10% of one another across the stream. (Vennard 1963). The velocity at any point in a channel from the maximum velocity to the stream bed is nearly inversely proportional to the logarithm of the depth and the steepness of the gradient of velocity towards the bottom depends on the roughness of the stream bed. (Hynes 1970). For the greatest accuracy, vertically adjacent readings that also agree to within 10% should be used but normally the standard depths are adopted. The mean velocity is found at about 0.6 of the total depth from the surface in a wide open channel although for more accurate results the mean value for velocities at 0.2 and 0.8 of the water depth have been suggested. (Grover and Harrington 1943, Vennard 1963). (Fig. 4.1.2A)

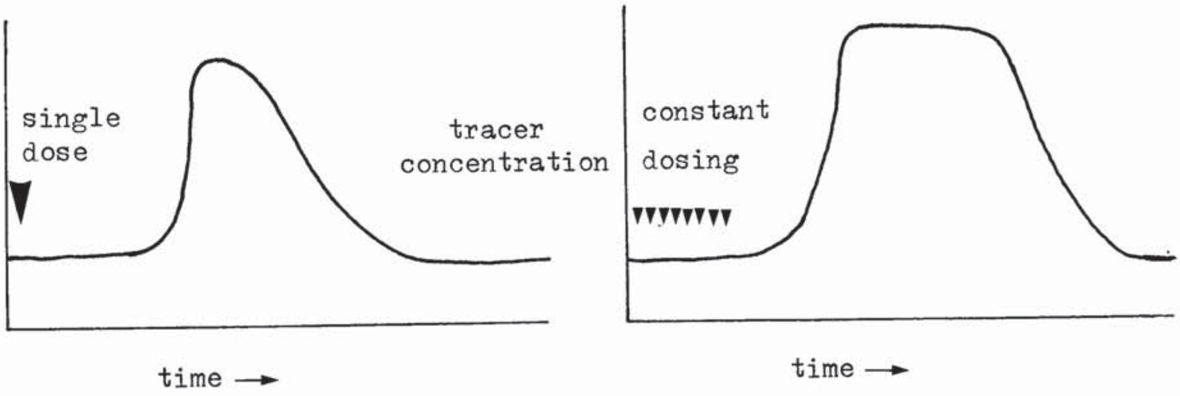
The use of Pitot tubes, particularly by Grenier (1949) and the

Fig. 4.1.2. Discharge determinations.

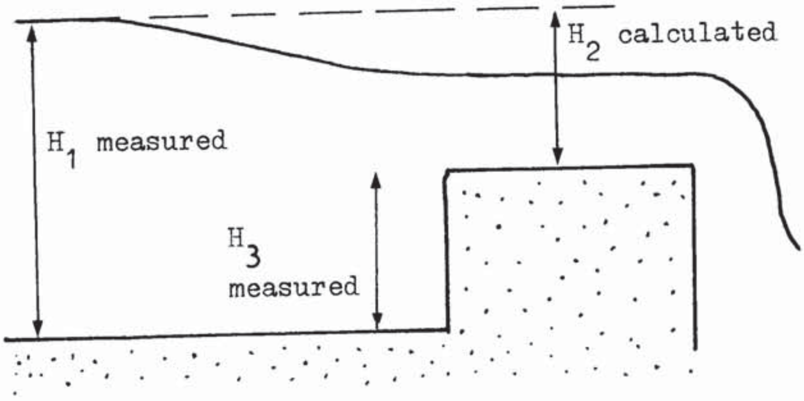
(a) standard velocity distribution in a vertical in open flow



(b) concentration of tracer downstream after a single injection and after constant rate of injection.



(c) Flow over a broad crested weir



cooling rates of heated wires (Kolin 1944; Ruttner 1963; Vennard 1963) or of warmed thermistors (Kalman 1966; Vaprek 1963) are more suitable for measurement of velocities in the proximity of organisms than for the monitoring of discharges.

Floats with or without submerged vanes or ropes are more suitable for larger, deeper rivers with less abundant macrophytes than Englush chalk-streams (Hillebrand 1950, Hinrich 1966). The mean water velocity of a river is said to be 0.85 of that at the surface; the maximum velocity occuring between 0.05 - 0.25 of the depth.

An alternative method of velocity measurement is the tracer technique in which soluble substances, tracers, for example, dyes, salts or radioactive isotopes, are added to the system and their concentration estimated further downstream. This results in a pulse of chemical passing downstream with a sharp leading edge and a longer decline in concentration before returning to the normal state. (Fig. 4.1.2.B). The velocity is obtained from the geometric mean of the distribution of chemical with time at the sampling site. The cross-sectional areas must be measured before the discharge can be calculated. (British Standard Method 1966 (a)).

3. The application of chemical tracer at a constant rate produces a plateau which is the result of constant dilution by the stream flow; this dilution rate is the discharge. (Fig.4.1.2.B). An important aspect of this type of measurement is to ensure complete mixing of the chemical before sampling. Barsby (1967) suggests and compares two methods of checking the completeness of mixing; that of calculation from channel and flow parameters and that of the dispersion obtained by a preliminary injection and extrapolation of the result. Multiple injections proportional to the flow across the stream greatly shorten mixing distances.

The choice of chemical compound depends on the cost and solubility, the analytical apparatus available and the system to be studied. The choice is further limited to substances, which are not adsorbed onto surfaces or absorbed by organisms, which are chemically stable and which are easily analysed. For example, lithium is advocated by Agg et al (1961). They were working with flows in sewers and found that adequate accuracy for pollution problems could be obtained using flame photometry. Lower concentrations could be used than with salt and thus simpler and more portable dosing could be used. It was harmless compared to radioactive tracers e.g. bromine 82, and was stable in solution. It was not lost by deposition or adsorption on surfaces.

The final choice of chemical for an intensively studied biological system must be its effect on the system, for example, nutrients would not be used (unless perhaps if normally in great excess). Chemicals already present could be used as long as the resultant concentration does not excede the natural annual maximum by too much.

4.1.b.(ii). The method selected for and the result of, the determination of discharge at Millum Head.

The discharge of the major water source of the Bere Stream, Millum Head, was determined by calculation from water heights assuming the discharge relationship for the weir and screen together was similar to a broad crested weir for low flows. A slightly elevated value of discharge may be obtained from the theoretical formula Eq.(2) (Francis 1963 and British Standards Institute 1966 b).

Eq.(2) $$Q = 0.544\, g^{0.5} \cdot H_2^{1.5} \cdot b$$

Where

Q = Discharge m^{3}sec^{-1} or kl sec^{-1}

g = Gravitational forces m s^{-2}

H_2 = Height of water above weir but measured away from approach channel (see Fig.4.1.2.c.) m

b = Width m

Result and conclusion.

The estimates of discharge were made according to the formula (Eq.2) for the broad crested weirs and plotted on the main hydrograph (Fig. 4.1.1.).

An example of the type of calculation of discharge (Eq.(2)) for 10 cm of water flowing over the weir is :-

$$Q = \frac{0.544 \cdot 981^{0.5} \cdot 10^{1.5} \cdot 290}{1 \cdot 10^{6}}$$

$$= 0.15 \text{ m}^{3} \text{ sec}^{-1} \text{ or kl sec}^{-1}$$

The annual discharge pattern is offset by six months from the calendar year and depends in particular on the timing of the autumn rainy period. The discharge for the year 1971 was 1.47 Gl, however, the flow from the lake for the following season 1971-2 did not start until the beginning of 1972 as happened previously in 1970-1 (Fig.4.1.1). The annual discharge for 1972 was 1.46 Gl (Table 4.1.1.). The lake water as measured passing the weir board was 40% and 30% of the total stream discharge for 1971 and 1972 respectively. However, if the discharge is considered by season, August to August, as is found convenient for the middle screen, the lake contributed 41% and 34% or 1.75 and 1.46 Gl. respectively.

Units

Table 4.1.1.

Total discharge, Millum Head, 1970-2. kl month^{-1}.

Month		Season.		
		1970-1 Ml		1971-2 Ml
	1970		1971	
Nov.		16		0
Dec.		264		0
	1971		1972	
Jan.		231		0
Feb.		497		198
Mar.		339		525
Apr.		250		329
May		143		196
June		10		124
July		3		86
Aug.		0		0
Total Discharge		1753		1458
Estimated		Daily		Weekly.

4.1.b.(iii). The methods selected for discharge determinations, section D, Holly Bush.

The discharge through the main study stretch, section D, was monitored continuously, using a water level recorder at the downstream limit of this section, and periodically by measurements at selected sites within the section to obtain data for calculation of the seasonal effect of standing crops of R. calcareus. (both methods group one). The estimation of discharge by subjectively choosing suitable Chezy-Manning coefficients was not attempted after a preliminary calculation indicated that totally unsatisfactory results would be produced. There are no tables for seasonal changes in coefficients related to aquatic macrophyte standing crops. The water level recordings were related at regular intervals to the discharge determined by the maintained plateau tracer technique (group three method).

The chemical analysis (Table 4.1.4.) of the stream water indicated that sodium chloride would be a suitable compound after considering its cost, its high solubility and the availability of analytical apparatus. A velocity current meter was used in several occassions in 1970 (group two method) and compared with discharge determinations by the tracer method.

Water level (group 1 method)

Method.

A commercial level recorder, embodying a counter-balanced float linked to a drum, was used. The site selected was of uniform cross-section with steep sides, at the downstream limit of the main study site, section D. There was a 300 m section of stream below this from which the weed was removed periodically; however, I had little control of times of weed - cutting.

The level recorder had a pulley to drum ratio of 1 : 1 in order to give unmagnified changes over the whole expected range. The recorder chart was changed weekly. A subjective smoothed curve was drawn through rapid fluctuation in level caused by wave action and the mean daily value, or the maximum value at times of rain were read to the nearest one tenth of an inch from the chart and used for graphing results.

Three, one foot square concrete blocks were buried to their upper surfaces in the stream bed. They were situated at the upstream, middle and downstream positions within the study reach (D). Iron stakes were driven into the bed at intermediate distances.

The heights above datum of the blocks and stakes were surveyed using a standard type of theodolite near the beginning and towards the end of the experimental period.

The stream was measured at 34 different cross-sections, including those with blocks and stakes present, on several occasions; depths of water, mud and presence or absence of plant material was recorded every 25 cm across the stream. A taut tape-measure was used as a distance guide and with a wooden metre rule depth measurements were taken.

Result.

The daily changes in water depth (Fig.4.1.1.) were calculated from the continuous recordings of water level by relating the latter to the mean stream bed level; this was determined from the cross-section at the water level recorder site. For example, on November 26, 1969, there was 7.3 cm of water over the bridge block, which was 8.3 cm above the mean level of the stream bed at the bridge; this was equated to the height of the recorder of -6.4 cm, and 22.0 cm was added to all values. The block at the bridge was used for frequent spot checks of the level of water as indicated by the recorder.

The daily water depths were used in the estimation of daily discharges (Fig.4.1.1.), assuming that for short intervals of time (on average one month) the relation between the changes in height for short intervals was linear. A further correction was then applied to slight increases in depth, due to rainfall, from assumed general line of change between the monthly known estimates of discharge. Discharge determinations were always made close to weed cuts, and these estimates were adjusted to coincide with the actual weed cut day..

An overall correction factor was calculated on the above assumptions according to the following expression :-

Eq.(3.)

$$x = \frac{\left[d_n \cdot \frac{Q_1}{Q_n} \right] - d_1}{n}$$

Where.

x = overall correction factor

d_1 , d_n = depth of water on day 1 or n, in cm

Q_1 , Q_n = discharge on day 1 or n, in $m^3 sec^{-1}$

n = number of days between discharge estimates

This factor was then used on daily water depths to calculate the discharge as follows :-

Eq.(4.)

$$q_n = \frac{d_n}{d_1 + x.n} \cdot Q_1$$

Where.

q_n = estimated discharge on day n, m^3sec^{-1}

and as above.

The height of the top of the block or stake at the selected sites was related to the mean bed level and also to the datum point (Table 4.1.2.) These data were used in the calculation of Chezy-Manning coefficients. (see later).

Table 4.1.2.

Vertical heights of block and stakes, cm.

Distance upstream from datum m	Position	Height relative to bridge block		Correction factor[1] to mean bed level			Stream bed height relative to datum point
		Sept 69	May 72	Oct7 69	Nov26 69	Mean	
0	Bridge block (Datum point)	0	0	-8.1	-8.5	-8.3	-8.3
0	Bridge stake	24.6	24.6	-32.6	-33.1	-32.9	-32.9
5	Downstream side[2] of lower screen	-9.2	-4.1				-4.2
25	post 30,stake	19.0	19.3	38.2	37.0	37.6	-18.6
60	post 24,block	1.0	1.3	3.0	2.9	3.0	-2.0
115	post 15,stake	28.0	28.3	-17.5	-17.3	-17.4	10.6
170	Downstream side of middle screen		46.0				46.0
175	post 1, stake	52.8	54	-15.4	-14.6	-15.0	37.8

Note - see below.

Notes (Table 4.1.2.)

- 1 - Mean level of stream bed does not include soft sediment lying on it, as this moves seasonally.
- 2 - Height of downstream edges of screens increased by 5.1 cm on June 14 1970, to support fine nets. All values of water height corrected for this addition.

Current meter (group 2 method)

Method and result.

Early in the experimental period an Ott current meter was used to construct a velocity profile at time of low discharge. (Fig.4.1.3.) The cross-section was at the downstream end of section D near the level recorder. Significantly different values of discharge were not obtained using four combinations of the resulting figures; values at 0.6 (see Fig.4 1.2.a), the mean of the values at 0.2 and 0.8 of the depth, 0.85 of the values at surface and the mean area weighted values of all the determinations of velocity. (Table 4.1.3.) The profile was produced from a total of fifty five readings, which were laterally spaced every 25 cm across the 3 m of stream and at suitable depths. The profile shows that when the 0.6 values were considered the value of discharge was obtained from only three accurate readings and nine inaccurate ones. The latter were obtained by extrapolation below the minimum calibration value for the slowest available propellor (5 cm sec^{-1}) provided by the manufacturers. The discharge based on the 0.2 and 0.8 depths had more acceptable readings, but was also invalid. At low flow conditions it is therefore impossible to produce a true velocity profile without approximations.

A current meter was used by Dr. M. Ladle of the River Laboratory to estimate the discharge on several occasions during 1970 at high discharges. The method was to take 3 fifty second readings in each of the five screen channels of the lower screen at 0.6 of the depth from the surface.

Fig. 4.1.3.

Fig. 4.1.3. Velocity profile using Ott current meter, at downstream edge of section D, Octeber 29 1969

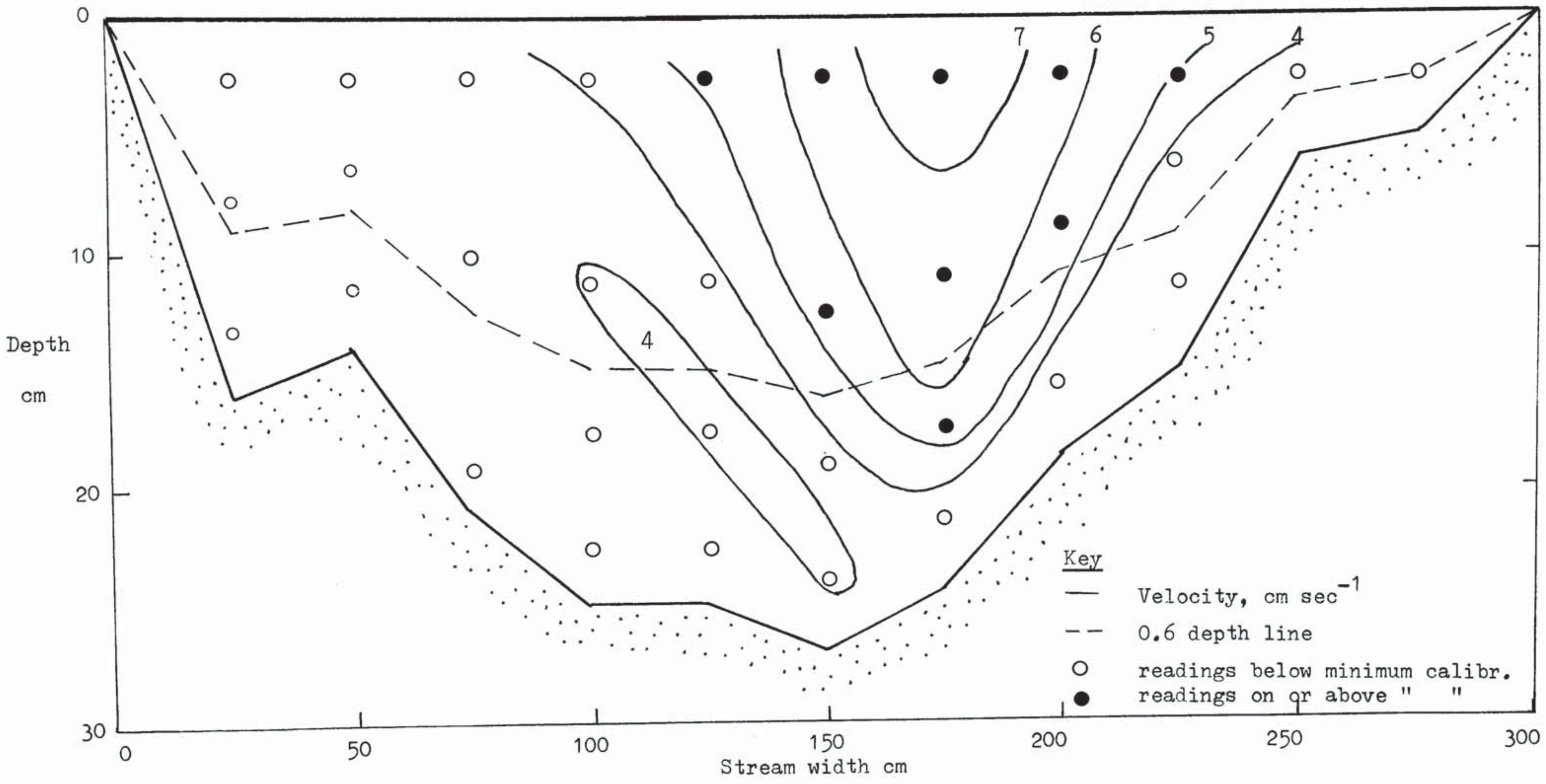


Table 4.1.3.

A comparison of current meter estimates of discharge at section 34.

October 29 1969.

Average depth	0.163 m
Width	3.00 m
Area	0.489 m^2

Values used	Velocity cm sec^{-1}.	Discharge in kl sec^{-1}
0.6 depth	3.84	0.0188
0.2 + 0.8 depth	3.99	0.0195
0.85 of surface	3.90	0.0191
all values	4.04	0.0198
velocity-area planimetry	4.00	0.0196
Salt dilution Oct. 28 1969.	-	0.022

Maintained plateau tracer technique (group 3 method).

A concentrated solution of a chemical was added to the stream at a constant rate and samples of stream water were withdrawn downstream after mixing had taken place.

Thus,

$$Q = \frac{C_1 - C_2}{C_2 - C_0} \cdot q$$

Where

Q = discharge of stream in kl sec^{-1}

C_0 = Concentration in normal stream water in g kl^{-1}

C_1 = Concentration of injected solution in g kl^{-1}

C_2 = Mean concentration of diluted samples in g kl^{-1}

q = Discharge rate of injected solution in kl sec^{-1}

The standard method was for 0.25 - 2.5 l of 25% sodium chloride (technique grade) to be added to the stream at the input screen once a minute from a set of suitable containers, to elevate the sodium concentration from 10 - 12 mg l^{-1} to about 20 mg l^{-1}. The salt solution was distributed across the stream to make mixing more rapid and the container washed in stream water before the next injection.

Samples were collected in 30 ml glass vials, previously washed in chromic acid, swilled three times in distilled water, sealed and washed twice in stream water immediately before use. The sampling position was normally immediately downstream of the centre of the lower screen. Twenty to thirty samples were taken at suitable time intervals so spread as to include five during the initial background salt concentration, three on the rising edge of the plateau, fifteen to twenty on the plateau and five on the falling edge. The quantity and the length of time for the salt addition was determined to maintain the plateau for at least twice the retention time of the system to establish an equilibrium condition. The samples were analysed using a simple flame photometer. It was necessary to dilute the samples about five times to bring them within the linear response of the photometer, (0 - 5 (-10) mg l^{-1}), before determination. The results were plotted on a graph and the experiment repeated if the increase in salt concentration was less than five mg l^{-1} above the background.

Result and discussion of method.

The method of discharge by the maintained plateau tracer technique gave consistent results (Appendix 6 Table 1 and 2). Initially, the change in conductivity was investigated but as the total dissolved salts are high in chalk streams, about 300 mg l^{-1}, the addition of sodium chloride sufficient to change the conductivity by 3% would raise the sodium ion concentration from ten to twenty milligrams per litre. The analysis of sodium and potassium is simple and accurate using a flame photometer. Chlorides and carbonates of both sodium and potassium were used to estimate discharge but no difference was observed. Lithium was considered but apart from being more expensive, interference from the high background of sodium occurs when estimated by normal flame photometry which was available. Sodium chloride was used and estimated as sodium ion by flame photometry, as it was cheap, very soluble and considered harmless to the system.

The mode of application was investigated for a single peak determination (Fig. 4.1.4. and Table 4.1.4.). Single peak or pulse discharge estimates were found satisfactory if frequent samples were taken, but it was necessary to determine the geometric mean of the concentration-time graph which depended on all samples throughout the series being correct. The line of best fit was drawn by eye through the curve before calculation. The mean cross sectional area had still to be found before the discharge could be calculated. The error in this latter determination was mainly due to difficulties in determining the depth of water when plant cover and soft muds were present.

The injection of salt to maintain a plateau was attempted using constant head devices e.g. a Merriot jar and various nozzles but these were either inaccurate or not easily portable. Wide neck containers were used to spread the salt solution across the stream at minute intervals. Towards the end of the experiment a battery-operated pump was used at a time of very high flow to aid the rate of salt injection.

The single pulse result was studied in detail and the result of the best line fit were tabulated. (Table 4.1.4.). These results were used to calculate a series of summations of this curve offset by one minute intervals in order to produce the plateau effect. The single pulse curve was used in contracted and expanded forms to simulate varying retention times for the system. The time needed to establish the plateau was equal to the time of passage of a single pulse. (Fig.4.1.5.). The plateau level was

Fig. 4.1.4. Discharge determination using a single pulse of sodium chloride, October 7 1969.

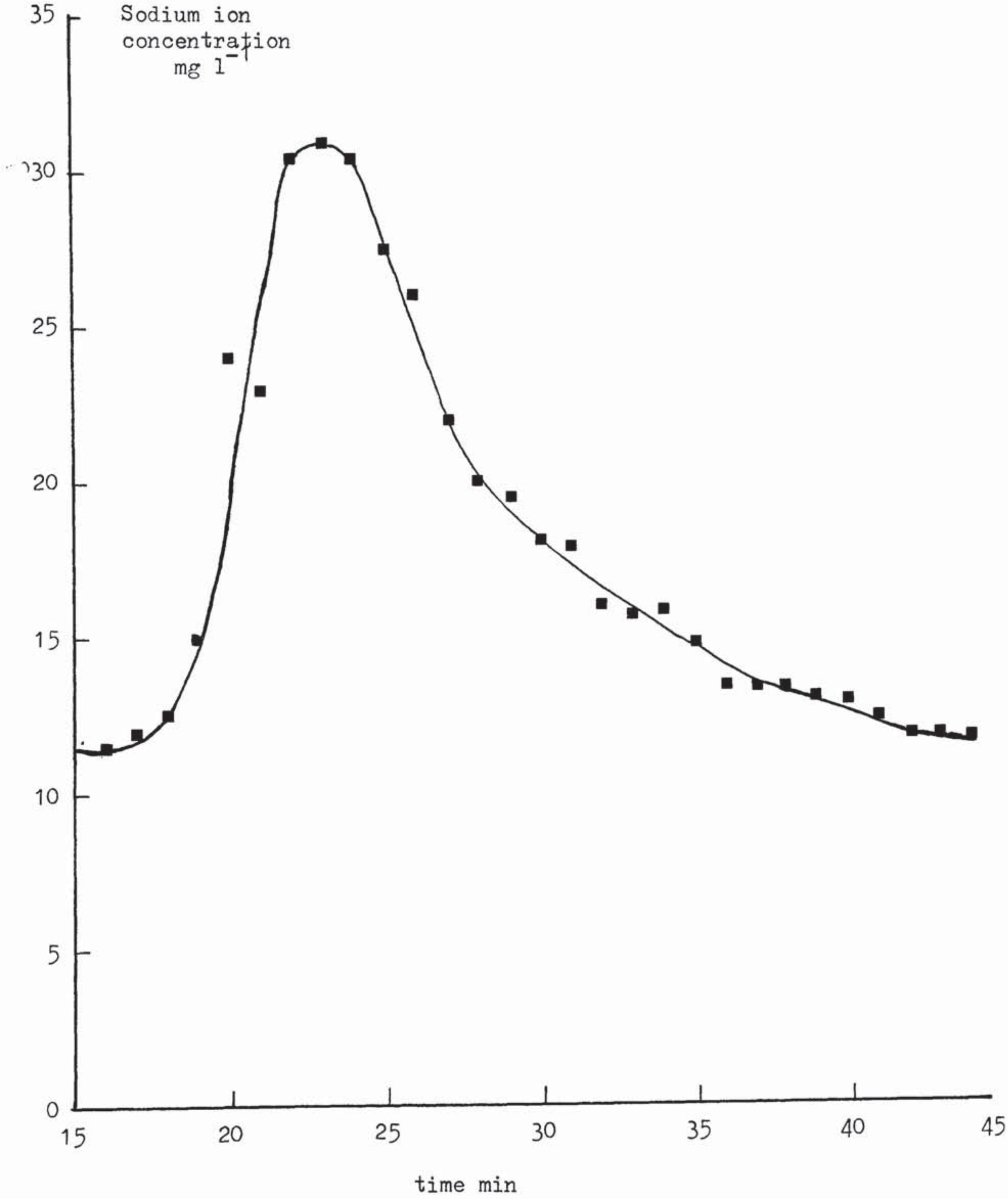


Table 4.1.4.

Discharge estimation by single pulse of sodium chloride, October 7 1969.

Time from start Min	Time from increase Min	Concentration above background mg l^{-1}	Time from start Min	Time from increase Min	Concentration above background mg l^{-1}
16	0	0	30	14	7.0
17	1	0.5	31	15	7.0
18	2	1.0	32	16	5.0
19	3	2.5	33	17	4.3
20	4	12.5	34	18	4.5
21	5	11.5	35	19	3.5
22	6	19	36	20	2.0
23	7	19.5	37	21	2.0
24	8	19	38	22	2.0
25	9	16	39	23	1.8
26	10	14.5	40	24	1.5
27	11	10.5	41	25	1.0
28	12	8.5	42	26	0.5
29	13	8.0	43	27	0

Table 4.1.5.

Variation of salt concentration across the 175 m sample site. May 30 1972.

Time	Samples left to rightbank. concentration mg l^{-1}.					
min	1	2	3	4	5	
17.5	71	65	66.5	66.5	65.5	Before plateau
32.5	84.5	84.5	85	84	84.5	Stable
47.5	85	84.5	85	85.5	84	Stable
67.5	81.5	81	80	80	81.5	End of plateau

needed for twice this time to be certain of a true reading and in practice, the level was maintained for up to four times. If the plateau is not reached, discharge is overestimated. The values for salt concentration once established were constant showing a dynamic equilibrium condition.

The analysis of single curves and plateaux demonstrated a useful relationship between the mean velocity obtained from a single pulse and a value of the plateau type determination. The mean velocity was estimated from the time when the 60% value of the plateau was reached. (see Fig.4.1.5.). The mixing length i.e. the length required for adequate dispersion of the salt, is important. If a series of samples are taken downstream of an input site the values of discharge should remain constant. The results from an experiment of this type confirm this, sampling sites were chosen at distances of 110 m, 175 m, 320 m and 450 m downstream of the injection site. Insignificantly different values (difference of means, $P = 0.05$) of the salt concentration were found in the samples at the plateau. (Fig.4.1.6.) The main difference between sites was in longitudinal dispersion of the salt, the farthest sampling point indicated that the injection time was not long enough to be certain of reaching the plateau. The plateau was just reached but not maintained.

Samples were taken across the stream at the normal sampling site 175 m below the salt input site. There was no significant difference, (difference of means, $P = 0.05$) between the result obtained from samples from the centre of the stream and the above samples when the plateau was established, indicating sufficient mixing had taken place.(Table 4.1.5.). No variation in concentration with depth was found.

Conclusion (methods 1 - 3)

Where direct comparisons are available between discharges estimated by salt plateaux or by velocity profiles measured with an Ott current meter (used either by Dr. M. Ladle or Mr. I. Farr.) the correspondence was erratic. (Table 4.1.6.).

Fig. 4.1.5.

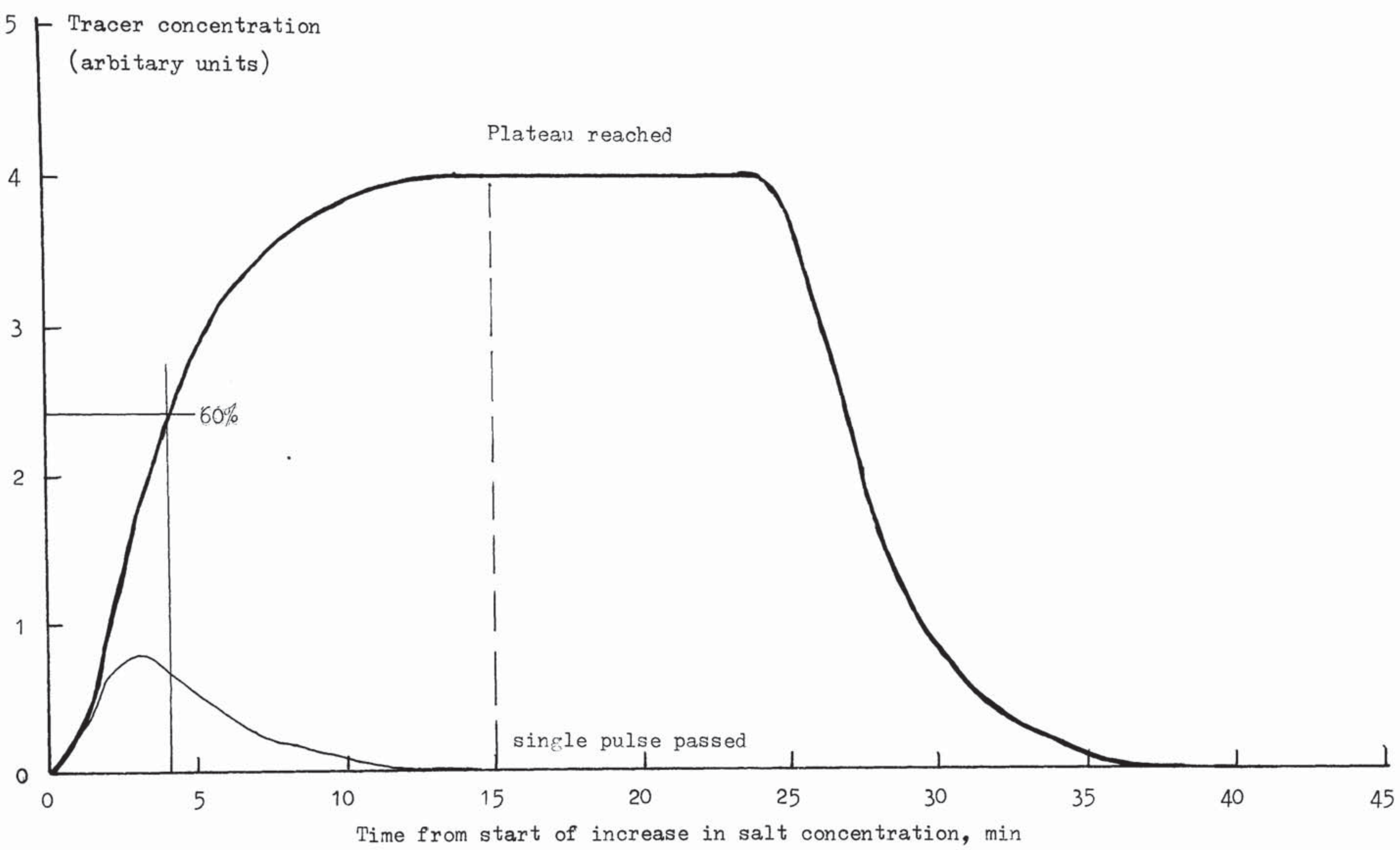


Fig. 4.1.5. Simulation of 25 min of salt injection using the accumulation of a single 15 min peak repeated at 1 min intervals.

Fig. 4.1.6.

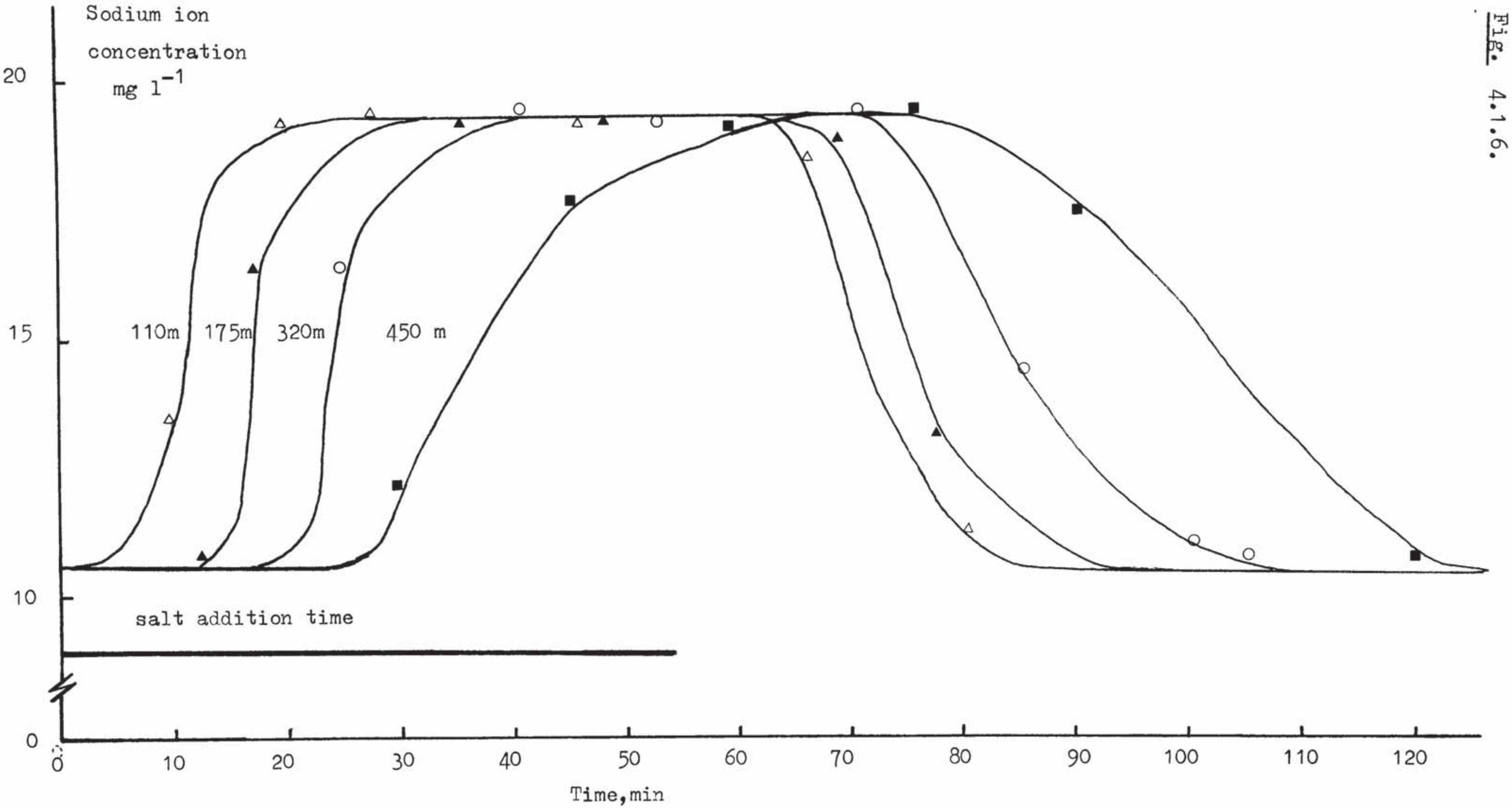


Fig. 4.1.6. Discharge determination, sodium chloride, sampled at varying distances from site of addition.

(test of mixing length) March 30, 1969

Table 4.1.6.

Comparison of discharges by salt plateaux and current meter methods.

Date	Current meter $m^3 sec^{-1}$	Salt plateau $m^3 sec^{-1}$	Difference from salt plateau %
1969			
Oct. 7	0.026	0.031	- 19
Oct. 28	0.0195	0.022	- 12
1970			
Apr. 4	0.25	0.31	- 19
1972			
Mar. 30	0.37	0.41	- 11
May 2	0.21	0.306	- 31
May 30	0.18	0.181	0
July 3	0.127	0.115	+ 10
Aug. 1	0.080	0.037	+ 116
Oct. 13	0.031	0.031	0

In general the differences between these two main methods must either be attributed to an error in the current meter calibration or its method of use or to an error in the salt dilution procedures. The latter could give the observed higher estimate of discharge if the value for salt concentration at the plateau was decreased. This could occur in several ways, either by insufficient time allowed for the plateau to stabilise, incorrect addition rate of salt, poor sampling or analysis or by ad- or ab-sorption of the salt. The former methodological problems have been discussed; the latters were shown also to be insignificant in two ways. The first was to show that salt recovery was total, within the experimental error of its determination. The second was to attempt to saturate the demand of the system by using double the normal concentration of salt and then reduce it to normal. March 30 1972 (Appendix 6 Table 1). This made no difference in the estimate of discharge.

The discharge was determined on an average once a month over the period July 1969 - October 1972, seven tenths of which were by the maintained plateau tracer technique. (Appendix 6 Table 1). Two-thirds of the remainder were by current meter, mostly in 1970. When sodium sulphite was used in deoxygenation of the river for reaeration rate estimates, samples were taken for discharge estimates and the conductivity changes determined.

Distinct hydrographic cycles were observed starting in the autumn or winter, rising rapidly and gradually falling away to a late summer low of discharge. (Fig.4.1.7 and Appendix 6 Table 2.). The 1970 - 71 cycle started earlier than in the other two seasons 1969 - 70 and 1971 - 2 as a result of an offset in the normal precipitation cycle. (see also screen operations, section 4.2.). The total annual discharge, as opposed to total seasonal discharge, was also affected; the 1971 discharge was three-quarters of that in the other two years.

The non-coincidence of the velocity and discharge curves is attributable to the plant standing crop. (Fig. 4.1.7.). The velocity rapidly increases with increasing discharge in winter, reaching its maximum before that of discharge, in the early spring. The velocity falls fairly rapidly as the plants grow and back up the water, even though discharge is still quite high. During the summer, as the plants die off and are washed out, the velocity falls less than the discharge and finally may even rise because of reduced restrictions on flow; the water levels also drop rapidly at this time.

The seasonal evaporation regime was observed in diurnal changes of water height of up to 8mm in the low discharges of summer, at otherwise constant discharges.

However, after this preliminary season, the necessary water heights and slopes were measured regularly, to allow calculation of the Chezy-Manning coefficients. (Appendix 6 Table 3.) The values found

Fig. 4.1.7.

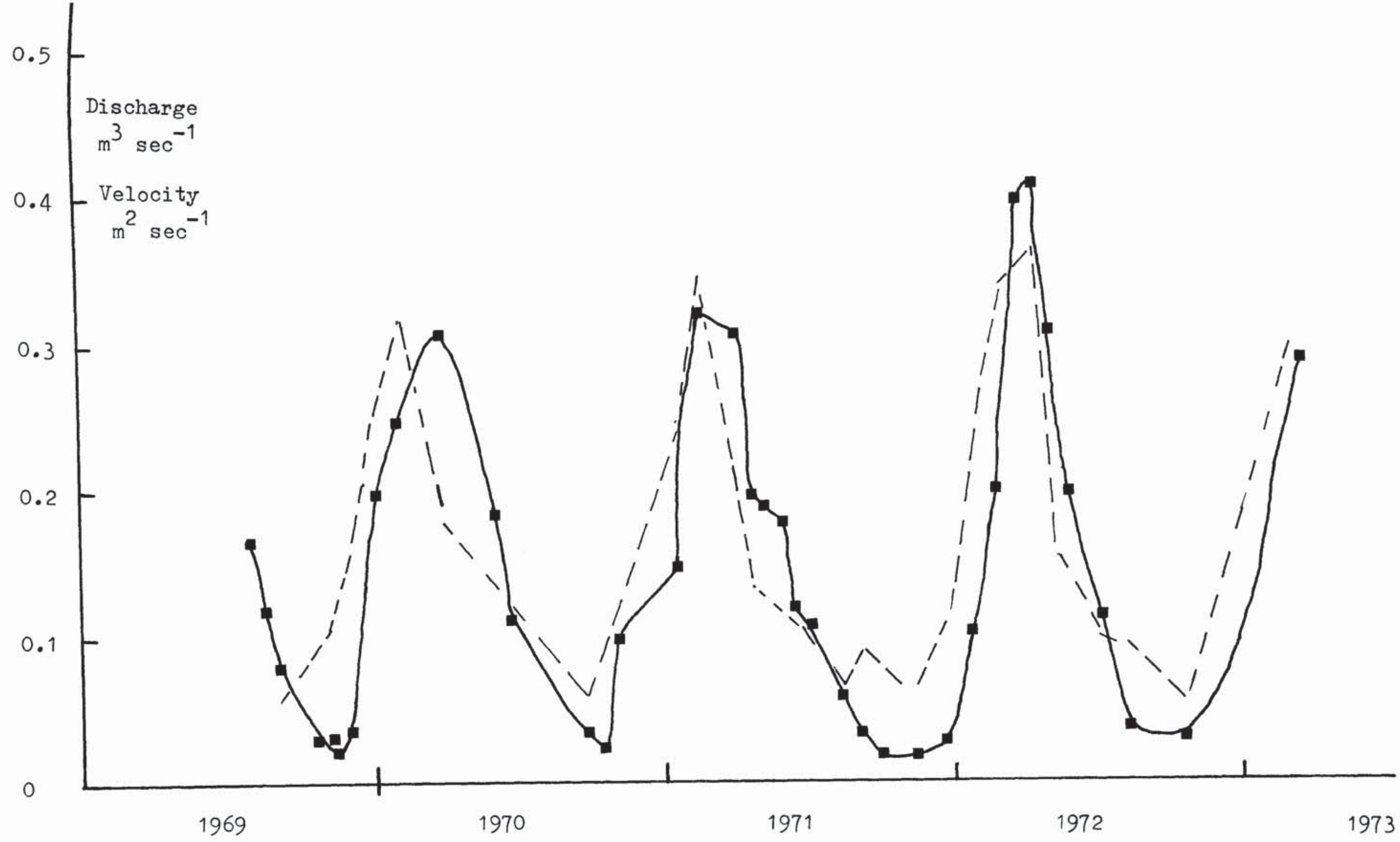


Fig. 4.1.7. seasonal changes in discharge, 1969 - 1973,(section D) Bere stream, Holly Bush.

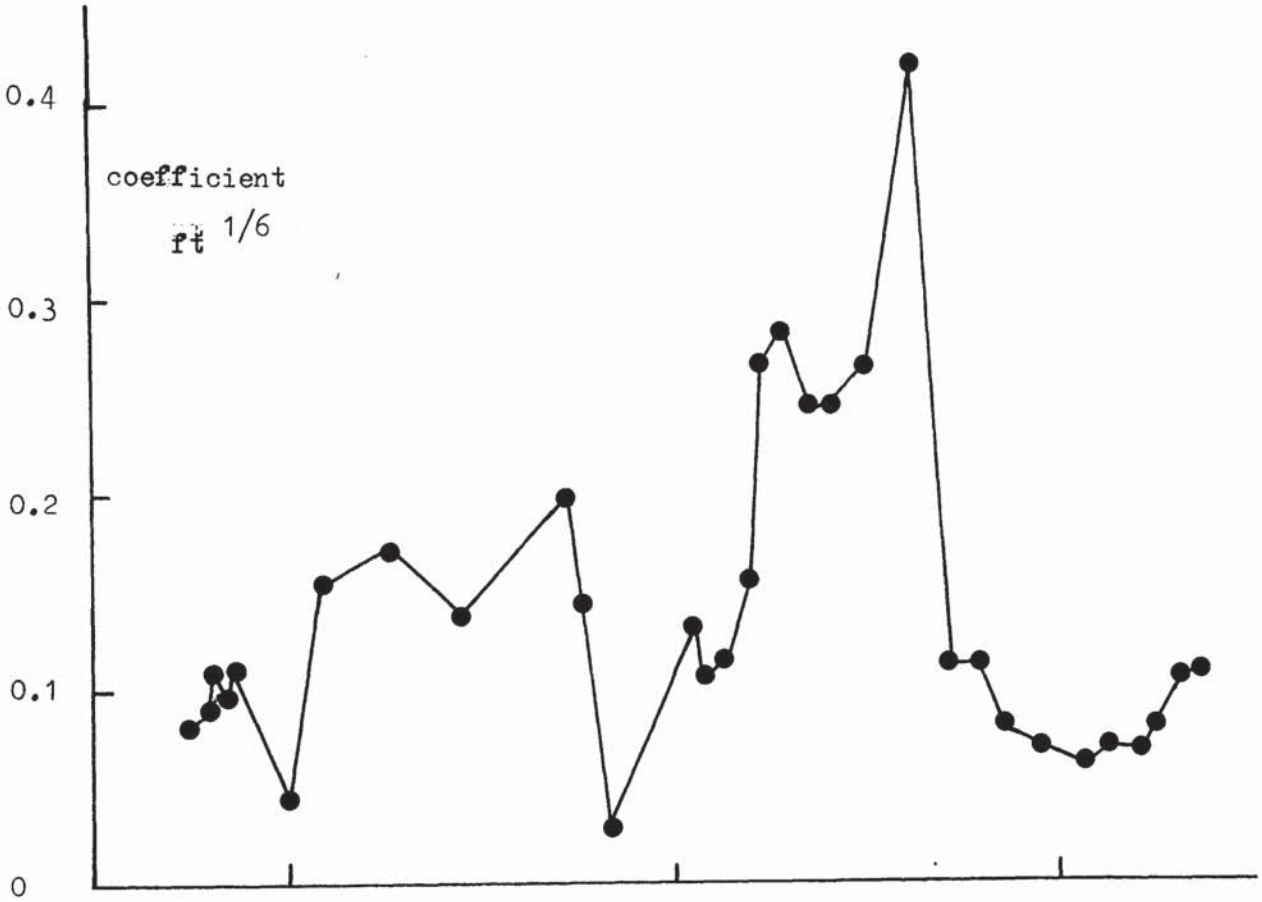
Key
■—■ Discharge m^3 sec^{-1}
– – Velocity m sec^{-1}

varied seasonally with standing crop, as was expected, rising from 0.030 - 0.050 with little or no macrophyte present, to 0.150 - 0.300 and exceptionally 0.340 at the times of maximum standing crop. (Fig.4.1.8.). There was a poor correlation between biomass and Chezy-Manning coefficient, though a seasonal pattern of coefficients coinciding with the biomass estimates; in 1970 - 71 the macrophyte grew earlier, producing very much higher coefficients than in the previous year. The extra material retained from the middle screen in 1972 did not appear to effect the coefficient even though a large proportion of this material was caught up on the macrophytes and undoubtedly restricted water passage. During the latter part of the season, in August, the macrophytes started to decay and were washed out, causing a rapid decrease in the coefficient. This latter situation is unusual for any but a small stream, the macrophytes would normally have been overgrown by marginal-emergent species of dicotyledons but this stream was managed to exclude them.

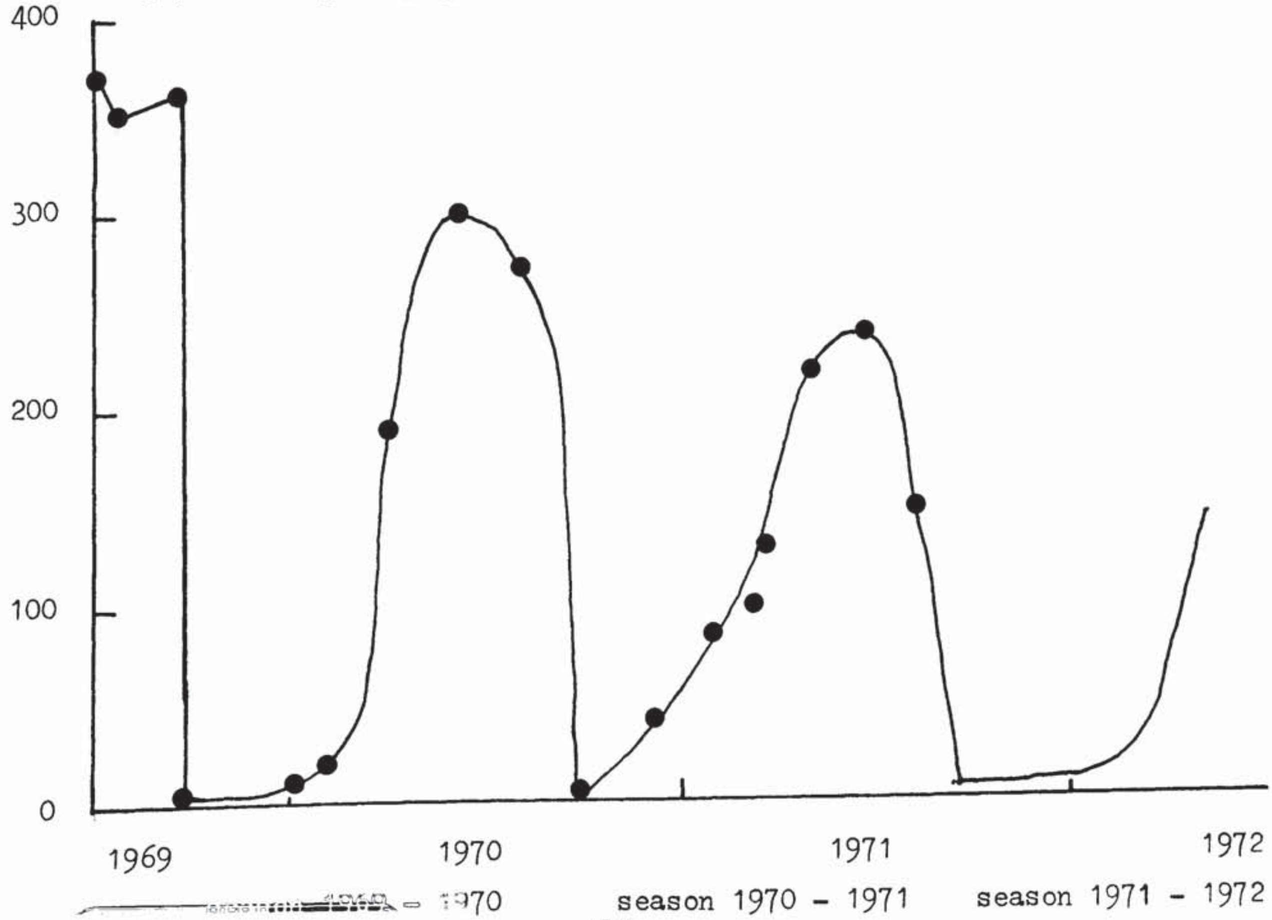
The coefficients were calculated for both the slope of the stream water surface and also the stream bed, the latter, gave slightly higher values for the coefficients under most conditions.

Fig. 4.1.8. Seasonal changes in the Chezy-Manning coefficient for the stream bed and the standing crop of *R. calcareus*.

(a) Chezy-Manning coefficient



(b) standing crop g m^{-2}



4.1.c. The chemical composition of the water at Upper Bere Stream and an adjacent bore hole.

The chemical analysis of the water at the study site was kindly undertaken by Mr. Casey, the chemist at the River Laboratory.

The methods used are described in Casey 1969, which he used in a survey of typical southern English chalk streams, and are outlined below :-

Alkalinity - The sample was titrated with N/100 hydrochloric acid using B.D.H. 4.5 indicator.

Calcium - The sample was titrated with E.D.T.A. using Patton and Readers indicator. (H.S.N. or 2-hydroxy-4-sulpho-1-3-napthoic-acid III)

Sodium and Potassium were measured using an E.E.L. flame photometer or later an E.E.L. 227 intergrating flame photometer.

Nitrate - The procedure was essentially that of the diphenylsulphonic acid method described in the Standard Methods for the Examination of Water and Waste Water of 1960.

Phosphate - The method used was a single solution analysis. The molybdenum blue was extracted with redistilled hexanol.

Silicate - The method was that of Mullen and Riley (1955).

Conductivity - A portable conductivity meter was used manufactured by Electronic Switchgear, Type M.C.1 (IV).

All measurements of optical density were made using a Unicam S.P.500 spectrophotometer.

Samples were taken between 9 and 10 a.m. on Mondays except on Bank Holidays.

Results and Discussion.

The chemical analysis of the stream water passing through the study site (Table 4.1.4.) showed it to be a typical hardwater chalk-stream relatively rich in most plant nutrients. (Casey 1969, 1972, 1973).

Most available carbon at the pH of 7.8 - 7.9 would be in the form of bicarbonate ion; this is considered to be the normal form of uptake of carbon by macrophytes in such systems. Under such conditions of pH, iron may be expected to be unavailable but there are no signs of iron deficiency. (Westlake _et al_ 1972).

The water entering the main study section was analysed weekly for the first two years and found to be nearly constant in composition. (Table 4.1.4.). The water leaving this section was analysed during the subsequent two years. A small farm effluent seeped into the section near the middle screen and flowed intermittently after rainy periods. The change in composition of the stream water caused by this discharge amounted to a doubling of the potassium and phosphate-phosphorus concentrations and a slight increase in nitrate-nitrogen concentration. These changes were expected but the incomplete mixing of this discharge for some distance downstream within the study section, made a nutrient uptake study impossible. (see general discussion).

The water of a bore-hole of Abyssian-type, adjacent to the stream, was also analysed weekly during the study period. (Table 4.1.5.). The indication is that the passage of water downstream, from similar but shallower sources supplying the stream, caused a slight increase in potassium, phosphate-phosphorus and pH and a slight decrease in nitrate-nitrogen concentrations.

The effects of nutrients on plant growth will be considered in the general discussion.

The change in sodium concentration between 1970 and 1971 was a result of an improved analytical method; a flame photometer was used which suffered less from calcium interference.

Table 4.1.4.

Chemical analysis of Upper Bere Stream water with confidence limits (P = 0.05).

		Above section D			Below section D		
		Year					
		1968	1969	1970	1970	1971	1972
Alkalinity as HCO_3	meq l^{-1}	N/A	4.67 ± 0.05	4.51 ± 0.02		4.53 ± 0.03	4.46 ± 0.04
Calcium	mg l^{-1}	N/A	96.82 ± 0.86	94.17 ± 0.78		94.10 ± 0.83	95.35 ± 0.53
Sodium	mg l^{-1}	N/A	11.19 ± 0.12	11.32 ± 0.16		10.33 ± 0.11	10.16 ± 0.11
Potassium	mg l^{-1}	N/A	0.84 ± 0.03	0.83 ± 0.05	1.72 ± 0.49	1.62 ± 0.37	1.11 ± 0.14
Magnesium	mg l^{-1}	N/A	2.32 ± 0.03	2.29 ± 0.03		2.36 ± 0.06	2.38 ± 0.03
Nitrate	mg l^{-1} N	4.39 ± 0.14	4.54 ± 0.15	4.56 ± 0.15		4.83 ± 0.30	4.84 ± 0.18
Phosphate	$\mu g\ l^{-1}$ P	11.48 ± 2.2	11.55 ± 0.89	10.89 ± 1.78	43.65 ± 32.89	27.72 ± 6.62	21.74 ± 3.79
Silicate	mg l^{-1}	4.08 ± 0.18	4.24 ± 0.24	4.51 ± 0.16		4.41 ± 0.18	4.36 ± 0.11
Conductivity	µmhos	517 ± 20					
pH			7.9 ± 0.04			7.87 ± 0.05	7.82 ± 0.43
Annual discharge	G 1			5.99		3.64	4.93

Note.

- Section D, see Fig. 3.4.1.
- Discharge given in Appendix 6, Table 2.

Table 4.1.5.

Chemical analysis of Abyssian Bore Hole, Holly Bush, with confidence limits (P = 0.05)

		Year				
		1968	1969	1970	1971	1972
Alkalinity as HCO_3	meq l^{-1}	4.52 ± 0.05	4.55 ± 0.02		4.43 ± 0.02	4.30 ± 0.16
Calcium	mg l^{-1}	94.34 ± 0.38	96.15 ± 0.44	94.89 ± 0.26	94.27 ± 0.69	94.89 ± 0.53
Sodium	mg l^{-1}	10.53 ± 0.20	10.77 ± 0.08	10.36 ± 0.14	9.43 ± 0.10	9.24 ± 0.07
Potassium	mg l^{-1}	0.78 ± 0.01	0.79 ± 0.01	0.79 ± 0.01	0.74 ± 0.03	0.71 ± 0.04
Magnesium	mg l^{-1}		2.4 ± 0.03	2.33 ± 0.04	2.32 ± 0.05	2.33 ± 0.03
Nitrate	mg l^{-1} N	5.37 ± 0.18	6.0 ± 0.14	5.54 ± 0.08	5.47 ± 0.12	5.15 ± 0.08
Phosphate	µg l^{-1} P	9.88 ± 0.37	9.51 ± 0.36	10.34 ± 0.26	10.87 ± 0.55	10.55 ± 0.47
Silicate	mg l^{-1}	3.99 ± 0.34	4.39 ± 0.11	4.52 ± 0.11	4.67 ± 0.32	4.79 ± 0.19
pH			7.74 ± 0.05		7.66 ± 0.04	7.33 ± 0.18

4.1.d. The water temperature.

