THE RIVER AS ECOSYSTEM

The Fluvial Ecology refers to the study of the biological structure of rivers and it maintains relationships with the environment, referred to in this case both the water system in the water as that of ecotone that develops between him and the terrestrial environment slopes leading.

The Fluvial Ecology is part of Limnology, more general science includes the study of inland waters (rivers and lakes).

In the development of Limnology previously developed study lakes, isolated systems because these are well defined, with an adequate size to more easily analyze the complex relationships between biological components and the aquatic environment.

The study of rivers is much more recent, though they represented a natural element of much greater importance for human populations, constituting the natural drainage of the land surface, providing numerous resources to Man with moving water.

As with any ecosystem, a river we must distinguish between system structure and functioning. By structure we mean the lace and the interrelationships of its three components: a) the biological community, b) material and energy resources, and c) the physical habitat. For performance we mean the set of biological, chemical and physical material flow controllers and power running through the ecosystem.

The structure can be described in terms of ecological dominance, diversity of species or trophic pyramids. However, if we want an approach to ecosystem productivity is considered simultaneously optimal functioning and structure. This is facilitated by the classification of organisms into functional groups (Cummins, 1975) to directly link the biological component to the processes of energy flows. The members of each functional group performed a similar process (see Figure 1): primary producers (periphyton, phytoplankton and macrophytes) determine the energy of the sun, fungi and bacteria decompose organic matter and the functional consumers groups mainly include macroinvertebrate and fish, which use the energy accumulated by previous groups.

