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# Kinal and kinon, habitat and coenosis of the surface drift as seen in Amazonian running waters *

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ABSTRACT

In tropical rain forest regions litter of vegetation bordering the riversystem is important for structure and function of ecosystems in running waters. Primarily the litter offers food and substrate for the aquatic biocoenoses. A part of this allochthonous organic material derived from the forest, especially wood, flowers, fruits and also insects, drifts on the water surface and is accumulated at appropriate localities. At such places organic material, which originates in the biocoenoses of the river (mainly dead and hatched insects and their pupal skins together with nectonic living microorganisms) is found. These accumulations form a biotope characterised by its instability, but inhabited by several adapted organisms. Oscillations of the water surface may destroy or displace these habitats and their fauna which may form their own coenosis in certain waterbodies.

Until the present time the terms neuston and pleuston have been used in different ways to describe organisms living on the water surface. The terms kinon and kinal are now proposed for the coenoses and habitat respectively of organisms drifting on the water surface. The terms rhithro—, potamo— and limnokinal may be used in correspondingly differing freshwater habitats.

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All Amazonian rivers and streams flow through rainforest or are bordered by woods. The surrounding forests continuously contribute organic material to the water. This material consists primarily of litter, leaves, rotting wood, flowers, pollen, seeds and fruits but material of animal origin in the form of living or dead insects and other invertebrates is also contributed. Such contributions are transported to the streams and rivers by wind, rain or surface run-off water. That part of this material which is not immediately eaten by fish and other animals sinks into deeper water, drifts further on or is stored at suitable localities. All of the material which does not sink or has not been eaten continues as surface drift on the

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water and accumulates in part, at favourable sites of the streams and rivers. Such accumulations consist not only of allochthonous material but also autochtonous material, such as living and entire or fragmented dead organisms, which originate in the water itself. The accumulated surface drift leads to, as we shall see, the establishment of a rather independent coenosis under favourable conditions within the ecosystem of running waters.

In streams, particularly in the upper regions, the surface drift, including the allochthonous component, is retained frequently and at irregular distances by barriers of fallen trees or branches and layers of leaves lying in the water and by roots growing in the water. At such barriers older material, not eaten by the stream fauna, decreases most sinking as a result of its microbiological decay. At the same time new stationary surface drift accumulates as long as a change in the water level does not remove or render the barrier ineffective.

In rivers the surface drift accumulates only to a small extent and in general only in places separated by long distances. Often it is concentrated in front of fallen trees or near the river banks where branches or roots are submerged and the current allows accumulation to take place. Such accumulations can be retained in some places for a long period of time if water levels are stable. In other places, however, a slight fluctuation in water level may break it up after a short time.

Where the surface drift can collect for a long duration the material is arranged in a regular manner (Fig. 1). The larger pieces of wood and fruit lie adjacent to, and thus strengthen, the barrier. The drift material is arranged in decreasing size

Fig. 1 Surface drift of the Rio Marauia, a northern tributary of the Rio Negro, Amazonas.

away from the barrier. The posterior edge of this floating mass is normally formed by more or less broad, often foamy, brown sean. This seam is a thin mixed layer of former epi— or hyponeustic living organisms (micro-organisms living on or directly under the water surface film) such as bacteria and fungi and also pollen and « detritus ». This detritus mays in part be derived from proteins and other organic materials which are released into the water forming a film on the upper surface which can accumulate at the barriers (GOLDACRE1949, 1958 ; WHEELER 1975). The whole mass often contains a large number of pupal and larval exuviae of aquatic insects as well as the remains of dead aquatic and terrestrial insects. This slimy mass is not evident amongst the coarser fraction of the surface drift where exuviae and further fresh plant and animal material, which could serve as nutrient to the surface dwelling organisms, are not found. In streams the foamy bacterial/ fungal « detritus » is generally only weakly expressed or is completely absent. This is probably due to the small size or unstable nature of the water surface which does not give sufficient opportunity for the development of neustic organisms.

In streams the gradient is high and the volume of water relatively low. In rivers the gradient is low but the volume of water, as a rule, is relatively high. This hydrographic separation and hydraulic relationship provides vastly differing biotopes containing correspondingly adapted organisms. One can differentiate generally between the ecosystems of streams and rivers, the rhithrocoen and the potamocoen respectively.