The water temperature was measured as it left the study section of stream using a Sixe's maximum and minimum thermometer, held inside a many-holed tube in the main flow. Measurements were later extended to include hourly recording using a Grant multipoint thermograph and still later by using thermistor temperature sensors and circuits recording at shorter intervals on a Solartron-Schlumberger data logger (see field respiration studies). Spot temperatures were recorded, at least weekly, using a 0 - 50 °C, 0.05 °C interval mercury-in-glass thermometer, checked against a standard at the laboratory. The mean temperature shown by the two columns of mercury in the Sixe's thermometer was compared with the 0.05°C interval thermometer and was never found to differ by more than 0.4 °C.

The mean annual range for the study period 1969 - 72 was 5.4 - 15.1 °C with the mean of the weekly means varying only slightly from 10.56 (± 0.49)°C (Table 4.1.6.). The daily range varied with discharge and insolation, for example, in late summer at low flows, a range up to 5 °C was frequent. Within the plants the temperature then rises very much higher, however the plants are generally moribund by this time. Temperature gradients within plants were noted during lower flows, but local variation was so high that any results were inconclusive. During the higher discharges temperature gradients were not observed.

The springs supplying the stream were within the Millum Head lake but because the water remained in the lake for some while, the temperature of the water leaving was not quite as constant as is typical of springs in general.

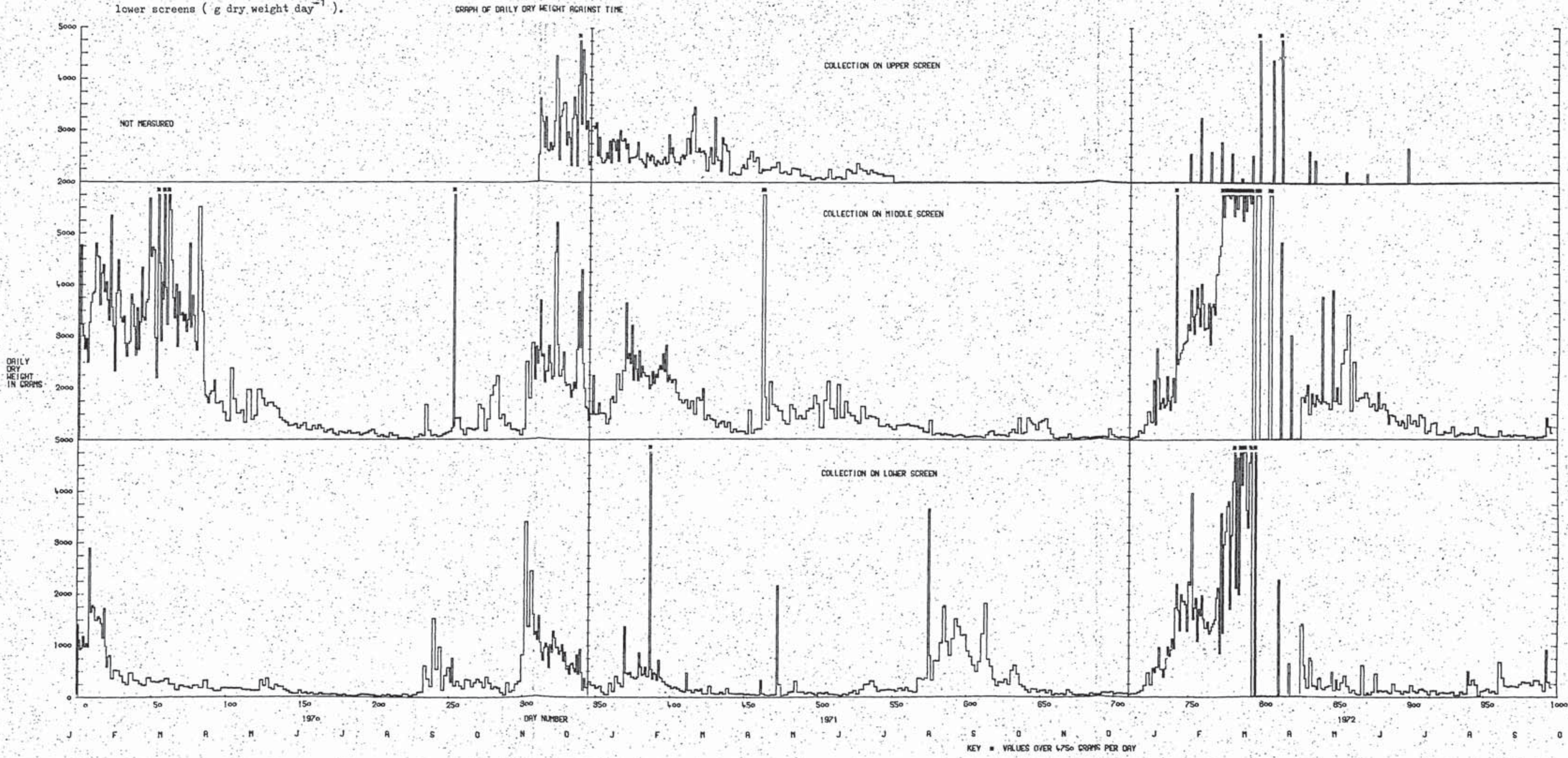
Water from an aquifer within 3 km downstream of this site is reported by Crisp (1970) to have a range from the highest daily maximum for the year of 11.7 °C to the lowest daily minimum of 10.0 °C with an annual mean of 10.7 °C and a mean monthly range of 0.3 °C. The effect of the springs on the water temperature was estimated for a year by weekly maximum and minimum temperatures in the middle of section C (see Fig. 3.4.1) The annual range was 2.6 °C less than at the lower screen, which was 6.7 - 13,8 °C, but it had a similar mean of weekly estimates; the range of confidence interval ($P = 0.05$) of this was also a little lower. Temperature recordings in summer showed that water may warm up by up to 0.5 °C during its passage from the middle to lower screen depending on the velocity.

Table 4.1.6.

Annual temperature range, Upper Bere Stream.

Year	Temperature °C (weekly means)					
	At lower screen			Middle of section C		
	Mean	Lowest	Highest	Mean	Lowest	Highest
1969	10.76 ± 0.46	5.9	14.8	10.47 ± 0.37	6.7	13.8
1970	10.65 ± 0.45	5.0	15.5			
1971	10.40 ± 0.60	5.0	15.5			
1972	10.41 ± 0.46	5.5	14.5			
Mean	10.56 (0.49)	5.4	15.1			

Fig. 4.2.4. Dry weight of material collected at upper, middle and lower screens (g dry weight day^{-1}).



4.2. THE SCREENING OUT OF LARGE SUSPENDED MATERIAL.

Introduction.

The import and export of large suspended and bed-load materials drifting downstream through the different study stretches were estimated using screens having 5 mm square holes and extending across the whole stream. Three screens were situated in relation to the study stretches as shown in Fig. 3.4.1. and using these screens the following estimates were obtained :

(1) The export from a small lake (Millum Head), one of the main sources of water feeding the main study stretch (upper screen).

(2) The export of material from the stretch of stream shaded by a wooded area (sections A – C), where the import from leaf-fall was being estimated (see section 4.3.). (middle screen).

(3) The import and export of material from the main unshaded study stretch, D, in which the production of R. calcareus was being estimated. (the middle and lower screens).

The material collected on these screens was removed and weighed before drying or returned to the stream after taking a sub-sample throughout a three year period 1970 – 72.

For a period January – September 1970 a comparison was made between the composition of the more buoyant material caught on the upper part of the screens and the bed-load material from the lower part of the screens.

Field collection.

Upper screen.

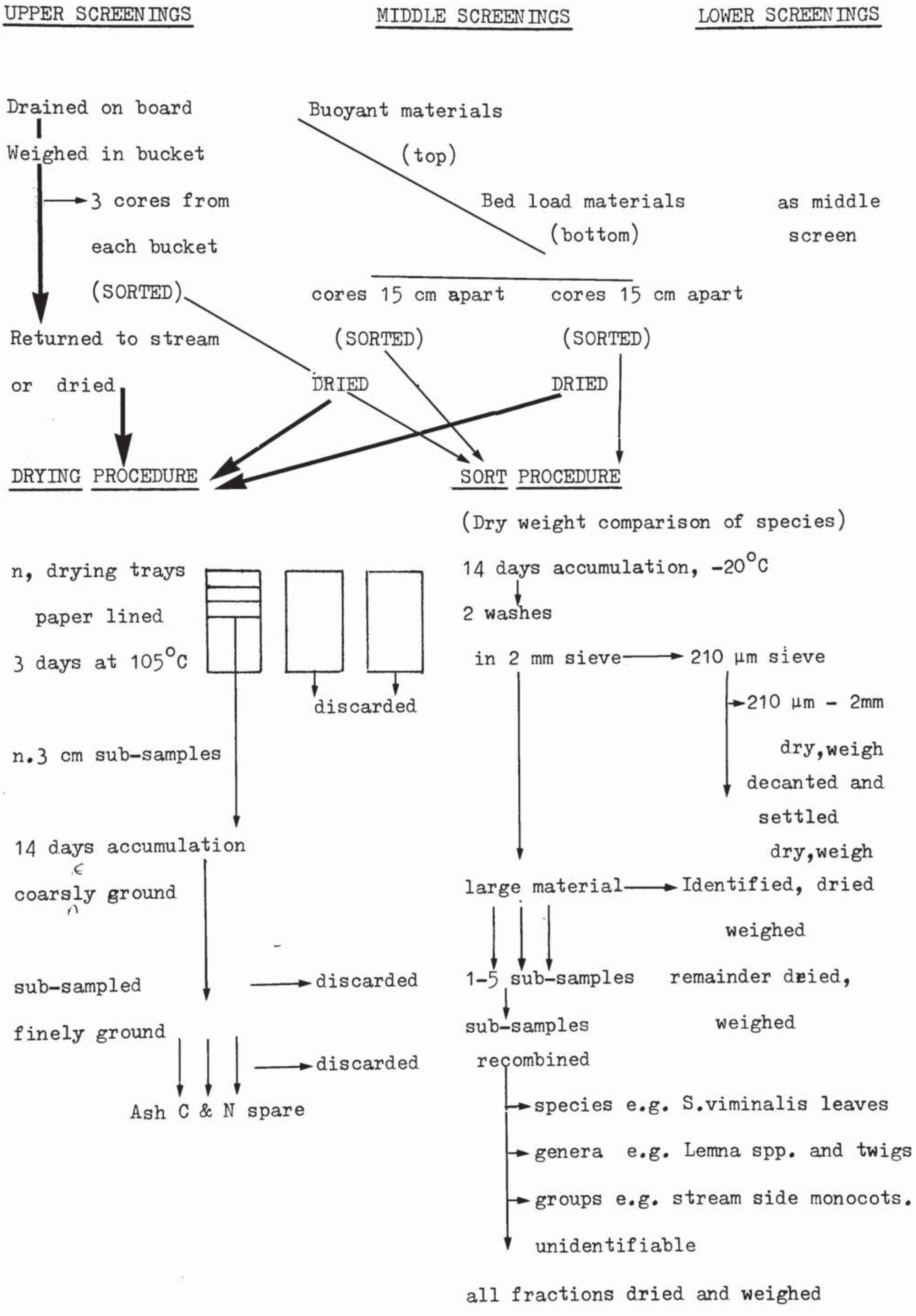
The material leaving Millum Head lake was screened out of the water using a flat bed screen (section 3.4.) which was left in position and cleaned by scraping with a wooden pole (see later). The material collected was drained for 10 minutes, weighed in a bucket to within 0.1 kg on a spring balance (Salter 0-25 kg), and sampled for analysis to species by taking three cores symmetrically from the bucket of material using a 3.7 cm corer. Once every week all the material after weighing was sealed in polythene bags and returned to the laboratory for drying at 105 °C (see below) in order to determine the dry to fresh weight ratio.

Middle and Lower Screens.

The upstream sets of the paired screens (see section 3.5.) were used for the normal collection of material. Prior to cleaning, (see later) the downstream sets of the pairs were pushed into position to collect material, while the upstream ones were partially removed from the water and left to drain for 10 - 15 min.,on the upper half of the supporting ladders. Each of the screens was then carried to a large flat board on the stream bank, carefully reversed and each side banged on the board to dislodge the screenings. (Fig. 4.2.1.). The original vertical distribution of the material on the screens was thus preserved. The buoyant materials from the stream surface remained together at one end of the board, as did the less buoyant bed load materials from the bottom. The corer was again used to take symmetrically arranged samples for species analysis; samples were taken about every 15 cm along the material from the most to the less buoyant. Samples were stored in small labelled polythene bags at - 20 °C. The upstream set of screens were replaced before cleaning the downstream ones. While material was draining on the lower screen there was sufficient time to prepare the middle screen for draining, before returning to the lower set.

The collected materials on the boards by the stream were stood for 24 hr on the river bank during 1972 to drain to a uniform weight in a perforated basket (Addis plastic linen basket) before being weighed and either returned to the water, dumped on the bank, or dried. Material returned to the water was added slowly and dispersed well.

Fig. 4.2.1. Sampling Procedure



Laboratory Processing.

Material from the boards was normally transferred in polythene dustbins or bags to the laboratory for drying. The screenings were packed to a depth of 6 cm in oven trays lined with a sheet of coarse paper of standard size to prevent loss of fine material and dried at 105 °C for three days. (see section 4.5. for a description of the oven). Each day, before further materials were added the relevant dried trays were removed and the paper and screenings rapidly placed in polythene bags. The bags were sealed with clothes pegs, to prevent absorption of water vapour while cooling. When cool, the bags were weighed complete and the weights of similar dried standard sheets, the polythene bag or bags and the clothes pegs were subtracted, pro rata.

A weighted sample of dried screenings for fourteen day periods for each of the daily fractions of material from the middle and lower screens was prepared for ash weight, carbon and nitrogen determinations. (see section 4.1.). These samples were obtained from one of the paper trays by cutting off about 3 x n cm of its length, where n is the total number of trays used for that fraction.

The material was scraped from the paper into polythene bags and accumulated for the 14 day periods before being ground. The samples were coarsely ground in a fixed hammer mill (Starbeater Mill, manufactured by Glen Creston of Stanmore) through a 5 mm grid. The material was sub-sampled by slowly and evenly pouring it in a traverse across the mouth of a 400 ml beaker until it had all been spread in a long even arc of which the beaker was only a small part. The traverse was lengthened according to the quantity of material ground. This sub-sample was finely ground in a shear mill to 1 mm (Grain Mill, manufactured by Casella). The ground sample was then sub-sampled again by traverse across three 3.6 ml vials.

The cored samples were normally grouped into 14 day periods (Fig. 4.2.1.). These grouped samples were washed twice in water in a 2 mm sieve to remove small particles which were generally unidentifiable. The materials not passing through were gently squeezed to remove excess water and fine particles. The sieved washings were again sieved at 210 µm; the remaining washings were settled for 30 min before being decanted. The large materials e.g. twigs, large leaves, were sorted out from this washed material before taking at least five small sub-samples from it and combining these to form a representative sub-sample or sub-samples. This sub-sample was sorted into fractions so far as recognisable, for example, a leaf could be grouped by species, by genus, or as an unidentified leaf fragment of terrestial or aquatic origin.

The residues and large samples were dried in suitable sized pre-weighed beakers at 105 °C for 24 hr. The sub-samples were sorted to fractions in pre-weighed flat bottomed glass tubes, dried and weighed.

The weights of the groups of material from the sort and sub-sample sort of the materials were recorded on a standard form from which computer cards were prepared. Computer programmes were written (a Fortran 4 dialect for a General Electric - Leo computer the K.D.F. 9) to calculate percentages and total mean weights of specific and grouped materials for the 14 day periods and to graph the results using a graph plotter (Benson-Lehner Incremental graph plotter).

The results are analysed and discussed by calender year and because of the non-coincidence of the major factor, discharge, with the calender year they are also discussed by season August - August. Samples are compared on a dry weight basis not organic weight.

Results and discussion.

Day numbers, not dates, were used to identify days, starting from Day 1 as the 24 hr sampling period ending between 9 - 10 am on 22 January 1970. In this section dates are used for ease of comprehension, followed by the day number in brackets for comparison with the graphs and appendix.

The daily total dry weights for the three screens are shown in Fig.4.2.2.

Upper screen.

The upper screen was sampled daily from 27 November 1970 (310) until mid March and then every two days until 24 July 1971 (549). This period was the duration of flow in the 1970-1 hydrological cycle. In the following flow period, 1971-2, the washout was late because the rain during the autumn was not sufficient to cause the lake to flow over the weir board. The material was sampled for one day only each week during the season of flow from 3 February 1972 (741) until 7 July 1972 (898).

The dry to fresh weight ratios of the upper screen material were normally measured once a week. A mean value for every 14 day interval was used to convert the daily fresh weight results to dry weights. A mean or a running mean for longer than 14 days was not used because of the changing nature of the materials collected on the screen. During the 1972 season one in two samples were dried because of the long interval between estimations.

The total dry weight of material leaving the lake in the flow period of 1970-71, and collected on the upper screen, was 123 kg. The sub-samples which were sorted into their individual components were 2% of this (Appendix 1 Table 1a). The dry to fresh weight ratio changed, being influenced particularly by the type of material present and the discharge. (Fig.4.2.3.). The percentage dry weight was initially fairly high for aquatic materials, at 10.8%, but it fell during the season to 6-8%. This fall was due to the increased water retention of the material, mainly *Fontinalis antipyretica*. Towards the end of the flow period, as the flow decreased, less frequent cleaning was necessary and the percentage dry weight of material increased again, because some of the material had spent up to two days on the screen which made it possible for some of it to drain.

During the period, 377 - 461, some material was washed over from the collection screen, because of the high discharge and the nature of the material collected.

The total weight of material leaving the lake in the flow period in 1972 was given by the weekly samples as 130 kg. An estimate of the error involved in this method was obtained by calculating seven annual totals each corresponding to totals from each day of each week e.g. all Tuesdays, from the previous year's data. This gave for 1970-71 a range of 116 - 128 kg. The overall mean was of 122 ± 4.8 kg ($P = 0.05$, $n = 7$), that is, a weekly estimate from one day a week has 90 -95% chance of being within 95% of the mean or alternatively, a probability of 0.1 - 0.05 of being within 95% of the true mean value. The output from the lake can therefore be regarded as being from 125 - 135 kg when $P = 0.05$.

The <u>mean daily collection rate</u> (kg dry weight day^{-1}) increased very rapidly to its maximum within a month of the start of flow and then continued to fall despite a doubling of discharge in the following two months (Fig. 4.2.2.). Rain caused day to day fluctuations as did wind direction and strength, but these were considerably damped considering 14 day periods. The day to day discharge did not vary as much as its effect on the wash-out of materials; a slight increase in discharge, particularly in the early autumn, caused large quantities of material to be brought into circulation in the lake.

If the material is considered in terms of <u>concentration</u>, then a rapid increase to 15 mg l^{-1} was measured in the first two months. This concentration equally fell rapidly to 3 - 5 mg l^{-1} at which the level was maintained throughout the season. The end of season increase was at the time of greatest error in discharge estimation and the rise is probably of no significance.

The <u>ash weights</u> of several samples were determined. Great difficulty was experienced in grinding the material which contained

Fig. 4.2.2. Upper screen, season 1970 - 1 (14 day periods).

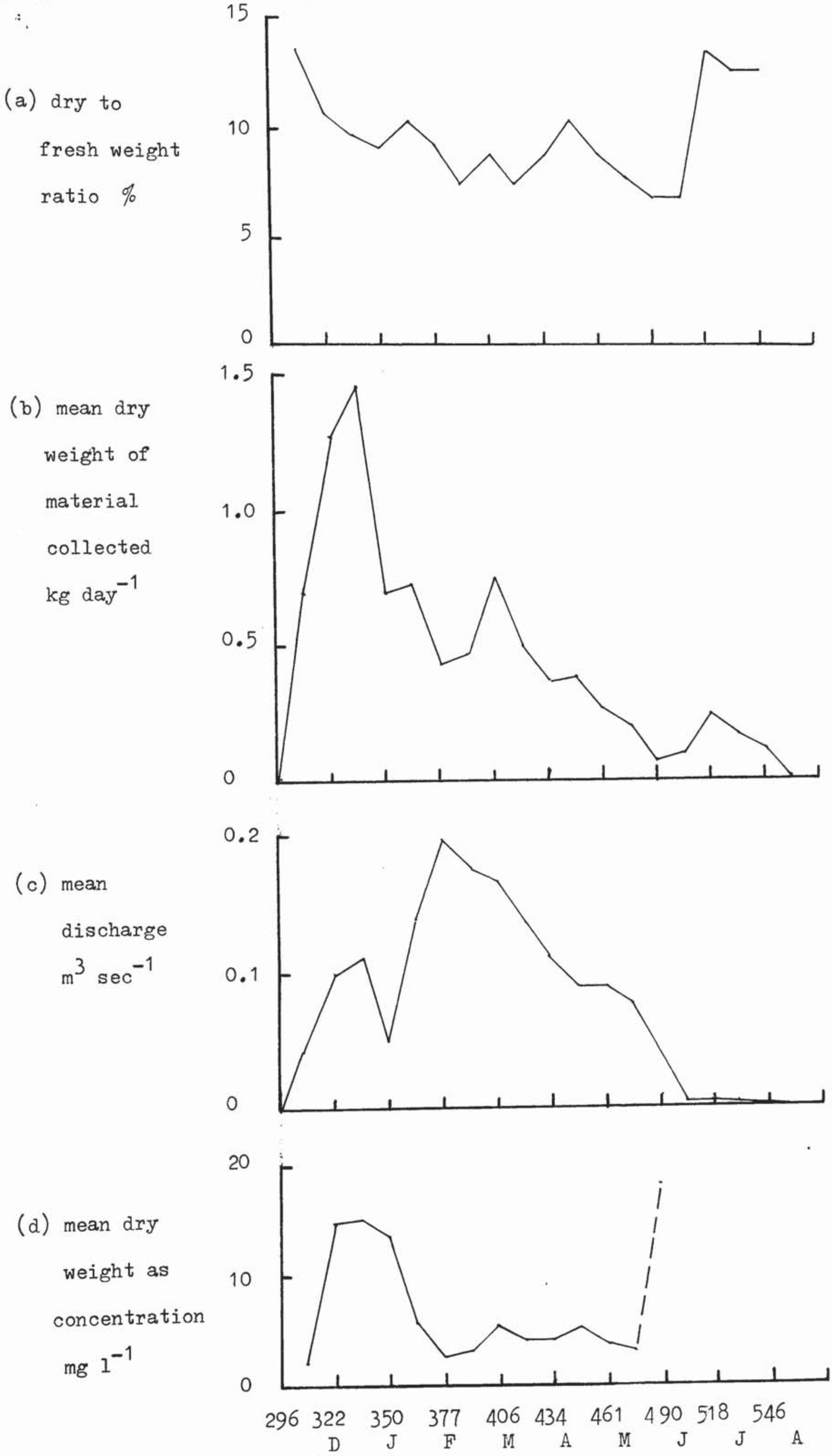
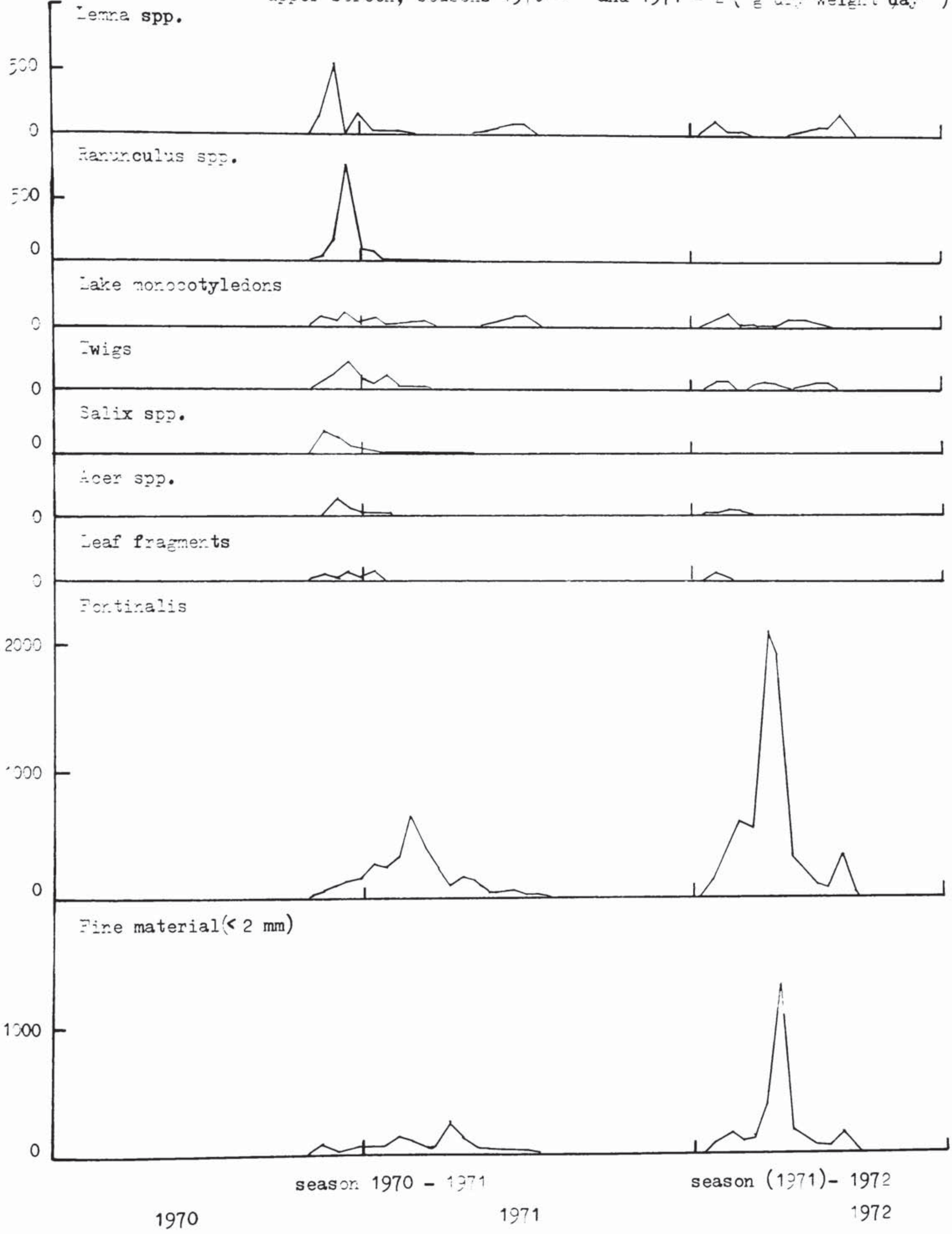


Fig. 4.2.3. Species composition of materials collected on the upper screen, seasons 1970 - 1 and 1971 - 2 (g dry weight day^{-1})



F. antipyretica and it was necessary to assume uniformity of samples over a long period. (Table 4.2.1.). In both seasons the organic output of the large suspended material was 80 kg and the output of inorganic carbon was 3 kg, although the first season was 74 days longer than the second (see section 4.4. for details of analysis).

Since the two seasons 1970-71 and (1971)-1972 were not markedly different from one another in total output, the species composition of the large suspended material lost from the lake will be discussed by comparison of percentages. [The fortnightly results are in Appendix 1 Table 1a and 1b, and are summarised in percentage form in Table 4.2.2].

In the 1970-1 season a species succession of materials was washed out according to a combination of their buoyancy and resistance to water movement. Increasing water heights lifted materials free and allowed them to be wind blown across the water surface or water borne. Increasing water velocities caused other materials to be lost from the lake, for example, Fontinalis antipyretica. The succession started with the free-floating Lemna species (13%), L. polyrhiza and L. minor in November and December, together with floating dead leaves from trees especially of Salix caprea (4.8%) (Fig. 4.2.3.). Ranunculus spp., twigs and leaf fragments (1.8%) followed before, finally, vast quantities of F. antipyretica (34%) in the spring and early summer. This includes much fine material less than 2 mm (13%) towards the end of the season, as the flow decreased. (Fig.4.2.3.).

This season of 241 days was longer than the following season of 167 days, which also started three months later in February of 1972. The species succession of materials was restricted and only the last members of the series, F. antipyretica and fine materials were collected on the screen (Fig. 4.2.3.). The other materials were probably fragmented and washed out as small suspended material. (see section 4.4.). F. antipyretica increased as a proportion of the total collected, from a third to two thirds, which could be accounted for by the effects of the timing of the wash-out on the

Table 4.2.1.

Mean dry weight (kg day^{-1}), organic and inorganic carbon (% of dry weight) for material collected at the upper screen and mean discharge, season 1970-1 and 1971-2.

14 day sample period starting day no.	Period mean discharge m^3sec^{-1}	Daily mean dry weight kg	Percentage	
			Organic %	Inorganic carbon %
Season 1970-1				
308	0.038	0.669	69	-
322	0.100	1.27	72	2.9
336	0.112	1.45	75	2.1
350	0.052	0.596	69	1.9
364	0.138	0.634	79	-
378	0.198	0.416	75	1.4
392	0.175	0.462	65	-
406	0.166	0.744	67	2.1
420	0.134	0.489	56	3.0
434	0.109	0.360	-	-
448	0.088	0.384	-	-
462	0.086	0.258	-	-
476	0.077	0.200	-	-
490	0.005	0.082	62	2.4
504	0.004	0.106	-	-
518	0.003	0.241	-	-
532	0.002	0.169	-	-
546	0.001	0.120	-	-
Mean	0.083	0.480	(69)	(2.2)
Season 1971-2				
742	0.073	0.55	-	-
756	0.087	1.26	-	-
770	0.202	0.68	67	1.8
784	0.206	6.65	-	-
798	0.184	2.59	68	2.5
812	0.093	3.26	-	-
826	0.076	0.50	-	-
840	-	-	-	-
854	0.064	0.23	-	-
868	0.032	0.18	62	2.8
882	-	-	-	-
896	0.032	0.66	51	4.4
Mean	-	-	(62)	(2.9)

Table 4.2.2.

Species composition of the output of large suspended materials from Millum Head (upper screen).

Material group	Material	Season 1970-1			Season 1971-2		
Aquatic							
	rhizoidal macrophytes						
	Fontinalis antipyretica	34.21	34.21		65.0	65.0	
	rooted macrophytes						
	Ranunculus spp.	13.21			0.01		
	Hippurus vulgaris	0.79			0.10		
	Monocotyledons (lake)	4.43	18.43		2.2	2.31	
	Free floating macrophytes						
	Lemna spp.	13.35			2.6		
	filamentous lagae	0.35	13.70		0.1	2.7	
	Marginal plants						
	Dicotyledons	0.94			0.2		
	monocotyledons (bank)	0.26	1.20	67.54	0.2	0.4	70.6
Terrestial							
	twigs	7.52	7.52		2.4	2.4	
	leaves						
	Salix spp.	4.76			0.1		
	Acer pseudoplanatus	2.70			0.3		
	other	1.95			0.9		
	Leaf fragments	1.83	11.24	18.76	0.4	1.7	4.1
Remainder							
	fine material 2 mm	13.38			25.5		
	peat	0.05			0		
	Animal	0.11		13.54	0.02		25.52

plants productivity. In the 1970-1 season much of this material was washed out before regeneration had taken place and in consequence the total could be expected to be lower when compared to the longer period available for growth, until and during the 1972 season (June 1971 to January 1973.).

The autochthonous materials contributed two thirds of the total output in both years (Table 4.2.2.). The recognisable materials of terrestial origin were markedly decreased in the second season compared to the first, which was however, countered by an increase in the fine material which collected on the screen. This increase might not be due to fragmented terrestial material because the ratio of fine material to F. antipyretica remained constant at 0.4 : 1. This bryophyte has dense clogging effect on screens and filters, or brings fine materials, and this could account for the increased fine material collected.

The quantity of material from terrestial and aquatic sources as food for invertebrates will be discussed later.

Middle and lower screens.

General results.

During the initial stages of the screening operations from 22 January (1) until 19 April (92) for both screens, and until 7 July 1970 (169) for the middle screen only, screened material was weighed fresh and sub-sampled daily for the estimation of the dry to fresh weight ratio. (Appendix 2 Table 1). Three large handsful were taken from the top, middle and bottom part of the heap of fresh weighed material with as little squeezing as possible. Samples were sealed in polythene bags and returned to the laboratory for drying. There was no significant difference between the total dry weight and the estimated dry weight over a 28 day period in April 1970 when comparing the results using a paired t-test. ($P = 0.05$).

The dry weight of materials for the remaining two seasons were obtained, by drying for three days at 105 °C; this time was necessary because trays had to be paperlined to prevent loss of fine dust and filled to the top in order that the oven could accomadate all the material. Less than three days was insufficient to dry the material packed in this way; material dried for longer periods continued to loose weight slowly and the material began to char. It was not efficient to decrease the amount of material packed into the trays and to shorten the drying period because more time was needed to prepare and weigh the trays.

During the spring material was not drained on the screens first but was removed immediately; this lead to a steadily increasing problem with silt running off the board. From 25 May 1970 (124) the material on the screens was drained for 10 - 15 min on the ladder supports, as described in the general method.

Although the system of sampling was expected to collect all the large materials and estimate the small, it was observed that materials of an intermediate size, that is, 1 - 5 mm approximately were not collected by the screens especially at times of high flow and were too large to be collected in the automatic water samplers. This large suspended matter (1 - 5 mm nominal) passing through the screens was estimated using conical nets of 1 mm square mesh, supported on 60 cm square frames. These were used to collect material on several occasions, from September to November 1970. They were normally inserted into the channels behind the screens and left until after the screen was next cleaned, ensuring collection typical of normal usage.

The proportion of such material passing through the middle and lower screens was on average 15% and 17% of that collected on the screens in the same period (Appendix 1 Table 4.). The material was predominantly Lemna spp. and a mollusc, Potamopyrgus jenkinsi, neither of which was expected to be collected on 5 mm screens. There was no significant difference in the collection of material at the two screens ($P = 0.05$, $n = 14$); both screens allowed similar amounts of this intermediate sized material to pass. The amount of large suspended material was about a quarter of the small suspended material and therefore the error in the total passage of materials becomes even smaller (see general discussion).

Middle screen.

The middle screen was cleaned every day at rising flows above 0.15 kl/sec^{-1} and every two days when flows fell below about 0.25 kl/sec^{-1} at the end of the season's washout period, except for 33 days from 25 March 1972 (794) to 27 April 1972 (827). The flow rose over 0.35 kl/sec^{-1} within a month (see hydrograph 4.1.1.). Just before and at the beginning of this period very large quantities of material were washed to the screen which soon became clogged making cleaning necessary every few hours. The screens were removed and estimates were only undertaken weekly. To avoid unduly affecting the collection on one screen by the cleaning or collection of material of another, they were cleaned in order upstream, from downstream.

After the initial period mentioned above, all the material collected was dried, until 28 September 1971 after which the material was returned to the stream after being cored, drained for 24 hr and weighed. Once a week all the material was taken for drying at the laboratory to obtain the fresh to dry weight ratio. The totals for the screen periods were corrected for this loss to the system which was 11% of the input.

The total dry weight of material which would have passed the middle screen in the calendar year 1970 and 1971 was 382 kg and 154 kg respectively (Table 4.2.3.). The former year's total was incomplete because screening only started on 20 January of that year and the increase in the flow before that was sufficient to have washed out up to 15% of the total when compared with the following years. (see also discharge graph 4.1.1.). In 1972 417 kg of material was collected at the screen of which 374 kg was returned to the stream and the remainder was dried to determine the dry to fresh weight ratio.

Table 4.2.3.

Annual and seasonal totals of dry organic and inorganic carbon and ash, weights for the middle screen. 1970 - 1972.

Year. (days)	Total dry weight kg	Organic weight kg	Inorganic carbon kg	Ash kg
1970 (1 - 349)	382	267	(7)	115
1971 (350 - 713)	154	120	(3)	29
1972 (714 - 999) Corrected.	417	283	(8)	134
Season (days)				
(1969) - 1970 (1 - 209)	281	187	(5)	94
1970 - 1971 (210 - 559)	236	188	(3)	48
1971 - 1972 (560 - 937) Corrected.	424	290	(8)	134

The hydrodynamic cycle between minima is not a calendar year but starts between August to January. The total weight of material in the season August - August is therefore a better comparison than January - December. During the first season (1969) - 1970 of which only the 1970 portion was sampled, 281 kg was collected, while in the second season the total was 236 kg. Of 424 kg collected in 1971-2, 381 kg was returned to the stream.

The mean daily rate of material passing for the season (1969) - 1970, after allowing for a correction of 15%, (see below), was 0.89 kg day^{-1}. The mean for the following two seasons were 0.65 and 1.16 kg day^{-1} respectively, while the total discharges for the three seasons were 5.0, 4.2, and 4.3 Gl respectively. (Appendix 6 Table 2.). The annual mean concentrations of material were 56, 56 and 100 $\mu g\ l^{-1}$.

The mean daily rates for the years 1970, 1971 and 1972, were 1.05, 0.42 and 1.14 kg dry wt day^{-1}, and the total annual discharges were 5.1, 3.6 and 4.9 Gl respectively with corresponding annual mean concentrations of 75, 42 and 85 $\mu g\ l^{-1}$.

The mean daily rate for the 14 day periods was similar in pattern to the hydrodynamic cycle, following the velocity pattern slightly better than the discharge (Fig. 4.2.5.). As the velocity increased material was washed out of the lake and the wooded areas (section A, B and C) reaching 5 kg mean dry weight per day for a short period in 1972 (Fig. 4.2.5.). Immediately after this high value it became impossible to estimate the passage of material because the screen clogged very quickly. Short period samples gave erratic results which probably overestimated the total passage of material and therefore a correction was applied, based on the experience of 1970 and on the weekly samples during this period. A mean rate of 4 kg day^{-1} was considered applicable and this period of a month was corrected by substituting this rate. (Appendix 1 Table 2b (iii).

As the velocity decreased there was a disproportional reduction in material collected. If the velocity ceased to rise as quickly as previously, for example, in the autumn, a decrease in the amount of material passing per day was observed. There were large day to day fluctuations, the importance of which is not seen in a 14 day mean weight figure, but these are shown in Fig. 4.2. They were caused by rain and management of ditches, etc.

The <u>ash weight</u> of <u>screened materials</u> vary from an overall seasonal mean of 33% in (1969) - 1970 and 1971 - 1972 to 20% in 1970 - 1971 (Table 4.2.4.). The 14 day mean vary from a basal one of 10 - 20% during summer flows, increasing with increasing discharge to 40 - 50%, because the denser mineral particles are more easily suspended at these velocities (Fig. 4.2.5. and Appendix 1 Table 2a).

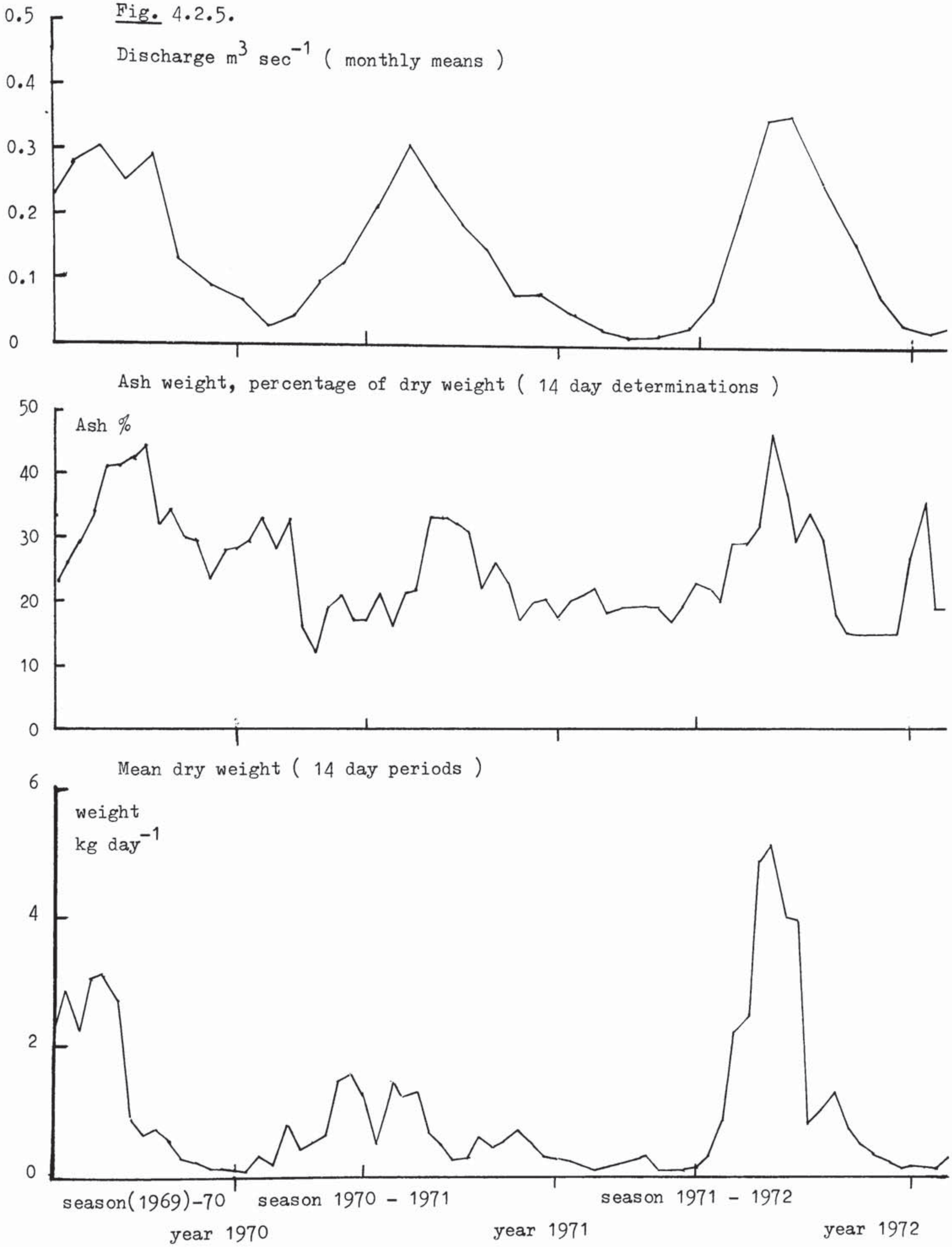


Fig. 4.2.5. Discharge, Ash and mean dry weight variations for the middle screen, 1970 - 1972.

Material from 1970 - 1 was lower in ash as was the organic material probably because of the generally lower discharges not picking up denser mineral particles. Analysis of materials taken direct from their sources and typical of those found in screenings gave ranges of ash weights from 6.7% for *Salix viminalis* and 9 - 10% for *Fraxinus excelsior* to 16 - 35% for *R. calcareus* at various times of the season which were close to the level. (Appendix 4 Tables 1 and 2.).

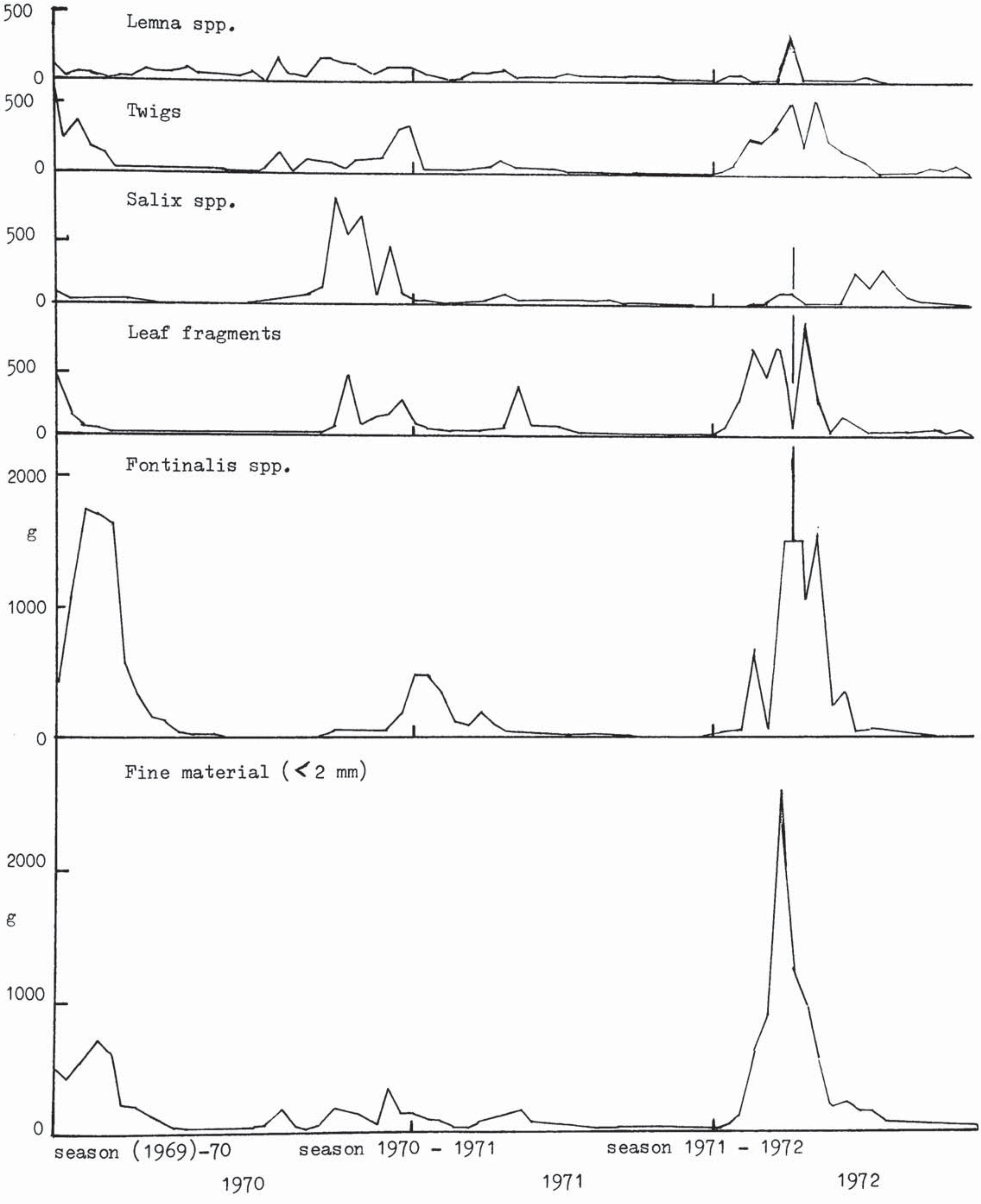
From January to September 1970 (1 - 251), the screened material collected from the top half of the screen, the buoyant materials, was separated from that of the bottom half, the less buoyant or bed load materials, and each was treated separately. The two fractions were of similar weight, approximately, and a comparison of the species composition shows that out of the major constituents *Ranunculus* spp., *Hippurus vulgaris*, monocotyledons from the lake, (mainly *Schoenoplectus lacustris*) twigs and *Hedera helix* were more often found on the top half of the screen than on the bottom. (Table 4.2.5. and Appendix 1 Table 2e and 3e.). These particular constituents were normally fresh and buoyant compared with those of the bottom half, in which tree leaf fragments and fine materials were important. *Fontinalis antipyretica* was found slightly more frequently on the bottom half and was generally observed to move in the main body of the water. *Lemma* spp. were found more frequently in the top half but there were two species groups present, the free floating L. *polyrhiza* and L. *minor* often at the surface and L. *triscula* found normally in the main body of flow or near the stream bed. Animals were foumd more often in the top half; during this period they were mostly Limmephilid caddis larvae which crawled up the screen.

The ratio of material from terrestial and from aquatic sources passing the middle screen derived from recognisable material from the lake and the wood was approximately 1 : 1 for the three study years. (Table 4.2.6 These two groups accounted for 80% of the material collected and sorted;

the remainder was fine material of indeterminate origin. Over half of the material of aquatic origin was composed of fresh F. antipyretica originating from the lake. During the 1970 - 1 season 42 kg left the lake and 31 kg arrived at the middle screen, but in the following season 1971 -2 253 kg (or if the correction was applied, 151 kg), arrived although only 85 kg left the lake. (Appendix 1 Table 2b (i), (ii) and (iii)). The correction applied was to convert the erratic results of April, during which only weekly samples were taken, to more reasonable ones based on the previous year's experience.

A succession of differing species of material was found at the middle screen starting in the late summer, August, but depending on the time of the autumnal increase in flow. (Fig. 4.2. and Appendix 1 Table 2a). Ranunculus spp., Lemna spp., mostly the floating forms, and twigs are the first components of the screen material to be lost from the wooded section. (Fig. 4.2.6.). Some fresh twigs were washed out at this time but their movement was generally very dependant on the intensity and duration of winds; the old water-logged twigs and branches were washed out when the flow increased still further, and particularly when the water started to flow over the lake weir board. Leaves of Fraxinus excelsior were first to fall, starting during September, and were followed by the Salix spp.. The amount of fresh leaves which reached the screen was dependent on the flow at the time and the distance which had to be travelled. The leaves of F. excelsior tree immediately above the screen, were collected fresh in both years as they floated downstream without becoming water-logged. The Salix spp. leaves from the section C above the road bridge were washed out in relatively large amounts in autumn 1970 than in the following season 1971 - 2 when the hydrological cycle was about three months later. This change is reflected in the relatively lower amount of leaf fragments found in the screenings of autumn 1970 when compared with the large amounts found in late winter 1972. The fine material is collected relatively more at times

Fig. 4.2.6. Species composition of materials collected on the middle screen, 1970 - 1972 (g dry weight day^{-1})



of slow discharge than at high discharge, except when F. *antipyretica* is being collected. The total amount of fine material is however greatest at the highest discharges.

During the 1970 - 1 season the species typical of the lake decreased in quantity by varying amounts during the passage downstream, as determined by collection on the middle screen. (Appendix 1 Table 1a and 2b) F. *antipyretica* and lake monocotyledons, stems of *Schoenoplectus lacustris*, were reduced by a third, others, *Hippurus vulgaris* and the *Salix caprea / cinerea* group were reduced still further. *Acer pseudoplanatus* was reduced to two thirds despite a large increase just below the upper screen (see budget discussion). *Ranunculus* spp. were reduced by a half but as material was continually growing, between the two screens to a limited extent, the apparent reduction is an underestimation. The species characteristic of the stream section, *Salix* spp. and leaf fragments, *Fraxinus excelsior*, together with twigs, increased greatly downstream as expected. The proportions of these materials from terrestial sources will be discussed later (see general discussion). There was an increase in dicotyledons, mainly *Rorippa nasturtium-aquaticum* and *Apium nodiflorum* coming especially from the lower part of section C. Dicotyledons leaves were rarely found unattached and never seen dead; this is because such leaves are very moribund when lost and easily fragmented or decomposed. Leaves of *Epilobium hirsutum* from section B were not found though occasional dead inflorescences were. *Lemna* spp. and filamentous algae apparently increased during the passage downstream. These two,together with the animal group were the least accurately estimated because they were smaller than the screen holes and their retention on the screens depended on other materials already present.

Lower screen.

The lower screen was generally cleaned every day at flows above $0.15 \mathrm{kl\ sec}^{-1}$ in the autumn washout, and every two days during the remainder

Table 4.2.5.

The ratio of composition of material collected on the top and bottom half of the middle screen. January - September 1970.

Species group no.	Screen half top %	Screen half bottom %	Percentage of total top %	Percentage of total bottom %
1	5.6	4.0	58	
2	36.9	42.8		54
3	3.6	1.4	72	
4	0.1	0		
5	0	0		
6	7.3	4.1	64	
7	2.7	0.6	82	
8	0.2	0.4		
9	3.6	3.0	55	
10	10.2	7.7	57	
11	0.8	2.5		76
12	0.7	0.8		
13	0	0		
14	0	0		
15	1.0	0.8	56	
16	0.2	0.2		
17	0.1	0.1		
18	0	0		
19	1.1	0.5	67	
20	0	0.4		
21	0	0		
22	1.3	0.2	87	
23	0.2	0.1		
24 25	20.8	25.1		55
26	3.5	5.3		
27	0.2	0.1		
Total weight, kg.	8247	7445		

Note - see also Appendix 1 Tables 2e and 2f.

Table 4.2.6.

Species composition of the large suspended materials leaving section C of Bere Stream at Holly Bush (middle screen).

Material group.	Material	Year 1970 %	1971 %	1972 corrected %
Aquatic				
rhizoidal macrophytes				
	Fontinalis antipyretica	26.2	20.8	36.2
		26.2	20.8	36.2
rooted macrophytes				
	Ranunculus spp.	4.0	5.9	1.2
	Hippurus vulgaris	1.8	0.1	0
	Monocotyledons (lake)	1.4	1.9	1.0
		7.2	1.9	2.2
Free floating macrophytes				
	Lemna spp.	7.8	9.4	2.1
		7.8	9.4	2.1
Marginal plants				
	Dicotyledons	2.8	1.4	0.4
	monocotyledons (bank)	0.4	0.9	1.6
		3.2	2.3	2.0
		44.4	40.4	42.5
Terrestial				
	twigs	11.0	14.3	9.2
		11.0	14.3	9.2
leaves				
	Salix spp.	10.1	7.6	5.1
	Fraxinus excelsior	4.8	3.7	1.3
	Hedera helix	0.7	1.2	1.3
	other	1.6	0.7	0
	Leaf fragments	7.6	13.0	12.2
		24.8	26.2	19.9
		35.8	40.4	29.1
Remainder				
	fine material 0 - 2 mm	19.3	18.3	27.7
	Animal	0.6	0.5	0.8
		19.9	18.8	28.5

Table 4.2.6. (cont.)

Material group	Material	Year (1969)-1970			1970 - 71			1971 - 72 corrected		
Aquatic		%			%			%		
	rhizoidal macrophytes									
	Fontinalis antipyretica	37.1	37.1		13.3	13.3		35.5	35.5	
	rooted macrophytes									
	Ranunculus spp.	4.1			3.8			1.6		
	Hippurus vulgaris	2.6			0.1			0		
	Monocotyledons (lake)	1.8	8.5		1.4	5.3		1.0	2.6	
	Free floating macrophytes									
	Lemna spp.	5.1	5.1		10.9	10.9		2.5	2.5	
	Marginal plants									
	Dicotyledons	3.6			1.2			0.4		
	monocotyledons (bank)	0.4	4.0	54.7	0.7	1.9	31.4	1.6	2.0	42.6
Terrestial										
	twigs	11.5	11.5		12.6	12.6		9.0	9.0	
	leaves									
	Salix spp.	0.8			18.4			5.2		
	Fraxinus excelsior	1.0			7.3			1.4		
	Hedera helix	0.8			0.9			1.3		
	other	0.5			2.0			0		
	Leaf fragments	7.8	10.9	22.4	11.0	39.6	52.2	12.0	19.9	28.9
Remainder										
	fine material 0 - 2 mm	22.1			15.7			27.6		
	Animal	0.8		22.9	0.4		16.1	0.8		28.4

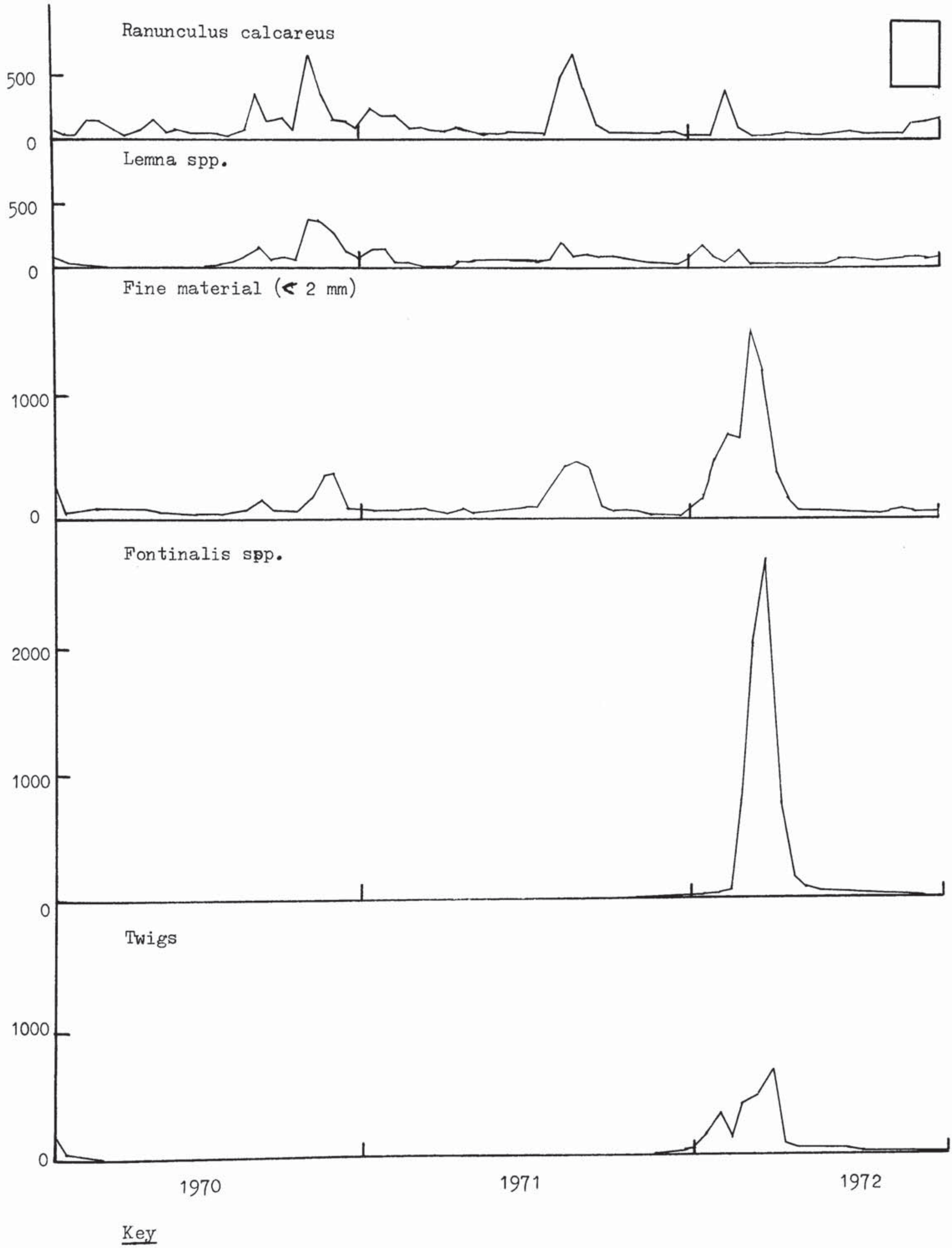
of the year, but there were three periods of exception to this. The first was during March to May 1970 when less fequent cleaning was thought necessary, but this was subsequently changed because losses due to fragmentation were considered important for material lying on the screens longer than two days. The second was from 29 September 1971 (616) after which the screen was cleaned similarly to the middle screen. The third was from 25 March 1972 (827), as mentioned previously, because so much material collected that cleaning of the screens would have been necessary every 12 hours or less. At these flows material clogged the middle screen and water then ran over carrying debris with it, which then clogged the lower screen. The screens were cleaned on the same day once a week during this period in order, starting from downstream and working upstream to avoid influencing the collection of material on the other screens.