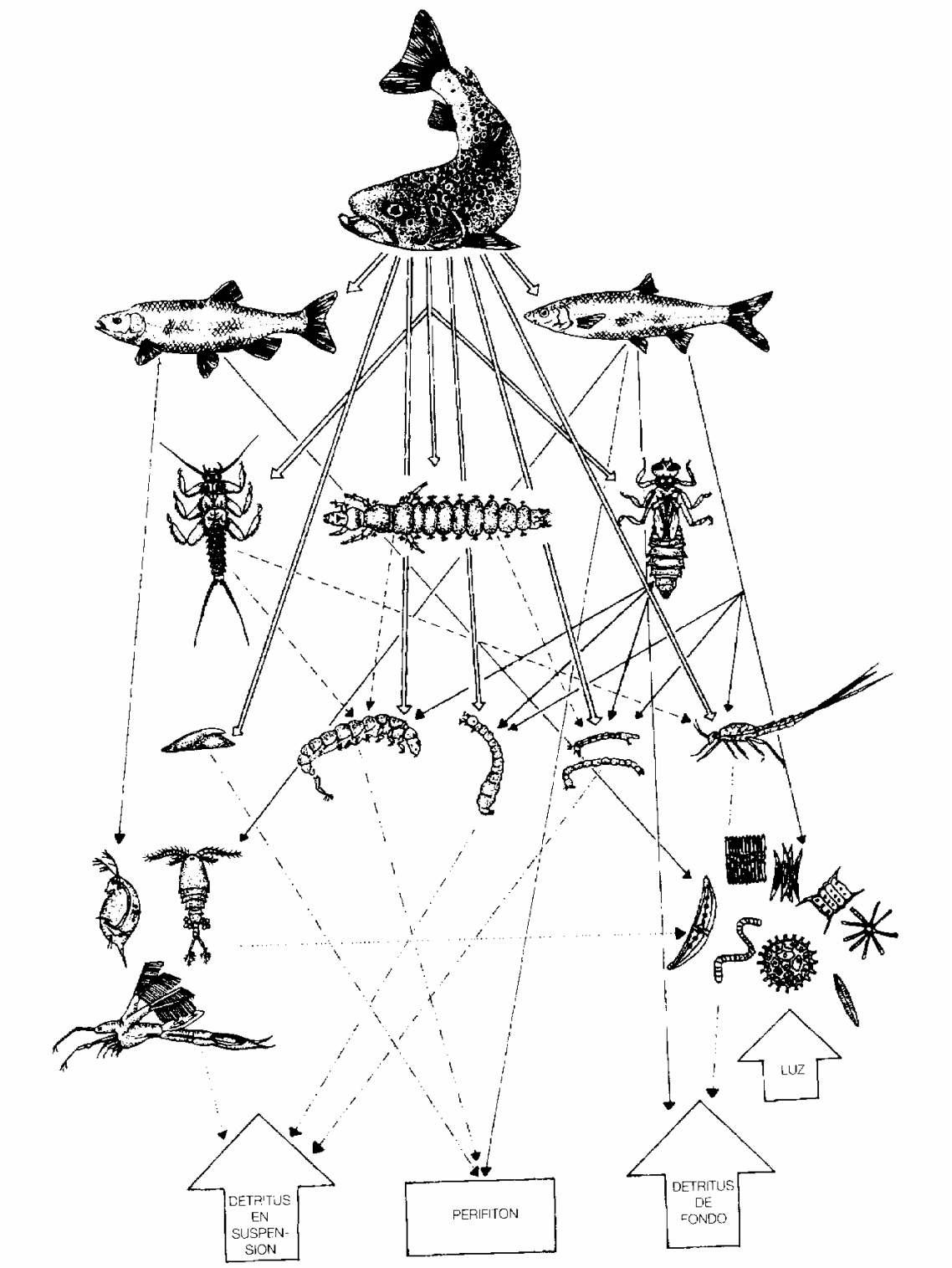

Figure 1 .- Diagram of the structure and functioning of the river ecosystem.

Consumers, in turn, are grouped by food type and according to the mechanisms they use in their food: a) the shredders feed on large particles of organic detritus (leaves, twigs, animal remains, macrophytes ,..); b) phytophagous feed on periphyton by scraping off surface they occupy, or by filtering phytoplankton, c) filtering collectors of fine particles of debris suspended in the water column, or collect them once sedimented, and the predators and parasites obtain their food from other animals.

The material and energy resources of ecosystems are represented by inorganic nutrients and different types of organic matter. Depending on the size of the particle organic matter consists of: dissolved organic matter (<0.5 µm) fine particulate organic matter (0.5 µm - 1 mm), coarse particulate organic matter (1mm - 1dm) woody material (> 1dm). The woody material is important not only as a resource, but also for their physical effects on the morphology of the bed. Anyway, this classification is somewhat artificial, since the size of the particles of organic matter form a continuum from large trunks that fall on the channel to the finer particles that have just been transformed.

The physicochemical characteristics that structure the fluvial ecosystem represent the platform or habitat where they develop biological communities and their resources. The physical habitat consists of those factors that form the structure within which they live the fluvial communities, including the characteristics of the submerged riverbed, the banks and the riverside.

Rivers and terrestrial ecosystems that comprise the drainage basin maintain multiple relationships. The flow regimes, sediment, nutrients and organic matter originating from the slopes of the basin shape the physical habitat of the river, and provide energy and resources to reofil communities. In particular, riparian vegetation stabilizes the banks of the bed, contributes with wood materials and vegetable waste to organic matter of the river and controlling the entry of light and the arrival of other organic matter and nutrients to the bed.

This chapter describes how the river and two key components structure, the group of macroinvertebrates living in the bottom of rivers, and the group of fish.

With this description is to demonstrate the complexity of fluvial ecosystem functioning, and the great diversity of forms and biological adaptations that develop within it.

Only through detailed knowledge of the river can correctly estimate the impacts caused by human activities (flow regulation, pipelines, pollution water, etc.), and to propose to mitigate these impacts or restoration projects that tend to recover a more favorable situation for the maintenance of their biology and conservation.

Longitudinal Zonation

Along the longitudinal gradient of the river from the headwaters the mouth, the fluvial system is gaining in size and organization, and the lateral terrestrial influence, and proportionately, by increasing the flow and sediment load coming from the upper reaches, decreasing in relative terms, the influence of the banks. Generally header rivers are confined in narrow valleys, and in the channel abundant the rocky outcrops, woody materials and coarse sediments. By contrast, in the lower reaches of rivers meanders in the alluvial valley, and in the channel predominantly fine sediments, which alternate its transportation and storage. In making the river wider, more light comes into the mainstream, and importance of riparian detritus of origin in the energy flow decreases, being surpassed by the flow of residual organic matter from upstream reaches.