In the rhithrocoen, the mosaic nature of the biotope, termed the rhithral, is characteristic for both lotic and lentic areas i.e. in continuously changing fast and slow water currents. In the Amazonian rain-forest streams water is mainly blocked by wood, roots or leaves or, more seldom, by rocks. There, where lentic conditions occur, « detritus » is both formed and sedimented on the sandy moddy substrate. The habitat in the current on firm substrate such as wood and roots is quite different. On gradual broadening of the stream, the rhithral or biotope of the stream, loses its initial high differentiation. The stream bed changes to an uniformly sandy plain. Firm substrates only occur here around the tree roots at the river bank. The water supply is more stable and the lentic conditions recede. This tendency increases the more the stream merges into a river where the potamal is established. The potamocoen has a much less differentiated ecosystem at its disposal. The extent of lotic and lentic interchange decreases in the course of a river. The effects of varying currents form different habitats in a cross section of a river. The extent and position of these is dependent on the path of the main flow of water in relation to the shape of the riverbed.

In the Central Amazonian region in particular the stream biocenosis or rhithrocoen, is relatively rich in biomass and shows a remarkable species diversity. The potamocoen, in contrast, exhibits a low biomass and species diversity. It is not possible here to discuss the reasons for the extreme impoverishment of the potamocoen of Central Amazonian rivers. It has been shown previously (FITTKAU 1973) that it is not the lack of suitable substrates which cause this impoverishment but here, where primary production as a source of food is of little significance, the structure and interactions of the ecosystem of these waters. The ecosystems of streams and rivers are based almost entirely on the allochthonous organic material which the forests contribute and which form a part of the surface drift. The high diversity of the stream fauna is evident not only in the rhithrobenthon but also in the rhithronecton, or fish fauna of the streams. This high diversity may be interpreted as ecological adaptation to the allochthonous food. It is to be expected that the most effective exploitation of this available food is made possible by the high number of different species-even with a reduced number of individuals. The specific differences in feeding and utilisation of the food allows for total exploitation of the allochthonous organic matter.

In the Amazonian streams the surface drift forms an important component of the rhithrocoen which, however, can not be considered in isolation since there is an obvious inter-relationship with the rhithrobenthon and rhithronecton. In addition to the epineustic animals living on the water surface, such as the species rich Gyrinidae (whirligig beetles) and Hemiptera (water bugs), other animals such as fish and many benthic insects and insect larvae have a profound influence on the surface drift since they find either food or substrate there. The surface drift of streams can only be interpreted with reservations.

In contrast, the biocoenotic divisions of rivers are clearly expressed. The potamobenthon has different expressions in the littoral area and the mid-channel of the river in relation to substrate and current speed. The potamonecton has its unique elements which do not need a direct connection with the benthon. The expression of potamoplankton is dependent on the influence of the general abiotic factors of rivers such as water current etc. The surface drift represents, also, a biotope more or less isolated from the benthon and containing its own fauna. There appears to be only a slight relationship between the littoral benthonic fauna and the surface drift.

Limnological literature does not clarify or define fully the way of life and biocoenosis of the surface dwelling organisms. In 1896 SCHRÖDER and KIRCHNER considered all vascular plants living free and floating on or in the water as pleuston. NAUMANN (1931) reject this term which RUTTNER (1962) expanded to include the biocoenosis of organisms drifting on the water surface of lakes (« Lebensgemeinschaft der auf der Wasseroberfläche des Sees treibenden Organismen»). NAUMANN (1917) first described a biocoenosis of microorganisms living on top of the surface film, which he defined as neuston. This concept was used by RUTTNER (1962) for the biocoenosis of water film dwellers («Lebensgemeinschaft des Wasserhäutchens»). There exist many outstanding works on microbiological structure of neuston in both limnology and marine biology (see VALKANOV 1968). Detailed accounts of investigations of pleuston appear to be lacking, at least in the field of limnology. WELCH (1952) used a broad concept of neuston to describe the coenosis of the micro-organisms on or in the water surface film and also included all the other higher water plants and at least the invertebrate animals there. There is no serious objection against this view of WELCH which