The total dry weight of material which was collected on the screen and would have been lost from the section, was 132 kg in 1970 and 97 kg in 1971 (Table 4.2.7). During 1972, when the material from the middle screen was returned, 290 kg was screened out. Seasons were not used because this would have separated growth from its subsequent wash-out.

The mean daily dry weights for the 14 day periods show no similarities to the hydrodynamic cycle as did the middle and upper screens during the first two years. (Fig. 4.2.2. and 4.2.5. and Appendix 1 Table 3a) The loss of material was characteristic only of the R. calcareus growth cycle. The plant starts to grow in the late autumn or in winter, occasionally shedding leaves and loosing stems, particularly at flowering time in the spring. After flowering, the crop declines and is washed out depending on the time of the increase in flow, August and September 1970 and 1971. (Fig. 4.2.7.). A very slight increase in flow is sufficient to start material moving downstream, which then increases the velocity, and this loss of material.

The initial peak in January and February was of material from the

Fig. 4.2.7. Species composition of materials collected on the lower screen, 1970 -1972 (g dry weight day^{-1}).



Key

— [illegible] in stream, 1972.

Table 4.2.7.

Annual totals of dry, organic and inorganic carbon and ash weights, for the lower screen. 1970 - 1972.

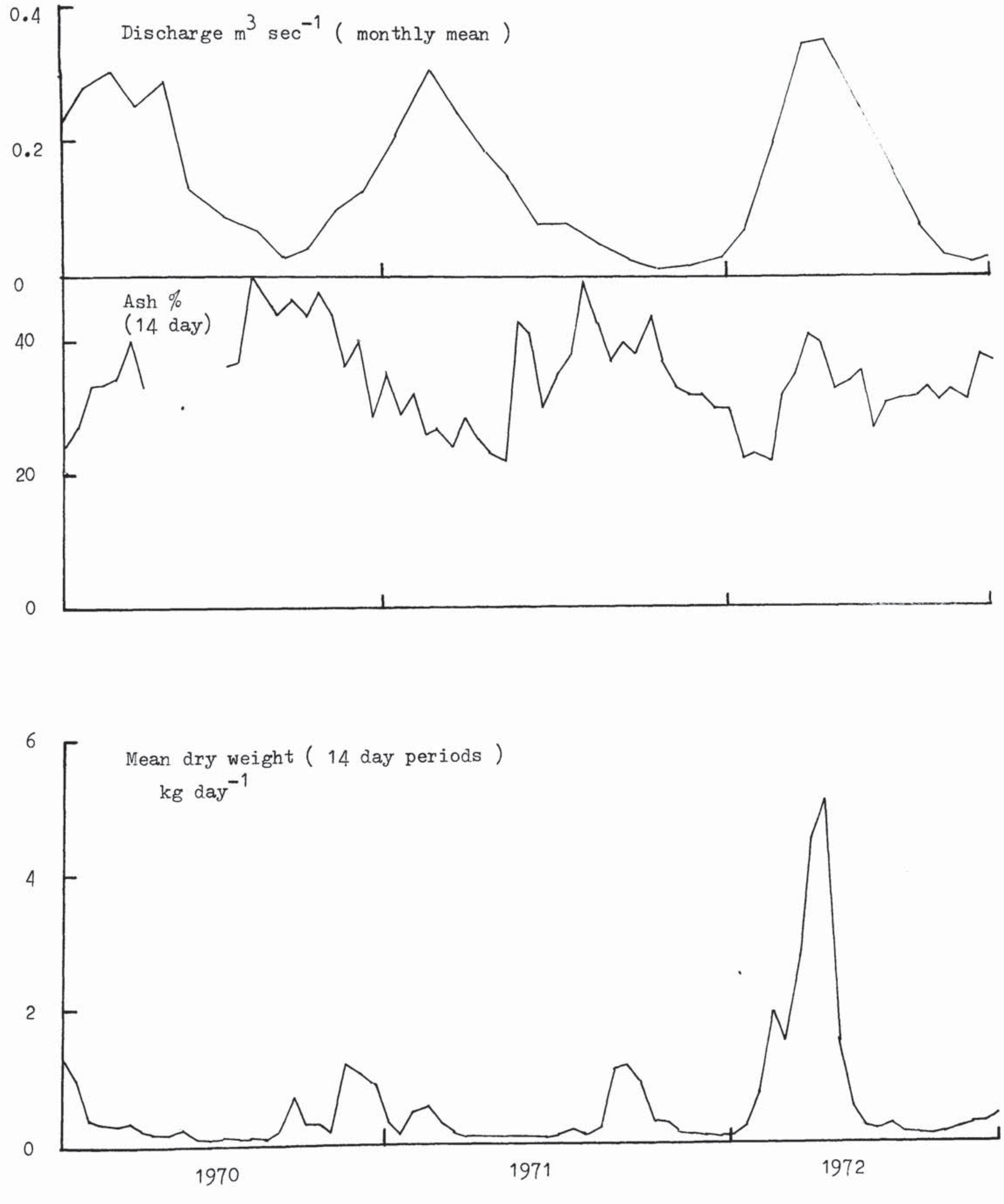
Year (days)	Total dry weight kg	Organic weight kg	Inorganic carbon kg	Ash kg
1970 (1 - 349)	132	88	(2)	44
1971 (350 - 713)	97	62	(2)	35
1972 (714 - 999)	290	188	(6)	102

the wood and lake being washed down, lasted a month after the middle screen had been introduced. The maximum mean daily rate of material passing was 5.1 kg dry weight day^{-1} for a period in early 1972, mainly from the middle screen passing through. Unlike the middle screen, corrections for this period were not necessary, the regrowing macrophyte held much material and that which did pass the middle screen was moderated and flowed evenly unlike the erratic behaviour of material arriving at the middle screen.

The annual mean ash weight of screen material varied from 33 - 36% for the three years. The variation for the 14 day periods varied from a basal level of 20 - 30% at times of high discharge to 40 - 50% at times of low discharge (Fig. 4.2.8. and Appendix 1 Table 3a.). This was the converse of the middle screen and probably due to absence of Fontinalis antipyretica.

The mean daily rate for the years 1970, 1971 and 1972 were 0.36, 0.27 and 0.79 kg dry weight day^{-1}; the third year included material from

Fig. 4.2.8. Seasonal changes in discharge, ash and mean dry weight for the lower screen, 1970 - 1972.



the lake and wood (Appendix 1 Table 2b) and is the natural situation for this stream. The annual mean concentrations of this screened material for the three years were 26, 27 and 59 $\mu g\ l^{-1}$. The annual losses of material recognisable as R. calcareus from the study area of stream were equivalent to a concentration of 9, 11 and 3 $\mu g\ l^{-1}$. (from Table 4.2.7. and Appendix 1 Table 3b.). In the third year however, 27.8 kg dry weight of the plant remained which would have eventually been lost but the study was ended in October before washout was complete. The material was removed manually, (see Fig. 4.2.7.). The annual concentration for this year would have thus been raised from 3 to 8 $\mu g\ l^{-1}$.

The material collected from January to September 1970 was separated into two halves, the top buoyant materials and the bottom bed load materials, and like the middle screen each was treated separately. The top half was slightly heavier than the bottom. (Appendix 1 Table 3e and 3f). A comparison of species showed that R. calcareus, marginal dicotyledons, in particular Rorippa nasturtium-aquaticum and Apium nodiflorum, and the stream side monocotyledons (Graminae) were more often found in the top half (Table 4.2.8). During the initial period Fontinalis antipyretica was found on the bottom half as were leaf fragments and leaves of Hedera helix. Twigs were evenly distributed between the two halves as were Lemna spp.; the latter was however divided as the middle screen, L. trisulca near the stream bed and L. polyrrhiza and L. minor near the surface. The unidentifiable fine materials were more abundant on the bottom half.

The ratio of the recognisable material from terrestial and aquatic sources in the total passing the lower screen in the third year of the study was 1 : 2.2, with 28% of the total being fine material of indeterminate origin (Table 4.2.9.). This ratio is not applicable to 1970 or 1971 because all the material which would have entered was collected on the middle screen. In 1970, the 8.8% of material from terrestial sources and 0.7% of Fontinalis antipyretica found, were mainly from the material

Table 4.2.8.

The ratio of composition of material collected on the upper and lower halves of the lower screen. January - September 1970.

Species group no.	Screen half top %	Screen half bottom %	Percentage of total top %	Percentage of total bottom %
1	32.3	18.4	64	
2	1.0	1.9		66
3	0	0		
4	0	0.1		
5	0.8	0.2	80	
6	5.4	4.6	54	
7	0.8	0		
8	5.6	2.1	73	
9	9.5	1.1	90	
10	7.3	7.8		52
11	3.0	8.2		73
12	0.2	1.0		
13	0	0		
14	0	0		
15	0.1	0.3		
16	0.1	0.1		
17	0	0		
18	0	0		
19	0.1	0.5		83
20	0	0		
21	0	0		
22	1.5	1.2	56	
23	0	0		
24	24.2	36.5		60
25	-			
26	5.8	13.1		
27	2.2	2.8		

Note

- see also Appendix 1 Tables 3e and 3f.

Table 4.2.9.

Species composition of the large suspended material leaving section D of Bere Stream at Holly Bush (lower screen).

Material group	Material	Year								
		1970			1971			1972		
		%			%			%		
Aquatic										
	rhizoidal macrophytes									
	Fontinalis antipyretica	0.7	0.7		0	0		32.7	32.7	
	rooted macrophytes									
	Ranunculus calcareus	35.9			42.1			4.0		
	others	0.2	36.1		0.1	42.2		0.7	4.7	
	Free floating macrophytes									
	Lemna spp.	18.4	18.4		13.7	13.7		3.4	3.4	
	Algae	0.5	0.5		0.5	0.5		2.9	2.9	
	Marginal plants									
	Dicotyledons	2.4			1.9			1.6		
	monocotyledons (bank)	1.1	3.5	59.2	1.8	3.7	60.1	4.3	5.9	49.6
Terrestial										
	twigs	3.0	3.0		0.5	0.5		11.5	11.5	
	leaves									
	Salix spp.	0.3			0			5.6		
	Hedera helix	0.1			0			0.7		
	Fraxinus excelsior	0.3			0.2			0		
	Leaf fragments	5.1	5.8	8.8	0.2	0.4	0.9	4.8	11.2	22.7
Remainder										
	fine material 0 - 2 mm	29.5			34.9			26.8		
	Animal	1.4			3.1			0.9		
	peat	1.1		32.0	1.0		39.0	0		27.7

still in transit between the two screens. In 1971 leaves of *Fraxinus excelsior* totalling 0.4% were collected at the lower screen after being blown over the middle screen. The 3% of twigs passing in 1970 was reduced to 0.5% of the total by 1971. Fine material was approximately a third of the total collection each year.

The loss of recognisable R. *calcareus* material from the study area was averaged over the three years of the study. 7% of the maximum standing crop were lost as shoots from January to the beginning of July. A further 18% was lost during the late summer and autumn washout as moribund stems and leaves (Appendix 1 Table 3c and 3d). The average value is raised by the third year 1972, by including the material for autumn washout which remained and was removed by hand in October (Table 4.2.10.). It is probable that if it had been washed out normally, greater fragmentation would have occured reducing the identifiable loss.

Table 4.2.10.

Seasonal loss of R. calcareus from the standing crop between the middle and lower screens 1970 - 1972.

Year	Loss(% of maximum standing crop)		Loss kg	
	Jan. - June	July - Dec.	Jan. - June	July - Dec.
1970	4.6	12.1	10.5	27.4
1971	10.3	16.7	15.7	25.4
1972	6.2	(24.4)*	8.8	(34.7)[1]

Note

- 1 - see text
- * - input to section from middle screen was 3.1 kg in period January - June and 2.1 kg from July - October 1972.

Plate 3. Leaf-fall basket, showing inner and outer parts.

4.3.. MEASUREMENT OF LEAF-FALL.

Introduction.

Leaf-fall was estimated as part of the study to determine the ratio of materials from terrestial and aquatic sources to the stream (see general discussion). The importance of leaf-fall as an organic source to the stream was indicated by a pilot survey in autumn 1969 just before the screens were introduced. In 1970 and 1971, the survey was expanded to twelve sites scattered in sections A – C of the stream at Holly Bush.

The suitable methods are surveyed in Newbold (1967).

Methods.

The area of origin of leaves above the middle screen was mapped and the areas occupied by the dominant trees were marked. The leaf-fall was determined using square baskets of expanded plastic supported on a double diagonal of wood fixed to four posts in the stream just above the highest water levels. The baskets were double walled to form a square inner part of side 31.6 cm (0.1 m^2), and an outer part of side 61 cm (0.277 m^2, excluding the inner part). The walls were 15 cm high (plate 3) and also made of expanded plastic. The double wall was intended to reduce the effects of wind by decreasing the velocity and turbulance above the basket and preventing leaves either blowing out or failing to settle.

Baskets were sited over the stream, at random, within the dominant species areas according to the relative area covered by each species and the number of baskets available.

The baskets were emptied at weekly intervals in 1969 and 1970 and fortnightly in 1971. Leaves from the inner and outer parts of the baskets were collected and treated separately. The leaves were sorted into species and dried at 105 °C for 24 h, cooled in a descicator and weighed.

The loss of soluble substances from leaves was determined by subjecting samples of fresh fallen leaves of <u>Salix viminalis</u>, collected in the baskets, to a slow stream of tap water for five days. Leaf samples were halved and fresh weighed. Both samples were dried for 24 h, the control immediately and the other after leaching, cooled in a descicator and weighed.

Samples of the dried leaves were ground in a shear mill and analysed for ash and carbon and nitrogen. (as in section 4.2.).

<u>Results and discussion</u>.

In 1969 only two sets of baskets were used, one in the area dominated by <u>Salix viminalis</u> and the other in the area dominated by <u>Fraxinus excelsior</u>. In 1970 and 1971 however, a further ten baskets were used, extending the survey to five in the S .<u>viminalis</u> area, three in the F. <u>excelsior</u> area, two in the <u>Acer pseudoplanatus</u> area, one in a mixed stand of S. <u>fragilis</u> and F. <u>excelsior</u> and one midway between two F. <u>excelsior</u> stands.

The leaf-falls for 1970 and 1971 (Table 4.3.1.(a) and (b)) were subjected to a normal analysis of variance (Table 4.3.2.) (Snedacor and Cochran 1967). The total variance for the determination of leaf-fall can be divided amongst four sources of variance and it was found that three of these contributed a greater variance than could be accounted for by chance.

1. Leaf-fall varied between sites and appeared to be related to the degree of cover by branches and to the difference in leaf-fall between species, but this was not tested in detail.
2. Leaf-fall differed between years; 1970 was lower than 1971.
3. There was interaction, among baskets, some collected more than average in 1970 but less than average in 1971 and <u>vice versa</u>.

There was however, no significant difference in the inner and outer parts of the baskets, in either year, when the results were treated

Table 4.3.1.(a).

Annual leaf-fall, 1969 - 1971, baskets 1 - 12. (g dry weight m^{-2})

Basket.	outer	Autumn 1969		Autumn 1970		Autumn 1971		Dominant	
no.	inner	Weight $g\ m^{-2}$	Mean $g\ m^{-2}$	Weight $g\ m^{-2}$	Mean $g\ m^{-2}$	Weight $g\ m^{-2}$	Mean $g\ m^{-2}$	Species	
1	outer			122		163			
	inner			139	131	156	160	S.vim.	
2	outer	210		195		271			baskets
	inner	225	218	206	201	261	266	"	
3	outer			250		259			
	inner			252	251	306	283	"	adjacent
4	outer			213		235			
	inner			220	217	256	246	"	
5	outer			158		217			
	inner			157	158	222	220	"	
6	outer			375		378			
	inner			347	361	382	380	Mixed S. and F.	
7	outer	408		362		362			
	inner	372	390	415	389	370	366	F.	
8	outer			291		260			
	inner			282	287	269	265	F.	
9	outer			63		40			
	inner			60	62	40	40	Open, between F.	
10	outer			349		515			
	inner			336	343	485	500	F.	
11	outer			355		284			
	inner			416	386	239	262	Acer	
12	outer			132		159			
	inner			151	142	148	154	Acer	

Key :-

S. vim.	-	Salix viminalis
F.	-	Fraxinus excelsior
Acer	-	Acer pseudoplanatus

Table 4.3.1.(b).

Mean weight of leaf-fall by species, 1969 - 1971, g m^{-2}.

Basket no.[2]	Species area	Leaf-fall g m^{-2} Autumn 1969		Autumn 1970	Autumn 1971
1	Salix viminalis	218		131	160
2				201	266
3				251	283
4				217	246
5				158	220
			Mean	191 ± 33	235 ± 34
7	Fraxinus excelsior	390		389	366
8				287	265
10				343	500
			Mean	339 ± 52	377 ± 113
11	Acer pseudoplanatus			386	262
12				142	154
			Mean	264 ± 232	208 ± 105
Grand Total		304 ± 163		260 ± 43	282 ± 44

Note.

1. - Confidence limits, $P = 0.05$, for individual weights from inner and outer halves of baskets.

2. - Excludes baskets 6 and 9, under mixed species or in the open.

in separate analyses of variance.

In the S. viminalis area section C (see map 3.4.1.) the tree cover varied in the extent to which it covered the stream; this was not investigated. The results for individual baskets showed that areas well covered by branches, estimated subjectively, could give higher or lower leaf-fall estimates than those areas less well covered by branches. The

Table 4.3.2.

Summary of analyses of variance for leaf-fall in 1970 and 1971.

Source of variance	Sum of squares	Degrees of freedom	Mean squares	F	P
Between sites 70 71	527797	11	47982	324	$\ll 0.05$
70	268281	11	24389	206	$\ll 0.05$
71	310931	11	28266	103	$\ll 0.05$
Between years 70 71	3870	1	3870	26	< 0.05
Between duplicates 70 71	583081	23			
Interaction of sites and years 70 71	51414	11	4674	31	< 0.05
Error 1970	1302	11	118		
1971	3011	11	274		
1970 71	4879	33	148		
Total 1970	270144	23			
1971	313945	23			
1970 71	587960	47			
Between inner and outer baskets 1970	561	1	561	4.75	> 0.05
1971	3	1	3	0.01	$\gg 0.05$

siting of baskets at random was intended to adequately represent this variation. Mathews and Kowalczewski (1969) have shown significant differences between areas.separated by up to 2 meters. The area covered by branches to some extent was 79% of the stream area C for S. viminalis and 4.8% for S. caprea, but there was no area more than two meters from a branch. The mean value for all sites in this area was used as an estimate of leaf-fall by S. viminalis (Tables 4.3.3. and 4.).

The area covered by F. excelsior, 60 m of stream, was more distinct and the cover denser than for S. viminalis. It was adjacent to 5 m and 15 m of stream occupied by S. viminalis and S. fragilis.

Acer pseudoplanatus was present in the area A as two trees covering an area of 75 m^2 beneath branches. No account was taken of the leaves falling in the surrounding area.

The total leaf-fall per unit area of Acer for Millum Head lake was taken as similar to basket eleven which was under a mature tree. Mathews and Kowalczewski (1969) indicate that 15% of a tree's leaves from a line of trees fall outside the branch area; a correction factor was applied to the results for Millum Head.

Marginal herbaceous plants rarely shed leaves into the baskets except occasionally, Epilobium hirsutum.

The main difference between leaf-fall near streams and in forests is the one way passage of leaves from bank to water as discussed in 2.5. The additional input from this source was not considered as wind action within the wooded area was negligable. The banks of the stream were distinct and the area within them was considered as stream area even though it was not covered totally with water at the start of the leaf-fall period September to November.

The actual times of leaf-fall were variable ranging from August, to November with peaks of fall varying by as much as a month between species and between years.

Bray and Gorham (1964) considered a litter production of 300 - 350 g m^{-2} was typical for this latitude and elevation. The mean value found here of 271 g m^{-2}, for all species in the two years, 1970 and 1971, is lower than expected but twigs were not included in this latter estimate (Table 4.3.1.b.). The density of cover, by branch and by size and numbers of trees in this area was less than a typical forest. The area was a 'withy bed', comprising of small trees overhanging the stream, growing on poorly drained soil and allowing a ground flora beneath, in particular R. calcareus, to develop in the water. A typical forest reduces the light to less than 10%; the annual reduction in the light for this type of woodland, found 3 km from this site, is 75%, Westlake (1970). The summer light was reduced to 10%, whereas the winter was reduced only to 40%, allowing growth of a ground flora during the period from autumn to early spring.

The leaves of S. viminalis which fell during the middle of leaf-fall, subjected to 5 days leaching, lost 15% of their dry weight when compared to the controls. This was within the range given by Nykvist (1963) (see budget discussion).

The analysis of leaf components shows S. viminalis to have the lowest ash content of the species present (6.6%), compared to F. excelsior (9.4%0 and A. pseudoplanatus (9.0%) (Appendix 5 Table 1.).

Table 4.3.3.

Leaf-fall into stream above middle screen.

Section	Area	Species	Leaf-fall			
			1970		1971	
	m^2		Mean $gm\ m^{-2}$	Total kg	Mean $gm\ m^{-2}$	Total kg
A.	75	Acer	264	19.8	208	15.6
	20	S.vim.	191	3.8	235	4.7
B.	186	Frax.	339	63.1	377	70.1
	16	S.vim.	191	3.1	235	3.8
	47	S.frag.	361	17.0	380	17.9
C.	537	S.vim.	191	102.6	235	126.2
Sub-total.	881			209.4		238.3
Millum Head	824	Acer	386	318.1	262	215.9
	80	S.caprea	199	15.9	235	18.8
sub-total.	904			334.0		234.7
Total	1785			543.4		473.0

Table 4.3.4.

Total leaf-fall by species above middle screen.

Species	Stream		Lake		Total			
	1970 kg	1971 kg	1970 kg	1971 kg	1970 kg	± t.S.E.	1971 kg	± t.S.E.
S.vim.	109.4	134.7	-	-	109.4	18.9	134.7	19.5
S.frag.	17.0	17.9	-	-	17.0		17.9	
S.capr.	pres.	pres.	15.9	18.8	15.9+		18.8+	
F.excel.	63.1	70.1	-	-	63.1	9.67	70.1	21.1
Acer	19.8	15.6	318.1	215.9	337.9		231.5	
Total					543.4		473.0	

4.4. SMALL SUSPENDED MATERIALS.

The passage of small suspended materials which were not retained on the screens, (5 mm square holes), was determined using membrane filters.

The contribution to suspended material of autochthonous material produced between the middle and lower screens (section D) was estimated by continually monitoring the input and output. In an ideal situation the difference would be due to fragmentation of material produced within the section; this value could then be used to correct the standing crop and obtain a better estimate of production. The system was however, complicated by the accumulation of settled input material and its respiration, combined with autochthonous settlement and respiration.

The small suspended material was analysed for carbon in organic and inorganic form. A change in inorganic may take place caused by the increased carbon dioxide levels from respiration within the sediments dissolving carbonate which then leaves the study section as soluble bicarbonate.

Method.

Samples of stream water were taken from the middle of the stream below each of the screens by carefully plunging 2.7 l wide-neck polythene containers into the water making sure there was no disturbance to settled material. Samples were normally taken by kneeling on the screen supports, especially at times of low velocity. If a disturbance was caused, for example, by fish or the operator, the system was allowed to stabilise for a quarter of an hour. The frequency of sampling at the three screen sites is discussed later.

Samples were also taken at 20 minute intervals by a sampling machine (Impulse sampler manufactured by Rock and Taylor of Warley, Worcestershire) operated from a 12 volt car battery. The velocity of water in the pipes of the sampler was in excess of the stream velocity and this prevented settlement of suspended material during the operation. The machine was set to pump for one minute, to wash out any settled material in the pipes, then to deliver a representative 60 ml of stream water to a composite sample. The 5.4 1 wide neck containers were changed daily.

The samples were filtered using 0.8 μm, 4.7 cm diameter, Millipore membrane filters, at reduced pressure, (not less than half atmospheric). The filters were dried overnight at 105 °C, not pre-washed, cooled in a desiccator, weighed and stored in small flat bottomed tubes. To prevent cracking, the filters were floated into position on the sintered disc of a standard 250 ml Millipore filter holder. The outsides of the sample containers were washed and drained before removal of the lid. The supernatent liquid was decanted into the filter holder; this prevented early clogging of filters. The settled material was left until the end and after it was filtered the container was washed vigorously twice, with distilled water and the washings were also filtered. The filter holder was 'bobbied' and washed with distilled water before the removal of the filter; the filter was folded twice with tweezers to seal in the contents and prevent it sticking to the walls of the tube into which it was returned for overnight drying. More than one filter was occasionally necessary and the same procedure was adopted.

Ash weight determinations were made on monthly batches of filters which were pre-ignited after 'wetting' in ethanol, put in a muffle furnace at 550 °C overnight, cooled in a desiccator and weighed and then heated to 900 °C for 1 - 2 hours, cooled and weighed. Before use containers, filter holders and crucibles were cleaned in 'chromic acid', usually overnight, washed in tap water and then distilled water, before air drying. The sample pipes of the automatic sampler were also cleaned frequently with 'chromic acid' and washed in stream water.

Sample procedure, results and discussion.

The efficiency of 0.8 μm membrane filters for removal of suspended material was estimated by comparison with samples taken at the same time and subjected to continuous centrifugation (M.S.E. High Speed 18) by Mr. I. Farr of the River Laboratory. No significant differences were obtained between single determinations of suspended material by centrifugation and, on average, four spot samples estimated by membrane filtration, over a three month period. (Table 4.4.1.). Results from samples obtained from the centrifuge sample itself were also close but showed more variation probably due to the physical difficulties of resuspension of particles in the 50 l containers used for collection. (Table 4.4.1.). The effluent from the centrifuge contained less than 0.3% of the material separated when it was subsequently passed through a membrane filter.

As a check on both methods of estimation the numbers of bacteria in both filtrates were estimated by dilution plate counts on a media previously shown to be conducive to growth of stream bacteria, by Mr. I. Farr. Both methods reduced bacterial numbers by 99%. About 3% or 0.1 mg l^{-1} of the suspended material is bacterial. (I. Farr, pers. comm.).

Millipore AA filters and Sartorius membrane filters were compared. No significant differences in estimates of suspended material were observed, the latter had, however, a much slower filtration rate.

The use of membrane filters, instead of glass fibre filters, was prefered because the lighter weight of the membrane filter was smaller in proportion to the weight of material collected. This was important because the head waters have a particularly low concentration of suspended material.

Membrane filters were not pre-washed to elute material before drying because this causes them to be difficult to rewet and they were more liable to cracking. A further reduction in pressure was also needed for filtration. Even though 2 - 3% of the dry filter weight was reported by Cahn (1967) as soluble in saline solution less than 0.6% was found to be

Table 4.4.1.

Comparison of the removal of suspended material by 0.8 µ membrane filters and continuous centrifugation.

Samples taken from centrifuge sample.

Date		Centrifuge mg l^{-1}	Membrane filter mg l^{-1}	No. of samples
1969				
Sept.	10	3.93	3.41 ± 0.24	3
	16	3.79	2.92 ± 0.82	2
Oct.	15	2.2	2.71 ± 1.01	2
	21	4.74	5.69 ± 0.19	6
Nov.	4	3.86	4.22 ± 2.16	5

Samples taken during removal of centrifuge sample from stream.

1969				
Sept.	9	6.1	6.75 ± 1.55	3
Oct.	7	2.39	2.52 ± 1.11	3
	15	2.2	2.16 ± 0.31	5
	21	4.74	5.1 ± 0.66	6
	29	2.37	2.58 ± 0.38	5
Nov.	4	3.86	3.44 ± 0.40	2
	11	1.97	2.21 ± 0.39	4
	18	1.88	1.97 ± 0.15	3
Dec.	2	4.4	4.0 ± 2.12	4
	16	4.4	4.60 ± 3.75	4
	31	23.6	23.0 ± 0.84	4

leached out by the normal sample of 2.7 l.

Membrane filters were found to become brittle and to lose weight at 0.3 - 0.5 mg day^{-1} if left at 105 °C for long periods, therefore they were not dried for longer than overnight.

Local variations in small suspended materials. Initially only 1 litre samples were used but the experimental errors were too great at such low weights, for example, on 22nd January 1969 a range of confidence interval as a percentage of the mean of ± 35% was obtained for a suspended material estimate of 3.1 ± 1.2 mg l^{-1} dry weight. The size of samples was increased to 2.7 litres, except for special samples and at times of rain. The experimental error was reduced,

the confidence interval ranged from ± 10 - 20% of the mean. This could probably have been reduced by taking more samples but time did not allow this alternative.

The concentration of suspended material sampled at different points across the stream was insignificantly different from samples taken at the same site in the centre of a stream. In May 1969 sets of five samples were taken in random order from $^1/4$, $^1/2$ and $^3/4$ the distance across the stream at the sites of the middle and lower screens. At the middle screen the concentration in the centre was 1.14 ± 0.07 mg l^{-1} and for the lateral samples 1.25 ± 0.07 mg l^{-1}, while at the lower screen the concentrations were 1.61 ± 0.22 and 1.69 ± 0.18 mg l^{-1} respectively.

The concentrations of suspended material was estimated every few hours, from August 12 - 13, and a distinct <u>diurnal variation</u> in suspended material was observed. The concentration rose to a maximum at night of double the daily mean and fell to a minimum in the afternoon, of half the daily mean. (Table 4.4.2.). This variation may be due to the difficulty of sampling by torch light at night or to increased animal activity.

This diurnal variation was not investigated further but the sampling procedure was changed in favour of automatic sampling machines in

Table 4.4.2.

Diurnal variation in suspended material .

Date	Time	Dry weight of suspended material Middle screen $mg\ l^{-1}$	Lower screen $mg\ l^{-1}$
12.8.69	15.00	1.25	0.98
	18.00	-	0.83
	21.00	2.96	1.55
13.8.69	00.00	2.38	1.98
	6.00	2.18	0.76
	9.00	1.11	0.76
	12.00	0.67	0.72
	15.00	0.67	0.63
	18.00	0.70	0.43
	21.00	1.63	1.13
	Mean	1.51	0.98

order to sample such fluctuations.

The automatic sampling machines were used for sampling at the lower screen from February 1970 and at the lower and middle screens from October 1970 until the end of the study. The collection pipes were held in mid water in the second screen channel from the right bank, at both screens, throughout the study. The sample pipe depth was considered to be near the mean water velocity and thus carrying a representative suspended material load. Samples were not integrated in depth or by velocity.

During the first half of the study period, samples were collected at twenty minute intervals for five days a week. The sampling interval was later increased to one hour for weekends only and sampling was then continuous. Slight but insignificant deterioration of samples was observed over three day periods but samples were normally processed within six hours of the time of change of collection containers. Spot samples were taken twice weekly at times of change-over of sample bottles or daily if a machine failed to collect samples. These failures were mainly due to the clock and the freezing of pipes in winter; with occasional failures of batteries.

There was no significant difference between machine-pumped samples and spot samples, for example, on 22nd May 1969 the machine-pumped sample estimate was 2.65 ± 0.31 mg l^{-1} and the spot sample estimate was 2.53 ± 0.49 mg l^{-1}, for three samples each. At times of low flow and water height the sampling machines were also used to take spot samples because the containers caused too much disturbance to the system.

The material collected at each screen was bulked separately each month, because the quantities were so small, and subjected to a proximate analysis. Ash and organic weights were determined by difference after heating the samples to 550°C overnight. The inorganic carbon, assumed to be in calcium carbonate, was estimated by difference, after reheating to 900 °C for one hour. The method was confirmed using A.R. Grade calcium carbonate; the loss of other volatile fractions was determined as less than 0.5% between 550°C and 900°C by conversion of the calcium carbonate present in samples, to sulphate before the ignition. (Calcium sulphate is stable at 900°C). Some of the inorganic carbon as magnesium carbonate is included in the organic material as it is unstable at 550 °C. The ratio of calcium to magnesium is probably large; in the stream water it is about 40 : 1.

Results and discussion.

The aim ,' continuous sampling, at both the middle and lower screens resulted in about two thousand two hundred determinations being made in the period 1969 - 72. In 1969, weekly spot samples were taken at the lower screen' site; these averaged six samples per week, totalling 290 estimates. In 1970, from January to October, the continuous sampling programme at the lower screen averaged six samples per week, some spots and other continuous samples, totalling 250 samples. The middle and lower screens were continuously sampled, adding a further 214 estimates in this year, and a further 1,450 samples in 1971 and 1972.

The output of the lake was estimated from 84 dip samples for the 1970 - 71 season.

The monthly mean suspended material passing the sampling points was estimated after completing the daily results by interpolation using the following assumptions :-

(a) if there was no change in water height then there was no change in suspended material concentration; the mean value of the day previous and following was used.

(b) if there was a continuous change in water height then the concentration of suspended material changed continuously between known limits; estimates were made assuming a first order curve for this relationship.

The two assumptions can be shown to be valid from the study of normal day to day records. (Table 4.4.3. and Fig. 4.4.1.).

The screens seasonally caused backing up of water and settlement of small material because of the large quantities of material collecting on them. Several of the rapid changes in suspended materials associated with screen cleaning were studied and an approximately first order relationship was established (see Fig.4.4.2.),for both screens, above the daily mean.

The results were analysed to decide whether to include the samples taken during the hour immediately following cleaning or to stop sampling during this period and to add a correction to the daily mean. An example, the daily mean for 26th November, if sampling continued at twenty minute intervals, was calculated to range from 14.8 - 20.8 mg l^{-1} depending on the time between screen cleaning and the first subsequent sample ($> 0 < 20$ min). The daily mean if one minute sample periods were used, i.e effectively continuously during the first hour after screen cleaning and the subsequent 23 hours, was 12.6 mg l^{-1}. The background level was a further difficulty because it decreased steadily from about an hour after screen cleaning until the subsequent screen cleaning as the large material collected on the screen. This level 10 mg l^{-1} was determined by samples every 20 minutes. Therefore, samples were not taken by the automatic samplers during the hour following screen cleaning. Weekly estimates were made for this hourly period by taking samples before, immediately after (1 - 2 minutes) and 5 - 15 minutes, after screen cleaning depending on conditions. The estimates were plotted on semilogarithmic paper and the weight passing during this hour, estimated and added as a correction factor to the total for the remaining twenty three hours. (Appendix 3 Table 5). The corrections were small except in January 1972 when material was being washed out of the wooded section which would normally not have been fragmented but washed out earlier in the season as large drift. (see section 4.2.).

Table 4.4.3.

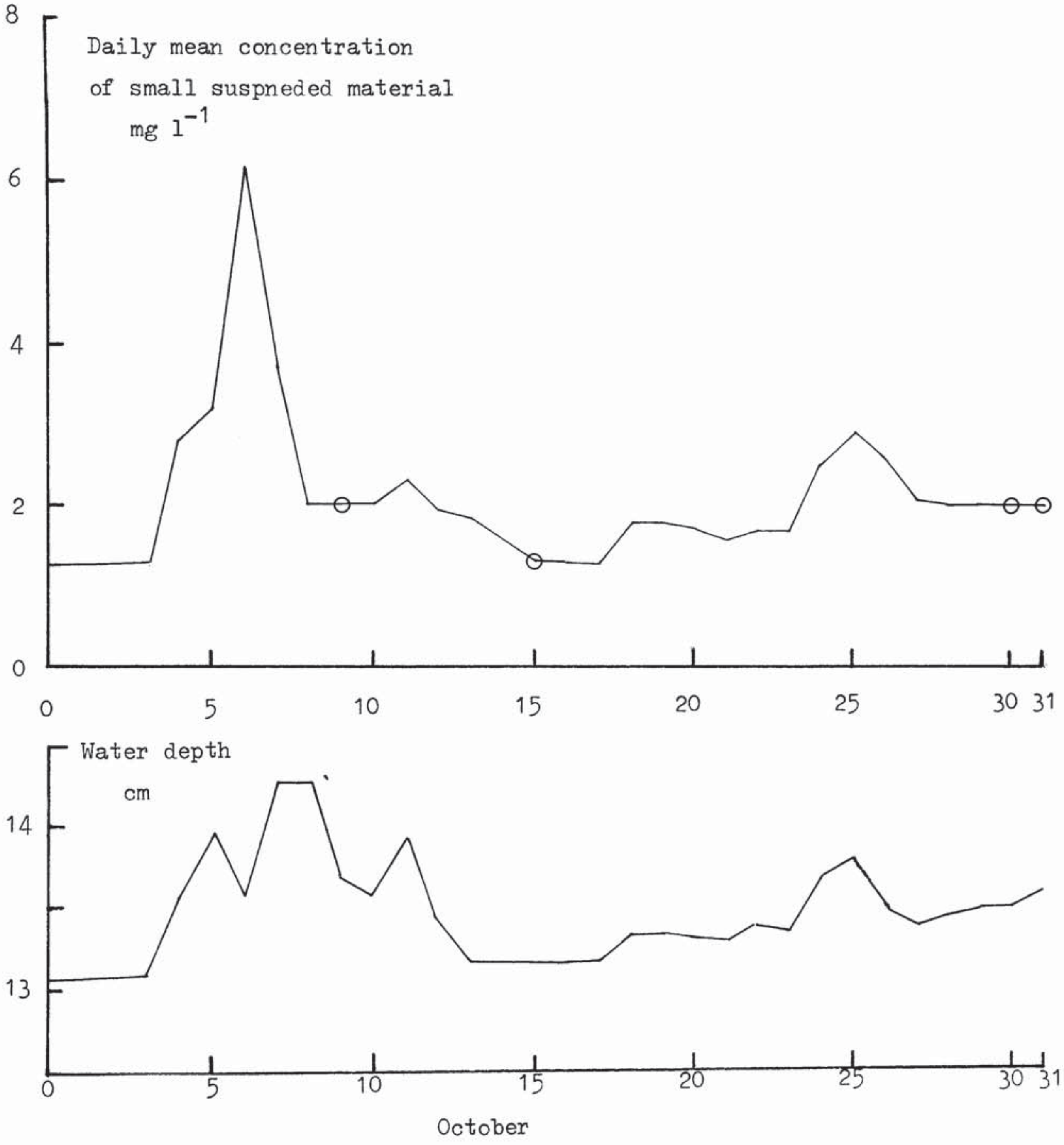
Small suspended material passing middle screen - October 1971.

Date	mg l^{-1}	Date	mg l^{-1}	Date	mg l^{-1}
1	1.3	11	2.3	21	1.6
2	(1.3)	12	1.9	22	1.7
3	1.3	13	1.8	23	1.7
4	2.8	14	0.6 ?	24	2.5
5	3.2	15	(1.3)	25	2.9
6	6.2	16	1.3	26	2.6
7	3.7	17	1.3	27	2.1
8	2.0	18	1.8	28	2.0
9	(2.0)	19	1.8	29	2.0
10	2.0	20	1.7	30	(2.0)
				31	(2.0)

( ) values estimated

The seasonal variations in small suspended matter measured at the lower screen site during 1969, without screens, and 1970 - 71 and 1971 - 72,

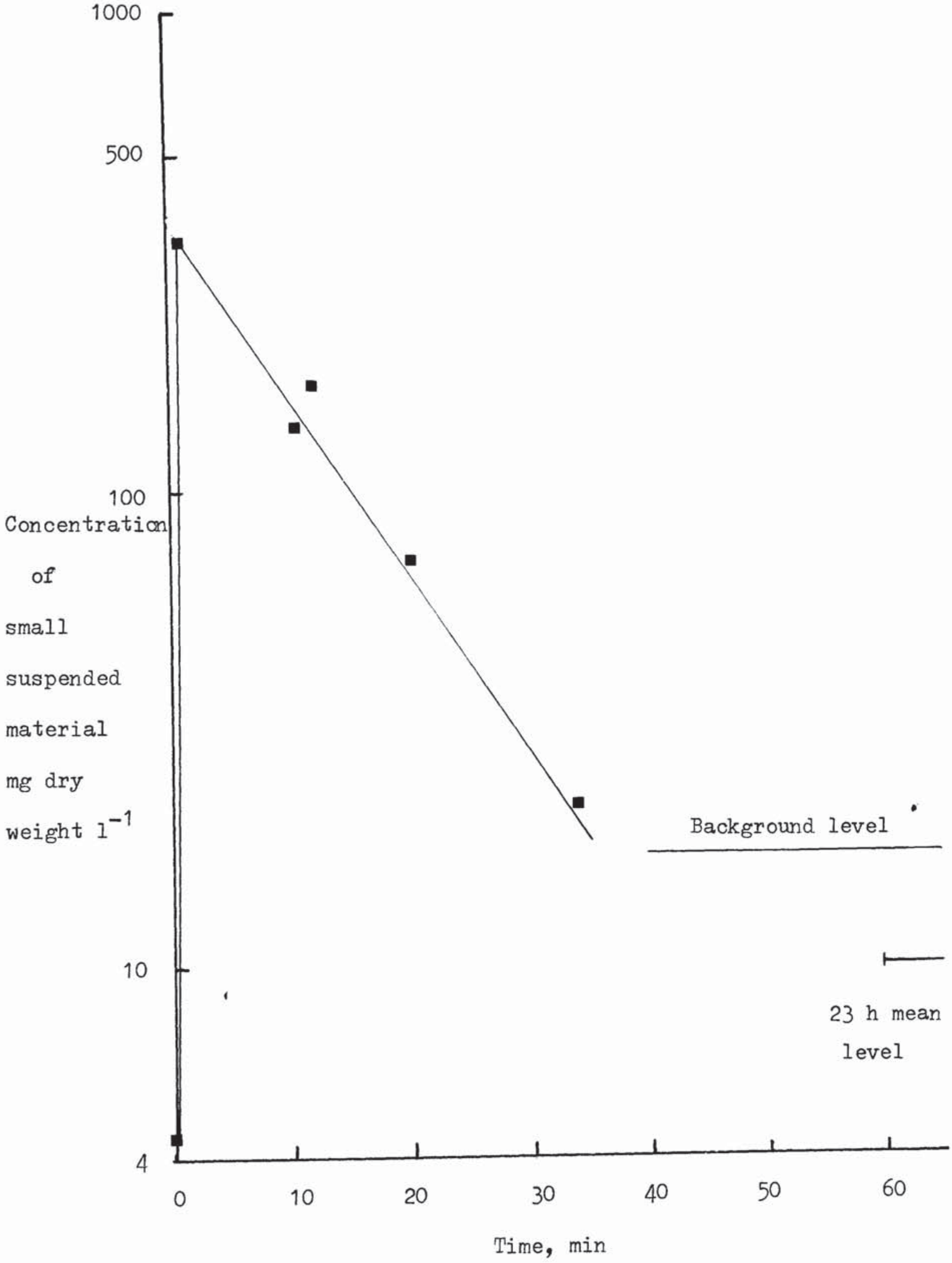
Fig. 4.4.1. Concentration of small suspended material passing middle screen in October , 1971.



Key

○ estimated value

Fig. 4.4.2. Change in concentration of small suspended material immediately after screen cleaning.



with screens, showed similar seasonal patterns over each period. (Fig. 4.4.3. and Appendix 3 Table 1). The maximum concentration of material is in the autumn or winter depending on the seasonal hydrodynamic pattern and falls to a minimum in mid-summer. (Fig. 4.1.7. and Appendix 3 Table 4.). The increase in standing crop of plant caused an increase in the retention of small suspended material but this also coincides with the seasonal decrease in discharge. The autumnal wash-out of R. calcareus is accompanied by a large proportion of the resuspended sediment, but a further increase in small suspended material was observed when the lake started to flow and increased the total discharge even higher. The latter increase washed material from the deep reach of section D leaving the stream nearly devoid of organic sediment, until plant growth restarted for the following season.

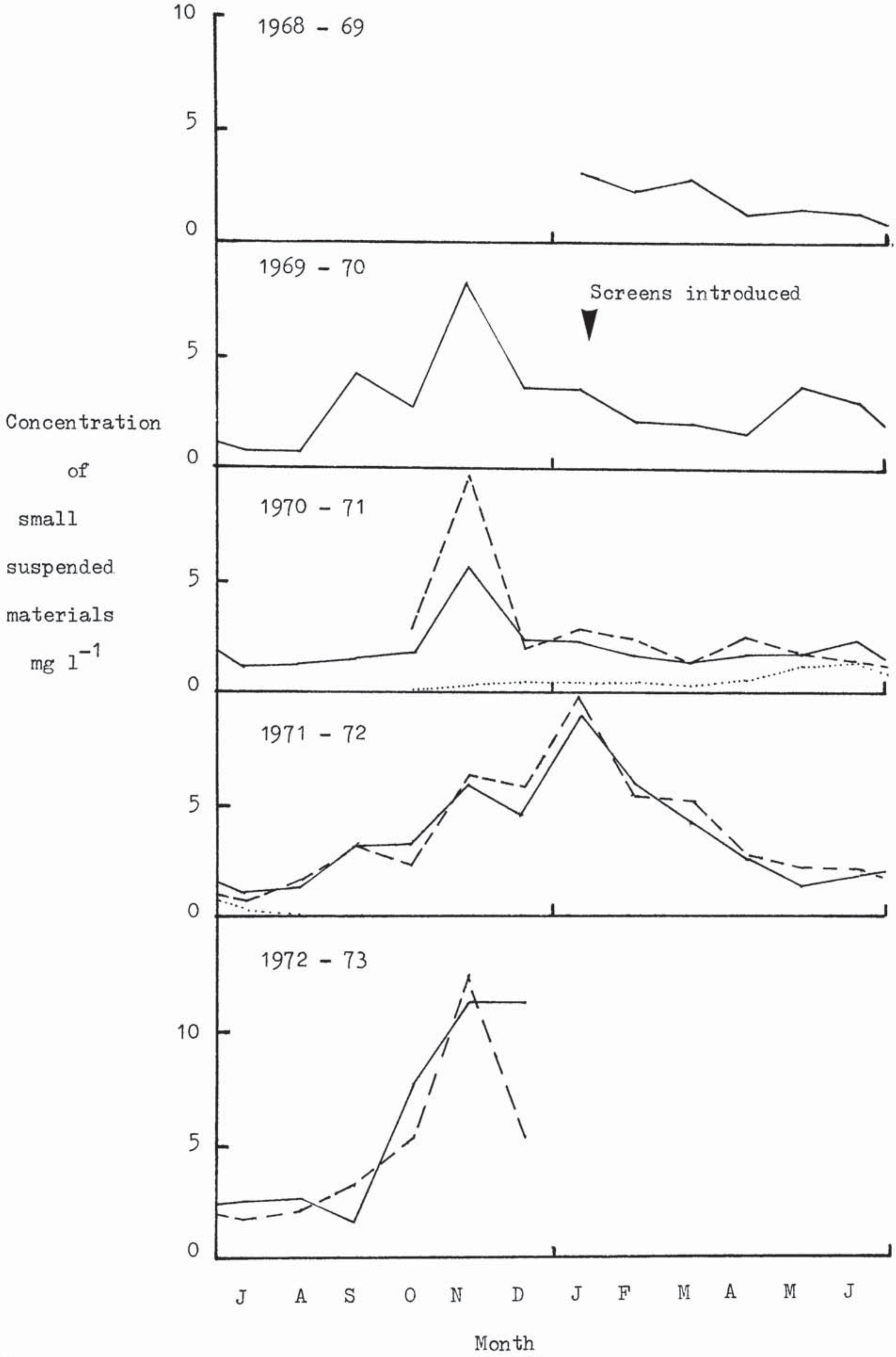
The concentration of the small suspended material passing the middle screen showed a similar seasonal pattern to that of the lower screen (Appendix 3 Table 2.). It was a little higher than the lower screen during the spring and lower during the early autumn; this difference in concentration reflected the accumulation effect of the macrophyte standing crop in section D and also the autumnal washout of the sediments remaining, (Fig. 4.4.3. and Appendix 3 Table 1), after the macrophyte crop was washed out.

Seasonal variations in the percentage of organic and ash weights were not clear. The suspended material passing the lower screen was lower in organic material at the high flows of late winter but also during the summer. (Appendix 3 Table 1). The percentage of organic material passing the middle screen also varies inversely with flow but to a lesser extent (Appendix 3 Table 2.).

The concentration of small suspended material passing the upper screen from the lake gradually increased as the discharge decreased during the season, reaching a maximum in the penultimate month of flow, June. (Appendix 3 Table 3.).

The annual and seasonal total organic throughputs at the middle

Fig. 4.4.3. Seasonal change in concentration of small suspended materials passing the upper, middle and lower screens, 1969 - 1972.



Key

...... Upper screen

— — Middle screen

Fig. 4.4.4. The accumulation of small suspended organic material predicted from monthly budgets for section D of the stream at Holly Bush.

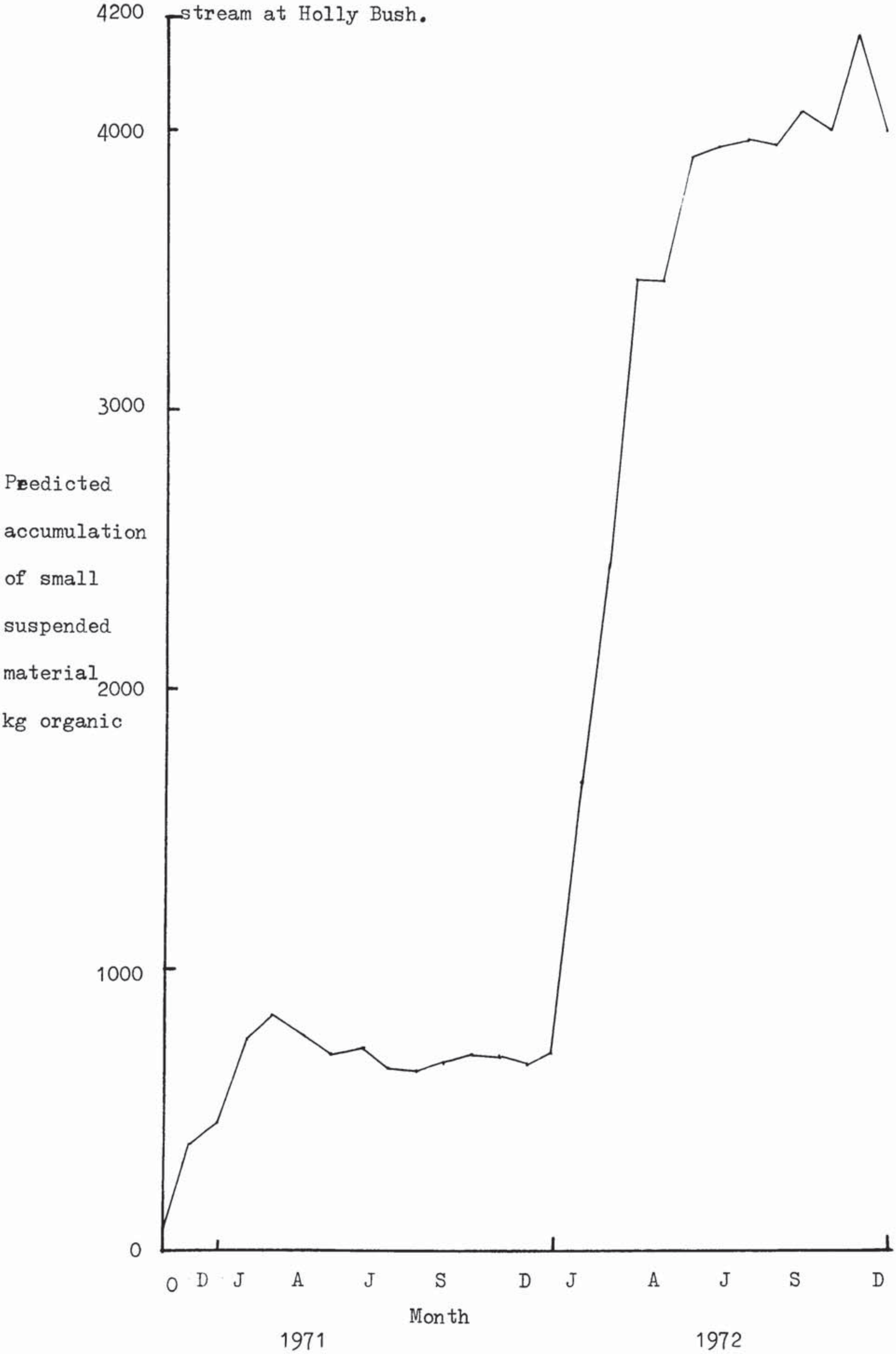


Table 4.4.4.

Annual and seasonal totals of small suspended materials.

Upper screen	Organic		Inorganic carbon	Total	Concentration of total
	kg	%	kg	dry weight kg	mg l^{-1}
1970 - 1	373	39	18	958	0.55
Middle screen					
1971	2763	36	352	7612	2.09
1972	8669	43	946	19 910	4.05
Season					
1970 - 71*	> 3510	(36)	> 505	> 9704	
1971 - 72	6473	45	709	14 416	3.39
1972*				> 6785	
Lower screen					
1970	3589		-	12 780	2.51
1971	2477	36	278	6585	1.81
1972	6174	30	1050	20 455	4.16
Season					
1969 - 70	3302		-	12 769	2.56
1970 - 71	3057	38	> 354	8111	1.92
1971 - 72	3898	26	796	14 289	3.36
1972*				> 7369	

Note

1. - A season includes August to the following July.

* - Incomplete.

and lower screens imply a continuing accumulation of organic material within section D (Summary Table 4.4.4. and 4.4.5. and Appendix 3 Table 4). This is, however, not consistent with observation, since the system is obviously washed clean every autumn or winter.

Table 4.4.5.

The annual organic balance for small suspended materials in section D of Upper Bere Stream.

Period	Input	Output	Balance	
Year	kg	kg	kg	% of Input
1970	-	3589	-	-
1971	2763	2477	+ 286	+ 10
1972	8869	6174	+2495	+ 28
Season				
1969 - 70	-	3302	-	-
1970 - 71	> 3510	3057	> + 453	> + 12
1971 - 72	6473	3898	+2575	+ 39

The apparent inbalance of small suspended organic material is substantially different between the years 1971 and 1972. In the former year, no large suspended material was allowed to pass the middle screen, whereas in the latter year, nearly all the material which would have been passing naturally was returned after weighing and sampling. (section 4.2.). Much of this material accumulated in the spring and summer of 1972, between the middle and lower screens (section D) and was substantially reduced in quantity by the time it was collected on the lower screen.

Organic balances for the small suspended materials were calculated each month and used to predict the amount of material which should be present between the middle and lower screens. (Appendix 3 Table 4 and Fig. 4.4.4.). The accumulation of the differences of monthly balances predicts a continual increase of material over the period late 1970 - December 1972, with rapid accumulations in the spring. There was, however, no sediment observed in October 1970, November 1971 and December 1972. The differences must therefore be attributed to respiration or a change to soluble organic carbon (or at least particles smaller than those removed by 0.8 µm membrane filters) and possibly a little loss from higher trophic levels. The latter, for example, the emergence of the adults of aquatic insect larvae, or fish being eaten by birds is very small. (see general discussion and Westlake et al 1972). If the loss were due to a change to soluble organic material an appreciable increase would occur with distance downstream in rivers. This does not occur, therefore these substances are probably respired as fast as they are produced. (see general discussion).

The difference between the observed, and the predicted difference between the input and output, of small suspended material increased greatly with increased amounts of input material; thus in section D, in 1971, 2.8Mg entered and 2.5 Mg left, a difference of 0.3 Mg which was unaccounted for excluding, in addition, that loss of material produced within the section. In 1972, 8.7 Mg entered and 6.2 Mg left leaving a difference of 2.5 Mg, again without including loss by material produced within the section, D. In this year material from the middle screen was also returned.

Analysis of the centrifuge samples by Mr. I. Farr gave values of organic carbon of about 50% of the organic weight.

The annual rate of loss of organic material in the small suspended material fraction from section D was for the season 1970 - 1, 1.77 g m^{-2} day^{-1} of organic material or 0.89 g Carbon m^{-2} day^{-1}; if this material were all respired it would have an oxygen demand of 0.099 g oxygen m^{-2} h^{-1}. The loss from this section in 1971 - 2 was 10.08 g organic material m^{-2} day^{-1} or 5.04 g Carbon m^{-2} day^{-1} with an oxygen demand of 0.56 g oxygen m^{-2} h^{-1}. These values are in agreement with the range of respiration rates given by Edwards and Rolley(1965) for re-suspended surface sediments of the River Gade (a chalk stream). The depth of the accumulated material was never more than 12 cm and was observed to be, substantially, aerobic. A representative bulked sample of sediment taken in July from section D, was 72% Ash (550°C) and 28% organic, the latter contained 19.5% carbon, organic and inorganic and 1.06% nitrogen, thus having a carbon to nitrogen ratio of 18.4 : 1.