Therefore the fluvial ecosystem in each reach, functions as an open system in which fauna and flora, organic matter, nutrients and physico-chemical form a dynamic structure in time and space, from birth to mouth in turn closely linked to the riparian forest. The energy that enters, crosses and out of the river system is both solar and from detritus, and is processed by aquatic communities that draw from it the energy for activity, growth and reproduction. This function varies along the longitudinal gradient of the river, and for analysis should distinguish basically three reaches, high, medium and low within each river.

Upper reaches, or river header

This is the case of mountain rivers, with steep slopes, on slopes and in the channel, and generally clear waters. The channel width is small in these cases, especially in relation to the dominant size of the substrate, 2-6 meters, and trees shade the banks of all or most of the channel, so the energy input light is scarce. In this case the only primary producers are algae periphyton boulders lining the bed, being limited the growth of other plants green on the oligotrophic conditions (low nutrient) waters, the flow velocity and the lack of light.

The main source of organic matter on the river is produced out of it, falling to the waters in the form of twigs, leaves, etc.., and decomposes slowly by the action of bacteria and fungi, resulting in detritus in the form of “coarse particles” of organic material, which are well used by consumers in that stretch of the river (Figure 2). The speed with which decomposes to be utilized by various aquatic organisms depends on the plant species from which it comes. Thus, the leaves of alder, poplar, ash and maples move swiftly, while the oak and pine are more resistant.

In these upper reaches, the river also carry dissolved organic matter and “fine particles” that come from streams and reaches higher than those considered, although still in small quantities because of the relative unimportance of the latter.

The benthic communities of these reaches of header are abundant and rich in species as these primary consumers use every sources of energy in the form of organic matter. The different trophic groups of macrobenthos are well represented: the group of shredders is the most important, taking care of processing the coarse particles of organic

matter and transform a large proportion fine particles and in dissolved organic matter; the scrapers leverage the existing periphyton; the collectors are mainly fed by filtering out fine particles in the seston, and the predators feed on all other groups.

The fish community of these upper reaches is mainly composed of salmonids, whose diet is based on benthic macroinvertebrates.

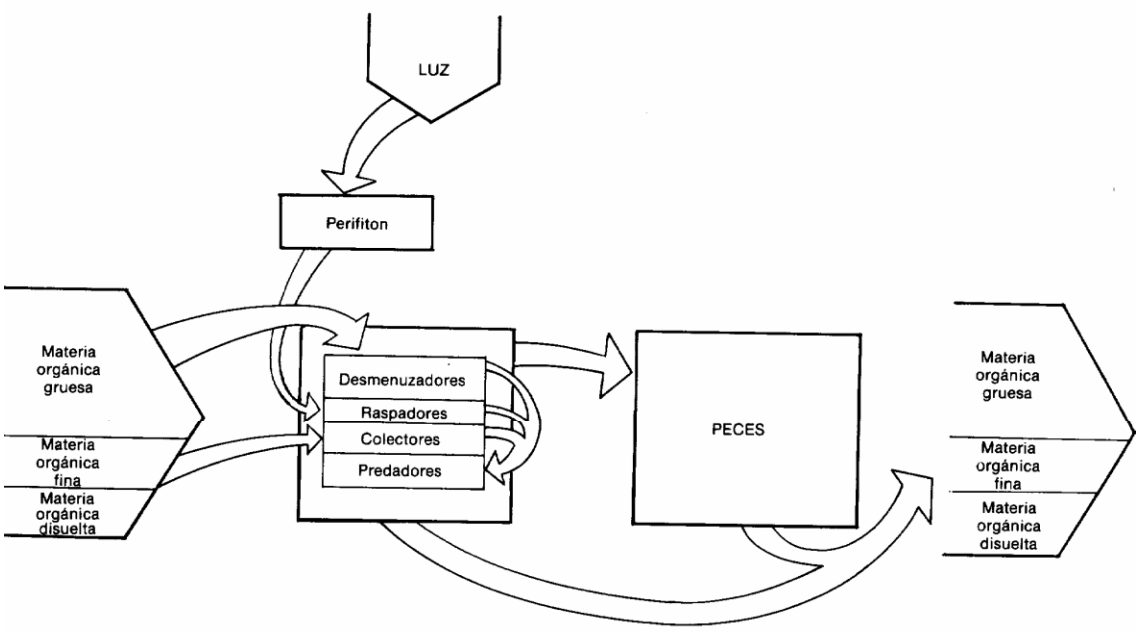

Figure 2 .- Interactions between different biological components of an ecosystem for the stretch of river Rhithron.