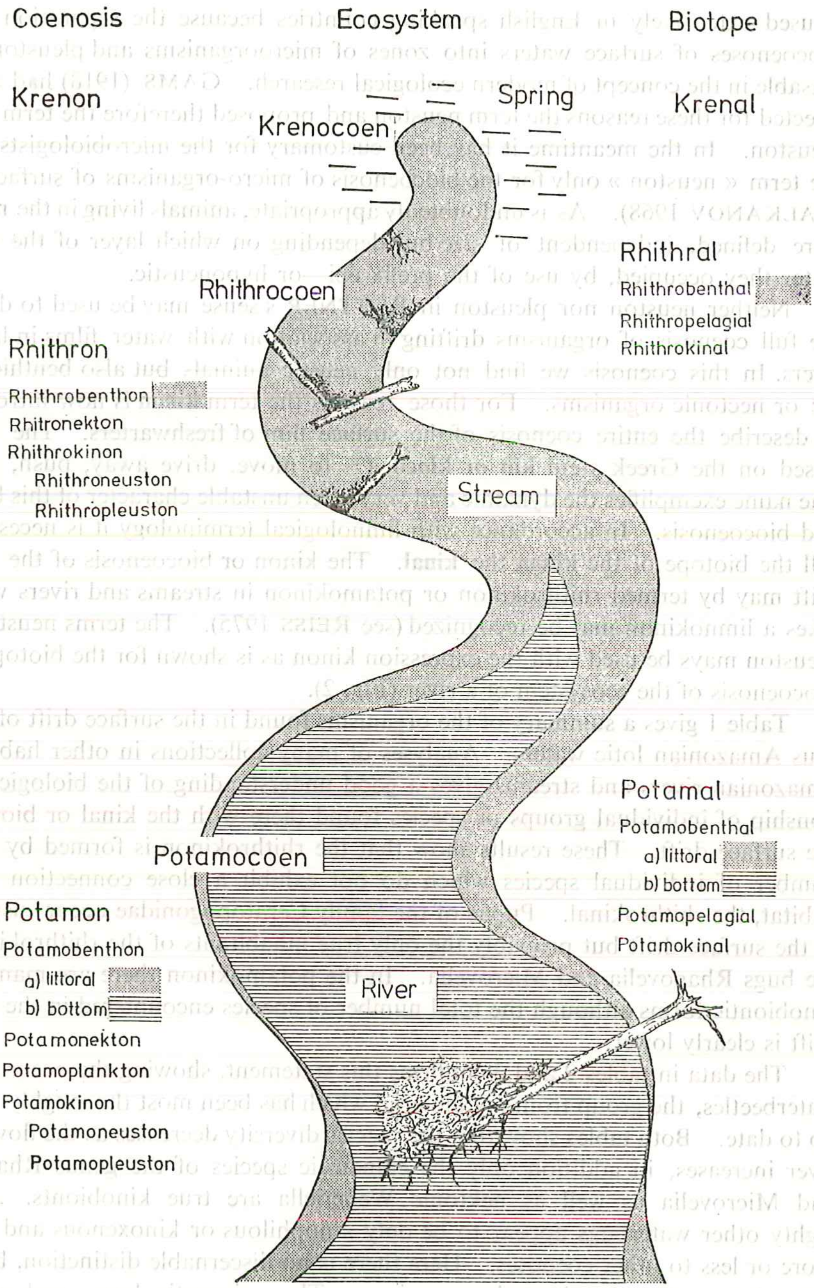


**Fig. 2 Habitats and coenosis of running waters.**

is used extensively in English speaking countries because the separation of the biocoenoses of surface waters into zones of microorganisms and pleuston is not feasable in the concept of modern ecological research. GAMS (1918) had already rejected for these reasons the term neuston and proposed therefore the term micro-pleuston. In the meantime it has been customary for the microbiologists to use the term « neuston » only for the biocoenosis of micro-organisms of surface films (VALKANOV 1968). As is undoubtedly appropriate, animals living in the neuston were defined, independent of size but depending on which layer of the surface water they occupied, by use of the prefix epi—or hyponeustic.