The balance of non-carbonaceous ash, that is silica and metal oxide compounds, is approximately correct for 1971 (Table 4.4.6.). Only small material entered the section in this year, but in 1972 large suspended material was returned and therefore this must be considered in a budget for that year (see general discussion).

Table 4.4.6.

The annual and seasonal non-carbonaceous ash balance of the small suspended materials for section D.

Period	Input kg	Output kg	Balance kg	Balance % of Input
Year				
1971	4497	4108	+ 389	+ 8
1972	10295	13231	- 2936	- 29
Season				
1970 - 71	5689	4700	+ 989	+ 17
1971 - 72	7234	9595	- 2361	- 33

This section of the study is combined with the large suspended material budgets and is discussed in the general discussion (section 7).

4.5. STANDING CROP ASSESSMENT.

Introduction.

The seasonal changes in standing crop of R. calcareus can be determined in two ways, the removal of biomass or the estimation of changes in cover. The latter can be estimated by photographic or mapping techniques (Vollenweider et al 1969), however, for a new population study, the plants from an estimated sample area must be removed, at least seasonally, to calibrate the method. The method of measuring biomass from cover assumes a uniform or standard density for areas covered. This is frequently not the case and is not sufficiently accurate for detailed investigations; a modified method is available utilising the attenuation of light by plant cover, Westlake (1964) and Owens et al (1967). But this is difficult to operate in shallow streams, especially near the rooting area of a plant. Although the optical density of a suspension of water plant is directly proportional to the concentration, calibrations are still necessary for different species and circumstances.

Efficient sampling of aquatic macrophytes in the study of their production must incorporate their temporal and spatial variability and the pratical solution must involve the balance between time and labour available, the minimum of damage to the system and the accuracy required by the experiment. (Grieg Smith 1964).

Initially, sampling techniques were investigated to find one of suitable accuracy to show significant differences between monthly estimates of standing crop . This survey considered the size, sampling loss and damage caused by using quadrats. The damage could be expected to be proportional to the width across the stream as R. calcareus grows in a contagious undirectional manner. Estimates of cover of the stream by plants, and standing crop from plant covered places only, could be used to increase sampling efficiency compared with samples from the whole stream area; alternatively the analysis of results for the total stream area could exclude plant free areas, the mean then being corrected by the percentage cover but not the variance. Complete randomising of sample sites produces the unbiased results required by statistics, providing sufficient samples are taken. Equally weighted strata or divisions ensure equal representation of all areas within the system and sample sites are selected at random within each stratum thus satisfying the statistical requirements.

A large river, the River Frome, was sampled to relate the growth of R. calcareus in the small study stream to a large river, in which the plant is dominant rather than a dominant maintained by removal of other species. The Frome was sampled, by transects, from equal stratifications between Dorchester to Wareham in 1969. A more detailed study was made in 1970 to examine the causes of the large variation in samples found the previous year.

The weed cuts, by the local river board, were also studied.

4.5. (1). Stream sampling.

4.5. (1a). Development of methods.

The optimum quadrat size for sampling in the study area (section D) at Holly Bush was determined in February 1969 using the following samplers :-

1) a one meter square of iron pipe, the plant material at the edges was cut using hand shears.
2) a one quarter-meter square of wood, operated as 1.
3) a one twentieth-meter square aluminium open ended box, thirty cm high and extendable upwards using a polythene tube. (Ladle and Casey 1971)
4) a one sixty-third meter round corer (see description of method below).

Ten samples were taken at random, as above, from a typical section of stream of 50 m^2, starting with the smallest quadrat. The plant lost as a result of sampling (i.e. damage caused) was collected in a hand net and treated separately as was that accidently lost during the removal of plant from within the quadrats (i.e. the normal error in collecting samples). Increasing the sample size increased damage caused in two ways, the first, because in larger samples more anchoring roots were removed and the second, because of the increase in width across the stream (Table 4.5.1 The damage increased proportionally to the width of the sampler across the stream (see 3.2. description of the plant).

The two methods of determining standing crop, that of sampling from the whole stream area and that of sampling from the plant areas only and combining this with the determination of cover by plants of the stream bed, gave estimates ranging from 207 - 310 for the former and 266 - 347 g m^{-2} for the latter, excluding the 1 m^2 samples. Additional samples were needed for the latter method to bring the number to ten. (Table 4.5.1.). The whole of the section used for quadrat testing was subsequently cleared to stream bed level and the plants were weighed wet after draining for 5 min. The total dry weight was estimated from a dry to wet ratio determined from large sub-samples which were sealed on site in polythene bags,weighed fresh wet, dried at 105 °C and reweighed. The total standing crop removed, which included samples and losses caused by sampling,was 340 g m^{-2} dry weight. This value was only reached by the smallest sampler, the others giving an underestimate even after allowing for the lower estimates of cover (Table 4.5.1.). Plotting the results as a running mean against sample number (Grieg-Smith 1964) showed a definite but unfinished trend towards the true mean but that insufficient samples were taken. (Fig.4.5. 1.). The determinations for cover corrected plant-only areas ranged from 212 - 312 g m^{-2}.

The operation of the one meter quadrat was based on the results of two previous samples of 48 and 449 g m^{-2}, the previous month, June 1969, from the same area, having indicated a very high variance. Samples were

Table 4.5.1.

Determination of Quadrat size.

sections 1 - 3, 10 February 1969.

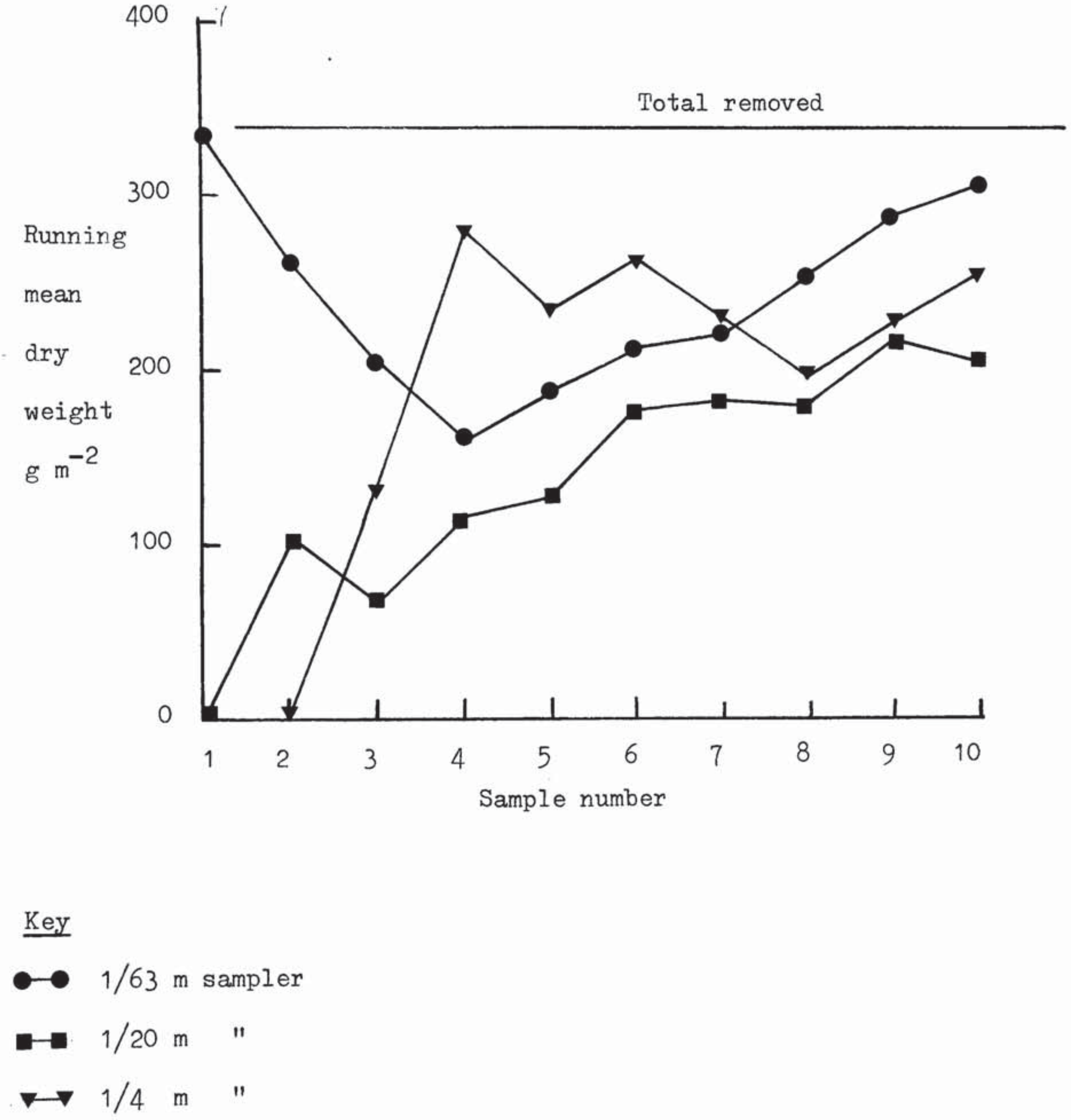
Sample no.	Sample weights, (g dry weight per sample) for quadrate sizes m^2			
	1/63	1/20	1/4	1[1]
1	5.3	0	0	0
2	3.2	10.3	0	0
3	1.5	0	99.0	0
4	0	13.0	181.5	0
5	5.0	8.8	11.0	0
6	5.9	21.5	107.0	0
7	3.6	10.5	0	0
8	8.6	8.5	0	0
9	8.6	26.5	114	0
10	7.5	4.3	121	0
11	4.0	9.3	48.0	0
12		20.5	68.5	625
13			90.0	1023
14			148	1001

Total stream area[2]	1/63	1/20	1/4	
Mean g	4.92 ± 2.08	10.34 ± 6.06	63.35 ± 49	
Mean $g\ m^{-2}$	310 ± 131	207 ± 121	253 ± 196	
Plant area[3]	1/63	1/20	1/4	1[1]
Mean g	5.32 ± 1.67	13.3 ± 4.37	98.8 ± 39.2	883 ± (1400)
Mean $g\ m^{-2}$	347 ± 105	266 ± 87	395 ± 157	
Cover % [4]				
	90	80	60	5
Mean x cover $g\ m^{-2}$	312	212	237	
Damage caused by sampling				
Mean g	24 ± 11	28 ± 10	138 ± 110	570
Mean $g\ m^{-1}$ across stream[5]	170	128	276	570

Note.

1. - only three possible samples
2. - 1 st ten sample sites, with or without plant present.
3. - 1 st.ten sample sites with plant present.
4. - based on the presence of plant in quadrat-sizes areas.
5. - width of quadrat across stream.

Fig. 4.5.1. Quadrat size determination, running mean of sample weights for three sizes of sample.



only taken from plant areas and corrected with a factor for plant cover. This proved unsatisfactory, large samples were destructive to the system, for example, one sample could remove up to 5% of the standing crop per month.

The initial results of the quadrat size determination were used to determine the number of samples required where the probability is 0.05 (Snedacor and Cochran 1967, P.58) (Table 4.5.2.). The number of samples indicated was high especially for the larger areas: the one meter quadrat was ignored. The estimate of sample number is proportional to the variance but the latter increases only with disproportionate increases in sample variations and may decrease with more samples being taken. This variance was investigated on two areas of 100 m^2, each of which was divided into two and from which ten samples were taken; the results of each pair were later combined to provide two sets of twenty samples. (Table 4.5.3.). In the first group of samples (section 1 and 2), in an area of very low standing crop, that had been previously cleared, the samples necessary were about the number taken. However, for the more typical sections of stream, (section 3 and 4), ten samples were insufficient, when the probability was 0.05, fourteen times that taken, were required. When the two sites were combined the same number of samples were still necessary. This area was 4% of the total sample area and, if sampling damage is included, about 8%. This was considered too much for monthly sampling; one sample only was

Table 4.5.2.

Quadrat size and sample number for a 10 m stratum (50 m^2).

Quadrat size m^2	$^1/_{63}$	$^1/_{20}$	$^1/_4$	1
Samples necessary[1] (for P = 0.05)	136	558	(5868)	(4534)
Proportion of total sample area	0.05	0.54	(30)	(90)
Sample area m^2	2.16	27.9	(1467)	(4534)

Table 4.5.3.

Determination of sample variability and number necessary ($P = 0.05$) for material collected with a $^{1}/_{63}$ m^2 sampler.

12 February 1969.

Sample no.	Sample weight (g dry weight) for section no. 1	2	3	4
1	0.46	0.15	7.43	0.55
2	0.23	0.14	4.10	2.37
3	0	0.58	0	0.25
4	0.01	0.12	2.35	0.58
5	0.15	0.62	1.62	4.45
6	0.36	0	4.68	5.33
7	0.45	0.02	2.12	0
8	0.15	0.18	2.28	0.77
9	0.02	0.29	0.32	3.26
10	0.39	0.01	3.44	5.48
11	0.16	0.35	0.54	6.99

Plant area.

	1	2	3	4
Mean g	0.22 ± 0.13	0.21 ± 0.16	2.83 ± 1.57	2.60 ± 1.52
Mean g m^{-2}	14.0 ± 8.2	13.3 ± 10.1	179 ± 99	164 ± 95
Sample number necessary	12	19	136	138

15

130

taken from each 29 strata monthly, even though this meant a much increased range of confidence intervals and therefore, ingeneral, significant changes from one month to the next were not expected to be detected (Table 4.5.4.). However, a definite trend was established through the mean values.. The system was not subject to violent fluctuations during the growing season, such as loss, only to redistribution of the biomass and to leaf - fall from the plants.

Analysis was not undertaken to prove that the strata were better than unstratified samples.

The individual estimates were combined from the equal strata and analysed assuming a normal distribution of samples. The number of samples obtained at any particular sampling time were insufficient to establish the samples distribution; a histogram of individual sample weights from a total stream area determination during 1969, showed a Poisson type distribution for low standing crops which tends to normal, if gravel and very high plant accumulation areas are excluded (those over 800 $^{-}$2 gm m^{-2}).(Fig.4.5.2.). Table 4.5.4. shows a comparison between means and their confidence limits and means calculated for weeded areas only and their limits but corrected for bare gravel.

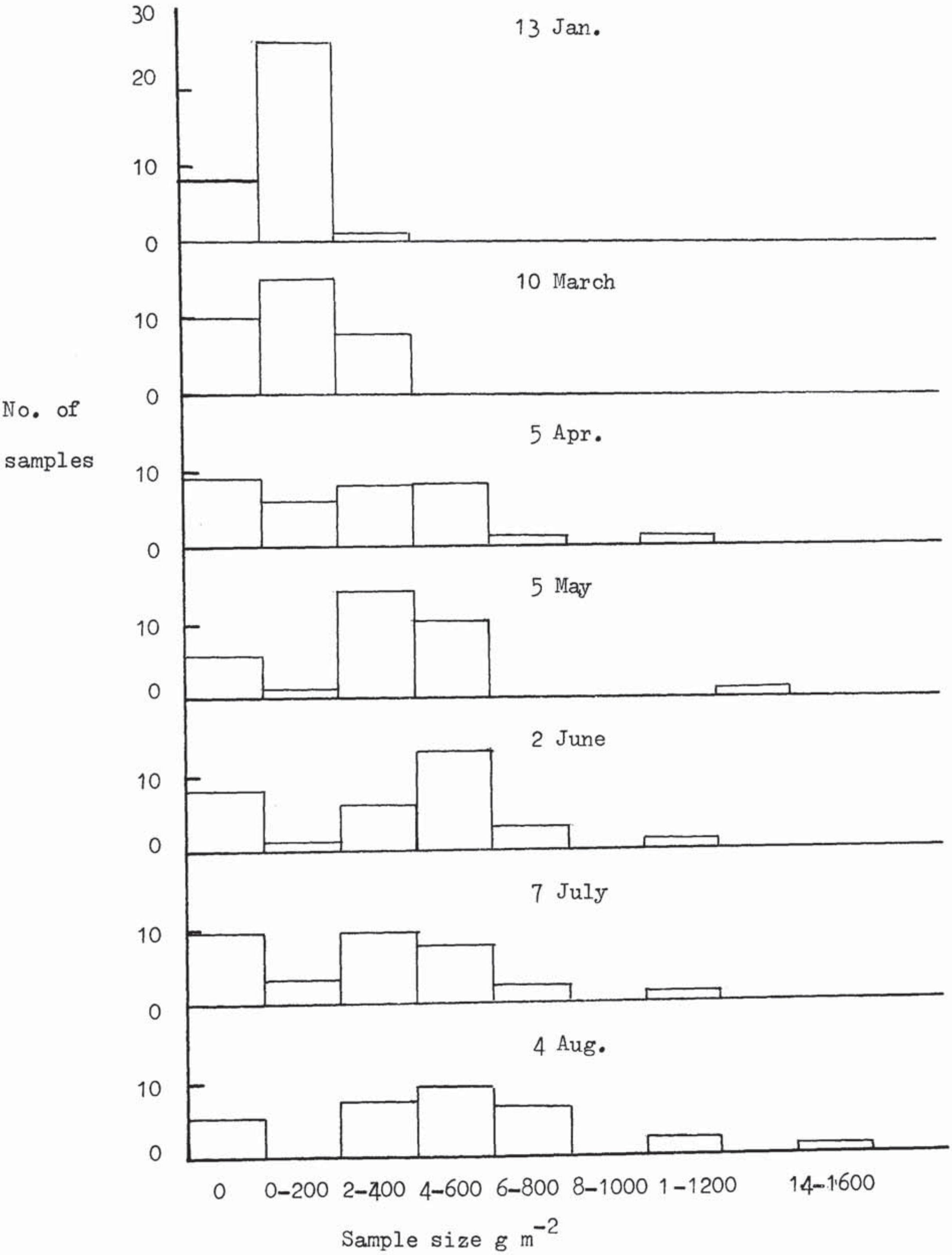
The plant cover was determined by considering the presence or absence of plant in 10 quadrat sized areas for each sample area or strata. In the sample area, section D, there were 29 such strata, producing 290 estimates for the cover. The values for each strata were not used to correct the standing crop estimates individually but as a total (Table 4.5.4.). This correction had little effect, because the bare gravel areas offset the high values but with these removed the variance was still quite high. These high values are found particularly during the decline in growth phase because pieces of plant break off and collect on downstream plants and locally increase the standing crop. If many more samples could have been obtained from the system, an analysis to remove this 'harmonic' could have been attempted.

Table 4.5.4.

Standing crop and cover of R. calcareus at section D, of Bere Stream, Holly Bush (P = 0.05).

	Plant area	Cover	Cover x plant area	Total stream area	Confidence limit for plant area only
	$g\ m^{-2}$	%	$g\ m^{-2}$	$g\ m^{-2}$	
1968					
June 20		0			
1969					
Jan. 13		30		47 ± 12	
Mar. 10	178 ± 41	58	103	138 ± 52	53
Apr. 9	382 ± 76	72.4	277	279 ± 97	98
May. 5	378 ± 89	72.1	273	356 ± 97	94
June 2	473 ± 71	73.8	349	382 ± 100	73
July 7	411 ± 103	78	321	353 ± 117	119
Aug. 4		81.7		367 ± 144	149
Sept. 3		0		272 ± 21	
Oct.				0	
Nov.				2	
Dec. 15		12		5.9	
1970					
Feb. 2		27		10.4	
Apr. 20	313 ± 87	56.2	176	190 ± 85	102
June 21	436 ± 105	88.5	386	323 ± 96	91
Aug. 3	367 ± 68	76.6	281	257 ± 89	87
Sept.		1		0	
Oct.		1		5	
Nov. 16		12		12	
1971					
Jan. 13	139 ± 39	52.1	73	88 ± 37	36
Mar. 8	155 ± 31	67.2	104	101 ± 38	37
Apr. 20	209 ± 33	88.3	186	183 ± 41	35
May 18	256 ± 40	90.0	230	217 ± 50	43
Aug. 2	223 ± 54	86.6	193	145 ± 53	56
Sept.		0		1	
Oct.		1		1	
Nov.		1		2	
Dec. 17		5		4	
1972					
Jan. 12		10		5	
Feb. 9		15		7	
Mar. 10		30.2		29 ± 11	
Apr. 4		53		130	
May 22	279 ± 43	73.6	205	203 ± 54	45
July 18	238 ± 61	71	169	182 ± 55	

Fig. 4.5.2. Histogram of individual samples for standing crop determination using 1/63 m sampler for section D Holly Bush, 1969.



In the main study area, estimates without removal of weed were not used, except as part of the modified standing crop estimates. Attempts using measurements of optical density of the weed '<u>in situ</u>' were unsuccessful. The positioning of the probe within root areas was too difficult due to density of weed and also the agitation and suspension of the silt.

Attempts were made at serial photographs along the stream using a cable operated camera on a gimbal, suspended between two poles held by two operators. The method was not used extensively, the difficulties of estimating areas were similar to other area estimates. In spring the plants were seen developing, the cover however, developed much faster, changing by 70% in 3 months and continuing at this near total cover for 3 months until washed out in the autumn. Area estimates from photographs or maps, or even of regular grids were very time consuming, the estimates only as good as the majority or all of the determinations. Line transects across the stream were considered but analysis of results is difficult except by several repeats offset by random distances from the first. Estimates improve with the number of transects taken but they took much more time. Several variations were attempted; firstly, estimates of cover less or greater than fifty per cent of 25 cm squares, twenty hours for the study area; secondly, a presence or absence record every 25 cm across transects 25 cm apart, 16 hours; thirdly, estimates every one meter along one meter transects, 8 hours. The error increased with each method but the final estimate using ten points from each strata (as previously described) were still sufficient during development of the population to show monthly variations. (Table 4.5.4.). The cover during the decline in growth phase was reasonably constant and only a very sensitive method would have detected the increase in variance due to redistribution of crop.

4.5. (1b). Method selected for stream.

The standing crop, excluding roots buried in the gravel, of the study section D was determined using quadrat samples taken randomly from equal sampling stratifications or divisions along the stream; the strata were marked with posts. (section 1 - 34 , 29 after introduction of screens).

The quadrat sampler was a cylinder of cross-sectional area 1/63 m^2 and 2/3 m long. A bar could be inserted through the upper end for ease of handling and removed during collection of the samples. The lower, sharpened, end of the corer was thrust rapidly downwards over the sampling site cutting the plants before striking the stream bed. The total number of samples available was calculated for the 5 m strata as 1 600, assuming total plant cover. Two pairs of random numbers were selected from tables and used as rectangular co-ordinates to position the corer in each stratum; each random number unit being taken as 0.1 m (e.g. 01 = 0.1 m and 20 = 2.0 m). Values above that needed at a site were discarded and a subsequent set selected. The definition of a sample was at least three stems in the quadrat area, approximately 2 g m^{-2}. Live material collected on the top of plant clumps was also included as this was considered part of the standing crop.

Plant cover determination was combined with that of standing crop. Ten pairs of co-ordinates were used and the presence or absence of plant in a quadrat sized area, recorded. The first co-ordinate was the site of the standing crop sample above. The determination of plant cover combined with standing crop determinations of plant areas only, provided another estimate of plant biomass in the study section. Therefore, if plant material was absent from the sample site as above, a quadrat sample was taken from the first of the other nine sites to have plant material present.

After coring, the plant material tended to float to the surface and was removed; the bar was inserted to the stream bed and used to dislodge any further material. The samples were put into polythene bags and sealed. They were stored overnight at 5 °C if necessary. Normally, samples were washed in cold water and all the material retained by a 2 mm sieve, excluding stones and other debris accidently collected, was dried at 105 °C for 24 h. The material was placed on paper trays in an oven (Unitherm oven, manufactured by S. and T. Engineering Co. Ltd.,Birmingham.) The samples were cooled in polythene bags and weighed rapidly on a 100 g torsion balance (manufactured by The Torsion Balance Co. Ltd., (Great Britain)). All dried material was ground in a shear mill (Casella) using a 1 mm mesh; three sub-samples of about 1 - 2 g were taken by pouring the powder evenly in an arc across the mouths of vials and the tray, until no powder was left in the collection jar. This was to ensure that heavier particles, settling during grinding were properly represented in sub-samples.

Two sub-samples were ashed, complete, at 525 - 550 °C overnight in a muffle furnace, taking the normal precautions especially the initial burning-off of the sample. The samples were gently heated with a Bunsen burner until smouldering. The third sample was analysed for carbon and nitrogen. (Hewlett Packard, F. and M. Scientific C, H and N. analyser 185)

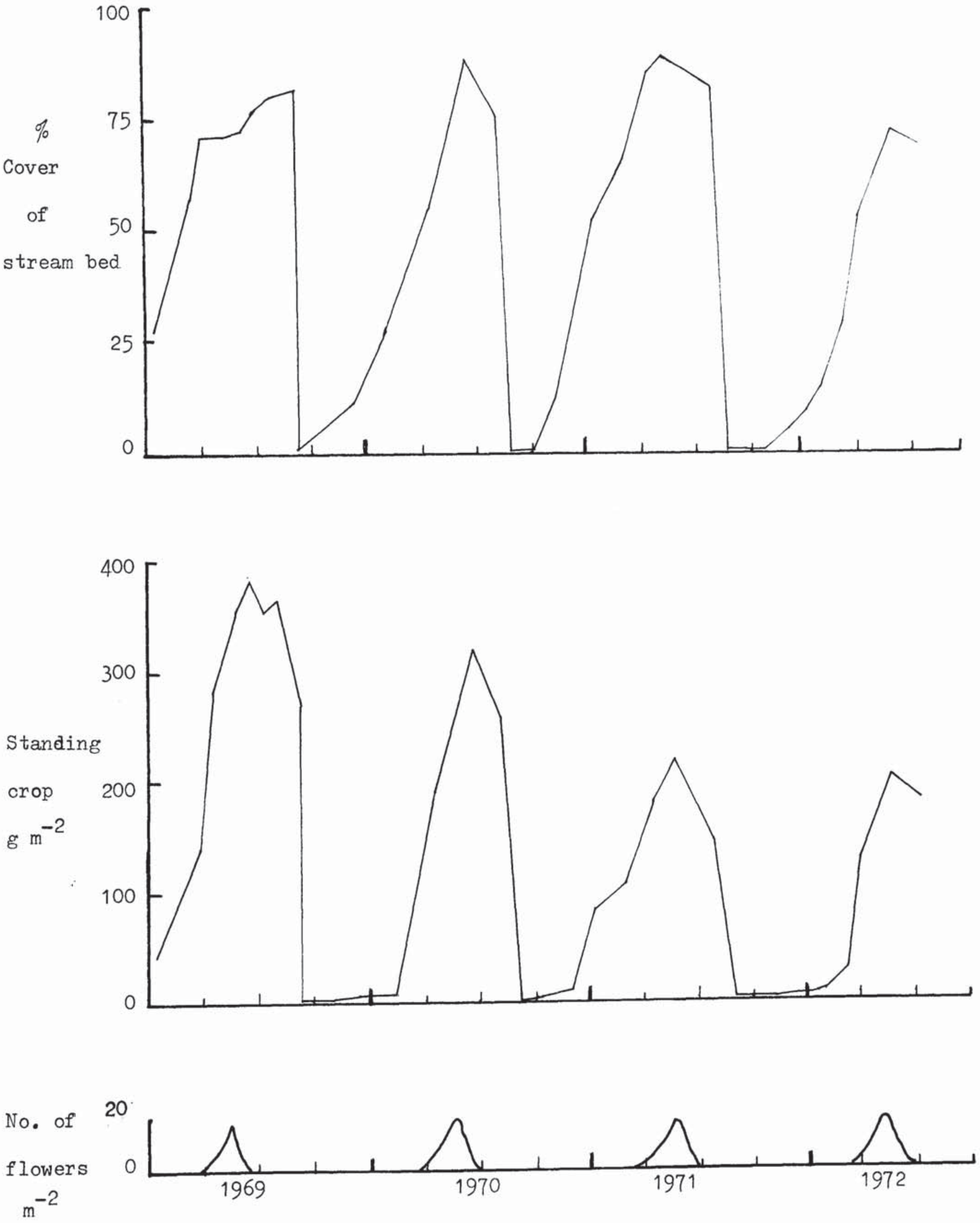
Occasional assistance was undertaken by several people in carrying samples from the site. Mr. P. Henville and Miss. F. Ashcroft were responsible for a third of the ash weight results.

4.5. (1c). Results and discussion.

The growth season starts in the autumn as the plants begin to regrow following the washout period (Fig. 4.5.3.). Growth is rapid if good flow conditions prevail because the higher and faster the flow, the shorter the time spring water has to cool down to ambient before passing the study site, especially in winter.

There are four phases of development, the regrowth phase already

Fig. 4.5.3. Seasonal changes in standing crop (g dry weight m^{-2}) and cover (%).



mentioned, the extension phase in early spring followed by the consolidation and flowering phase, before the decline phase of late summer. The second, the expansion phase is characterised by a rapid increase in cover of the stream surface usually by long stems trailing downstream. A logarithmic growth rate occurs during this and the late establishment phase but ceases towards the end of March (Fig. 4.5.4.). During the consolidation phase there is little further increase in surface cover of the stream bed but the standing crop continues to rise for a time. Flowering and seed production reduces the apparent growth rate as reproductive material is shed during this phase. The flower stems especially, as previously discussed, are very brittle and are soon broken; they collect in slacker areas of water and are washed out in vast quantities when the autumn rainy period starts.

The maximum standing crops declined over the four years of the study period from 382 ± 100 g dry weight m^{-2} in 1969 to 203 ± 54 g dry weight m^{-2} in 1972 (Fig. 4.5.3.). These standing crop determinations were based on quadrat samples from the total stream area using the $1/63\ m^2$ sampler. A significant difference between values of plant crop per stream area and the cover corrected plant-only areas was observed, especially at the end of the growth cycle. (Student's T-test for paired observations, Snedacor and Cochran 1967 P.59) (Table 4.5.5.). This difference was due to plants tending to drift downstream and be caught on other plant clumps, leaving clear areas and causing difficulty in sampling this extremely contagious plant distribution. The sample number was not increased as minimal damage was necessary during the study on leaf-fall and stem loss from these plants in section D.

In June 1968, Mr. Westlake removed the entire crop, including the emergent species from section D, of the stream at Holly Bush, and found 380 gm m^{-2} of Ranunculus spp. (Table 4.5.5.). This cutting before the end of the normal seasonal growth pattern may well have promoted

Fig. 4.5.4. Seasonal changes in standing crop of Ranunculus calcareus.

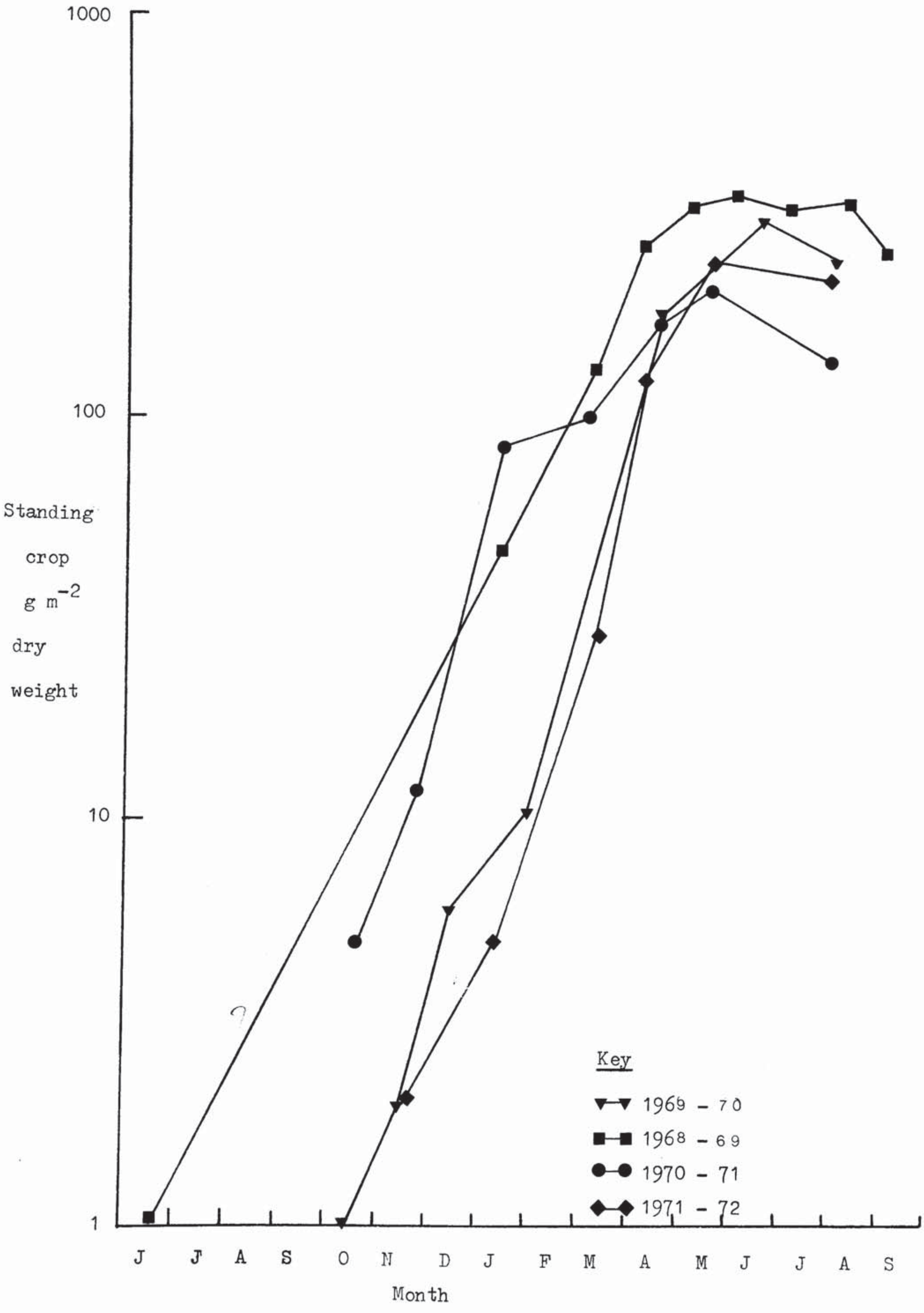


Table 4.5.5.

Standing crop of macrophytes in June 1968. Upper Bere Stream.
(data supplied by Mr. Westlake, of the River Laboratory.)

	Fresh weight.	
	Total kg	Unit area. kg m^{-2}
Ranunculus spp.	2 239	3.7
Rorippa spp.	1 863	3.1
Apium spp.	1 711	2.8
Oenanthe spp.	129	0.2
Veronica spp.	26	0.1
Epilobium spp.	1	
Indeterminate	100	0.2
	6.069	10.1

growth in the autumn resulting in a higher standing crop in 1969. The crop in 1969 was removed in late August and early September, at the end of the seasonal cycle to check on sample procedure and estimates, but was not removed in subsequent years. (Table 4.5.4.).

Marginal emergent plants were removed at monthly intervals; however, from June 1969 they were allowed to grow and reached 452 ± 59 g m^{-2} by early September, which was a little lower than 590 g m^{-2} for 1968. (Table 4.5.5 & 6.). The growth rate was 7 g day^{-1} which is half that of a commercial cress bed for a similar period (Crisp 1970) and reaching a maximum similar to that at a site 3 km away. (Westlake *et al* 1972).

The carbon and nitrogen contents of the standing crops show a similar pattern for all four seasons, though only two were studied in detail. The carbon to nitrogen ratio rose slowly from 10 - 12 : 1 in winter to a maximum of 13 - 15 : 1 in mid summer, falling slightly in late summer before washout. The ash free percentage of carbon and of nitrogen fell

Table 4.5.6.

Standing crop of Rorrippa nasturtium-aquaticum in Upper Bere Stream.

Date	Weight[1] g dry weight m^{-2}	Comments.
1968		
June 20	306	Total removal
1969		
July 7	43	
August 4	174 ± 159	
September 3	452 ± 59	Total removal

Note.

1. - Confidence limit, $P = 0.05$.

slowly as the year progressed. (Appendix 4. Table 1.)

The ash content of the standing crop samples did not vary much and no seasonal trends were evident.

The standing crop results are compared with the determinations from the River Frome, in the general discussion.

4.5. (2). Method selected for river.

One and five meter wide belt transects were used to estimate the standing crop of the River Frome. Initially the upstream edge of the transect line was marked using a heavy link chain lying across the weed, but later a nylon cord was stretched across ten cm above the water level, as a reference, on the upstream and downstream edges of the transect. The weed was collected and put into strengthened plastic linen baskets and weighed, to 0.1 kg, after five minutes draining (the field weight). About 10% of these samples were immediately sealed in polythene bags and returned to the laboratory. A commercial spin-dryer was used to reduce the adhering water to a standard value; five minutes spinning was sufficient. Small sub-samples were dried at 105 °C; correction factors were applied to change the wet field weights to dry weight.

suit
A wet/was worn and a snorkle or S.C.U.B.A. equipment as necessary. Mr. H. Leatham , assisted in collection of material.

Sample sites were selected on a random stratified basis, one a mile for the first survey, 1969, and one every 200 m in the second survey, 1970. Sample times were limited by fishing seasons and permission from riparian owners.

Results and discussion.

The standing crop of the River Frome was determined between Dorchester and East Stoke by one meter wide transects, before (18) and after (11) the river board removed some of the weed for flood relief control. Standing crop determinations ranged from 30 g m^{-2} in deep water to 480 g m^{-2} in shallow water. (Table 4.5.7.). The correlation of mean depth on weight per square meter was highly significant, within the depth range 0.55 - 2.75 m. The mean for the standing crop of the river between Dorchester and East Stoke before the weed cut, was 202 ± 70 g dry weight m^{-2} for the reduced area sampled after the weed cut. These figures agree well with Owens and Edwards (1960, 1961 and 1962.) for the River Ivel, a chalk stream. Westlake(1968), obtained an estimate of the summer standing crop of the River Frome by utilising the weed cutting operations of the local river board; he reported a removal of weed equivalent to 130 - 260 g dry weight m^{-2} for the summers of 1967 and 1968.

The effect of the weed cutting operations on the reduced area from Wool to East Stoke, was a reduction to 53 ± 22 g m^{-2}; this was not a significant decrease. (Table 4.5.7.). However, a significant regression of material removed, to material present was obtained and indicated a 62% removal of the crop by the river board. (Fig. 4.5.5 and Table 4.5.7.).

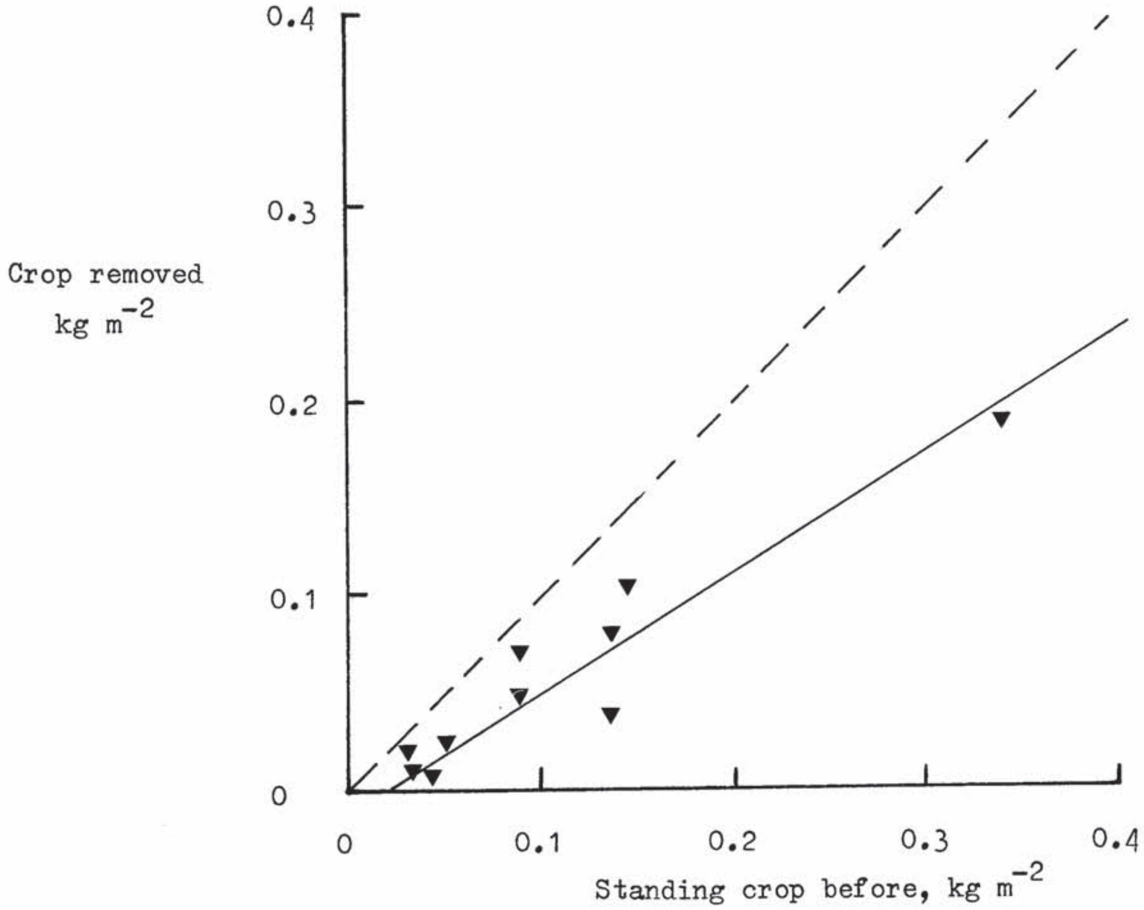
In the 1970 survey a much restricted area was studied near the River Laboratory at East Stoke, in an attempt to explain local variation. A series of five meter wide transects were sampled in mid-April, mid-August

Table 4.5.7.

Standing crop of aquatic macrophytes, mainly R. calcareus, in River Frome before and after river board weed cut, July and September 1969.

	Location.	Width	Depth	Standing crop dry weight	
	(see Fig.3.3.1.)		July	Before	After
		m	m	kg m^{-2}	kg m^{-2}
1	Bockhampton	7.0	0.45	0.127	
2	"	8.8	0.55	0.305	
3	West Stafford	10.0	0.75	0.482	
4	"	13.4	1.05	0.292	
5	Woodsford	21.3	0.55	0.206	
6	Hurst Bridge	12.8	0.70	0.349	
7	"	12.8	0.70	0.423	
8	Morton	13.6	0.45	0.157	
9	Hyford Bridge	12.8	1.05	0.125	
10	"	12.8	1.05	0.148	
11	Wool	11.2	1.05	0.148	0.043
12	"	12.0	1.05		0.045
13	"	14.0	2.20	0.023	0.034
14	"	15.0	1.20		0.046
15	Bindon Abbey	14.0	1.25	0.049	0.025
16	" "	13.1	0.85	0.086	0.018
17	" "	13.2	0.85		0.036
18	East Stoke	17.4	0.75	0.343	0.153
19	" "	9.8	0.70	0.134	0.097
20	" "	9.7	0.75		0.057
21	" "	9.2	2.75	0.035	0.027
	Mean(all).			0.202 ± 0.07	
	Mean (11 - 21)			0.117 ± 0.099	0.053 ± 0.022

Fig. 4.5.5. The standing crop of aquatic macrophytes in the River Frome before and after a river authority weed cut, July and Sept. 1969.



Key

— 62% removal

– – 100% removal

and late October from three types of area, those normally shallow (less than 1 m), those always deep (deeper than 1.5 m) and those between (1-1.5m) (Table 4.5.8.). The standing crop in April was half that of the previous summer; this was reasonable considering the seasonal growth pattern. A similar pattern to the previous year of decrease in standing crop to increase in depth, was obtained. The remaining two sample periods produced inconclusive results because two weed cuts were considered necessary for flood relief control, one in May and the other in August.

The standing crop results are compared with determinations from the Bere Stream at Holly Bush in the general discussion.

Table 4.5.8.

Five meter belt transects of the River Frome at East Stoke.

Station	Mid April 1970				Mid August 1970			Late October 1970		
	Area	Depth	Dry weight g / m^2 Ran	Dry weight g / m^2 Total	Depth	Dry weight g / m^2 Ran	Dry weight g / m^2 Total	Depth	Dry weight g / m^2 Ran	Dry weight g / m^2 Total
1	60	1.9	3.3	6.6	1.5	3.7	37	1.5	3.2	3.5
2	65	0.9	229	235	0.5	25	26	-	-	-
3	70	0.9	-	-	0.6	62	69	0.7	47	47
4	65	0.9	60	60	0.4	38	38	-	-	-
5	55	1.2	64	64	0.9	83	83	-	-	-
6	60	1.4	45	45	1.2	28	28	1.2	19	19
7	65	-	-	-	-	-	-	1.2	63	63
8	70	-	-	-	-	-	-	1.3	85	85

Mean value for wet to spun-dry fresh weight = 78%.

Assumed that dry weight is 10% of fresh spun weight (see survey results for one meter transects on July 9 - 14 1970).

Ran - Ranunculus calcareus

Key to stations.

1 - Below pool at East Stoke flume, with P. perfoliatus, Ceratophyllum and P. pectinatus.

2 - Mid way to fence 200 m below 1, with P. perfoliatus.

3 - Fence 350 m below 1, with Elodea.

4 - 20 m below 3.

5 - 20 m upstream of start of railway enbankment.

6 - 35 m above road bridge.

7 - 80 m downstream of road bridge.

8 - 30 m below concrete seat downstream of 7.

5. LABORATORY EXPERIMENTAL WORK.

5.1. RESPIRATION STUDY.

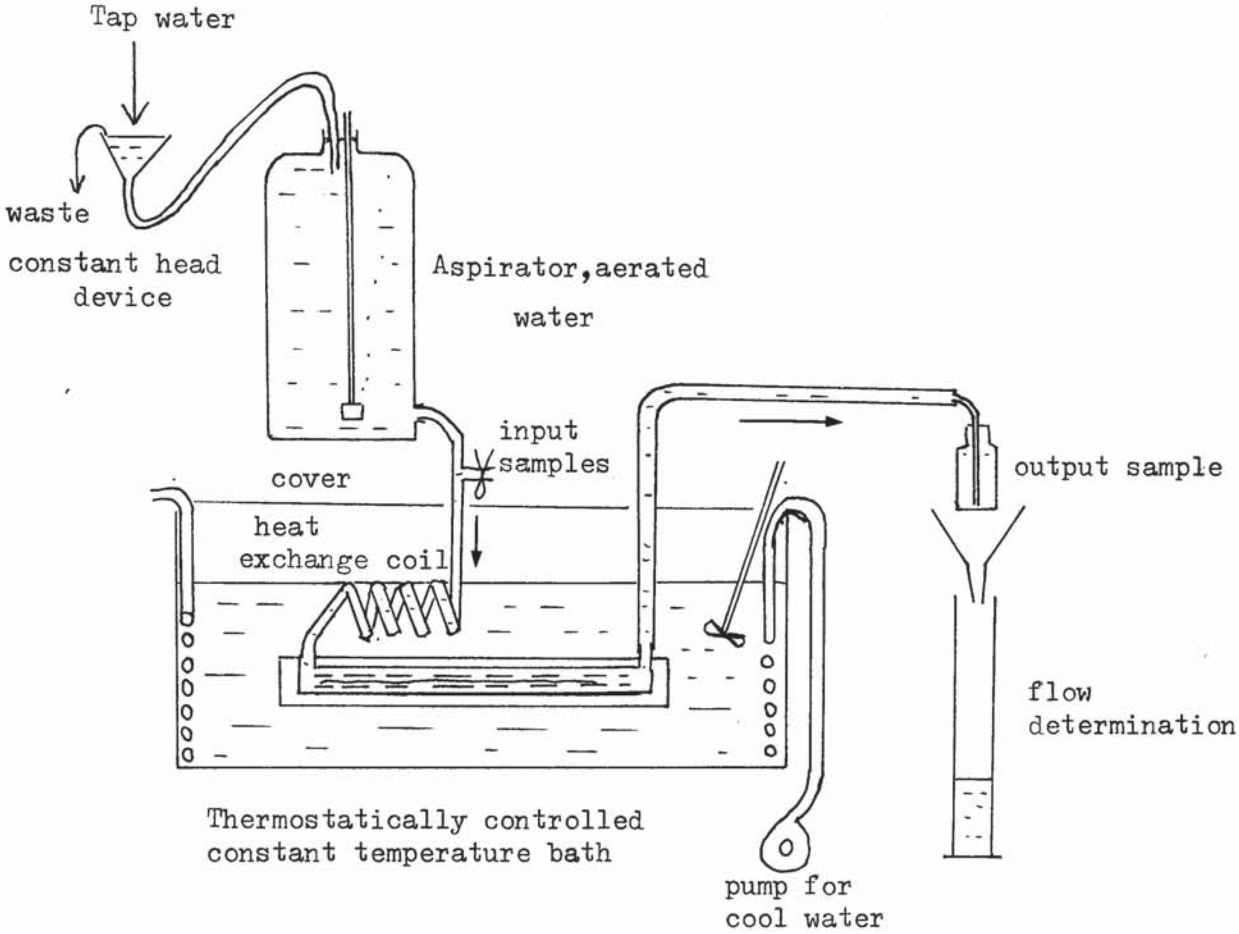
Introduction.

The respiration rate of typical complete shoots of *Ranunculus penicillatus* var. *calcareus* were estimated seasonally using the improved respiration chamber proposed in Westlake (1967). The variations of rate per unit biomass with temperature and in different seasons were to be used together with the measured biomass to determine the part played by plant respiration in the total community respiration. It was to be assumed that the determined dark respiration rate was similar to the total respiration rate in the light. The total community respiration was then to have been obtained by studying the oxygen balance of section D of the stream at Holly Bush.

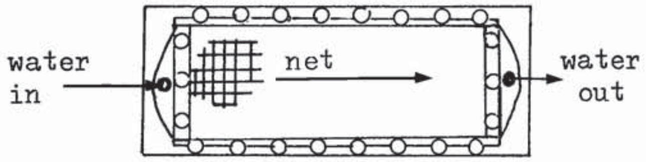
Method.

The respiration apparatus consisted of a flat oblong chamber of internal dimensions 31x17x3.1 cm with a 1.3 cm mesh net held one cm from the internal faces (Fig. 5.1.1.). The net kept plant material spread out and was originally designed to reduce self-shading during photosynthesis experiments, as well as good flow characteristics during respiration experiments. Hard tap water was used; its quality was similar to the stream water at Holly Bush (see chemical section). The water was aerated in a large aspirator fitted with a constant-head device and fed to the chamber through a heat-exchanging coil. The initial temperature of the water was normally near 15 °C thus avoiding supersaturation when cool and the possible release of bubbles in normal experiments (5 - 15 °C). The height of the outlet into the downstream sample bottle, controlled the flow rate, which was normally 100 ml min^{-1}, giving a mean velocity of 0.32 mm sec^{-1} in the chamber. Samples were taken at regular intervals from the inlet and

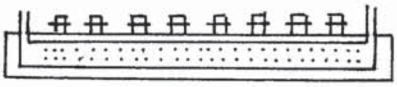
Fig. 5.1.1. Respiration chamber.



Chamber



lid clamped down onto rubber gaskets



outlet water and their oxygen concentrations determined using the Winkler method (Mackereth 1963). Grade A quality glassware and Analar chemicals were used.

Typical complete shoots were collected at random from the upper, middle and lower thirds of the section D, at Holly Bush, on three successive days. They were cut off as near the base as possible, roots, laterals and flowers being included as found. They were returned to the laboratory, and this agitation (for 15 min) was sufficient to remove much of the attached debris and epiphytes. Any remaining were carefully washed off. At the height of the growing season one shoot was sufficient, at other times however, more than one was used to make the fresh weight up to 30 - 50 g. The cleaned material was put into the chamber and the lid clamped down. After testing for leaks the chamber and heat-exchanger were immersed in the constant temperature bath in the dark. The plants were equilibrated for 1½ - 2 h to utilise any internal oxygen produced as a result of prior photosynthesis. Flow rates were constantly measured using a large measuring cylinder and funnel beneath the outlet bottle. The temperature of the outlet water was within 0.05 °C of the water-bath temperature. After a run the plant material was removed and dried at 105 °C for 24 h. The chamber was also cleaned and dried in the air.

Results and discussion.

The equilibrium time necessary to reduce any internal oxygen before sampling was determined by monitoring the respiration rate for two days. The temperature was maintained at 10 °C, near the collection temperature of 8.8 °C. The temperature range in the study stream for this week was 7.5 - 10.0 °C. One and a half hours was found necessary to bring the respiration rate to equilibrium. The flow was maintained overnight and an increase of 4.5% was recorded the following morning, probably due to bacterial build-up. A later experiment showed an increase of 9% in 24 hr.

experiments were limited to 12 hr from collection.

The flow rate necessary for efficient determination of oxygen uptake was determined as 100 ml min^{-1} for the normal 5 g dry weight of plant material (Table 5.1.1. and Fig. 5.1.2.); slower flows than this reduced the respiration significantly. Increasing the flow rate gave a decreasing difference between inflow and outflow oxygen concentrations, thus increasing the titration error relatively.

The effect of temperature on the rate of respiration for three typical shoots during March 1971 shows a decreasing rate of change in respiration rate with increasing temperature. (Fig. 5.1.3. and Table 5.1.2.). At the normal mean temperature for the stream at Holly Bush of 10 °C, the slope of the line indicates a Q_{10} of over 2. Above 15 °C the slope of the line indicated a lower Q_{10} more characteristic of a physical process, for example, diffusion, or that the upper limit of temperature tolerance was being approached.

After March, the determinations were limited to the annual temperature range, that is, 5 - 15 °C; increases over this were occasionally observed locally within weed beds during the summer. (see temperature section 4.1.d.).

The respiration rates at differing oxygen concentrations were not investigated. The normal range of oxygen concentration during both experiments and in the Holly Bush stream was normally 80 - 120% oxygen saturated (air) at 5 - 15 °C. Owens and Maris (1964) and Westlake (1967) show an increase in oxygen consumption with an increase in oxygen concentration; the change was 0.5% and 0.7% per change in oxygen concentration around 100% saturation for excised shoots in the above temperature range. A correction factor was applied to the results of the temperature run of 0.5% per 1% (Table 5.1.2.) to correct respiration rates to 100% saturation for the input water.

No bubbles were observed in experiments even when supersaturated

Table 5.1.1.

The effect of flow on respiration and the errors of analysis.

15 and 16 March 1971. 10 °C.

Flow ml min^{-1}	 mm sec^{-1}	Respiration rate. oxygen uptake mg g^{-1} h^{-1}	Titration difference ml	Oxygen, % saturation (air) in input water
	March 15th			
210	0.67	1.17 ± 0.17	0.42 ± 0.06	98
150	0.48	1.10 ± 0.12	0.54 ± 0.06	97
100	0.32	1.10 ± 0.07	0.81 ± 0.05	97
48	0.16	0.80 ± 0.04	1.17 ± 0.06	98
	March 16th			
100	0.32	1.20 0.04	0.88 0.03	98

Notes.

1. - Confidence intervals, P = 0.05

Table 5.1.2.

Effect of temperature on respiration.

16 March. Flow rate 0.32 mm s^{-1}

Temperature °C	Respiration rate. oxygen uptake mg g^{-1} h^{-1}	Oxygen % saturation of input water	Respiration rate corrected to 100% saturation rate[1]. oxygen uptake mg g^{-1} h^{-1}
5	0.57 ± 0.08	86	0.61
10	1.20 ± 0.05	98	1.21
15	1.63 ± 0.10	108	1.57
20	2.04 ± 0.08	118	1.87
25	2.52 ± 0.12	130	2.19
Run 4 March 18			
5	0.55 ± 0.02	85	0.59
15	1.97 ± 0.20	108	1.89
25	2.59 - 0.16	126	2.16

Note

1. - see text, and section 2.1.
2. - Confidence limits, P = 0.05.

Fig. 5.1.2. & 3.

Fig. 5.1.2. The effect of velocity on respiration rate, March 1970 Run 3 a.