Middle reaches or river piedmont

As they approached the plains, the waters of the rivers lose velocity, the channel widens (15-30 m) and the bed of the fund is constituted in general by gravel and boulders of smaller size. The coverage of the bed by streamside vegetation is less in proportion to the width of the river, and solar radiation reaching to the bottom perfectly, being actively exploited by periphyton and especially by a dense macrophyte vegetation The river already has its own organic matter synthesized in the same (matter autochthonous organic) and it only takes directly the periphyton, which is consumed by macrobenthos scrapers and phytophagous vertebrates and some fish, and poultry (ducks and coots). Macrophytes surprisingly not used by any primary consumer of the river, so the end of its life cycle are decomposed by the action of bacteria and fungi, and in this way, and transformed into particles can be digested and recycled in the system in the downstream reaches. The input of energy from overland systems (alien) is still important in these reaches but less than in the header, because of the photosynthesis carried out in the stretch. The organic matter provided by the riparian vegetation is proportionately less important than in the high altitudes, and organic matter coming from the upper reaches, mostly in the form of fine particles and dissolved dominates.

The trophic structure of macroinvertebrates of these reaches is a result of the types of energy available to them, prevailing in this case the group of collectors, filtering and collecting the fine fraction of seston; also abundant periphyton scrapers, and predators represent about one third part of this community, which is a ratio common in the aquatic environment, ultimately, shredders organisms are less abundant than in the previous case, due to lower proportion of coarse particles of organic matter in water.

In the fish community dominated by omnivorous species such as catfish, and between typical predators of this stretch are eels and pike.

Lower Reaches and River Plain

The plain rivers run through wide valleys and broad floodplains, generally describing sharp bends on a channel whose bed is dominated by fine sediments. The waters are murky, indicating an abundance of dissolved salts and fine particles in suspension, and depth often exceeds 2 or 3 m, so the macrophytes are restricted to the banks, not enough light reaching the bottom, in mid-stream. The waters flow slowly, allowing the intense development of phytoplankton in the layers closer to the surface. This phytoplankton is eaten by zooplankton, which in turn is part of the diet of some macroinvertebrates (filtering-collectors), omnivorous fish and all kinds of ducks (Figure 3).