Neither neuston nor pleuston in RUTTNER's sense may be used to describe the full coenosis of organisms drifting in association with water films in lakes or rivers. In this coenosis we find not only neustic animals but also benthic, pelagic or nectonic organisms. For those reasons the term **kinon** is now introduced, to describe the entire coenosis of the surface film of freshwarters. The term is based on the Greek stem **kin** or **kineo**, (= to move, drive away, push, shape). The name exemplifies the dynamic and very often unstable character of this biotope and biocoenosis. In accordance with limnological terminology it is necessary to call the biotope of the **kinon** the **kinal**. The kinon or biocoenosis of the surface drift may by termed rhithrokinon or potamokinon in streams and rivers while in lakes a limnokinon may be recognized (see REISS 1975). The terms neuston and pleuston mays be used with the expression kinon as is shown for the biotopes and biocoenosis of the ecosystem of a river (Fig. 2).

Table 1 gives a summary of the organisms found in the surface drift of numerous Amazonian lotic waters. Analyses of many collections in other habitats of Amazonian rivers and streams gives a good understanding of the biological relationship of individual groups or species found there with the kinal or biotope of the surface drift. These results show that the rhithrokinon is formed by a large number of individual species which do not exhibit a close connection to this habitat, the rhithrokinal. Pupae of the family Ceratopogonidae occur suspended in the surface drift but probably the only true inhabitants of the rhithrokinal are the bugs Rhagovelia and Microvelia. In the potamokinon there are many more kinobiontic forms although the total number of species encountered in the surface drift is clearly lower.

The data in tables 2 and 3 confirms this statement, showing the occurrence of waterbeetles, the group from my material which has been most thoroughly worked up to date. Both tables show that the species diversity decreases as the flow of the river increases, in addition only the epineustic species of the genus Rhagovelia and Microvelia as well as nektonic Weberiella are true kinobionts. Almost eighty other waterbugs appear to be only kinophilous or kinoxenous and belong more or less to other coenoses. Here there is no discernable distinction, between the submerged and epineustic organisms. The epineustic bugs, and also the whirligig beetles (Gyrinidae) exhibit a close association with the river bank and only appear to make short excursions out on to the water surface. The Veliidae also occur at the river bank where, however, a kinal is not expressed.

Table 1. COENOSIS OF SURFACE DRIFT (KINON) IN RUNNING WATERS OF AMAZONIA.

| | stream (Rhithron) | river (Potamon) |
|---|---|---|
| + BACTERIA | O | ● |
| + FUNGI | O | ● |
| OLIGOCHAETA, div. gen. spec. | O | O |
| Aulophorus carteri | O | ● |
| HYDRACHNIDA, div. gen. spec. | O | O |
| COLLEMBOLA, div. gen. spec. | O | O |
| EPHEMEROPTERA, div. gen. spec. | O | — |
| PLECOPTERA, Acroneura, div. spec. | O | — |
| ODONATA, div. gen. spec. | O | — |
| Hagenia spec. | O | ● |
| + HEMIPTERA, larvae, div. gen. spec. | O | — |
| HEMIPTERA, div. gen. spec. | O | O |
| Weberiella rhomboides | — | ● |
| + Rhagovelia div. spec. | ● | ● |
| + Microvelia div. spec. | ● | ● |
| COLEOPTERA, larvae, div. gen. spec. | O | O |
| + Gyrinidae, div. gen. spec. | O | — |
| Hydrophilidae, div. gen. spec. | O | O |
| Gen. A. spec. 1 | O | ● |
| Dystiscidae, div. gen. spec. | O | O |
| Gen. B. spec. 2 | O | ● |
| Elminthidae, div. gen. spec. | O | — |
| TRICHOPTERA, div. gen. spec. | O | — |
| Leptoceridae, gen. A. spec. 1 | ? | ● |
| DIPTERA, larvae, div. gen. spec. | O | — |
| Ceratopogonidae, larvae, div. gen. spec. | O | — |
| Ceratopogonidae, pupae, div. gen. spec. | ● | ● |
| Chironomidae, larvae, div. gen. spec. | O | O |
| Chironomidae, pupae, div. gen. spec. | O | — |
| Polypedilum spec. A 72 | ? | ● |
| Polypedilum spec. A 73 | ? | ● |
| Simuliidae, larvae, div. gen. spec. | O | — |
| Fishes, div. gen. spec. | O | O |

+ epineustic living ● kinobiont O kinophil (kinoxen)