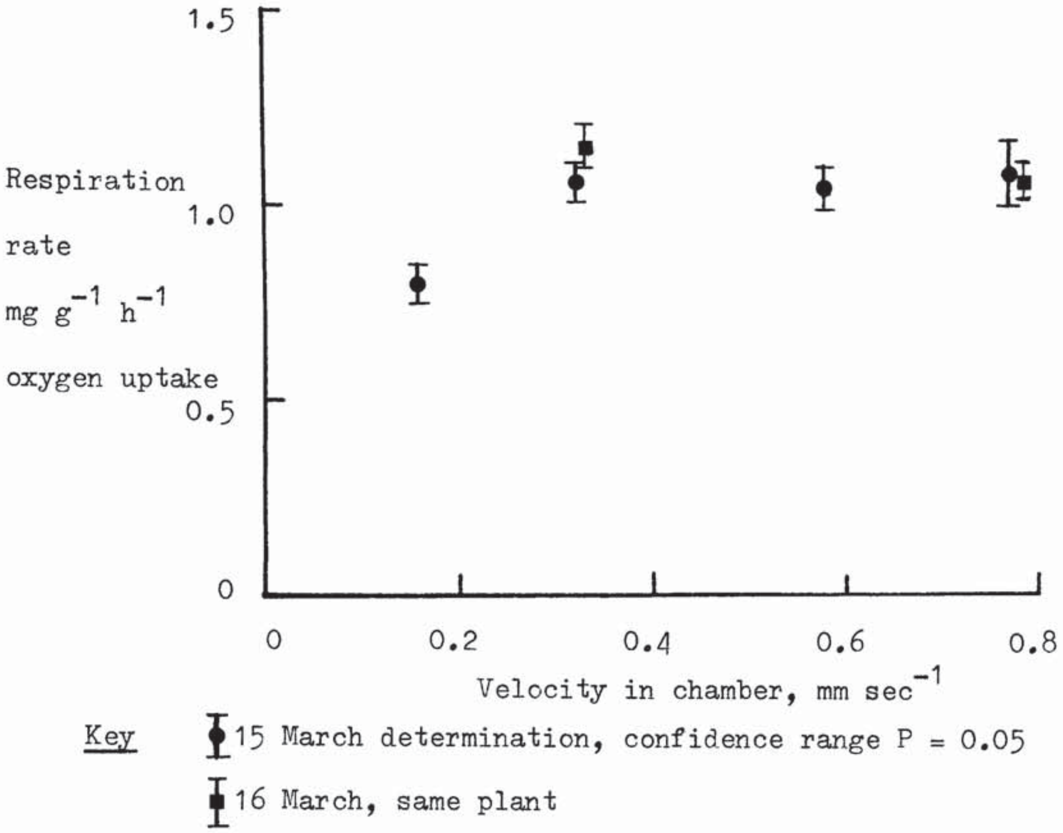
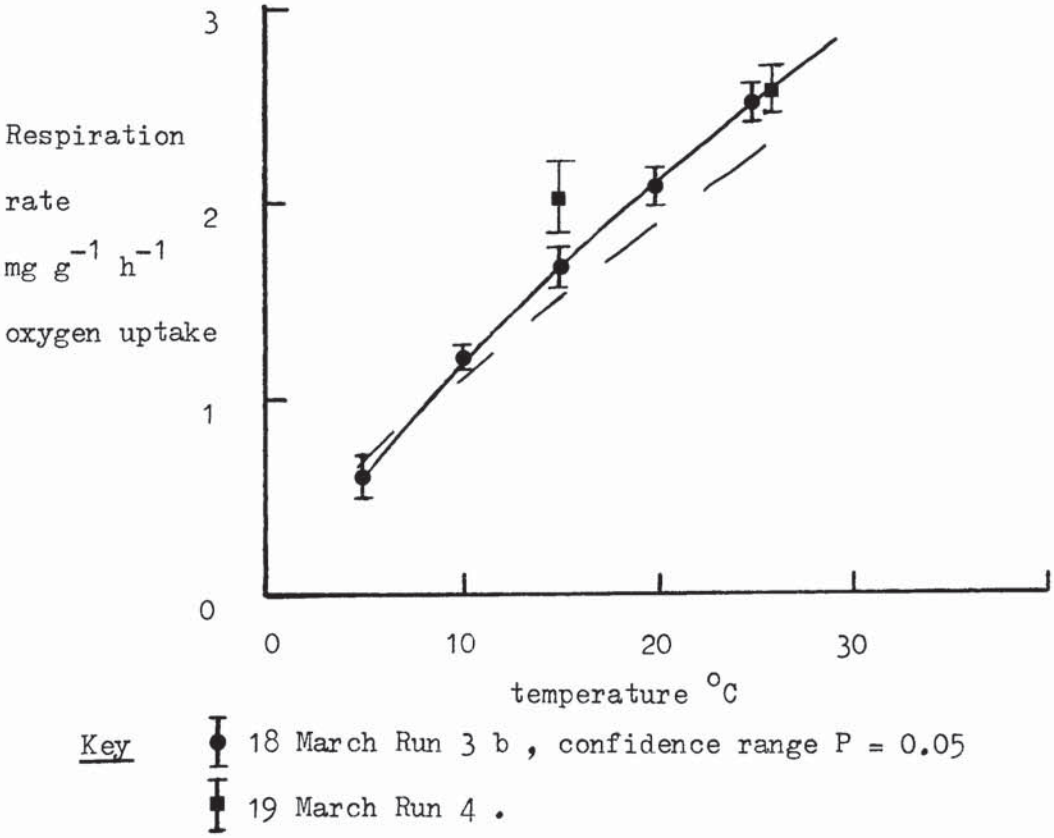


Fig. 5.1.3. The effect of temperature on respiration rate March 1970 Run 3b and 4



Respiration rate corrected to 100% saturation (air).

water was passed through the respiration chamber, that is, at 25 °C determinations (Table 5.1.2.).

A typical run repeated seasonally on three consecutive days consisted of;

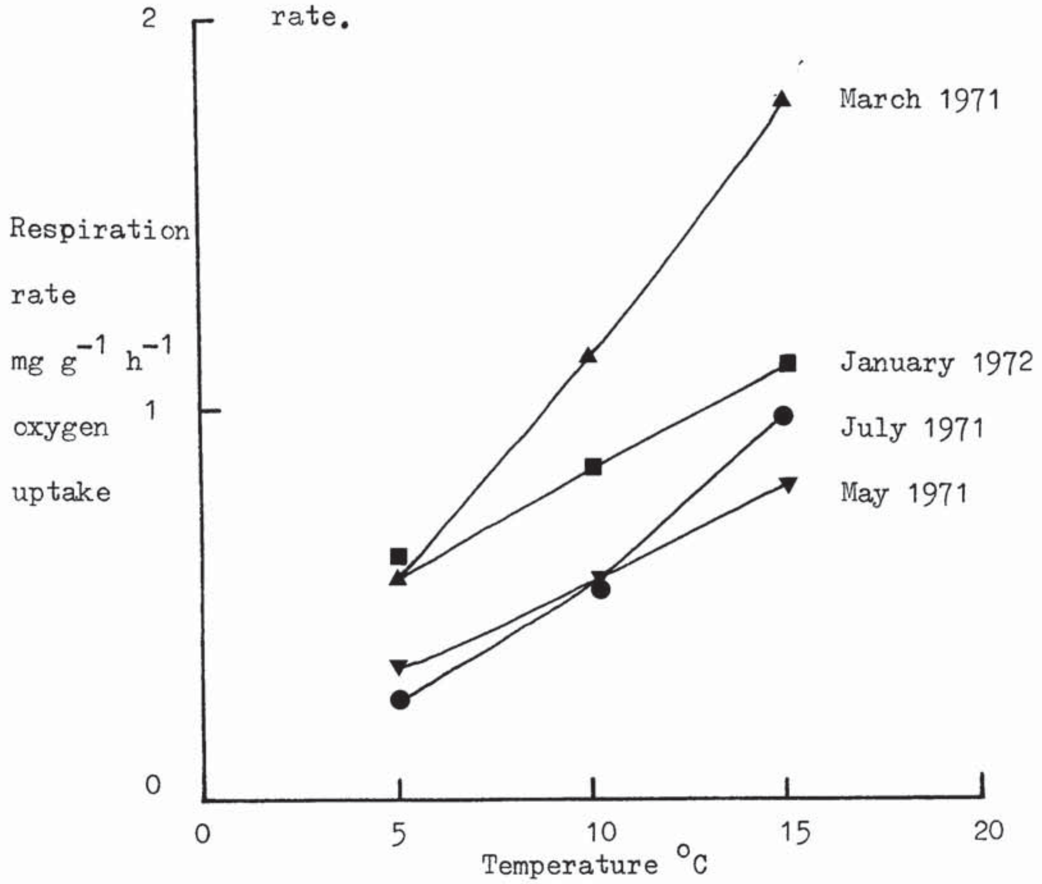
Two hour equilibration at 5 °C, sampled until stable (½h)
One h " " 10 °C " " " (1 h)
" " " " 15 °C " " " "
" " " " 5 °C " " " "

The seasonal effect of temperature on the rate of respiration was studied, on samples from the three sub-areas of section D. There was a considerable decrease after the period of maximum growth rate ending in March until July. In this period erratic individual results were an effect of a mixed population, some plants dying off and starting to wash away, while others were still growing or regrowing. The respiration rate during the winter period was 0.87 mg oxygen uptake $g^{-1}\ h^{-1}$ at 10 °C, increasing to 1.1 mg oxygen uptake $g^{-1}\ h^{-1}$ at 10 °C during the spring (Fig. 5.1.4. a and b. and Table 5.1.3.).

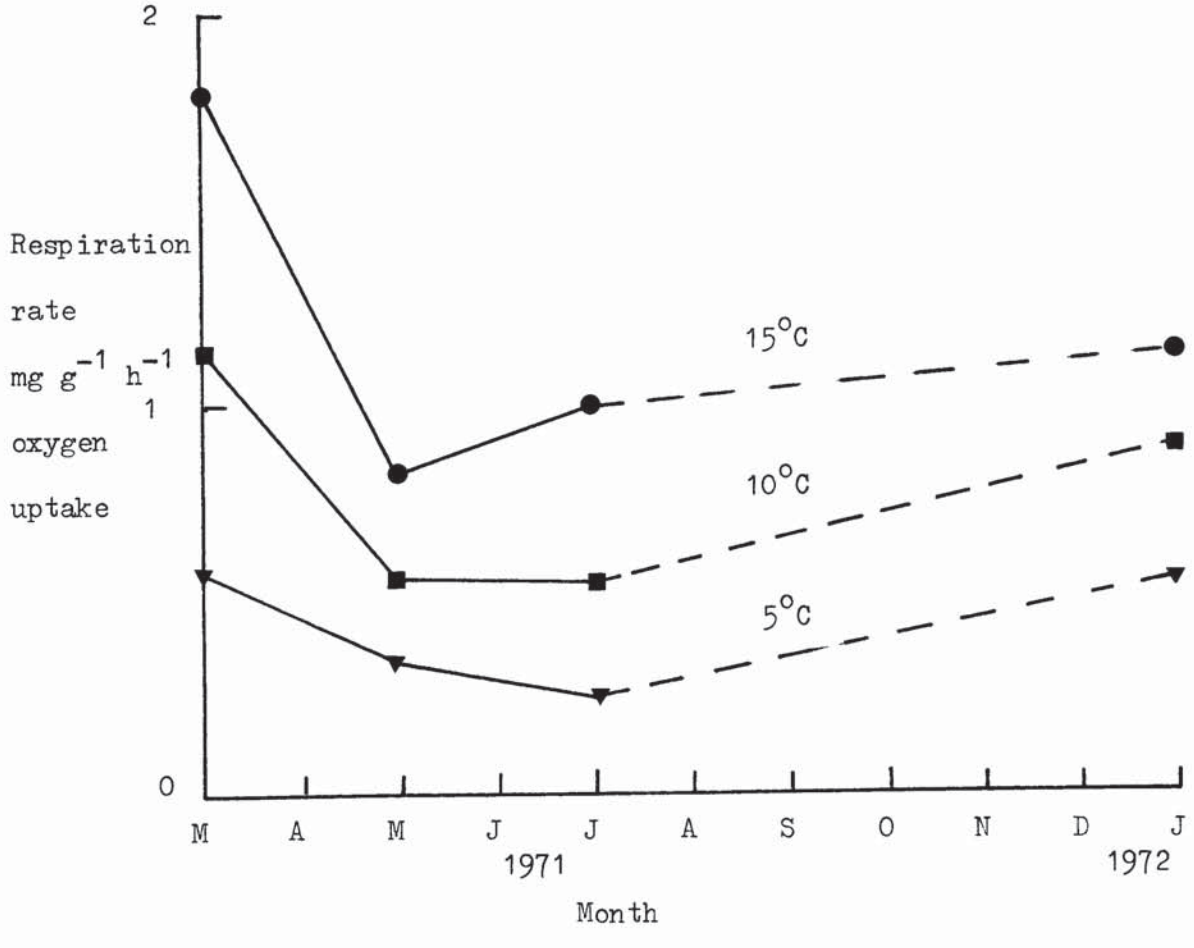
The values from the three sub-areas were averaged as the measurements represented typical plants from the sub-sections of stream; weighting of results was not considered necessary as the standing crops were equivalent within sections.

Loose shoots were not included in respiration samples but were included in standing crop estimates. Two estimates of shoot loss were made (see section on standing crops) one of 12% up to June, the time of maximum standing crop, of material from the plants and one of 7% for material lost from the section. The shoots lost in the early part of the growing season were fresh and apparently viable, forming only a small proportion of the population. These shoots probably have a similar respiration rate to the intact shoots. The greatest losses occur during summer before the

Fig. 5.1.4. (a) Seasonal differences in effect of temperature on respiration rate.



(b) seasonal changes in respiration rate at three temperatures.



plant material is washed out in the first autumn rains. The July estimates of respiration were very low for poor moribund plants but where regrowth was taking place an increased respiration rates were found. A representative mean value at this time shows little change compared to the May estimate.

In order to help prediction of this fraction of the community respiration results, the mean plant respiration was calculated from the standing crop, mean monthly temperature and respiration rate at that temperature. (Table 5.1.4.).

Table 5.1.4.

Predicted plant respiration rate of the stream.

Date	Standing crop	Mean monthly temperature	Respiration rate oxygen uptake			Discharge	Predicted oxygen change in stream
			Unit plant	Unit area	Total area		
	g dry weight m^{-2}	^{o}C	mg g^{-1} h^{-1}	mg h^{-1} m^{-2}	mg h^{-1} $area^{-1}$	$m^{3}sec^{-1}$	mg l^{-1} h^{-1}
1971							
Mar.	110	9.2	1.07	118	88.5	0.3	0.082
May	180	11.5	0.65	117	87.8	0.15	0.163
July	200	12.4	0.70	140	105	0.1	0.292
1972							
Jan.	10	8.2	0.82	8.2	6.2	0.11	0.017

Table 5.1.3.

Seasonal changes in respiration rate. 5 - 15 °C.

mg g^{-1} h^{-1}

Date	Run no.		Respiration rate in mg oxygen uptake g^{-1} h^{-1} at temperature °C.			
			5°C	10 °C	15 °C	Other
1971						
March	1			1.11		
	3 a			1.1		
	3 b		0.57	1.2	1.63	
	4		0.55		1.97	
		Mean	0.56	1.14	1.80	
May	5		0.33	0.57	0.89	8 °C 0.43
	6		0.31	0.51	0.77	7.5 °C 0.42
						12.5 °C 0.69
	7		0.37	0.57	0.77	
		Mean	0.34	0.55	0.81	
July	8		0.10	0.17	0.66	
	9		0.32	0.72	1.23	25 °C 2.07
	10		0.35	0.73	1.09	
		Mean	0.26	0.54	0.99	
1972						
Jan.	11		0.58	0.87	1.12	
	12		0.54	0.86	1.13	
		Mean	0.56	0.87	1.13	

6. SUPPLEMENTARY STUDIES ON FLOWERING.

Introduction.

Flowering was observed to start at different times at different sites. Examination of these plants showed they had a similar morphology of stem, leaf and flower and on these characters keyed out to *R. penicillatus* var. *calcareus*. It was seen that at the main study site, Holly Bush, the start of flowering coincided with a decline in growth rate, followed by a decline in the standing crop of the plant. (see section 4.5 fig.4.5.4.) It was therefore thought possible that flowering could be affecting the extent to which the standing crops could grow at different sites and hence their importance as nuisances might be influenced by factors affecting flowering.

Salisbury (1963) lists about 240 species of plants for which the photoperiodic response has been determined and he assigned them to some 48 combinations of quantity and duration of light and temperature, necessary for flower initiation. Temperature and length of photoperiod were considered the factors upon which to start the investigation, though it was realised that they may not be the prime initiators in this case.

The hypotheses considered to explain the start of flowering, were based on the observations that from year to year there was little change in flowering time at specific sites, where the temperature regimes were obviously different. Minimum temperatures were considered, but at two sites which were spring fed the water temperature was almost the same in winter and summer, and was certainly not as low as has been required for stimulation of land plants. The sites were within 20 km of each other and therefore day-length differences were not considered important.
The first hypothesis -

(1) suggests that, after initiation, a cumulative temperature

effect, as degree-days, was operating and it was assumed that growth only occured above a basal threshold temperature e.g. 5°C.

An alternative hypothesis -

(2) proposes that a certain minimum time, in days, above a basal threshold temperature was necessary for flowering.

The effect of temperature on flowering time was investigated over a range of temperature regimes.

Transplant experiments were also undertaken, to grow plants which flowered at different times, from different sites, together under the same temperature regime.

The length of photoperiod was investigated in three flowing-water growth chambers. The water for these chambers was taken from the river and the temperature and nutrient concentration were common to the three light regimes. Artificial 'natural' light was used, the red to far-red ratio of which was similar to daylight. The influence of this ratio on the phytochrome system, photomorphogenesis and flowering, has been reviewed recently by Smith (1970).

6. 1. Methods.

Field Observations.

Survey of temperatures and times of flowering of R. calcareus in the River Piddle.

The main study site and seven other sites on the River Piddle were chosen,from the source to the upper tidal limit. These sites were chosen as places which were as comparable as possible, having beds of gravel with flint and being fairly shallow with rapid flows. (see section 3.3 for details of sites).

Maximum and minimum thermometers (Sixes) were anchored in the main flow inside perforated plastic tubes, securely attached to stakes. Before use, the calibration of the thermometers was checked at the upper and lower limits of the expected range.

During the survey the maximum and minimum positions of the riders were recorded and the mean of the temperature of the water at the time of sampling was found using both mercury columns on this thermometer, without removal from the water. The water temperature was also recorded to 0.1 °C using a calibrated 0 - 50 °C thermometer and compared with the mercury reading of the site thermometer. A correction factor was applied to the site thermometers if there was a constant difference of greater than 0.5 °C. The thermometers were reset weekly during the winter, spring and up to the time of opening of the first flower, and then fortnightly or monthly during the remainder of the year. The time of opening of the first flower was recorded; the value of this observation will be discussed in detail later.

Generally three samples of main axis of the plants in the locality of the thermometers were taken weekly during the spring, up until flowering time. These apical regions were examined under the microscope and the size of each flower bud measured. Flower buds were easily distinguished from leaf buds as they were spherical and compact, when compared with the more diffuse nature of the leaf buds. The size of buds in the first year and for some of the second, were measured by myself, but the measurements of the remainder in the second year were undertaken by Miss N. Bisset.

The numbers of flowers and lengths of time for which the flowers were open, were determined during 1970. The number of open flowers were counted weekly in area D. Small plastic rings (see section 3) were used to label the petioles of about 30 flowers which were just opening, on three occasions from early April, to late May. The marked flowers were observed every two days until petal fall. Samples of flowers were dried and weighed during the flowering season.

Laboratory Studies.

A plant from Holly Bush was split into three and grown in aluminium mesh baskets for two years at Holly Bush before being moved to growth chambers in April 1971. The growth chambers were constructed by placing three lighting hoods over a channel 5m. long, 60 cm wide and 25 cm deep, through which river water flowed. The hoods were light tight; each chamber was separated by a transverse weir rising from the bottom, either side of which was a flap of roofing felt supported from a shelf-like top about 20 cm away from the weir. (Fig 6.1.1.) These flaps prevented light passing between the boxes. A system of artificial 'natural' daylight, designed by D.F. Westlake of the River Laboratory, was used. It attempts to match the spectral energy distribution of daylight, as found by Henderson and Hodgkiss (1963), Tarrant (1968) and Westlake (pers. comm.) Each system was controlled by a time clock and contained 23 fluorescent tubes and 50 incandescent bulbs combined to give the following ratios of imput wattages, spread over the channel area :-

24 w of Colour-matching, Osram, fluorescent tubes
18 w of blue, Atlas Blue,
4 w of Actinic, Philips 05,
25 w of Tungsten, Philips tubular, or Mazda pygmy bulbs.

The spectral energy distribution of this combination was measured every two months using a recording spectroradiometer (manufactured by ISCO of Lincon, Nebraska, U.S.A.). Three continuous records were made, to show the general changes, after which specific wavelengths were checked. The ratio for the near-red (660 nm) to far-red (730 nm) light, was maintained between 1.25 and 1.5 : 1 by renewal of bulbs and tubes as the output per bulb decreased or failed (Carpenter et al 1960, 1964, 1965 and 1967). Cumming (1963) gives the ratio of red to far-red as 1.3 : 1 for daylight in the open. Spence et al (1971) have shown a greater absorption of the far-red than of the near-red in water, as the depth increases.

Fig. 6.1.1.

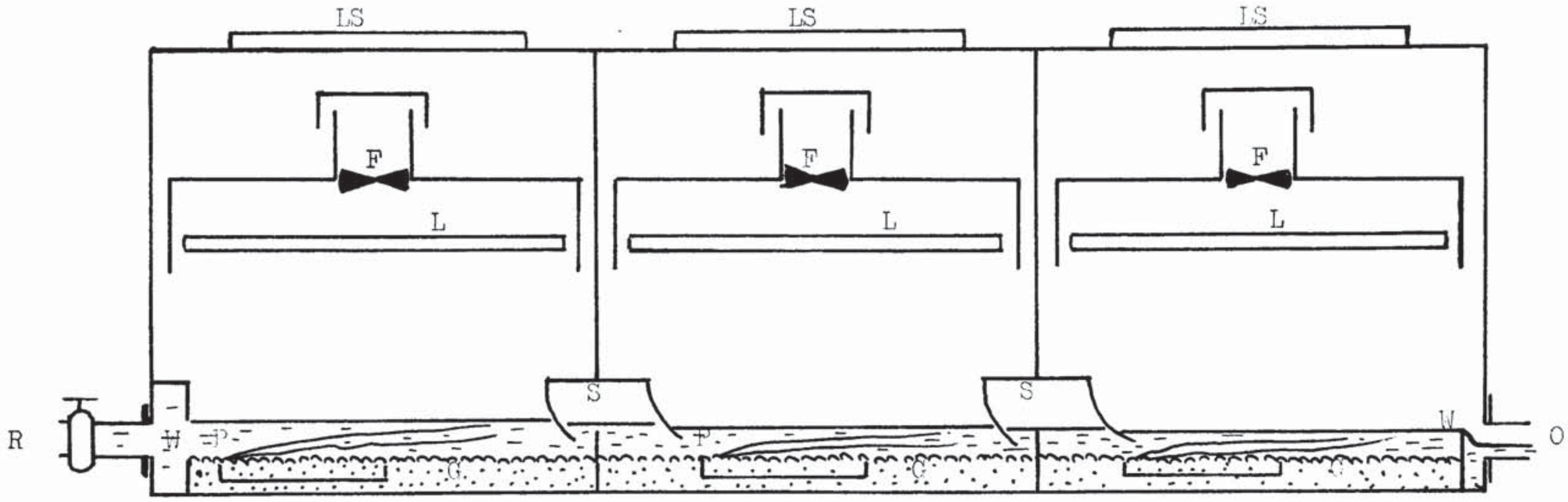


Fig. 6.1.1. Flowing water growth chambers.(Vertical section)

Key

R	River water inlet and valve
P	Plants , rooted in gravel in aluminium tray
G	Gravel
W	Weirs to control flow and water depth
O	water outlet to waste
L	Light system (see text)
S	Shelf supporting felt light deflectors
F	Fan to keep lights cool
LS	Lighting switch gear

The ratio changed from about 1.5 : 1 in the surface layer (0 cm) to about 4.5 : 1 at 1 m. This change in favour of near-red light would normally promote biological reaction, including flowering. (Smith 1970).

About half of the spectroradiometer recordings were undertaken by Mr. P. Henville.

Plants were also transplanted from the sites on the River Piddle to the main channels of the fluvarium at the River Laboratory in autumn 1971. (see section 3 for site descriptions and map). The fluvarium is a flowing water aquarium in which there are two channels, each 6 m long and 1.4 m wide and deep. (LeCren 1971). The bed of these channels was lined with 20 cm of gravel similar to that of the river bed. It was attempted to maintain the two channels at two typical river velocities, 25 cm sec^{-1} and 50 cm sec^{-1}. The plants were grown under the natural river temperature regime of East Stoke.

Plants were also transplanted from Holly Bush to outdoor channels at East Stoke in 1969. These channels were 20 m long and 1 m wide and fed with river water from a 12.5 cm pipe. The flow rate was not constant because the water from the downstream end ran back to the river some distance further downstream and this return channel was liable to flooding by backing-up.

6. 1. Results and Discussion.

Field Observations.

During the years 1969 - 73 the flowering of R. calcareus was recorded for a number of areas on the River Piddle. The results are presented in Table 6.1.1. and expressed graphically in fig. 6.1.2.

Table 6.1.1.

The times of start of flowering.

Site (in order downstream)	1969	1970	1971	1972	1973
Piddletrenthide		15 May	14 May	2 May	
Puddletown		8 April	5 March	21-28 March	
Waterston				28 March	16 March
Athelhampton		10 May	30 April	18-24 April	
Throop		27 April	16 April	11-17 April	
Holly Bush	11-17 March	22 March	15 March	19 March	23 March
Bere Heath	14 April	3 May	16 April	20-27 April	
Trigon Farm		22 May	30 April	20-27 April	
Wareham		18 May	14 May		

The development of the flowers followed a distinct sequence e.g. this sequence, from Athelhampton in 1970, is a typical example ;-

16 March.	Enlarged and swollen stems float to the surface.
13 April.	First flower buds swelling, shoot apices turning pink.
20 April.	Second flower buds swelling, apex pink and tassel-like bent at an angle to the flow.
27 April.	Petiole elongating, second flower bud expanding.
4 May.	First petiole above the surface, second extending.
10 May.	First flower open.

Many more flowers opened soon after this first flower; the majority of these were the first flowers on the main stems. (Table 6.1.2.). These flowers were followed by many others, some from later buds on the main axis and others from the lateral stems.

During the six weeks after the first flower opened, a very rapid increase in the numbers of flowers occured. At the Holly Bush site, section D, the maximum of 15 000 flowers was reached after 7 weeks. (Table 6.1.2.)

Fig. 6.1.2. The times of start of flowering at sites on the River Piddle for *R. calcareus*, 1969 - 1973.

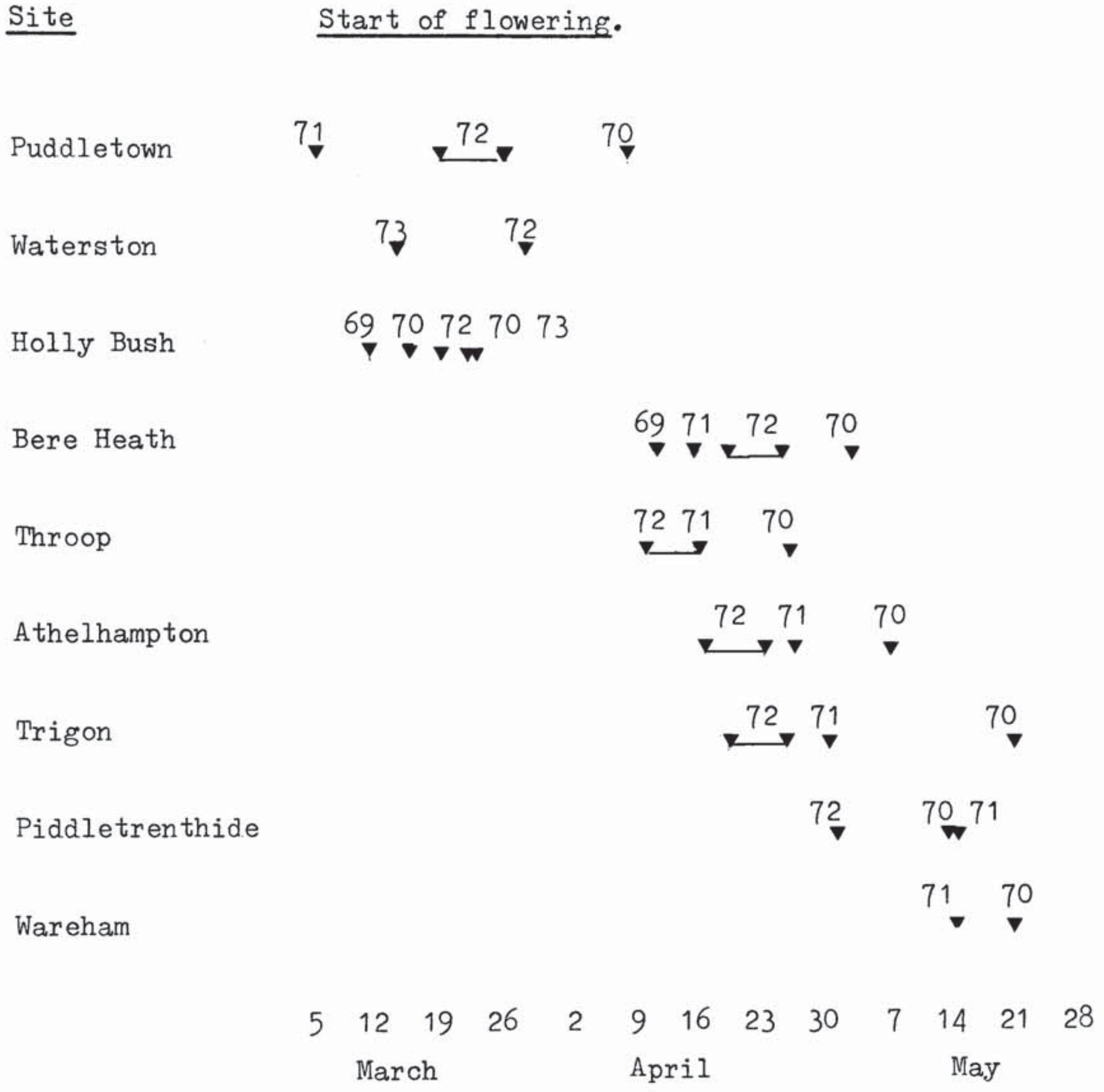
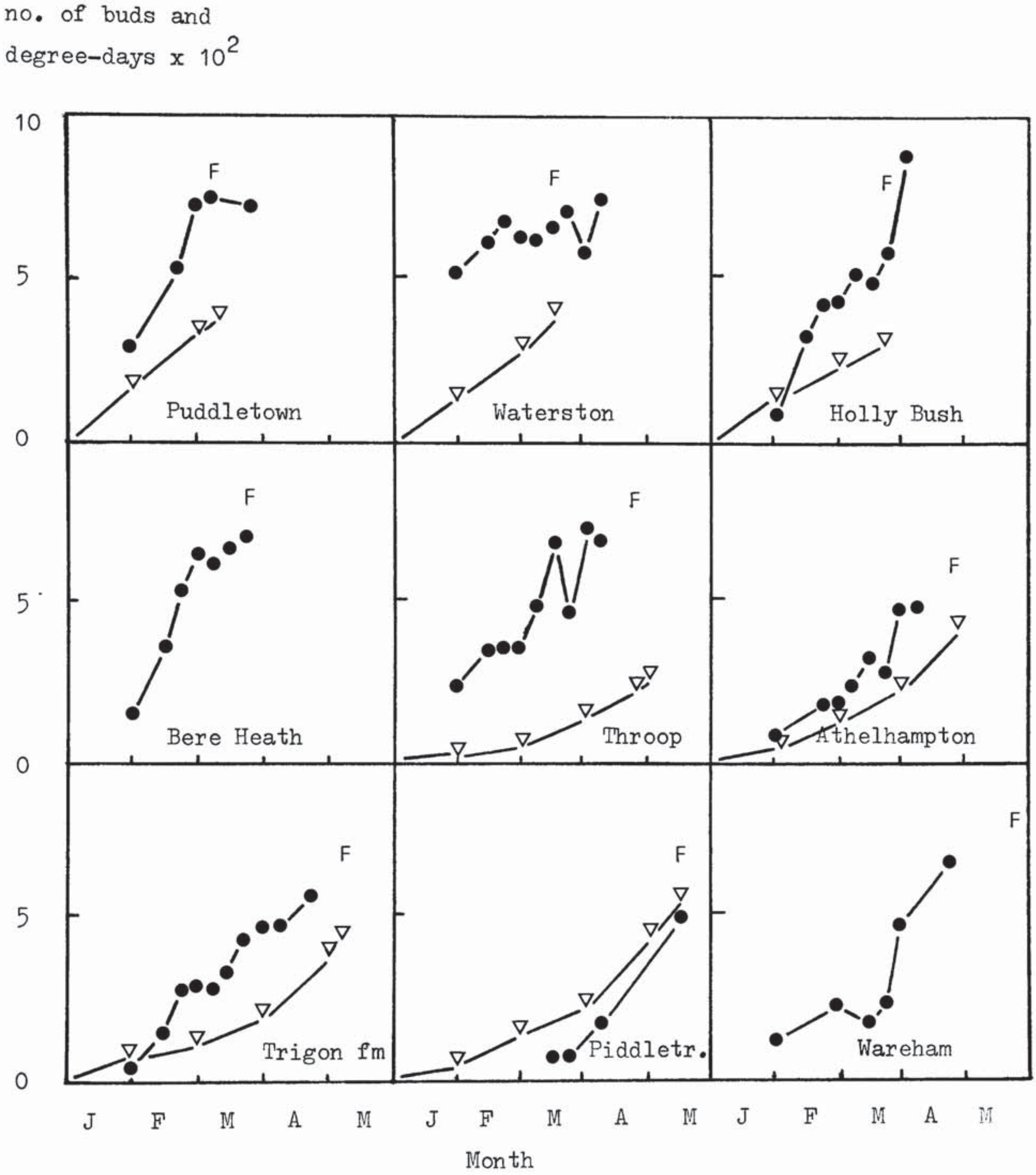


Fig. 6.1.3. Seasonal changes in the number of flower buds per apex and the number of degree-days above 5°C for the sites on the River Piddle.



Key

● Mean number of buds per apex

▽ Cumulative degree-days above 5°C

F First flower

At this time there were about 20 flowers per square meter. The labelling study showed that the life of flowers was about seven days from the time of opening of the petals until petal-fall was complete. (Table 6.1.3.)

Table 6.1.2.

The seasonal change in numbers of flowers at Holly Bush (section D).

Date.	March			April				May				June	
	15	22	31	6	13	20	27	4	11	18	26	1	8
Nos. of flowers.	0	1	16	50	170	750	1800	8000	15000	8100	1600	700	0

Table 6.1.3.

Length of time flowers were open until petal-fall at Holly Bush 1970.

Date		6 th April	4 th May	18 th May
No. of flowers labelled		20	35	30
Petal- fall completed on	2 nd day	0	1	2
	4 th day	1	2	2
	6 th day	4	9	3
	8 th day	5	9	6
	10 th day	2	0	2
No. of labels lost		8	14	15

The total number of flowers produced at the Holly Bush site of 700 m^2 was therefore about 36 000. The mean weight of these was 26 mg dry wt (13 April 27 mg, 4 May 24.5 mg and 26.5 mg 18 May). The total weight of flowers produced was about 940 g, that is, 1.3 g m^{-2} or 0.5% of the maximum standing crop. The weight of reproductive structures did not account for changes after petal-fall, that is, during the maturation of the achenes. The number of achenes is low and variable per inflorescence because the plants are probably infertile hybrids.

The time of opening of the first flower was used as a basis of comparison for the different sites investigated, because it signalled the start of the flowering sequence. During 1972, the sites were only visited monthly and the previous data on flowering pattern and flower numbers was used to calculate the first day of flowering.

The time of opening of the first flower each year at a particular site was very similar, generally within a fortnight, in the years studied. (Table 6.1.1. and fig 6.1.2.) The site at Puddletown was three weeks later relative to the other sites in 1970, than in the following two years, this was because of winter weed removal operations; all the shoots being removed and little regrowth took place. The results however, show that there was an appreciable difference in the time of flowering at different sites.

In an attempt to determine the initiation time of flower buds, the seasonal change in the numbers of flower buds (including primordia) per apex was determined for nine sites in 1971 at weekly intervals. The numbers of flower primordia were difficult to count below 0.2 mm and this accounts for the erratic nature of some of the results.

This study also allowed the assessment of the rate of development of flowers (Table 6.1.4.). Buds are initiated and differentiate growing to about 0.4 mm in diameter, before the peduncle rapidly elongates to bear the open flower. The total number of buds in any apex was 6 - 9, by the time the first flower opened on that stem, having been initiated at a rate of about one per two weeks depending on the site as indicated by the slopes of the lines in graphs (fig 6.1.3.). This continuum of initiation balancing the development and change to open flowers, finally produces a constant number of buds in any apex.

Table 6.1.4.

The seasonal change in flower bud size
in apices from plants at Holly Bush 1971.

Date	No. of buds examined	Mean number of buds Diameter of bud mm (0)-0.49	0.5-0.99	1.0-1.49	1.5-1.99	2	Total
29 Jan.	2	1	0	0	0	0	1
12 Feb.	2	1.5	1	0.5	0.5		3.5
19	4	2.3	0.8	0.5	1		4.5
26	2	2.5	0	1	1		4.5
5 Mar.	3	3	0.7	0.7	0.7	0.3	5.4
12	2	3	0.5	0.5	0.5	0.5	5.0
19	3	2	1.3	0.7	0.7	2	6.7
Flowering							
26	2	4	1.0	1.5	1	1.5	9.0*

* two flowers present but not included.

In general the sites examined indicate a start of flower bud initiation in January, if the plot of numbers of flower buds per apex against time, is extrapolated back to zero buds. (Table 6.1.5. and dotted lines in Fig. 6.1.3.). The development of flower buds was well advanced at Waterston and Puddletown when the study started, whereas it was very late at Piddletrenthide.

The flowering time was early in the year, mid-March, at the two spring source sites, Waterston and Holly Bush; it was also early at Puddletown, a site close to Waterston, when the weed was not removed during the winter. The sites at Athelhampton, Bere Heath and Throop were large stream sites some distance from the source, these flowered in mid-April. The two sites, Wareham and Trigon Farm, downstream on the main river flowered generally in May. The latter site was unusual, because the plants had been transplanted from the main River Frome near Wool, several years previously, but had never really increased in area subsequently. (Edwards, pers. comm.) The plants flowered in May at about the same time as their site of origin.

Table 6.1.5.

Seasonal changes in the mean number of flower buds per apex.

1971

Date	1 Puddletown	2 Waterston	3 Holly Bush	4 Bere Heath	5 Throop	6 Athelhampton	7 Trigon	8 Piddletrenthide	9 Wareham
29 Jan.	3	5.3	1.0	1.7	2.3	1	0.5	-	1.5
5 Feb.	-	-	-	-	-	-	-	-	-
12	-	6.3	3.5	3.7	3.7	-	1.5	-	-
19	5.5	7.0	4.5	5.6	3.7	2	3	-	-
26	7.3	6.5	4.5	6.6	3.7	2	3	-	2.5
5 Mar.	7.6	6.3	5.4	6.3	5.0	2.5	3	1	-
12	-	6.7	5.0	6.7	7.0	3.5	3.5	1	2
19	7.5	7.3	6.7	7.0	4.7	3	4.5	-	2.7
26		6.0	9.0	10.0	7.3	5	5	2	5
2 Apr.		7.5		7	7	5	5	-	-
9				-	-	-	-	-	-
16				-	-	-	6	-	7
23						-	-	-	-
30						-	-	-	-
7 May								5.3	-
14									-

Key :- ———— = first flower open.

Most plants have a certain minimum size which must be reached and before which initiation cannot take place. (Salisbury 1963). Plants as small as 1 m long have flowered at the same time as very large ones of

3 m long. It was apparent that there is probably a minimum size for this plant but at no site was this the apparent cause of the variation in flowering time. i.e. there were often many large plants at sites, where late flowering was common e.g. Trigon.

To test the first hypothesis (1) explaining the development of flowers after initiation, the temperatures for the sites were accumulated as degree-days above 5 °C, that is, the sum for all days of the positive differences between the mean temperature and the basal temperature of 5 °C. Weekly mean values were used for the calculation, that is, each degree above 5 ° C was counted as 7 degree-days, instead of daily values. (Table 6.1.6.). Two starting dates were considered, 1 January and 1 November of the previous year. The earlier date was used because although January was indicated as the start of initiation (fig 6.1.3.), the smallest buds, on which the prediction was made, were over 0.2 mm, and it was possible that they may have been formed as primordia before January. There was a greater scatter between years for the Holly Bush site when degree-days were calculated from 1 November than from 1 January. The remaining sites were little altered.because the waters were in general much colder in winter than the spring-fed sites of Holly Bush and Waterston (four week means, Table 6.1.6.). Daily temperature results were not available for analysis to determine the errors involved in using weekly not daily maxima and minima. Macan (1958) gives the possible error for this difference as up to 1 °C, but notes that over long periods the average was not different. Considering the results which Macan used the range of error this represents is up to about ± 5 - 10%.

Hypothesis (1) is not applicable to the development of flowers because of the wide scatter of results from the expected single value of total degree-days for all the sites. The plot of number of days to flowering from 1 January against degree-days (fig. 6.1. 4) shows an oblique line ranging from low values of degree-days for sites flowering early, that

Table 6.1.6.

Hypothesis (1) The effect of cumulative degree-days on the time of flowering.

Site in order of flowering	Year	No. of days from Jan.1 to flowering	Degree-day above 5 °C until flowering from		Mean of 4 wks.		Frequency of sampling
			1 Nov.	1 Jan.	1st.	last.	
Waterston	1972	87	-	291	23	28	w
	1973	75	400	248	27	22	f
Holly Bush	1969	(73)	596	297	29	28	w
	1970	81	462	304	28	29	w
	1971	74	572	303	25	29	w
	1972	78	501	298	22	33	w
	1973	82	579	335	34	32	w
Bere Heath	1969	104	-	354	20	39	w
	1970	123	476	299	19	38	w
Throop	1971	106	441	245	3	36	w
	1972	(100)	369	268	14	42	m
Athelhampton	1970	131	595	439	11	47	w
	1971	120	690	420	15	41	w
	1972	(110)	530	374	21	42	m
Trigon Farm	1970	142	667	520	8	61	w
	1971	120	610	405	9	53	w
Piddletrenthide	1970	135	458	452	6	56	w
	1971	134	670	512	8	54	w
	1972	122	474	300	5	44	m

Key :-

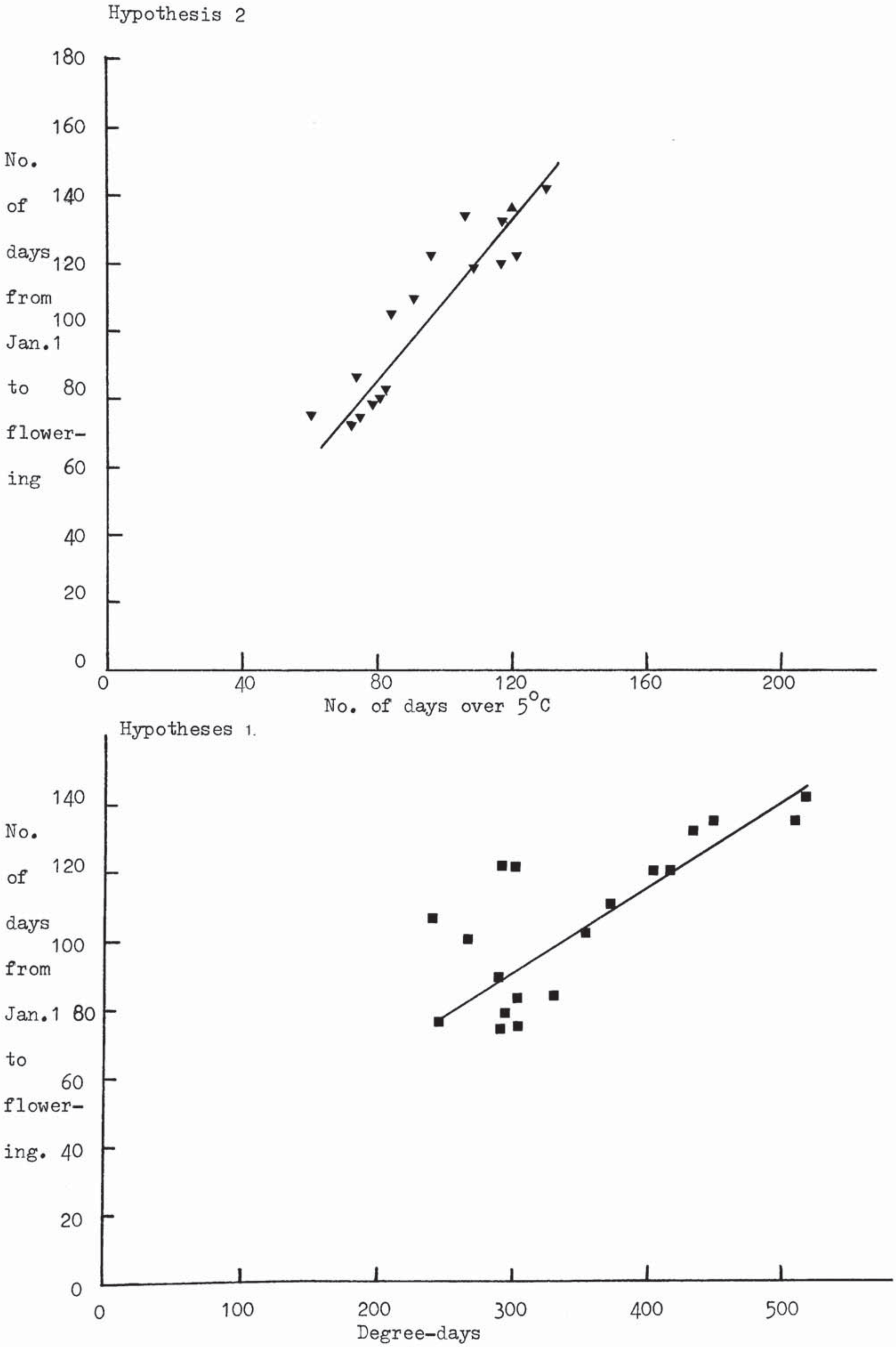
Sampling frequency - w = weekly

m = monthly

f = fortnightly

( ) - approximate value only (see Table 6.1.1.)

Fig. 6.1.4. The hypotheses to explain the development of flowering.



is, near the spring sources, to high values for late flowering sites downstream instead of the expected single vertical line showing similar day-degree totals for all sites. The flowering is independant of the environmental temperature and such a plot reflects the spacial and temporal distribution of water temperatures. The extrapolation of this line towards zero produces a nonsense.

The second hypothesis (2) was tested by examining the temperature results for a possible critical temperature below which flower buds do not develop or continue to develop. The temperature range was split relative to the critical temperature and the time interval proportioned accordingly counting only the portion, as days, above the critical temperature. For example, if for a critical temperature of 5 °C, the weekly range was 2 - 9 °C, then only 4 days were counted. This approximation was necessary because only weekly, not daily, results were available. The results of which are given in Table 6.1.7.

Hypothesis (2) is also not applicable, for similar reasons, to hypothesis (1). The plot of the number of days to flowering from 1 January against the number of days over 5 °C also produced an oblique line rather than the expected single vertical one. (fig. 6.1. 4.)

Laboratory Study.

The plants in the three growth chambers were subjected, from April 1971, to normal photoperiods of 15 h and 8 h per day and 4 h alternating, making a total of 12 h, every 24 h. The water temperature was ambient to within 0.1 °C for the River Frome at East Stoke. The three plants were initially cut back, and reflowered by late May. The flow rate was slower than at Holly Bush, their collection site, and unfortunately proved ideal for several filamentous algae and for _Lemna trisulca_, which were periodically removed. The plants under observation continued to follow their normal growth cycle and flowered on 25 March 1972 at a similar time

Table 6.1.7.

Hypothesis (2) The number of days above 7 °C and 5 °C. from 1 January up to the time of flowering.

Site in order of flowering	Year	No. of days from 1 Jan. above mean daily temperature of 5°C	7°C
Waterston	1972	75	76
	1973	61	61
Holly Bush	1969	73	73
	1970	81	77
	1971	74	72
	1972	78	75
	1973	82	82
Bere Heath	1970	121	98
Throop	1971	85	53
Athelhampton	1970	119	91
	1971	117	96
	1972	(91)	(76)
Trigon	1970	130	106
	1971	110	85
Piddletrenthide	1970	(120)	(80)
	1971	106	90
	1972	96	74

Key :-

( ) - approximate value only (see Table 6.1.1.)

to those at Holly Bush. (19 March 1972) (Table 6.1.9.). The plants under the short days were very much weaker and comparable to slow water forms but despite this they produced flowers. In autumn 1972, the photoperiods were altered in each box to 14.5 h light per day. The flowering time, 28 March 1973, was however similar to that at their site of origin,(23 March 1973.)

The indigenous plants in the river outside the fluvarium flowered in June. The degree-days total above 5 °C reached by the time of flowering on 24 March 1972, was 205 from 1 January 1972, and 380 from 1 November 1971, a reduction in both, compared to Holly Bush, of one third. The number of days above 5 °C and 7 °C was similarly reduced by about a third, to 80 and 50 respectively.

The plants from the River Piddle transplanted to the fluvarium did not grow, probably because of low light intensities within the building.

The plants transplanted to the outside channels, from Holly Bush in 1969, flowered on average only two weeks later than those at their site of origin, in 1970, 1971 and 1972. (Table 6.1.9.)

Table 6.1.9.

Time of first flower on plants moved from Holly Bush.

Year	Holly Bush site	Growth chambers	Outside channels	Indigenous plants in River Frome
1971	15 March	-	30 March	Late June
1972	19 March	25 March	2 April	June
1973	23 March	28 March	No observation	No observation

General Conclusion.

As a result, of these laboratory and field studies, the initiation of flowering can be described as independant of the photoperiod, or any quantitive or critical temperature effect and would appear to be controlled by an endogenous rhythm within the plant. An ecocline of genetic variants or subspecies is suggested (Table 6.1.5. and map 3.3.) differing by up to eight weeks in their time of initiation. (extrapolation of lines in Fig. 6.1.2.) The variation ranges from sites with warmer water in the winter and spring, flowering early, to those with cooler water, flowering later. This temperature variation coincides with a downstream distribution of plants because the small streams are spring-fed, with water at about 10 °C throughout the winter. (Table 6.1.5. and map 3.3. and description of sites 3.3.)

7. GENERAL DISCUSSION.

The production ecology of *R. calcareus* was investigated in detail at one site only, though comparisons of some aspects were made at other sites. At the main study site, Holly Bush on the Bere Stream, the plant was maintained as a dominant by the periodic removal of the emergent species.

The determination of the net productivity by changes in biomass.

The changes in biomass produced a growth curve similar to that discussed by Westlake (1965) for plant with annual regrowth. (Fig. 4.5.3.). *R. calcareus* is a herbaceous perennial which starts to grow in spring or the previous winter, depending on the temperature and flow conditions, from fine rhizomes in the stream bed. There are two situations in which roots and rhizomes are found, in the stream bed and in sediment banks. Those in the sediment banks are washed out seasonally by floods, whereas those in the stream bed remain to regrow in the following season. The latter were determined to be about 3.8 g dry weight m^{-2}, that is, about 1 - 2% of the maximum standing crop.

The maximum standing crops, 200 - 380 g dry weight m^{-2}, were similar to those previously reported for submerged aquatic macrophytes in chalk streams by Edwards and Owens (1960, 1962). There were no problems with encrustations of calcium carbonate, though the ash weights were high, 0.16 - 0.35 of the dry weight. The high values were not, in particular, during the periods of rapid growth as suggested by Wetzel (1960). The increase in the proportion of ash is due to carbon uptake. There was an algal bloom in the late spring associated with the plants but samples were washed thoroughly to remove as much of this material as possible.

The plants and their changes in biomass were also studied by transplanting plants, in baskets, to within a natural community. The analysis of the results was complicated by their large size and a paucity of sample baskets. The plants were therefore used for phenological observations and later transplanted to growth chambers for flowering studies.

The indirect determination of biomass was attempted by studying the length to weight ratio and distribution of stems and complete plants and by determining the area covered. The former method suffered from highly variable behaviour of the plants whereas the latter was handicapped by the seasonal changes in plant density. There was a very rapid increase in cover during a short period in spring, bringing the cover up to nearly 100% in large areas but this was not accompanied by a similar rapid increase in biomass.

The rate of growth reached a maximum before flowering, mid March-May, after which it declined, the maximum standing crop being reached in June. The plants turned moribund soon after, started to decompose and were washed out in the first autumn floods. The decline in growth rate coincided with a decline in discharge rate of water, following the decrease in velocity caused by plant growth which also resulted in a decrease in the degree of turbulance. This decrease would increase the boundary layer around the plant stems and leaves making uptake of nutrients more difficult. Self-shading is also an important factor limiting the standing crop and contributing to the decline. Westlake (1966) considered that self-shading is important over about 175 g dry weight m^{-2} in shallow chalk streams. No conclusion as to the cause of the decline in growth rate could be drawn from the evidence, although all these factors probably contributed. Flowering itself affects the plants morphologically by causing large hollow floating stems and both leaves and flowers to be produced by the apex. The reproductive structures were about 1% of the maximum biomass but their disruptive effect on plant growth was much greater e.g. the increased fragility of stems.

The variation of flowering time with site on the River Piddle suggested a genetic ecocline or set of sub-species ranging from sites with warmer waters in the late winter and spring flowering earlier to those with cooler waters, flowering later. This temperature variation coincided with a downstream distribution of plants because the streams were spring fed with water at about 10 °C. There was no evidence to associate changes in maximum biomass at different sites with the differing flowering times.

The respiration rate of the plant was at a maximum at the time of maximum growth rate in the spring as Westlake (1965) suggests is typical. It declined shortly afterwards as the rate of growth declined. The optimum temperature for respiration based on the calculation of temperature coefficients was 10 °C; above 15 °C the rate declined rapidly.

The biomass was not directly limited by the availability of nutrients because there was between 30 and 400 times as much nitrogen, phosphorus, potassium and carbon passing at the time of maximum growth, mid March to mid May, as was taken up (Table 7.1.). The net primary production at this period was 220 g dry weight m^{-2} in a 60 day period or 1.36 g carbon m^{-2} day^{-1}. The carbon available was calculated on the basis of uptake of bicarbonate ion and assuming that the concentration of carbon dioxide was negligible. It has been recently shown however, that the River Frome water is supersaturated with carbon dioxide. If the water is brought into equilibrium with air the pH is altered from 7.5 - 8.0 to about 8.6 (H. Casey pers. comm.).

The utilisation efficiency of photosynthetically useful light was at maximum 0.012 of that available at the plant surface. This was calculated taking into account useful energy is only 0.45 of the total energy, that 0.1 of the light was reflected at the water surface, that the plant cover was only 0.65 of the stream bed and assuming a conversion of 4.5 k cal g organic $^{-1}$. The utilisation of the light incident at the water surface was 0.0032 which is very similar to that reported by Edwards and

Table 7.1.

The uptake of nutrients by plants from stream water.

Mid-March to mid-May 1970.

Element	Concentration		Uptake	Throughput	Uptake / throughput ratio, by weight
	in plant dry weight mg g^{-1}	in water mg l^{-1}	by plant kg	kg	
Phosphorus	0.002	0.0097	0.44	12.6	0.035
Nitrogen	0.05	5.9	11	7650	0.0014
Potassium	0.036	0.8	7.9	1037	0.0076
Carbon	0.37	C 25	81.4	32400	0.0025

Owens (1960) for the River Ivel, a chalk stream.

There was a significant decline in the maximum standing crop achieved by R. calcareus in the years 1969 - 72 at the Holly Bush site when the crop was not removed but allowed to decline naturally. In 1968 the total crop was removed in June and about 370 g dry weight m^{-2} was found. However, in the following year the crop was allowed to start a natural decline before removal as a check on sampling techniques. In the following years 1970 - 2 no further full scale removal was undertaken and the maximum crop declined by half to 200 g dry weight m^{-2}. It is considered that cutting the crop, particularly before flowering, stimulates regrowth. On a small scale experiment this was confirmed. When standing crops were compared with a large river, the River Frome an adjacent chalk stream, where R. calcareus is naturally dominant and cut annually, they were about 200 g dry weight m^{-2} in early July 1969. (Table 4.5.7.). This is the same as the probable minimum value after 4 years of not cutting, for the biomass at the study site. The River Frome survey however, included transects of water of up to four times as deep as Holly Bush. The shallow sites on the River Frome were as densely weeded as at the study site, Holly Bush. The stream at Bere Heath, a tributary of the River Piddle, is unmanaged and the standing crop here is 120 - 200 g dry weight m^{-2} in June, however, this part of the stream is invaded by Rorippa nasturtium-aquaticum in the late summer which can reach 600 g dry weight m^{-2}. This invasion does not in fact directly affect the current season's crop because it generally occurs after the maximum biomass of R. calcareus is reached. It may however, influence the size of the following year's growth of R. calcareus depending on the time at which it is killed by frost or washed out. If the material is lost early in the autumn then regrowth of R. calcareus can take place building up the crop and producing a high biomass in the following year.

In order to confirm the effect of reducing the biomass by not cutting and also the effects of time of starting of regrowth on the biomass, experiments with plants kept at maintained velocities should be undertaken. This is more typical of large rivers, but should be combined with a study of reduction of flood risk.

The annual production of R. calcareus and the production to biomass ratio (P/B ratio)were derived from the results of seasonal biomass by adding the leaf-loss and the stem loss. (Fig. 7.1.). The loss of leaves was estimated by study of phenology and labelling and periodic morphological investigations as by Borutskii (1950). Difficulty was found in determining the contribution of stems from plants, upstream to the plant studied; these stems were included in standing crop estimates because they were impossible to separate. From 1970 to 1972 screens were used to collect all material entering and leaving the system. In 1970 and 1971, the large material was prevented from entering the section and the upstream contribution to the standing crop was therefore absent. The potential input up to the time of maximum standing crop in June was 2.2% of the maximum crop of R. calcareus. In a normal situation the loss from the lower part of the stream would have balanced the input. The passage of broken stems is impaired by the plants downstream and they are caught, increasing the

Fig. 7.1. Composite growth curve, R.calcareus.