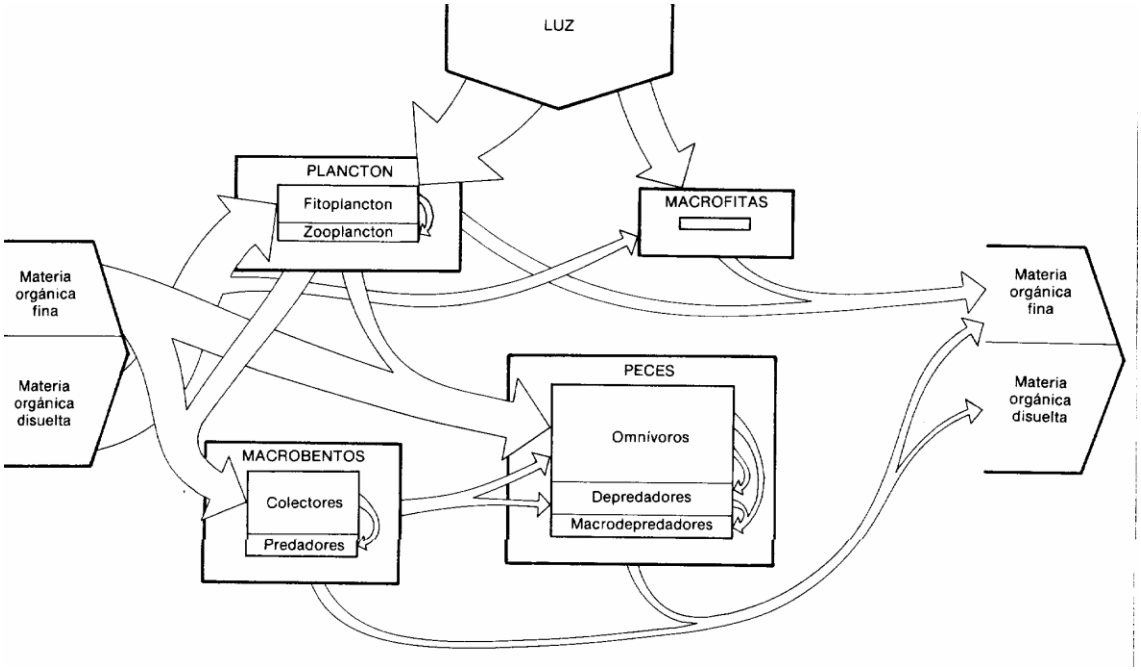

Figure 3 .- Interactions between components of the biological community of a lowland river (Potamon).

The organic matter contained in these waters is mostly dissolved, also dragging the fine fraction of suspended solids. The macrobenthos is relatively scarce in these reaches due to the instability of the substrate, consisting of very fine elements, and is composed of collectors and predators almost exclusively.

The community of vertebrates (see Figure 4) is more important and is composed of omnivorous species as ducks and cyprinids (carp, crucian carp, chub, tench and barbel) and predators such as herons, cormorants, eels, black bass, sheatfish or catfish.

Figure 4 .- Community of vertebrates from a lower stretch of river.

Zonation systems

Just as functional and structural aspects of the ecosystem of the river change from the upper reaches to the low reaches, there is also a change in the composition of their communities. Analyzing the distribution of species from the source to the mouth of the river can be seen that there are species that are restricted to the portions of head or the lower reaches (the stenotic species), and species that inhabit almost the entire route of the river (species with wide ecological valence). In general there is a continuous substitution of species to the river, called longitudinal succession.

The man, in his eagerness to classify nature for better understanding and management has transformed, ideally such succession in a continuous or discrete stepwise zoning. According to this theoretical zonation can be distinguished in the rivers homogeneous "zones", characterized by some associations of species and abiotic conditions of the river environment.

Perhaps the best known zonation in European rivers is of Huet (1954) which was adapted to Spanish for Gutiérrez Calderón River (1968), where each fluvial zone is defined by a main fish species and a list of associated species as follows:

* ***Trout zone.*** (the cavilat and minnow as associated species). Refers to streams of steep slopes and fast flowing water with bedrock and boulders, among which may exist sometimes gravel. The depth is usually small and contain cold water and well airy, with temperatures rarely exceed 20 º C.

* ***Transition zone to the catfish***. This zone was characterized by the grayling, a species that does not exist in Iberian waters. The associated species are a mixture salmonid and reofil cyprinid (minnow, barbel, vogue, loin, chub and gudgeon). It represents rivers wide and deep (up to 2 m) with less slopes and with a bed of small stones and gravel, with alternating fast and backwaters.

* ***Catfish zone***. It dominates the barb, associated with other reofil cyprinids in the absence of salmonids, which are substituted by other predators (eels and pike). It refers to the mild slope rivers, which are alternated with stretches of fast water stretches of backwater, and the latter dominating.

* ***Zone of the tent*****.** Domain zone of calm water cyprinids (carp, crucian carp and tench), where they live horns, roach, gobies, eels, pike and black bass. It corresponds to the lower reaches of major rivers and their tributaries in lowland. In them the water velocity is slow and uniform, while summer temperatures are high and often the water is turbid and deep.

Huet also fish these areas characterized by morphological, considering mainly the slope of the river and its width.

Illies and Botosaneanu Later (1963) proposed another zoning of rivers with a more universal, based on all biotic community´s river. Zoning criteria considered as the water temperature (summer mean) and the channel width, both linked to the magnitude

of the flows and their relationship to the confluence of rivers with some other, distinguishing the following areas:

* ***Crenon*****.** Corresponding to the stages of birth, creeks and streams header, where the water is cold all year round, with very small temperature variations and the channels narrower than two meters.

* ***Rhithron.*** Define mountain rivers where the mean monthly temperature of the water does not exceed 20 º C. The flow velocity is fast and flows are generally small. The bed substrate consists of large rocks, stones, gravel and sand and only in areas of accumulated silt backwater. In this zone are distinguished in turn three subzones row, the Epirhithron (creeks whose width varies between 2 and 10 m), Metarhithron (rivers 10 to 20 m wide) and Hyporhithron (20-30 m wide).