Table 2. AQUATIC HEMIPTERA FOUND IN THE KINON OF RUNNING WATERS IN THE AMAZON REGION

| A) living in the water | | stream | river small | river large |
|---|---|---|---|---|
| Corixidae | Heterocorixa anduzei | O | — | — |
| | Heterocorixa chapadiensis | O | — | — |
| | Heterocorixa genupes | O | — | — |
| | Heterocorixa hungerfordi | O | — | — |
| | Heterocorixa minuta | O | — | — |
| | Heterocorixa similis | O | — | — |
| | Tenagobia spec. spec. | O | O | O |
| | Trichocorixa orinocensis | O | — | — |
| Notonectidae | Buenoa amnigenus | O | O | — |
| | Buenoa fittkaui | — | — | O |
| | Buenoa pallipes | O | — | — |
| | Buenoa platicnemus | — | O | — |
| | Buenoa tarsalis | O | — | — |
| | Buenoa truxalis | O | — | — |
| | Martarega brasiliensis | — | O | — |
| | Martarega chinai | O | — | — |
| | Marterega gonostyla | O | — | — |
| | Martarega hungerfordi | — | O | O |
| | Martarega mcateei | — | O | O |
| | Martarega membranacea | O | O | O |
| | Notonecta disturba | — | O | — |
| Pleidae | Neoplea spec. | — | — | O |
| Naucoridae | Ambrysus bafidus | O | O | — |
| | Ambrysus fittkaui | O | O | — |
| | Ambrysus galladoi | O | — | — |
| | Ambrysus stali | O | — | — |
| | Ambrysus usingeri | O | — | — |
| | Heleocoris spinipes | — | — | — |
| | Limnocoris brudii | — | O | — |
| | Limonocoris burmeisteri | O | — | — |
| | Limnocoris fittkaui | — | O | — |
| | Limnocoris illiesis | — | — | O |
| | Pelocoris binotatulus | — | — | O |
| Belostomatidae | Belostoma bachmanni | O | O | — |
| | Belostoma discretum | — | — | O |
| | Belostoma fittkaui | — | O | — |
| | Belostoma micanthulum | O | O | — |
| | Weberiella rhomboides | — | ● | — |
| Nepidae | Ranatra doesburgi | O | — | — |
| | Ranatra moderata | O | — | — |
| | Ranatra sattleri | O | — | — |
| | Ranatra surinamense | O | — | — |
| | Ranatra usingeri | O | — | — |

Table 3. AQUATIC HEMIPTERA FOUND IN THE KINON OF RUNNING WATERS IN AMAZON REGION

| B) living epineustic | | stream | river small | river large |
|---|---|---|---|---|
| Gerridae | Brachimetra albinervis | — | O | — |
| | Brachimetra lata | O | O | — |
| | Brachimetra shawi | O | — | — |
| | Cylindrostethus erythropus | — | — | O |
| | Cylindrostethus hungerfordi | O | — | — |
| | Cylindrostethus linearis | O | — | — |
| | Cylindrostethus palmaris | O | — | — |
| | Halobatopsis platensis | O | — | — |
| | Limnogonus aduncus | O | — | — |
| | Limnogonus celevis | O | O | — |
| | Limnogonus ignotus | O | — | — |
| | Limnogonus lotus | O | — | O |
| | Limnogonus lubricus | — | O | — |
| | Limnogonus profugus | O | — | — |
| | Limnogonus visendus | O | — | — |
| | Rheumatobatis crassifemur schroederi | — | — | O |
| | Tachygerris adamzoni | O | O | — |
| | Tachygerris opacus | O | — | — |
| | Tachygerris surinamensis | O | — | — |
| Veliidae | Rhagovelia spec. spec. | ● | ● | — |
| | Microvelia spec. spec. | ● | ● | — |
| Hydrometridae | Bacillometra ventralis | O | — | — |
| | Hydrometra argentina | O | O | O |
| | Hydrometra caraiba | O | — | — |
| | Hydrometra guianana | O | — | — |
| Hebridae | Hebris spec. | — | — | O |
| Mesovelia | Mesovelia spec. | — | — | O |

● kinobiont O kinophil (kinoxen)

The various elements of the potamokinon of a small Amazonian river are given in fig. 3. The bacteria appear to form an important food component for a series of organisms in this coenosis. The bacteria drift as neuston and most