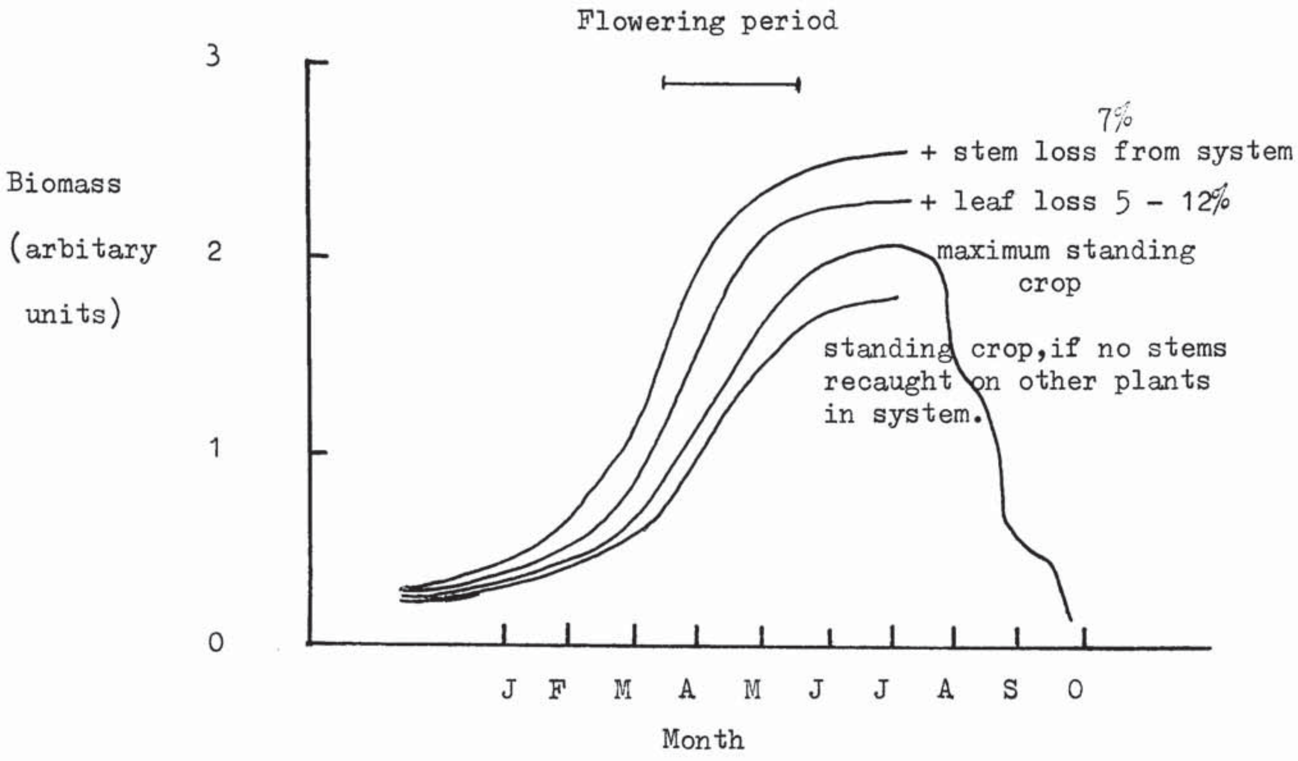


Table 7.2.

The production of R.calcareus.

Year	Maximum standing crop		Loss from section		Net[1] Production.	P/B ratio
	Month	Weight g m^{-2}	Weight kg	% of maximum crop		
1969	June	382 ± 73	-	(7)	443	1.16
1970	June	319 ± 91	10.5	4.6	361	1.13
1971	June	217 ± 43	15.7	10.3	258	1.19
1972	June	203 ± 45	8.8	6.2	233	1.15
			Mean	7		1.16

Note

1. Leaf-fall assumed to be 8.5% (5 - 12%) of the maximum standing crop each year.

standing crop, and so on, downstream. Neglecting the difference in sites of origin the biomass in this section must be under-estimated by the difference between the input and output, that is, 7 - 2%. The estimate of stem fall from both plants and from the system, allows the loss to be partitioned such that of the 10 - 15% stem fall from the plants, 3 - 8% is returned to the crop and 7% is lost downstream.

There was little loss of leaf from the system identifiable as leaf and therefore the estimate of leaf-fall from the plant was used in the production estimate, because leaves are usually shed in a moribund state and any not so are not capable of regrowing or continuing to grow.

The annual production of R. calcareus is the sum of the maximum biomass, the leaf-fall and the loss from the section considered, expressed per unit area. (Table 7.2.). In 1969 leaf loss was estimated but not the loss from the section, whereas in 1970 - 2 the loss from the section was determined. The results were averaged for the four years 1969 - 72, but there was season to season variation in the stem loss before June though the main difficulty was because of the steady decline in the standing crop. It is assumed that the leaf-fall is the mean of 0.05 to 0.12 of the standing crop each year. The production changed from 443 to 233 g dry weight m^{-2}, over a four year period. The mean production to maximum biomass ratio was 1.16 and ranged from 1.13 to 1.19. The loss of soluble organic material was not estimated but Wetzel and Manny have suggested that 4% is normal.

The seasonal effect of biomass on discharge was described by calculating the Chezy-Manning coefficient. It was extremely difficult to determine the true cross-sectional area, and thus the mean bed level, because the silt banks were always covered with weed. The silt was highly organic and soft in nature making depth measurement very inaccurate. The silt depth was determined after washout of the crop as 2 cm on average over the whole stream and this was not considered to alter the cross-section to any extent as it was only 4 - 6% of the summer water depths. The maintained plateau tracer method, using salt, for discharge measurement was also used to give the mean velocity of the section which should equate with the discharge to give the mean cross-sectional area, however this was not investigated. The resistance to flow did vary seasonally with biomass but the extent to which it did was very variable. The coefficient varied from 0.040-0.050 to 0.200 -0.400 ft. $^{0.167}$; the upper values were for two years with only slightly differing biomass.

Organic budget for the Holly Bush sections of the Bere Stream.

Organic budgets were constructed for the three sections of the stream studied, the lake Millum Head, the wooded section (A - C) and most importantly the treeless section (D) in which the production of *R. calcareus* was studied. (Tables 7.4., 7.5. and 7.3.).

The lake was studied primarily to consider its effect on the species composition of the large suspended materials collected on the middle screen. It was apparent that much of the material produced in and around the lake remained in it, accumulating and being respired. When related to area, estimated outputs of terrestial material were slightly greater than the outputs of aquatic macrophyte but only 4% of the estimated input was lost as large suspended material while 20% was lost as small suspended material. (Table 7.3.).

The results for the wooded stretch of stream showed that about two thirds of the terrestial leaf-fall was fragmented, converted to small suspended material or respired within the stretch within three months. The degree of change to which this material was subjected varied with the retention time in the system each year and was therefore dependent on the hydrological cycle. The most striking feature of the budget is the increase in small suspended material by an order of magnitude between the upper and middle screen. (Table 7.4.). If this organic material is compared to the

Table 7.3.

Summary table.

Organic budget for Millum Head, Holly Bush.

Gain kg	1970 - 71	1971 - 72	Loss kg	1970 - 71	1971 - 72
1. Material produced in lake aquatic macrophytes[1]	(1590)	(1590)	1. Material retained in lake 2y respiration.	?	?
2. Material entering lake			2. Material leaving lake, collected on or passing upper screen.		
(a) Terrestrial leaf-fall[2]	305	214			
(b) Material in water			(a) Material in water		
(i) large suspended			(i) large suspended aquatic macrophytes	54	56
	0	0	terrestrial, leaves etc.	15	3
(ii) small suspended	?	?	(ii) small suspended	383	>20
(iii) dissolved, in spring and surface water drainage[3]	?	?	(iii) dissolved	?	?
	>1895	>1804		>452	≫ 79

Key

? = not determined. ( ) = estimate

Note

1. Macrophyte production based on 300 g dry weight m^{-2} y^{-1}, 0.80 of dry weight is organic for 6620 m^2 .
2. Leaf-fall Table 4.3.3. and Appendix 7 Table 1.
3. The dissolved organic material concentration range for spring waters is 0.4 - 0.8 mg l^{-1}, giving 1000 kg season^{-1}.

Table 7.4.

Summary Table.

Organic budget for the sections A – C of Bere Stream, Holly Bush.

	Gain kg				Loss kg		
	1969 – 70	1970 – 71	1971 – 72		1969 – 70	1970 – 71	1971 – 72
1. Material produced between screens aquatic macrophytes[1]	(95)	(95)	(95)	1. Material lost between screens, 2 y respiration.	?	?	?
2. Material entering section (cf. Table 7.4.)				2. Material leaving section collected on or passing middle screen.			
(a) Terrestrial leaf-fall[2]	(200)	195	220				
(b) Material in water				(a) Material in water			
(i) Large suspended aquatic macrophytes	54	56	?	(i) Large suspended aquatic macrophytes	104	59	124
terrestrial, leaves etc. from lake	15	3	?	terrestrial, from A – C (& lake)	42	98	84
(ii) small suspended in water from lake[3]	?	383	> 2.0	(ii) small suspended			
in water from withy bed	?	?	?		≫ 41	> 3540	6553
(iii) dissolved, in water from lake and withy bed	?	?	?	(iii) dissolved	?	?	?
	≫ 364	> 732	≫ 335		≫ 187	> 3697	> 6761

Key

? = not determined. ( ) = estimated

Note

1. Macrophyte production estimated as 300 g dry weight m^{-2} for 0.30 of the area not covered by trees, 380 m^2. Includes dissolved organic material estimated as 4% of net production.
2. This is immediately partitioned into solid and leaf leachate. (1969 – 70 32 kg , 1970 – 71 31 kg and 1971 – 72 36 kg)
3. Includes 0.5 – 3.0% of fine material collected on screen.

Table 7.5.

Summary table.

Organic budget for section D of Bere Stream, Holly Bush.

	Gain kg				Loss kg		
	1969-70	1970-71	1971-72		1969-70	1970-71	1971-72
1. Material produced between screens				1. Material lost between screens, 2 y respiration.			
R.calcareus[1]	197	142	138		?	(535)	(2814)
other aquatic macrophytes[2] and epiphytic and epilithic algae	?	?	?				
2. Material entering section (cf. Table 7.4.).				2. Material leaving section collected on or passing lower screen.			
(a) terrestrial leaf-fall	0	0	0				
(b) material in water				(a) Material in water			
(i) large suspended				(i) large suspended			
R.calcareus	0	0	5	*R.calcareus*	32	26	8
other aquatic macrophytes	0	0	119	other aquatic macrophytes	22	11	86
terrestrial, leaves etc.	0	0	84	terrestrial, leaves etc.	8	1	43
(ii) small suspended	?	>3510	6553	(ii) small suspended	3328	3079	3948
(iii) dissolved[3]	?	?	?	(iii) dissolved	?	?	?
	≫ 197	>3652	6899		>3390	3652	6899

Key

? = not determined. ( ) = estimated

Notes

1. Organic weight of *R.calcareus* calculated from ashed samples at time of maximum standing crop, includes an estimated 4% of dissolved organic matter.
2. 'Other aquatic macrophytes' includes *Fontinalis*, *Lemna* and other marginal dicotyledons; this source of Gain is probably insignificant.
3. Dissolved organic and surface drainage were small

total ash content of the lake small suspended material then there was about one fifth of that reaching the middle screen compared to one tenth for the organic material; the discharge from the lake was about 30 - 40% of the flow passing the middle screen. This indicates that half the flow came from drainage of an organically rich source, the complex of channels within the withy bed and from a small adjacent pond. The major ones were netted but no large suspended material was collected.

The budget for the treeless section between the middle and lower screens was undertaken to confirm the estimate of leaf-loss from *R. calcareus* and its *in situ* decomposition within or close to its site of production. The budget (Table 7.5.) shows that the major effect was the accumulation, particularily by the plants, and the subsequent respiration of the organic material in the small suspended material input. The throughput of this small material was about 30 times greater than the large suspended material. During the first two years when the large suspended material was not returned to the stream after sampling at the middle screen, the annual respiration rate of accumulated material was estimated from the small suspended material budgets to need 0.118 g oxygen m^{-2} h^{-1} in the 1970 - 1 season, September to September. In the following season 1971 - 2 however, when this material was returned to the stream, the rate was about five times higher, 0.62 g oxygen m^{-2} h^{-1}. The material returned to the stream increased the large suspended input by 208 kg and the large loss by approximately 90 kg. The material also caused a large increase in the amount of small suspended material retained. The season 1971 - 2 chosen for return of large material was also a season in which there was a much higher input of small suspended material. This increase was probably caused by a later than normal increase in discharge which allowed the leaf fragmentation sequence to procede further than in the other years. This sequence was also presumed to occur in the streamlets in the withy bed, doubling the small fraction compared to the previous year. The increase in respiration rate of five times depends upon the accuracy of analysis of the organic analyses of the small suspended material in February and March 1972. The organic content of the material passing the lower screen was very low but coincided with the highest discharge of the experimental period. High discharges allow heavier particles to be brought into suspension. However, the material passing the middle screen was more organic than that leaving. The factor used for correcting the small suspended material during screening operations was also at its maximum during this period. The dry weight balance for this fraction was approximately in balance and indicated a decrease of 200 kg within section D in the season 1971 - 2. (Appendix 3 Table 5.). This would however, be expected to balance because the respiration of materials would increase the proportion of ash in the output, unless of course, the ash were calcium carbonate which is being dissolved possibly by the elevated carbon dioxide concentrations within the sediment banks. However, the analysis of the ash fraction indicated only 10% present. The non-carbonaceous ash budget would be expected to balance but in fact did not in either season. (Table 4.4.6.) In 1970 - 1 17% of the input, about 1000 kg was estimated to have been added to the system; this is equivalent to a gain in material 5 mm deep if spread evenly over the entire section. It is possible for this amount of material to have been present in the lower, deeper third of the section D because the change in sediment depth in this area was difficult to determine because the bed was soft chalk, unlike the firm flint bed of the upper two thirds.

The concentration of dissolved organic material (D O M) was not determined, though it was realised that it could be significant. The input from allochthonous sources, in particular leaf-fall leachate, (0.15 of the leaf dry weight) is estimated for the leaf-fall total of 500 kg a season for the areas upstream of the middle screen as 75 kg. Leaching is very rapid once the leaves are in the water and therefore the dissolved organic matter concentration is expressed for the leaf-fall period September to October. The mean total water flow of 170 Ml for these two months in the years 1969 - 72, was giving a concentration of 0.44 mg l^{-1}. Farr (pers. comm.) has found an increase of about 0.03 mg carbon km^{-1} in the River Piddle, at steady flows in winter. The difference in D O M between the middle and lower screens was therefore expected to be small. (0.002 mg).The contribution by macrophytes is also small; Wetzel and Manney (1972) found that 4% of the macrophyte production of some lake species was released as D O M . Most of the leachate present from terrestial leaves and aquatic macrophytes is probably biologically labile and is removed from solution as it leaches out; the remaining material, which increases downstream, is probably the refractory portion.

The small suspended material is not composed of identifiable material; it arises from plant debris by fragmentation and passage through the guts of animals. A distinct pattern related to discharge was found over which was superimposed the effect of the seasonal changes in retention by macrophytes, as was also found by Ladle and Casey (1971). The concentration increased rapidly with slight increases in flow and returns to a basal level if the flow remains at a particular level without rising further. The basal level varies seasonally and is a function of the system. The majority of the material moves at the time of maximum discharge in the winter and early spring. The flow pattern was altered by the collection of material on the screen, particularly at high discharges and this necessitated the calculation and use of a correction factor. The screen made it even more necessary to continuously monitor the concentration of small suspended material.

The determination of the concentration of small suspended material obtained by filtration on membrane filters compared well with those obtained by continuous centrifugation. The former method allowed rapid monitoring of levels while the latter was necessary if accurate analyses were required.

The quantity and composition of large suspended material passing downstream is governed by the source area, the velocity at the site where it falls and the degree of obstruction or the presence of areas conducive to the settling of material. The mean annual rate of collection of materials at the three screens and their related inputs are compared in Table 7.6. The daily rate of collection of materials at the middle and lower screens were approximately the same, only the species composition had changed. The ratio of materials from terrestial and aquqatic sources was approximately 1 : 1 for large material leaving section C. This relatively high proportion of aquatic plants from the tree-shaded section (A – C) was due to large quantity of <u>Fontinalis</u> entering from the lake and passing unchanged through the section. The ratio for the lower screen when screened material was returned was 1 : 2.2. The average loss of input material collected at the middle screen was 175 kg in 165 m. The full balances for individual fractions for 1972 is given in Appendix (Table 2.) 2. The leaf fall contribution in section C is reduced by a half in the 200 m above the middle screen and to a sixth in the 165 m of section D. If the leaf fall is considered as falling mid-way in its source area of stream above the middle screen and considering the further reduction in section D, then its life before total fragmentation measured in distance travelled instead of time can be given, assuming that the reduction is a first order reaction, as 100 m. Applying similar reasoning to the <u>R. calcareus</u> in section D, then it has a much shorter half life in terms of distance of about 30 m. A major factor in this expression must be the velocity of water in the system at the time of supply either as leaf fall or detachment of stems. Macrophytes play an important role in reducing velocities. A simple comparison of the degree of fragmentation between a early and a late wash-out illustrates this point well. (Table 7.6.). The quality of the material as a food and the ease of fragmentation are also important in determining

Table 7.6.

Mean annual collections of large suspended material, Holly Bush.

Source or site of estimation	Total	Fontinalis		Total leaves (and fragments) washout[1]			Salix whole leaves		Ranunculus total
	kg dry	kg	kg	N-D		F-M			
Lake output	125	42	85	[illegible]	-	[illegible]	6	0	8
Input between screens				209	-	238	126	152	
Middle screen	315	31	151	93	-	84[1]	43	22	10
				(25	-	51)			
Macrophyte production									284
Lower screen	115[2] /290	-	92			32	-	16	41
						(14)			

Note

1. - Early washout November and December and a late washout in February and March.
2. - Material not returned after collection at the middle screen.

the half life.

Screens undoubtedly affected the system but this effect was minimised as much as possible by relating the frequency of cleaning to the amount of material to be collected. The total movement of the large material was smoothed out or averaged over the periods between cleaning. The period in April 1972 when sampling was only undertaken for a hour or so at a time illustrates the rapid variations possible, up to a factor of two in six hours.

Recommendation.

It is suggested that in order to aid management and to maintain high organic availability and therefore production, a fairly low density tree canopy is established on the smaller chalk streams. This canopy would reduce the light available for aquatic plant growth, reducing the flood risk but maintaining organic material production for input in the autumn. The presence of winter growing aquatic plants is necessary for when more light is available; this growth tends to retain organic material within the section of the river, preventing it being lost downstream to the sea.

8. CONCLUSIONS.

1. *Ranunculus penicillatus* var. *calcareus* is a submerged aquatic hydrophyte found in highly calcareous rapidly flowing waters.

2. It is the dominant plant in Southern English chalk streams at depths of between 0.5 and 1.5 m; it is a spring dominant in shallower streams often being over-grown later by emergent-marginal plants. e.g. *Rorippa nasturtium-aquaticum*.

3. It is characteristic of plants of rapidly flowing waters; it has a rapid growth rate, a tough flexible stem and leaves, which do not resist the current, the ability to develop adventitious roots at its nodes and a fairly well developed subterranean system from which it regrows each year.

4. It reduces the velocity of the water by its growth and accumulates sediment, the type which depends on the supply.

5. The seasonal maximum biomass attained by *R. calcareus* at the study site at Holly Bush on the Bere Stream was 380 g dry weight m^{-2}. In the four successive years of the study there was a decrease in the maximum crop to 200 g m^{-2}. During this period the total crop was only removed in late August of the first year, just before washout, as a check on the sampling technique.

6. The maximum biomass was similar to that in the adjacent River Frome, at a similar depth, where the weed was removed in May - June every year. A decrease in biomass was observed there with depth down to about 1.5 m below which the plant seemed unable to colonise. The removal of weed during a river authority weed cut was determined as two thirds of that present.

7. A seasonal growth cycle was found, starting in the late autumn or late winter, depending on the temperature and discharge of the water.

8. Flower production coincided with a decline in the growth rate (mid - March) and subsequently the maximum biomass was reached (June) before the plants turned moribund (July - August) and the remainder lost, (18%), in the first autumn rains.

9. Although R. calcareus flowered earlier at upstream sites this could not wholly be accounted for by the higher average winter and spring water temperatures of these sites. Flowering was not initiated by day length.

10. The growth of the plant is not directly limited by nutrients or carbon substrate concentrations, but the physical availability, by diffusion, through the water boundary layer around the leaves and stems may limit growth at low flows.

11. A seasonal change in respiration rate was shown for typical stems in vitro. The optimum temperature was 10 °C, the rate decreased markedly over 15 °C. The maximum rate found was in the spring at the time of maximum growth.

12. The loss of plant stems from the study section, in the period before the maximum biomass was achieved, was 7% of the maximum standing crop. However, 10 - 15% was lost from individual plants, but half of this was retained on plants within the system.

13. The loss from the plant by leaf-fall was 5 - 12% of the maximum biomass as determined by labelling studies.

14. The annual net production, October - October, decreased from 443 to 233 g dry weight over the four years 1969 - 72 at Holly Bush. These values were derived from maximum biomass, which was determined by monthly quadrat sampling, the stem loss from the study section and the leaf fall estimated by labelling studies up to the time of the maximum biomass. The net production to biomass ratio was 1.16, excluding possible dissolved organic material losses.

15. Discharge was determined monthly by the dilution rate of sodium chloride introduced at a constant rate into the stream. This method is more accurate than propeller meters at low flows in particular, but is more laborious.

16. The problems of relating water levels and discharge to the seasonal biomass were not amenable to the methods used (calculation of the Chezy-Manning hydraulic coefficients).

17. The quantity of organic material passing downstream, as determined by removal by screens and sorting to species or groups, is a function of the relative areas occupied by them upstream and their fragmentation and respiration rates, the distance travelled and the degree of obstruction e.g. aquatic plants or the areas conducive to settling out of material.

18. The litter fall by Salix viminalis, Fraxinus excelsior and Acer pseudoplanatus was 260 - 280 g dry weight m^{-2}, in the withy bed at Holly Bush. The irradiance reaching the stream within the withy bed was reduced by 90% in summer but only by 60% in the winter allowing the growth of macrophytes during the period between leaf fall and bud break.

19. Leaves were rapidly leached reducing their weight by 15% in five days and thus supplying the system with dissolved organic material.

20. The small suspended material varied seasonally from a maximum in the winter or spring, falling to a minimum at the time of maximum standing crop of plants in the summer; and the unrespired part was washed out seasonally in the autumn after the plants. The concentration increased rapidly with slight increases in flow and fell again rapidly to a basal level if the flow ceased to continue increasing.

21. Monthly budgets of the organic input and output of small suspended material for a treeless part of the stream, section D, in which the macrophytes were studied, allowed a prediction of the accumulation or loss from the system which was used to estimate the rate of respiration in the system, 0.1 - 0.5 g oxygen m^{-2} h^{-1}.

22. The mean annual concentration of small suspended material at the middle and lower screens was approximately 2 - 4 mg l^{-1} of which 30 - 45% was organic material.

23. The small suspended material was 30 times that of the large suspended material.

24. Aquatic plants play an important part in holding back material partly by decreasing the velocity and preventing their rapid flow through the system.

25. The succession of leaf breakdown depends on the hydrodynamic cycle, if the increase is early then the washout has a larger proportion of whole leaves.

26. The fragmentation and breakdown of materials can be described by analogy with a first order reaction. The half life distance for leaves is 100 m, in winter and 30 m for R. calcareus in summer, but the velocity and amount of weed at the season when the material falls in or is released, is very important.

9. APPENDICES.

Table

1. Collection and sorting of screened materials.
2. Comparisons of screened materials.
3. Small suspended materials.
4. Standing crops of *R. calcareus*.
5. Leaf fall determinations.
6. Hydrology and hydro-dynamics.
7. Plant species mentioned.

Appendix 1.

Tables 1 - 6

The collection and sorting to species groups of material from the upper (Tables 1a - b), middle (Tables 2a - f) and lower (Table 3a - f) screens.

The passage of 'identifiable' material through the screens estimated using 1 mm nets. (Table 4).

The composition of the species groups used for sorting screened material (Table 5).

Carbon and Nitrogen content of materials from the middle and lower screens. (Table 6).

Table 1a.

Average rate of collection of material (g day^{-1}) on the upper screen, sorted into species.

Species group no.	14 day sample periods starting sample day no.											
	308	322	336	350	364	378	392	406	420	434	448	461
1	33.3	188.1	776.4	58.7	83.9	4.8	0.1	0.2	1.0	8.7	7.7	0
2	72.4	103.6	110.6	122.3	285.5	262.1	308.8	630.8	394.1	238.5	87.1	170.1
3	10.4	0	19.1	21.4	11.2	0	0	5.1	0	0.05	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	133.8	554.3	0	180.5	19.2	4.8	19.7	0.2	0	0.1	0	0
7	79.9	28.2	108.6	17.6	60.4	0	11.9	23.2	15.0	8.8	5.2	1.4
8	0	0	0	0	0	0	1.3	0	3.3	2.8	6.1	1.4
9	0	42.7	15.2	3.7	4.6	0	0.1	0	4.2	11.1	1.0	0
10	55.2	112.8	223.2	109.9	16.2	101.4	9.8	2.5	8.6	3.0	5.2	8.5
11	27.2	0	52.1	0	79.8	0	0	0	0.2	0	0	0
12	0.04	0	0	2.9	5.4	1.6	0	0	0	3.0	0	0
13	0	0	0	0	0	1.6	0	0	0	0	5.2	0
14	187.2	131.2	52.4	23.1	0	4.8	0	0	0	0	0	0
15	0	0	52.4	0	5.4	0	0	0	0	0	0	0
16	0.04	132.7	60.0	20.2	21.7	3.2	0	0	0	0	0	0
17	0	0	7.6	0	5.4	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	4.79	23.5	30.3	3.7	8.4	0	13.0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	1.47	0	7.6	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	4.8	0	0	0	0	1.0	0.9
23	10.6	0	0	0	0	0	0	0	0	0	0.2	0
24	71.6	0	0	41.2	27.9	18.0	102.1	52.1	46.7	59.3	172.5	50.4
25	15.3	0	0	15.2	19.9	17.1	10.3	46.3	26.6	11.5	95.7	58.5
26	0	0	0	0	0	4.8	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0

Note

- Two sub-samples sorted for period 308 - 460, one subsample only 461-549
- 32 day sample for period starting 518, i.e. sample for 518 - 549

Table 1a. (cont.)

Species group no.	14 day sample periods starting sample day no.				Total Weight	Percentage
	476	490	504	518–549		
1	0	0	0	0	16280.6	13.21
2	137.7	29.8	23.6	34.6	42162.4	34.21
3	0	2.61	0	0	978.0	0.79
4	0	0	0	0	0	0
5	0	0	4.7	11.5	433.8	0.35
6	0.1	21.8	35.3	89.9	16454.0	13.35
7	0	6.2	6.4	7.5	5459.2	4.43
8	2.2	0.2	0.6	2.3	324.2	0.26
9	0	0.2	0	0	1155.0	0.94
10	0	3.2	2.8	0	9272.2	7.52
11	0	0.5	1.4	0	2261.0	1.83
12	0	0	0	0	181.2	0.15
13	0	0	0	0	95.2	0.08
14	0	0	0	0	5581.8	4.53
15	0	0	0	0	809.2	0.66
16	0	0	0	0	3329.8	2.70
17	0	0	0	0	182.0	0.15
18	0	0	0	0	0	0
19	0	0	0	3.5	1283.7	1.04
20	0	0	0	0	0	0
21	0	0	0	0	127.0	0.10
22	2.2	0.5	0	0	131.6	0.11
23	0	0	0	0	151.2	0.12
24	34.2	14.1	13.2	13.0	10262.2	8.33
25	19.0	11.6	18.6	34.6	6225.6	5.05
26	0	0	0	0	67.2	0.05
27	0	0.02	0	0	0.3	0.00
					123208.3	

Table 1b.

Rate of collection of material (g day^{-1}) on the upper screen sorted into species, 1972.

Species group no.	Sample day no.										
	751	758	765	772	779	786	793	798	807	812	831
1	0	1.0	0.9	0	0	0	0	0	0	0	0
2	179.0	911.5	262.5	595.9	556.0	595.6	422.4	2262	1912	1888	351.0
3	1.80	0	11.3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	6.2	5.2	0	0
6	104.7	4.7	4.4	18.4	0	0	0	0	0	0	0
7	57.2	19.7	185.9	2.3	2.0	4.3	0	6.2	5.2	0	38.3
8	0	0	0.9	0	0	2.1	0	6.2	5.2	5.7	1.3
9	8.5	13.2	1.7	3.5	0	0	0	0	0	0	0
10	63.9	61.1	32.3	1.15	0	38.0	17.6	62.0	52.4	13.2	3.9
11	40.8	0	0	0	0	2.1	0	6.2	5.2	0	6.5
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	5.7	9.7
15	0	0	0	0	0	0	0	0	0	0	0
16	0	21.6	22.7	20.7	0	4.3	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	37.7	5.6	4.4	0	0	4.3	6.4	0	0	51.0	16.2
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0
24	77.9	243.4	87.2	162.2	20.4	105.5	103.5	349.2	295.2	1059	151.8
25	0	0	0	0	0	64.2	0	132.9	112.3	256.8	51.9
26	0	6.57	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Note

- Only one sub -sample sorted during each period

Table 1b. (cont.)

Species group no.	Sample day no.				Mean	
	835	856	870	882	Weight	Percentage
1	0	0	0	0	0.1	0.01
2	249.0	91.4	75.5	320.2	711.4	65.0
3	0	0	0	0	0.9	0.1
4	0	7.5	6.2	0	0.9	0.1
5	0	0	0	3.4	1.0	0.1
6	0	69.9	57.7	165.3	18.3	2.6
7	27.2	4.3	3.6	10.3	24.4	2.2
8	0.9	0	0	10.3	2.2	0.2
9	0	0	0	0	1.8	0.2
10	2.8	23.7	19.5	0	26.1	2.4
11	4.6	0	0	0	4.4	0.4
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	6.9	0	0	0	1.5	0.1
15	0	0	0	0	0	0
16	0	0	0	0	4.6	0.4
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	11.5	8.6	7.1	0	10.2	0.9
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	0	0	0	3.4	0.2	0.02
23	0	0	0	0	0	0
24	107.7	13.7	11.3	85.6	191.6	17.5
25	36.8	18.0	14.9	78.3	88.1	8.0
26	0	0	0	0	0.4	0.04
27	0	0	0	0	0	0
					1 095.13	

Table 2a.

Mean dry weight, (kg day^{-1}), ash-free dry weight, (kg day^{-1}) and inorganic Carbon weight (g day^{-1}) for material collected at the middle screen and mean discharge 1970 - 2 (1 - 999.)

14-day sample period starting day no.	Monthly mean discharge m^3sec^{-1}	Velocity $m\ sec^{-1}$	Daily mean dry weight kg	Percentage Organic	Percentage Ash	Percentage Inorganic	Daily mean Organic kg	Daily mean Ash kg	Daily mean Inorganic g
1	0.228	0.32	2.30	77	23	-	1.77	0.53	-
13	0.278	0.30	2.93	74	26	1.5	2.17	0.76	44
27	0.278	0.28	2.27	71	29	1.5	1.61	0.66	34
42	0.300	0.24	3.05	66	34	2.0	2.01	1.04	61
56	0.300	0.24	3.08	59	(41)	(2.0)	1.82	1.26	62
70	0.256	0.16	2.76	59	(41)	(2.4)	1.63	1.13	66
84	0.256	0.16	0.97	58	42	(2.4)	0.56	0.41	23
98	0.290	0.13	0.66	56	44	(1.2)	0.37	0.29	7
112	0.290	0.13	0.70	68	32	(1.4)	0.48	0.23	10
126	0.132	0.12	0.59	66	34	(1.4)	0.39	0.20	8
140	0.132	0.12	0.29	70	30	-	0.20	0.09	-
154	0.093	0.10	0.22	71	29	-	0.15	0.06	-
168	0.093	0.10	0.15	77	23	-	0.12	0.04	-
182	0.093	0.10	0.14	72	28	-	0.10	0.04	-
196	0.063	0.08	0.11	72	28	-	0.08	0.03	-
210	0.063	0.08	0.06	71	29	-	0.04	0.02	-
224	0.033	0.07	0.17	67	33	(1.1)	0.11	0.06	2
238	0.033	0.07	0.11	72	28	-	0.08	0.03	-
252	0.045	0.07	0.86	67	33	-	0.58	0.28	-
266	0.045	0.07	0.44	84	16	-	0.37	0.07	-
280	0.097	0.09	0.56	88	12	-	0.49	0.07	-
294	0.097	0.09	0.68	81	19	(1.2)	0.55	0.13	8
308	0.127	0.12	1.52	79	21	1.2	1.20	0.32	18
322	0.127	0.12	1.59	83	17	1.2	1.32	0.27	19
336	0.216	0.25	1.25	83	17	1.1	1.04	0.21	14
350	0.216	0.25	0.55	79	21	1.4	0.44	0.12	8
364	0.216	0.25	1.48	84	16	1.5	1.24	0.24	22
377	0.307	0.34	1.24	79	21	(1.3)	0.98	0.26	16

Table 2a (cont.)

14-day sample period starting day no.	Monthly mean discharge $m^3 sec^{-1}$	Velocity $m\ sec^{-1}$	Daily mean dry weight kg	Percentage			Daily mean		
				Organic	Ash	Inorganic	Organic kg	Ash kg	Inorganic g
392	0.307	0.34	1.33	78	22	1.1	1,04	0.29	15
406	0.245	0.20	0.70	67	33	(1.4)	0.47	0.23	10
420	0.245	0.20	0.47	67	33	1.6	0.31	0.15	7
434	0.182	0.15	0.23	68	32	1.8	0.16	0.07	4
448	0.182	0.15	0.22	69	31	1.2	0.15	0.07	3
462	0.147	0.12	0.58	78	22	-	0.45	0.13	-
476	0.147	0.12	0.44	74	26	-	0.33	0.12	-
490	0.080	0.11	0.53	77	23	-	0.41	0.12	-
504	0.080	0.11	0.70	83	17	-	0.58	0.12	-
518	0.080	0.10	0.51	80	20	-	0.41	0.10	-
532	0.080	0.09	0.36	80	20	-	0.29	0.07	-
546	0.080	0.09	0.26	83	17	(1.5)	0.21	0.04	4
560	0.048	0.08	0.23	80	20	-	0.19	0.05	-
574	0.048	0.08	0.16	79	21	-	0.12	0.03	-
588	0.027	0.08	0.08	78	22	-	0.06	0.02	-
602	0.027	0.08	0.07	82	18	-	0.06	0.01	-
616	0.017	0.06	0.11	81	19	-	0.09	0.02	-
630	0.017	0.06	0.25	81	19	-	0.20	0.05	-
644	0.018	0.09	0.31	81	19	-	0.25	0.06	-
658	0.018	0.09	0.06	81	19	-	0.05	0.01	-
672	0.018	0.09	0.04	83	17	-	0.03	0.01	-
686	0.030	0.15	0.06	81	19	1.0	0.05	0.01	1
700	0.030	0.15	0.05	77	23	1.1	0.04	0.01	1
714	0.075	0.25	0.31	78	22	-	0.25	0.07	-
728	0.075	0.25	0.86	80	20	-	0.69	0.17	-
742	0.203	0.30	2.23	71	29	-	1.58	0.65	-
756	0.203	0.30	2.51	71	29	-	1.78	0.73	-
770	0.352	0.37	4.91	68	32	1.8	3.34	1.57	88
784	0.352	0.37	5.19	54	46	2.1	2.80	2.39	109
798	0.360	0.25	4.0	62	37	2.4	2.52	1.48	96
812	0.360	0.25	4.0	71	29	1.9	2.84	1.16	76
826	0.255	0.15	0.76	66	34	1.5	0.50	0.26	11

Table 2a. (cont.)

14-day sample period starting day no.	Monthly mean discharge $m^3 sec^{-1}$	Velocity $m\ sec^{-1}$	Daily mean dry weight kg	Percentage			Daily mean		
				Organic %	Ash %	Inorganic %	Organic kg	Ash kg	Inorganic g
840	0.255	0.15	1.02	70	30	1.4	0.71	0.31	14
854	0.255	0.15	1.32	82	18	1.1	1.08	0.24	15
868	0.160	0.12	0.72	85	15	1.0	0.61	0.11	7
882	0.160	0.12	0.45	85	15	1.0	0.38	0.07	4
896	0.081	0.10	0.35	85	15	1.0	0.30	0.05	3
910	0.081	0.10	0.19	85	15	1.0	0.16	0.03	2
924	0.035	0.09	0.13	85	15	0.9	0.11	0.02	1
938	0.035	0.09	0.12	73	27	1.0	0.09	0.03	1
952	0.032	0.06	0.08	64	36	2.0	0.05	0.03	2
966	0.032	0.06	0.07	81	19	1.1	0.06	0.01	1
980	0.031	0.08	0.15	81	19	1.2	0.12	0.03	2

Note

- Days 1 - 251, mean values for two or three sub-samples of dry and ash weights.
- Daily ash weight means for 14 day periods between days 294 - 335.
- Exceptions to sample periods days 1 - 12 and 980 - 999.
- Brackets indicate incomplete representation of sub-samples.

Table 2b (i)

Total weight of species groups for years 1970 - 2, from the middle screen.

Species	Year 1970		Year 1971		Year 1972	
group	(13)- 349		350 - 713		714 -(999)	
no.	g	%	g	%	g	%
1	13 443	4.0	8 210	5.9	5 201	0.9
2	89 274	26.2	29 075	20.8	252 855	43.3
3	6 006	1.8	119	0.1	0	0
4	70	0.02	0	0	0	0
5	6	0	1	0	0	0
6	26 566	7.8	13 119	9.4	8 834	1.5
7	4 736	1.4	2 713	1.9	4 614	0.8
8	1 390	0.4	1 240	0.9	8 243	1.4
9	9 590	2.8	2 003	1.4	1 562	0.3
10	37 374	11.0	20 058	14.3	43 022	7.4
11	16 355	4.8	17 364	12.4	58 856	10.1
12	32 064	9.4	8 492	6.1	19 089	3.3
13	797	0.2	1 064	0.8	969	0.2
14	1 627	0.5	930	0.7	1 200	0.2
15	16 282	4.8	5 236	3.7	5 221	0.9
16	1 648	0.5	241	0.2	0	0
17	2 307	0.7	157	0.1	0	0
18	206	0.1	18	0	0	0
19	2 458	0.7	1 684	1.2	5 279	0.9
20	512	0.2	461	0.3	0	0
21	154	0.1	64	0.1	0	0
22	2 090	0.6	742	0.5	2 638	0.5
23	463	0.1	546	0.4	0	0
24	59 825	17.6	13 503	9.7	111 916	19.1
25	5 643	1.7	12 020	8.6	55 080	9.4
26	8 793	2.6	708	0.5	0	0
27	519	0.2	95	0.1	0	0
	340 198		139 865		584 579	

Table 2b (ii)

Total weight of species groups for seasons 1970 - 2, from the middle screen.

Species group no.	Season(1969)-70 (13)- 209		Season 1970-71 210 - 559		Season 1971-2 560 - 937	
	g	%	g	%	g	%
1	9 752	4.1	8 821	3.8	6 940	1.2
2	87 206	37.1	30 771	13.3	253 077	42.7
3	6 006	2.6	153	0.1	0	0
4	70	0	0	0	0	0
5	6	0	1	0	0	0
6	11 998	5.1	25 162	10.9	10 755	1.8
7	4 264	1.8	3 185	1.4	4 614	0.8
8	892	0.4	1 586	0.7	8 396	1.4
9	8 477	3.6	2 859	1.2	1 795	0.3
10	27 103	11.5	29 191	12.6	43 315	7.3
11	9 089	3.9	24 254	10.5	59 233	10.0
12	1 863	0.8	38 350	16.6	19 432	3.3
13	66	0	1 557	0.7	1 207	0.2
14	0	0	2 502	1.1	1 119	0.2
15	2 332	1.0	16 964	7.3	6 146	1.0
16	451	0.2	1 438	0.6	0	0
17	213	0.1	2 247	1.0	4	0
18	1	0	217	0.1	6	0
19	1 855	0.8	2 051	0.9	5 516	0.9
20	510	0.2	451	0.2	13	0
21	0	0	195	0.1	24	0
22	1 784	0.8	909	0.4	2 778	0.5
23	253	0.1	616	0.3	0	0
24	51 821	22.0	20 630	8.9	112 466	19.0
25	161	0.1	15 730	6.8	56 316	9.5
26	8 568	3.7	934	0.4	0	0
27	452	0.2	95	0.1	67	0
	235 192		230 869		593 219	

Table 2b (iii).

Correction table for middle screen sample period 798 - 825.

Species	Total weight					
group	Year 1972		Season 1971-2		Year 1972	Season 1971-2
no.	Uncorrected g	Corrected g	Uncorrected g	Corrected g	Corrected %	Corrected %
1	5 201	5 125	6 940	6 864	1.2	1.6
2	252 855	150 689	253 077	150 911	36.2	35.5
3	0	0	0	0	0	0
4	0	0	0	0	0	0
5	0	0	0	0	0	0
6	8 834	8 834	10 755	10 755	2.1	2.5
7	4 614	4 162	4 614	4 162	1.0	1.0
8	8 243	6 787	8 396	6 940	1.6	1.6
9	1 562	1 562	1 795	1 795	0.4	0.4
10	43022	38 164	43 315	38 457	9.2	9.0
11	58 856	50 854	59 233	51 231	12.2	12.0
12	19 089	19 089	19 432	19 432	4.6	4.6
13	969	969	1 207	1 207	0.2	0.3
14	1 200	1 200	1 119	1 119	0.3	0.3
15	5 221	5 221	6 146	6 146	1.3	1.4
16	0	0	0	0	0	0
17	0	0	4	4	0	0
18	0	0	6	6	0	0
19	5 279	5 279	5 516	5 516	1.3	1.3
20	0	0	13	13	0	0
21	0	0	24	24	0	0
22	2 638	3 365	2 778	3 505	0.8	0.8
23	0	0	0	0	0	0
24	111 916	65 264	112 466	65 814	15.7	15.5
25	55 080	50 201	56 316	51 437	12.0	12.1
26	0	0	0	0	0	0
27	0	0	67	67	0	0
	584 579	416 765	593 219	425 405		

Table 2c.

Average rate of collection of material (g day^{-1}) on the middle screen sorted into species 1970 - 2.

Species group no.	14 day sample periods starting day no.										
	13	27	42	56	70	84	98	112	126	140	154
1	45.0	27.0	59.4	57.5	82.8	71.0	46.0	111.4	61.3	27.3	42.1
2	460.2	1069	1718	1764	1665	578.3	321.7	194.0	166.1	26.0	7.8
3	108.0	33.7	25.2	226.2	29.4	4.0	2.5	0	0	0	0
4	0.1	4.9	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0.2	0	0	0	0
6	114.8	59.9	56.8	55.1	14.2	28.4	38.1	90.3	74.0	82.1	103.5
7	98.8	37.5	35.6	50.9	64.6	7.5	0	0	0	5.1	2.9
8	19.2	0.1	16.1	0.8	1.7	2.8	0.3	9.7	12.2	0	0
9	107.4	70.9	181.5	61.2	100.2	13.9	7.1	13.1	35.4	6.7	1.3
10	672.1	298.5	400.7	208.6	175.8	38.6	27.8	31.1	37.8	23.2	11.9
11	419.2	153.0	42.4	17.2	2.0	0	6.8	4.7	2.4	0	0
12	95.3	9.9	3.0	3.7	2.2	1.1	0	3.5	0	4.6	5.9
13	0	4.1	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	100.5	15.7	3.3	0.6	0.5	0	0	0.6	4.0	18.6	7.9
16	0	24.9	5.6	0	0	0	0	0.8	0	0	0
17	7.6	0.9	3.7	0	0	3.0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	22.9	19.8	44.1	22.1	9.9	6.4	2.8	0	0.7	3.0	0
20	15.3	0.1	1.6	1.0	0	0	0	0	0	0	0.4
21	0	0	0	0	0	0	0	0	0	0	0
22	3.7	1.1	7.5	4.9	6.0	19.8	37.3	32.4	7.9	5.2	0.7
23	0	1.3	7.2	0	2.7	0	0	0	0	6.0	0
24	508.5	422.4	528.0	723.5	666.1	211.5	205.8	172.5	116.6	60.6	34.9
25	-	-	-	-	-	-	-	-	-	-	-
26	193.0	94.8	57.4	25.3	0	35.9	0.9	72.6	97.8	34.2	0
27	0.9	1.0	9.0	3.2	9.4	2.1	0	0	0	6.2	0

Note

- Weekly samples, 7 days, sorted from 13 - 83 only; results weighed and combined to give one sample see Table 2d.

Table 2c (cont.)

Species group no.	14 day sample periods starting day no.										
	168	182	196	210	224	238	252	266	280	294	308
1	51.2	63.4	22.2	16.0	32.1	32.6	48.7	17.5	22.0	28.6	1.1
2	12.3	9.9	1.4	0.3	0.5	5.1	0.5	0	1.0	0.2	47.7
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0.2	0	0	0	0	0	0	0	0	0	0
6	62.5	47.5	30.0	22.7	76.5	5.1	189.6	19.5	18.9	199.2	203.7
7	1.2	0.3	0.2	0.4	1.9	0	1.3	0	0	0	0.1
8	0.2	0	0.6	0	0	0	0.1	0	0	35.5	0
9	3.3	1.6	1.9	0.7	2.8	3.5	6.9	3.1	7.3	20.4	32.0
10	3.3	3.3	3.2	5.3	6.0	9.6	176.6	16.5	112.5	90.5	96.1
11	0	1.5	0	0.3	4.5	0	0	5.7	0	0	15.0
12	2.9	0.7	0.3	0	0	1.7	59.9	24.8	43.4	101.5	736.8
13	0	0	0.6	0.5	1.4	0	0	6.9	4.5	5.5	25.4
14	0	0	0	0	0	0	0	5.9	4.5	5.5	37.8
15	4.2	2.0	8.7	1.0	2.8	3.5	165.6	273.7	305.6	85.5	91.1
16	0.3	0	0.6	0	0	0	0	0	0	3.9	0
17	0	0	0	0	0	0	5.3	1.4	28.0	21.6	60.4
18	0	0	0.1	0	0	0	0	0	8.9	0	5.7
19	0.8	0	0	0	0	1.4	2.2	6.9	1.6	0.2	8.0
20	0	0	18.0	0	0	0	0	0	0	0.2	0
21	0	0	0	0	0	0	0	0	2.7	3.8	0
22	0.1	0.6	0.2	0.2	0.3	0	10.2	3.5	7.6	[illegible].0	0.1
23	0	0	0.9	0	0	0	0	0	15.0	0	0
24	16.5	14.7	19.9	7.9	39.0	40.7	22.3	66.1	3.8	50.5	151.8
25	–	5.3	6.0	5.2	5.1	4.5	175.7	9.1	0.02	39.1	50.5
26	0	0	0.1	0	0	0	0.7	0	0	0	0
27	0.7	0	0	0	0	0	3.3	1.5	0	0	0

Table 2c. (cont.)

Species group	14 day sample periods starting day no.										
no.	322	336	350	364	378	392	406	420	434	448	461
1	34.0	31.0	34.1	50.1	0.1	3.2	0.2	6.4	20.5	25.4	24.5
2	42.1	50.3	24.4	56.3	189.8	500.8	462.2	305.4	102.6	48.9	193.8
3	0	0	0	7.9	0	0.1	0.1	0	2.8	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	155.8	149.4	62.0	107.3	133.5	126.6	56.1	20.4	2.5	0.1	84.4
7	20.8	9.2	12.0	42.2	27.9	63.5	32.6	2.0	0	0	7.0
8	0	0	0	0	4.3	0	0.9	9.8	4.6	37.8	1.6
9	0	2.8	16.8	39.7	4.1	6.1	9.4	11.3	6.4	3.0	14.9
10	38.4	102.7	103.8	137.2	362.1	389.0	13.7	22.7	39.4	27.0	45.7
11	433.0	60.5	120.6	141.3	270.5	97.2	20.0	0	0.3	3.0	9.0
12	562.5	626.6	54.0	427.3	20.7	0	0	0	0	3.0	9.0
13	0	8.0	0	7.1	20.7	0	0	0	0.1	0	0
14	16.9	45.6	6.2	7.1	20.7	0	0	0	0	0	0
15	35.6	32.0	29.2	67.7	11.1	28.6	0	2.2	11.3	13.9	0
16	55.7	25.9	0.1	7.1	0	0	5.5	0	0	0	4.5
17	29.5	3.4	0.9	0	6.0	0	0	0	0	0	0
18	0	0	0.9	0	0	0	0	0	0	0	0
19	13.5	9.3	11.3	0.1	6.0	0	0	2.0	0.2	0	0
20	0	0	0	0	5.5	0.1	0.1	0	0	0	22.3
21	0	4.5	0.9	0	0	0	0	2.0	0	0	0
22	0	0	0	0	8.6	0	0	12.2	1.2	8.7	0
23	0	0	0	0	2.4	0	0	0	0	0	36.6
24	107.5	82.1	52.8	277.0	119.0	70.8	73.4	55.2	35.9	25.5	33.7
25	63.5	38.9	34.9	119.0	55.7	72.9	36.5	22.2	12.3	24.2	48.9
26	15.4	0	0	0	0	0	0	0	0	0	50.6
27	0	0	0	2.0	0	0	0	0	0	0	0

Table 2c. (cont.)

species group no.	14 day sample periods starting day no.										
	476	490	504	518	560	574	588	602	616	658	672
1	54.9	53.4	36.3	57.4	61.3	69.5	20.8	31.7	10.5	4.7	8.5
2	80.4	19.0	5.4	61.2	3.3	4.7	13.0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0.1	0	0	0	0	0	0	0
6	47.5	88.3	9.4	18.8	42.3	14.8	24.3	17.4	48.1	2.2	5.4
7	2.6	4.0	0	0	0	0	0	0	0	0	0
8	9.9	4.8	4.0	0	6.5	0.6	0	1.9	0	0	0.6
9	4.9	8.1	0	0	0	0	0	1.4	5.2	0.2	2.1
10	37.2	110.8	35.0	27.8	14.4	6.0	4.3	0	4.3	6.2	6.0
11	45.3	49.9	374.0	82.3	6.5	0	3.3	1.4	0	2.1	2.7
12	7.7	19.4	9.4	31.6	11.1	1.0	2.5	0.7	5.1	2.5	0
13	7.7	19.4	4.0	0	0	1.0	0	0	14.6	1.4	0
14	7.7	19.4	0	1.4	0	1.0	0	0	2.9	0.9	0
15	0	0	12.1	39.2	18.3	14.1	7.4	1.9	84.0	26.6	6.4
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	4.0	0	0	0	0	0	0	0.3	0
18	0	0	0	0	0	0	0	0	0	0.4	0
19	19.0	16.2	32.3	16.3	7.2	1.6	1.2	1.6	0	1.1	0
20	0	0	4.0	0	0	0	0	0	0	0.9	0
21	0	0	0	0	0	0	0	0	0	1.7	0
22	0	2.8	8.1	1.4	0	0	2.6	0	7.4	0	0
23	0	0	0	0	0	0	0	0	0	0	0
24	39.7	54.1	44.4	20.4	18.8	12.6	5.7	6.5	8.4	1.3	1.8
25	87.8	73.7	122.6	21.3	39.9	20.7	2.4	10.5	29.0	4.9	3.6
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	3.5	1.3	0

Note

- 42 day sample starting day no. 518.
- 42 day sample starting day no. 616.

Table 2c. (cont.)

Species group no.	14 day sample periods starting day no.										
	686	700	714	728	742	756	770	784	* 798	* 812	826
1	11.3	1.6	11.3	6.8	3.0	0	0	37.0	13.4	0	2.8
2	1.7	3.9	15.3	64.2	699.3	80.6	819.9	3575	10415	1602	234.9
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	17.3	8.4	102.6	87.4	3.0	5.0	0	352.0	0	0	0
7	0	0	16.0	0	0	25.2	207.9	18.5	40 .3	0	0
8	1.3	0	0	23.2	44.3	5.0	0	83.4	188.2	107.8	99.0
9	7.6	1.9	28.0	23.2	0	5.0	0	18.5	0	0	2.8
10	9.3	12.4	52.7	282.8	224.3	327.5	516.9	203.8	577.8	249.2	198.1
11	2.7	8.2	27.3	236.3	631.5	440.9	689.2	27.8	860.1	215.5	0
12	0	1.6	0	0	0	629.9	0	0	0	0	0
13	0	0	0	0	0	63.0	0	46.3	0	0	0
14	0	0	0	0	0	63.0	0	0	0	0	0
15	0	0	0	0	0	0	0	46.3	0	0	17.0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	3.7	0.5	5.3	5.5	0	63.0	0	92.6	0	0	17.0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	148.1	0
23	0	0	0	0	0	0	0	0	0	0	0
24	3.5	4.0	33.8	90.2	329.1	385.4	940.7	933.0	4402	441.6	108.2
25	6.4	9.2	25.0	45.2	295.0	417.0	1743	243.4	551.0	181.5	77.9
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Note

- * Uncorrected results.

Table 2c. (cont.)

Species group no.	14 day sample periods starting day no.										
	840	854	868	882	896	910	924	938	952	966	980
1	1.8	24.7	56.3	49.2	17.6	40.9	11.0	32.9	34.9	12.1	15.8
2	349.8	84.1	69.7	21.4	17.6	0	0.7	3.3	4.8	0.9	1.8
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	0	26.8	0	0	2.7	8.5	9.9	9.7	7.6	15.8
7	18.4	0	18.8	1.6	0	1.4	0	0	0	0	0
8	18.4	0	18.8	0	0	0.7	0	0	0	0	0
9	0	0	0	0	31.6	0.7	0	0	0	0	1.8
10	162.0	94.0	0	9.9	31.6	34.7	47.3	23.1	1.9	35.4	0
11	242.0	573.7	249.5	0	0	0	9.2	0	0	0	0
12	0	202.8	91.2	264.0	145.6	30.0	0	0	0	0	0
13	0	0	0	1.6	4.6	0	0	0	0	0	0
14	0	0	0	1.6	4.6	6.8	0	4.4	0	0	5.3
15	0	24.7	56.3	42.9	35.3	21.8	36.0	30.7	12.6	5.4	43.9
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	128.6	29.5	9.9	22.3	3.4	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	39.6	0	0	0	0.7	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0
24	134.3	65.1	54.7	11.2	12.2	26.1	2.4	4.0	4.1	3.5	11.7
25	89.4	80.8	52.3	35.1	25.9	20.4	12.9	11.4	7.3	9.2	10.4
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Table 2d.

Average rate of collection of material (g day^{-1}) on the top and bottom halves and during cleaning, of the middle screen, combined to give 14 day averages.

Key :-

Sample code (see text). All samples are corrected to average rate of collection of material during period stated.

T = Top half of screen.
B = Bottom half of screen.
W = Wash out of material onto second screen pairs during cleaning operations.
A = No division of material into fractions, as above.

T1, T2, T3.
B1, B2, B3.
A1, A2, A3. = Sub-samples from top, bottom and undivided total screened material.
$\bar{T}$, $\bar{B}$, $\bar{A}$. = Mean values of sub-samples.

Sum = Sum of fractions of screen samples giving total for each species group.
Mean = Mean value for 14 day periods, weighted if necessary for irregular sorting or sampling; results used in Table 2c.

Table 2d. (cont.)

Starting day no.	13							21				13
Sample period days	7							7				14
Species	Sample g day^{-1}											Mean
group no.	T	B1	B2	B3	$\bar{B}$	W	Sum	T	B	W	Sum	
1	19.6	8.5	11.0	12.2	10.6	8.6	38.8	26.4	19.7	5.1	51.2	45.0
2	71.7	14.7	20.3	15.5	16.8	59.7	148.2	272.3	340.7	159.2	772.2	460.2
3	17.9	293.7	81.3	61.4	145.5	0	163.4	29.3	12.7	10.5	52.5	108.0
4	0	0	0	0	0	0	0	0	0.1	0	0.1	0.1
5	0	0	0	0	0	0	0	0	0	0	0	0
6	83.1	11.7	38.6	30.9	27.1	21.3	131.5	81.4	13.0	3.7	98.1	114.8
7	68.6	10.1	20.7	27.5	19.4	45.2	133.2	64.4	0	0	64.4	98.8
8	0	0	0	0	0	0	0	0.1	22.3	16.0	38.4	19.2
9	53.0	8.0	65.3	14.2	29.1	38.9	121.0	35.6	22.6	35.6	93.8	107.4
10	327.3	188.7	213.7	217.1	206.5	246.1	779.9	101.3	230.1	232.8	564.2	672.1
11	39.0	174.5	179.4	221.8	191.9	470.3	701.2	1.6	0	135.5	137.1	419.2
12	5.2	19.9	11.4	17.3	16.2	17.2	38.6	60.6	82.3	9.1	152.0	95.3
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	7.2	4.1	3.6	0	2.6	45.8	55.6	60.6	82.3	2.5	145.4	100.5
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	15.1	0	0	15.1	7.6
18	0	0	0	0	0	0	0	0	0	0	0	0
19	10.5	8.7	9.0	9.0	8.9	0	19.4	21.4	0	5.0	26.4	22.9
20	0	0	0	0	0	0	0	0	18.3	12.2	30.5	15.3
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0.1	0	0	0	0	1.6	1.7	0.1	0	5.6	5.7	3.7
23	0	0	0	0	0	0	0	0	0	0	0	0
24	103.4	320.0	340.8	360.3	340.4	257.8	701.6	156.9	39.4	119.1	315.4	508.5
25	0	0	0	0	0	0	0	0	0	0	0	0
26	87.3	36.9	104.1	111.9	84.3	92.5	264.1	23.1	94.0	4.7	121.8	193.0
27	0	0	0	0	0	1.75	1.75	0	0	0	0	0.9

Table 2d. (cont.)