* ***Potamon.*** Represents the lower reaches of streams where the average monthly temperatures exceed 20 º C, the flow velocity is small, more homogeneous regime, and the riverbed is principally composed of sand, silt and clay, although there may be some areas of gravel in the rapids that are sometimes formed. At the same time in this area also are three sub-areas, Epipotamon (transition zone and small rivers of the plains), Metapotamon (large plain rivers) and Hypopotamon (deltas and estuaries).

Generally speaking, one can establish a correlation between the two zonations, considering that the area of the trout ranging from Crenon to Metarhithron; the transition zone corresponds to Hyporhithron; the area Epipotamon catfish, and the area of the tent to Metapotamon.

River as a continuum

Vannote et al. (1980) proposed the ecological and conceptual interpretation of the river as a continuum, in contrast to previous ideas, based mainly on the study of isolated sections. In reality, this new concept is only the continuous integration of river morphology (Leopold et al., 1964) with existing biological theories, tightly crimped together, providing cohesion for the first time the concept of the river as ecosystem.

Under this concept of the river is discussed in detail the evolution of organic matter in water, as the main source of energy in them, and the development of different functional groups that take advantage of that material as their physical condition, size particles, etc.., continuously producing a succession of species along the river (see Figure 5) to comply with that food availability and physical conditions of the waters along the same.