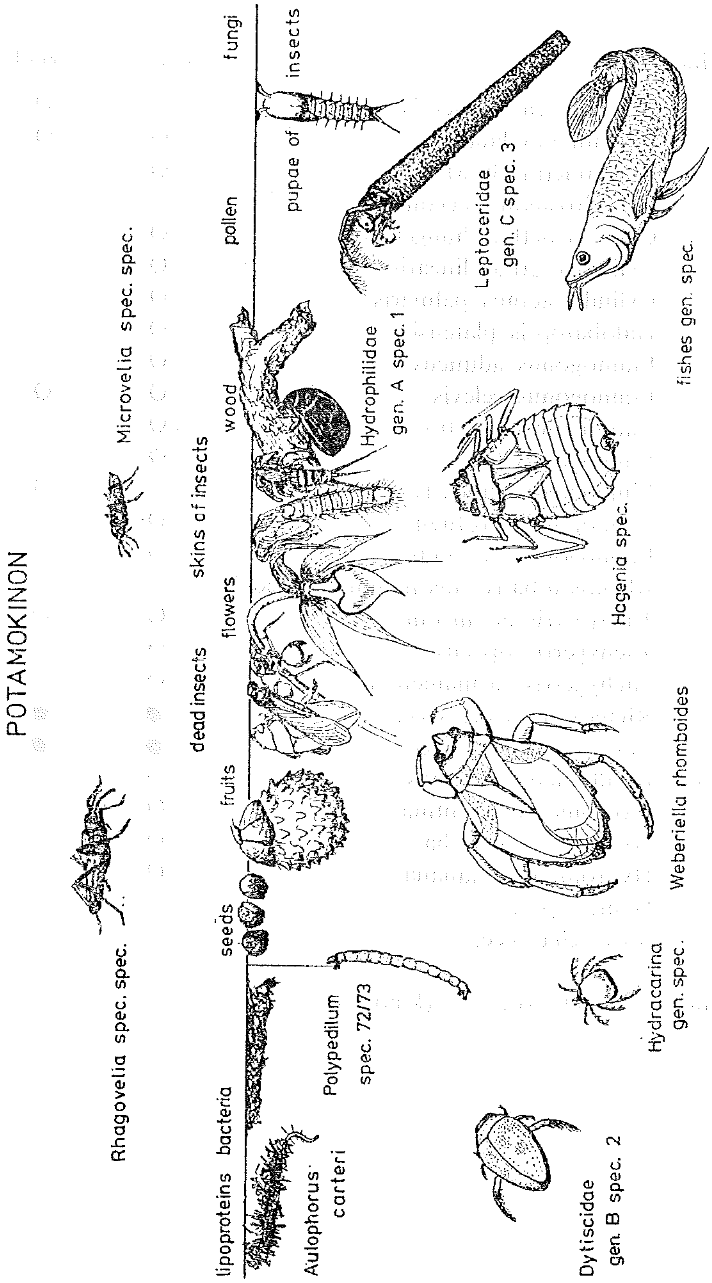


Fig. 3 Typical organisms of the kinon of small Amazonian rivers.

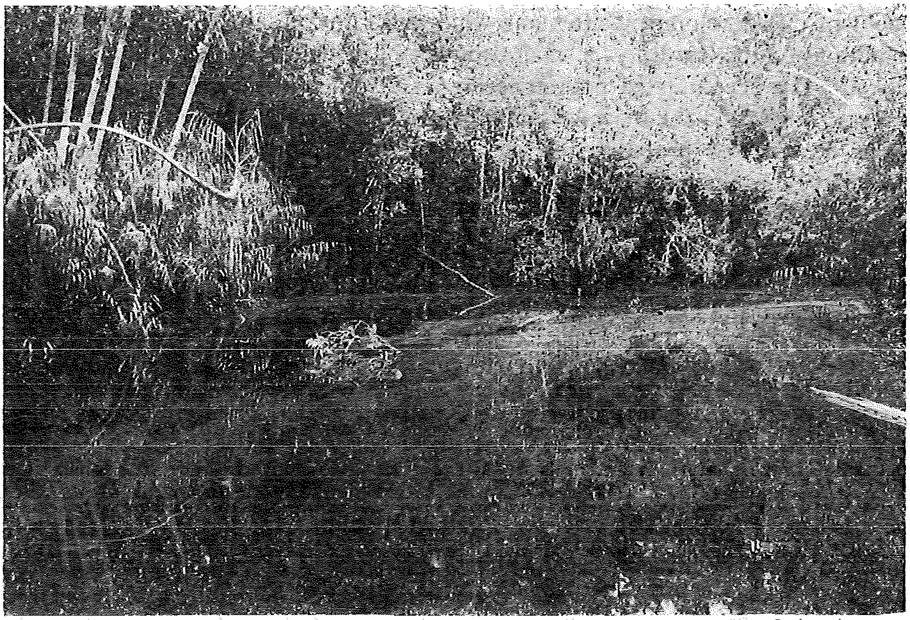

Fig. 4 Neuston of a tributary of the Rio Negro in the northern part of the Amazon basin. (Rio Itú)