Starting day no.	27				35				27
Sample period days.	7				7				14
Species group no.	Sample g day^{-1}								Mean
	T	B	W	Sum	T	B	W	Sum	
1	23.2	4.8	1.9	29.9	13.0	9.6	1.5	24.1	27.0
2	371.7	424.7	205.9	1002	456.4	514.0	165.1	1136	1069
3	8.9	0.1	0	9.0	55.6	0.9	1.9	58.4	33.7
4	8.9	0	0	8.9	0	0.9	0	0.9	4.9
5	0	0	0	0	0	0	0	0	0
6	65.0	13.6	3.9	82.5	28.7	6.4	2.1	37.2	59.9
7	24.2	8.7	9.2	42.1	23.9	4.0	4.9	32.8	37.5
8	0.1	0	0	0.1	0	0	0	0	0.1
9	58.0	33.3	6.4	97.7	39.1	1.0	3.9	44.0	70.9
10	177.3	42.2	115.5	335.0	121.1	88.3	52.6	262.0	298.5
11	31.9	69.3	112.4	213.6	14.7	53.1	24.5	92.3	153.0
12	5.4	5.4	7.8	18.6	1.1	0	0	1.1	9.9
13	0	0	0	0	0	4.9	3.3	8.2	4.1
14	0	0	0	0	0	0	0	0	0
15	11.7	1.1	17.5	30.3	0	1.0	0	1.0	15.7
16	0	24.9	0.4	25.3	24.5	0	0	24.6	24.9
17	0	0	0	0	0	1.8	0	1.8	0.9
18	0	0	0	0	0	0	0	0	0
19	13.3	1.1	0	14.4	5.6	14.8	4.7	25.1	19.8
20	0.1	0.1	0	0.2	0	0	0	0	0.1
21	0	0	0	0	0	0	0	0	0
22	0	1.3	0	1.3	0.3	0	0.6	0.9	1.1
23	0	0	0	0	2.6	0	0	2.6	1.3
24	115.0	219.0	57.8	391.8	193.9	219.7	39.3	452.9	422.4
25	0	0	0	0	0	0	0	0	0
26	36.5	84.9	0	121.4	0.1	46.0	22.0	68.1	94.8
27	0.1	0	0	0.1	0	0	1.8	1.8	1.0

Table 2d. (cont.)

Starting day no.	42				49				42
Sample period days	7				7				14
Species group no.	Sample g day^{-1}								Mean
	T	B	W	Sum	T	B	W	Sum	
1	19.2	6.7	2.0	27.9	33.2	50.9	6.8	90.0	59.4
2	634.6	663.2	238.2	1536	612.4	690.4	596.3	1899	1718
3	16.2	3.5	17.6	37.3	6.2	3.9	3.0	13.1	25.2
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	49.8	10.7	3.1	63.6	30.0	13.7	6.3	50.0	56.8
7	11.4	0	0	11.4	21.8	16.9	21.0	59.7	35.6
8	11.4	11.2	8.2	30.8	0.7	0.4	0.2	1.3	16.1
9	46.2	15.3	11.3	72.8	28.0	225.7	36.4	290.1	181.5
10	251.0	172.1	79.1	502.2	110.3	72.5	116.3	299.1	400.7
11	17.4	17.2	33.7	68.3	3.6	0	12.8	16.4	42.4
12	0.8	0	1.9	2.7	0	2.3	1.0	3.3	3.0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	1.0	4.8	0	5.8	0.7	0	0	0.7	3.3
16	0	0	6.3	6.3	0	3.7	1.1	4.8	5.6
17	0	4.1	1.2	5.3	0	2.0	0	2.0	3.7
18	0	0	0	0	0	0	0	0	0
19	41.2	12.4	6.1	59.7	19.5	1.3	7.7	28.5	44.1
20	0	0	0	0	0	0	3.2	3.2	1.6
21	0	0	0	0	0	0	0	0	0
22	0	1.6	4.2	5.8	3.2	0	5.9	9.1	7.5
23	14.2	0	0.1	14.3	0	0	0	0	7.2
24	217.3	245.2	20.2	482.7	314.0	172.4	86.9	573.3	528.0
25	0	0	0	0	0	0	0	0	0
26	48.2	23.2	0	71.4	29.6	0	13.8	42.4	57.4
27	0	0	5.1	5.1	0	0	4.8	4.8	8.0

Table 2d. (cont .)

Starting day no.	56				63				56
Sample period days.	7				7				14
Species group	Sample g day^{-1}								Mean
no.	T	B	W	Sum	T	B	W	Sum	
1	26.4	12.1	13.1	51.5	51.4	35.6	6.3	63.3	57.5
2	595.3	722.4	579.4	1897	623.3	655.0	352.7	1631	1764
3	423.3	7.1	5.7	436.1	5.8	9.2	1.3	16.3	226.2
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	12.4	25.7	18.4	56.5	39.5	10.0	4.2	53.7	55.1
7	19.8	0.4	2.7	22.9	63.8	14.1	1.0	78.9	50.9
8	0	0	0.1	0.1	0	0	1.5	1.5	0.8
9	23.8	11.6	18.3	53.7	38.6	26.3	3.7	68.6	61.2
10	72.3	126.5	68.6	267.4	102.0	31.0	16.8	149.8	208.6
11	2.7	6.6	3.0	12.3	8.1	11.6	2.4	22.1	17.2
12	0	0	0	0	6.1	1.3	0	7.4	3.7
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	1.2	0	0	1.2	0.6
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	4.4	2.7	3.6	10.7	9.0	23.4	1.0	33.4	22.1
20	0	0	0	0	0	0	1.9	1.9	1.0
21	0	0	0	0	0	0	0	0	0
22	2.9	0.9	3.1	6.9	2.7	0.1	0	2.8	4.9
23	0	0	0	0	0	0	0	0	0
24	239.7	425.6	147.0	812.3	212.4	269.7	152.6	634.7	723.5
25	0	0	0	0	0	0	0	0	0
26	11.5	11.9	0	23.4	0	27.1	0	27.1	25.3
27	6.3	0	0	6.3	0	0	0	0	3.2

Table 2d. (cont.)

Starting day no.	70				84				98			
Sample period days.	14				14				14			
Species group no.	Sample g day^{-1} T	B	W	Mean Sum	T	B	W	Mean Sum	T	B	W	Mean Sum
1	50.9	19.7	12,2	82.8	36.1	31.5	3.4	71.0	28.2	3.4	14.4	46.0
2	726.8	527.7	410.3	1665	238.1	272.2	68.1	578.3	89.6	165.2	66.9	321.7
3	9.9	9.5	10.0	29.4	2.3	1.0	0.7	4.0	2.4	0	0.1	2.5
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0.2	0.2
6	12.4	0	1.8	14.2	17.1	6.7	0.6	28.4	25.2	8.9	4.0	38.1
7	58.3	5.0	1.3	64.6	6.5	1.0	0	7.5	0	0	0	0
8	0	0	1.7	1.7	2.8	0	0	2.8	0	0.3	0	0.3
9	70.6	20.7	8.9	100.2	9.1	4.0	0.8	13.9	4.7	0.2	2.2	7.1
10	97.1	26.9	51.8	175.8	20.4	8.2	10.0	38.6	21.6	0.6	5.6	27.8
11	2.0	0	0	2.0	0	0	0	0	2.8	0	4.0	6.8
12	1.7	0	0.5	2.2	1.1	0	0	1.1	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0.5	0.5	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	3.0	0	0	3.0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	4.7	3.2	2.0	9.9	4.5	0.7	1.2	6.4	2.3	0.5	0	2.8
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	6.0	0	0	6.0	14.4	5.4	0	19.8	35.6	0.4	1.3	37.3
23	1.8	0.9	0	2.7	0	0	0	0	0	0	0	0
24	200.8	381.6	83.7	666.1	106.7	90.2	14.6	211.5	94.8	105.4	5.6	205.8
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	25.5	4.9	5.5	35.9	0	0	0.9	0.9
27	7.9	0	1.3	9.2	2.1	0	0	2.1	0	0	0	0

Table 2d. (cont.)

Starting day no.	112				126			140		
Sample period days.	14				14			14		
Species group no.	Sample g day^{-1}									
	T	B	W	Mean Sum	T	B	Mean Sum	T	B	Mean Sum
1	60.3	28.1	23.0	111.4	40.4	20.9	61.3	14.4	12.9	27.3
2	91.1	74.6	28.3	194.0	67.5	98.6	166.1	3.8	22.2	26.0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	43.0	39.5	7.8	90.3	56.2	17.8	74.0	57.4	24.7	82.1
7	0	0	0	0	0	0	0	4.5	0.6	5.1
8	4.1	4.8	0.8	9.7	2.8	9.4	12.2	0	0	0
9	7.1	5.7	0.3	13.1	35.1	0.3	35.4	3.5	3.2	6.7
10	17.2	13.3	0.6	31.1	16.1	21.7	37.8	15.3	7.9	23.2
11	0	4.7	0	4.7	0	2.4	2.4	0	0	0
12	3.5	0	0	3.5	0	0	0	3.5	1.1	4.6
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0.6	0	0	0.6	4.0	0	4.0	14.3	4.3	18.6
16	0.8	0	0	0.8	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0.7	0	0.7	0	3.0	3.0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	27.2	5.2	0	32.4	7.9	0	7.9	5.2	0	5.2
23	0	0	0	0	0	0	0	0	6.0	6.0
24	50.9	121.6	0	172.5	44.5	72.1	116.6	21.5	39.1	60.6
25	0	0	0	0	0	0	0	0	0	0
26	0	72.6	0	72.6	0	97.8	97.8	0	34.2	34.2
27	0	0	0	0	0	0	0	0	6.2	6.2

Table 2d. (cont.)

Starting day no.	154			168			182			196		
Sample period days.	14			14			14			14		
Species group no.	Sample g day^{-1} T	B	Mean Sum	T	B	Mean Sum	T	B	Mean Sum	T	B	Mean Sum
1	23.0	19.1	42.1	31.5	19.7	51.2	32.1	31.3	63.4	15.7	6.5	22.2
2	0.9	6.9	7.8	4.8	7.5	12.3	2.6	7.3	9.9	0.5	0.9	1.4
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0.2	0.2	0	0	0	0	0	0
6	49.9	53.6	103.5	43.5	19.0	62.5	26.5	21.0	47.5	30.0	0	30.0
7	0.7	2.2	2.9	0.9	0.3	1.2	0.3	0	0.3	0.1	0.1	0.2
8	0	0	0	0.2	0	0.2	0	0	0	0	0.6	0.6
9	0.5	0.8	1.3	2.2	1.1	3.3	0.9	0.7	1.6	1.0	0.9	1.9
10	7.8	4.1	11.9	3.3	0	3.3	1.9	1.4	3.3	2.3	0.9	3.2
11	0	0	0	0	0	0	1.3	0.2	1.5	0	0	0
12	4.3	1.6	5.9	2.0	0.9	2.9	0	0.7	0.7	0.3	0	0.3
13	0	0	0	0	0	0	0	0	0	0	0.6	0.6
14	0	0	0	0	0	0	0	0	0	0	0	0
15	7.0	0.9	7.9	3.6	0.6	4.2	0.9	1.1	2.0	1.6	7.1	8.7
16	0	0	0	0	0.3	0.3	0	0	0	0	0.6	0.6
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0.1	0.1
19	0	0	0	0	0.8	0.8	0	0	0	0	0	0
20	0.4	0	0.4	0	0	0	0	0	0	0	18.0	18.0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0.7	0.7	0	0.1	0.1	0	0.6	0.6	0.2	0	0.2
23	0	0	0	0	0	0	0	0	0	0.3	0.6	0.9
24	9.2	25.7	34.9	8.5	8.0	16.5	4.9	9.8	14.7	8.0	11.9	19.9
25	0	0	0	0	0	0	1.8	3.5	5.3	2.3	3.7	6.0
26	0	0	0	0	0	0	0	0	0	0	0.1	0.1
27	0	0	0	0	0.7	0.7	0	0	0	0	0	0

Table 2d. (cont.)

Starting day no.	210			224			238	244		238
Sample period days.	14			14			6	8		14
Species	Sample g day^{-1}									Mean
group			Mean			Mean				
no.	T	B	Sum	T	B	Sum	A	A1	A2	
1	8.4	7.6	16.0	13.5	18.6	32.1	32.6	10.2	9.7	9.9
2	0	0.3	0.3	0.5	0	0.5	5.1	2.4	2.7	2.5
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0.03	0.2	0.1
5	0	0	0	0	0	0	0	0	0	0
6	13.7	9.0	22.7	33.5	43.0	76.5	5.1	34.1	33.1	33.6
7	0.1	0.3	0.4	0	1.9	1.9	0	0	0	0
8	0	0	0	0	0	0	0	0	0.1	0.1
9	0.4	0.3	0.7	0.9	1.9	2.8	3.5	0.2	0.4	0.3
10	5.0	0.3	5.3	4.8	1.2	6.0	9.6	2.2	1.3	1.7
11	0	0.3	0.3	0	4.5	4.5	0	0	0	0
12	0	0	0	0	0	0	1.7	0.3	0	0.2
13	0.5	0	0.5	1.4	0	1.4	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0.7	0.3	1.0	2.8	0	2.8	3.5	3.3	5.4	4.4
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	1.4	0	0	0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	0.1	0.1	0.2	0.3	0	0.3	0	0	0.4	0.2
23	0	0	0	0	0	0	0	0	0	0
24	2.6	5.3	7.9	23.0	16.0	39.0	40.7	37.9	37.6	37.8
25	2.4	2.8	5.2	1.9	3.2	5.1	4.5	18.9	18.8	18.9
26	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0

Table 2d. (cont.)

Starting day no.	252			266			280			294		
Sample period days.	14			14			14			14		
Species group no.	Sample g day^{-1} A1	A2	Mean	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	56.0	41.4	48.7	14.7	20.3	17.5	24.1	20.0	22.0	20.7	36.5	28.6
2	0.9	0.2	0.5	0	0	0	0	2.0	1.0	0.4	0	0.2
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	174.3	204.9	189.6	18.1	20.9	19.5	17.3	20.5	18.9	223.2	175.1	199.2
7	2.6	0	1.3	0	0	0	0	0	0	0	0	0
8	0	0.2	0.1	0	0	0	0	0	0	5.5	65.6	35.5
9	13.7	0.2	6.9	2.4	3.9	3.1	4.3	10.3	7.3	10.9	29.8	20.4
10	165.4	187.7	176.6	14.6	18.3	16.5	54.2	170.9	112.5	123.6	57.4	90.5
11	0	0	0	4.9	6.5	5.7	0	0	0	0	0	0
12	57.7	62.1	59.9	29.4	20.1	24.8	48.6	38.2	43.4	82.0	121.0	101.5
13	0	0	0	10.5	3.2	6.9	4.8	4.3	4.5	7.8	3.3	5.5
14	0	0	0	10.6	1.2	5.9	4.8	4.3	4.5	7.8	3.2	5.5
15	189.0	142.2	165.6	263.8	283.5	273.7	334.6	276.7	305.6	91.5	79.4	85.5
16	0	0	0	0	0	0	0	0	0	0	7.9	3.9
17	2.2	8.4	5.3	0	2.9	1.4	37.8	18.3	28.0	20.0	23.3	21.6
18	0	0	0	0	0	0	10.6	7.2	8.9	0	0	0
19	4.5	0	2.2	13.9	0	6.9	3.1	0	1.6	0.4	0	0.2
20	0	0	0	0	0	0	0	0	1.0	0.4	0	0.2
21	0	0	0	0	0	0	2.9	2.6	2.7	7.5	0	3.8
22	0	20.3	10.2	3.5	3.5	3.5	6.7	8.6	7.6	0	0	0
23	0	0	0	0	0	0	30.1	0	15.0	0	0	0
24	22.0	22.7	22.3	66.4	65.9	66.1	3.8	3.8	3.8	50.7	50.4	50.5
25	172.8	178.5	175.7	9.1	9.0	9.1	0.02	0.02	0.02	39.2	39.0	39.1
26	1.4	0	0.7	0	0	0	0	0	0	0	0	0
27	6.5	0	3.3	0	2.9	1.5	0	0	0	0	0	0

Table 2d. (cont.)

Starting day no.	308			322			336			350		
Sample period days.	14			14			14			14		
Species	Sample g day^{-1}											
group no.	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	2.1	0.1	1.1	44.2	23.8	34.0	32.3	29.6	31.0	31.0	37.1	34.1
2	28.0	67.4	47.7	43.8	40.5	42.1	68.1	32.5	50.3	30.4	18.4	24.4
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	209.8	197.7	203.7	194.5	117.1	155.8	145.6	153.2	149.4	47.3	76.7	62.0
7	0	0.1	0.1	16.1	25.4	20.8	5.6	12.8	9.2	15.1	8.9	12.0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	63.9	32.0	0	0	0	5.6	0	2.8	10.7	23.0	16.8
10	88.0	104.1	96.1	71.1	5.6	38.4	120.0	85.3	102.7	173.3	34.2	103.8
11	29.9	0	15.0	439.8	426.2	433.0	121.0	0	60.5	99.7	141.5	120.6
12	791.2	682.4	736.8	466.0	659.0	562.5	542.9	710.2	626.6	35.3	72.7	54.0
13	37.7	13.0	25.4	0	0	0	16.0	0	8.0	0	0	0
14	7.1	68.5	37.8	0	33.9	16.9	39.5	51.7	45.6	10.7	1.7	6.2
15	75.3	106.9	91.1	37.7	33.5	35.6	9.6	54.4	32.0	24.7	33.7	29.2
16	0	0	0	111.4	0	55.7	45.0	6.8	25.9	0.03	0	0.02
17	79.8	41.0	60.4	27.6	31.3	29.5	0	6.8	3.4	0	1.7	0.9
18	0	11.4	5.7	0	0	0	0	0	0	0	1.7	0.9
19	11.3	4.7	8.0	0	27.1	13.5	9.6	9.1	9.3	0.03	22.6	11.3
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	9.1	4.5	0	1.7	0.9
22	0.2	0	0.1	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	152.1	151.5	151.8	108.0	107.1	107.5	82.3	81.8	82.1	53.1	54.4	53.8
25	50.6	50.4	50.5	63.7	63.2	63.5	39.0	38.8	38.9	34.5	35.3	34.9
26	0	0	0	0	30.9	15.4	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 2d. (cont.)

Starting day no.	364			378			392			406		
Sample period days.	14			14			14			14		
Species group no.	Sample g day^{-1} A1	A2	Mean	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	50.4	49.9	50.1	0.1	0.1	0.1	6.3	0.2	3.2	0.1	0.2	0.2
2	53.7	59.0	56.3	159.3	220.3	189.8	573.9	427.8	500.8	462.1	462.2	462.2
3	15.7	0	7.9	0	0	0	0.3	0	0.1	0.1	0	0.1
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	118.7	95.9	107.3	58.7	208.2	133.5	174.7	78.5	126.6	50.0	62.2	56.1
7	64.1	20.4	42.2	20.1	35.6	27.9	127.0	0	63.5	42.6	22.6	32.6
8	0	0	0	1.9	6.6	4.3	0	0	0	0	1.9	0.9
9	59.0	20.4	39.7	8.2	0	4.1	0.3	11.9	6.1	18.7	0	9.4
10	62.3	212.1	137.2	498.8	225.4	362.1	219.0	559.0	389,0	27.1	0.2	13.7
11	282.5	0	141.3	254.6	286.5	270.5	86.8	107.7	97.2	0	40.0	20.0
12	282.5	572.2	427.3	19.2	22.1	20.7	0	0	0	0	0	0
13	14.2	0	7.1	19.2	22.1	20.7	0	0	0	0	0	0
14	14.2	0	7.1	19.2	22.1	20.7	0	0	0	0	0	0
15	68.0	67.4	67.7	22.2	0	11.1	26.4	30.8	28.6	0	0	0
16	14.2	0	7.1	0	0	0	0	0	0	0	11.1	5.5
17	0	0	0	0.1	11.1	6.0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0.1	0.1	1.0	11.1	6.0	0	0	0	0	0	0
20	0	0	0	0	11.1	5.5	0	0.2	0.1	0.1	0	0.1
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	6.1	11.1	8.6	0	0	0	0	0	0
23	0	0	0	4.7	0	2.4	0	0	0	0	0	0
24	277.3	276.7	277.0	118.8	119.2	119.0	71.0	70.5	70.8	73.2	73.6	73.4
25	119.8	118.3	119.0	55.6	55.8	55.7	73.2	72.7	72.9	36.4	36.6	36.5
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	4.1	2.0	0	0	0	0	0	0	0	0	0

Table 2d. (cont.)

Starting day no.	420			432			448		
Sample period days.	14			14			14		
Species group no.	Sample g day^{-1} A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	5.2	7.6	6.4	9.5	31.6	20.5	38.3	12.4	25.4
2	332.8	278.1	305.4	80.6	124.6	102.6	45.4	52.3	48.9
3	0	0	0	5.2	0.5	2.8	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0.2	40.6	20.4	0.1	5.0	2.5	0.1	0	0.1
7	0	4.0	2.0	0	0	0	0	0	0
8	5.6	14.1	9.8	4.3	5.0	4.6	0.1	75.6	37.8
9	22.5	0.1	11.3	0	12.9	6.4	3.5	2.5	3.0
10	5.6	39.8	22.7	68.4	10.5	39.4	40.2	13.9	27.0
11	0	0	0	0.1	0.5	0.3	0	5.9	3.0
12	0	0	0	0	0	0	6.0	0	3.0
13	0	0	0	0	0.3	0.1	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	4.4	2.2	22.2	0.3	11.3	19.6	8.3	13.9
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	4.0	2.0	0.1	0.3	0.2	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	4.0	2.0	0	0	0	0	0	0
22	24.4	0	12.2	2.0	0.3	1.2	17.3	0.1	8.7
23	0	0	0	0	0	0	0	0	0
24	55.4	55.1	55.2	35.6	36.2	35.9	25.6	25.4	25.5
25	22.3	22.2	22.2	12.3	12.4	12.3	24.5	24.3	24.2
26	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0

Table 2d, (cont.)

Starting day no.	797	798	806	798	813	820	812
Sample period days.	1	1	1	14	1	1	14
Species			Sample g day^{-1}				
group				Mean			Mean
no.	A	A	A		A	A	
1	25.0	9.8	5.5	13.4	0	0	0
2	19370	7632	4243	10415	2095	1109	1602
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0
6	0	0	0	0	0	0	0
7	75.0	29.5	16.4	40.3	0	0	0
8	349.9	137.9	76.7	188.2	140.9	74.6	107.8
9	0	0	0	0	0	0	0
10	1075	423.4	235.4	577.8	325.8	172.5	249.2
11	1600	630.2	350.4	860.1	281.7	149.2	215.5
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0	0	0	0	193.7	102.5	148.1
23	0	0	0	0	0	0	0
24	6948	2738	1522	4403	577.5	305.7	441.6
25	1025	403.7	224.5	551.0	237.3	125.6	181.5
26	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0

Table 2e.

Average rate of collection of material (g day^{-1}) on the top half of the middle screen, January - September 1970.

Species group	14 day sample periods starting day no.										
no.	13	27	42	56	70	84	98	112	126	140	154
1	23.0	18.1	26.2	38.9	50.9	36.1	28.2	60.3	40.4	14.4	23,0
2	171.8	414.1	623.5	609.3	726.8	238.1	89.6	91.1	67.5	3.8	0.9
3	23.6	32.3	11.2	214.6	9.9	2.3	2.4	0	0	0	0
4	0	4.5	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	82.3	46.9	39.9	26.0	12.4	17.1	25.2	43.0	56.2	57.4	49.9
7	66.5	24.1	16.6	41.8	58.3	6.5	0	0	0	4.5	0.7
8	0	0	6.1	0	0	2.8	0	4.1	2.8	0	0
9	44.3	48.6	37.1	31.2	70.6	9.1	4.7	7.1	35.1	3.5	0.5
10	214.3	149.2	180.7	87.2	97.1	20.4	21.6	17.2	16.1	15.3	7.8
11	20.3	23.3	10.5	5.4	2.0	0	2.8	0	0	0	0
12	32.9	3.3	0.4	3.1	1.7	1.1	0	3.5	0	3.5	4.3
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	34.0	5.9	3.4	0.6	0	0	0	0.6	4.0	14.3	7.0
16	0	12.3	3.2	0	0	0	0	0.8	0	0	0
17	0	0	2.7	0	0	3.0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	15.0	9.5	50.5	6.7	4.7	4.5	2.3	0	0.7	0	0
20	0	0	0	0	0	0	0	0	0	0	0.4
21	0	0	0	0	0	0	0	0	0	0	0
22	0.9	0.2	2.9	2.8	6.0	14.4	35.6	27.2	7.9	5.2	0
23	0	1.3	14.3	0	1.8	0	0	0	0	0	0
24	402.5	154.5	350.0	226.1	200.8	106.7	94.8	50.9	44.5	21.5	9.2
25	0	0	0	0	0	0	0	0	0	0	0
26	175.7	18.3	59.8	5.8	0	25.5	0	0	0	0	0
27	0.9	0	2.6	3.2	7.9	2.1	0	0	0	0	0

Table 2e. (cont.)

Species group no.	14 day sample periods starting day no.						
	168	182	196	210	224	Sum	%
1	31.5	32.1	15.7	8.4	13.5	460.7	5.6
2	4.8	2.6	0.5	0	0.5	3044.9	36.9
3	0	0	0	0	0	296.3	3.6
4	0	0	0	0	0	4.5	0.1
5	0	0	0	0	0	0	0
6	43.5	26.5	30.0	13.7	33.5	603.5	7.3
7	0.9	0.3	0.1	0.1	0	220.4	2.7
8	0.2	0	0	0	0	16.0	0.2
9	2.2	0.9	1.0	0.4	0.9	297.2	3.6
10	3.3	1.9	2.3	5.0	4.8	844.2	10.2
11	0	1.3	0	0	0	65.6	0.8
12	2.0	0	0.3	0	0	56.1	0.7
13	0	0	0	0.5	1.4	1.9	0
14	0	0	0	0	0	0	0
15	3.6	0.9	1.6	0.7	2.8	79.4	1.0
16	0	0	0	0	0	16.3	0.2
17	0	0	0	0	0	5.7	0.1
18	0	0	0	0	0	0	0
19	0	0	0	0	0	93.9	1.1
20	0	0	0	0	0	0.4	0
21	0	0	0	0	0	0	0
22	0	0	0.2	0.1	0.3	103.7	1.3
23	0	0	0.3	0	0	17.7	0.2
24	8.5	4.9	8.0	2.6	23.0	1708.5	20.8
25	0	1.8	2.3	2.4	1.9	8.4	20.8
26	0	0	0	0	0	285.1	3.5
27	0	0	0	0	0	16.7	0.2
						8247.1	

Table 2f.

Average rate of collection of material (g day^{-1}) on the bottom half of the middle screen, January - September 1970.

Species group no.	14 day sample periods starting day no.										
	13	27	42	56	70	84	98	112	126	140	154
1	15.2	7.2	28.8	23.9	19.7	31.5	3.4	28.1	20.9	12.9	19.1
2	178.8	469.4	676.8	688.7	527.7	272.2	165.2	74.6	98.6	22.2	6.9
3	79.1	0.5	3.7	8.2	9.5	1.0	0	0	0	0	0
4	0	0.5	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	20.1	10.0	12.2	17.9	0	6.7	8.9	39.5	17.8	24.7	53.6
7	9.7	6.4	8.5	7.3	5.0	1.0	0	0	0	0.6	2.2
8	11.2	0	5.8	0	0	0	0.3	4.8	9.4	0	0
9	25.9	17.2	120.5	19.0	20.7	4.0	0.2	5.7	0.3	3.2	0.8
10	218.3	65.3	122.3	78.8	26.9	8.2	0.6	13.3	21.7	7.9	4.1
11	96.0	61.2	8.6	9.1	0	0	0	4.7	2.4	0	0
12	49.3	2.7	1.2	0.7	0	0	0	0	0	1.1	1.6
13	0	2.5	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	42.5	1.1	2.4	0	0	0	0	0	0	4.3	0.9
16	0	12.5	1.9	0	0	0	0	0	0	0	0
17	0	0.9	3.1	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	4.5	8.0	6.9	13.1	3.2	0.7	0.5	0	0	3.0	0
20	9.2	0.1	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0.7	0.8	0.5	0	5.4	0.4	5.2	0	0	0.7
23	0	0	0	0	0.9	0	0	0	0	6.0	0
24	189.9	219.4	208.8	347.7	381.6	90.2	105.4	121.6	72.1	39.1	25.7
25	0	0	0	0	0	0	0	0	0	0	0
26	89.2	65.5	11.6	19.5	0	4.9	0	72.6	97.8	34.2	0
27	0	0	0	0	0	0	0	0	0	6.2	0

Table 2f. (cont.)

Species group no.	14 day sample periods starting day no. 168	182	196	210	224	Sum	%
1	19.7	31.3	6.5	7.6	18.6	294.4	4.0
2	7.5	7.3	0.9	0.3	0	3189.8	42.8
3	0	0	0	0	0	102.0	1.4
4	0	0	0	0	0	0.5	0
5	0.2	0	0	0	0	0.2	0
6	19.0	21.0	0	9.0	43.0	303.4	4.1
7	0.3	0	0.1	0.3	1.9	43.3	0.6
8	0	0	0.6	0	0	32.1	0.4
9	1.1	0.7	0.9	0.3	1.9	222.4	3.0
10	0	1.4	0.9	0.3	1.2	571.2	7.7
11	0	0.2	0	0.3	4.5	187.0	2.5
12	0.9	0.7	0	0	0	58.2	0.8
13	0	0	0.6	0	0	3.1	0
14	0	0	0	0	0	0	0
15	0.6	1.1	7.1	0.3	0	60.3	0.8
16	0.3	0	0.6	0	0	15.3	0.2
17	0	0	0	0	0	4.0	0.1
18	0	0	0.1	0	0	0.1	0
19	0.8	0	0	0	0	40.7	0.5
20	0	0	18.0	0	0	27.3	0.4
21	0	0	0	0	0	0	0
22	0.1	0.6	0	0.1	0	14.5	0.2
23	0	0	0.6	0	0	7.5	0.1
24	8.0	9.8	11.9	5.3	16.0	1852.5]	25.1
25	0	3.5	3.7	2.8	3.2	13.2]	-
26	0	0	0.1	0	0	395.4	5.3
27	0.7	0	0	0	0	6.9	0.1
						7445.3	

Table 3a.

Mean dry weight, (kg day^{-1}), ash-free dry weight, (kg day^{-1}) and inorganic Carbon weight, (g day^{-1}) for material collected at the lower screen and mean discharge 1970 - 2 (1 - 999.)

14-day sample period starting day no.	Monthly mean discharge		Daily mean dry weight	Percentage			Daily mean		
				Organic	Ash	Inorganic	Organic	Ash	Inorganic
	m^3sec^{-1}	Velocity $m\ sec^{-1}$	kg				kg	kg	g
1	0.228	0.32	1.24	76	24	-	0.94	0.30	-
13	0.278	0.30	1.00	73	27	1.4	0.73	0.27	14
27	0.278	0.28	0.39	67	33	1.6	0.26	0.13	6
42	0.300	0.24	0.30	67	33	1.3	0.20	0.10	4
56	0.300	0.24	0.27	66	(34)	1.0	0.18	0.09	3
70	0.256	0.16	0.24	60	40	-	0.14	0.09	-
84	0.256	0.16	0.18	67	33	1.8	0.12	0.06	3
98	0.290	0.13	0.17	67	(33)	-	0.12	0.06	-
112	0.290	0.13	0.16	67	(33)	-	0.11	0.05	-
126	0.132	0.12	0.22	70	30	-	0.15	0.07	-
140	0.132	0.12	0.09	67	(33)	-	0.06	0.03	-
154	0.093	0.10	0.05	67	(33)	-	0.04	0.02	-
168	0.093	0.10	0.04	64	36	-	0.03	0.02	-
182	0.093	0.10	0.03	63	37	-	0.02	0.01	-
196	0.063	0.08	0.04	50	50	-	0.02	0.02	-
210	0.063	0.08	0.04	54	(46)	-	0.02	0.02	-
224	0.033	0.07	0.19	56	44	-	0.11	0.08	-
238	0.033	0.07	0.67	54	46	-	0.36	0.31	-
252	0.045	0.07	0.31	56	44	-	0.17	0.13	-
266	0.045	0.07	0.27	52	48	-	0.14	0.13	-
280	0.097	0.09	0.15	56	44	-	0.08	0.07	-
294	0.097	0.09	1.23	64	(36)	-	0.79	0.44	-
308	0.127	0.12	1.04	60	40	2.4	0.62	0.42	25
322	0.127	0.12	0.82	71	29	1.6	0.58	0.24	13
336	0.216	0.25	0.39	65	35	1.7	0.26	0.14	7
350	0.216	0.25	0.15	71	29	1.5	0.10	0.04	2
364	0.216	0.25	0.44	68	32	(1.4)	0.30	0.14	6
377	0.307	0.34	0.50	74	26	(1.4)	0.37	0.13	7

Table 3a. (cont.)

14-day sample period starting day no.	Monthly mean discharge	Velocity	Daily mean dry weight	Percentage			Daily mean		
	$m^3 sec^{-1}$	$m\ sec^{-1}$	kg	Organic	Ash	Inorganic	Organic kg	Ash kg	Inorganic g
392	0.307	0.34	0.29	73	27	1.4	0.21	0.08	4
406	0.245	0.20	0.15	76	24	(1.2)	0.12	0.04	2
420	0.245	0.20	0.12	71	29	1.0	0.08	0.03	1
434	0.182	0.15	0.09	75	25	1.2	0.07	0.02	1
448	0.182	0.15	0.05	77	23	-	0.04	0.01	-
462	0.147	0.12	0.09	78	22	-	0.07	0.02	-
476	0.147	0.12	0.11	57	43	-	0.06	0.05	-
490	0.080	0.11	0.07	59	41	-	0.04	0.03	-
504	0.080	0.11	0.05	70	30	-	0.03	0.01	-
518	0.080	0.10	0.13	55	45	-	0.07	0.06	-
532	0.080	0.09	0.20	52	48	-	0.10	0.10	-
546	0.080	0.09	0.13	50	50	-	0.07	0.07	-
560	0.048	0.08	0.21	57	43	-	0.12	0.09	-
574	0.048	0.08	1.06	63	37	-	0.67	0.39	-
588	0.027	0.08	1.16	60	40	-	0.70	0.46	-
602	0.027	0.08	0.90	62	38	-	0.56	0.34	-
616	0.017	0.06	0.35	56	44	-	0.20	0.15	-
630	0.017	0.06	0.32	63	37	-	0.20	0.12	-
644	0.018	0.09	0.12	67	33	-	0.08	0.04	-
658	0.018	0.09	0.07	68	32	1.3	0.05	0.02	1
672	0.018	0.09	0.04	68	32	1.3	0.03	0.01	1
686	0.030	0.15	0.05	70	30	(1.2)	0.04	0.02	1
700	0.030	0.15	0.06	71	29	(1.2)	0.05	0.02	1
714	0.075	0.25	0.22	78	22	1.2	0.17	0.05	3
728	0.075	0.25	0.72	77	23	1.0	0.56	0.17	7
742	0.203	0.30	1.94	78	22	1.4	1.51	0.43	27
756	0.203	0.30	1.47	68	32	2.5	1.00	0.47	37
770	0.352	0.37	2.82	65	(35)	(2.5)	1.83	0.99	71
784	0.352	0.37	4.47	59	41	2.7	2.64	1.83	121
798	0.360	0.25	5.10	60	40	2.4	3.06	2.04	122
812	0.360	0.25	1.45	67	33	1.5	0.97	0.48	22
826	0.255	0.15	0.51	66	34	1.6	0.33	0.17	8

Table 3a, (cont.)

14-day sample period starting day no.	Monthly mean discharge		Daily mean dry weight	Percentage			Daily mean		
		Velocity		Organic	Ash	Inorganic	Organic	Ash	Inorganic
	m^3sec^{-1}	$m\ sec^{-1}$	kg				kg	kg	g
840	0.255	0.15	0.21	64	36	1.6	0.14	0.08	3
854	0.255	0.15	0.17	73	27	(1.5)	0.13	0.05	3
868	0.160	0.12	0.21	68	32	1.4	0.15	0.07	3
882	0.160	0.12	0.13	68	32	1.4	0.09	0.04	2
896	0.081	0.10	0.13	68	32	1.5	0.09	0.04	2
910	0.081	0.10	0.10	67	33	1.8	0.07	0.03	2
924	0.035	0.09	0.75	69	31	1.7	0.05	0.02	1
938	0.035	0.09	0.20	67	33	1.7	0.14	0.07	3
952	0.032	0.06	0.24	69	31	1.9	0.16	0.07	4
966	0.032	0.06	0.23	62	38	2.2	0.14	0.09	5
980	0.031	0.08	0.40	63	37	2.0	0.25	0.15	8

Note

- Days 1 - 251, mean values for two or three sub-samples of dry and ash weights.
- Daily ash weight means for 14 day periods between days 294 - 335.
- Exceptions to sample periods days 1 - 12 and 980 - 999.
- Brackets indicate incomplete representation of sub-samples.

Table 3b.

Total weight of species groups for years 1970 - 2, from the lower screen.

Species group no.	Year 1970 (13)- 349 g	%	Year 1971 350 - 713 g	%	Year 1972 714 -(999) g	%
1	37 902	32.4	40 256	41.1	10 457	3.6
2	820	0.7	14	0	94 671	32.7
3	120	0.1	0	0	225	0.1
4	21	0	265	0.3	0	0
5	544	0.5	223	0.2	8 425	2.9
6	21 511	18.4	13 423	13.7	9 852	3.4
7	168	0.1	71	0.1	1 596	0.6
8	1 263	1.1	1 769	1.8	12 355	4.3
9	2 849	2.4	1 830	1.9	4 634	1.6
10	3 449	3.0	488	0.5	33 243	11.5
11	5 985	5.1	210	0.2	14 118	4.9
12	315	0.3	0	0	13 079	4.5
13	0	0	40	0	1 583	0.5
14	0	0	0	0	1 614	0.6
15	357	0.3	153	0.2	0	0
16	48	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	105	0.1	0	0	1 897	0.7
20	0	0	0	0	0	0
21	0	0	0	0	0	0
22	1 632	1.4	3 012	3.1	2 621	0.9
23	43	0	0	0	0	0
24	28 427	24. 3	14 385	14.7	55 404	19.2
25	6 067	5.2	19 803	20.2	22 070	7.6
26	4 073	3.5	2 030	2.1	1 281	0.4
27	1 323	1.1	0	0	0	0
	117 022		97 972		289 125	

Table 3c.

Average rate of collection of material (g day^{-1}) on the lower screen sorted into species 1970 - 2.

Species group no.	14 day sample periods starting day no.										
	13	27	42	56	70	84	98	112	126	140	154
1	50.4	19.7	37.4	140.2	114.5	78.3	32.3	59.2	125.4	53.9	37.3
2	28.7	4.1	6.0	1.3	0	0	0.1	0.1	0	0	0.1
3	0	0	0	0	0	0	0	0	0	0	0
4	1.3	0.1	0.1	0	0	0	0	0	0	0	0
5	1.3	1.2	0.6	0	0	0	0	0	1.6	1.5	0.6
6	47.5	10.6	9.8	2.4	1.3	0.8	0.1	0.1	1.1	0.3	0.4
7	3.3	5.6	2.8	0	0	0	0	0	0	0	0
8	28.5	10.9	12.3	6.5	6.3	2.5	3.3	1.7	2.8	1.6	0.5
9	68.7	10.3	11.9	26.7	47.5	5.5	1.3	0	3.5	1.7	0.8
10	158.8	18.3	11.1	2.2	1.7	0.6	15.5	14.6	15.3	6.2	1.5
11	229.0	27.0	14.4	0.5	0.7	0	0.5	1.1	1.8	0.2	0.6
12	18.8	1.0	0.6	0	0	0	0	0.2	0	0.1	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	4.5	0.1	0.1	0	0	0	0	0	0	0	0
16	0	0	1.1	0	0	0	0	2.3	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	1.5	3.9	2.1	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	8.0	0.7	2.1	1.3	1.9	5.6	8.2	6.1	6.4	1.9	0.3
23	0	0	0	0	0	0	0	0	0	0	0
24	283.3	62.6	86.9	108.4	68.4	88.3	30.7	56.7	51.2	23.1	15.7
25	0	0	0	0	0	0	0	0	0	0	0
26	197.7	30.3	19.0	19.3	3.3	0	3.6	11.3	4.1	1.5	0.5
27	0	0	0	0	0	0.1	79.0	10.1	0.2	0	0

Table 3c. (cont.)

Species group	14 day sample periods starting day no.										
no.	168	182	196	210	224	238	252	266	280	294	308
1	18.0	19.9	7.3	2.8	60.7	319.9	113.7	137.6	37.4	639.9	320.5
2	0	0	0.1	0	0.5	0	1.2	0	0	14.9	1.5
3	0	0	0	0	8.6	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0.5	0.4	0.6	0.3	9.6	5.5	0.5	0.3	1.5	0	0
6	3.3	6.9	6.5	10.1	65.1	131.6	63.2	86.4	35.1	353.8	321.2
7	0	0	0	0	0	0	0	0	0	0	0
8	0.3	0	0	0.1	3.1	1.4	1.2	0	0	2.8	3.9
9	0	0.7	0.3	0.2	3.4	7.7	1.2	0.3	1.5	2.8	3.9
10	0	0	0	0.1	0.3	0.2	0	0	0	0	0
11	0	0	0	0	0	0	2.1	0	2.2	2.8	69.6
12	0	0	0	0	0.4	0	1.4	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	1.4	0	5.2	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0.4	0.1	0.1	0.7	3.4	2.8	31.7	0.1	29.6	2.8	2.4
23	0	0	0	0	0	3.1	0	0	0	0	0
24	17.6	16.1	15.8	19.1	38.6	146.5	69.8	54.8	41.5	185.0	234.2
25	3.1	3.3	2.7	7.3	13.4	56.2	28.6	7.8	0.3	42.5	108.0
26	0.3	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	5.1	0	0	0

Table 3c. (cont.)

Species group no.	14 day sample periods starting day no.										
	322	336	350	364	378	392	406	420	434	448	461
1	158.5	122.5	55.7	213.1	187.6	189.2	89.7	88.8	42.5	27.9	87.1
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0.9	18.0	0	0	0	0	0	0	0
5	12.9	0	0	0	10.5	0	0	0	0.3	0.4	4.7
6	268.3	110.6	38.1	104.0	127.8	0.1	0	0	0	0	27.0
7	0	0.3	0	0	0	0	0	0	0	0	0
8	0	0.5	4.3	15.4	6.6	11.6	5.9	3.0	0.8	1.2	11.6
9	2.8	0.8	8.8	24.1	0	10.4	9.9	0.8	0.7	1.8	7.7
10	0	0	1.0	11.8	0	10.7	0	0	2.6	0.7	4.7
11	21.4	53.6	1.1	11.9	0	0.9	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	14.2	1.0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	1.3	22.3
23	0	0	0	0	0	0	0	0	0	0	0
24	153.0	63.2	30.9	42.0	57.5	16.3	26.7	20.2	14.5	10.2	40.7
25	120.2	40.0	9.6	25.2	26.9	45.9	13.2	4.0	7.8	4.5	38.7
26	0	0	0	0	91.2	12.6	11.7	1.3	19.7	8.5	0
27	0	0	0	0	0	0	0	0	0	0	0

Table 3c. (cont.)

Species group no.	14 day sample periods starting day no.										
	476	490	504	518	560	574	588	602	616	644	658
1	58.2	35.1	18.7	31.3	3.8	453.7	647.0	357.3	79.8	44.8	24.1
2	0	1.0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	0	8.4	8.8	16.1	59.1	188.7	70.1	109.6	67.3	14.2	11.6
7	0	3.1	0.1	1.9	0	0	0	0	0	0	0
8	2.3	3.1	3.6	5.5	5.7	4.0	5.3	9.9	7.3	2.7	2.5
9	8.1	0.7	0.2	0	0.2	0	0	28.6	5.6	5.0	7.5
10	0	0	0.3	0	0	0	0	0	0	0	0.7
11	0	0	0	1.1	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	3.2	0.3	0	0	0	0	0	0	6.2	0.2
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	2.2	6.4	0	0	0	0	0	0	80.8	13.9	3.8
23	0	0	0	0	0	0	0	0	0	0	0
24	21.0	4.9	5.0	43.3	98.5	220.9	159.2	138.4	21.8	5.9	12.4
25	17.1	8.4	12.9	55.2	193.1	192.8	299.0	260.8	73.1	26.0	6.1
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Note

- 42 day sample starting, day no. 518.
- 28 day sample starting, day no. 616.
- Material from middle screen returned after day 644.

Table 3c. (cont.)

Species group no.	14 day sample periods starting day no.										
	672	686	700	714	728	742	756	770	784	798	812
1	16.0	21.6	22.6	65.6	2.8	3.8	2.0	372.9	66.4	24.1	3.1
2	0	0	0	0	15.2	23.0	31.6	799.1	2006	2721	743.4
3	0	0	0	0	0	0	0	0	0	16.1	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	601.8	0
6	9.8	11.9	18.9	36.3	162.8	53.8	2.0	122.9	0	0	0
7	0	0	0	0	0	19.2	0	0	0	84.2	0
8	5.1	0.2	1.4	20.3	64.9	88.3	103.9	131.1	119.6	0	134.9
9	0.2	2.0	2.8	12.8	4.1	0	33.6	77.9	19.9	90.8	0
10	0	1.6	0.8	43.7	172.5	307.1	144.2	409.8	471.7	663.2	69.1
11	0	0	0	3.2	118.7	305.6	31.6	225.4	192.6	38.1	31.4
12	0	0	0	0	0	428.5	436.9	0	0	6.0	62.8
13	0	0	2.8	0	0	107.1	0	0	0	6.0	0
14	0	0	0	0	0	107.1	0	0	0	6.0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	16.6	0	31.6	0	0	52.2	31.4
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	1.8	0.6	1.2	10.7	0	3.8	2.0	69.7	0	4.0	44.0
23	0	0	0	0	0	0	0	0	0	0	0
24	2.0	7.2	6.2	12.8	98.6	289.7	421.5	406.4	1189	900.0	288.0
25	2.9	9.2	9.0	13.5	67.8	206.0	228.8	210.3	279.2	250.0	75.3
26	0	0	0	0	0	0	0	0	0	52.2	0
27	0	0	0	0	0	0	0	0	0	0	0

Table 3c. (cont.)

Species group no.	14 day sample periods starting day no.											
	827	840	845	868	882	896	910	924	938	952	966	980
1	18.4	28.5	17.4	17.3	4.5	31.6	38.8	8.3	43.6	119.0	123.0	128.8
2	183.1	43.6	13.6	47.9	37.7	20.1	10.6	2.3	37.7	2.3	8.6	13.9
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0.8	0	31.7	26.8	20.1	25.6	39.1	39.9	42.5	40.7	58.7
7	0	0.8	9.8	0	0	0	0	0	0	0	0	0
8	43.0	68.9	15.1	15.8	16.0	12.3	5.3	9.0	8.9	11.6	7.1	6.5
9	14.3	0	0	0	0	9.3	0	0	6.7	0	0	1.6
10	8.4	20.6	22.7	28.8	5.1	0	0	1.5	1.5	4.6	0	0
11	36.8	0	17.4	0	1.9	0	1.8	0	0	3.9	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	2.2	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	3.7	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	21.5	0	0	0	0	0	1.8	0	9.6	19.3	0	0.8
23	0	0	6.8	0	0	0	0	0	0	0	0	0
24	94.6	27.6	10.9	29.8	22.5	19.8	4.6	7.9	23.0	23.2	32.5	55.0
25	28.8	21.3	22.0	42.8	14.4	20.4	13.5	7.8	29.9	11.0	18.9	14.7
26	0	0	39.3	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 3d.

Average rate of collection of material (g day^{-1}) on the top and bottom halves and during cleaning, of the lower screen, combined to give 14 day averages.

Key

Sample code (see text). All samples are corrected to average rate of collection of material during period stated.

T = Top half of screen.

B = Bottom half of screen.

W = Wash out of material onto second screen pairs during cleaning operations.

A = No division of material into fractions, as above.

T1, T2, T3.

B1, B2, B3.

A1, A2, A3. = Sub-samples from top, bottom and undivided total screened material.

$\bar{T}$, $\bar{B}$, $\bar{A}$. = Mean values of sub-samples.

Sum = Sum of fractions of screen samples giving total for each species group.

Mean = Mean value for 14 day periods, weighted if necessary for irregular sorting or sampling, results used in Table 2c.

Table 3d. (cont.)

Starting day no. 13

Sample period days. 7

Species group no.	Sample g day^{-1}										
	T1	T2	T3	$\bar{T}$	B1	B2	B3	B4	B5	$\bar{B}$	Sum
1	52.6	66.8	63.5	61.0	0.2	3.6	5.1	87.0	4.1	20.0	81.0
2	5.9	28.4	5.3	13.2	9.9	18.7	17.3	134.5	8.0	37.7	50.9
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0
6	27.6	37.5	30.7	31.9	6.0	16.9	25.0	19.5	11.5	15.8	47.7
7	0	0	0	0	0	0	0	0	0	0	0
8	34.6	22.9	38.6	32.0	40.0	32.1	10.2	16.6	7.8	21.3	53.3
9	65.9	73.4	68.9	69.4	0	0	0	0.4	3.3	0.7	70.1
10	117.4	66.5	92.3	92.1	226.3	154.7	200.9	9.8	260.7	170.5	262.6
11	25.6	14.9	29.4	23.3	65.2	108.1	102.0	95.1	148.7	103.8	337.1
12	9.4	3.0	6.9	6.4	13.8	16.9	54.1	12.3	22.5	23.9	30.3
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0.1	4.8	8.0	4.3	4.4	15.5	4.6	0	6.7	6.2	10.5
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	2.7	7.6	0	3.4	7.1	0	13.8	0	17.1	7.6	10.7
23	1.9	0	0	0.6	0	0	0	0	0	0	0
24	161.3	155.7	159.4	158.8	248.1	224.0	189.5	303.9	210.6	235.2	394.0
25	0	0	0	0	0	0	0	0	0	0	0
26	41.7	65.2	43.7	50.2	277.7	307.9	275.9	219.4	197.7	255.7	305.9
27	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	21			13	27			35			27
Sample period days.	7			14	7			7			14
Species	Sample g day^{-1}										
group				Mean							Mean
no.	T	B	Sum		T	B	Sum	T	B	Sum	
1	13.4	6.4	19.8	50.4	34.7	4.3	19.5	21.2	18.4	19.8	19.7
2	5.2	1.2	6.4	28.7	5.9	2.8	4.3	0.9	6.8	3.9	4.1
3	0	0	0	0	0	0	0	0	0	0	0
4	0	2.6	2.6	1.3	0	0.2	0.1	0	0	0	0.1
5	0	2.6	2.6	1.3	0	2.0	1.0	2.7	0	1.3	1.2
6	32.6	14.7	47.3	47.5	15.0	2.9	9.0	12.8	11.4	12.1	10.6
7	6.6	0	6.6	3.3	0	0	0	22.4	0	11.2	5.6
8	1.0	2.6	3.6	28.5	28.3	3.4	15.9	0	11.7	5.8	10.9
9	57.5	10.7	67.2	68.7	23.5	0.8	12.2	16.3	0.2	8.3	10.3
10	46.2	18.8	65.0	158.8	25.7	0	12.8	30.5	16.9	23.7	18.3
11	49.2	73.2	122.4	229.8	14.2	36.6	25.4	21.2	35.9	28.6	27.0
12	0.6	6.7	7.3	18.8	0.6	1.6	1.1	0	1.6	0.8	1.0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0.9	1.9	2.8	4.5	0	0.5	0.2	0	0	0	0.1
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	1.8	1.2	3.0	1.5	0	15.6	7.8	0	0	0	3.9
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	5.2	0	5.2	8.0	0	0.5	0.2	0.1	2.4	1.2	0.7
23	0	0	0	0	0	0	0	0	0	0	0
24	133.8	38.7	172.5	283.3	72.9	48.8	60.9	51.7	76.7	64.2	62.6
25	0	0	0	0	0	0	0	0	0	0	0
26	22.5	67.0	89.5	197.7	33.6	47.0	40.3	11.0	29.4	20.2	30.3
27	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	42			49			42
Sample period days	7			7			14
Species group no.	Sample g day^{-1}						Mean
	T	B	Sum	T	B	Sum	
1	27.8	20.2	24.0	58.7	51.5	55.1	37.4
2	4.8	1.8	3.3	3.5	12.4	7.9	6.0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0.1
5	0	0	0	0	0	0	0.6
6	2.6	3.5	3.0	3.3	14.7	9.0	9.8
7	0	0	0	0	0	0	2.8
8	92.7	7.1	49.9	19.0	8.1	13.6	12.3
9	7.7	0	3.8	22.0	5.0	13.5	11.9
10	8.5	5.2	6.9	4.6	3.2	3.9	11.1
11	2.2	13.9	8.1	0.5	3.0	1.7	14.4
12	0	0	0	0	0.2	0.1	0.6
13	0	0	0	0	0	0	0
14	0	0.1	0.1	0	0	0	0
15	0	0.3	0.2	0	0	0	0.1
16	0	0	0	0	4.2	2.1	1.1
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0.3	0	0.2	2.1
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0.8	0.5	0.6	2.5	1.0	3.5	2.1
23	0	0	0	0	0	0	0
24	12.0	39.8	25.9	41.0	70.2	111.2	86.9
25	0	0	0	0	0	0	0
26	26.0	21.4	23.7	5.9	1.7	7.6	19.0
27	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	56			63			56	70		
Sample period days.	7			7			14	14		
Species group no.	Sample g day^{-1}						Mean			Mean
	T	B	Sum	T	B	Sum		T	B	Sum
1	105.3	61.4	166.7	91.9	21.9	113.8	140.2	69.8	44.7	114.5
2	0.5	1.1	1.6	0.5	0.5	1.0	1.3	0	0	0
3	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0
6	0.5	4.2	4.7	0	0.1	0.1	2.4	0.3	1.0	1.3
7	0	0	0	0	0	0	0	0	0	0
8	6.2	1.2	7.4	3.2	2.4	5.6	6.5	5.5	0.8	6.3
9	44.5	1.7	46.2	6.3	0.8	7.1	26.7	42.6	4.9	47.5
10	1.6	2.2	3.8	0.5	0	0.5	2.2	1.3	0.4	1.7
11	0.8	0.2	1.0	0	0	0	0.5	0.1	0.6	0.7
12	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0
22	1.5	0	1.5	0	1.1	1.1	1.3	1.9	0	1.9
23	0	0	0	0	0	0	0	0	0	0
24	35.4	88.6	124.0	45.8	46.9	92.7	108.4	13.1	55.3	68.4
25	0	0	0	0	0	0	0	0	0	0
26	8.6	0	8.6	30.0	0	30.0	19.3	3.3	0	3.3
27	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	84	93		84			84	98	98	105		98
Sample period days.	7	7		14			14	14	7	7		14
Species group no.	T	T	$\bar{T}$	B1	B2	$\bar{B}$	Mean Sum	T	B	B	$\bar{B}$	Mean Sum
			Sample g day^{-1}									
1	70.6	19.4	52.3	26.3	25.7	26.0	78.3	22.8	12.6	6.4	9.5	32.3
2	0	0.1	0	0	0	0	0	0	0	0.1	0.1	0.1
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0	0	0	0
6	0	0	0	0.8	0.7	0.8	0.8	0	0	0.1	0.1	0.1
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0.1	0.5	0.2	2.1	2.4	2.3	2.5	2.3	1.8	0.2	1.0	3.3
9	8.0	0.9	5.5	0	0	0	5.5	0.4	1.7	0.1	0.9	1.3
10	0.3	1.0	0.6	0	0	0	0.6	9.2	9.4	3.2	6.3	15.5
11	0	0.1	0	0	0	0	0	0.1	0	0.7	0.4	0.5
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	2.8	10.4	5.5	0.1	0.1	0.1	5.6	3.3	8.9	0.8	4.9	8.2
23	0	0.1	0	0	0	0	0	0	0	0	0	0
24	12.4	12.0	12.3	75.7	76.2	76.0	88.3	12.4	25.0	11.5	18.3	30.7
25	0	0	0	0	0	0	0	0	0	0	0	0
26	0	0	0	0	0	0	0	2.3	0	2.5	1.3	3.6
27	0	0.2	0.1	0	0	0	0.1	34.0	80.9	9.1	45.0	79.0

Table 3d. (cont.)

Starting day no.	112	118	124		112	118	124		112
Sample period days.	6	6	2		6	6	2		14
Species			Sample g day^{-1}						
group no.	T	T	T	$\bar{T}$	B	B	B	$\bar{B}$	Mean Sum
1	32.8	36.4	62.4	38.6	7.0	9.5	94.5	20.6	59.2
2	0	0	0.6	0.1	0	0	0	0	0.1
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0	0	0	0	0.2	0	0	0.1	0.1
7	0	0	0	0	0	0	0	0	0
8	0.7	0.3	4.5	1.1	0.8	0	1.6	0.6	1.7
9	0	0	0	0	0	0.1	0	0	0
10	4.0	12.7	15.7	9.4	1.8	1.8	25.3	5.2	14.6
11	0	0	0.5	0.1	4.3	0.4	4.7	1.0	1.1
12	0.4	0	0	0.2	0	0	0	0	0.2
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	16.0	2.3	0	0	0	0	2.3
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	6.8	0.4	9.7	4.5	2.0	1.5	0.9	1.6	6.1
23	0	0	0.2	0	0	0	0	0	0
24	29.4	39.6	47.2	36.3	20.4	9.4	53.6	20.4	56.7
25	0	0	0	0	0	0	0	0	0
26	5.7	11.1	0	7.2	0.5	4.1	14.8	4.1	11.3
27	18.8	0	0	8.1	4.7	0	0	2.0	10.1

Table 3d. (cont.)