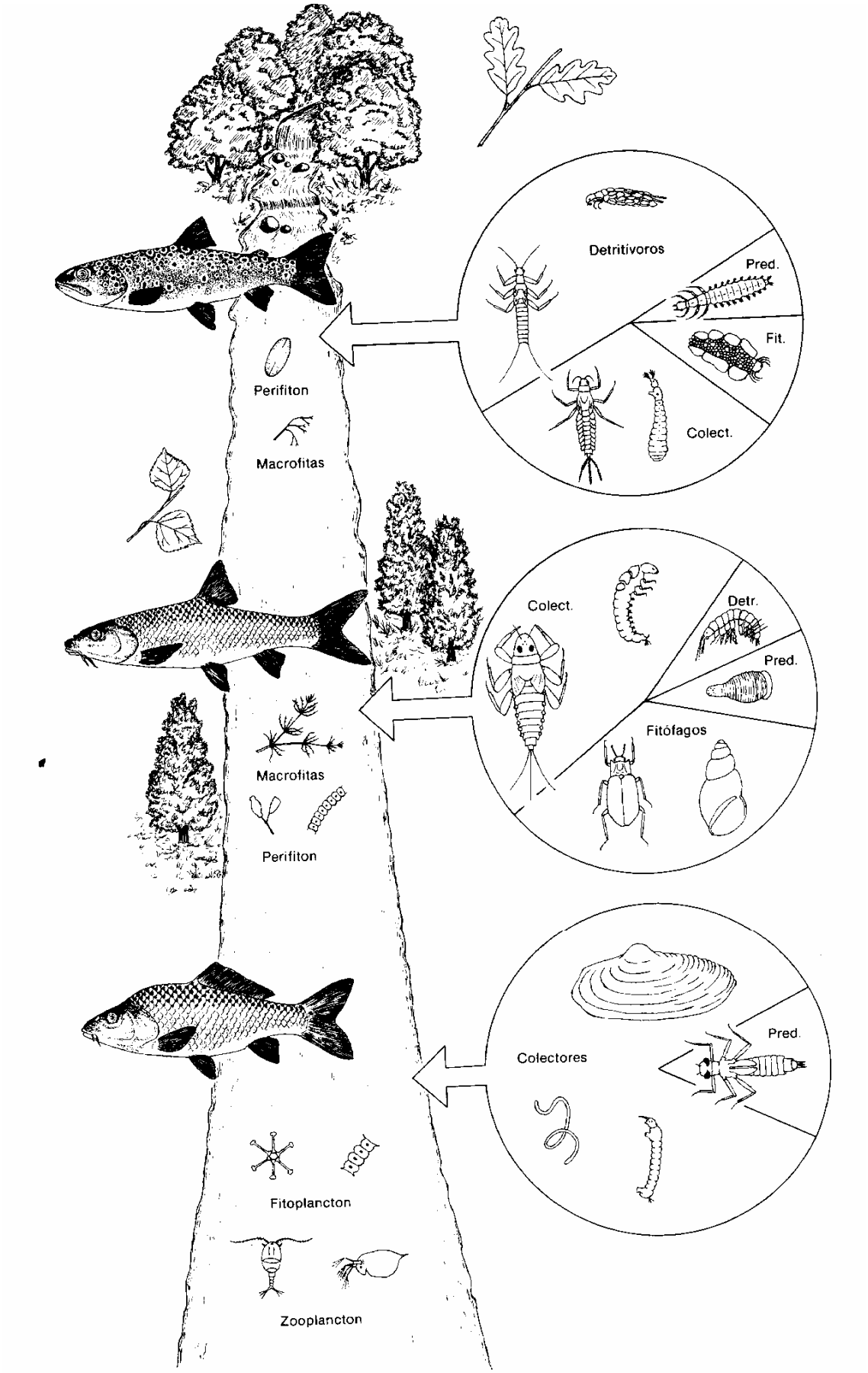

Figure 5 .- Interpretation of continuous river in a typical Iberian river, pointing macrobenthic communities, fish and primary producers.

This new approach includes in his conception of ideas and theories River fluvial geomorphology, where it is necessary to consider the river as a continuous entity emphasis on the energy gradient of water and the equilibrium tends to be attained in each section between the hydraulic power function of flow and slope, and physical characteristics of the channel (width, depth, substrate type, speed, etc..) that depend on it.

Nutrient spiraling

As a consequence of the dynamics of the river system, due to the flow of water is what determines the continuity of the other characteristics, in rivers is steadily producing energy flow downstream, and in each section is to maximize the power passing through it, causing minimal or export this energy output by storage or retention of it in form of organic matter (biomass of living organisms or organic sediments) in that stretch.

Thus, by looking at a carbon atom or any nutrients such as nitrogen or phosphorus, we see that in its route does not make closed loops as in other ecosystems (lakes, forests, etc.) but water moves down, washed away in some sections, and others captured and processed and assimilated by the biological communities that ultimately excreted into the water, again being swept downstream to once again be exploited by other communities in lower reaches.

This type of movement of nutrients is a spiral, with a translation immediately downstream of a biological cycle is repeated successively along the river course. This spiral movement of nutrients and other elements is characteristic of river ecosystem functioning and is defined by the "length of spiral" which is the average distance of each particle river that runs between two consecutive cycles, which is much more shorter stable complex where the river runs, the more simplified and higher you are (eg in channelized sections, where they control the translation of organic detritus on the cycles of assimilation).

The kind of movement or use of organic compounds river, with a constant downstream exports in an increasingly degraded or dissolved to be utilized by the producing organisms (green plants) contributes significantly to the self-purification capacity of rivers, with the potential for aeration and water own biological activities of other aquatic organisms.

Stability and Organization

Each river system will stabilize naturally downstream. From a geomorphological perspective, the streams and tributaries are converging and organizing head in a drainage system with fewer and fewer channels, from a hydrological point of view, different flow regimes and velocities of each river water will offsetting when they join the main, and from a chemical standpoint, they will mix water physicochemical characteristics very different basins draining different geological nature, determining from its confluence increased the total area drained, becoming less influence it can have

on the waters of the main channel specific characteristics of a portion of its basin, and the greater the homogenizing effect of it.

From a biological point also downstream will produce greater competition stabilization and continuous relationship between different populations and communities that are emerging in the river, while the species richness and diversity decrease.

The communities of the lower reaches, where there is "breathing" against "cloning, taking advantage of the relative ineffectiveness of communities in the upper reaches, which are not able to harness all the energy in the form of organic material they receive. But these upper reaches communities, perhaps because of greater heterogeneity of other characteristics of the river, have a greater diversity than those of the lower reaches, and have better matched.

Where the characteristics of the river are more stable (in the low reaches), the biological contribution to stability is very small, and this translates into a low diversity of the communities.

By contrast, in the stretches of river where environmental fluctuations on river flow, temperature, organic matter, etc. (upper reaches and especially media), usually a high number of species that are very different communities, being very competitive relations eased so they can live among them in the case of a position below the optimum for most species.

Finally, the reaches of river where these fluctuations are very large we are very stressed systems, tolerated only by the pioneer species, which also significantly reduces biodiversity.