likely feed lipoproteins and other organic substances which accumulate and form a film on the water surface. The bacterial colonies, as mentioned above, are often found mixed with fungi, pollen and « detritus », and form the slimy foam margin of the anterior part of the kinal. These microbiological and biochemical components can very often form a dense film on the water surface. Fig. 5 shows the

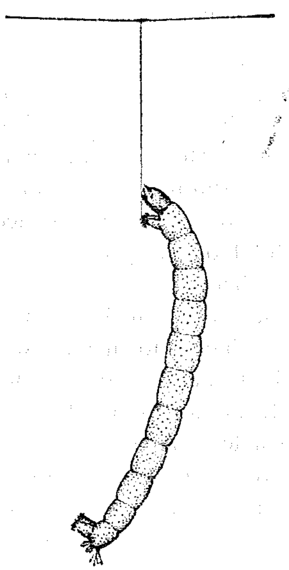

Fig. 5 Larva of Polypedilum spec. (Chironomidae, Dipt.) hanging on a thread attached to the water film.

extent of this development after one wind and rain free night during high water conditions on the Rio Itu — a small tributary of the Rio Negro in the « Igapo »— region. The accumulated potamoneuston and other plant and animal material is a source of food for the case building oligochaetes, chironomid larvae, hydrophilid beetles and probably for the leptocerid trichopteran larvae also. The secondary consumers are the carnivorous Dytiscidae, Belostomatidae, and the larvae of Odonata. Various fish belong to this category of consumers but precise information on these fish is still lacking. The potamokinal is inhabited by high numbers of different rhagovelid and microvelid species which probably feed on dead insects in the surface drift.

Our knowledge of the Amazonian invertebrate fauna, with the exception of the Hemiptera, is still very inadequate. It is likely that many more beetle, chironomid and hydrachnid species will be found which belong to the potamokinon.

The Potamokinon is an extreme biotope, poor in species when compared with other lotic coenoses. Evidence that the potamokinon has existed as a biotope for a long time is seen in the very suitable adaptations exhibited by various insect orders and other animal taxa. Weberiella rhomboides has only been found in the potamokinon of two widely separated river systems of the Amazon. A particularly good adaptation is exhibited by the larvae of Polypedilum spec. 72 and 73. If these larvae are dislodged from their substrate they immediately spin a short thread and hang, hyponeustically, attached to the water film while passively drifting to the next potamokinal. The pupae are also able to attach their pupal cases to the surface-film when another substrate is not available.

The actual density and diversity of animals in the potamokinon is dependent on the age of the kinal. In relatively new accumulations of surface drift there are much fewer species but those occuring often do so in high numbers.

Accounts of the cœnosis of surface film drift are not often given in the literature. A communication on the « Epineuston » of streams (in the sense of WELCH 1952) was given by RAPOPORT and SANCHEZ (1965). They produced detailed information on the Collembolidae of Argentinian rivers. There, as in many parts of the world, the collembolids play a clear role in the rhithro— or potamokinon. More than 50 % of the organisms found drifting in the rivers investigated in Argentinia belong to this animal taxon. From a total of 34 species found living on the water, 4 may be considered as kinobionts. There are approximately 110 partially aquatic Collembolidae known in the world, and about 30 of these have an exclusive neustic distribution. Stomach analyses have shown that they feed on the bacteria of neuston and probably also on the proteins of the surface film. It is noteworthy that the collembolids are absent from the kinon of Central Amazonian running waters which are poor in electrolytes. Apart from the investigations of RAPOPORT and SANCHEZ there are sufficient indications that the kinon forms a measurable part of freshwater ecosystems. The influence of man may have prevented the full expression of this coenosis in European rivers.

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