Starting day no.	126	128	130	132	134	138	126	126	128	130	132	136
Sample period days.	2	2	2	2	4	2	14	2	2	2	4	2
Species group no.			Sample g day^{-1}									
	T	T	T	T	T	T	$\overline{T}$	B	B	B	B	B
1	67.4	96.4	60.7	52.7	106.1	128.1	88.2	36.2	105.4	6.5	22.9	37.0
2	0	0	0	0.2	0	0	0	0.2	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	11.0	1.6	0	0	0	0	0
6	2.2	0	0	0	2.2	0	1.0	0.6	0	0	0	0
7	0	0	0	0	0	0	0	0	0	0	0	0
8	5.9	3.0	3.8	1.9	0.3	0.4	2.2	1.4	0	0.4	0.7	0.8
9	0.7	1.1	2.4	11.0	1.7	1.2	2.8	0	4.6	0	0	0
10	18.7	5.9	19.2	1.1	9.1	9.2	10.3	9.3	6.7	5.2	6.1	3.0
11	0.5	0.8	1.5	0	0	0.4	0.5	3.0	1.2	1.5	2.0	0.8
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	11.1	6.7	4.5	7.8	0	0	4.3	0	5.5	1.2	0	4.9
23	0	0	0	0	0	0	0	0	0	0	0	0
24	32.6	44.7	53.0	17.5	23.3	20.2	27.3	13.1	80.2	8.1	13.7	22.6
25	0	0	0	0	0	0	0	0	0	0	0	0
26	9.9	1.5	0	0	0	2.0	1.9	8.0	0	0	0	7.1
27	0	0	0	0	0	1.2	0.2	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	138	126	126	140	142	144	146	148	150	152	140
Sample period days.	2	14	14	2	2	2	2	2	2	2	14
Species group no.	Sample g day^{-1}		Mean								
	B	$\bar{B}$	Sum	T	T	T	T	T	T	T	$\bar{T}$
1	15.2	37.2	125.4	71.9	40.1	26.1	19.0	20.7	44.4	18.4	34.4
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	0	1.6	5.1	1.0	0.3	1.3	0.5	0.9	1.4	1.5
6	0	0.1	1.1	0.3	0	0	0	0	1.5	0	0.3
7	0	0	0	0.3	0	0	0	0	0	0	0
8	0	0.6	2.8	2.8	0.3	2.3	0.2	0.5	0	0.2	0.9
9	0	0.7	3.5	0.2	0.4	0.5	0	0.4	3.3	1.9	1.0
10	1.7	5.0	15.3	0	3.7	4.8	1.2	1.8	2.2	2.3	2.3
11	0.4	1.3	1.8	0	0.1	0	0	0.1	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	3.3	2.1	6.4	4.9	0.4	0.7	0.8	0	3.0	1.3	1.6
23	0	0	0	0	0	0	0	0	0	0	0
24	6.7	23.9	51.2	13.2	28.9	6.5	9.8	9.3	14.4	7.7	12.8
25	0	0	0	0	0	0	0	0	0	0	0
26	0	2.2	4.1	0.5	0	1.5	0.9	0	0	1.0	0.8
27	0	0	0.2	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	140	142	144	146	148	150	152	140	140
Sample period days.	2	2	2	2	2	2	2	14	14
Species group no.	Sample g day^{-1} B	B	B	B	B	B	B	$\bar{B}$	Mean Sum
1	27.3	20.3	16.1	16.7	12.6	26.3	17.3	19.5	53.9
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0.2	0	0	0	0	11.5
6	0	0	0	0	0	0	0	0	0.3
7	0	0	0	0	0	0	0	0	0
8	0.4	0.8	0.4	0.5	0.1	1.4	0	0.7	1.6
9	3.6	0	0	0	0	0	0	0.7	1.7
10	0.7	5.3	5.4	1.7	5.7	3.6	5.2	3.9	6.2
11	0	0.5	0.1	0.4	0.1	0	0	0.2	0.2
12	0	0	0	0	0	0.3	0.3	0.1	0.1
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	1.6	0	0	0.4	0.6	0	0	0.3	1.9
23	0	0	0	0	0	0	0	0	0
24	9.4	11.2	7.8	6.5	6.4	18.7	12.1	10.3	23.1
25	0	0	0	0	0	0	0	0	0
26	0.7	0.4	0.2	0	0.7	3.0	0	0.7	1.5
27	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	154	156	158	154	154	156	158	154	154	168		
Sample period days.	2	2	10	14	2	2	10	14	14	14		
Species group no.	Sample g day^{-1}											
	T	T	T	$\bar{T}$	B	B	B	$\bar{B}$	Mean Sum	T	$\bar{B}$	Mean Sum
1	40.9	22.0	31.3	31.3	10.4	8.8	4.6	6.0	37.3	15.8	2.2	18.0
2	0	0	0.1	0.1	0	0	0	0	0.1	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0.9	0	0	0.1	0.4	3.4	0	0.5	0.6	0.5	0	0.5
6	0	0.8	0.4	0.4	0	0	0	0	0.4	3.3	0	3.3
7	0	0	0	0	0	0	0	0	0	0	0	0
8	1.4	0.2	0.2	0.4	0.1	0.9	0	0.1	0.5	0.3	0	0.3
9	0.2	0.6	1.0	0.8	0	0	0	0	0.8	0	0	0
10	5.5	0	0.1	0.9	2.1	1.2	0.2	0.6	1.5	0	0	0
11	0.7	0	0	0.1	1.7	0	0.4	0.5	0.6	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0.4	0.3	0	0	0	0	0.3	0	0.4	0.4
23	0	0	0	0	0	0	0	0	0	0	0	0
24	11.7	8.2	7.0	7.8	10.5	8.5	7.3	7.9	15.7	12.7	4.9	17.6
25	0	0	0	0	0	0	0	0	0	1.6	1.5	3.1
26	0	0	0.5	0.4	0	0	0.2	0.1	0.5	0.3	0	0.3
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	182	184	186	188	190	192	194	182	182	184	186
Sample period days.	2	2	2	2	2	2	2	14	2	2	2
Species			Sample g day^{-1}								
group no.	T	T	T	T	T	T	T	$\bar{T}$	B	B	B
1	5.1	8.8	6.3	10.0	15.0	13.0	15.0	10.5	1.6	7.0	5.2
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0.2	0	0.2	0.5	1.0	1.0	0	0.4	0	0	0
6	1.1	1.4	2.1	3.0	5.0	3.7	5.0	3.0	0	0	3.2
7	0	0	0	0	0	0	0	0	0	0	0
8	0.1	0.1	0	0	0	0	0	0	0	0	0
9	0	0.4	0.5	0.5	1.0	1.0	1.8	0.7	0	0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0.3	0.1	0
23	0	0	0	0	0	0	0	0	0	0	0
24	4.1	2.9	2.5	2.5	8.5	13.5	19.1	7.6	3.5	7.0	3.2
25	0.5	1.4	0.9	1.7	2.2	3.5	1.6	1.7	1.1	0.9	0.5
26	0.1	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Table 3d, (cont.)

Starting day no.	188	190	192	194	182	182	196	198	200	202	204
Sample period days.	2	2	2	2	14	14	2	2	2	2	2
Species			Sample g day^{-1}								
group						Mean					
no.	B	B	B	B	$\bar{B}$	Sum	T	T	T	T	T
1	8.5	12.0	19.4	12.0	9.4	19.9	12.3	10.0	5.5	4.5	2.4
2	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0.0
5	0	0	0	0	0	0	0	0	0	1.0	0.1
6	5.0	6.5	6.5	6.2	3.9	6.9	4.0	6.3	2.0	2.0	2.2
7	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0	0	0	0.7	0	1.0	0	1.0	0
10	0	0	0	0	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0.3	0.2	0	0.1	0.1	0	0	0	0.2	0
23	0	0	0	0	0	0	0	0	0	0	0
24	6.1	13.2	8.6	17.7	8.5	16.1	10.8	9.3	11.4	4.0	3.0
25	0.6	0.7	1.0	6.6	1.6	3.3	0.9	1.2	5.2	0.8	0.6
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	206	208	196	196	198	200	202	204	206	208	196	196
Sample period days.	2	2	14	2	2	2	2	2	2	2	14	14
Species			Sample g day^{-1}									
group no.	T	T	$\bar{T}$	B	B	B	B	B	B	B	$\bar{B}$	Mean Sum
1	2.7	1.1	5.5	7.0	0.7	2.8	0.8	0.3	0.3	0.7	1.8	7.3
2	0	0	0	0	0	0	0	0	0	0.9	0.1	0.1
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0.5	0.2	0.3	0	0	0	0	0.8	1.7	0	0.3	0.6
6	6.0	3.9	3.8	3.3	2.0	6.0	2.0	1.9	3.9	0.4	2.7	6.5
7	1.0	0.1	0	0	0	0	0	0	0	0.1	0	0
8	0	0	0	0	0	0	0	0	0	0	0	0
9	0	0	0.3	0	0	0	0	0	0	0	0	0.3
10	0	0	0	0	0	0	0	0	0	0.2	0	0
11	0	0	0	0	0	0	0	0	0	0.1	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0.2	0	0.1	0	0	0	0	0	0	0	0	0.1
23	0	0	0	0	0	0	0	0	0	0	0	0
24	8.2	7.1	7.9	7.9	8.4	4.9	4.2	3.5	13.2	13.8	7.9	15.8
25	1.5	1.2	1.6	1.3	1.6	0.5	0.6	0.7	1.7	1.2	1.1	2.7
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	210	212	214	216	218	220	210
Sample period days.	2	2	2	2	2	4	14
Species	Sample g day^{-1}						
group no.	T	T	T	T	T	T	$\bar{T}$
1	3.5	1.0	1.0	0.8	0.3	3.2	1.9
2	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0.3	0.2	0.2	0.1	0.1	0.1	0.2
6	8.9	6.8	11.4	4.7	6.6	7.7	7.7
7	0.1	0	0	0	0	0	0.0
8	0	0	0	0	0.4	0	0.1
9	0.5	0.1	0.1	0.1	0	0	0.1
10	0	0	0	0	0	0	0
11	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0.2	0	0	0	0	0.3	0.1
23	0	0	0	0	0	0	0
24	2.3	6.1	10.4	4.1	6.2	11.3	7.4
25	3.2	0.1	1.6	0.9	1.2	3.1	1.9
26	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	210	212	214	216	218	220	210	210
Sample period days.	2	2	2	2	2	4	14	14
Species		Sample g day^{-1}						
group no.	B	B	B	B	B	B	$\bar{B}$	Mean Sum
1	0.1	0.1	0.3	0.2	0.9	2.4	0.9	2.8
2	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0
5	0.1	0	0	0.4	0.2	0	0.1	0.3
6	1.7	0.6	4.4	1.6	1.7	3.4	2.4	10.1
7	0	0	0	0	0	0	0	0
8	0	0	0	0	0.1	0	0	0.1
9	0	0	0	0	0	0.7	0.1	0.2
10	0	0	0	0	0.6	0	0.1	0.1
11	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0
22	0.7	0	0	1.1	0	1.2	0.6	0.7
23	0	0	0	0	0	0	0	0
24	13.9	6.1	10.9	10.2	5.5	17.5	11.7	19.1
25	15.7	2.4	1.4	1.5	1.0	7.9	5.4	7.3
26	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	224	230	232	234	224	224	230	232	234	224	224
Sample period days.	6	2	2	4	14	6	2	2	4	14	14
Species			Sample g day^{-1}								
group no.	T	T	T	T	$\bar{T}$	B	B	B	B	$\bar{B}$	Mean Sum
1	2.0	13.2	4.0	70.3	33.2	2.3	6.6	9.5	84.8	27.5	60.7
2	0	0	0	0.7	0.3	0	0	0	0.8	0.2	0.5
3	0	0	0	0	0	0	0	0	0	0	8.6
4	0	0	0	0	0	0	0	0	0	0	0
5	0.8	0	0	20.1	8.7	0.2	2.1	0.8	1.3	0.9	9.6
6	6.4	16.3	16.2	91.0	33.4	3.6	12.8	21.1	88.7	31.7	65.1
7	0	0.1	0	0	0	0	0	0	0	0	0
8	0	0	0.4	8.9	2.6	0.1	0	0.2	1.6	0.5	3.1
9	0.5	0	0.3	6.9	2.2	0	0.1	0	4.2	1.2	3.4
10	0	0	0	0	0	0	0	0	1.1	0.3	0.3
11	0	0	0	0	0	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	2.6	0.4	0.4
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0.3	3.2	1.4	0	5.7	2.9	0	2.0	3.4
23	0	0	0	0	0	0	0	0	0	0	0
24	6.9	14.2	34.1	11.2	13.7	12.4	16.7	8.5	56.1	24.9	38.6
25	1.6	3.8	1.8	8.1	4.7	3.1	4.7	3.4	21.9	8.7	13.4
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	238	244			238	252			266		
Sample period days.	6	8			14	14			14		
Species	Sample g day^{-1}										
group					Mean			Mean			Mean
no.	A	A1	A2	$\bar{A}$		A1	A2		A1	A2	
1	386.8	235.9	270.1	253.0	319.9	104.3	123.1	113.7	137.8	137.4	137.6
2	0	0	0	0	0	1.1	1.4	1.2	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	10.9	0	0	0	5.5	1.1	0	0.5	0.5	0.1	0.3
6	85.0	190.4	165.8	178.1	131.6	70.2	56.3	63.2	90.9	81.9	86.4
7	0	0	0	0	0	0	0	0	0	0	0
8	2.8	0	0	0	1.4	1.1	1.4	1.2	0	0	0
9	8.3	5.7	8.3	7.0	7.7	1.1	1.4	1.2	0.5	0.1	0.3
10	0	0.8	0	0.4	0.2	0	0	0	0	0	0
11	0	0	0	0	0	4.1	0.1	2.1	0	0	0
12	0	0	0	0	0	0	2.7	1.4	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	2.7	1.4	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	0	11.1	0	5.6	2.8	35.1	28.3	31.7	0.1	0.1	0.1
23	6.1	0	0	0	3.1	0	0	0	0	0	0
24	137.2	155.8	155.6	155.7	146.5	69.6	69.9	69.8	54.8	54.9	54.8
25	38.5	74.0	73.9	73.9	56.2	28.5	28.6	28.6	7.8	7.8	7.8
26	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	10.1	5.1

Table 3d. (cont.)

Starting day no.	280			294			308			322		
Sample period days.	14			14			14			14		
Species	Sample g day^{-1}											
group no.	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	47.8	27.0	37.4	687.6	592.3	639.9	284.3	356.7	320.5	177.8	139.2	158.5
2	0	0	0	0	29.7	14.9	3.0	0	1.5	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	1.9	1.1	1.5	0	0	0	0	0	0	25.7	0	12.9
6	26.4	40.8	35.1	318.9	388.8	353.8	290.4	351.9	321.2	139.9	396.7	268.3
7	0	0	0	0	0	0	0	0	0	0	0	0
8	0	0	0	3.3	2.3	2.8	3.0	4.8	3.9	0	0	0
9	1.9	1.1	1.5	3.3	2.3	2.8	3.0	4.8	3.9	0	5.5	2.8
10	0	0	0	0	0	0	0	0	0	0	0	0
11	4.3	0	2.2	3.3	2.3	2.8	139.1	0	69.6	25.0	17.8	21.4
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	10.4	5.2	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	27.2	32.1	29.6	3.3	2.3	2.8	0	4.8	2.4	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	41.5	41.4	41.5	185.1	184.9	185.0	234.2	234.2	234.2	291.8	214.2	253.0
25	0.3	0.3	0.3	42.5	42.5	42.5	107.9	108.0	108.0	176.8	63.6	120.2
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	336			350			364			378		
Sample period days.	14			14			14			14		
Species group no.	Sample g day^{-1} A1	A2	Mean	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	130.9	114.1	122.5	50.5	60.9	55.7	181.5	244.6	213.1	154.2	221.1	187.6
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	1.8	0.9	24.5	11.4	18.0	0	0	0
5	0	0	0	0	0	0	0	0	0	21.0	0	10.5
6	113.3	107.9	110.6	38.5	37.8	38.1	117.2	91.1	104.0	134.2	121.4	127.8
7	0	0.6	0.3	0	0	0	0	0	0	0	0	0
8	1.1	0	0.5	8.6	0	4.3	22.2	8.7	15.4	6.7	6.5	6.6
9	1.1	0.6	0.8	10.1	7.5	8.8	24.5	23.8	24.1	0	0	0
10	0	0	0	0	2.0	1.0	8.6	15.1	11.9	0	0	0
11	56.1	51.1	53.6	0.1	2.0	1.1	8.6	15.3	11.9	0	0	0
12	0	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0	0
15	0	28.4	14.2	0	2.0	1.0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0	0	0	0	0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	63.3	63.2	63.2	34.0	27.8	30.9	53.4	30.7	42.0	54.5	57.4	57.4
25	40.0	39.9	40.0	9.6	9.6	9.6	25.2	25.2	25.2	26.9	26.9	26.9
26	0	0	0	0	0	0	0	0	0	113.6	80.8	91.2
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	392			406			420		
Sample period days.	14			14			14		
Species group no.	Sample g day^{-1}								
	A1	A2	Mean	A1	A2	Mean	A1	A2	Mean
1	192.0	186.4	189.2	85.5	94.0	89.7	89.5	88.0	88.8
2	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	0	0	0	0
6	0.2	0.1	0.1	0	0	0	0.1	0	0
7	0	0	0	0	0	0	0	0	0
8	15.3	8.0	11.6	10.1	1.7	5.9	0.5	5.6	3.0
9	10.2	10.6	10.4	10.4	9.4	9.9	1.4	0.3	0.8
10	1.7	19.7	10.7	0	0	0	0	0	0
11	1.7	0	0.9	0	0	0	0	0	0
12	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0
15	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0
22	0	0	0	0	0	0	0	0.1	0
23	0	0	0	0	0	0	0	0	0
24	16.4	16.3	16.3	26.7	26.8	26.7	20.1	20.2	20.2
25	46.1	45.8	45.9	13.2	13.2	13.2	4.0	4.0	4.0
26	14.2	11.0	12.6	11.4	12.1	11.7	2.6	0	1.3
27	0	0	0	0	0	0	0	0	0

Table 3d. (cont.)

Starting day no.	434			448			798	805	798	812	819	812
Sample period days.	14			14			1	1	14	1	1	14
Species	Sample g day^{-1}											
group			Mean			Mean			Mean			Mean
no.	A1	A2		A1	A2		A	A		A	A	
1	29.4	55.6	42.5	34.2	21.6	27.9	25.8	22.4	24.1	4.8	1.4	3.1
2	0	0	0	0	0	0	2843	2600	2721	149.0	337.8	743.4
3	0	0	0	0	0	0	17.2	14.9	16.1	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0	0
5	0	0.5	0.3	0	0.8	0.4	643.9	559.6	601.8	0	0	0
6	0	0	0	0	0	0	0	0	0	0	0	0
7	0	0	0	0	0	0	90.1	78.3	84.2	0	0	0
8	1.5	0	0.8	1.0	1.4	1.2	0	0	0	208.5	61.3	134.9
9	1.3	0.2	0.7	2.1	1.4	1.8	99.4	82.1	90.8	0	0	0
10	5.2	0	2.6	0.4	1.0	0.7	709.6	616.7	663.2	106.7	31.4	69.1
11	0	0	0	0	0	0	40.8	35.4	38.1	48.5	14.3	31.4
12	0	0	0	0	0	0	6.4	5.6	6.0	97.0	28.5	62.8
13	0	0	0	0	0	0	6.4	5.6	6.0	0	0	0
14	0	0	0	0	0	0	6.4	5.6	6.0	0	0	0
15	0	0	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	0	0	0	55.8	48.5	52.2	48.5	14.3	31.4
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	0	0	0	0	2.7	1.3	4.3	3.7	4.0	67.9	20.0	44.0
23	0	0	0	0	0	0	0	0	0	0	0	0
24	14.4	14.5	14.5	10.3	10.2	10.2	1000	800.0	900.0	445.1	130.8	288.0
25	7.8	7.8	7.8	4.5	4.5	4.5	300.0	200.0	250.0	116.3	34.2	75.3
26	29.2	10.3	19.7	4.0	13.0	8.5	55.8	48.5	52.2	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0

Table 3e.

Average rate of collection of material (g day^{-1}) on the top half of the lower screen, January - September 1970.

Species group no.	14 day sample periods starting day no.										
	13	27	42	56	70	84	98	112	126	140	154
1	37.2	28.0	43.3	98.6	69.6	52.3	22.8	38.6	88.2	34.4	31.3
2	9.2	3.8	4.2	0.5	0	0	0	0.1	0	0	0.1
3	0	0	0	0	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0	0	0	0	0
5	0	1.4	0	0	0	0	0	0	1.6	1.5	0.1
6	32.3	13.9	3.0	0.3	0.3	0	0	0	1.0	0.3	0.4
7	3.3	11.2	0	0	0	0	0	0	0	0	0
8	16.5	14.2	55.9	4.7	5.5	0.2	2.3	1.1	2.2	0.9	0.4
9	63.5	19.9	14.9	25.4	42.6	5.5	0.4	0	2.8	1.0	0.8
10	69.2	28.1	6.6	1.1	1.3	0.6	9.2	9.4	10.3	2.3	0.9
11	36.3	17.7	1.4	0.4	0.1	0	0.1	0.1	0.5	0	0.1
12	3.5	0.3	0	0	0	0	0	0.2	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0	0	0	0	0
15	2.6	0	0	0	0	0	0	0	0	0	0
16	0	0	0	0	0	0	0	2.3	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0.9	0	0.2	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	2.3	0.1	1.7	0.8	1.9	5.5	3.3	4.5	4.3	1.6	0.3
23	0.3	0	0	0	0	0	0	0	0	0	0
24	146.3	62.3	26.5	40.6	13.1	12.3	12.4	36.3	27.3	12.8	7.8
25	-	-	-	-	-	-	-	-	-	-	-
26	36.4	22.3	16.0	19.3	3.3	0	2.3	7.2	1.9	0.8	0.4
27	0	0	0	0	0	0.1	34.0	8.1	0.2	0	0

Table 3e. (cont.)

Species group no.	14 day sample periods starting day no.						
	168	182	196	210	234	Sum	%
1	15.8	10.5	5.5	1.9	33.2	611.4	32.3
2	0	0	0	0	0.3	18.2	1.0
3	0	0	0	0	0	0	0
4	0	0	0	0	0	0	0
5	0.5	0.4	0.3	0.2	8.7	14.7	0.8
6	3.3	3.0	3.8	7.7	33.4	102.7	5.4
7	0	0	0	0	0	14.5	0.8
8	0.3	0	0	0.1	2.6	106.9	5.6
9	0	0.7	0.3	0.1	2.2	180.1	9.5
10	0	0	0	0	0	139.0	7.3
11	0	0	0	0	0	56.7	3.0
12	0	0	0	0	0	4.0	0.2
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0	0	0	0	0	2.6	0.1
16	0	0	0	0	0	2.3	0.1
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	1.1	0.1
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0	0	0.1	0.1	1.4	27.9	1.5
23	0	0	0	0	0	0.3	0
24	12.7	7.6	7.9	7.4	13.7	447.0	24.2
25	1.6	1.7	1.6	1.9	4.7	11.5	
26	0.3	0	0	0	0	110.2	5.8
27	0	0	0	0	0	42.4	2.2
						1893.5	

Table 3f.

Average rate of collection of material (g day^{-1}) on the bottom half of the lower screen, January - September 1970.

Species group no.	14 day sample periods starting day no.										
	13	27	42	56	70	84	98	112	126	140	154
1	13.2	11.4	35.9	41.7	44.7	26.0	9.5	20.6	37.2	19.5	6.0
2	19.5	4.8	7.1	0.8	0	0	0.1	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0
4	1.3	0.1	0	0	0	0	0	0	0	0	0
5	1.3	1.0	0	0	0	0	0	0	0	0	0.5
6	15.3	7.2	9.1	2.2	1.0	0.8	0.1	0.1	0.1	0	0
7	0	0	0	0	0	0	0	0	0	0	0
8	12.0	7.6	7.6	1.8	0.8	2.3	1.0	0.6	0.6	0.7	0.1
9	5.7	0.5	2.5	1.3	4.9	0	0.9	0	0.7	0.7	0
10	94.7	8.5	4.2	1.1	0.4	0	6.3	5.2	5.0	3.9	0.6
11	88.5	36.2	8.5	0.1	0.6	0	0.4	1.0	1.3	0.2	0.5
12	15.3	1.6	0.1	0	0	0	0	0	0	0.1	0
13	0	0	0	0	0	0	0	0	0	0	0
14	0	0	0.1	0	0	0	0	0	0	0	0
15	4.1	0.2	0.2	0	0	0	0	0	0	0	0
16	0	0	2.1	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0
19	0.6	7.8	0	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0
22	3.8	3.5	0.8	0.6	0	0.1	4.9	1.6	2.1	0.3	0
23	0	0	0	0	0	0	0	0	0	0	0
24	137.0	62.8	55.0	67.8	55.3	76.0	18.3	20.4	23.9	10.3	7.9
25	-	-	-	-	-	-	-	-	-	-	-
26	161.4	38.2	11.6	0	0	0	1.3	4.1	2.2	0.7	0.1
27	0	0	0	0	0	0	45.0	2.0	0	0	0

Table 3f. (cont.)

Species group	14 day sample periods starting day no.						
no.	168	182	196	210	224	Sum	%
1	2.2	9.4	1.8	0.9	27.5	307.5	18.4
2	0	0	0.1	0	0.2	32.6	1.9
3	0	0	0	0	0	0	0
4	0	0	0	0	0	1.4	0.1
5	0	0	0.3	0.1	0.9	4.1	0.2
6	0	3.9	2.7	2.4	31.7	76.6	4.6
7	0	0	0	0	0	0	0
8	0	0	0	0	0.5	35.6	2.1
9	0	0	0	0.1	1.2	18.5	1.1
10	0	0	0	0.1	0.3	130.3	7.8
11	0	0	0	0	0	137.3	8.2
12	0	0	0	0	0.4	17.5	1.0
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0.1	0
15	0	0	0	0	0	4.6	0.3
16	0	0	0	0	0	2.1	0.1
17	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0
19	0	0	0	0	0	8.4	0.5
20	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0
22	0.4	0.1	0	0.6	2.0	20.8	1.2
23	0	0	0	0	0	0	0
24	4.9	8.5	7.9	11.7	24.9	592.6	35.5
25	1.5	1.6	1.1	5.4	8.7	18.3	
26	0	0	0	0	0	219.6	13.1
27	0	0	0	0	0	47.0	2.8
						1674.9	

Table 4.

Rate of collection, by nets, of material passing the middle and lower screens.

Starting day no.	255	257	259	278	292	232	254	256	264	274	284	300
Sample period	Middle screen					Lower screens						
days.	1	1	1	2	2 /	2	2	2	2	2	3	2
Species group no.												
1	1	0	0	0	2	9	7	0	10	0	0	0
2	0	0	0	0	0	0	0	0	0	0	0	0
3	0	0	0	0	0	0	0	0	0	0	0	0
4	1	0	0	0	0	0	0	0	0	0	0	0
5	0	0	0	0	0	7	68	43	39	0	0	0
6	48	1	0	50	18	14	6	3	29	79	65	5
7	0	1	0	0	0	0	0	0	0	0	0	0
8	0	0	0	0	0	2	0	0	0	0	0	0
9	0	0	0	0	0	0	0	0	0	0	0	0
10	0	2	0	0	0	0	0	0	0	0	0	0
11	0	2	0	0	0	0	0	0	0	0	0	0
12	2	0	0	0	0	0	0	0	0	0	0	0
13	0	0	0	0	0	0	0	0	0	0	0	0
14	0	91	0	0	0	0	0	0	0	0	0	0
15	17	0	0	0	21	4	0	0	0	0	0	0
16	0	0	0	0	0	0	0	0	0	0	0	0
17	0	0	0	0	0	0	0	0	0	0	0	0
18	0	0	0	0	0	0	0	0	0	0	0	0
19	0	0	0	3	0	0	0	0	0	0	0	0
20	0	0	0	0	0	0	0	0	0	0	0	0
21	0	0	0	0	0	0	0	0	0	0	0	0
22	24	3	0	45	57	64	4	31	19	20	20	11
23	0	0	0	0	0	0	0	0	0	0	0	0
24	0	0	0	1	1	0	7	15	3	2	5	8
25	0	0	0	0	1	0	7	8	0	0	3	0
26	0	0	0	0	0	0	0	0	0	0	0	0
27	0	0	0	0	0	0	0	0	0	0	0	0
E	112	106	67	140	96	26	79	166	73	78	80	143
%	13	13	18	18	25	13	18	26	11	21	24	9

% - Percentage of total material collected on screen.

Appendix 1.

Table 5.

Composition of species groups used for sorting screened materials.

No.	Group.	Composition.	
1	Ranunculus.	R. *calcareus* from sections A - D. Ranunculus spp.(circinatus?) from lake.	
2.	Fontinalis.	*F. antipyretica* from Millum Head.	
3.	Hippurus.	*H. vulgaris* from Millum Head.	
4.	Chara	*C. fragilis*.	
5.	Fil. Algae.	Filamentous algae, including *Cladophora* spp., *Vaucheria* spp., *Batrachospermum* spp.	
6.	Lemna.	*L. minor*, *L. poyrrhiza*, *L. trisulca*.	
7.	Monocots 1.	Lake marginals, *Schoenoplectus lacustris* and *Sparganium erectum*.	
8.	Monocots 2.	Stream bank species, Graminae, other than from lake.	
9.	Dicots.	Marginal/emergent herbaceous plants; *Rorippa nasturtium-aquaticum*, *Apium nodiflorum*, *Berula erecta*, *Veronica beccabunga* and *Mentha aquatica*.	
10.	Twigs.	Terrestial twigs and branches.	
11.	Leaf frag.	Leaf fragments, unidentified, generally small, less than about 1 cm^2.	
12.	Salix vim.	*Salix viminalis*	leaves, flowers and seeds.
13.	S. frag./purp.	*Salix fragilis* and *S. purpurea*	
14.	S. capr./cin.	*Salix caprea* and *S. cinerea*	
15.	Fraxinus.	*F. excelsior*	
16.	Acer.	*A. pseudoplanatus*	
17.	Carpinus.	*C. betulus*	

18.	Corylus.	*C. avellana*	leaves, flowers and seeds.
19.	Hedera.	*H. helix*	
20.	Rubus.	*R. fruticosa*, *R. idaeus* (escape)	
21.	Crataegus.	*C. monogyna*	
22.	Animals.	Animals, *Cottus gobio*, *Salmo trutta*, *Gasterosteus aculeatus*, *Phoxinus phoxinus*, *Gammarus pulex*, *Potamopyrgus jenkinsi* and *Limnephilus rhomicus* and others.	
23.	Human.	Rubbush, eg. bottles, shot gun waddings, fishing line. (considered seperately).	
24.	SSO - 210 mμ	Small sediments 0 - 210 mμ, see methods.	
25.	SS 210 mμ - 2 mm	Small sediments 210 mμ - 2 mm, see methods.	
26.	Other.	Other materials, found infrequently	
27.	Other.	eg. *Equisetum* spp., *Cladonia* spp., *Phylitilis* spp., misc. bryophytes, *Menyanthes* sp., *Ilex* sp. *Ligustrum* sp.	

Table 6.

Carbon and Nitrogen content of material collected on the middle and lower screens October 1970 - October 1972. (selected samples)

14 day period	Middle screen			Lower screen		
Starting day	Percentage			Percentage		
no.	Carbon	Nitrogen	C/N Rate	Carbon	Nitrogen	C/N Rate
252	35.7	2.35	15.2	30.5	2.66	11.5
280	45.0	1.33	(33.8)	30.1	2.90	10.4
308	-	-	-	31.1	2.49	12.5
336	30.7	2.26	13.6	34.6	2.73	12.7
364	43.6	2.07	21.1	35.2	2.36	14.9
392	41.5	2.90	14.3	41.3	3.06	13.5
420	36.2	2.55	14.2	38.0	2.63	14.4
448	36.2	2.35	15.4	37.1	3.06	12.1
476	39.2	2.79	14.1	29.2	2.63	11.1
504	42.0	2.21	19.0	36.5	3.06	11.9
532	39.3	2.63	14.9	31.8	2.52	12.6
560	38.6	2.66	14.5	26.0	2.49	10.4
588	35.7	2.63	13.6	-	-	-
616	-	-	-	24.5	2.42	10.1
642	45.8	1.66	(27.6)	-	-	-
670	43.8	2.35	18.6	35.9	2.90	12.4
700	38.8	2.52	15.4	35.3	2.90	12.2
728	40.7	2.39	17.0	40.4	2.32	17.4
756	-	-	-	41.1	2.04	20.1
784	27.5	2.26	12.2	33.9	2.30	14.7
812	37.3	2.13	17.5	33.8	2.65	12.9
840	36.5	2.39	15.3	32.3	2.49	13.0
868	42.9	2.35	18.3	35.9	3.04	11.8
896	46.0	2.54	18.1	33.5	3.03	11.8
924	33.9	2.63	12.9	35.7	2.77	12.9
952	32.2	2.52	12.8	34.6	2.70	12.8
980	40.9	2.32	12.3	31.2	2.77	11.3

Appendix 2.

Dry to fresh weight ratio for material collected on middle and lower screens. (Table 1)

Dry weight balance of species groups between middle and lower screens. Season 1971 - 1972.

Table 1.

Dry to fresh weight ratio for material collected on middle and lower screens, January - July 1970.

Sample period	Middle screen			Lower screen	
	top	bottom	washout	top	bottom
	%	%	%	%	%
13 - 20	9.55	12.41	12.69	10.56	13.13
21 - 26	9.12	9.71	9.01	9.94	10.93
27 - 34	10.97	10.47	11.97	10.43	10.87
35 - 41	9.77	9.29	10.59	9.32	11.75
42 - 48	10.74	9.60	8.83	9.51	8.79
49 - 55	8.90	9.02	9.47	8.05	8.68
56 - 62	8.82	9.38	9.37	7.13	8.16
63 - 69	9.00	9.00	9.0	8.0	8.0
77 - 83	9.44	8.62	8.30	7.95	7.02
84 - 97	8.95	9.30	8.36	6.43	5.79
98 - 111	8.76	6.72	9.43	-	-
112 - 125	9.40	11.76	11.15	-	-
126 - 139[1]	7.99	9.63	12.15	10.20	7.65
140 - 153	8.05	8.81	17.2	7.93	7.43
154 - 167	7.33	8.38	-	8.95	4.94
168 - 181	7.04	7.21	-	8.27	7.95
182 - 195	6.57	6.91			
196 - 209	6.81	7.04			
210 - 223	6.65	6.45			

Note

- 1 - change over to draining screens 10 - 15 min (see text, section 4.2.).

Table 2.

Dry weight balance of species groups between the middle and lower screens, season 1971 - 1972.

Species group no.	Input (corrected) kg	Output kg	Change kg
1	5	10	+5
2	151	95	-56
3	0	0	
4	0	0	
5	0	8	+8
6	9	10	
7	5	2	- 3
8	7	12	+5
9	2	5	+3
10	38	33	- 5
11	51	14	-37
12	19	13	- 6
13	1	2	
14	1	2	
15	5	0	- 5
16	0	0	
17	0	0	
18	0	0	
19	5	1	- 4
20	0	0	
21	0	0	
22	3	3	
23	0	0	
24	65	55	-10
25	50	22	-22
26	0	1	
27	0	0	
	425	289	-133

Appendix 3.

Small suspended materials and proximate analyses for lower screen (Table 1), middle screen (Table 2) and upper screen (Table 3).

Monthly organic budgets for small suspended materials between middle and lower screens, section D, (Table 4) and correction factors for the effects of screen cleaning (Table 5).

Table 1.

Small suspended material (dry weight month $^{-1}$) and proximate analyses, for lower screen.

	Small suspended material					Total small suspended material per month		
Date	Concentration	Ash	Organic	Inorganic Carbon	Discharge for month	Organic	Inorganic carbon	Total
	mg l^{-1}	%	%	%	G l	kg	kg	kg
1969[1]								
Jan.	3.0	63	37	-	-			
Feb.	2.3	61	39	-	-			
Mar.	2.7	67	33	-	-			
Apr.	1.3	77	23	-	-			
May	1.6	75	25	-	-			
June	1.3	62	38	-	-			
July	0.8	75	25	-	0.410	82	-	328
Aug.	0.7	71	29	-	0.241	49	-	169
Sept.	4.1	63	37	-	0.119	181	-	488
Oct.	2.7	44	56	-	0.075	113	-	203
Nov.	8.2	70	30	-	0.078	192	-	640
Dec.	3.5	63	37	-	0.348	451	-	1218
1970								
Jan.	3.41	70	30	-	0.611	625	-	2084
Feb.[2]	1.96	70	30	-	0.673	396	-	1319
Mar.	1.98	88	22	-	0.804	350	-	1592
Apr.	1.45	66	34	-	0.664	327	-	963
May	3.60	85	15	-	0.777	420	-	2797
June	2.90	70	30	-	0.342	298	-	992
July	1.22	67	33	-	0.249	100	-	304
Aug.	1.35	59	41	-	0.169	94	-	228
Sept.	1.79	-	-	-	0.086	(70)	-	154
Oct.[3]	1.74	75	25	-	0.121	53	-	211
Nov.	5.54	54	46	5.2	0.251	640	72	1391
Dec.	2.19	71	29	7.1	0.340	216	53	745
					5.087	3589	-	12780

Note.

1. \- 1969, weekly samples only, samples Ashed separately for month
2. \- 1970. February onwards continuous and spot samples
3. \- 1970. Oct. onwards, continuous and spot samples, monthly mean estimated using the assumptions in text.

Table 1. (cont.)

		Small suspended material				Total small suspended material per month		
Date	Concentration	Ash	Organic	Inorganic Carbon	Discharge for month	Organic	Inorganic carbon	Total
	mg l^{-1}	%	%	%	G l	kg	kg	kg
1971								
Jan.	2.32	68	32	4.8	0.579	430	64	1343
Feb.	1.55	74	26	5.0	0.743	299	58	1152
Mar.	1.20	64	36	4.6	0.656	283	36	787
Apr.	1.61	49	51	2.6	0.472	388	20	760
May	1.68	56	44	4.1	0.394	291	27	662
June	2.15	52	48	2.9	0.207	214	13	445
July	1.09	66	34	4.9	0.214	79	11	233
Aug.	1.48	63	37	3.8	0.129	71	7	191
Sept.	3.20	70	30	5.7	0.070	67	13	224
Oct.	3.31	67	33	5.6	0.046	50	9	152
Nov.	5.90	55	45	3.4	0.047	125	9	277
Dec.	4.49	50	50	3.2	0.080	180	11	359
					3.637	2477	278	6585
1972								
Jan.	8.92	60	40	5.3	0.200	714	95	1784
Feb.	5.93	88	12	8.4	0.491	349	245	2912
Mar.	4.11	83	17	7.1	0.943	659	275	3876
Apr.	2.50	60	40	3.7	0.933	933	86	2333
May	1.35	68	32	2.2	0.683	295	20	922
June	1.68	55	45	2.0	0.415	314	14	697
July	2.59	75	25	-	0.217	141	(12)	562
Aug.	2.63	71	29	4.8	0.094	72	12	247
Sept.	1.65	73	27	4.9	0.083	37	7	137
Oct.[4]	7.64	59	41	5.7	0.079	247	34	604
Nov.	11.16	66	34	4.3	(0.260)	987	125	2902
Dec.[5]	11.15	59	41	3.6	(0.520)	1426	125	3479
					4.918	6174	1050	20455

Notes.

4. - Includes special management on 16th & 19th, an attempt to brush out all the sediment banks, Special ash weights and corrected for in total suspended material columns. 20% of monthly total moved on two days approximately 109Kg total weight.

5. - Part of month only.

Table 2.

Small suspended material (dry weight month^{-1}) and Proximate analyses for middle screen.

Date	Concentration	Small suspended material Ash	Organic	Inorganic Carbon	Discharge for month	Total small suspended material per month Organic	Inorganic carbon	Total
	mg l^{-1}	%	%	%	G l	kg	mg	mg
1970								
Oct.	2.78	68	32	-	0.121	108	17	336
Nov.	9.51	60	40	6.1	0.251	955	146	2387
Dec.	1.94	61	39	6.4	0.340	257	42	660
1971								
Jan.	2.71	51	49	4.4	0.579	769	69	1569
Feb.	2.39	80	20	4.8	0.743	355	85	1776
Mar.	1.17	68	32	5.5	0.656	246	42	768
Apr.	2.40	72	28	5.5	0.472	317	62	1133
May	1.65	52	48	3.8	0.394	312	25	650
June	1.36	56	44	3.8	0.207	124	11	282
July	0.67	53	47	3.9	0.214	67	6	143
Aug.	1.67	56	44	4.2	0.129	95	9	215
Sept.	3.08	54	46	4.3	0.070	99	9	216
Oct.	2.47	56	44	3.1	0.046	50	4	114
Nov.	6.21	65	35	5.3	0.047	102	15	292
Dec.	5.67	50	50	3.2	0.080	227	15	454
1972					3.637	2763	352	7612
Jan.	10.40	51	49	4.5	0.200	1019	94	2080
Feb.	5.28	62	38	5.9	0.491	985	153	2592
Mar.	5.03	64	36	5.4	0.943	1708	256	4743
Apr.	2.61	62	38	3.8	0.933	925	93	2435
May	2.14	49	51	2.1	0.683	745	31	1462
June	1.91	54	46	2.4	0.415	365	19	793
July	1.76	60	40	3.0	0.217	153	11	382
Aug.	2.08	65	35	4.4	0.094	68	9	196
Sept.	3.24	49	51	3.4	0.083	137	9	269
Oct.	5.26	59	41	3.6	0.079	170	15	416
Nov.	12.39	59	41	4.2	(0.260)	(1321)	(135)	(3321)
Dec.	(5.16)	(60)	(40)	(4.5)	(0.520)	(1073)	(121)	(2683)
					4.918	8669	946	19910

Table 3.

Small suspended material (dry weight month^{-1}) and proximate analyses for upper screen.

		Small suspended material				Total small suspended material per month		
Date	Concentration mg l^{-1}	Ash %	Organic %	Inorganic Carbon %	Discharge[1] per month G l	Organic kg	Inorganic carbon kg	Total kg
1970								
Nov.	0.46	-	-	-	0.016	(3)	0	7
Dec.	0.51	50	50	1.8	0.264	68	2	135
1971								
Jan.	0.43	57	43	4.0	0.231	42	4	99
Feb.	0.50	62	38	2.4	0.497	95	6	249
Mar.	0.37	50	50	1.0	0.339	63	1	125
Apr.	0.61	76	24	1.1	0.250	37	2	153
May	1.22	-	-	-	0.143	(57)	(3)	174
June	1.39	58	42	2.7	0.010	6	0	14
July	0.52	-	-	-	0.003	(1)	0	2
					1.753	373	18	958

Note.

1. - Discharge of lake, see also 4.1.1.

Table 4.

Monthly organic budget of small suspended material, (section D, Holly Bush).

	Organic input material passing middle screen		Organic output material passing lower screen		Corrected accumulation of organic material	
	Total	Corrected total	Total	Corrected total	Monthly	Total
	kg	kg	kg	kg	kg	kg
1970						
Oct.	108	108	53	53	+ 55	+ 55
Nov.	955	1017	640	736	+ 281	+ 336
Dec.	257	307	216	273	+ 34	+ 370
1971						
Jan.	769	792	430	456	+ 336	+ 706
Feb.	355	367	299	301	+ 66	+ 772
Mar.	246	246	283	283	- 37	+ 735
Apr.	317	317	388	388	- 71	+ 664
May.	312	312	291	291	+ 21	+ 685
June	124	124	214	214	- 90	+ 595
July	67	71	79	86	- 15	+ 580
Aug.	95	97	71	74	+ 23	+ 603
Sept.	99	102	67	71	+ 31	+ 634
Oct.	50	50	50	50	0	+ 634
Nov.	102	102	125	125	- 23	+ 611
Dec.	227	228	180	181	+ 47	+ 658
1972						
Jan.	1019	1744	714	734	+1010	+ 1668
Feb.	985	1120	349	365	+ 755	+ 2423
May	1708	1708	659	659	+1049	+ 3472
Apr.	925	925	933	933	- 8	+ 3464
May	745	745	295	295	+ 450	+ 3914
June	365	365	314	314	+ 51	+ 3965
July	153	153	141	141	+ 12	+ 3977
Aug.	68	68	72	72	- 4	+ 3973
Sept.	137	137	37	37	+ 100	+ 4073
Oct.	170	186	247	255	- 69	+ 4004
Nov.	1321	1374	987	1014	+ 360	+ 4364
Dec.	1073	1073	1426	1426	- 353	+ 4011

Table 5.

Correction factors for small suspended material passing middle and lower screens during screen cleaning.

Month	Correction factor for screens. Concentration		Total		Organic	
	Middle	Lower	Middle	Lower	Middle	Lower
	mg l^{-1}	mg l^{-1}	kg month^{-1}		kg month^{-1}	
1970						
Nov.	+ 0.62	+ 0.83	+ 156	+ 208	62	96
Dec.	+ 0.38	+ 0.58	+ 129	+ 197	50	57
1971						
Jan.	+ 0.08	+ 0.14	+ 46	+ 81	23	26
Feb.	+ 0.08	+ 0.01	+ 59	+ 7	12	2
July	+ 0.04	+ 0.10	+ 9	+ 21	4	7
Aug.	+ 0.04	+ 0.06	+ 5	+ 8	2	3
Sept.	+ 0.08	+ 0.25	+ 6	+ 18	3	6
Oct.	+ 0	+ 0.02	+ 0	+ 1	0	0
Dec.	+ 0.03	+ 0.03	+ 2	+ 2	1	1
1972						
Jan.	+ 7.4	+ 0.25	+1480	+ 50	725	20
Feb.	+ 0.72	+ 0.3	+ 354	+147	135	16
Oct.	+ 0.4	+ 0.2	+ 40	+ 19	16	8
Nov.	+ 0.5	+ 0.3	+ 130	+ 78	53	27
Dec.	-	-	-	-		

Appendix 4.

Table 1.

Analysis of standing crop samples of R. calcareus from section D, Holly Bush, for carbon, nitrogen and ash content.

Date		Section		Inorganic			Carbon	Ash free	
			Ash	carbon	Carbon	Nitrogen	nitrogen	Carbon	Nitrogen
			%	%	%	%		%	%
1969									
April	9	1–10	29.5						
		11–20	31.3		33.2[1]	2.69	12.6	46.9	3.80
		21–32	26.8						
May	5	1–32	29.6		36.1	2.60	13.9	51.3	3.69
June	2	1–15	23.8						
		16–32	34.8		35.6	2.42	14.7	50.4	3.42
July	7[2]		24.1		37.4	2.56	14.6	49.3	3.37
Aug.	4		28.2						
Sept.[2]			31.3						
[3]			25.7						
Dec.			24.5						
1970									
Aug.	3				38.3	2.16	17.7		
1971									
Jan.	13		21.5	1.27	38.7	3.77	10.3	49.3	4.80
March	8		16.4	1.06	42.0	3.91	10.7	50.2	4.68
April	20		26.8	1.96	37.2	3.37	11.0	50.8	4.60
May	18		26.6	1.51	35.8	2.69	13.3	48.8	3.66
Aug.	2		28.3	2.07	33.4	2.69	12.4	46.6	3.75
1972									
July	18		18.3	1.44	38.7	2.56	15.1	47.4	3.13

Notes.

1. – Mean values used in table; sample groups not weighted.

2. – R. calcareus only

3. – Marginal plants only, Rorippa nasturtium-aquaticum

Appendix 5.

Table 1.

Ash, carbon and nitrogen content of leaves collected in baskets, section A - C Holly Bush, 1970.

Species	Basket no.	Month	Ash (550°C) %	Ash (900°C less 550°C) %	Carbon %	Nitrogen %	Carbon to nitrogen ratio
S.vim.	1	Sept.	6.90	0.26	51.9	1.86	27.9
"	2	Oct.	6.25	0.42	49.6	1.85	19.7
"	3	Sept.	6.77	0.44	52.5	2.52	20.8
"	5	Oct.	6.61	0.41	51.2	1.86	27.5
Frax.	7	Sept.	9.33	0.61	47.6	1.80	26.4
"	8	Oct.	9.52	0.76	47.7	1.77	26.9
Acer	11	Sept.	8.76	0.55	48.5	1.66	29.2
"	12	Oct.	9.27	0.62	47.6	1.7	28.0
Mean values.							
S. vim.			6.63		51.3	2.02	24.0
Frax.			9.43		47.7	1.79	26.7
Acer			9.02		48.1	1.68	28.6
Mean values for Ash free percentage of Carbon and Nitrogen							
S. vim.					54.9	2.15	
Frax.					52.7	1.98	
Acer					52.9	1.85	

Key :-

S. vim. - Salix viminalis

Frax. - Fraxinus excelsior

Acer - Acer pseudoplanatus

Appendix 6.

Discharge Determinations (Table 1), monthly mean and total discharges (Table 2) for Section D, Holly Bush 1969 - 72. Estimation of Chezy-Manning hydraulic coefficients for Section D, Holly Bush, (Table 3).

Table 1.

Discharge and mean velocity determinations, section D, Holly Bush.

Date		Discharge. $m^3 sec^{-1}$	Mean velocity cm sec^{-1}	Method.
1969				
July	7	0.17	-	C.M.Edd.
Aug.	3	0.12	-	C.M.Edd.
	11	0.08	5.5	Na cond.
Oct.	7	0.031	11.0	Na peak
	7	0.026	-	C.M.Ott
	16	0.029	10.4	K carbonate
	16	0.029	10.4	Na carbonate
	28	0.022	11.0	Na
Nov.	11	0.026	10.5	Na
	25	0.036	15	Na
1970				
Jan.	2	0.20	25	Na
Feb.	9	0.25	32	C.M.Ott
Apr.	1	0.31	18	Na
	4	0.25	-	C.M.Ott
May	8	0.185	-	C.M.Ott
June	18	0.112	-	C.M.Ott
Sept.	9	0.033	6.1	Na
Oct.	8	0.025	-	C.M.Ott
Nov.	26	0.107	-	C.M.Ott
1971				
Jan.	13	0.148	25	Na
	26	0.281	25	Na
Feb.	10	0.321	34	Na
Mar.	3	0.311	20	Na
	16	0.198	14	Na
Apr.	1	0.190	12.5	Na
	27	0.180	11.9	Na
June	2	0.121	10.6	Na
	28	0.107	10.2	Na
Aug.	4	0.055	6.1	Na
Sept.	7	0.032	9.5	Na

Table 1. (cont.)

Date		Discharge $m^3 sec^{-1}$	Mean velocity $cm\ sec^{-1}$	Method.
1971				
Oct.	5	0.016	-	Na sulphite cond.
Nov.	16	0.019	6	Na
Dec.	21	0.027	11.5	Na
1972				
Jan.	27	0.109	27.5	Na
Feb.	16	0.21	34	Na
Mar.	23	0.4	-	Na sulphite cond.
	30	0.41	37	Na Level 1.
	30	0.41	37	Na Level 2.
May	2	0.306	16	Na
	30	0.200	15.5	Na
July	3	(0.115)	10.2	Na sulphite (flame) 3 stations
Aug.	1	0.037	9.8	Na (2 stations)
Oct.	13	0.031	5.7	Na

Key to Methods.

C.M.Ott. = Current meter Ott.

C.M.Edd. = Current meter, Eddington and Molyneux.

Na cond. = Sodium chloride by conductivity, single pulse.

Na peak = Sodium chloride as sodium by flame photometry single pulse.

Na = Sodium chloride as sodium by flame photometry maintained plateau method.

K carbonate = potassium carbonate as Potassium by flame photometry, single pulse.

Na carbonate = Sodium carbonate as Sodium by flame photometry single pulse

Na sulphite = Sodium sulphite by conductivity, samples taken during deoxygenation experiments.

Table 2.

Monthly mean and total discharges 1969 - 1972.

Monthly mean discharges, l sec^{-1}

	1969	1970	1971	1972
Jan.	-	228	216	75
Feb.	-	278	307	203
Mar.	-	300	245	352
Apr.	-	256	182	360
May	-	290	147	255
June	-	132	80	160
July	153	93	80	81
Aug.	90	63	48	35
Sept.	46	33	27	32
Oct.	28	45	17	31
Nov.	30	97	18	-
Dec.	130	127	30	-
Mean	-	162	116	(160)
Total discharge, Ml month^{-1}				
Jan.	-	611	579	200
Feb.	-	673	743	491
Mar.	-	804	656	943
Apr.	-	664	472	933
May	-	777	394	683
June	-	342	207	415
July	410	249	214	217
Aug.	241	169	129	94
Sept.	119	86	70	83
Oct.	75	121	46	79
Nov.	78	251	47	-
Dec.	348	340	80	-
Total	-	5987	3637	(4930)

Table 3.

Determination of Chezy-Manning Coefficients, section D, Holly Bush

(ft - lb - sec units)

Date	Discharge $ft^3 sec^{-1}$	Mean cross sectional area ft^2	Gradient of stream bed	Chezy-Manning coeft. $ft^{\frac{1}{6}}$	Gradient of water surface	Chezy-Manning coeft. $ft^{\frac{1}{6}}$
1969						
Oct. 7	1.09	2.86	0.0034	0.080	0.0032	0.077
7	0.92	2.86	0.0034	0.096	0.0032	0.092
16	1.02	3.06	0.0034	0.094	0.0031	0.092
28	0.78	2.85	0.0034	0.112	0.0033	0.110
Nov. 11	0.92	2.91	0.0034	0.097	0.0034	0.096
25	1.27	3.95	0.0034	0.115	0.0032	0.112
1970						
Jan. 2	7.06	6.40	0.0034	0.044	0.0086	0.069
Feb. 9	8.83	16.0	0.0040	0.169	0.0011	0.091
Apr. 1	11.0	16.2	0.0040	0.140	0.0011	0.073
4	8.83	16.2	0.0040	0.173	0.0011	0.090
May 8	6.46	12.8	0.0040	0.161	0.0030	0.138
June 18	3.95	8.80	0.0040	0.144	0.0032	0.128
Sept. 9	1.17	4.93	0.0040	0.203	0.0034	0.186
Oct. 8	0.88	3.56	0.0040	0.156	0.0034	0.143
Nov. 26	3.78	3.32	0.0040	0.031	0.0034	0.029
1971						
Jan. 13	5.22	10.1	0.0040	0.141	0.0030	0.122
26	9.92	12.5	0.0040	0.102	0.0028	0.085
Feb. 10	11.30	14.4	0.0040	0.112	0.0030	0.097
Mar. 3	11.0	17.4	0.0040	0.160	0.0037	0.153
16	6.99	18.7	0.0040	0.278	0.0037	0.265
Apr. 1	6.71	18.7	0.0040	0.295	0.0042	0.300
27	6.36	16.8	0.0040	0.259	0.0037	0.247
June 2	4.27	13.0	0.0040	0.256	0.0032	0.227
28	3.78	12.4	0.0040	0.267	0.0028	0.222
Aug. 4	1.94	11.0	0.0040	0.425	0.0026	0.343
Sept. 7	1.13	3.48	0.0040	0.117	0.0037	0.112
Oct. 5	0.56	2.23	0.0040	0.112	0.0037	0.107
Nov. 16	0.67	1.96	0.0040	0.076	0.0036	0.072
Dec. 21	0.95	2.24	0.0040	0.067	0.0035	0.062
1972						
Jan. 27	3.85	4.44	0.0040	0.052	0.0034	0.047
Feb. 16	7.42	8.29	0.0040	0.069	0.0027	0.057
Mar. 23	4.12	12.0	0.0040	0.070	0.0031	0.061
30	14.50	13.6	0.0040	0.080	0.0030	0.070
May 2	10.80	13.5	0.0040	0.106	0.0027	0.086

Appendix 7.

Table 1.

Plant species and authorities.

Acer pseudoplatanus L.
A. saccharinum L.
Acorus calamus L.
Alnus glutinosa (L.) Gaertn.
A. rugosa
A. tenuifolia
Alternathera philexeroides (Mart.) Griseb.
Apium nodiflorum (L.) Lag.

Berula [Sium] erecta (Huds) Coville
Betula pendula [verrucosa] Roth

Callitriche stagnalis Scop.
Carpinus betulus L.
Carya glabra
Ceratophyllum demersum L.
Chara fragilis
Corylus avellana L.
Crataegus monogyna Jacq.

Eichornia crassipes (Mart.) Solms
Elodea canadensis Michx.
Epilobium hirsutum L.

Fagus grandifolia
F. sylvatica L.
Fontinalis antipyretica Hedw.
Fraxinus excelsior L.

Hedera helix L.
Hippurus vulgaris L.
Hordeum vulgare L.

Table 1. (cont.)

Justicia americana (L.) Vahl.

Lemna minor L.
L. polyrrhiza L.
L. trisulca L.

Mentha aquatica L.

Najas flexilis (Willd.) Rostk. and Schmidt
Nuphar lùtea (L.) Sm.

Pinus sylvestris L.
Potamageton crispus L.
P. lucens L.
P. pectinatus L.
P. perfoliatus L.
P. thunbergii Cham. and Schlect.

Quercus alba
Q. rober L.

Ranunculus fluitans Lam.
R. peltatus Schrank
R. penicillatus var calcareus (R.W.Butcher) C.D.K. Cook
[R. pseudo-fluitans, R. calcareus]
Ror ippa nasturtium-aquaticum (L.) Hayek
Rubus fruticosa agg.
R. idaeus L.

Sagittaria subulata (L.) Buchen
Salix caprea L.
S. cinerea ssp. atrocinerea (Bròt.) Silva and Sobr.
S. fragilis L.
S. purpùrea L.
S. viminalis L.
Schoenoplectus lacustris (L.) Palla
Sparganium erectum [simplex] L.

Table 1. (cont.)

Ulmus americana

Veronica beccabunga L.

Zannichellia palustris L.
Zostera marina L.

Key :-

[square brackets] - previously used names.

References.

general - Clapham, Tutin and Warburg 1962

Ranunculus - Cook 1966

bryophytes - Watson 1968

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Species Group No.	
1	Ranunculus
2	Fontinalis
3	Hippurus
4	Chara
5	Fil.algae
6	Lemna
7	Monocots 1
8	Monocots 2
9	Dicots.
10	Twigs
11	Leaf frag.
12	Salix vim.
13	S.frag/purp.
14	S.capr/cin.
15	Fraxinus
16	Acer
17	Carpinus
18	Corylus
19	Hedera
20	Rubus
21	Crataegus
22	Animal
23	Human
24	SS 0 - 210 mu
25	SS 210 mu - 2 mm
26	Other
27	Other